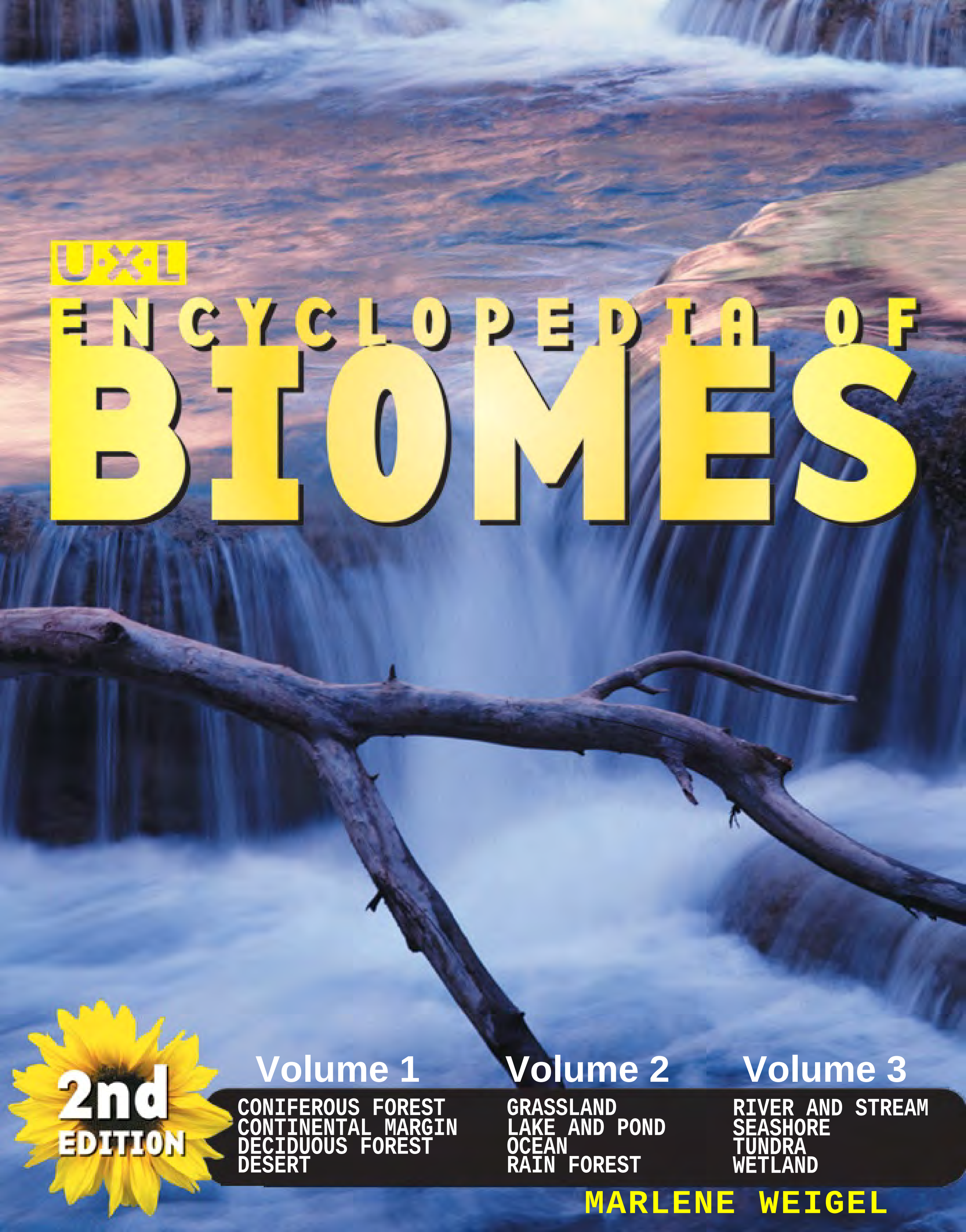

U•X•L

ENCYCLOPEDIA OF BIOMES

2nd EDITION

Volume 1
CONIFEROUS FOREST
CONTINENTAL MARGIN
DECIDUOUS FOREST
DESERT

Volume 2
GRASSLAND
LAKE AND POND
OCEAN
RAIN FOREST

Volume 3
RIVER AND STREAM
SEASHORE
TUNDRA
WETLAND

MARLENE WEIGEL

U•X•L Encyclopedia of Biomes

Second Edition

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Second Edition

Marlene Weigel

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Reader's Guide

This second edition of U•X•L Encyclopedia of Biomes offers readers comprehensive, easy-to-use, and current information on twelve of Earth's major biomes and their many component ecosystems. Arranged alphabetically across three volumes, each biome chapter includes: an overview; a description of how the biomes are formed; their climate; elevation; growing season; plants, animals, and endangered species; food webs; human culture; and economy. The information presented may be used in a variety of subject areas, such as biology, geography, anthropology, and current events. Each chapter includes a "spotlight" feature focusing on specific geographical areas related to the biome being discussed and concludes with a section composed of books, periodicals, Internet addresses, and environmental organizations for readers to conduct more extensive research.

Additional Features

Each volume of *U•X•L Encyclopedia of Biomes* includes color maps and at least 60 photos and illustrations pertaining to each biome, while sidebar boxes highlight fascinating facts and related information. All three volumes include a glossary, a bibliography, and a subject index covering all the subjects discussed in *U•X•L Encyclopedia of Biomes.*

Note

There are many different ways to describe certain aspects of a particular biome, and it would be impossible to include all of the classifications in *U•X•L Encyclopedia of Biomes.* However, in cases where more than one classification seemed useful, more than one was given. Please note that the classifications represented here may not be those preferred by all specialists in a particular field.

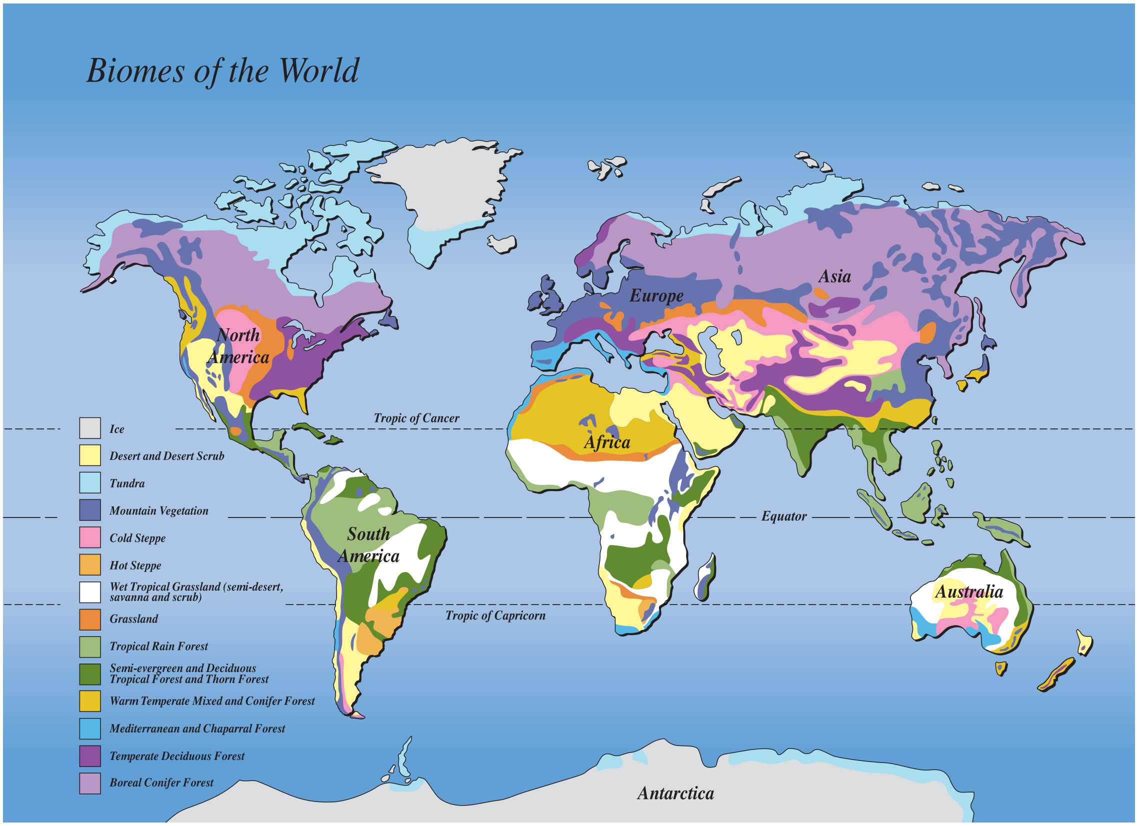
Every effort was made in this set to include the most accurate information pertaining to areas and other measurements. Great variations exist in the available data, however. Sometimes differences can be accounted for in terms of what was measured: the reported area of a lake, for example, may vary depending upon the point at which measuring began. Other differences may result from natural changes that took place between the time of one measurement and another. Further, other data may be questionable because reliable information has been difficult to obtain. This is particularly true for remote areas in developing countries, where funds for scientific research are lacking and non-native scientists may not be welcomed.

The U•X•L editors would like to thank author Marlene Weigel for her work on the original edition of this title. We also thank contributing writer Rita Travis for her work on the Coniferous Forest, Grassland, Tundra, and Wetland chapters. All the entries were updated by Lubnah Shomali for this new edition, and we relied heavily on our expert, Dr. Dan Skean, of Albion College to provide academic insight and additional feedback.

Comments and Suggestions

We welcome your comments on this work as well as your suggestions for topics to be featured in future editions of *U•X•L Encyclopedia of Biomes* Please write: Editors, *U•X•L Encyclopedia of Biomes,* U•X•L, 27500 Drake Rd., Farmington Hills, MI 48331-3535; call toll-free: 1-800-877-4253; fax: 248-699-8097; or send e-mail via www.gale.cengage.com.

Biomes of the World Map



Words to Know

A

Abyssal plain: The flat midportion of the ocean floor that begins beyond the continental rise.

Acid rain: A mixture of water vapor and polluting compounds in the atmosphere that falls to Earth as rain or snow.

Active margin: A continental margin constantly being changed by earthquake and volcanic action.

Aerial roots: Plant roots that dangle in midair and absorb nutrients from their surroundings rather than from the soil.

Algae: Plantlike organisms that usually live in watery environments and depend upon photosynthesis for food.

Algal blooms: Sudden increases in the growth of algae on the ocean's surface.

Alluvial fan: A fan-shaped area created when a river or stream flows downhill, depositing sediment into a broader base that spreads outward.

Amphibians: Animals that spend part, if not most, of their lives in water.

Amphibious: Able to live on land or in water.

Angiosperms: Trees that bear flowers and produce their seeds inside a fruit; deciduous and rain forest trees are usually angiosperms.

Annuals: Plants that live for only one year or one growing season.

Aquatic: Having to do with water.

Aquifier: Rock beneath Earth's surface in which groundwater is stored.

Arachnids: Class of animals that includes spiders and scorpions.

Arctic tundra: Tundra located in the far north, close to or above the Arctic Circle.

Arid: Dry.

***Arroyo*:** The dry bed of a stream that flows only after rain; also called a wash or a *wadi.*

Artifacts: Objects made by humans, including tools, weapons, jars, and clothing.

Artificial grassland: A grassland created by humans.

Artificial wetland: A wetland created by humans.

Atlantic blanket bogs: Blanket bogs in Ireland that are less than 656 feet (200 meters) above sea level.

Atolls: Ring-shaped reefs formed around a lagoon by tiny animals called corals.

B

Bactrian camel: The two-humped camel native to central Asia.

Bar: An underwater ridge of sand or gravel formed by tides or currents that extends across the mouth of a bay.

Barchan dunes: Sand dunes formed into crescent shapes with pointed ends created by wind blowing in the direction of their points.

Barrier island: An offshore island running parallel to a coastline that helps shelter the coast from the force of ocean waves.

Barrier reef: A type of reef that lines the edge of a continental shelf and separates it from deep ocean water. A barrier reef may enclose a lagoon and even small islands.

Bathypelagic zone: An oceanic zone based on depth that ranges from 3,300 to 13,000 feet (1,000 to 4,000 meters).

Bathyscaphe: A small, manned, submersible vehicle that accommodates several people and is able to withstand the extreme pressures of the deep ocean.

Bay: An area of the ocean partly enclosed by land; its opening into the ocean is called a mouth.

Beach: An almost level stretch of land along a shoreline.

Bed: The bottom of a river or stream channel.

Benthic: Term used to describe plants or animals that live attached to the seafloor.

Biodiverse: Term used to describe an environment that supports a wide variety of plants and animals.

Bio-indicators: Plants or animals whose health is used to indicate the general health of their environment.

Biological productivity: The growth rate of life forms in a certain period of time.

Biome: A distinct, natural community chiefly distinguished by its plant life and climate.

Blanket bogs: Shallow bogs that spread out like a blanket; they form in areas with relatively high levels of annual rainfall.

Bog: A type of wetland that has wet, spongy, acidic soil called peat.

Boreal forest: A type of coniferous forest found in areas bordering the Arctic tundra. Also called taiga.

Boundary layer: A thin layer of water along the floor of a river channel where friction has stopped the flow completely.

Brackish water: A mixture of freshwater and saltwater.

Braided stream: A stream consisting of a network of interconnecting channels broken by islands or ridges of sediment, primarily mud, sand, or gravel.

Branching network: A network of streams and smaller rivers that feeds a large river.

Breaker: A wave that collapses on a shoreline because the water at the bottom is slowed by friction as it travels along the ocean floor and the top outruns it.

Browsers: Herbivorous animals that eat from trees and shrubs.

Buoyancy: Ability to float.

Buran: Strong, northeasterly wind that blows over the Russian steppes.

Buttresses: Winglike thickenings of the lower trunk that give tall trees extra support.

C

Canopy: A roof over the forest created by the foliage of the tallest trees.

Canyon: A long, narrow valley between high cliffs that has been formed by the eroding force of a river.

Carbon cycle: Natural cycle in which trees remove excess carbon dioxide from the air and use it during photosynthesis. Carbon is then returned to the soil when trees die and decay.

Carnivore: A meat-eating plant or animal.

Carrion: Decaying flesh of dead animals.

Cay: An island formed from a coral reef.

Channel: The path along which a river or stream flows.

Chemosynthesis: A chemical process by which deep-sea bacteria use organic compounds to obtain food and oxygen.

Chernozim: A type of temperate grassland soil; also called black earth.

Chinook: A warm, dry wind that blows over the Rocky Mountains in North America.

Chitin: A hard chemical substance that forms the outer shell of certain invertebrates.

Chlorophyll: The green pigment in leaves used by plants to turn energy from the sun into food.

Clear-cutting: The cutting down of every tree in a selected area.

Climax forest: A forest in which only one species of tree grows because it has taken over and only that species can survive there.

Climbers: Plants that have roots in the ground but use hooklike tendrils to climb on the trunks and limbs of trees in order to reach the canopy, where there is light.

Cloud forest: A type of rain forest that occurs at elevations over 10,500 feet (3,200 meters) and that is covered by clouds most of the time.

Commensalism: Relationship between organisms in which one reaps a benefit from the other without either harming or helping the other.

Commercial fishing: Fishing done to earn money.

Conifer: A tree that produces seeds inside cones.

Coniferous trees: Trees, such as pines, spruces, and firs, that produce seeds within a cone.

Consumers: Animals in the food web that eat either plants or other animals.

Continental shelf: A flat extension of a continent that tapers gently into the sea.

Continental slope: An extension of a continent beyond the continental shelf that dips steeply into the sea.

Convergent evolution: When distantly related animals in different parts of the world evolve similar characteristics.

Coral reef: A wall formed by the skeletons of tiny animals called corals.

Coriolis effect: An effect on wind and current direction caused by Earth's rotation.

Crustaceans: Invertebrate animals that have hard outer shells.

Current: The steady flow of water in a certain direction.

D

Dambo: Small marsh found in Africa.

Dark zone: The deepest part of the ocean, where no light reaches.

Deciduous: Term used to describe trees, such as oaks and elms, that lose their leaves during cold or very dry seasons.

Decompose: The breaking down of dead plants and animals in order to release nutrients back into the environment.

Decomposers: Organisms that feed on dead organic materials, releasing nutrients into the environment.

Deforestation: The cutting down of all the trees in a forest.

Dehydration: Excessive loss of water from the body.

Delta: Muddy sediments that have formed a triangular shape over the continental shelf near the mouth of a river.

Deposition: The carrying of sediments by a river from one place to another and depositing them.

Desalination: Removing the salt from seawater.

Desert: A very dry area receiving no more than 10 inches (25 centimeters) of rain during a year and supporting little plant or animal life.

Desertification: The changing of fertile lands into deserts through destruction of vegetation (plant life) or depletion of soil nutrients. Topsoil and groundwater are eventually lost as well.

Desert varnish: A dark sheen on rocks and sand believed to be caused by the chemical reaction between overnight dew and minerals in the soil.

Diatom: A type of phytoplankton with a geometric shape and a hard, glasslike shell.

Dinoflagellate: A type of phytoplankton having two whiplike attachments that whirl in the water.

Discharge: The amount of water that flows out of a river or stream into another river, a lake, or the ocean.

Doldrums: Very light winds near the equator that create little or no movement in the ocean.

Downstream: The direction toward which a river or stream is flowing.

Drainage basin: All the land area that supplies water to a river or stream.

Dromedary: The one-humped, or Arabian, camel.

Drought: A long, extremely dry period.

Dune: A hill or ridge of sand created by the wind.

Duricrusts: Hard, rocklike crusts on ridges that are formed by a chemical reaction caused by the combination of dew and minerals such as limestone.

E

Ecosystem: A network of organisms that have adapted to a particular environment.

Elfin forest: The upper cloud forest at about 10,000 feet (3,000 meters) which has trees that tend to be smaller, and twisted.

Emergents: The trees that stand taller than surrounding trees.

Epiphytes: Plants that grow on other plants with their roots exposed to the air. Sometimes called "air" plants.

Etermy: A current that moves against the regular current, usually in a circular motion.

Elevation: The height of an object in relation to sea level.

Emergent plants: Plants that are rooted at the bottom of a body of water that have top portions that appear to be above the water's surface.

Emergents: The very tallest trees in the rain forest, which tower above the canopy.

Engineered wood: Manufactured wood products composed of particles of several types of wood mixed with strong glues and preservatives.

Epilimnion: The layer of warm or cold water closest to the surface of a large lake.

Epipelagic zone: An oceanic zone based on depth that reaches down to 650 feet (200 meters).

Epiphytes: Plants that grow on other plants or hang on them for physical support.

Ergs: Arabian word for vast seas of sand dunes, especially those found in the Sahara.

Erosion: Wearing away of the land.

Estivation: An inactive period experienced by some animals during very hot months.

Estuary: The place where a river traveling through lowlands meets the ocean in a semi-enclosed area.

Euphotic zone: The zone in a lake where sunlight can reach.

Eutrophication: Loss of oxygen in a lake or pond because increased plant growth has blocked sunlight.

F

Fast ice: Ice formed on the surface of the ocean between pack ice and land.

Faults: Breaks in Earth's crust caused by earthquake action.

Fell-fields: Bare rock-covered ground in the alpine tundra.

Fen: A bog that lies at or below sea level and is fed by mineral-rich ground-water.

First-generation stream: The type of stream on which a branching network is based; a stream with few tributaries. Two first-generation streams join to form a second-generation stream and so on.

Fish farms: Farms in which fish are raised for commercial use; also called hatcheries.

Fjords: Long, narrow, deep arms of the ocean that project inland.

Flash flood: A flood caused when a sudden rainstorm fills a dry riverbed to overflowing.

Floating aquatic plant: A plant that floats either partly or completely on top of the water.

Flood: An overflow caused when more water enters a river or stream than its channel can hold at one time.

Floodplain: Low-lying, flat land easily flooded because it is located next to streams and rivers.

Food chain: The transfer of energy from organism to organism when one organism eats another.

Food web: All of the possible feeding relationships that exist in a biome.

Forbs: A category of flowering, broadleaved plants other than grasses that lack woody stems.

Forest: A large number of trees covering not less than 25 percent of the area where the tops of the trees interlock, forming a canopy at maturity.

Fossil fuels: Fuels made from oil and gas that formed over time from sediments made of dead plants and animals.

Fossils: Remains of ancient plants or animals that have turned to stone.

Freshwater lake: A lake that contains relatively pure water and relatively little salt or soda.

Freshwater marsh: A wetland fed by freshwater and characterized by poorly drained soil and plant life dominated by nonwoody plants.

Freshwater swamp: A wetland fed by freshwater and characterized by poorly drained soil and plant life dominated by trees.

Friction: The resistance to motion when one object rubs against another.

Fringing reef: A type of coral reef that develops close to the land; no lagoon separates it from the shore.

Frond: A leaflike organ found on all species of kelp plants.

Fungi: Plantlike organisms that cannot make their own food by means of photosynthesis; instead they grow on decaying organic matter or live as parasites on a host.

G

Geyser: A spring heated by volcanic action. Some geysers produce enough steam to cause periodic eruptions of water.

Glacial moraine: A pile of rocks and sediments created as a glacier moves across an area.

Global warming: Warming of Earth's climate that may be speeded up by air pollution.

Gorge: A deep, narrow pass between mountains.

Grassland: A biome in which the dominant vegetation is grasses rather than trees or tall shrubs.

Grazers: Herbivorous animals that eat low-growing plants such as grass.

Ground birds: Birds that hunt food and make nests on the ground or close to it.

Groundwater: Freshwater stored in rock layers beneath the ground.

Gulf: A large area of the ocean partly enclosed by land; its opening is called a strait.

Gymnosperms: Trees that produce seeds that are often collected together into cones; most conifers are gymnosperms.

Gyre: A circular or spiral motion.

H

Hadal zone: An oceanic zone based on depth that reaches from 20,000 to 35,630 feet (6,000 to 10,860 meters).

Hardwoods: Woods usually produced by deciduous trees, such as oaks and elms.

Hatcheries: Farms in which fish are raised for commercial use; also called fish farms.

Headland: An arm of land made from hard rock that juts out into the ocean after softer rock has been eroded away by the force of tides and waves.

Headwaters: The source of a river or stream.

Herbicides: Poisons used to control weeds or any other unwanted plants.

Herbivore: An animal that eats only plant matter.

Herders: People who raise herds of animals for food and other needs; they may also raise some crops but are usually not dependent upon them.

Hermaphroditic: Term used to describe an animal or plant in which reproductive organs of both sexes are present in one individual.

Hibernation: An inactive period experienced by some animals during very cold months.

High tide: A rising of the surface level of the ocean caused by Earth's rotation and the gravitational pull of the sun and moon.

Holdfast: A rootlike structure by which kelp plants anchor themselves to rocks or the seafloor.

Hummocks: 1. Rounded hills or ridges, often heavily wooded, that are higher than the surrounding area; 2. Irregularly shaped ridges formed when large blocks of ice hit each other and one slides on top of the other; also called hammocks.

Humus: The nutrient-rich, spongy matter produced when the remains of plants and animals are broken down to form soil.

Hunter-gatherers: People who live by hunting animals and gathering nuts, berries, and fruits; normally, they do not raise crops or animals.

Hurricane: A violent tropical storm that begins over the ocean.

Hydric soil: Soil that contains a lot of water but little oxygen.

Hydrologic cycle: The manner in which molecules of water evaporate, condense as clouds, and return to Earth as precipitation.

Hydrophytes: Plants that are adapted to grow in water or very wet soil.

Hypolimnion: The layer of warm or cold water closest to the bottom of a large lake.

Hypothermia: A lowering of the body temperature that can result in death.

I

Insecticides: Poisons that kill insects.

Insectivores: Plants and animals that feed on insects.

Intermittent stream: A stream that flows only during certain seasons.

Interrupted stream: A stream that flows aboveground in some places and belowground in others.

Intertidal zone: The seashore zone covered with water during high tide and dry during low tide; also called the middle, or the littoral, zone.

Invertebrates: Animals without a backbone.

K

Kelp: A type of brown algae that usually grows on rocks in temperate water.

Kettle: A large pit created by a glacier that fills with water and becomes a pond or lake.

Kopjes: Small hills made out of rocks that are found on African grasslands.

L

Labrador Current: An icy Arctic current that mixes with warmer waters off the coast of northeastern Canada.

Lagoon: A large pool of seawater cut off from the ocean by a bar or other landmass.

Lake: A usually large body of inland water that is deep enough to have two distinct layers based on temperature.

Latitude: A measurement on a map or globe of a location north or south of the equator. The measurements are made in degrees, with the equator, or dissecting line, being zero.

Layering: Tree reproduction that occurs when a branch close to the ground develops roots from which a new tree grows.

Levee: High bank of sediment deposited by a very silty river.

Lichens: Plantlike organisms that are combinations of algae and fungi. The algae produces the food for both by means of photosynthesis.

Limnetic zone: The deeper, central region of a lake or pond where no plants grow.

Littoral zone: The area along the shoreline that is exposed to the air during low tide; also called intertidal zone.

Longshore currents: Currents that move along a shoreline.

Lowland rain forest: Rain forest found at elevations up to 3,000 feet (900 meters).

Low tide: A lowering of the surface level of the ocean caused by Earth's rotation and the gravitational pull of the sun and moon.

M

Macrophytic: Term used to describe a large plant.

Magma: Molten rock from beneath Earth's crust.

Mangrove swamp: A coastal saltwater swamp found in tropical and subtropical areas.

Marine: Having to do with the oceans.

Marsh: A wetland characterized by poorly drained soil and by plant life dominated by nonwoody plants.

Mature stream: A stream with a moderately wide channel and sloping banks.

Meandering stream: A stream that winds snakelike through flat countryside.

Mesopelagic zone: An oceanic zone based on depth that ranges from 650 to 3,300 feet (200 to 1,000 meters).

Mesophytes: Plants that live in soil that is moist but not saturated.

Mesophytic: Term used to describe a forest that grows where only a moderate amount of water is available.

Mid-ocean ridge: A long chain of mountains that lies under the World Ocean.

Migratory: Term used to describe animals that move regularly from one place to another in search of food or to breed.

Mixed-grass prairie: North American grassland with a variety of grass species of medium height.

Montane rain forest: Mountain rain forest found at elevations between 3,000 and 10,500 feet (900 and 3,200 meters).

Mountain blanket bogs: Blanket bogs in Ireland that are more than 656 feet (200 meters) above sea level.

Mouth: The point at which a river or stream empties into another river, a lake, or an ocean.

Muck: A type of gluelike bog soil formed when fully decomposed plants and animals mix with wet sediments.

Muskeg: A type of wetland containing thick layers of decaying plant matter.

Mycorrhiza: A type of fungi that surrounds the roots of conifers, helping them absorb nutrients from the soil.

N

Neap tides: High tides that are lower and low tides that are higher than normal when the Earth, sun, and moon form a right angle.

Nekton: Animals that can move through the water without the help of currents or wave action.

Neritic zone: That portion of the ocean that lies over the continental shelves.

Nomads: People or animals who have no permanent home but travel within a well-defined territory determined by the season or food supply.

North Atlantic Drift: A warm ocean current off the coast of northern Scandinavia.

Nutrient cycle: Natural cycle in which mineral nutrients are absorbed from the soil by tree roots and returned to the soil when the tree dies and the roots decay.

O

Oasis: A fertile area in the desert having a water supply that enables trees and other plants to grow there.

Ocean: The large body (or bodies) of saltwater that covers more than 70 percent of Earth's surface.

Oceanography: The exploration and scientific study of the oceans.

Old stream: A stream with a very wide channel and banks that are nearly flat.

Omnivore: Organism that eats both plants and animals.

Ooze: Sediment formed from the dead tissues and waste products of marine plants and animals.

Oxbow lake: A curved lake formed when a river abandons one of its bends.

Oxygen cycle: Natural cycle in which the oxygen taken from the air by plants and animals is returned to the air by plants during photosynthesis.

P

Pack ice: A mass of large pieces of floating ice that have come together on an open ocean.

Pamir: A high altitude grassland in Central Asia.

Pampa: A tropical grassland found in South America.

Pampero: A strong, cold wind that blows down from the Andes Mountains and across the South American pampa.

Pantanal: A wet savanna that runs along the Upper Paraguay River in Brazil.

Parasite: An organism that depends upon another organism for its food or other needs.

Passive margin: A continental margin free of earthquake or volcanic action, and in which few changes take place.

Peat: A type of soil formed from slightly decomposed plants and animals.

Peatland: Wetlands characterized by a type of soil called peat.

Pelagic zone: The water column of the ocean.

Perennials: Plants that live at least two years or seasons, often appearing to die but returning to "life" when conditions improve.

Permafrost: Permanently frozen topsoil found in northern regions.

Permanent stream: A stream that flows continually, even during a long, dry season.

Pesticides: Poisons used to kill anything that is unwanted and is considered a pest.

Phosphate: An organic compound used in making fertilizers, chemicals, and other commercial products.

Photosynthesis: The process by which plants use the energy from sunlight to change water (from the soil) and carbon dioxide (from the air) into the sugars and starches they use for food.

Phytoplankton: Tiny, one-celled algae that float on ocean currents.

Pingos: Small hills formed when groundwater freezes.

Pioneer trees: The first trees to appear during primary succession; they include birch, pine, poplar, and aspen.

Plankton: Plants or animals that float freely in ocean water; from the Greek word meaning "wanderer."

Plunge pool: Pool created where a waterfall has gouged out a deep basin.

Pocosin: An upland swamp whose only source of water is rain.

Polar climate: A climate with an average temperature of not more than 50°F (10°C) in July.

Polar easterlies: Winds occurring near Earth's poles that blow in an easterly direction.

Pollination: The carrying of pollen from the male reproductive part of a plant to the female reproductive part of a plant so that reproduction may occur.

Polygons: Cracks formed when the ground freezes and contracts.

Pond: A body of inland water that is usually small and shallow and has a uniform temperature throughout.

Pool: A deep, still section in a river or stream.

Prairie: A North American grassland that is defined by the stature of grass groups contained within (tall, medium, and short).

Prairie potholes: Small marshes no more than a few feet deep.

Precipitation: Rain, sleet, or snow.

Predator: An animal that kills and eat other animals.

Primary succession: Period of plant growth that begins when nothing covers the land except bare sand or soil.

Producers: Plants and other organisms in the food web of a biome that are able to make food from nonliving materials, such as the energy from sunlight.

Profundal zone: The zone in a lake where no more than 1 percent of sunlight can penetrate.

Puna: A high-altitude grassland in the Andes Mountains of South America.

R

Rain forest: A tropical forest, or jungle, with a warm, wet climate that supports year-round tree growth.

Raised bogs: Bogs that grow upward and are higher than the surrounding area.

Rapids: Fast-moving water created when softer rock has been eroded to create many short drops in the channel; also called white water.

Reef: A ridge or wall of rock or coral lying close to the surface of the ocean just off shore.

Rhizomes: Plant stems that spread out underground and grow into a new plant that breaks above the surface of the soil or water.

Rice paddy: A flooded field in which rice is grown.

Riffle: A stretch of rapid, shallow, or choppy water usually caused by an obstruction, such as a large rock.

Rill: Tiny gully caused by flowing water.

Riparian marsh: Marsh usually found along rivers and streams.

Rip currents: Strong, dangerous currents caused when normal currents moving toward shore are deflected away from it through a narrow channel; also called riptides.

River: A natural flow of running water that follows a well-defined, permanent path, usually within a valley.

River system: A river and all its tributaries.

S

Salinity: The measure of salts in ocean water.

Salt lake: A lake that contains more than 0.1 ounce of salt per quart (3 grams per liter) of water.

Salt pan: The crust of salt left behind when a salt or soda lake or pond dries up.

Saltwater marsh: A wetland fed by saltwater and characterized by poorly drained soil and plant life dominated by nonwoody plants.

Saltwater swamp: A wetland fed by saltwater and characterized by poorly drained soil and plant life dominated by trees.

Saturated: Soaked with water.

Savanna: A grassland found in tropical or subtropical areas, having scattered trees and seasonal rains.

Scavenger: An animal that eats decaying matter.

School: Large gathering of fish.

Sea: A body of saltwater smaller and shallower than an ocean but connected to it by means of a channel; sea is often used interchangeably with ocean.

Seafloor: The ocean basins; the area covered by ocean water.

Sea level: The height of the surface of the sea. It is used as a standard in measuring the heights and depths of other locations such as mountains and oceans.

Seamounts: Isolated volcanoes on the ocean floor that do not break the surface of the ocean.

Seashore: The strip of land along the edge of an ocean.

Secondary succession: Period of plant growth occurring after the land has been stripped of trees.

Sediments: Small, solid particles of rock, minerals, or decaying matter carried by wind or water.

Seiche: A wave that forms during an earthquake or when a persistent wind pushes the water toward the downwind end of a lake.

Seif dunes: Sand dunes that form ridges lying parallel to the wind; also called longitudinal dunes.

Shelf reef: A type of coral reef that forms on a continental shelf having a hard, rocky bottom. A shallow body of water called a lagoon may be located between the reef and the shore.

Shoals: Areas where enough sediments have accumulated in the river channel that the water is very shallow and dangerous for navigation.

Shortgrass prairie: North American grassland on which short grasses grow.

Smokers: Jets of hot water expelled from clefts in volcanic rock in the deep-seafloor.

Soda lake: A lake that contains more than 0.1 ounce of soda per quart (3 grams per liter) of water.

Softwoods: Woods usually produced by coniferous trees.

Sonar: The use of sound waves to detect objects.

Soredia: Algae cells with a few strands of fungus around them.

Source: The origin of a stream or river.

Spit: A long narrow point of deposited sand, mud, or gravel that extends into the water.

Spores: Single plant cells that have the ability to grow into a new organism.

Sport fishing: Fishing done for recreation.

Spring tides: High tides that are higher and low tides that are lower than normal because the Earth, sun, and moon are in line with one another.

Stagnant: Term used to describe water that is unmoving and contains little oxygen.

Star-shaped dunes: Dunes created when the wind comes from many directions; also called stellar dunes.

Steppe: A temperate grassland found mostly in southeast Europe and Asia.

Stone circles: Piles of rocks moved into a circular pattern by the expansion of freezing water.

Straight stream: A stream that flows in a straight line.

Strait: The shallow, narrow channel that connects a smaller body of water to an ocean.

Stream: A natural flow of running water that follows a temporary path that is not necessarily within a valley; also called brook or creek. Scientists often use the term to mean any natural flow of water, including rivers.

Subalpine forest: Mountain forest that begins below the snow line.

Subduction zone: Area where pressure forces the seafloor down and under the continental margin, often causing the formation of a deep ocean trench.

Sublittoral zone: The seashore's lower zone, which is underwater at all times, even during low tide.

Submergent plant: A plant that grows entirely beneath the water.

Subpolar gyre: The system of currents resulting from winds occurring near the poles of Earth.

Subsistence fishing: Fishing done to obtain food for a family or a community.

Subtropical: Term used to describe areas bordering the equator in which the weather is usually warm.

Subtropical gyre: The system of currents resulting from winds occurring in subtropical areas.

Succession: The process by which one type of plant or tree is gradually replaced by others.

Succulents: Plants that appear thick and fleshy because of stored water.

Sunlit zone: The uppermost part of the ocean that is exposed to light; it reaches down to about 650 feet (200 meters) deep.

Supralittoral zone: The seashore's upper zone, which is never underwater, although it may be frequently sprayed by breaking waves; also called the splash zone.

Swamp: A wetland characterized by poorly drained soil, stagnant water, and plant life dominated by trees.

Sward: Fine grasses that cover the soil.

Swell: Surface waves that have traveled for long distances and become more regular in appearance and direction.

T

Taiga: Coniferous forest found in areas bordering the Arctic tundra; also called boreal forest.

Tallgrass prairie: North American grassland on which only tall grass species grow.

Tannins: Chemical substances found in the bark, roots, seeds, and leaves of many plants and used to soften leather.

Tectonic action: Movement of Earth's crust, as during an earthquake.

Temperate bog: Peatland found in temperate climates.

Temperate climate: Climate in which summers are hot and winters are cold, but temperatures are seldom extreme.

Temperate zone: Areas in which summers are hot and winters are cold but temperatures are seldom extreme.

Thermal pollution: Pollution created when heated water is dumped into the ocean. As a result, animals and plants that require cool water are killed.

Thermocline: Area of the ocean's water column, beginning at about 1,000 feet (300 meters), in which the temperature changes very slowly.

Thermokarst: Shallow lakes in the Arctic tundra formed by melting permafrost; also called thaw lakes.

Tidal bore: A surge of ocean water caused when ridges of sand direct the ocean's flow into a narrow river channel, sometimes as a single wave.

Tidepools: Pools of water that form on a rocky shoreline during high tide and that remain after the tide has receded.

Tides: Rhythmic movements, caused by Earth's rotation and the gravitational pull of the sun and moon, that raise or lower the surface level of the oceans.

Tombolo: A bar of sand that has formed between the beach and an island, linking them together.

Trade winds: Winds occurring both north and south of the equator to about 30 degrees latitude; they blow primarily east.

Transverse dunes: Sand dunes lying at right angles to the direction of the wind.

Tree: A large woody perennial plant with a single stem, or trunk, and many branches.

Tree line: The elevation above which trees cannot grow.

Tributary: A river or stream that flows into another river or stream.

Tropical: Term used to describe areas close to the equator in which the weather is always warm.

Tropical tree bog: Bog found in tropical climates in which peat is formed from decaying trees.

Tropic of Cancer: A line of latitude about 25 degrees north of the equator.

Tropic of Capricorn: A line of latitude about 25 degrees south of the equator.

Tsunami: A huge wave or upwelling of water caused by undersea earthquakes that grows to great heights as it approaches shore.

Tundra: A cold, dry, windy region where trees cannot grow.

Turbidity current: A strong downward-moving current along the continental margin caused by earthquakes or the settling of sediments.

Turbine: An energy-producing engine.

Tussocks: Small clumps of vegetation found in marshy tundra areas.

Typhoon: A violent tropical storm that begins over the ocean.

U

Understory: A layer of shorter, shade-tolerant trees that grow under the forest canopy.

Upstream: The direction from which a river or stream is flowing.

Upwelling: The rising of water or molten rock from one level to another.

V

Veld: Temperate grassland in South Africa.

Venom: Poison produced by animals such as certain snakes and spiders.

Vertebrates: Animals with a backbone.

W

***Wadi*:** The dry bed of a stream that flows only after rain; also called a wash or an *arroyo.*

Warm-bodied fish: Fish that can maintain a certain body temperature by means of a special circulatory system.

Wash: The dry bed of stream that flows only after rain; also called an *arroyo* or a *wadi.*

Water column: All of the waters of the ocean, exclusive of the sea bed or other landforms.

Water cycle: Natural cycle in which trees help prevent water runoff, absorb water through their roots, and release moisture into the atmosphere through their leaves.

Waterfall: A cascade of water created when a river or stream falls over a cliff or erodes its channel to such an extent that a steep drop occurs.

Water table: The level of groundwater.

Waves: Rhythmic rising and falling movements in the water.

Westerlies: Winds occurring between 30 degrees and 60 degrees latitude; they blow in a westerly direction.

Wet/dry cycle: A period during which wetland soil is wet or flooded followed by a period during which the soil is dry.

Wetlands: Areas that are covered or soaked by ground or surface water often enough and long enough to support plants adapted for life under those conditions.

Wet meadows: Freshwater marshes that frequently dry up.

X

Xeriscaping: Landscaping method that uses drought tolerant plants and efficient watering techniques.

Xerophytes: Plants adapted to life in dry habitats or in areas like salt marshes or bogs.

Y

Young stream: A stream close to its headwaters that has a narrow channel with steep banks.

Z

Zooplankton: Animals, such as jellyfish, corals, and sea anemones, that float freely in ocean water.

Coniferous forest

A tree is a large woody plant with one main stem, or trunk, and many branches that lives year after year. A forest is a large number of trees covering at least 25 percent of an area where the tops of the trees, called crowns, interlock to form an enclosure or canopy at maturity. Coniferous (koh-NIH-fuhr-uhs) forests primarily contain conifer trees including spruces, pines, firs, larches, cedars, and junipers. Almost all coniferous trees, such as pines and firs, bear their seeds inside cones. Most also have stiff, flattened or needlelike leaves that usually remain green all winter.

Coniferous forests are found in Asia, primarily in Siberia, China, Korea, and Japan, and on the slopes of the Himalaya and Hindu Kush Mountains. In Europe, they cover much of Scandinavia and the coast of the Baltic Sea and are found on the primary mountain ranges—the Alps, the Vosges, and the Carpathians. In North America, coniferous forests stretch across the northern part of the continent from Alaska to Newfoundland; down into Washington, Oregon, and California; and along the Cascades, the Sierra Nevadas, and the Rocky Mountains. In the Southern Hemisphere, they are found in Mexico, along the western coast of South America, in parts of Argentina and Brazil, in parts of the Australasia region, and in portions of Africa.

How Coniferous Forests Develop

The first forests evolved during Earth's prehistoric past. Since then, all forests have developed by means of a process called succession.

The first forests The first forests evolved from clubmosses, ferns, and other prehistoric plants, which, over time, adapted to the surrounding environment, and grew more treelike. Trees that preferred a warm, humid, tropical climate developed first, followed by those that gradually adapted to drier, cooler weather. Coniferous forests flourished during the Jurassic Period, about 160 million years ago.

WORDS TO KNOW

Boreal forest: A type of coniferous forest found in areas bordering the Arctic tundra. Also called taiga.

Clear-cutting: The cutting down of every tree in a selected area.

Deciduous: Term used to describe trees, such as oaks and elms, that lose their leaves during cold or very dry seasons.

Epiphytes: Plants that grow on other plants or hang on them for physical support.

Montane forest: The moist and cool sloped areas near mountains.

Muskeg: A type of wetland containing thick layers of decaying plant matter.

Pioneer trees: The first trees to appear during primary succession; they include birch, pine, poplar, and aspen.

Predator: An animal that kills and eat other animals.

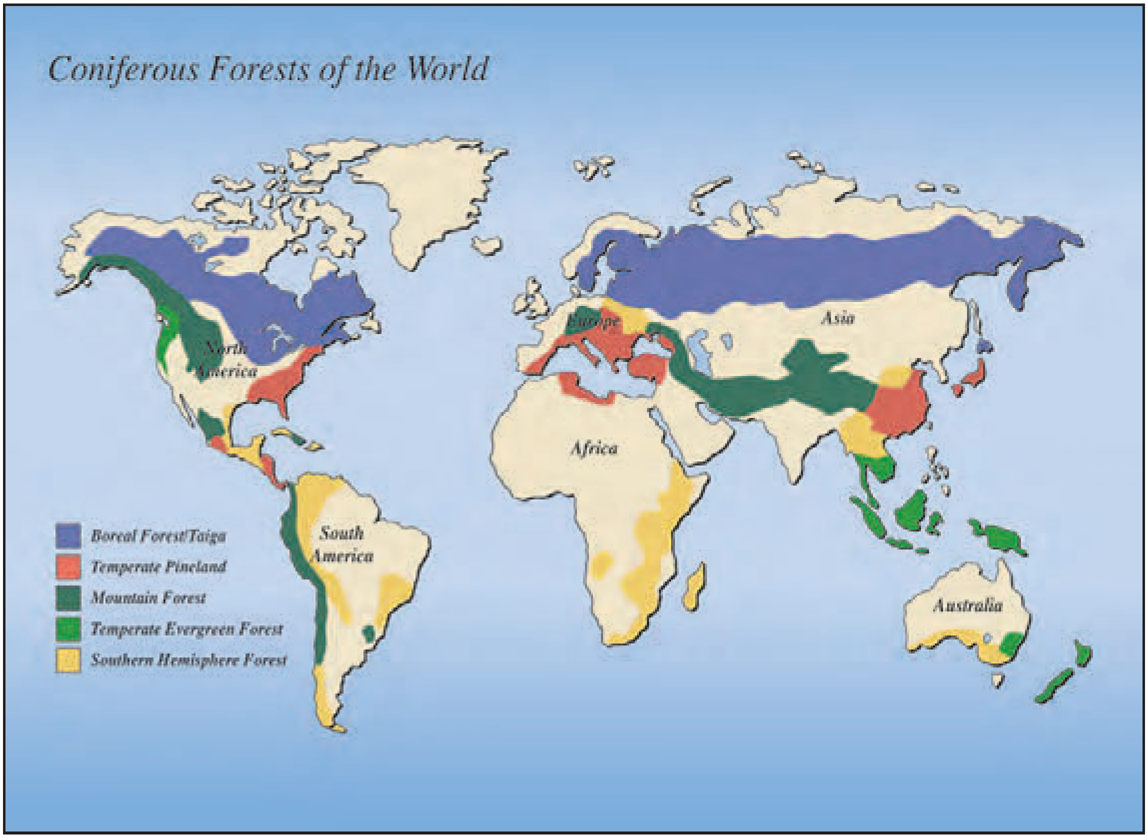
Succession: The process by which one type of plant or tree is gradually replaced by another.

Taiga: Coniferous forest found in areas bordering the Arctic tundra; also called boreal forest.

About one million years ago, during the Ice Ages, glaciers (slow-moving masses of ice) covered about one-third of the land surface of the Earth. Eventually, the glaciers retreated, but not before they had destroyed many of the world's forests and scoured the land of plants. Roughly twelve thousand years ago, trees began to repopulate the land that had been covered by ice. Spruce, larch, ash and birch trees were among the first species to make a comeback, preparing the way for other trees.

Succession Trees compete with one another for sunlight, water, and nutrients, thus a forest is constantly changing. The process by which one type of plant or tree is gradually replaced by others is called succession. During succession, different species of trees become dominant as time progresses and the environment changes. Succession began following the last Ice Age and continues today. It can occur naturally, when different species of trees become dominant as time progresses and the environment changes. It can also occur from natural disasters, such as forest fires.

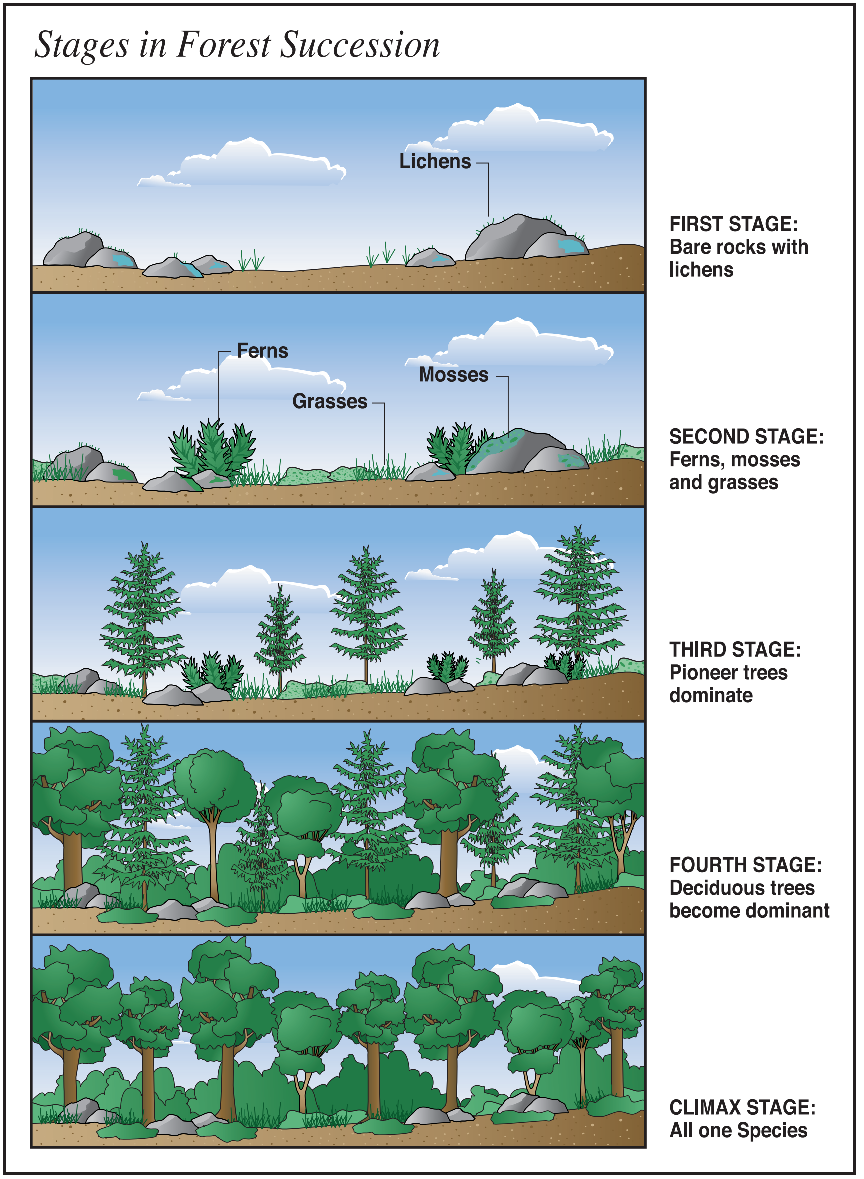
Primary succession Primary succession usually begins on bare soil or sand where no plants grew before. When the right amount of sunlight, moisture, and air temperatures are present, seeds begin to germinate (grow). These first plants are usually made up of the grasses and forbs (a non-woody broad-leaved plant) type. They continue to grow and eventually form meadows. Over time, and as conditions change, other plants



begin to grow such as shrubs and trees. These plants become dominant and replace or take over where the grasses and forbs originally grew.

As primary succession continues, "pioneer" trees begin to thrive. In North America, examples of pioneer trees include birch, pine, poplar, and aspen. They are all tall, sun-loving trees, and they quickly take over the meadow. However, they also change the environment by making shade. If conditions are right, a mixed forest of sun-loving and shade-loving trees may continue for many years. Eventually, more changes occur.

The climax forest Seedlings from pioneer trees do not grow well in shade; therefore, new pioneer trees do not grow. As the mature trees begin to die from old age, disease, and other causes, the broad-leaf, shade-loving trees become dominant. The shade from these trees can be too dense for their own seedlings as well. As a result, seedlings from the trees that prefer heavy shade, such as beech and sugar maple, begin to thrive and dominate



the forest. These trees produce such deep shade that only trees or plants that can survive in complete shade succeed there. When this happens, the result is a climax forest characteristic of a certain region, for example an oak-hickory forest in the eastern United States.

Few true climax forests actually exist because forests are dynamic and changes take place that interfere with stability. Fires, floods, high winds,

Fire in the forest

About 12,000,000 acres (4,800,000 hectares) of forest in the United States are damaged or destroyed by fire every year. Forest fires can spread as fast as 10 miles (15 kilometers) per hour downwind. Most forest fires are caused by humans and occur in coniferous forests, where both the air and the wood tend to be dry. Also, pine needles contain resin (sap), which burns easily.

Fires not only burn trees, but they also destroy other plant and animal life. Ground fires burn up organic material beneath the vegetation on the forest floor. Although ground fires move slowly, they do much damage. Fires that burn small vegetation and loose material are called surface fires. A crown fire is one that moves quickly through the tops of trees or shrubs.

Forests can actually benefit from fire. The huge fire in Yellowstone National Park in 1988 is an example. In the beginning, it was a controlled fire. The park's managers allowed it to burn naturally in order to restore the natural balance of the forest. The fire eventually got out of control and destroyed about 20 percent of the park. It left ashes rich in minerals such as calcium and phosphorous. These minerals promoted the growth of new plants, such as pine grass, that grows beneath Douglas firs and flowers only after a fire. The standing dead trees now attract certain types of birds, like the woodpecker and tree swallow. Smoke and heat killed harmful insects and parasitic fungi that endangered trees. The comparatively few animals that died provided food for other species. Many of the burned areas now support tree seedlings, as well as many other plants.

and people can all destroy a single tree or several acres of trees. Glaciers can mow them down; volcanoes can smother them with ash or molten rock or knock them over with explosive force. When this happens, the process of succession starts over.

Secondary succession When the land has been stripped of trees, it will eventually be covered with them again if left alone. This is called secondary succession and can take place more quickly than primary succession. Seeds from other forests in neighboring regions are blown by the wind or carried by animals to the site. The seeds take root and seedlings sprout restarting the process.

Kinds of Coniferous Forests

Forests can be classified in many ways. In general, coniferous forests are categorized as boreal/taiga, mountain, temperate evergreen, temperate pine, or Southern Hemisphere forests.

Boreal forest/taiga The word boreal (BOHR-ee-yuhl) means "northern," and taiga (TAY-guh) is a Russian word for "little sticks." Boreal forests, or

A conifer for St. Nick

The most popular tree used as a Christmas tree is the coniferous fir. Fir trees are cone-shaped and can grow between 30 and 150 feet (9 and 46 meters) tall. Their needles are very fragrant and remain on the tree for a long time after it has been cut. Most of the trees used for Christmas trees are not wild but are grown on tree plantations.

taiga, are found in regions bordering the Arctic tundra (a region so dry and cold that no trees can grow). These are the great northern forests of Canada, Alaska, Russia, and Scandinavia. They form some of the largest forest biomes in the world. About 11 percent of the Earth's land surface is considered to be taiga.

Trees in the boreal forest grow at higher latitudes (a distance north or south of the equator measured in degrees), usually between 45° and 70° North, than trees in any other type of forest. The most common are spruce, pine, and fir.

The boreal forest may be divided into three zones. The northernmost zone is the forest-tundra, where trees meet treeless land. Few species are able to survive here. The second zone is the lichen (LY-ken; an algae and fungi combination) woodland, or sparse taiga. Here, trees grow far apart and a lichen mat covers the forest floor. The southernmost region is the closed-canopy forest where many species of conifers grow close together and the forest floor is covered with mosses that grow well in shade.

Mountain coniferous forest Mountain coniferous forests are found on mountains below the permanent snowfields. They are located in the Rockies, Cascades, and Sierra Nevadas of North America; the Alps and Carpathians in Europe; and the Hindu Kush and Himalayas in Asia.

COMMON SOFTWOOD TREES

Europe	North America	South America
Austrian pine	Balasam fir	Alerce
Cedar	Cedar	Manio
European larch	Douglas fir	Monkey-puzzle tree (Chile pine)
Maritime pine	Larch	Parana pine
Norway spruce	Norway spruce	
Siberian yellow pine	Pine	
Silver fir	Sequoia	
Southern cypress		

Forests on the upper slopes just below the snowfields are called subalpine forests. At these higher elevations, where the weather is harshest, trees such as the bristlecone pine are long-lived but often stunted in growth. Lodgepole pines grow erect, but alpine firs grow close to the ground, as if shrinking from the harsh climate. Forests on the lower and middle slopes are called montane forests. In this more moderate climate conifers grow taller.

Trees common in mountain forests vary from region to region. In North America, Douglas fir, sierra redwood, and ponderosa pine predominate. Silver fir and larch are found in Europe, and chir pines, Himalayan firs, and morinda spruces grow in Asian forests.

Temperate evergreen forest Temperate evergreen forests grow in regions with moderate, humid climates. Summers are warm and winters may be cool, but temperatures are seldom extreme. In North America, these forests range along the Pacific coast from Alaska and British Columbia to west central California, where they are sometimes called temperate rain forests. Common tree species include western hemlock, western red cedar, Douglas fir, and coast redwood.

The giant redwoods of California and southern Oregon are the tallest trees in America, many exceeding 300 feet (91 meters) in height and measuring up to 22 feet (7 meters) in circumference. The tallest individual tree, Hyperion, measures 379.1 feet (115.5 meters). A species of redwoods found on the western slopes of the Sierra Nevada Mountains, giant Sequoias, are among the world's oldest trees. One Sequoia, named

COMMON SOFTWOOD TREES

Africa	Asia	Australia	Central America
Pencil cedar	Benguet pine	Celery-top pine	Caribbean pitch pine
Podo	Chir	Kauri	Yellowwood
Radiata pine	Hemlock	Radiata pine	
Thuya	Himalayan silver fir	Rimu	
Yellowwood	I-Ching pine		
	Indian juniper		
	Japanese fir		
	Pencil cedar		
	Sugi		

The Bachelor and the Three Graces are redwoods in Yosemite National Park. IMAGE COPYRIGHT CHEE-ONN LEONG, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

"General Sherman", stands 275 feet (84 meters) tall, has a diameter of 36.5 feet (11 meters), and may be as many as 2,000-2,300 years old. It is also the largest tree by volume in the world, measuring 52,500 cubic feet (1,515 cubic meters).

Where winters are mildest, temperate evergreen forests often contain broad-leaved evergreen trees. The humid conditions help the growth of moss and other moisture-loving plants on the forest floor.

Temperate pine forest Temperate pinelands grow in hilly or upland regions with warm, dry climates. In the United States, they are found in southern California and in the region stretching from New Jersey to southern Florida and west to Texas. They also occur in Mexico, China, and throughout the regions bordering the Mediterranean Sea.

Southern hemisphere coniferous forest Coniferous forests located primarily in the Southern Hemisphere, including those of Africa, Southeast Asia, Australia, and New Zealand, are not the same as forests in the Northern Hemisphere. In general, the native coniferous trees are smaller and their leaves have different forms. Members of the monkey-puzzle family are common. Most are found in the mountains or high plateaus.

In South America, native conifers include the Parana pine, monkey-puzzle, Patagonian cedar, and Chilean cedar. In Australia, bunya pine, white cypress pine, and hoop pine grow. Forests of kauri pine grow in New Zealand, and the South African yellowwood is found in southern Africa. The Norfolk Island pine, native to the island of that name, is a popular ornamental tree worldwide.

Climate

The climate of a coniferous forest depends upon where it is located. In general, the farther north the latitude, the cooler the climate. The presence of mountain ranges and oceans also affects the climate of

Cedar

Different conifer genera have species called cedar. They are durable and fragrant woods that have been used by humans since at least 2000 BC. True cedars (*Cedrus*) are in the pine family. They do not easily rot and are resistant to fire and high winds. Great cedar forests were once found in Algeria, Morocco, the Himalayas, the Pacific Northwest in the United States, and Lebanon in the Middle East. The Phoenicians, who lived in Lebanon, were excellent carpenters and sold much of their wood.

Some of the Phoenicians' best customers were ancient Egyptians who lived in the Nile Valley where few trees grow. Because cedar is so strong, the Egyptians used it to construct homes and other buildings and for wooden rollers that moved huge stones into place for the construction of the pyramids. Cedar sawdust was used in the process of mummifying the dead, and the resin was used for embalming and coating coffins.

Cedar was also used in the construction of King Solomon's temple in Jerusalem between 965 to 926 BC. The Romans used it to build ships, and the Roman emperor Hadrian brought about legislation to conserve the cedars of Lebanon between 117 and 138 AD.

The North American western red cedar (*Thuja plicata*) is a member of the cypress family (Cupressaceae). Native Americans on the Pacific coast made clothing and baskets from the bark, rope from the branches, and canoes and lodges from the trunks. Various types of Cupressaceae have also long been valued in Japan, where conservation was first practiced during the sixteenth century. These trees form stands more than 1,000 years old.

Although most of the once mighty cedar forests are gone, the western red cedar and the Atlantic white cedar (*Chamaecyparis thyoides*, also a member of the cypress family) is still used for building boats and homes. The cedar used in clothes closets and chests, where the aroma of cedar is said to repel cloth-eating moths, comes from junipers (*Juniperus*) and eastern red cedar (*J.virginiana*).

an area. In Japan, for example, Siberian air masses bring severe winters to some forests, while other forests are influenced by warm ocean currents, and have a more tropical climate.

Boreal forest/taiga The most severe climate is found in the boreal forest, or taiga, where temperatures are below freezing for more than half of the year. Winter temperatures range from -65° to 30°F (-54° to -1°C), and summer temperatures from 20° to 70°F (-7° to 21°C). However, because the taiga is a land of extremes, temperatures can drop as low as -76°F (-60°C) in winter or climb as high as 104°F (40°C) in summer.

Record holding trees!

Not to be outdone by the redwoods with their reputation as the world's tallest trees, the Mexican cypress has its own world record. An outstanding individual cypress in Tule, Mexico, known as "El Gigante," is the world's fattest tree. Although El Gigante is only 140 feet (43 meters) tall, the circumference of its trunk measures 115 feet (35 meters).

Most of the precipitation (rain, snow, or sleet) in the boreal forest comes from summer rain, which averages 12 to 33 inches (30 to 85 centimeters) per year.

Mountain coniferous forest Mountain forests face cold, dry climates and high winds. The higher the elevation, the harsher the conditions. Scientists estimate that for every 300 feet (91 meters) in elevation, the temperature drops more than 1°F. On Alaskan mountains, temperatures in January average about 8°F (-13°C) and in July only 47°F (8°C).

In general, northern hemisphere forests found on the northern side of mountains are shaded from the sun and the air is cooler. The forests receive more rainfall and have denser stands (groups) of trees and other plants. Forests on the southern side of mountains are drier, warmer and have less vegetation.

Temperate evergreen forest The redwood and Pacific Northwestern forests have a climate that is moderated by the Pacific Ocean and the coastal mountain ranges. In the Olympic Rain Forest in Washington, for example, the temperature is always above freezing in winter and is seldom higher than 85°F (29°C) in summer. Up to 145 inches (368 centimeters) of rain fall annually.

Temperate pine forest In the Mediterranean and parts of California, winters are warm and wet, while summers are hot and dry. Droughts (extremely dry periods) may be common. In the Mediterranean region, for example, winter temperatures usually do not fall below freezing.

Southern hemisphere coniferous forest The climate in Southern Hemisphere forests varies, depending upon where they are located. In the tropics (the regions around the equator), where the forests are at higher elevations, clouds of mist may blanket them creating cool and damp conditions. In more temperate regions, such as in the mountains of Chile, conditions are drier and colder.

Geography of Coniferous Forests

The geography of coniferous forests includes landforms, elevation, soil, mineral resources, and water resources.

The oldest of all living things?

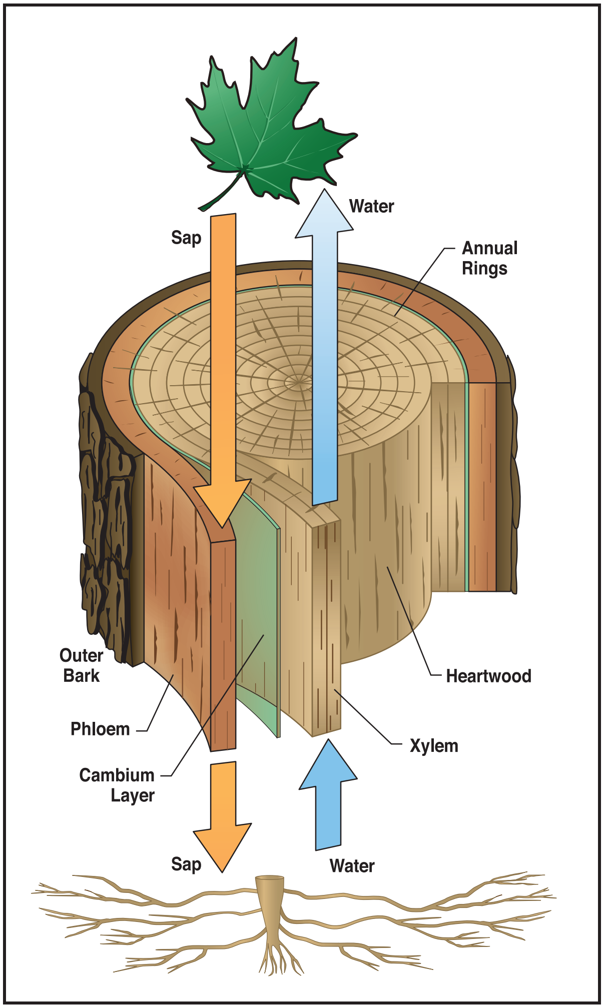
High in the Rocky Mountains of southwest California, Nevada, Utah, Arizona, New Mexico, and Colorado live the bristlecone pines, the oldest trees in the world. A tree cut down on Wheeler Ridge contained 4,900 rings of growth, and the oldest living specimen, the Methuselah Tree of California, is estimated at 4,800 years old. These twisted, ancient trees exist only at high altitudes—between 8,000 and 10,000 feet (2,432 and 3,040 meters)—and seldom grow more than 30 feet (9 meters) tall.

Landforms Coniferous forest landforms vary, depending upon the location, and may include mountains, valleys, rolling hills, or flat plateaus. The boreal forest landscape is dotted with wetlands, lakes, and ponds. Unique to the Canadian and Alaskan forest is the muskeg, a type of bog or marsh with thick layers of decaying plant matter. The muskeg looks like moss-covered ground, but is actually so wet and spongy that hikers may sink while passing through. When the muskeg freezes in winter, irregularly shaped ridges, called hummocks, may form.

Treeless hollows are often found in coniferous forests in the Northern Hemisphere. These hollows are usually created when glaciers move over the area and destroy the trees. The glaciers also leave behind basins that eventually fill with water and become lakes. Streams and rivers are common in these forests as well.

Elevation Coniferous forests grow at different elevations throughout the world, from sea level (the average height of the surface of the sea) to more than 15,000 feet (4,600 meters) above sea level. Temperate rain forests along the northern Pacific coast are usually found below 2,700 feet (820 meters). The mountain forests in the Pacific Northwest range between 3,000 and 7,000 feet (910 and 2,100 meters), and those in the Rocky Mountains between 4,000 and 7,500 feet (1,200 and 2,300 meters). The giant Sequoias in the Sierra Nevada Mountains grow between 4,500 and 8,000 feet (1,400 and 2,400 meters). Subalpine forests in the Sierra Nevadas are found between 6,500 and 11,000 feet (2,000 and 3,400 meters) and in the Rockies between 7,500 and 11,500 feet (2,300 and 3,500 meters).

In Peru, mountain forests begin around 9,800 feet (3,000 meters) and subalpine forests grow to an altitude of 15,000 feet (4,500 meters). In central Japan, mountain forests are common above 6,560 feet (2,000 meters), however, on the island of Hokkaido, coniferous forests are



The parts of a tree, including the annual rings and the direction of water and sap.

found at sea level. Himalayan conifers dominate below 10,000 feet (3,000 meters) and Himalayan firs above that point.

Soil The presence of trees protect soil from erosion by holding it in place with their roots. Even fallen trees are important in conserving and cycling nutrients back into the soil and in reducing erosion. Trees also create windbreaks that help prevent topsoil from being blown away. A coniferous forest's soil is acidic because the needles of coniferous trees have high acid content. The soil is also affected by both climate and location.

In the boreal forest, for example, soil is poorly developed because of the cold temperatures. In areas adjacent to tundra, a layer of permafrost (permanently frozen soil) prevents rain and melting snow from being absorbed deep into the ground. The topsoil is soggy because the moisture stays close to the surface. Cold temperatures are also responsible for the slow rate of decomposition of dead plants and animals, which means that soil forms slowly and there are not a lot of soil-mixing creatures.

Mountain soil is usually dry because the sloping terrain allows rain and melting snow to run off. This runoff washes away nutrients. The soil often makes up only a thin layer over a rocky foundation. As a result, tree roots do not penetrate deeply.

In the temperate evergreen forests of North America, the soil is often reddish in color and high in aluminum and iron. Decomposition takes place rapidly because of the high moisture content. This richer soil supports more plant growth on the forest floor.

Broad-leaved evergreens—the trees-in-between

In northern climates, most broad-leaved trees lose their leaves in the autumn. However, some that live in climates where winters are mild but wet and summers are hot and dry remain green all year long. They are not conifers, because they are flowering plants that produce seeds enclosed in fruits, but they have learned to conserve moisture as conifers do by producing small leaves that they retain for several years. In effect, they are somewhere in-between conifers and deciduous trees, having characteristics of both. Common species include the olive tree of the Mediterranean region, the eucalyptus of Australia and South America, the cork oak of Spain and Portugal, and the canyon live oak of California.

Certain broad-leaved evergreens have other unusual characteristics. For example, the cork oak produces bark as thick as 1 foot (30 centimeters), which can be harvested and used for corks. Another example is the eucalyptus, the giant tree of the southern hemisphere. Called the "giant gum" in Australia, some trees attain heights of 300 feet (91 meters), rivaling the giant Sequoias of the Northern Hemisphere.

Mineral resources Mineral resources found deep in the ground below coniferous forests began developing millions of years ago. As ancient trees died and soil gradually built up over them, their remains were compressed and evolved into coal, oil, and natural gas in a process that takes millions of years.

In northern Russian forests, coal, oil, and gas are found beneath the forest floor. In other parts of the taiga, aluminum is mined. In the province of Cita in far eastern Russia, mining and primary-ore processing dominate the economy. Gold, tin, tungsten, molybdenum, and lead are among the many minerals found there.

Gold was often mined from the rivers and streams that run through the forests of the Pacific northwest in the United States and Canada, and nickel was occasionally found in the northern forest of Manitoba, Canada.

A job in the woods

Forestry is the profession that deals with development and management of forests. The main objective is to ensure that there will always be trees and a supply of timber. Foresters are also involved with the conservation of soil, water, and wildlife resources, and with preserving land for recreation. By the mid-1990s, there were more than 20,000 foresters and conservation scientists in the United States, and about 50 colleges and universities offered degrees in the field.

Silviculture is a branch of forestry focused on forest growth. Foresters in this branch cultivate different types of forests and encourage them to grow as quickly as possible using such methods as fertilizers. Some forests are developed for lumber, paper, or pulp. Researchers use scientific breeding methods to raise the type of tree best fit for each purpose.

With a need for superior quality trees grown for specific uses, cloning may become a tool of the forester. A clone is the genetically identical copy of an organism. An entire forest could be cloned from one ideal parent tree.

Water resources In temperate regions, water resources include rivers, streams, springs, lakes, and ponds. Permafrost prevents water from sinking very deeply into the soil, so wetlands, lakes, and ponds form in the boreal forests. Mountain forests are often dotted with lakes and ponds that were carved out by glaciers. Mountains formed by volcanic action usually have craters that filled with water and became lakes. Crater Lake in Oregon is an example of such a lake.

Plant Life

Most forests contain a mixture of trees, and coniferous forests are no different. Stands of deciduous (dee-SID-joo-uhs) trees, such as larches (a type of conifer), birches, and poplars, may exist within their boundaries. (Deciduous trees lose their leaves at the end of each growing season.)

These mixed trees and smaller plants grow to different heights forming "layers" in the forest. The tallest trees create a canopy, or roof, over the rest. In the coniferous forest, these trees are often spruces and firs. Beneath the canopy grows the understory, a layer of shorter, shade-tolerant trees, such as the Pacific dogwoods of California. The next layer, only a few feet off the ground, is composed of small shrubs, such as junipers, blueberry, witch-hobble, and mountain laurel. Growing close to the ground are wild flowers, grasses, ferns, mosses, and mushrooms. In a coniferous forest, the canopy is so dense that little light is able to penetrate down to the forest floor. As a result of this limited light and high humidity, organisms such as algae, fungi, and lichens tend to flourish.

Algae, fungi, and lichens It is generally recognized that algae (AL-jee), fungi (FUHN-ji), and lichens do not fit neatly into the plant category. In this chapter, however, they will be discussed as if they were plants.

Algae Many algae are single-celled organisms, although quite a few are multicellular. Most algal species have the ability to make their own food by means of photosynthesis (foh-toh-SIHN-thuh-sihs), the process by which plants use the energy from sunlight to change water and carbon dioxide into the sugars and starches they use for food. Others absorb nutrients from their surroundings.

Algae may reproduce in one of three ways. Some algae split into two or more parts, each part becoming a new, separate plant. Other algae form spores (single cells that have the ability to grow into a new organism). A few algae can reproduce sexually, during which cells from two different plants unite to create a new plant.

Fungi Unlike algae, fungi cannot make their own food by means of photosynthesis. Some fungi, like mold and mushrooms, obtain nutrients from dead or decaying organic matter (derived from living organisms). They assist in the decomposition (breaking down) of this matter and in releasing into the soil the nutrients needed by other plants. Parasitic fungi attach themselves to other living things. Fungi reproduce by means of spores.

One type of fungi, called mycorrhizae, surround the roots of conifers, helping them absorb nutrients from the soil. Slippery jack, a toadstool fungus that grows in coniferous forests, gets its name from the slimy material on its cap.

Lichens Lichens are combinations of algae and fungi that live in cooperation. The fungi surround the algal cells, and the algae produce food for themselves and the fungi by means of photosynthesis. The fungi may help keep the algae moist. In harsher climates, such as that of the forest-tundra, lichens are often the only vegetation to survive. They have no root system and they can grow on bare rock. While their growth is slow, lichens often live for hundreds of years. Hemlock forests may contain as many as 150 species of lichens. Reindeer moss, a common type of lichen, is found in many coniferous forests.

Like algae, lichens can reproduce in several ways. If a spore from the fungus lands next to an algea, they can join together to form new lichen. Lichens can also reproduce by means of soredia. Soredia are algal cells with a few strands of fungus around them. When soredia break off, they may form new lichens wherever they land.

Green plants other than trees Most green plants need several basic things to grow: light, air, water, warmth, and nutrients. In the coniferous woodland, light, water, and warmth are not always abundant. Nutrients, such as nitrogen, phosphorus, and potassium, are obtained from the soil,

Moss covered branches of Douglas Fir are seen in the Olympic National Park rain forest. IMAGE COPYRIGHT STEFFEN FOERSTER PHOTOGRAPHY, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

which may not always have a large supply. For this reason, plants beneath many coniferous trees can be sparse and must often make special adaptations in order to survive. The pitcher plant, for example, catches insects for food, while others compete with trees for space and nutrients by emitting chemicals into the soil that prevent the germination of trees.

Coniferous woodlands are home to both annual and perennial plants. Annuals live only one year or one growing season. Perennials live at least two years or two growing seasons, often appearing to die when the climate becomes too cold or dry, but returning to life when conditions improve.

Common coniferous forest green plants other than trees Typical green plants found in coniferous forests include mosses, forbs, and ferns.

Mosses Mosses are plentiful in forests; as many as 25,000 species exist. They grow on the ground, tree trunks, decaying logs, and rocks. Mosses range in size from a few millimeters to rare varieties that reach 6.5 feet (2 meters) long. Each moss plant is formed like a tiny tree, with a single straight trunk and leaflike structures growing from it. Mosses grow close together and can store large quantities of water.

Plume moss, also called feather moss or boreal forest moss, resembles an ostrich plume. It forms dense, light-green mats on rocks, rotten wood, or peaty (highly rich, organic) soil, especially in mountain forests of the Northern Hemisphere.

Some mosses are epiphytes, plants that grow on other plants for physical support. Epiphytes are found in warmer climates, such as that of the Pacific Northwest. They absorb water and nutrients from rain and debris that collects on the supporting plants rather than from their own roots.

Forbs Forbs are non-grass, non-woody, flowering plants. They have extensive root systems, and some can live as long as 50 years. Yellow trout lilies, large-flowered trilliums, and lupines are most common in non-conifer forests. Because little sunlight may reach the forest floor, some forbs store food in bulbs and rootstocks beneath the ground. Their small flowers grow low to the ground, and bloom before taller plants block all sunlight.

Ferns Many species of ferns grow in coniferous forests. Ferns are nonflowering perennial plants, which reproduce by means of spores. Sword ferns are long and wispy, with toothed leaflets. Licorice ferns grow on tree trunks and stumps and are often seen draped over branches. Deer ferns prefer the moist forest floor.

Growing season Location, soil, and moisture all help to determine the number and types of green plants that grow in the forest. Many different plants are found in the temperate evergreen forests, where the rich soil, warm climate, and moisture promote growth year-round. Fewer plants are found in the colder, drier, boreal forests where the growing season may last only about twelve weeks. In the hot, dry climate of the Mediterranean forests, plant growth prospers during the rainy, winter season.

Reproduction Most green plants, such as wildflowers, reproduce by means of pollination (the process during which pollen is carried by visiting animals or the wind from the male reproductive flower part to the female reproductive part). As the growing season comes to an end, seeds are usually produced. The seed's hard outer covering protects it during cold winters, or long dry seasons until it sprouts.

A few woodland plants, such as ferns, reproduce by means of spores. Perennial grasses produce rhizomes—long, rootlike stems that spread out below ground. These stems develop their own root systems and send up sprouts that grow into new plants.

Coniferous trees Most coniferous trees have a single strong stem, or trunk, and live 100 to 250 years. Some of the oldest living things on Earth are the bristlecone pines of the western United States, which may be as old as 5,000 years. Most of the tree's growth is directed upward. Redwoods

This photo shows the blooming stage of the pine cone. IMAGE COPYRIGHT MAXIM TUPIKOV, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

can reach nearly 400 feet (122 meters) in height and their trunks may weigh over 1,000 tons (907 metric tons). While broad-leaved trees spread their limbs and branches out from the trunk to create a crown of leaves, conifers devote their energy to growing taller. Without interference from diseases, natural disasters, and human interference, these trees can attain huge proportions.

Each year a tree grows, its trunk is thickened with a new layer, or ring, of cells. When the tree is cut down, its age can be determined by how many of these rings are present, although those in conifers are not as pronounced. As the tree ages, the cells from the center outward become hardened to produce a sturdy core. Like all green plants, trees grow by means of photosynthesis, during which they release the oxygen essential to animals and humans back into the air.

In general, trees are divided into two groups according to how they bear their seeds. Angiosperms have flowers and produce their seeds inside fruits, and many shed their leaves during cold or very dry periods. Broad-leaved trees, such as oaks and elms, are often angiosperms. Conifers are gymnosperms that produce seeds on scales that are usually clustered to form a cone, which may be woody or berrylike. Gymnosperm seeds are "naked," not enclosed in fruits.

Conifers are well adapted to cool or cold temperatures and long dry periods. Their stiff, narrow needles prevent loss of moisture and offer less resistance to strong winter winds, which results in less wind damage. They stay green all year and are often called "evergreens." They remain ready for sudden warm weather and can take advantage of a short growing season. Coniferous trees do not shed their needles every autumn. However, evergreens do shed the inner growth of needles approximately every two to three years. Since these needles were formed during past growth, their loss does not hinder new growth of the tree.

Fir trees are cone-shaped and can grow between 30 and 150 feet (9 and 46 meters) tall. Their needles are very fragrant and remain on the tree long after it has been cut. These characteristics make them a popular choice as a Christmas tree.

Common coniferous trees Common coniferous trees include parana pine, bunya pine, lodgepole pine, white pine, yew, Norway spruce, and yellowwood.

Parana pine In South America, the parana pine, or candelabra tree, is a conifer found in the hilly countries of Brazil and Argentina. It is a slow-growing tree with a very straight trunk that can reach a height of 150 feet (46 meters) with a diameter of 12-70 inches (30-180 centimeters). It is an important source of timber because its trunk has no branches up to 100 feet (30 meters)—it can produce up to six, 16 foot (5 meter) logs. The parana pine is being overharvested because it grows very slowly, so it is being replaced by other types of faster-growing pines. It is commonly found on high mountain ranges at elevations 1,800-3,500 feet (550-1,100 meters) above sea level.

Bunya pine The fast-growing bunya pine is a large Australian conifer native to the ranges and rain forests of Brisbane. Reaching 147 feet (45 meters) or more in height, it is known for its large leafy crown and symmetrical branches. The wood is used for boxes, plywood, and veneers. The bunya produces both male and female cones. The female cones contain edible seeds and can weigh as much as 22 pounds (10 kilograms). Even though the trees can only be harvested every three years, the food is plentiful enough to be useful.

Lodgepole pine The lodgepole pine is common in British Columbia, the Pacific Northwest, the Rocky Mountains, and along the Alaskan coast. Its needles are about 2 inches (5 centimeters) long and very sharp. Cones are yellowish brown, often grow in clusters of six or more, and are 0.8 to 1.6 inches (2 to 4 centimeters) long. Because the tree is so straight, Native Americans used the trunk as the main support in their lodges, giving the tree its name. Today it is also commonly used as plywood and paneling.

White pine The white pine is a valuable North American timber tree for its large trunk and soft, even wood. Capable of reaching 200 years of age, it ranges between 50 and 100 feet (15 and 30 meters) in height, has a trunk more than 3 feet (1 meter) in diameter, and needles 3 to 5 inches (8 to 13 centimeters) long. Eastern white pines once grew in large stands in Maine and Minnesota, as well as Manitoba, Canada. Western white pines once flourished in British Columbia and the northwestern United States. However, because of overharvesting, very few of either species remain.

A Lodgepole pine forest in Colorado. IMAGE COPYRIGHT CHRIS BIANCO, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Yews Once widespread in Europe, the Yew is now rare and protected. Native to Scandinavia and North Africa, it can also be found from Great Britain to the Asia minor, as well as in Syria, Iran and the Himalayas. This small tree, not usually taller than 82 feet (25 meters), is quite poisonous, though it has been historically used in medicinal remedies, and is currently used to treat some cancers. The Fortingall Yew tree in Glen Lyon, Perthshire, Scotland is estimated to be 3,000 to 5,000 years old. This tree does not form the rings traditionally used to calculate age, so its age can not be determined accurately.

Norway spruce Norway spruces have thick crowns and grow symmetrically, sometimes to heights of 150 feet (46 meters). Cones are long and tapered, and male cones produce so much pollen that the forest floor is often yellow from it. Norway spruces are common in Europe and Asia.

Growing season In general, forests need at least 10 to 15 inches (25 to 38 centimeters) of annual precipitation and at least 14 weeks of weather warm enough to promote growth. However, these conditions vary depending upon the location of the forest.

The growing season in the taiga, for example, is short, lasting only about 12 weeks. With little precipitation and cold temperatures, trees do not develop well. Even the oldest of trees is short and stunted. Sub-alpine forests also experience harsh climates, but their growing season is longer, enabling trees to grow taller.

Forests in more temperate climates have more moisture, warmer weather, and a longer growing season. Growing conditions are so favorable in the Pacific Northwest, trees like the redwoods grow to gigantic proportions. Warm pineland climates also produce rapid growth, as long as the rainy season is consistent.

Reproduction Coniferous plants have female and male cones, many of which grow on the same tree. Male cones are small and soft. They produce pollen that fertilizes the eggs in the female cone. These eggs become seeds, which eventually fall from the cones and produce new trees.

Conifers also reproduce by layering. Layering occurs when a branch that is low to the ground is covered by soil. Roots form from the buried portion of the branch and grow into a new tree.

We're back!

Lodgepole pines and jack pines are among the first trees to grow after a fire. Their seeds are sealed in cones by resins (sap) and may remain inactive for a long time on the forest floor. Some lodgepole pine seeds, for example, have been known to survive this way for more than 80 years. Only the heat from a fire can melt the resin, thus releasing the seeds. The seeds quickly germinate in the ash-enriched soil, and a new forest begins to grow.

Endangered species Trees can be threatened by natural dangers, such as forest fires, animals, and diseases, as well as by humans. Fires are more of a threat in dry climates, while animals and diseases seem prevalent in all climates. For example, when deer populations get too large, they can destroy forests by eating wildflowers and tree seedlings. Also, if enough insects attack a stand of trees, all the leaves are eaten and the trees die. Pollution is a serious threat because it appears to weaken trees, allowing pests and diseases to overtake them more easily.

In New Zealand, the kauri pine, once threatened by overharvesting, is now protected. At 200 feet (61 meters) tall, it is one of the largest commercial trees in the world. Similarly, forests in the Himalayan Mountains in Asia are currently being overharvested. In the European Alps, people have interfered with forest growth to such an extent that the trees now grow 500 feet (152 meters) lower on the mountain slopes than they did 1,000 years ago. According to the World Conservation Union (IUCN), 25 percent of all conifers in the world are endangered.

Animal Life

Coniferous forests support a wide range of animals, and different regions are home to different species. These animals can be classified as microorganisms, invertebrates, amphibians, reptiles, birds, and mammals.

Microorganisms A microorganism is an animal, such as a protozoan, that cannot be seen without the aid of a microscope. Every forest is host to millions of these tiny creatures. Microscopic roundworms, or nematodes, for example, live by the thousands in small areas of soil in coniferous forests and aid the process of decomposition.

Bacteria Bacteria are microorganisms that are always present in woodland soil where they help decompose dead plant and animal matter. In temperate climates, bacteria help create nutrient-rich humus (broken down organic matter). Fewer bacteria are at work in dry climates or in moist climates with long dry seasons.

Invertebrates Animals without backbones are called invertebrates. They include simple animals such as worms, and more complex animals such as the wasp and the snail. Certain groups of invertebrates must spend part of their lives in water. These types are not usually found in the trees, but in ponds, lakes, and streams, or in pools of rainwater.

The mantid is one of many insects that live in the coniferous forest. IMAGE COPYRIGHT AITOR BOUZO ATECA, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Insects are found in abundance in coniferous forests and they multiply very quickly when the weather warms up. Mosquitoes and midges swarm in clouds in boreal forests.

Common coniferous forest invertebrates The pine panthea moth caterpillar and white pine weevil live on white pine trees. The caterpillar eats the needles and the weevil's larva eats the new shoots at the tips of stems. Because the weevil kills the shoots at the top, new shoots grow out of the sides of the stem instead, and the tree grows crookedly.

Engelmann spruce bark beetles, which bore under tree bark, live in the high spruce forests in Colorado. At one time the beetle population became so numerous that millions of spruce trees were killed.

The caterpillar of the pine hawk moth does serious damage to European pine trees. However, the adult moth, which lives only long enough to mate and lay eggs, eats very little.

Food The green plants in the forest provide food for some insects, such as caterpillars and moths. Other insects, like wood ants and pine-bark beetles, eat dying or dead trees. Certain insects have very specific food requirements. Caterpillars of the Pandora moth feed on healthy pine trees, often killing them. White pine butterfly larvae feed only on the needles of the Douglas fir. Some insect larvae store fat in their bodies and do not have to look for food.

Snails prefer to eat plants, while bees, butterflies, and moths gather pollen and nectar (sweet liquid) from flowers. Arachnids (spiders), which are carnivores, prey on insects. If they are big enough, certain spiders can eat small lizards, mice, and birds.

Reproduction The first part of an insect (the most common invertebrates) life cycle is spent as an egg. The second stage is the larva (such as a caterpillar), which may actually be divided into several stages between which the outer casing is shed as the animal increases in size. During the third, or pupal, stage, the animal's casing offers as much protection as an egg. An example of this stage is seen when a caterpillar spins a cocoon to live in while it develops into a moth. Finally, the adult emerges, usually by chewing its way out of its casing.

In coniferous forests, insect eggs and pupae are found on twigs, under the snow, or in tree cracks. Caterpillars often emerge from eggs laid in the bark of trees. Some insects are picky about the trees they use. The white pine butterfly, for example, deposits its eggs only in Douglas firs. Pools of water on the damp forest floor provide a good location for the breeding of insects that require water, especially mosquitoes and midges.

Amphibians Amphibians are vertebrates (animals with backbones) that usually spend part, if not most, of their lives in water. Most amphibians are found in warm, moist, freshwater environments and in temperate zones (areas where temperatures are seldom extreme). Amphibians found in coniferous forests include salamanders, newts, toads, and frogs. They generally live in moist areas like the underside of a log or beneath a mass of leaves. Only a few amphibians are found in the colder boreal forests.

Amphibians breathe through their skin, and only moist skin can absorb oxygen. Therefore, they usually remain close to a water source, although mature animals leave the pools for dry land where they feed on both plants and insects. In warm climates, amphibians must find shade during the day or risk dying in the heat of the sun.

Amphibians are cold-blooded animals, which means their bodies are about the same temperature as their environment. As temperatures get cooler, they slow down, seeking a warm environment in order to remain active. During the winter season in temperate climates, they hibernate (remain inactive). In hot, dry climates, amphibians go through estivation, an inactive period similar to hibernation. While the soil is still moist from the rain, they dig themselves a foot or more into the ground, where they remain until the rain returns. Only their nostrils remain exposed to the surface.

Salamanders generally live in the moist areas of the forest floor. IMAGE COPYRIGHT ANITA HUSZTI, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Common coniferous forest amphibians The black salamander is commonly found in the high mountain forests in Europe, especially where Norway spruces grow. The black coat of the salamander absorbs heat and helps maintain a higher body temperature. The salamander is viviparous (vy-VIP-ah-ruhs), meaning that the young are kept inside the mother's body until they are fully developed.

The Pacific tree frog, which lives in the Pacific coast coniferous forests, is small and slender with long legs and suction cups on the bottom of its toes that aid in climbing.

Food Amphibians often use their tongues to capture their prey. Even though some have teeth, they swallow their food whole without chewing. Their larvae are mostly herbivorous, feeding on vegetation. Adult frogs and toads feed not only on algae and other plants, but also on insects, such as mosquitoes.

Reproduction Mating and egg-laying for most amphibians must take place in water. Usually, male sperm are deposited in the water and swim to and penetrate the jellylike eggs laid by the female. As the offspring develop into larvae and young adults, they often have gills for breathing that require a watery habitat. Once they mature, they develop lungs and can live on land. Male salamanders deposit sperm directly into the female for internal fertilization of the eggs.

Some amphibian females carry their eggs inside their bodies until they hatch. Certain species protect the eggs until the young are born, while others lay the eggs and abandon them.

Most amphibians reach maturity at three or four years. They breed for the first time about one year after they become adults.

Reptiles Reptiles are cold-blooded vertebrates, such as lizards, turtles, and snakes, that depend on their environment for warmth. They are usually most active when the weather is warm. Reptiles do not do well in extreme temperatures, whether hot or cold. During hot, dry periods, they find shade or a hole in which to wait for cooler weather. During chilly nights, they become slow and sluggish. In temperate climates, snakes may hibernate in burrows during the long winter.

Common coniferous forest reptiles Garter snakes, rattlesnakes, western pond turtles, and skinks are all found in the California redwood forests. Skinks are lizards, some of which climb trees. Some species are herbivorous, while others eat mostly insects.

The web of life: Predator and prey

Some people shudder at the thought of predators killing deer. After all, deer are so cute and those mountain lions and wolves so bloodthirsty! But a balance is needed between predators and prey or other problems arise. For example, in 1905, the Kaibab Forest in Arizona supported about 4,000 deer. Because the forest had the potential of supporting up to 30,000, people who wanted to enlarge the deer herd destroyed the predators that fed on the deer. They killed 7,000 coyotes, 716 mountain lions, and a number of wolves.

By 1918, the deer herds had increased to more than 40,000, and the plants the deer used for food began to diminish. By 1923, the herd had increased to 100,000, and many food plants had been completely wiped out. During the winter of 1924–25, 60,000 deer, many of which were fawns, died of starvation. The only solution was to restore the balance and return the predators to the forest.

African pine forests are home to the agama lizard. Other reptiles found in dry regions include many species of snakes such as the night, the puff, and the Gabonan adders.

Food Most reptiles are carnivorous. Snakes consume their prey whole—and often alive—without chewing. Their teeth can curve backward, which keeps their prey from escaping. It can take an hour or more to swallow a large prey.

A lizard's diet varies, depending upon the species. Some have long tongues with sticky tips and specialize in insects. Many are carnivores that eat small mammals and birds. The water they need is usually obtained from the food they eat. Turtles, for example, feed on soft plant material, small animals, or both.

Reproduction Most reptiles reproduce sexually, and their young come from eggs. The eggs are leathery and tough, and the offspring are seldom coddled. Some females remain with the eggs, but most reptiles bury the eggs in a hole and abandon them. The young are left to hatch by themselves. Once free of the eggs, the babies dig themselves out of the hole and begin life on their own.

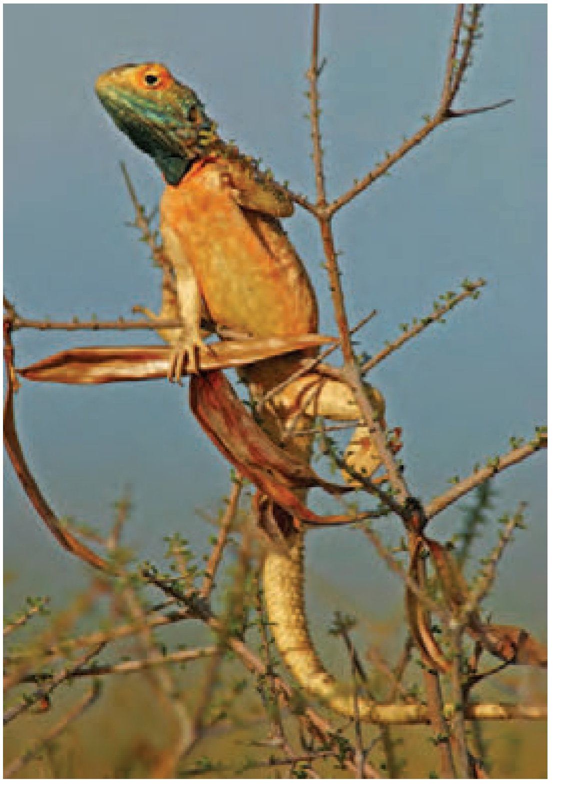
Birds Coniferous forests are home to hundreds of bird species. Some, such as insect-eating wood warblers, Canada geese, and northern goshawks, are migratory, which means they travel from one seasonal breeding place to another. Canada geese and northern goshawks return to northern forests by the thousands each spring and summer from areas with warmer winter climates.

During excessively cold or dry periods, birds can fly to more comfortable regions. Some birds, such as the blue jay, live in a particular forest year-round. If food is plentiful, the evening grosbeak, pine siskin, and red crossbill also choose to not migrate during the winter weather.

Feathers protect birds not only from cold winters but also from tropical heat. Air trapped between the layers of feathers acts as insulation.

Common coniferous forest birds In temperate forests, common birds include screech owls, great horned owls, hummingbirds, woodpeckers, nuthatches, wood thrushes, American redstarts, hawks, blue jays, cardinals, scarlet tanagers, chickadees, and turkey vultures. Wrens, falcons, weaverbirds, thrushes, and chats are found in dry regions. Other common forest birds include the American dipper and the crossbill.

American Dipper The American dipper lives year-round in the mountain forests along the Pacific coast, from Alaska to Mexico. These birds stay near swift streams in which they wade and swim in search of insects, freshwater shrimp, snails, and fish. Since the dipper must dive into the water to catch its food, it maintains a waterproof covering. The dipper spreads oil over its feathers from oil glands and a special flap keeps water out of its nostrils. Its long toes help it grasp underwater surfaces. Dippers can stay submerged for about 30 seconds and dive as deep as 30 feet (9 meters).



A male ground agama in bright breeding colors is seen here in Kalahari, South Africa. IMAGE COPYRIGHT ECOPRINT, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Dippers breed in February or March and lay their eggs in nests made out of materials found along the streams in which they hunt for food. Baby birds hatch after about two weeks and learn to dive very quickly.

Crossbill The crossbill lives year-round in coniferous forests and has a beak specially designed for digging the seeds out of pine cones. Only 5.5 to 6 inches (14 to 15 centimeters) in length, crossbills eat about 1,000 seeds each day. Different species of crossbills vary in color, like red or yellow, and their beaks are shaped differently depending upon where they live and what kind of cones they must open. The birds summer in the more northern forests in Alaska and Canada and winter in the warmer mountain forests of North Carolina and Oregon.

Food Millions of insects attract summer birds, such as kinglets, woodpeckers, and flycatchers, to coniferous forests. Birds that stay in the forest all year must work hard for their food during the winter. For example, the nutcracker uses its powerful jaws to rip open cones for seeds. Blue grouse and the capercaillies, the largest species of European

Rare bird in a rare forest

Kirtland's warblers are rare songbirds that breed only in young jack pine forests in north-central Michigan. They usually build their nests on the ground under the small, growing trees. After jack pines reach more than 20 feet (6 meters) in height and no longer provide enough shelter, the birds abandon them. However, new jack pines will sprout and grow only after a forest fire, many of which are put out by humans. As a result, few new trees grow and, therefore, few warblers can raise families.

grouse, have an easier time, preferring to eat the conifer needles. Small birds and rodents are food for predators like eagles, owls, and hawks.

Reproduction All birds reproduce by laying eggs. One parent sits on the eggs to protect them from heat or cold until they hatch.

Mammals Mammals are warm-blooded vertebrates having some hair. They bear their live young and produce their own milk. A few large mammals, such as mountain lions, bears, and deer, live in northern coniferous forests. Most coniferous forests are home to many small mammals, including mice, squirrels, woodchucks, and foxes.

During cold winters, mammals may burrow underground or find shelter among thick evergreens or under the snow. Snow dens are used by shrews and voles that remain active all winter. Some mammals, such as black bears, hibernate. In a study completed by the University of Iowa, the bear's heart rate dropped from 40–50 beats per minute to only 8 beats per minute while in hibernation. This is the bear's method of conserving body energy. Chipmunks accumulate deposits of fat below their skin that help insulate them and provide nourishment while they hibernate. In dry, warm climates, small mammals may remain inactive during hot weather.

Common coniferous forest mammals Common mammals found in the boreal forest are wolverines, grizzly bears, lynxes, pine martins, minks, ermines, and sables. These animals are all predators and feed on other common boreal mammals like voles, snowshoe hares, marmots, and tiny tree mice. Chamois, red deer, moose, and elks live in the European mountain forests, while the mountain forests in Canada are home to moose, beavers, Canadian lynxes, black bears, and wolves.

Tree Vole The tree vole spends most of its life at the top of fir trees in the Pacific Northwest and almost never walks on the ground. This small mammal is a type of rodent with a stout body and short tail. Voles construct treetop nests and tunnels from twigs and eat parts of pine needles.

Wolverine The wolverine is the largest member of the weasel family and grows to be about 4 feet (1.2 meters) long from the tip of its nose to the end of its tail. This stocky carnivore can weigh up between 24 and 40 pounds (10.9 and 18.1 kilograms). Thick fur protects them from the snow and cold. Wolverines live in North America and Eurasia and are famous as savage hunters and ravenous eaters, capable of killing and eating an entire deer. They may wander up to 15 miles (24 kilometers) at a time to locate food, and can live up to twelve years in the wild.

Female wolverines give birth in early spring to two to four pups. The nest is usually in a crevice or other protected spot.

Chamois The chamois (SHAM-ee) is a small goatlike, antelope found in European mountain forests in the Alps, Pyrenees, and Dolomites. The males range from 65-110 pounds (29-59 kilograms) in size, and measures from 3 to 4 feet (1 to 1.2 meters) in length. The females are typically slightly smaller. Both males and females grow straight horns with backward-bending tips. In the summer, the chamois is reddish-brown in color with a black stripe on the rump. In the winter, its coat turns black or brown to help absorb heat.

The chamois has adapted to the mountains by developing rubbery hoof pads that help the animal keep its footing on slippery rocks. It eats mountain vegetation, especially clover, and some fir needles. If winter is especially harsh, the chamois moves to deciduous forests at lower elevations to find food. The chamois can live up to seventeen years in captivity.

Grizzly Bear The grizzly bear is one of the fiercest animals in North America. They are strong enough to carry full-grown cattle. Most have broad heads, extended jaws, big paws, and powerful claws. Grizzlies eat insects, like ants and bees, as well as seeds, roots, nuts, and berries. They also eat salmon, and are famous for their fishing skills.

Food Mammals may be herbivores (plant eaters), carnivores (meat eaters), or omnivores (plant and meat eaters). Moss and lichens provide food for caribou, while downed trees and brush feed beaver and elk. Green plants, such as rushes, feed marmots and voles. Shrews eat insects that they dig out of the ground. Some carnivores, like the wolf, hunt in packs for deer and other animals. Bears are omnivores.

Reproduction Mammals give birth to live young that have developed inside the mother's body. Some mammals, like the hare, are helpless at birth, while others, such as deer, are able to walk and even run almost immediately.

Endangered species In the United States, acid rain (a mixture of water vapor and polluting compounds in the atmosphere that falls to Earth as rain or snow) has endangered the peregrine falcon. The grizzly bear,

The chamois is well adapted to its rocky, rugged terrain because it is very surefooted and nimble. IMAGE COPYRIGHT RADOVAN SPURNY, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

beaver, and timber wolf are threatened in the United States and Canada. In Australia some species of kangaroos are threatened.

Kirtland's warblers Kirtland's warblers are endangered songbirds that conceal their nests in shrubs below five- to twenty-year-old jack pines in north-central Michigan. New jack pines sprout and grow only after a forest fire, many of which are put out by humans. As a result, few new trees grow and few warblers can raise families, making it a rare bird.

Grizzly bears fish for salmon in Alaska. Besides being one of the fiercest animals in North America, the grizzly bear is also quite large, weighing up to 1,000 lbs (454 Kg). IMAGE COPYRIGHT OKSANAPERKINS, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Grizzly bear Before the great expansion of the population westward, it is estimated that 100,000 grizzly bears lived in North America. By the 1990s, fewer than 1,000 existed, with most of them living in preserves such as Yellowstone National Park, though some can be found in British Columbia, Alberta, the Yukon, and the Northwest Territories. Even though grizzly bears are occasionally shot, the greatest threat to the bear's survival is destruction of its habitat. Since bears are huge animals, weighing as much as 1,000 pounds (454 kilograms), they require large spaces to roam and huge quantities of food. In 2006, the World Conservation Union (IUCN) listed the grizzly bear as low risk and conservation dependent.

Beaver The beaver once ranged over North America from Mexico to the Arctic regions. It was widely hunted for its fur and for a liquid called castorium, produced in the beaver's musk glands and used in perfume. The beaver is now confined largely to northern wooded regions. Beavers were also common throughout northern Europe, where they are now almost extinct, except in some parts of Scandinavia, Germany, and Siberia.

Human Life

Many animals, including humans, are creatures of the forest. In early North America, native tribes, such as the Nootka and Haida, lived in the forests, hunting, trapping, and gathering for their survival.

Impact of the coniferous forest on human life Forests have an important impact on the environment as a whole by contributing to the environmental cycles. From the earliest times, forests have offered food and shelter, a place to hide from predators, and many useful products. Forests are an integral part of life on Earth.

Environmental cycles Trees, soil, animals, and other plants all interact to create a balance in the environment from which humans benefit. This balance is often maintained in cycles.

The oxygen cycle Plants and animals take in oxygen from the air and use it for their life processes. When animals and humans breathe, the oxygen they inhale is used and carbon dioxide is given off as a byproduct. This oxygen must be replaced, or life could not continue. Trees help replace oxygen during photosynthesis when they release oxygen into the atmosphere through their leaves.

The carbon cycle Carbon dioxide is also necessary to life, but too much is harmful. During photosynthesis, trees and other plants pull carbon dioxide from the air. This helps maintain the oxygen/carbon dioxide balance in the atmosphere.

When trees die, the carbon in their tissues is returned to the soil. Decaying trees become part of Earth's crust, and after millions of years, this carbon is converted into oil and natural gas.

The water cycle Coniferous forests shade the snow, allowing it to remain in deep drifts. The trees' root systems and fallen needles help build an absorbent covering on the forest floor, letting water from rain and melting snow trickle down into the Earth to feed underground streams and groundwater.

Not only do forests help preserve water in this way, but they also protect the land from erosion during heavy rain by acting as a wall or barrier. When forests are cut down, there are no trees to act as barriers, and no tree roots to hold the soil in place, so it washes away. As a result, flooding is more common. For example, by 2007, 19 million residents of India and Bangladesh had been evacuated from their homes due to severe flooding, caused in part by cutting of forests in the nearby Himalaya Mountains.

Trees take up water through their roots and use it for their own life processes. Extra moisture is then released through their leaves back into the atmosphere, helping to form clouds and continue the water cycle.

The nutrient cycle Trees get the mineral nutrients they need from the soil. Dissolved minerals are absorbed from the soil by the tree's roots and are sent upward throughout the tree. These mineral nutrients are used by the tree much like humans take vitamins. When the tree dies, these nutrients, which are still contained within parts of the tree, decompose and are returned back into the soil making them available for other plants and animals to use.

Food Since the earliest times, forests have been home to game animals, such as rabbits, which have supplied meat for hunters and their families. Forests also supply fruits, seeds, berries, and nuts. Several species of pines, for example, produce edible seeds (pine nuts) that are still collected by hand.

Shelter During prehistoric times, humans lived in the forest because it offered protection from predators and the weather. Today, people who choose to live in forested areas usually do so because they enjoy their beauty.

Economic values Forests are important to the world economy, since many commercially used products, such as wood, medicine, resins and oils, are obtained from forests.

Wood Trees produce one of two general types of wood, hardwood or softwood, based on the trees' cell wall structure. Hardwoods are usually produced by deciduous trees, such as oaks and elms, while most coniferous trees produce softwoods. These names can be confusing because some softwood trees, such as the yew, produce woods that are harder than many hardwoods and some hardwoods, such as balsa, are softer than most softwoods.

Wood is used not only for fuel, but also for building structures and manufacturing other products, such as furniture and paper. Hardwood from deciduous trees is more expensive because the trees grow more slowly. As a result, it is used primarily for fine furniture and paneling. Wood used for general construction is usually softwood, such as white pine, Douglas fir, and spruce. Araucaria and kauri are commercially important conifers of the Southern Hemisphere. In order to conserve trees and reduce costs, some manufacturers have created engineered wood, which is composed of particles of several types of wood, combined with strong glues and preservatives. Engineered woods are very strong and can be used for many construction needs.

Medicines Since the earliest times, plants have been used for their healing properties. For example, the yew was once considered a worthless "weed" tree and was burned by loggers after clearing a section of forest. Then taxol, an anti-cancer drug, was discovered in the bark of the yew. It takes the bark of six trees to make enough medicine for one cancer patient. In 1994, a synthetic form of taxol was created in the laboratory (though difficult to make) reducing the need for yew trees.

Resins and oils Tree resins (REH-zihns; sap) and oils are also valuable. Conifer resins are used to make turpentine, paints, and varnish, while their oils are used as the fragrance in air fresheners, disinfectants, and cosmetics.

Recreation More people live in cities today than ever before, and many feel the need to occasionally escape to more natural surroundings. The beauty and quiet of coniferous forests draw many visitors for hiking, horseback riding, skiing, fishing, hunting, bird watching, or just sitting and listening to the sounds of nature.

Other resources Forest rivers are often dammed to provide a source of water for hydroelectric power. Norway, Sweden, Canada, and Switzerland rely heavily on hydroelectricity. The United States, Russia, China, India, and Brazil also use hydroelectric power, but on a smaller scale.

Impact of human life on the coniferous forest Forests originally covered 48 percent of the Earth's surface. Half of this quantity is now gone, and about one-fifth of the remainder are, as of yet, undisturbed. In North America, more than 430,000 miles (692,000 kilometers) of road cut through U.S. National Forests. Although it was once thought that forests of the far north were so inhospitable they were safe from human interference, the building of railroads made the area accessible. As a result, each year more land is being cleared for logging and mining operations.

Use of plants and animals As more and more forest land is being developed, native vegetation and wildlife habitats are destroyed. Trees are cut down and used for lumber and other products. In Canada, for example, much of the timber in the southern forests is gone, and northern forests are now being invaded by logging companies.

Trees are not the only forest plants in danger from overharvesting. In northern forests, mosses from the forest floor are used as fuel by construction workers and are being removed in large quantities. Without the insulation provided by the moss, permafrost is melting and causing floods.

Timber!

Logging is the harvesting of trees, sawing them into logs, and transporting them to a sawmill. About one percent of the world's timber is cut down each year. Half of it is used for fuel, and the rest for wood products, paper, and packaging materials. Most trees used for paper products are raised on tree farms and do not come from wild forests.

In the nineteenth century, logging was done by men using hand axes and saws. This method took a lot of people and time. In the 1950s, power chainsaws were used, and, by the 1970s, a variety of machines had revolutionized the logging industry.

Because logging machines can cut trees no bigger than about 2 feet (0.6 meter) in diameter, large trees are still cut by hand. A wedge is chopped from the trunk on one side of the tree and a cut is made with a saw on the other side. This causes the tree to fall in the direction of the wedge. After the tree is down, the limbs are removed and it is cut into lengths that can be easily moved.

In general, trees are removed either selectively or by clear-cutting. With selective methods, only certain trees are cut from a stand (group of trees). With clear-cutting, all the trees from several acres (hectares) of land are removed. Ideally, trees of the same species are then replanted, but many times this is not the case.

In India, some logging is done by "girdling." In girdling, a circular cut made around the tree trunk prevents water or nutrients from being carried to the branches. Several years later, when the tree is dead, it is harvested.

As too much logging destroys mountain forests, villages are at risk from landslides and avalanches that were once held in check by the dense trees.

Clear-cutting disrupts wildlife habitats, and new roads give hunters better access to wildlife, which sometimes results in overhunting. In some Canadian areas, for example, grizzly bears and bighorn sheep are now easy targets. Despite conservation efforts, parks and other protected areas are not necessarily safe from development. In British Columbia, mining interests have gained access to once-protected areas in parks.

Quality of the environment The quality of the forest environment is threatened not only by the direct effects of logging, mining, and hydroelectric development, but also by pollution and visitors. Roads, drilling rigs, and pipelines, all a necessary part of mining, destroy wilderness and disrupt habitats. Mercury, a poisonous liquid metal used in gold mining operations, and waste from chemical and petrochemical plants contaminate forest water sources. In Lake Baikal in the Siberian taiga, for example, mining activities have destroyed life on the lake bottom.

Clear-cutting of forests disrupts habitats which may result in the endangernment of plants and animals. IMAGE COPYRIGHT JIM PARKIN, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Millions of acres (hectares) of forests in industrialized Europe, North America, and China are dead or dying from pollution and acid rain. Acid rain is a type of air pollution that forms when pollutants such as sulfur or nitrogen combine with moisture in the atmosphere to produce sulfuric or nitric acids. These acids can be carried long distances by the wind before they fall, either as dry deposits, or in the form of rain or snow. When acid rain is absorbed into the soil, it can destroy nutrients and make the soil too acidic to support some species of trees. In coniferous forests, acid rain causes needles to drop and their color to fade and turn brown. Forests in northern Europe, southern Canada, and the eastern United States have been damaged by acid rain.

A large increase in the number of tourists all over the world has also put a tremendous stress on the forest environment. Many "wilderness" areas are being developed, and fragile forests are endangered as tourists hike, bike, ski, and snowmobile over the vegetation and disturb wild animals with their noise.

Forest management The National Forest Service was established in the United States in 1905 to protect forest resources. More than 193,000,000 acres (78,000,000 hectares) of land are now publicly owned. Most of this acreage is west of the Mississippi. Forests in the eastern half of the United States are usually managed by state programs.

Forest fires consume trees, vegetation, animals, and insects, but are also an important part of the ecosystem, promoting wilderness diversity. IMAGE COPYRIGHT ARNOLD JOHN LABRENTZ, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Most of these forests consist of areas that can be used for logging and other commercial purposes. However, the rest of the land is kept for recreation and conservation.

Several other nations, including Great Britain, Japan, China, and India, have also established programs to conserve and replant forests.

Native people By 1950, native people in industrialized parts of the world had abandoned most of their tribal lands and customs. Many went to live in cities. In remote regions, some people still live a traditional lifestyle. For example, some taiga peoples are found in small Siberian towns that are accessible via the Trans-Siberian Railway. Other people live in mountain forests, especially in the Alps and Himalayas.

The Evenki In the northern Asian taiga of Siberia, Mongolia, and China live the Evenki (which means *he who runs swifter than a tiger*). Traditionally, the Evenki were nomads, surviving by means of hunting or reindeer herding. Although small groups still live this way, their traditional way of life is being threatened as oil, coal, and gas are mined and their homelands are taken over.

Many Evenki were removed from their lands by the government and settled onto collective farms after the Russian Revolution in 1917, and only 30,000 remain. In 1930, the Evenki national district was created, providing a permanent home for the people. This district contains some tundra vegetation and is covered by larch forest, but the climate is severe, with long, cold winters. The livelihood of the Evenki is supplemented by fur farming, farming, and jobs in industry or government.

Along with other native groups in Russia and China, like the Oroqen, the Evenki are working to preserve their culture.

The Cree The Ouje-Bougoumou Cree are a native people from the James and Hudson Bay area of Quebec in Canada. Some Cree tribes, collectively known as the Cree nation, lived on the plains and cultivated corn. Others lived in the forests and fished and hunted caribou, moose, bear, beaver, and hare.

The Cree believe they have a special relationship with nature—nature provides them with food and they take care of the land and hunt only what is necessary for life. Beginning in 1920 when the first non-native miners came onto their land searching for gold and copper, the Cree were forced to relocate their villages. About 14,500 Cree remain, primarily in the James and Hudson Bay regions. Clear-cutting of the boreal forests and hydroelectric development in the James Bay area continues to threaten their lifestyle. The Cree nation has been fighting since the 1970s to disband the James Bay hydroelectric project. They continue to negotiate treaties with the Canadian government involving the destruction in their homeland.

The Pehuenche The Pehuenche live in the forests of southeastern Chile. To them, the coniferous monkey-puzzle tree is sacred, and they refuse to cut it down. Its seeds are ground and turned into flour. Even though the Chilean government outlawed cutting the trees, logging continues and endangers the existence of both the people and the tree.

The Food Web

The transfer of energy from organism to organism forms a series called a food chain or food web. All the possible feeding relationships that exist in a biome make up its food web. In the forest, as elsewhere, the food web

A young Cree Indian with his face painted, and dressed in traditional costume.
AP IMAGES.

consists of producers, consumers, and decomposers. An analysis of the food web shows how energy is transferred within a biome.

Green plants are the primary producers in the forest. They produce organic materials from inorganic chemicals and outside sources of energy, primarily the sun. Trees and other plants turn energy into plant matter, such as pine cones, needles, and seeds.

Animals are consumers. Primary consumers are plant-eating animals like squirrels, voles, mice, and beetles. Secondary consumers eat the plant-eaters. Tertiary consumers are the predators, like owls, wolves, and humans that eat other animals. Bears and humans are also omnivores, eating both plants and animals.

Decomposers eat the decaying matter from dead plants and animals and help return nutrients to the environment. Small underground insects called springtails and mollusks, such as the banana slug, help the decomposition process by breaking down dead plants. This allows other organisms, like bacteria and fungi, to reach the decaying matter and decompose it further.

Spotlight on Coniferous Forests

Bonanza Creek Experimental Forest Bonanza Creek Experimental Forest was established in 1963 with 8,300 acres (3,359 hectares) and increased to 12,487 acres (5,053 hectare) in 1969. This area is located south of Fairbanks, Alaska, in the Yukon-Tanana uplands in the Tanana Valley State Forest, south of the Brooks Mountain Range and north of the Alaska Range.

Within the Yukon-Tanana uplands are forests, grasslands, wetlands, and alpine tundra (a cold, dry, windy region where no trees grow). The Tanana river crosses the region at 394 feet (120 meters) of elevation.

The climate in the Alaskan taiga is extreme, with temperatures ranging from -58° to 95°F (-50° to +35°C) in January and July, the coldest and warmest months. The average annual temperature is 26°F (-3.3°C). July is the warmest month with an average daily temperature of 61.5°F (16.4°C). For about 233 days each year, freezing temperatures are possible. About 70 percent of the area's precipitation falls as rain in the summer; the other 30 percent is snow, which falls from October to April. The annual average precipitation over the last 50 years is about 11 inches (28 centimeters).

Taiga soils are often poorly developed. In some areas, a layer of permafrost (permanently frozen soil) is on the lowlands and northern slopes of mountains, and prevents rain and melting snow from being absorbed into the ground. Since the moisture stays close to the surface, the soil is soggy.

Bonanza Creek Experimental Forest
Location: Alaska
Area: 12,487 acres (5,053 hectares)
Classification: Boreal forest/taiga

Predominant trees in the area are white spruce, black spruce, paper birch, and aspen.

Numerous insects found on the taiga include budworms, sawflies, midges, and beetles. The northern wood frog is one of the few amphibians that live there.

Woodpeckers, swallows, sparrows, peregrine falcons, great horned owls, snowy owls, and boreal owls are among the birds that make the Bonanza Creek Forest their home.

Mammals include a number of voles and lemmings, muskrats, red squirrels, and meadow jumping mice. Moose and caribou migrate here to breed. Carnivores include coyotes, gray wolves, and wolverines.

Olympic National Park Olympic National Park is a 922,000 acre (373,120 hectare) area located on the Olympic Peninsula in northwestern Washington state. Forests in the park lie between sea level and 2,000 feet (609 meters) above sea level. Just 90 miles (145 kilometers) from the thriving city of Seattle, 95 percent of this park has been declared as wilderness.

Among the coniferous forests in the park is a temperate rain forest found in its lower western and southern regions. Temperate rain forests grow at higher latitudes than tropical rain forests. Forests on the western side of the park experience heavy precipitation, 12-14 feet (3.6-4.3 meters) annually. Forests in the eastern portion of the park are the driest areas of the Pacific coast, north of Los Angeles. The nearness of the ocean keeps the temperatures somewhat moderate with very few days of below-freezing weather in winter. In summer, temperatures rarely exceed 85°F (29°C).

The forest floor supports toadstools, creepers, and ferns, such as sword, bracken, and licorice ferns. Club moss and algae hang from the trees. Shrubs found in the park include red huckleberry and salmonberry. The western thimbleberry can be recognized by its large, hairy, maplelike leaves. Wildflowers include western starflower, western trillium, and foamflower. The deerfoot vanillaleaf lives deep in the woods.

Douglas fir and Pacific silver fir are common trees. The species of the Sitka spruce found there rarely grows far from salt water. The grand fir also grows only in this region.

Invertebrates include the unusual banana slug, a scavenger and decomposer that helps to keep the forest floor and soil healthy.

Olympic National Park
Location: Washington
Area: 908,447 acres (363,379 hectares)
Classification: Temperate evergreen forest

Springtails, golden buprested beetles, and questing spiders can also be found here.

The Pacific tree frog and the bullfrog live in the park, as do several species of snakes.

More than 200 species of birds are common to the Olympic Peninsula including flicker, crow, cliff swallow, winter wren, water ouzel, pileated woodpecker, northern spotted owl, winter wren, raven, and jay. Both golden and bald eagles also frequent the area. Ruffled grouse stay all winter and grow long, feathery "snowshoes" on their toes.

The park is home to one of the largest herds of Roosevelt elk, and was nearly named Elk National Park. An adult male can weigh an average of 875 pounds (397 kilograms), and the elk are a major hunting and tourist attraction. Other mammals found on the peninsula are the coyote, mountain beaver, Olympic marmot, raccoon, skunk, Columbian black-tailed deer, Rocky Mountain goat, black bear, mountain cottontail rabbit, and snowshoe hare. Cougars may be found in remote areas.

Yellowstone National Park The first national park in the United States, Yellowstone is located primarily in the state of Wyoming, with small portions in southern Montana and eastern Idaho, and was established in 1872. It covers an area of 2,219,789 acres (898,317 hectares). Mountains, lakes, rivers, and waterfalls cross the terrain. Most of the park is coniferous forest, but Yellowstone is also famous for the geyser (GY-zuhr) called Old Faithful, and its hot springs, steam vents, and mud caldrons.

Located on a high plateau, Yellowstone is 11,358 feet (3,462 meters) above sea level at its highest point, Eagle Peak. Its lowest elevation is 5,282 feet (1,610 meters), Reese Creek. Eighty percent of the park is forested, while the other 20 percent is grassland and water.

Annual precipitation varies from one end of the park to the other. In the north the average is 10 inches (26 centimeters). In the south, it is 80 inches (205 centimeters). Average annual snowfall is about 150 inches (380 centimeters). The average temperature is 10°F (-12°C) in January and 80°F (27°C) in July.

Eight species of conifers grow in the park, with lodgepole pine being the most common. Smaller stands of Douglas fir are found at both lower and higher elevations. Engelmann spruce and alpine fir abound. The park also has more than 170 species of colorful flowering plants, 80 percent of which are exotic.

Yellowstone National Park
Location: Wyoming
Area: 2,219,791 acres (898,318 hectares)
Classification: Mountain coniferous forest

The park supports about ten species of reptiles and amphibians. Its lakes are stocked with fish, including some non-native species.

Hundreds of species of birds live in the park, including the western tanager, goshawk, bald eagle, and dipper.

Large mammals include buffalo, elk, bighorn sheep, moose, and grizzly bear. Wolves, which had been eliminated by ranchers who feared they would prey on cattle, were reintroduced to the park in 1995. The park also supports a large herd of wapiti deer, or American elk. This once common animal is now found only in the Rocky Mountains and southern Canada. The wapiti is hunted for its hide, flesh, and head, which is usually displayed as a trophy. The park also protects five threatened and endangered species; the bald eagle, the grizzly bear, the lynx, the whooping crane and the gray wolf.

Coniferous forests of Japan Japan is a 4,400 square mile (11,500 square kilometer) chain of four islands in the Pacific Ocean—Hokkaido, Honshu, Shikoku, and Kyushu. The coniferous forests in Japan are found primarily in northeastern Honshu and Hokkaido.

Japan's climate is influenced by the presence of mountain ranges, the Sea of Japan, and the range of latitudes it crosses. In general, Japan receives more than 40 inches (102 centimeters) of precipitation annually, mostly as rain during June and July. Typhoons (ocean storms) are not uncommon during this time. The southern islands are generally warmer. In Hokkaido, the average temperature in January, the coldest month, is 16°F (-9°C), and in August, the hottest month, it is 70°F (21°C).

Coniferous trees are found from sea level up to 5,900-9,800 feet (1,800-3,000 meters) in the mountains. Common conifers in the forests of Hokkaido are Hondo and Sakhalin spruce and Maries and Veitch firs. Mosses and lichens are found on the forest floor and hanging from tree branches.

Many native forests have been destroyed and replanted with coniferous forests that are managed as commercial plantations. Two of the most important timber trees are the hiba and the Japanese cedar. The cedars, often exceeding 150 feet (46 meters), have long trunks, reddish bark and spread 15-25 feet (4.6-7.6 meters).

Natural stands of Japanese cedars, with trees more than 2,000 years old, cover about 4,133 square miles (10,747 square kilometers) on Yaku Island south of Kyushu. These trees grow in rocky areas with little soil and light, and as a result, their growth is stunted. Because the grain of their

Coniferous forests of Japan
Location: Japan
Classification: Mountain coniferous forest and temperate evergreen forest

wood is tightly compacted and contains large quantities of resin, they do not easily decay. Many cedars on the island exceed the average life span of 500 years. The Yaku sugi tree, which also grows here, is a decay-resistant conifer related to the redwood. Also on Yaku are mixed forests containing broad-leaved trees. In 1993, the Yaku forests were declared a World Heritage Property by the World Heritage Convention.

Japan's forests are home to about 150 species of songbirds, as well as birds of prey such as eagles, hawks, and falcons. Bramblings and Eurasian nutcrackers are also common.

Brown bears, wild boars, Siberian chipmunks, Asiatic pika, and Hokkaido squirrels live in the forests. An unusual inhabitant is the raccoon dog, or tanuki, a native of eastern Asia that some scientists place in the dog family and others in the raccoon family. The tanuki looks like a raccoon, with dark face markings that stand out against a yellow-brown coat. Its long fur is sold commercially.

Lapland National Parks Much of Scandinavia (Norway, Sweden, and Finland) is covered in coniferous forest. The Lapland National Parks are comprised of three parks, Sarek National Park, Padjelanta National Park, and Stora Sjofallet National Park. Both Sarek and Stora were established in 1909; Padjelanta was established in 1962. All three parks are boreal forests and are interspersed with wetlands, lakes, and mountains. Of the three, Padjelanta is the most accessible park.

Many people visit Padjelanta, which has marked trails and cross-country ski paths. Scientists visit to conduct research on plants, animals, geology, glaciers, and water resources. The flora and fauna are impressive, with over 400 species spread across 490,257 acres (198,400 hectares) of land. The wildlife is also unique, and visitors may catch a glimpse of snowy owls, arctic foxes, and wolverines. The open mountain landscape and the large lakes make it a very scenic location.

To the left of the Padjelanta park lies the Sarek National Park. Sarek, with the most wilderness, is mostly alpine landscape with glaciers, tall mountain peaks, and alpine tundra (a cold, treeless region). Its 486,798 acres (197,000 hectares) is home to over 200 mountains and 100 glaciers that are mostly unspoiled. Though plants are more scarce than at Padjalenta, the animal population is rich in bears, wolverines, lynxes and elk. Of the three parks, Sarek is the least accessible and not recommended for beginners.

Lapland National Parks
Location: Scandinavia
Area: 1,292,300 acres (523,200 hectares)
Classification: Boreal forest/taiga

North of Sarek Park lies the Stora Sjofallet National Park. At 315,800 acres (127,800 hectares), it is the smallest of the three parks. The forest is nearly bisected by a hydroelectric power facility, which destroyed much of the original landscape.

Coniferous forests of New Zealand New Zealand is an island nation in the South Pacific, about 1,000 miles (1,600 kilometers) southeast of Australia. A temperate evergreen forest with mixed deciduous and coniferous trees grows in the north.

New Zealand's climate has no real extremes. In general, summer temperatures are above 70°F (21°C), and winter temperatures are rarely below 50°F (10°C). Annual rainfall ranges from 29 to 59 inches (64 to 150 centimeters).

Conifers make up most of the canopy in the forests and include the huge kauri tree, as well as trees in the plum pine family. The rimu, or New Zealand red pine, grows as tall as 150 feet (45 meters) and its wood is reddish-to-yellowish brown. Rimu is used in construction and furniture making, and its bark contains a tanning agent that colors leather red. The radiata pine, a native of California, was transplanted in New Zealand and has become a key species there. Only a few flowers, like yellow kowhai and pohutakawa (New Zealand's Christmas tree), grow in the New Zealand forests. The pohutakawa reaches averages of 100 feet (30 meters) high, and 3 feet (1 meter) wide. It can live anywhere between 700 and 800 years. Approximately 80 percent of the flora in the park is native to New Zealand.

Very few animals are native to New Zealand. They include several species of frogs and bats, as well as the gecko lizard and the tuatara. Europeans introduced deer, opossums, and goats.

Coniferous forests of Russia and Siberia At 2.5 billion acres (1 billion hectares), Russia and Siberia are home to 22 percent of the all the world's forests combined. The most popular trees are larch, spruce and pine.

The climate in the forests varies. In the more northern section, the weather is harsh and summers are short. In the Yakut taiga, located in eastern Siberia, for example, winter temperatures may reach -85°F (-65°C). The average annual temperature is only around 10°F (-12°C). Temperatures in the middle taiga, such as that near Lake Baikal, are less severe, and conditions for tree growth are better. There, the average annual temperature is about 19°F (-7°C), and the growing season lasts from twelve to seventeen

Coniferous forests of New Zealand
Location: New Zealand
Classification: Southern Hemisphere forest

Coniferous forests of Russia and Siberia
Location: Russia and Siberia
Classification: Boreal forest/taiga

weeks. An even milder climate is characteristic in the southernmost region of the taiga where the growing season may last more than twenty weeks.

Conifers found here include pine, spruce, fir, larch, cedar, Japanese stone pine, Jeddo spruce, and dwarf mountain pine. Many trees are stunted by the cold wind; reaching only about 19 feet (6 meters) in height. Where trees are protected from the wind, they grow about 50 feet (15 meters) tall. Shrubs like crowberry and bilberry grow in the understory. Mosses and lichens grow on the forest floor.

Some areas of the taiga are richer in wildlife than others. The more southern regions support hundreds of species of birds and about 50 species of mammals. The hazel hen and Siberian jay are unique to the taiga. Mammals include the moose, lynx, brown bear, Siberian red deer, wolverine, Asiatic chipmunk, northern pika, and sable. The sable is hunted for its highly prized fur, known as "soft gold." Once endangered, it is now being protected in nature reserves such as the Barguzin Nature Reserve near Lake Baikal.

Coniferous forests of the Southeastern United States Temperate pinelands in the United States are found primarily in New Jersey, Virginia, North Carolina, South Carolina, Georgia, Alabama, Mississippi, Louisiana, Arkansas, Florida, and Tennessee. The pines that grow here are called southern pines, and loblolly, slush, longleaf, and shortleaf pines predominate. Many of these trees took over farms and plantations abandoned after the Civil War (1861–65).

The temperate climate with its mild winters favors tree growth. In Georgia, for example, average annual temperatures are about 40°F (4.4°C) in the mountains and 54°F (12°C) on the southern coast. Average annual rainfall is about 50 inches (127 centimeters).

The soil of these forests tends to be rich and supports much tree growth, including oak and hickory, in addition to the many pines.

Wildlife includes many species of snakes and birds, as well as rabbits, squirrels, opossums, badgers, moles, deer, and wildcats.

Coniferous forests of the Southeastern United States
Location: Southeastern states
Classification: Temperate pineland

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Environmental Protection Agency, 401 M Street, SW, Washington DC 20460; Telephone:202-260-2090; Internet: http://www.epa.gov

Friends of the Earth, 1717 Massachusetts Ave. NW 300, Washington, DC 20036; Telephone:877-843-8687; Fax:202-783-0444; Internet: http://www.foe.org

Global ReLeaf, American Forests, PO Box 2000, Washington, DC 20013; Telephone:202-737-1944; Internet: http://www.amfor.org

Greenpeace USA, 702 H Street NW, Washington, DC 20001; Telephone: 202-462-1177; Internet: http://www.greenpeace.org

Izaak Walton League of America, 707 Conservation Lane, Gaithersburg, MD 20878; Telephone:301-548-0150; Internet: http://www.iwla.org

Sierra Club, 85 Street, 2nd fl., San Francisco, CA 94105; Telephone:415-977-5500; Fax:415-977-5799; Internet: http://www.sierraclub.org

The Wilderness Society, 1615 M St. NW, Washington, DC 20036; Telephone: 800-the-wild; Internet: http://www.wilderness.org

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Continental Margin

The continental margin is that part of the ocean floor at the edges of the continents and major islands where, just beyond the shoreline, it tapers gently into the deep sea. The continental margin is made up of the continental shelf, the continental slope, and the continental rise.

The continental shelf begins at the shoreline. It is flat and its width varies. For example, off the Arctic coast of Siberia it is 800 miles (1,280 kilometers) wide. Rich sediment (particles of soil and decaying matter) from rivers that flow to the sea filters down to the shelf. Over time, deposits of these sediments may become many thousands of feet (meters) thick. At its deepest points, the continental shelf is usually less than 660 feet (200 meters) below sea level (the level surface of the sea). Although the continental shelf is easier to explore than deeper areas of the ocean, there is still much to learn.

At the end of the continental shelf is a steep dip that marks the edge of the continent. This is called the continental slope, which descends to depths of 10,000 to 13,000 feet (3,048 to 3,962 meters) and ranges in width from 12 to 60 miles (20 to 100 kilometers). The continental slope usually resembles the edge of a mountain range, and in some places the drop is spectacular. Along the coast of Chile in South America, where the Andes Mountains meet the sea, the drop from the highest mountain peak on land—Aconcagua—to the bottom of the continental slope is more than 9 miles (14 kilometers).

Beyond the continental slope is the continental rise, where sediments drifting down from the continental shelf have collected. These deposits may extend as far as 600 miles (1,000 kilometers) out into the ocean floor, where the deep-sea basin begins.

Formation of the Continental Margins

The World Ocean, which is all the oceans taken together, covers a total of 139,782,000 square miles (363,433,200 square kilometers)—about 71 percent of Earth's surface. Over 200 million years ago, the World Ocean

WORDS TO KNOW

Abyssal plain: The flat midportion of the ocean floor that begins beyond the continental rise.

Canyon: A long, narrow valley between high cliffs that has been formed by the eroding force of a river.

Continental shelf: A flat extension of a continent that tapers gently into the sea.

Estuary: The place where a river traveling through lowlands meets the ocean in a semi-enclosed area.

Kelp: A type of brown algae that usually grows on rocks in temperate water.

Lagoon: A large pool of seawater cut off from the ocean by a bar or other landmass.

Salinity: The level of salt.

Subduction zone: Area where pressure forces the seafloor down and under the continental margin, often causing the formation of a deep ocean trench.

Tsunami: A huge wave or upwelling of water caused by undersea earthquakes that grows to great heights as it approaches shore.

Water column: All the waters of the ocean, exclusive of the sea bed or other landforms.

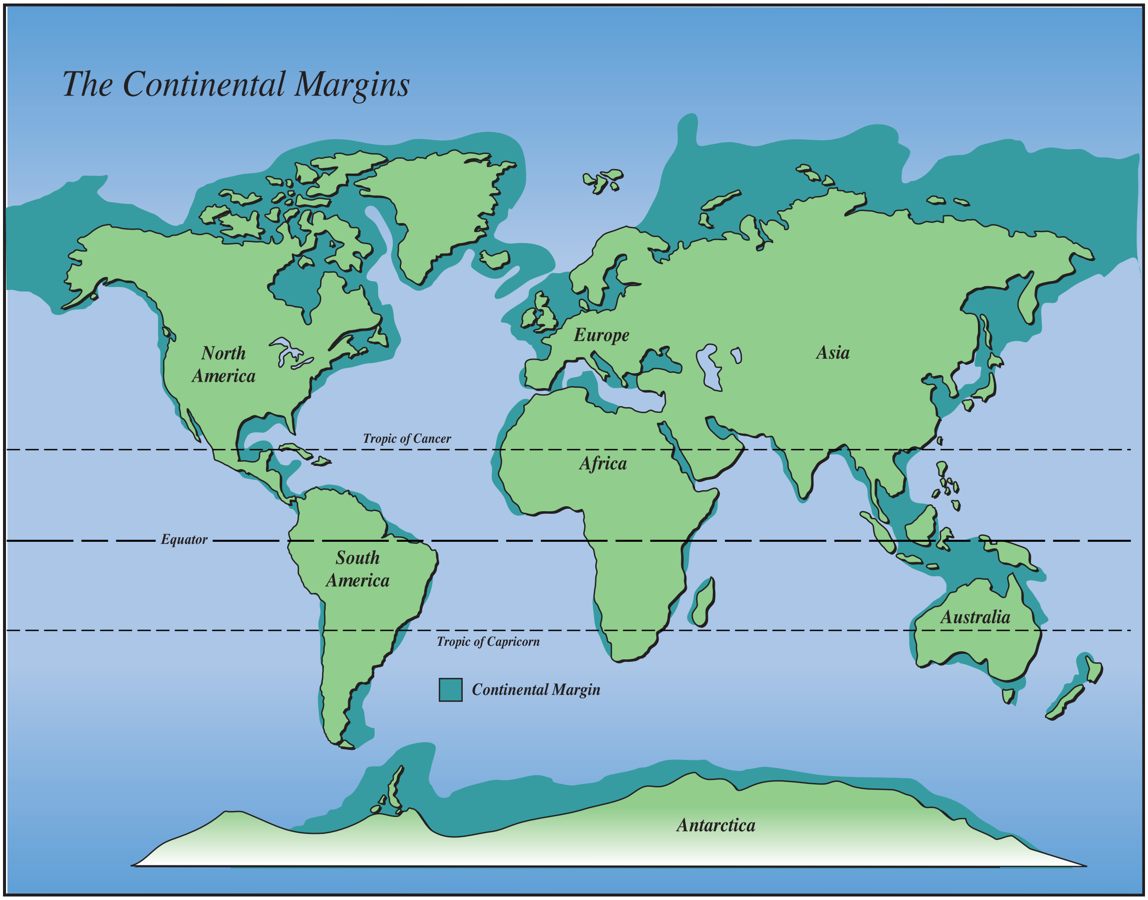
was one body of water that surrounded one large continent. As time passed, this land mass began to pull apart. As a result, the continents and islands were formed.

The breakup of that one large continent was caused by heat forces welling up deep within Earth. As earthquakes split the ocean floor, molten rock from below Earth's crust flowed into the fracture and became solid. For millions of years this process was repeated until the upper parts of Earth's crust, on which the continents sit, were pushed even farther apart. About 50 million years ago, the continents took their present shapes and positions.

About 20 million years ago, when the sea level was at its lowest, the area that now makes up the continental shelves was above water. Forests may have grown there and it may have been home to many animals. Over millions of years, rain, wind, and wave action eroded (wore away) the shelf surface, and rivers and glaciers flowed across it. Gradually, sediments from the shelves were washed into the water. Later, as the glaciers melted, the sea level rose and covered the shelves so that the entire continental margin was under water.

The Water Column

All of the waters of the ocean, exclusive of the sea bed or other landforms, is referred to as the water column.



Every element known on Earth can be found in ocean water. It is 3.5 percent dissolved salts by weight. The percentage of these salts determines the ocean's salinity (level of salts). These salts also make seawater heavier than fresh water. The ocean water closest to the surface is usually less salty because of rainfall and fresh water flowing in from rivers.

The temperature of the oceans varies. Temperature changes are greatest near the surface where the heat of the sun can be absorbed. In the warmest regions of the world, this heat absorption occurs to depths of 330 to 1,650 feet (100 to 500 meters).

Zones in the ocean Different parts of the ocean have different features and different kinds of creatures live in them. These different parts are called zones. Some zones are determined by the amount of light that reaches them.

Crashing waves wear at the shoreline, changing its shape over time. COPYRIGHT © 2005 KELLY A. QUIN.

Over the continental shelves and in the open ocean there is enough light to support photosynthesis, the process by which plants use the energy from sunlight to change water and carbon dioxide into the sugars and starches they use for food. These surface waters, called the sunlit zone, reach down as far as 660 feet (200 meters) below the surface. The sunlit zone supports more plant and animal life than any other zone.

Below the sunlit zone and extending about halfway down the continental slope is the twilight zone, which ranges from 650 to 3,300 feet (198 to 1,006 meters) in depth. Only blue light can filter down to this level. It is too dark for plant life here, but animals can live at this depth.

Beginning about halfway down the continental slope and extending into the deepest region of the oceans is the dark zone. Like the twilight zone, the dark zone is unable to support plant life, but a variety of animals are able to live in its depths.

Circulation The oceans are constantly, restlessly moving. This movement takes the form of tides, waves, and currents, all of which affect the continental margins.

Tides Tides are rhythmic movements of the oceans that cause a change in the surface level of the water. They are created by a combination of the gravitational pull of the sun and moon and Earth's rotation.

Low tide in the Bay of Fundy, Nova Scotia, leaving boats such as these scallop draggers completely exposed. IMAGE COPYRIGHT V. J. MATTHEW, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

High tide occurs when the water level rises. When the level lowers, it is called low tide.

Sea level refers to the average height of the ocean when it is halfway between high and low tides and all wave motion is smoothed out. Sea level changes over time.

Waves Waves are rhythmic rising and falling movements on the surface of the water. Most surface waves are caused by wind. Their size is due to the speed of the wind, the length of time it has been blowing, and the distance over which it has traveled. Breakers are waves that collapse on a shoreline because the water at the bottom of the wave is slowed by friction as it rolls along the shore. The top of the wave then outruns the bottom and topples over in a heap of bubbling foam.

One type of wave called a tsunami (soo-NAH-mee) is mainly caused by undersea earthquakes. When the ocean floor moves during the quake its vibrations create a powerful wave that travels to the surface. Tsunamis that strike inhabited coastal areas can destroy entire towns and kill many people.

Currents Currents are flows of water in a certain direction. They can be both large and strong. Most currents are caused by the wind, the rotation of Earth, and the position of continental landmasses. In the North Pacific, for example, currents moving west are pushed northward by Asia and southward by Australia. The same currents then move east until they reach North and South America, which send them

Tsunamis are caused by undersea earthquakes and are capable of causing massive destruction. AP IMAGES.

back toward the equator. Longshore currents are those that move along a shoreline.

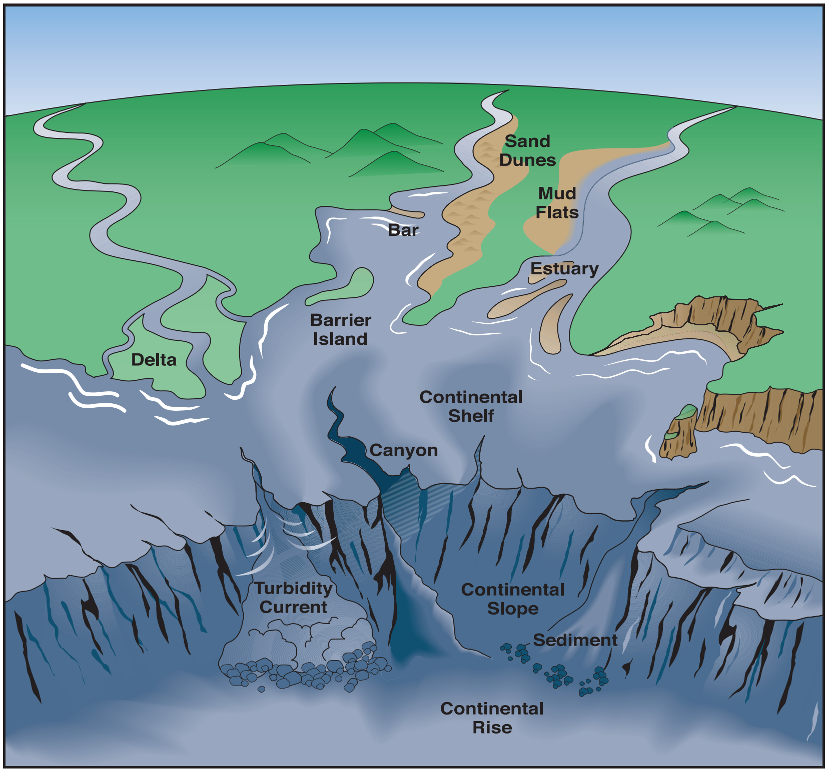
Upward and downward movement of water also occurs in the ocean. Vertical currents are mainly caused by differences in water temperature and salinity. In some coastal areas strong wind-driven currents carry warm surface water away. An upwelling (rising) of cold water from the deep ocean occurs to fill the space. This is more common along the western sides of the continents. These upwellings bring many nutrients from the ocean floor to the surface waters.

At the continental margins, large quantities of sediments enter the ocean and move out along the sea floor. The sediments are often sped along by turbidity (tur-BID-ih-tee) currents, which may be caused by earthquakes or sudden slumping of loose sediments. The thick mixture of sediment and water rushes down the continental slope and through any submarine canyons at considerable speeds for long distances, much like an avalanche of snow. They are so strong they have been known to break underwater cables that lay in their path hundreds of miles away. Turbidity currents can cause many changes to the margin floor.

Geography of Continental Margins

The general shape of the continental margin is usually determined by the shape of the coastline from which it extends. If it extends from a plain, then the margin will be broad and level. If it extends from a mountainous coast, then it will be steep and rocky. Steep cliffs that may have been formed by wave action when the level of the sea was lower may now be submerged and form part of the margin.

The present shape of a continental margin may be due to several influences. Movement of Earth's crust may have given it a folded appearance where the sea floor cracked and was pushed underneath the margin. Huge boulders and rocks may indicate that a glacier once moved across the region. The presence of a river may mean a larger quantity of sediment



A cross-section of the continental margin, including the continental shelf and continental slope.

where it enters the ocean, and the weight of tons of this sediment may have forced the underlying rock to sink.

A continental margin located in an area prone to many earthquakes or volcanoes is considered an active margin. It is constantly changing due to the continuous earthquake and volcanic activity. Active margins are often found in the Pacific Ocean, such as those along the west coast of South America. They are narrow and often drop sharply into a deep trench (steep valley).

Passive margins are less active and usually free of earthquakes and volcanoes. They are found where the ocean floor is still gradually spreading. In most cases there is a wide rise. Continental margins along the Atlantic and Indian Oceans are passive margins.

Dams Volcanic action, earthquakes, or a reef (a ridge of rock or other material) may create a dam at the end of the slope or rise. This dam causes sediments to build up and become an extension of the shelf. A new slope

Volcanic rock forms the coastline of a small cay in the Caribbean Sea. IMAGE COPYRIGHT LORI FROEB, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

and rise form at its end. Salt domes, huge mounds of salt that have moved upward from beds buried deep in the ocean floor, can form dams and trap sediment. A salt dam has helped form the shelf in the Gulf of Mexico off the U.S. coast.

Subduction zones and trenches The sea floor is continuously spreading. When it presses against the edges of the continents, they resist its movement. This results in an area of extreme pressure called a subduction zone. The enormous pressure forces the sea floor to crack, pushing it down and causing it to slide under the continental margin, often causing a deep, V-shaped trench to form. The greatest depths in the oceans are found in these trenches, and the deepest trenches are located in the Pacific Ocean. The Mariana Trench is the deepest at 36,201 feet (11,033 meters). Many earthquakes occur in subduction zones.

Underwater canyons The continental slope is often cut by deep, V-shaped, underwater canyons (deep, narrow depressions in Earth's crust). These canyons vary in size but are not as deep as trenches. A canyon off the coast of Africa extends 15 miles (25 kilometers) across, but its depth is only 1,480 feet (450 meters).

The origin of canyons is different from that of trenches. Some canyons appear to be related to rivers on land that during prehistoric times may have extended into the area now covered by ocean. The huge Monterey Canyon off the coast of California is an example. The Salinas River once flowed into its bed during the Ice Ages.

The method of formation for some canyons is a mystery. The Bering Canyon north of the Aleutian Islands in the North Pacific Ocean is an example. It cuts through the continental margin for more than 255 miles (410 kilometers) and is the longest canyon in the world. However, there is no evidence it was ever associated with a river and it is unknown why or how it was formed.

Reefs A reef is a ridge or wall of material lying close to the surface of the water just offshore. Reefs are made of rock or coral. A coral reef is a wall formed in shallow ocean areas by small, soft, jellylike animals called corals and marine algae that store calcium deposits. Corals attach themselves to hard surfaces and build a shell-like external skeleton. Many corals live together in colonies. Young coral builds its skeleton next to or on top of older skeletons. Gradually, over hundreds, thousands, or millions of years a wall, or reef, of these skeletons is formed. Reef corals cannot live in cold waters. They are found only in warm waters north and south of the equator. The water must be clear and free of sediment. Coral reefs do not form where rivers flow into the sea.

The rockslide in the foreground shows one of the ways the continental margin continues to change. IMAGE COPYRIGHT ROMAN KROCHUK, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

When a coral reef grows tall enough to break the surface of the water, it may begin to collect sand, gravel, weeds, and other matter. Gradually, an island, called a cay (KEE) or key, begins to form. The wind or visiting animals bring seeds, and plants begin to grow, especially small trees called mangroves. As the plants die and decay, soil forms. After a time, the island may be able to support certain larger species of trees.

Three main types of coral reefs are found on the continental margins: shelf reefs, fringing reefs, and barrier reefs. Shelf reefs form on a continental shelf having a hard, rocky bottom. A shallow body of water called a lagoon may be located between the shelf reef and the shore. Fringing reefs develop close to the land and no lagoon separates them from the shore. The longest is found in the Red Sea, where it stretches for 2,000 miles (3,200 kilometers). Barrier reefs line the edge of the continental shelf and separate it from deep ocean water. A barrier reef may enclose a lagoon and even small islands.

World's Biggest Ice Cubes

Thousands of icebergs form each year and float freely in the ocean. Those in the Arctic are usually produced by large glaciers moving across Greenland. As the glacier reaches the ocean, huge portions break off. Arctic icebergs often contain soil and other evidence of their origin on land. Antarctic icebergs are gigantic chunks of pack ice that form on open water. Unlike glacier ice, they do not originate on land, and therefore, contain no sediments.

The exposed portion of an iceberg may be more than 200 feet (61 meters) high, but this is only a hint of its actual size. About 90 percent of an iceberg remains underwater. That means its submerged portion could be 1,800 feet (549 meters) deep!

Estuaries and deltas When a river traveling through lowlands meets the ocean in a semi-enclosed channel (stream bed) or bay, the area is called an estuary. The water in an estuary is brackish—a mixture of fresh and salt water. In these gently sloping areas, river sediments collect, creating muddy shores. When the muddy sediments form a triangular shape over the continental shelf, the area is called a delta. The Mississippi Delta is one of the largest, spanning 60 miles (100 kilometers) across.

Glacial moraines A glacial moraine is a pile of rocks, gravel, and sand created when a glacier moves across the surface of the land. Glacial moraines are found on some continental shelves that were crossed by glaciers during the Ice Ages more than 10,000 years ago. When the glaciers shrank, the level of the sea rose and covered the area with water. The tops of some glacial moraines remain above the water and form islands. The Aland Islands in the Baltic Sea are an example.

Bars and shoals Bars and shoals can form where tides and currents move large quantities of sediment, such as sand or gravel. A bar is a ridge of sand that accumulates across a channel. Shoals are areas where enough sediment has accumulated that the water is very shallow and dangerous for navigation. The shoals around Nantucket Island, off Massachusetts, for example, have sunk at least 2,100 ships.

Tiny, But Deadly

Pfiesteria piscidia, a species of tiny, one-celled dinoflagellate algae, has suddenly become more dangerous than its size would indicate. In the late 1980s this normally nontoxic organism turned poisonous and began killing fish in North Carolina waters. Over a billion fish have been destroyed since 1991.

Pfiesteria release strong poisons into the water. The poisons cause fish to gasp for oxygen and develop bleeding sores on their bodies. *Pfiesteria* then feed on the dying tissues. The poisons are harmful to shellfish and even mammals, including humans, who develop impaired memory and learning abilities.

Most dinoflagellates obtain food by means of photosynthesis, but *Pfiesteria* passes through many different life stages, and in some stages, it appears to dine on other organisms. Experts suspect that the changes in *Pfiesteria* may have been caused by fertilizer and sewage runoff from hog and chicken farms in the area.

Plant Life

Most ocean plants live in waters above the continental shelf. They include tiny, one-celled organisms and many kinds of seaweed and seagrasses. Some scientists estimate that plants over the continental shelf produce more oxygen for Earth than all the forests on land.

Ocean plants are surrounded by salt water at all times. For this reason most have not developed the special tissues and organs needed by land plants for conserving water. Seaweeds, for example, use their "roots" only to anchor them in one spot, not to draw water from the soil.

Water also offers support to ocean plants. Trees on land require a tough, woody stem to hold it erect, but giant underwater plants do not require woody portions because the water helps hold them upright. Their stems are soft and flexible, allowing them to move with the current without breaking.

Marine plants can be classified as either plankton or benthos. Plankton (a Greek word meaning "wanderers") are plants that float freely on the water's surface. Benthic (a Greek word meaning "depth") plants anchor themselves in the sea floor.

Ocean plants can be divided into two main groups: algae (AL-jee) and green plants.

Algae Algae are single- or multi-celled organisms that do not fit neatly into the plant category. They can range from microscopic blue-green algae, which are really bacteria, to giant brown algae kelp nearly 200 feet (61 meters) long. Other algae are green or red. Green algae are the ancestors of land plants. Like plants, nearly all algae have the ability to make their own food by means of photosynthesis (foh-toh-SIHN-thuh-sihs). They use energy from sunlight to change water and carbon dioxide into the sugars and starches they need for food. Other algae absorb nutrients from their surroundings.

Phytoplankton are a form of algae so tiny they cannot be seen with the naked eye. They float freely in the water, allowing it to carry them from place to place. Other species of algae are massive and live in vast underwater forests anchored to the seafloor. These are the benthic species.

Common algae Two types of algae commonly found along the continental margins include phytoplankton and kelp.

Phytoplankton Phytoplankton are microscopic single-celled algae that float on the surface of waters within the sunlit zone. They are responsible for about 90 percent of the photosynthesis carried out in the oceans. During photosynthesis, phytoplankton release oxygen into the atmosphere. Two forms of phytoplankton, diatoms and dinoflagellates (dee-noh-FLAJ-uh-lates), are the most common.

Diatoms have simple, geometric shapes and hard, glasslike cell walls. They live in colder regions and even within arctic ice. Dinoflagellates have two whiplike attachments that make a swirling motion. They live in tropical regions around the equator.

Kelp Kelps are usually brown benthic algae that grow on rocks in temperate waters (41° to 72°F [5°C to 22°C]). In northern regions, benthic plants grow below 200 feet (61 meters). In tropical regions, where the sun's rays are more vertical and can penetrate farther into the water, kelps grow as deep as 400 feet (122 meters). There is evidence that some can grow as deep as 1,000 feet (305 meters), where no light penetrates, because they may obtain food from decomposing matter that filters down from above instead of by means of photosynthesis.

There are several different species of kelp but only two basic forms. One type has a simple trunk between 20 inches and 8 feet (50 centimeters and 2.5 meters) long and a leaflike frond (branches) on top. The second type may grow to more than 250 feet (76 meters) in length and has fronds all along its trunk. Some kelp have gas-filled chambers at the bases of their fronds that help them remain upright. Kelp resemble green plants, but they have no true leaves, stems, or roots. Instead they have a rootlike structure called a holdfast that anchors them to the ocean floor.

Kelp reproduce sexually; cells from a male and female plant unite to form another plant.

Kelp grow in huge, floating groups, or forests, that cover hundreds of square miles (square kilometers) and provide shelter and food for animals such as fish, crabs, and sea otters. On the water's surface, kelp can be so thick that sea otters can lie down on them as if in a hammock. Sea urchins, which also feed on kelp, can grow so numerous they eventually destroy the kelp beds unless checked by natural predators.

Growing season Algae contain chlorophyll, a green pigment used to turn energy from the sun into food. As long as light is available, algae can grow. In some species, the green chlorophyll is masked by orange-colored pigments, giving the algae a red or brown color.

Growth of ocean plants is often seasonal. In some areas, such as the Arctic, most growth occurs during the summer when the sun is more nearly overhead. In temperate (moderate) zones, growth peaks in the spring but continues throughout the summer. In regions near the equator, no growth peaks occur since growth is steady throughout the year.

Food Most algae grow in the sunlit zone where light is available for photosynthesis. Algae require other nutrients found in the water, such as nitrogen, phosphorus, and silicon. In certain regions, upwelling of deep ocean waters during different seasons brings more of these nutrients to the surface. This results in algal blooms, sudden increases in the number of algae. Algal blooms also occur when nitrogen and phosphorus are added to a body of water by sewage or by runoffs from farmland.

Reproduction Algae reproduce in one of three ways. Some split into two or more parts, with each part becoming a new, separate plant. Others form spores (single cells that have the ability to grow into a new organism). A few reproduce sexually, during which cells from two different plants unite to create a new plant.

Green plants The true green plants found in the ocean are seagrasses, such as turtle grass, and are similar to land plants. Green algae are often considered green plants. Unlike algae, green plants have roots and bloom underwater. Beds of seagrass occur in sandy bottoms in areas protected from currents, such as in lagoons or behind reefs. Large beds slow the movement of water and help prevent erosion of the shelf. Some marine animals use seagrasses for food and for hiding places.

Animal Life

The oceans are the largest animal habitat on Earth, and most species are found along the continental margins. The continental shelves underlie only about 8 percent of the total area of the oceans, but their shallow waters support more forms of life than any other area in the ocean—perhaps any other place on Earth. Scientists estimate as many as 30 million species of sea life may still be undiscovered. The types of animals found along the upper continental slope depend on whether the floor is sandy, muddy, or rocky. The lower slope and rise are home to fewer animals.

Animals that live in the sea have developed ways to cope with its high salinity. Naked (covered with thin "skins" or shells) animals maintain high levels of salt in their blood normally and do not need to expel any excess. Others, such as most fish, have special organs that remove extra salt from their system and release it into the water.

Water offers support to marine (ocean) animals as it does to plants. Many marine animals have special chambers in their bodies that allow them to adjust their buoyancy (BOY-un-see; ability to float) so they can float in either shallow or deep water. Some, such as seals, have flippers to make swimming easier. Others, such as octopi, forcefully eject water in a kind of jet stream to help them move.

Sea-Going Dinosaurs

About 63,000,000 years ago, a number of dinosaur species lived in the oceans. The Tylosaurus was 25 feet (7.6 meters) long and resembled a chubby crocodile with flippers rather than feet. Plesiosaurs, which could have been as long as 50 feet (15 meters), had flippers and long, giraffelike necks. Flying reptiles, called pteranodons, glided through the air over the ocean on leathery wings looking for fish. They returned to land only to lay their eggs.

Marine animals are classified as microorganisms, invertebrates, or vertebrates. Like plants, they can be classified according to their range and style of movement. Plankton drift in currents and include such animals as jellyfish. Many plankton move up and down the water column by regulating the amount of gas, oil, or salt within their bodies. (Production of gas or oil and removal of salt causes the organism to rise; the reverse causes them to sink.) Many larger animals spend part of their young lives as plankton. Crabs, which move about on legs as adults, but float with the current in their larval form, are an example. Larger animals that swim on their own, such as fish and dolphins, are called nekton. Benthos are the animals that live on the seafloor. These include snails and clams.

Microorganisms Most microorganisms are zooplankton (tiny animals that drift with the current). They include foraminiferans, radiolarians, acantharians, and ciliates, as well as the larvae or hatchlings of animals that will grow much larger in their adult form. Some zooplankton eat phytoplankton and are preyed upon by other carnivorous (meat-eating) zooplankton, such as arrow worms.

Bacteria Bacteria are another type of microorganism found throughout the ocean. They make up much of the dissolved matter in the water column and provide food for microscopic animals. Their numbers increase

The hairy clinging crab is found among the rocks and sand of the continental margin. COPYRIGHT © 2005 KELLY A. QUIN.

along the continental shelf where most animal life is found because they help decompose the dead bodies of larger organisms.

Invertebrates Animals without backbones are called invertebrates. They compose 95 percent of marine animals. Many invertebrate species, such as worms and squids, are found in the ocean. Perhaps the most numerous and diverse group of invertebrates are crustaceans, which have hard outer shells for protection from potential predators. Crustaceans include animals such as lobsters and crabs.

Common invertebrates Invertebrates found along the continental margins range from planktonic jellyfish to nektonic octopi to benthic starfish and corals.

Jellyfish are commonly found close to shore where they float on the surface. All jellyfish move by squeezing their bodies to push out water that forms a kind of jet stream behind them. Most of the time they live as plankton and simply float with the current. Jellyfish eat small prey, such as shrimp, tiny fish, and other plankton, which they catch by stinging them with their tentacles.

Another common invertebrate that lives along the continental margins is the octopus. Octopi may crawl around the ocean bottom using their tentacles, or move through the water by means of jet propulsion. Different species are found throughout the ocean, and they vary in size. Those found in shallow water are generally the smallest. Giant octopi with a tentacle spread of 32 feet (9.7 meters) have been found off the coast of Alaska.

Food Invertebrates may eat phytoplankton, zooplankton, or both. Some also eat plants or larger animals. The cone shell uses a harpoonlike tooth to spear its prey and inject it with poison. Others, including lobster, roam along the bottom to feed on dead organisms by grasping them with their large pincher front claws.

Reproduction Marine invertebrates reproduce in one of three ways. Two ways use external fertilization (outside the female's body) of eggs. The first way involves a parent watching over the young in the early stages and offspring number in the hundreds. The second way does not require parental care and offspring number in the millions. Survival depends upon the absence of predators and the direction of currents. The third method of reproduction is internal fertilization (inside the female's body). A parent cares for the young in the early stages and offspring number in the thousands.

The Clockwork Worm

Some animals seem to have built-in "clocks," like one species of marine worm called the palolo worm. This little creature, which lives in the waters of the central Pacific, develops eggs and sperm in the rear half of its body. This rear section detaches from the rest of its body and swims to the surface like clockwork on the day of the last quarter of the October-November moon. On this day, the surface waters grow thick with the rising egg sections from millions of worms.

Reptiles Reptiles are cold-blooded vertebrates, which means their body temperature changes with the temperature of their surroundings. In cold temperatures they become sluggish but can still function. This means they do not have to use energy keeping their body temperatures up as most do mammals and birds.

Only one species of lizard has adapted to life at sea, the marine iguana. There are only two species of crocodile, the Pacific saltwater crocodile and the American saltwater crocodile, that spend a large amount of time off shore. The reptiles most commonly found in the oceans are the sea turtle and the sea snake.

Common marine reptiles Sea turtles can be distinguished from land turtles by their paddlelike limbs called flippers, which enable them to swim. Sea turtles have glands around their eyes that remove excess salt from their bodies, a process that makes them appear to cry. At least one species of turtle hibernates on the seabed during winter. Green turtles are

Although sea turtles live in the water, they lay their eggs on shore. This is an endangered Kemp's Ridley sea turtle. AP IMAGES.

migratory and travel as far as 1,250 miles (2,000 kilometers) to return to a particular breeding area where they lay their eggs.

At least fifteen species of sea snakes live in tropical oceans (those around the equator). Half of these are found in regions around Australia and New Guinea. They have long bodies like land snakes, some of which attain 9 feet (2.7 meters) in length. Special salt glands help them maintain a body fluid balance. Their tails are paddle shaped to move them through the water. All sea snakes are venomous. The yellow-bellied sea snake may be the most abundant reptile on Earth.

Food Sea turtles eat soft plant foods as well as small invertebrates, such as snails and worms. Turtles have no teeth. Instead, the sharp, horny edges of their jaws are used to shred the food so they can swallow it. All seven species of sea turtle are either threatened or endangered.

Sea snakes are carnivorous, feeding primarily on fish and eels they find along the ocean bottom in rocky crevices. They first bite their prey, injecting it with venom so that it cannot escape.

Reproduction Both snakes and turtles lay eggs. Turtles dig a hole with their flippers on a sandy shore and lay their eggs. They cover the eggs with sand and abandon them, taking no interest in the offspring. Six weeks later the eggs hatch and the young turtles make a run for the water and immediately begin swimming. Sea snakes either come to shore to breed and lay their eggs on land or bear live young at sea, depending upon the species.

Fish Fish are primarily cold-blooded vertebrates that have gills and fins. Gills are used to draw in water from which oxygen is extracted, and fins help propel the fish through the water. Most fish are long and sleek in design, but shapes vary greatly. Manta rays, for example, are flat and round, while seahorses are narrow and swim in a vertical position.

Most fish species live over the continental shelf in the sunlit zone. In the twilight and dark zones species such as the hatchetfish, the swallower, and the black dragonfish can be found.

A Dentist's Dream

Sharks may have as many as 3,000 teeth in their mouths at one time. These teeth are arranged in rows, and only the first few rows are used. If a tooth is lost during feeding, the next tooth in line moves up to take its place.

Common fish Mackerels and rays are commonly found over the continental margins. Mackerels live over the continental shelves in temperate and tropical oceans. They gather in schools (groups) in the upper waters during the warm months and descend to deeper waters in the winter. Their primary food is zooplankton, such as fish eggs. Mackerels lay their eggs in mid-water where they drift with the currents. Some species are popular as game fish, and many species are important commercially in the fishing industry.

Rays are relatives of the shark, but they have flat, broad bodies. Their eyes are on top and their mouths are on the underside. They feed by flapping and gliding over the seabed in search of clams and similar prey. Some species have the ability to give an electric shock for defense or to kill prey. The largest species, the devil or manta ray, can grow as much as 20 feet (6 meters) in diameter. Most species bear live young.

The largest species of ray, the manta ray, can grow to as much as 20 feet (6 meters) in diameter. IMAGE COPYRIGHT SPECTA, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Food Plant-eating fish, such as anchovies, have a diet primarily of phytoplankton, benthic algae, or sea grasses. Fish that must swim in search of prey, such as swordfish, have more streamlined bodies than those, like the sea robin, that glide close to the bottom sediments in search of a meal. Many dark zone species eat carrion (decaying flesh).

Sea gulls often eat fish and other small creatures found in the ocean's continental margin. IMAGE COPYRIGHT STEPHEN ORSILLO, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Reproduction Most fish lay eggs. Some fish, like the Atlantic herring, abandon eggs once they are laid. Other fish build nests and care for the new offspring. Still others carry the eggs with them, usually in a special body cavity or in their mouths, until the eggs hatch. A few fish, such as certain species of sharks, bear live young.

Sturgeons are one type of fish that travel thousands of miles to return to a particular breeding area where they lay their eggs and then die. By some inherited means of guidance, their young will make the same journey when their turn comes to breed, and the cycle is repeated.

Seabirds Only 4 percent of bird species have adapted to sea life. Most seabirds remain near land where they can nest during breeding season. Many have adapted to marine environments by means of webbed feet and special glands for removing excess salt from their blood.

Common seabirds Birds living along the ocean's margins are divided into four groups. The first group includes pelicans and their relatives, such as frigate and cormorants. This is a varied group, but all members share the common trait of webbing on all four toes. The second group is called tubenoses and is known to be a group of superb flyers. Petrels, shearwaters, and albatrosses belong to this group. Another group contains a mix of gulls, terns, puffins, and auks. Finally, penguins, which do not fly but can swim in the water, are the last group. There are seventeen species of penguin and all of them live in the Southern Hemisphere (below the Equator).

Food Seabirds are carnivorous. They eat fish, squid, or zooplankton and live where food is plentiful. Several species, such as sea ducks, dive underwater to feed on shrimps, worms, or crabs. Other species, such as cormorants, spot their prey from high above in the sky and then plunge in just deep enough to catch it. Some, like terns, swoop down on fish swimming close to the surface.

Reproduction All seabirds nest on land. Some nest in huge colonies on the ground, others dig burrows, and still others prefer ledges on cliffs. Like land birds, seabirds lay eggs and remain on the nest until the young can leave on their own. Some birds live and feed in one area and migrate to another for breeding. Birds that nest on sandy shores tend to lay speckled or blotchy eggs in beige and brown colors that blend in with the sand and pebbles.

Marine mammals Mammals (warm-blooded vertebrates that bear live young nursed with milk) must come to the surface to breathe, and many, such as seals and polar bears, live part of the time on land. Whales, porpoises, sea cows, and their relatives remain in the water at all times.

Mammals must maintain a high body temperature. Most marine mammals have a special layer of fat below their skin to protect them from the cold water. Some, such as walruses, have very thick skins that make it difficult to keep cool in the sun. Others, such as seals, are covered with fur that helps insulate them against the cold.

Common marine mammals Whales, dolphins, and porpoises are mammals that resemble fish. The killer whale, a relative of the dolphin, hunts in large groups and feeds on other mammals as well as fish and birds. Another fishlike mammal, the narwhal, or sea unicorn, has a tooth that grows into a spiral as much as 10 feet (3 meters) in length.

Seals are common along the continental shelves where they may plunge as deep as 3,300 feet (1,000 meters) in search of fish. Some species can stay underwater for as long as 30 minutes. Seals usually gather in huge on-shore colonies to breed.

Although polar bears are usually thought of as land animals, they spend much of their time in the water and may swim 20 miles (32 kilometers) or more in search of food. Their primary prey is seal. They may wait for hours along a shore for a seal to surface. If they catch it, they drag it ashore to eat it.

Food Sea cows, such as the dugong, are the only plant-eating mammals that truly live in the sea. Marine mammals are typically carnivorous. Seals and walruses, for example, feed on fish and squid

The Web of Life: Animal Partners

Many animals of different species form partnerships that help them survive. Certain fish, such as the moray eel, attract parasites that irritate their skin, gills, and mouth. That is when a cleaner fish comes in handy. The cleaner fish swims into the mouth of the eel, picks off the parasites, and eats them. Sometimes the customer forgets why the cleaner fish is there and has it for a snack.

Another partnership is formed between the clownfish and the sea anemone. Sea anemones (ah-NEH-moh-nees) are soft-bodied animals that attach themselves to rocks and reefs. These colorful creatures look like underwater flowers. However, they have long, poisonous tentacles they use to kill their prey. The clownfish cautiously approaches and rubs itself against the anemone. For some reason, this prevents the anemone from stinging the clownfish, which settles in among the tentacles and waits for dinner to swim by. The clownfish feeds on prey that escape the anemone and draws other fish into the anemone's grasp so it, too, can eat.

The Brainiest Mammal

The mammal with the largest brain is the sperm whale, a species found in all oceans. The whale's head makes up one-third of its body. Since an average-sized male whale is about 63 feet (19 meters) long, its head would be about 20 feet (6 meters) long.

that live on the continental shelf. Other mammals, like killer whales, hunt for seals and other mammals.

Reproduction Marine mammals usually have only one offspring at a time. The young are nursed on the mother's milk until they are able to find food on their own. This is true whether the mammal spends all its time in the water or part of the time on shore.

Endangered species Sea turtles lay their eggs on beaches, which makes the eggs easy to hunt and/or destroy. Turtle eggs are a popular food among humans in many parts of the world, as are the turtles themselves. Turtles must come to the surface to breathe air where many get caught in fishing nets that pull them below the water, and they drown. Over 70 conservation laws have been passed to protect the sea turtles.

Many fish used as food have been caught in such large numbers that they are disappearing. Since the 1970s, the number of bluefin tuna has decreased 90 percent and Atlantic swordfish have decreased by 30 percent.

In certain areas, other animals are threatened. They include the starlet sea anemone, the giant clam, the Olive Ridley turtle, the loggerhead turtle, the coelacanth, the Dalmatian pelican, the West Indian manatee, the marine otter, the monk seal, and the polar bear.

About 11 percent of coral reefs were destroyed by human actions before 1998. Another 16 percent were lost during the El Niño event in 1997–98. El Niños are extreme weather conditions caused by the slackening of the southeast Pacific trade winds. Due to a resulting shift in temperature, the corals eject their color, which is created by the colorful dinoflagellate algae that live on them. This is called coral bleaching because the corals become pale. It is estimated that by the year 2020 another 30 percent of coral reefs will be lost. As a result, all of the animals that depend upon the reef for food and shelter will be affected.

Human Life

The waters over the continental shelves have been explored by humans more than any other area of the ocean because the water is fairly shallow

The monk seal is one of several animal residents of the continental margin that is also endangered. IMAGE COPYRIGHT DON LONG, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

and reachable by divers. Most commercial fishing areas are located over the shelves, as are those areas from which oil and natural gas are extracted.

The best-known shelves are those off the coasts of the United States, eastern Canada, western Europe, and Japan. In these places, scientific studies are routinely conducted and the information is made available to everyone. Oil companies that work in other areas, such as the Persian Gulf, obtain knowledge about them. Oceanographic organizations have studied the Red Sea, the Yellow Sea, and the shelf off the coasts of Argentina and northwestern Africa. A few developing countries have closed their waters to foreign scientists; as a result, little is known about those shelves.

Impact of the continental margin on human life The continental margin is the ocean area most easily reached by humans and so it has an important effect on human life.

Food About 90 percent of the world's marine food resources come from the waters over the continental shelves. Most of those resources consist of fish. Different methods and equipment are used to catch fish, depending upon the type of fish desired and where they are found. Some fish live in the water column and may be caught on the surface or in mid-water, while others

More than 400 million people live no more than 12 miles (20 kilometers) from a coast. Coastal waters provide food, transportation, employment, and recreation. COPYRIGHT © 2005 KELLY A. QUIN.

live on the ocean floor. These two categories may be divided further into fish caught at the shoreline, above the continental shelf, or in mid-ocean.

Sport fishing is done for recreation. The catch is taken home and may be eaten, but the family does not depend upon it for food. Subsistence fishing is done to obtain food for a family or even an entire community. Extra fish may be sold to neighboring communities. Native peoples who live on islands often do subsistence fishing.

Commercial fishing is done to earn money. When carried out by small owner-operated companies, much of the work is done by hand. The equipment is usually simple and the number of fishing boats small. Industrial, large-scale fishing usually involves modern, high-powered equipment. Huge factory ships may be as long as 330 feet (100 meters) and are equipped with automatic machinery needed to catch, handle, store, and process huge amounts of fish.

Energy Millions of years ago, sediments from dead animal and plant life collected on the ocean bottom. Over time, these sediments fossilized (turned to stone). More time, heat, and pressure from overlying rock worked to liquefy these sediments and turn them into fossil fuels, primarily gas and oil. To obtain fossil fuels, oil companies build large rigs—platforms high above the ocean surface but anchored to the sea bed. From these platforms, drilling is done into the rocky ocean floor, releasing the gas or oil, which is then pumped to shore through pipelines. Most gas and oil deposits have been obtained from offshore rigs. More than $1 billion worth of gas and oil is pumped from the continental shelves of the United States each year.

Ocean surface waters absorb large quantities of solar energy (energy from the sun). A process known as ocean thermal energy conversion is used to capture some of that energy for human use. Conversion plants are located in Hawaii and other tropical islands. Energy from ocean currents and waves is also being explored as a source of power. One day it may be possible to anchor a turbine (energy-producing engine) in a fast-moving current, such as the Gulf Stream, and use it to produce power.

The energy in the tides has already been harnessed in different ways. The tides are channeled into salt ponds, where salt from the water is collected for sale. The tides also lift ships in and out of drydock where repairs are made. The first tidal power station was developed in an estuary in France where turbines were built into a dam that spans the estuary. As the tides flow in and out of the estuary, they turn the turbine blades, which produce electricity.

A fishing ship comes into harbor. About 90 percent of the world's marine food resources come from the waters of the continenal shelves. IMAGE COPYRIGHT ERIC GEVAERT, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Minerals and metals Minerals and metals are other important oceanic resources. Rocks, sand, and gravel dredged from the sea bottom, especially in the North Sea and the Sea of Japan, are used in the construction of roads and buildings. Along the Namibian coast of southwest Africa, diamonds are mined from the sea floor. Some minerals, such as sulfur, are pumped from the ocean beds as liquids.

Impact of human life on the continental margin The area of the ocean most affected by human action is over the continental margin.

Use of plants and animals After World War II (1939–45) the technology of commercial fishing improved, and a growing population increased the demand for fish as a food source. By the 1970s major food species, such as herring and cod, had been greatly reduced. By 1995, 22 percent of marine fishing areas had been overused or depleted, and in 44 percent of fishing areas the maximum numbers of fish allowed by

Wells in the Sea

The first offshore oil well was drilled off the coast of California by 1897. This well, and those that followed, was drilled from a pier extending from shore. The first free-standing drilling structures were not built until the 1940s.

Since that time, the design of drilling rigs has changed. To stand in deep water and withstand storms at sea, they require long legs and a sturdy platform. One of the tallest platforms currently in operation is off the coast of Santa Barbara, California. The distance from its base anchored in the ocean floor to the top of a derrick on its platform high above the water is 1,165 feet (355 meters). This makes the rig only about 100 feet (30 meters) shorter than the Empire State Building in New York.

Exploration for wells is often done by mobile rigs positioned on drilling ships. The ships maintain their positions over the well using special propellers, and drilling in deeper waters is possible. During the 1980s, test wells were drilled from these ships in waters more than 6,500 feet (2,000 meters) deep.

regulations were being taken. Commercial fishing is done primarily with large nets that may also catch other unwanted creatures, many of which die. For every 1 pound (2.2 kilograms) of shrimp caught in the ocean, 5 pounds (11 kilograms) of other species are thrown away.

It has been said that human greed and carelessness have threatened many species of fish. However, not all scientists agree that the problems are serious or that they lack solutions. For example, between 1983 and 1993, the total number of fish available increased slightly. Conservation ideas include monitoring the numbers of fish in certain species to prevent overfishing and extending human consumption to more types of fish.

Fish farms are another means of helping maintain certain species of commercially popular fish. Also called aquaculture, fish farming involves raising fish species under the best growing conditions in farms built along waterways. The fish most commonly farmed are shellfish, such as oysters, mussels, scallops, clams, and shrimp. Crabs, lobsters, salmon, trout, and tilapia are also farm raised, but to a lesser extent. The output of fish farms has tripled since 1984, and it is estimated that more than 30 percent of all the seafood eaten comes from fish farms.

Other sea plants and animals are endangered because they are collected as souvenirs or art objects. Seashells left behind by dead animals can usually be taken with no harm. However, many shells available commercially are taken from living animals and, as a result, the animals are left to die.

In response to these problems, marine parks and reserves have been set up all over the world to protect endangered species. They include the Shiprock Aquatic Reserve in Australia and the Hervey Bay Marine Park in California.

Natural resources Large quantities of natural resources, such as oil and minerals, can be found in the ocean water or beneath the ocean floor.

These resources have not been used up because they are still too difficult or too expensive to obtain. As methods improve that may change. The first areas likely to be depleted are those around the continental margins. Already, some sections of the sea floor have slumped because underlying oil and gas have been removed.

The Law of the Sea After World War II, many countries began to expand their use of the oceans. Some countries started using ocean areas other countries had already claimed for themselves, and arguments resulted. In 1994, the United Nations approved a treaty among all nations called the Law of the Sea.

The Sneaky Vegetable

Although seaweed is popular as a food in some countries, particularly Japan, many people in the United States associate it with those slimy green things lying draped over the rocks at the beach. Most people have eaten seaweed and never realized it. As a product called carrageenan, seaweed is added to toothpaste, ice cream, gelatin, peanut butter, marshmallows, and even some meat products. It acts as a glue to help hold the other ingredients together.

The Law of the Sea Treaty maintains that a country's territory extends about 14 miles (22.2 kilometers) from its coast. That country has a right to defend that territory. The same country also has the right to control the natural resources on its continental shelf, or an area extending about 230 miles (370 kilometers) from its coast. This includes resources obtained from fishing and drilling for oil and natural gas. The rest of the ocean is international territory and all countries can share in its resources.

Quality of the environment In 1996, 14 billion pounds (31 billion kilograms) of waste were dumped into the oceans. Most oceanic pollution caused by humans is concentrated along the continental margins. Sewage and industrial wastes are contributed from coastal cities, adding dangerous metals and chemicals to the water. Discarded items, such as plastic bags and old fishing nets, pose a hazard for animals that get caught in them. Medical wastes, such as needles and tubing, are also a danger.

Insecticides (insect poisons) and herbicides (weed poisons) reach the oceans when rain washes them from fields into rivers that carry them to the sea. These poisons often enter the food chain, become concentrated in the bodies of some fish and other organisms, and are consumed by humans who eat the fish. Fertilizers and human sewage create another problem. They cause phytoplankton to reproduce rapidly. When the plants die, their decaying bodies feed bacteria. The bacteria rapidly multiply and use up the oxygen in the water, and other organisms, such as fish, soon die.

Refuse disposed of in the water can kill organisms, which disrupts the food web. IMAGE COPYRIGHT SASHA RADOSAVLJEVICH, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Oil spills from tanker ships and leaks from pipelines and offshore oil wells are major pollutants to oceans. Power plants and some industries often dump warm water into the oceans, causing thermal (heat) pollution. Organisms that require cooler water are killed by the heat.

Agriculture, construction, and removal of trees on land dig up the soil. Often the rain washes this loose soil into streams and rivers. Eventually, it enters the oceans and collects as sediment in coastal areas. This kills some organisms, such as clams, that cannot survive in heavy sediment.

The Food Web

The transfer of energy from organism to organism forms a series called a food chain. All the possible feeding relationships that exist in a biome make up its food web. In the ocean, as elsewhere, the food web consists of producers, consumers, and decomposers. These types of organisms all transfer energy within the ocean environment.

Phytoplankton are the major primary producers in the oceans. They produce organic materials from inorganic chemicals and outside sources of energy, primarily the sun. Producers are sometimes called autotrophs, meaning "self-feeders." Green plants are an example of producers because they manufacture the compounds they need through photosynthesis.

Zooplankton and other animals are consumers. Zooplankton that eat only plants are primary consumers in the oceanic food web. Secondary consumers eat the plant-eaters and include zooplankton that eat other zooplankton. Tertiary consumers are predators, such as tunas and sharks. Humans fall into this category. Humans are omnivores, which means they eat both plants and animals.

Decomposers feed on dead organic matter. These organisms convert dead organisms to simpler substances. Decomposers include lobsters and large petrels, as well as microscopic bacteria.

Dangerous to the oceanic food web are the concentration of pollutants and harmful organisms that become trapped in sediments where life forms feed. These life forms are fed upon by other life forms, and at each step in the food chain the pollutant becomes more concentrated. Finally, when humans eat these sea animals, they are in danger of serious illness. Diseases such as cholera, hepatitis, and typhoid, can survive and accumulate in certain sea animals. These diseases can be transmitted to humans who eat the infected animals.

Spotlight on Continental Margins

Queensland, Australia and The Great Barrier Reef The Great Barrier Reef, the longest structure in the world created by living organisms, consists of slightly fewer than 3,000 smaller reefs joined together. It covers approximately 132,974 square miles (344,400 square kilometers), which is almost the size of the state of Kansas. At least 500,000 years old, the reef can be seen from space and was first mapped by the *Apollo 7* astronauts in 1968.

Located at the edge of Australia's continental shelf, the Great Barrier Reef stands in water from 325 to 650 feet (100 to 200 meters) deep. On the landward side is a lagoon. On the seaward side, the continental slope plunges thousands of feet into the deep-ocean basin.

Many of the algae found on the reef live within the bodies of the corals, absorbing sunlight. Red algae, green algae, and kelp grow among the coral skeletons. Grasses and shrubs can be found on many cays, as well as banyan and breadfruit trees. The tree most commonly found is the mangrove.

The reef is home to millions of living creatures, including corals, sea urchins, sea slugs, oysters, and clams. The largest type of clam in the world, the giant clam, is found on the Great Barrier Reef. It weighs up to 1,000 pounds (454 kilograms) and has a diameter of up to 4 feet (1.2 meters). Many species of sea turtles come to the reef to lay their eggs. Parrot fish, squirrelfish, trumpet fish, lionfish, coral trout, and moray eels make the reef their home.

Seabirds nest on the cays and islands. More than 100,000 terns flock together annually on Raine Island. Frigate birds, gannets, and sea eagles can be seen skimming over the waters in search of food.

The sands that line the beaches are valuable to industry, and some people believe that oil lies beneath the shelf. To prevent the reef's

Queensland, Australia and the Great Barrier Reef
Location: The Coral Sea off the northeast coast of Australia
Area: 132,974 square miles (344,400 square kilometers)

destruction, the Australian government established the Great Barrier Reef Marine Park in 1975. The park is the world's largest protected marine area. Visitors are controlled, many areas are reserved only for study, and bird and turtle breeding areas found in the park are closed during breeding season so people do not disturb the animals.

Northwestern Australia and Southeast Asia On the continental shelf off the coast of northwestern Australia are the islands of Sumatra, Java, Borneo, and the Malaysian Peninsula, the most volcanic islands in the world. Other islands, including New Guinea, New Zealand, and the Philippines, are formed from part of the shelf. South of Java, the slope suddenly plunges into the Indonesian Trench, a deep, steep-sided valley in the ocean floor.

This continental shelf is approximately 140,000 square miles (300,000 square kilometers) and holds the most extensive beds of seagrass in the world, including such species as wireweed and paddleweed. Anchored by the grass, sandbanks over 33 feet (10 meters) thick and many miles (kilometers) long have built up over time.

Blue swimmer-crabs, pen shells, fan mussels, green turtles, and sea snakes are just a few of the marine animals that live over the shelf. Coastal waters yield herring, salmon, sardines, snapper, swordfish, and tuna.

A large colony of dugongs, plant-eating relatives of the manatee, are attracted to the ample supply of seagrass and make this area their home. The dugong population is declining because they are hunted by native peoples for food and are often killed by boat propellers.

In the shallow waters over the shelf, petroleum and natural gas are being extracted. Pearls are harvested here, although in sharply declining volume.

In 1986 the member nations of the South Pacific Forum declared the area a nuclear-free zone in an attempt to halt nuclear testing and prevent the dumping of nuclear waste.

Northwestern Australia and Southeast Asia
Location: Indian and Pacific Oceans
Area: Approximately 140,000 square miles (300,000 square kilometers)

Western United States The continental margin off the northwestern coast of the United States was partly formed by a dam of rock thrust up by earthquake action about 25 million years ago. Where the dam breaks the surface of the water, it forms the Farallon Islands off San Francisco. The shelf is so narrow here—only about 1 mile (1.6 kilometers) wide—that the heads of many submarine canyons reach almost to the shoreline. Large quantities of sand from the beaches are carried by currents down the canyon walls.

Western United States
Location: Pacific Ocean
Area: Approximately 173,700 square miles (450,000 square kilometers)

Rainfall and runoff from rivers occur only during the winter months. The California Current travels south in the summer, and in winter the Davidson Current appears and moves north.

The North Pacific waters are rich in marine life, including sponges, flying fish, sharks, manta rays, seals, and many species of whales.

Commercial fishing is done all along the coast but primarily in the waters around Alaska. Oil and gas are also obtained from the area.

Northeastern United States Between 270,000,000 and 60,000,000 years ago, a large dam created by earthquake action was formed off the northeastern coast of the United States. A trench on its landward side was gradually filled in with sediment over time, making it now part of the continental shelf, which measures 71,410 square miles (185,000 square kilometers). Sediment that spilled over the top formed a new continental slope that is unstable and subject to landslides. Few submarine canyons are found here, although the Hudson Canyon, associated with the Hudson River, extends from the river's mouth into the ocean.

Changes in sea level have altered the appearance of the coastline and shelf. Fifteen thousand years ago sea level was much lower and much of the continental shelf in the northeastern United States was exposed. Gradually, as sea levels rose, the shelf was covered by water.

Numerous rivers empty into the Atlantic along this shelf, and the presence of fresh water reduces the ocean's salinity. The warm Gulf Stream current affects water temperature and circulation.

Waters here support a variety of marine life, including sea slugs, starfish, mussels, many species of crabs and lobsters, poisonous toadfish, and sperm whales. Commercially important fish found along this shelf include ocean perch, cod, and haddock. Oil and gas are obtained from the shelf off the coast of Newfoundland and farther north.

Northeastern United States
Location: Atlantic Ocean
Area: 71,410 square miles (185,000 square kilometers)

The North Sea and Western Europe The continental shelf off the coast of Europe holds the entire United Kingdom (England and its islands). It measures 212,300 square miles (550,000 square kilometers). Waters over this shelf include the North Sea, the Skagerrak (an arm of the North Sea), and the English Channel. Under the North Sea the shelf slopes gently downward from south to north. Although the southernmost areas are shallow, a deep canyon lies off the mouth of the Humber River, an estuary on the east coast of England. In the northeast is the Norway Deep, or Trough, an underwater canyon running parallel to the Norwegian coast

The North Sea and Western Europe
Location: The North Atlantic
Area: 212,300 square miles (550,000 square kilometers)

and into the Skagerrak. Other troughs lie to the west of Ireland. In the north, the coastline is marked by steep cliffs.

Tides are important in the North Sea because they influence ocean traffic. Along the coast of Norway, the tidal range (difference between high tide and low tide) is often less than 3 feet (1 meter). On the French side of the English Channel, tidal ranges of more than 27 feet (8 meters) are common. Tidal currents deposit sand in areas along the coast, causing problems in shipping routes. Several large rivers, such as the Rhine and the Elbe, lower the salinity of the water and create currents where they flow into the sea.

Sediments from the rivers and upwelling from deep, cold waters makes the North Sea rich in nutrients. The rocky shelf supports much algae and plant life, such as kelp, and eel grass. Invertebrates like cockles, mussels, scallops, sponges, and snails thrive in the rocky areas.

More than 170 species of fish live in the North Sea, including sharks, rays, herring, mackerel, haddock, cod, and sole. The fish attract large numbers of sea birds, including puffins, gannets, terns, gulls, and ducks. Among mammals living here are gray seals, harbor seals, dolphins, porpoises, and killer whales.

Fishing has been done in the area since 500 AD. Herring, haddock, plaice, cod, and whiting are commercially important. Atlantic salmon are farmed in some areas.

The North Sea is also the site of offshore oil and gas drilling. By 1989, 149 oil platforms were operated in the North Sea by British, Dutch, Norwegian, Danish, and German companies.

More sand and gravel is removed from the North Sea—24.5 million tons (22 metric tons) annually—than anywhere else in the world. These operations occur close to shore in waters less than 115 feet (35 meters) deep. Lime, another mineral, is mined from the seabed (sea floor). All of these materials are used as construction materials.

The Persian Gulf The Persian Gulf lies between the Arabian Peninsula and Iran. Millions of years ago, it was much larger, but the floor beneath the Persian Gulf is shrinking as the floor beneath its neighbor, the Red Sea, on the opposite side of the peninsula, expands. It is estimated that after another 50,000 years, the Persian Gulf will be completely closed as the peninsula is pushed toward Iran. At one time the floor of the gulf was above sea level. Now it is part of the continental shelf, which measures 92,640 square miles (240,000 square kilometers). No earthquakes or volcanoes are found here, and the seafloor has both muddy and sandy areas.

The Persian Gulf
Location: The Arabian Sea, between Saudi Arabia and Iran
Area: 92,640 square miles (240,000 square kilometers)

Surrounded by desert, the water in the Persian Gulf is warm, salty, and only about 330 feet (100 meters) deep. A small amount of fresh water flows in from the Tigris and Euphrates Rivers, but the climate is so hot that more water is lost from evaporation than is gained.

Large stands of mangrove trees and beds of seagrass are found in the gulf. The mud in which they grow is low in oxygen, so the thickets are not as well developed as those found in other areas.

Few coral reefs are found in the Persian Gulf because the water is too warm. The gulf is home to many kinds of shellfish, such as mussels, shrimp, and oysters. Fish like sardines, anchovies, mackerel, and barracuda are also found here. The largest fish living in the area is the whale shark, which can reach 40 feet (12 meters) in length. Common birds of the gulf include terns, ospreys, and the fish-eating eagle, which travels several thousand miles to Scotland to nest. Porpoises are common, and the narwhal is seen occasionally.

The Persian Gulf has been important for oil production since 1935, and oil platforms dot its surface. Other commercially important minerals and metals found here include salt, copper, and zinc.

Sea cucumbers, shellfish, sardines, and anchovies are all important to the fishing industry. Bahrain, a tiny island in the gulf, has been the source of pearl oysters for 2,000 years. The pearl industry has declined since it became possible to artificially stimulate pearl growth.

Hudson Bay The continental shelf underlying Hudson Bay extends from the Canadian Provinces of Quebec, Manitoba, Ontario, and the Northwest Territories. It measures 480,000 square miles (768,000 square kilometers) and its depth ranges from 120 to 600 feet (36 to 182 meters). A deep canyon cuts through the bay and extends toward Hudson Strait.

The cold waters in Hudson Bay originate in the Arctic. The waters are low in salt because many rivers feed into the bay. From January until May, the bay is covered with floating ice, which in northern regions is slow to melt and makes navigation difficult.

Many fish live in the bay, including cod and salmon. Seabirds found here include ducks, geese, loons, and ptarmigans. Whales frequent the bay, and were at one time hunted. Native peoples still hunt and fish in the area.

During the last half of the twentieth century, the bay and strait became a popular shipping route for goods going to England. Oil and natural gas are being pumped from beneath the shelf in the northern regions, making the shelf important commercially.

Hudson Bay
Location: Northeastern Canada
Area: 480,000 square miles (768,000) square kilometers

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Friends of the Earth, 1717 Massachusetts Ave. NW, 300, Washington, DC 20036-2002, Phone: 877-843-8687; Fax: 202-783-0444; Internet: http://www.foe.org.

Greenpeace USA, 702 H Street NW, Washington, DC 20001, Phone: 202-462-1177; Fax: Internet: http://www.greenpeace.org.

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Deciduous Forest

A tree is a large woody plant with one main stem, or trunk, and many branches that lives year after year. A forest is a large number of trees covering at least 25 percent of the area where the tops of the trees, called crowns, interlock forming an enclosure or canopy when the trees mature. Deciduous (dee-SID-joo-uhs) forests primarily consist of deciduous trees, such as oaks, basswoods, and elms. Deciduous trees lose their leaves during cold or very dry seasons, as compared to evergreen trees that keep their leaves year-round, usually for several years at a time.

Temperate deciduous forests grow in areas with cold winters and warm summers. They are generally found in the Northern Hemisphere, the southern most part of South America, and New Zealand. These forests are located primarily in the Great Lakes region and the eastern half of the United States, parts of central and western Europe, parts of Russia, and parts of Japan and China. Tropical deciduous forests grow in areas around the equator where the weather is warm, such as the western coast of Chile and South Island, New Zealand. There are two types of tropical deciduous forests—those that grow in dry climates and those that grow in moist climates. Dry climate forests occur primarily in central India; parts of Brazil; and on the African continent from Angola to Tanzania, northward to the Sudan, and over much of West Africa. Moist climate forests are found primarily in northeastern Australia, eastern India, and parts of Burma, Thailand, and Indonesia.

How Deciduous Forests Develop

Forests evolved during Earth's prehistoric past. Since then, all forests have developed in essentially the same way, by means of a process called succession.

The first forests The first forests evolved from ferns, clubmosses, and other prehistoric plants that, over time, adapted to the surrounding environment and grew more treelike. Trees that preferred a warm, humid,

WORDS TO KNOW

Angiosperms: Trees that bear flowers and produce their seeds inside a fruit; deciduous and rain forest trees are usually angiosperms.

Conifer: A tree that produces seeds inside cones.

Consumers: Animals in the food web that eat either plants or other animals.

Decomposers: Organisms that feed on dead organic materials, releasing nutrients into the environment.

Food web: All of the possible feeding relationships that exist in a biome.

Gymnosperms: Trees that produce seeds that are often collected together into cones; most conifers are gymnosperms.

Mesophytic: Term used to describe a forest that grows where only a moderate amount of water is available.

Producers: Plants and other organisms in the food web of a biome that are able to make food from nonliving materials, such as the energy from sunlight.

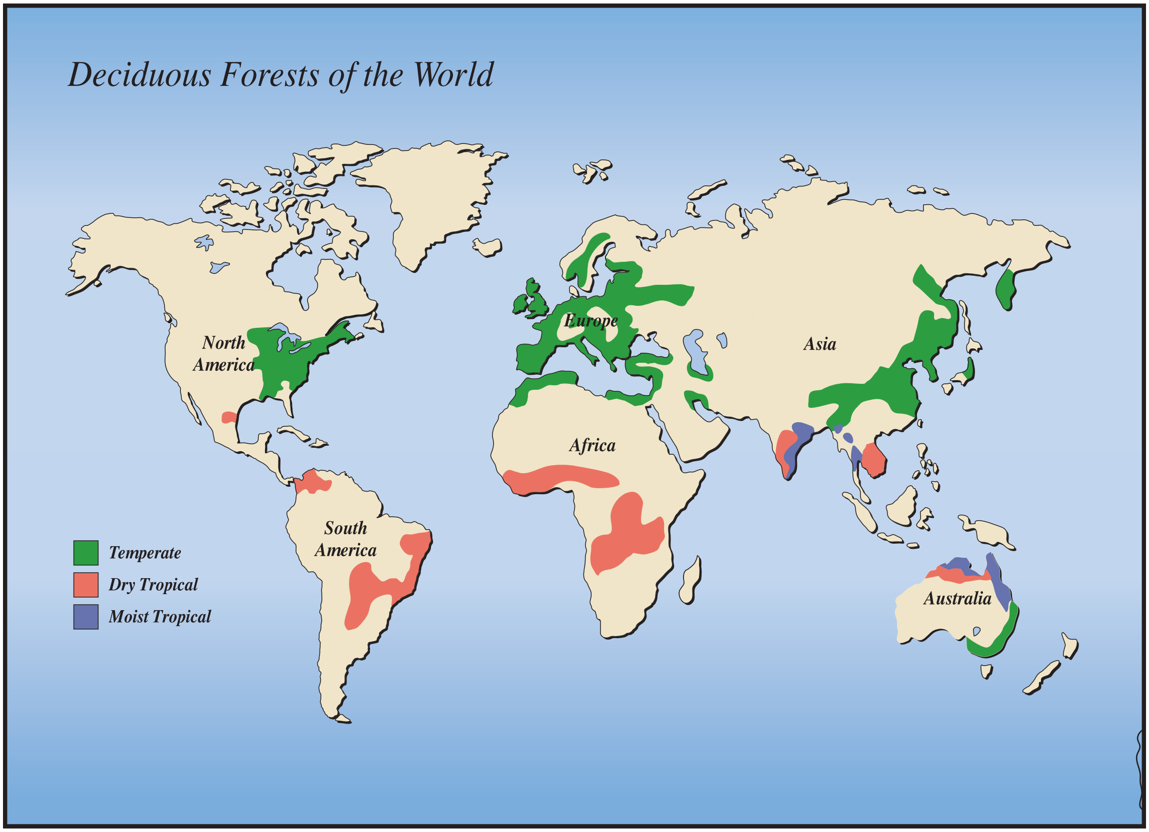
Succession: The process by which one type of plant or tree is gradually replaced by others.

Tannins: Chemical substances found in the bark, roots, seeds, and leaves of many plants and used to soften leather.

tropical climate developed first, followed by those adapted to drier, cooler weather. The first deciduous trees evolved about 145 million years ago, during the latter part of the Cretaceous period in the Mesozoic Era.

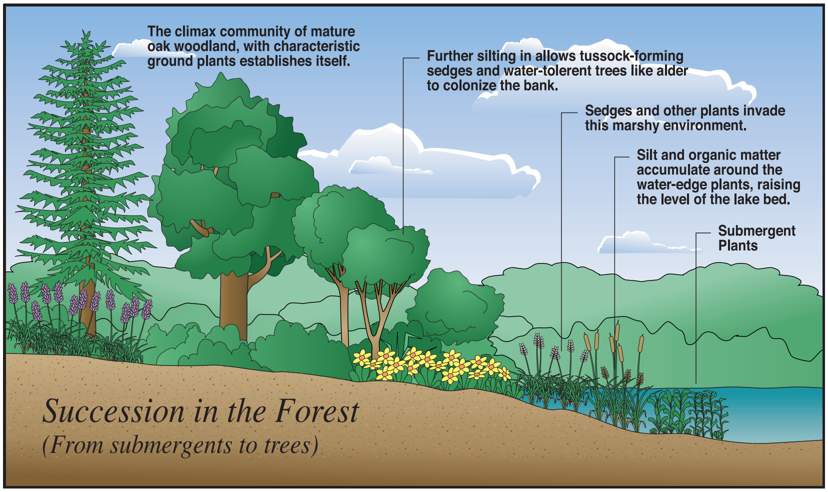
About 1 million years ago during the great Ice Ages, glaciers (slow-moving masses of ice) covered about one-third of the land surface of Earth. Eventually, the glaciers retreated, but not before they had destroyed many of the world's forests and scoured the land of plants. Roughly 12,000 years ago, trees began to repopulate the land that had been covered by ice. In some areas, spruce, larch, ash, and birch trees were among the first species to make a comeback, preparing the way for other trees.

Succession Trees compete with one another for sunlight, water, and nutrients, thus a forest is constantly changing. The process by which one type of plant or tree is gradually replaced by others is called succession. During succession, different species of trees become dominant as time progresses and the environment changes. Succession began following the last Ice Age, and continues today. Succession can occur naturally, when different species of trees become dominant as time progresses and the environment changes. It can also occur from natural disasters, such as forest fires.



Primary succession Primary succession usually begins on bare soil or sand where no plants grew before. When the right amounts of sunlight, moisture, and air temperature are present, seeds begin to germinate (grow). These first plants are often made up of mosses, grasses, and forbs (a nonwoody broad-leaved plant). They continue to grow and eventually form meadows. Over time, and as conditions change, other plants begin to grow such as shrubs and trees. These plants become dominant and replace or take over where grasses and forbs originally grew.

As primary succession continues, pioneer trees (in some cases birch, pine, poplar, and aspen) begin to thrive. These are tall, sun-loving trees, and they quickly take over the meadow. They change the environment by making shade. This allows trees with broader leaves that prefer some protection from the sun, such as red oaks, to take root. If conditions are



right, a mixed forest of sun-loving and shade-loving trees may continue for many years before more changes occur.

The climax forest Seedlings from pioneer trees do not grow well in shade; therefore, new pioneer trees do not grow. As the mature trees begin to die from old age, disease, and other causes, the broad-leaved trees become dominant. The shade from these broad-leaved trees can be too dense for their own seedlings too. As a result, seedlings from trees that prefer heavy shade, such as beech and sugar maple, begin to thrive and dominate the forest. These trees produce such deep shade that only those trees or plants that can survive in complete shade will succeed. When this happens, the result is a climax forest—one in which certain species of trees characteristic of the ecological conditions of an area are dominant.

Few true climax forests actually exist because forests are dynamic ecosystems and changes take place that interfere with a forest's stability. Fires, floods, high winds, and people can all destroy a single tree to acres of trees. Glaciers can mow them down; volcanoes can smother them with ash or molten rock or knock them over with explosive force. Then the process of succession starts over.

Secondary succession Land stripped of trees will eventually be covered with them again if left alone. This is called secondary succession and can take place more quickly than primary succession. Seeds from other forests in neighboring regions are blown by the wind or carried by animals to the site. Soon, the seeds take root and seedlings sprout, and the process begins again.

One of the common temperate region deciduous trees is the beech. IMAGE COPYRIGHT SERGE LAMERE, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Kinds of deciduous forests

Deciduous forests are broadly classified according to the climate of the region in which they grow—temperate, dry tropical, or moist tropical.

Temperate deciduous forest Temperate climates are moderate, and temperate deciduous forests can be categorized in terms of the species of trees that are most common. The following three types are common in North America, and similar species predominate in Europe and Asia:

- Beech-maple: American beech and sugar maple forests mixed with some conifers (trees bearing cones) are found in the southern Great Lakes region, in New England, and in southeastern Canada.
- Oak-hickory: In the southern United States, oaks, such as white oak and chestnut oak, are dominant. Farther west, red oak and black oak are mixed with hickory.
- Mixed mesophytic: Mesophytic means a forest that requires only a moderate amount of water, such as forests in the Appalachian Mountains. Mixed mesophytic forests can be dominated by any of ten or more species of trees, such as buckeye, magnolia, birch, ash, black cherry, sugar maple, and scattered evergreen conifers such as hemlock and white pine.

Dry tropical deciduous forest Dry tropical deciduous forests occur in regions with long, severe dry seasons, such as the savannas (grasslands) of Africa. The tallest trees are shorter and more twisted than those in a temperate forest, and the bark is thicker. Some trees may store water in their trunks. During the dry season, the trees lose their leaves and many produce flowers. Some, such as wattle trees in Australia, have adapted by producing thorns instead of many leaves.

This Land is My Land

Life in the forest is a constant struggle for food and living space, even among the trees. All around the foot of almost any tree are the seedlings of other trees, ready to take over the space if they can. Some trees have evolved ways to fight back. The black walnut, for instance, has a powerful poison in its leaves, roots, and nutshells. This poison kills the roots of any plants trying to grow in the same soil. Even if the tree is removed, the poison remains in the soil for a long time.

Moist tropical deciduous forest Moist deciduous forests are found in tropical regions where both rainy and dry seasons occur during the year. These forests are different from tropical rain forests in that the trees, including teak and rosewood, are not as tall and have rather thick bark. In the first month of the dry season the leaves fall. New leaves sprout just before the rainy season begins.

Climate

The three types of climates in which deciduous trees grow are temperate, dry tropical, and moist tropical.

Temperate climate Temperate climates, such as in the northeastern United States, are moderate. Winters are cold and summers are warm with few extremely cold and hot days. The average temperature of a temperate deciduous forest is about 50°F (10°C), due to the rare extreme temperatures during the summer and winter.

There is plenty of moisture and few long, dry periods. A temperate forest usually requires at least 20 inches (51 centimeters) of precipitation (rain, snow, or sleet) each year, though most of these forests average between 30 to 60 inches (76 to 152 centimeters). The weather in a temperate climate can be very unpredictable. Precipitation usually occurs throughout the year, but much of it may fall as part of a severe storm system.

Temperate climates have four distinct seasons—spring, summer, fall, and winter. Warm weather begins in spring and temperatures gradually increase through the summer months. In the fall, the cooler weather takes over, and temperatures gradually drop to winter's lows. During these cooler months the leaves of deciduous trees turn colors and then drop off. In winter, the trees are bare.

Dry tropical climate In dry tropical climates, such as that in parts of India and Africa, the drop in precipitation is often accompanied by hotter temperatures. The length of the dry period and the level of heat help determine the type of trees that will grow there. In Tanzania, for example, severe dry periods may last up to seven months. Precipitation is often undependable, and when it does occur it may fall in large amounts. In India, for example, as much as 35 inches (89 centimeters) of rain may fall in a single 24-hour period. Leaves fall from the trees at the start of the dry period and grow again when the rains come.

Moist tropical climate In tropical regions where moist climates occur, such as Myanmar and parts of India, temperatures remain high, but precipitation is more regular and predictable. In a rain forest, rain falls year-round, but in a moist tropical climate, dry periods occur. The dry periods are not as long or severe as in a dry tropical climate. As in dry climates, the trees shed their leaves when the dry period begins. New growth begins with the rains.

Geography of Deciduous Forests

The geography of deciduous forests includes landforms, elevation, soil, and water resources.

The blanket of snow keeps the soil warm, allowing bacteria and other organisms to continue to break down dead plant matter. IMAGE COPYRIGHT ANDREY STEPANOV, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Surviving the Ice Ages

During prehistoric times, before the great Ice Ages, North America and northern Europe were covered in deciduous trees such as walnut, hickory, sycamore, oak, maple, and chestnut. The climate was warmer than that of present times. As the ice advanced, the more delicate trees were forced to retreat to the south. In North America this was possible because the mountain ranges run north and south, which allowed the trees to spread along the valleys between them. In Europe, however, the mountains tend to run east and west, so the trees were trapped. For this reason, many European species did not survive, and the deciduous forests of Europe have fewer tree species than those of North America.

Landforms In the Northern Hemisphere, the landscape over which temperate deciduous forests grow includes mountains, valleys, rolling hills, and flat plateaus.

In the Southern Hemisphere, dry deciduous forests tend to occur near grasslands where the land is rolling or more nearly level. Moist deciduous forests are often found on mountainsides or rolling hills.

Elevation Elevation plays a major role in determining whether forest vegetation will survive because temperature can decrease rapidly with height. In addition, mountains tend to have a wetter climate than flat or low lands. On mountainsides, forests vary, mostly becoming smaller in overall size, and in individual tree size. The moist conditions appeal to lichens, mosses, and ferns, and these plants tend to thrive. Eventually, the elevation reaches a point where no tree can survive—this boundary is called the timberline or treeline. The timberline is contingent on temperature, not height, so it can occur in different places for different areas. For example, in Sierra Nevada, the timberline is located at 11,500 feet (3,500 meters), where as in the central Alps of Europe, the timberline is located at 6,800 feet (2,000 meters).

Soil The soil in temperate deciduous forests tends to be deep and rich with a wide variety of nutrients because it receives a new blanket of leaves every autumn. The foliage of low-lying plants dies off and adds its own nutrient characteristics to the soil. During the winter, snow blankets the ground. Beneath its protective layer, bacteria, earthworms, and insects continue to break down the dead vegetation, creating dark humus. Humus is the spongy matter produced when the remains of plants and animals are broken down. It contains chemicals, like nitrogen, that are vital to plant growth, and it is able to absorb water. Oak leaves are difficult to break down so the soil beneath oak trees is not as rich.

In tropical climates, the soil differs from region to region. Soils in dry grasslands are sandy and dusty. Long, dry periods between the rainy seasons inhibits decomposition of dead plant matter and the release of nutrients, making the soil less rich. Moist tropical regions may have poor soil because topsoil is often washed away during heavy rains. Also, the shade is so dense that few smaller plants may grow there.

The presence of trees helps protect soil from erosion by holding it in place. Fallen trees are important in conserving and cycling nutrients and in reducing erosion. Trees also create windbreaks, which help prevent topsoil from being blown away.

Squirrels, as well as chipmunks, are unwitting planters of deciduous trees. They bury nuts in the ground to save them for a later meal, but don't always return to dig them back up. COPYRIGHT © 2007 KELLY A. QUIN.

Water resources In temperate regions, water resources include rivers, streams, springs, lakes, and ponds. In tropical regions, rivers, seasonal streams, and rain are often the primary sources of water.

Plant Life

Most forests contain a mixture of several types of trees and plants, and deciduous forests are no different. Stands (groups) of coniferous and non-coniferous evergreen trees may exist within their boundaries.

The trees and smaller plants in a forest grow to different heights, forming layers. The crowns of the tallest trees create a canopy, or roof. In the deciduous forests of eastern North America, the tallest trees are often oaks and hickories. Beneath their canopy grow shorter, shade-tolerant trees, such as maples. This shorter layer is called the understory. The next layer, only a few feet off the ground, is composed of small shrubs, such as junipers, and some flowering plants. The very lowest layer consists of small plants that live atop the soil.

In addition to trees, plant life within most deciduous forests includes bacteria; algae, fungi, lichens and green plants other than trees.

Algae, fungi, and lichens Algae (AL-jee), fungi (FUN ji), and lichens (LY-kens) do not fit neatly into either the plant or animal category.

Algae Most algae are single-celled organisms, although some are multi-cellular, and have the ability to make their own food. During a process called

A Nose for Truffles

In France, pigs, dogs, and even goats are trained to hunt truffles. A truffle is a type of edible fungus that grows under the soil in deciduous woodlands. Pigs are trained to recognize the smell of a truffle and sound an alarm when they find one. The truffles are then dug up and sold to people who consider them a delicacy.

photosynthesis (foh-toh-SIHN-thuh-sihs), they use energy from sunlight to change water and carbon dioxide (from the air) into the sugars and starches they require as food. Other algae may absorb nutrients from their surroundings. Although most algae are water plants, blue-green algae, which are actually bacteria, do appear in woodlands. They survive as spores (single cells that have the ability to grow into a new organism) during dry periods, and return to life as soon as it rains.

Fungi Fungi cannot make their own food by means of photosynthesis. Some, like molds and mushrooms, obtain nutrients from dead or decaying organic matter (material derived from living organisms). They assist in the decomposition of this matter, thereby releasing the nutrients needed by other plants. Other types of fungi are parasites, attaching themselves to other living things. Fungi reproduce by means of spores.

Fungi prefer moist, dim environments, and they thrive in shadowy forests of temperate regions. Common types of fungi include jack-o-lanterns, pear-shaped puffballs, fawn mushrooms, turkey tails, and destroying angels. Some, like chantarelles, grow directly on the soil, while others grow on the trunks of trees. Many, such as the fly agaric, are mushroomlike. Still others,

Mushrooms help speed forest decay of leaf matter on the forest floor, which enriches the soil and enables new growth.

IMAGE COPYRIGHT FOTOSAV, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

such as tree ears, resemble a porch roof as they protrude from tree trunks. Some mycorrhizae, surround the roots of certain trees, such as beeches and oaks, and help the roots absorb nutrients from the soil.

A jack-in-the-pulpit grows comfortably in the shade provided by the shady trees of a deciduous forest. IMAGE COPYRIGHT SHARON D, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Lichens Lichens are actually combinations of algae and fungi that live in cooperation. The fungi surround the algae cells. The algae obtain food for themselves and the fungi by means of photosynthesis. It is not known if the fungi aid the algae organisms, although they appear to provide them with protection and moisture.

Lichens often appear on rocks and other woodland surfaces such as tree trunks and limbs. They are common in all types of forests and seem able to survive most climatic conditions. Lichens are a good indicator of air quality because many species will not grow in the presence of air pollution.

Green plants other than trees Most green plants need several basic things to grow: sunlight, air, water, warmth, and nutrients. In deciduous woodlands, water and warmth are often abundant, at least seasonally. Light may be more scarce, but deciduous trees tend to be well-spaced, allowing sunlight to reach the forest floor. The remaining nutrients, primarily nitrogen, phosphorus, and potassium, are obtained from the soil and may not always be in large supply.

Woodlands are home to both annual and perennial plants. Annuals live only one year or one growing season. Perennials live at least two years or two growing seasons, often appearing to die when the climate becomes too cold or too dry, but returning to life when conditions improve.

Common deciduous forest green plants In temperate climates, many species of small shrubs, mosses, ferns, herbs, and brambles thrive beneath the trees, along the edges of the forest, and in clearings. They include wildflowers such as lady's slipper and columbines, and shrubs such as witch hazel, sumac, and spicebush. Shade-loving plants also grow beneath the trees. These include mayapple, jack-in-the-pulpit, poison ivy, and many species of ferns.

Immortal Trees?

Trees have the ability to continue growing all their lives. This means that, in theory, they could live forever. When a tree dies, its death is usually caused by something in its environment, such as fire, wind, lightning, extremely dry periods, disease, insects, or being cut by humans. As a tree ages, it becomes more susceptible to disease and pests, and most trees die of several causes.

Growing season Green plants that grow close to the forest floor in temperate climates, such as the anemone, skunk cabbage, and trillium, appear in early spring when full sun can reach them. The primrose and the bluebell quickly bloom as the trees' leafy canopy begins to form overhead. Later, when the trees are in full leaf, only the shade-loving plants, such as fern, moss, and ivy, will thrive. Growth continues throughout the summer then stops in autumn. Annuals die, leaving their seeds to carry through the winter. Although the foliage (above ground growth such as leaves and stems) of perennials die, their roots remain alive to send up shoots again the following spring.

In tropical climates, both dry and moist, the growing season begins just before the onset of the rainy season. It ends as the dry season begins. As in temperate climates, annuals die. Perennials usually have some method of storing water, such as a large taproot (a large center root that grows downward), that enables them to survive long periods without rain.

Reproduction Most green plants reproduce by means of pollination (the transfer of pollen from the male reproductive flower part to the female). Pollen is carried by visiting animals, such as birds or insects, or by the wind, which blows it from one flower to another. As the growing season comes to an end, most green plants produce seeds. The seed's hard outer covering protects it during cold winters or long dry seasons.

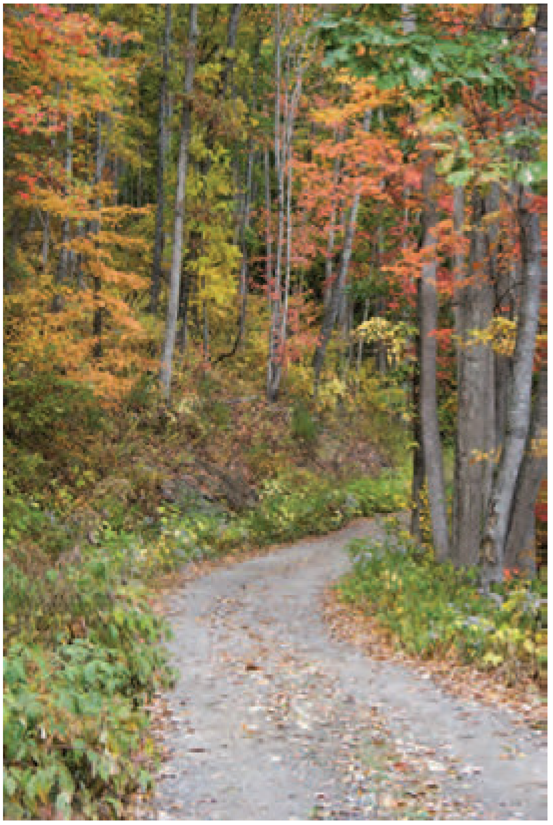
A few woodland plants, such as ferns, reproduce by means of rhizomes, long, rootlike stems that spread out below ground. These stems develop their own root systems and send up sprouts that develop into new plants. They also reproduce by spores that develop on the undersides of the leaf. When these spores mature, they are released from the plant and fall to settle on the soil where they begin to grow into a new fern plant.

In moist tropical regions, a layer of smaller evergreen trees often grows beneath the deciduous canopy. Both high- and low-climbing vines, and most smaller plants may in some cases be almost completely absent. In dry tropical regions, the lower layers may consist of thorny shrubs, cacti, grasses, and small palms.

Deciduous trees Deciduous trees lose their leaves, which tend to be broad and flat, during cold or very dry periods. When temperatures are warm year-round and rainfall is constant, such as in a rain forest, these same trees may become evergreen and keep their leaves year-round. Trees are hardy perennials, but a number of factors can affect their life spans. Some of these are due to the environment, such as lack of sunlight or water, severe climate changes, disease, and fires. Many trees have short lives due to human consumption for land and timber.

The fact that most trees have a single strong stem, or trunk, gives them an advantage over smaller woody plants in that most of their growth is directed upward. Conifers often devote their energy to growing ever taller, while deciduous trees spread out their limbs and branches from their trunks to create a crown of leaves.

During autumn, trees in temperate regions lose the green color in their leaves because chlorophyll, a green substance in the leaves, breaks down. As a result, other colors present in the leaves are then visible, creating the brilliant hues of the autumn forest. This color change is brought on by shorter days, where hours of sunlight are decreased, and cooler temperatures.



In autumn, tree leaves in deciduous forests provide a scene of brilliant colors. IMAGE COPYRIGHT JILL LANG, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Each year a deciduous tree grows, its trunk is thickened with a new layer, or ring, of vessels and other conduction cells that carry water and nutrients from the roots to the branches. When a tree is cut down, its age can be determined by how many of these rings are present. As a tree ages, the rings from the center outward become hardened to produce a sturdy core. In temperate climates, deciduous trees may grow from 2 to 5 feet (0.6 to 1.5 meters) in diameter and 60 to 100 feet (18 to 30 meters) in height during their life span.

Common deciduous trees Typical deciduous trees in temperate regions include the ash, oak, maple, elm, poplar, birch, ginkgo, and magnolia. Tropical deciduous trees include the acacia, southern beech, baobab, teak, casuarina, cannonball, ebony, peepul, sycamore, and rosewood.

Oak Oaks are perhaps the best-known deciduous trees in temperate regions. Oaks are very adaptable to different environmental conditions. They are found in dry sandy plains to coastal swamps. All species of

Cloning Trees

A clone is an exact genetic copy of its "parent," because it is grown from one of the parent's cells. Cloning may someday become an important part of the forest industry. Cells from a superior adult tree could be cloned in a laboratory and the resulting seedlings planted on tree farms. As the trees grew, they would resemble the parent tree and be more uniform than a natural forest. Cloned trees have been grown from cells of redwood, Douglas fir, apple, citrus, and poplar trees.

oak have at least one thing in common—the acorn, or nut, that bears a scaly cap. The leaves of some oaks, such as the red oak, turn a brilliant color in autumn, while others are less colorful. Oaks are the dominant trees of central and western Europe. They are known for their excellent timber, which is valued for furniture and hardwood floors.

Acacia Acacia (uh-KAY-shuh) trees are called thorn trees in Africa, wattles in Australia, and mimosas in North America and Europe. They are found in dry tropical climates as they can tolerate long, dry periods but they do not grow very tall. Acacias usually have an umbrella shape, yellow flowers, and sharp spines. Their seeds are used by both humans and animals for food.

Baobab Found in dry tropical regions, the baobab (BA-oh-bab) has a soft, spongy trunk and lower branches for storing large quantities of water. The trees lose their leaves during the dry seasons, which reduces water loss.

Baobabs do not grow very tall—about 16 to 82 feet (5 to 25 meters) in height. The trunk is often wide and may reach 23 feet (7 meters) in diameter. Giant baobabs are several thousand years old. Many animals

The baobab is known for its ability to store gallons of water inside its trunk, which it does to survive long, dry spells frequent to its habitat. IMAGE COPYRIGHT ROBERT HARDHOLT, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

use the baobab for food and shelter, and pollination of its flowers is done by bats.

Teak The teak is native to India, Myanmar, and Thailand, where it prefers well-drained soils. It is a large tree with a spreading crown and small white flowers. Mature trees may reach 98 to 131 feet (30 to 40 meters) in height. Teak timber is known for being indestructible, and is commonly used in furniture, flooring, and other woodworking projects.

Growing season Moisture and temperature conditions are two important environmental factors affecting the growing season of deciduous trees. In temperate climates, the growing season takes place during the spring and summer and may last five to seven months. Some trees, such as beech and maple, produce their leaves earlier in the season, while oaks produce leaves later. In the autumn, cooler temperatures make it harder to absorb the water needed to maintain broad leaves. Broad leaves tend to lose a lot of water into the atmosphere. For these reasons and other factors including temperature and day length, the leaves die and fall off.

In tropical climates, growth slows or stops during hot, dry periods and the trees drop their leaves. Growth begins again when the rain comes. When dry periods are very long, trees in these areas may be stunted and develop very thick bark to protect against moisture loss.

Reproduction Trees are divided into two groups according to how they bear their seeds. Gymnosperms produce seeds that are often collected together into cones. Most gymnosperms are conifers. In contrast, angiosperms have flowers and produce their seeds inside a fruit. Deciduous trees are usually angiosperms.

In temperate regions, many deciduous trees drop their seeds in the autumn. Some seeds may be contained in fruits in nut form, like acorns and beechnuts, or they may have papery wings, like the fruits of sycamores. In tropical regions, seeds fall just before or during the dry periods.

Endangered species Trees can be threatened by natural dangers, such as forest fires, animals, and diseases, as well as by humans. Fires are more of a threat in dry climates, while animals and diseases are prevalent in all climates. For example, when deer populations get too large, they can destroy forests by eating wildflowers and tree seedlings. The caterpillar of the gypsy moth eats the leaves from a variety of tree species. If enough of these insects attack a stand of trees, all the leaves are eaten and the trees die. Dutch elm disease, a fungus transmitted by the elm bark beetle first seen in Holland in 1921, destroyed millions of elm trees in the United States in 1930. It was then

Chestnut Blight in the United States

Until 1940 the United States was home to the American chestnut tree, a graceful species with creamy white blossoms that often grew more than 100 feet (30 meters) tall. In 1904 foreign chestnut trees were imported into New York. These trees carried a fungus, called chestnut blight, which soon spread to American chestnuts. Over the next 40 years the fungus destroyed almost all the American chestnuts in the eastern half of the country.

Fortunately, the blight did not travel to the far west, and scattered, healthy American chestnuts are still found there. The roots of stricken chestnuts survived because the blight could not reach them underground. They continue to send up shoots but the shoots soon die because the fungus is still in the soil. Researchers are attempting to cross the American chestnut with other species resistant to the fungus in hopes of reestablishing the trees.

introduced to England in logs exported from the United States. It killed many elms there as well.

Pollution is a threat to birch, beech, ash, and sugar maple trees in the northeastern United States. Pollution appears to weaken the trees so that pests and diseases overtake them more easily. In western Europe, the beech is in decline.

Animal Life

From their roots to their tips, deciduous trees support a wide range of plant-eating animals and wildlife, while many other types of animals live among or beneath the trees. The animals can be classified as microorganisms, invertebrates, amphibians, reptiles, birds, and mammals.

Microorganisms A microorganism is an animal, such as a protozoan, that cannot be seen without the aid of a microscope. Every forest is host to millions of these tiny creatures. Microscopic roundworms, or nematodes, for example, live by the thousands in small areas of soil in deciduous forests and aid the process of decomposition.

Bacteria Bacteria are always present in woodland soil where they help decompose dead plant and animal matter. In temperate climates, bacteria help create nutrient-rich humus. Fewer bacteria are at work in dry climates or in moist climates with long dry seasons.

Invertebrates Animals without backbones are called invertebrates. They include simple animals, such as worms, and more complex animals, such as wasps and snails. Certain groups of invertebrates must spend part of their lives in water. These types are not found in trees, but in ponds, lakes, and streams, or in pools of rainwater.

Some invertebrates, such as beetles, are well adapted to life in dry tropical forests. They have an external skeleton, a hard shell made from a substance called chitin (KY-tin). Chitin is like armor and is usually waterproof, protecting against the heat of the sun and preventing the animal from drying out. These same invertebrates do not survive as well in temperate forests because many adults die in the cold of winter. Their well-protected eggs or larvae may survive until the spring.

Common deciduous forest invertebrates Invertebrates found in temperate forests include the tent caterpillar, the woolly bear caterpillar, the luna moth, the stag beetle, and the wolf spider. Other common invertebrates include the earthworm, the slug, the forest snail, and the acorn snail.

In tropical climates, many species of invertebrates, including the silkworm, inhabit moist forests. Dry climates have fewer insects; termites and grasshoppers are common, as are many species of caterpillars.

Food Many invertebrates eat plants or decaying animal matter. The larvae of insects, such as caterpillars, are the primary leaf eaters in the deciduous forest. The tent caterpillar, the larvae form of a moth, spins a large, filmy, tent-like cocoon around a tree branch, which it soon picks clean. Weevils drill holes in acorns, which their larvae use for food, thus destroying the seed of the oak. Bees gather pollen and nectar (sweet liquid) from flowers, as do butterflies and moths, helping produce new plants through pollination. Arachnids (spiders), which are carnivores (meat eaters), prey on insects. Larger species may even eat small lizards, mice, and birds.

Reproduction Most invertebrates have a four-part life cycle. The first stage of this cycle is spent as an egg. The egg's shell is usually tough and resistant to long dry spells in tropical climates. After a rain and during a period of plant growth, the egg hatches. The second stage is the larva (such as a caterpillar). This may be divided into several stages between which there is a shedding of the animal's outer skin. Larvae often spend their stage below ground where it is cooler and moister than on the surface. The pupal, or third stage, is spent hibernating within a casing (such as a cocoon). When the animal emerges from this casing, it is an adult.

The Destructive Hitchhiker

In 1996, 2,400 trees in Brooklyn and Amityville, New York, were destroyed when the Asian long-horned beetle turned up in the United States. The 2-inch- (5-centimeter-) long insect lays its eggs just under the bark of maple, ash, elm, and horse chestnut trees. When the larvae hatch and seek food, they cut off vital nutrients to the trees starving them to death. It is believed that the beetle first made its way to this country in the wood packing materials of goods shipped from China.

In 1998 this black and white beetle was discovered in Chicago, Illinois. In an effort to stop the insect's spread, 470 trees had to be cut down and burned. Burning is done during the winter months while the beetle is inactive and cannot escape. Hopefully all the infested trees were identified and destroyed, but there is no guarantee the beetles will not turn up somewhere else in the future.

Hide and Seek

Many animals use camouflage (KAH-mah-flahj; protective coloration) to disguise themselves from predators. Some predators camouflage themselves to lurk among tree leaves, waiting for their prey to pass by. The yellow color of the goldenrod spider, for example, enables it to hide in goldenrod flowers where it can sneak up on an insect sipping the flower's nectar.

Amphibians Amphibians are vertebrates (animals with backbones) that spend part, if not most, of their lives in water. Frogs, toads, and salamanders live in significant numbers in temperate and moist tropical deciduous forests. Frogs and toads can also be found in dry tropical forests if there is a dependable source of water.

Because amphibians breathe through their skin, and only moist skin can absorb oxygen, they must remain close to a water source. Mating, egg-laying, and young-adulthood all take place in ponds, lakes, or pools of rainwater. Offspring that survive and reach maturity leave the pools for dry land where they feed on both plants and insects. In dry tropical forests, amphibians must find shade during the day or risk dying in the heat of the sun.

Amphibians are cold-blooded animals, which means their bodies are about the same temperature as their environment. They need a warm environment in order to be active. As temperatures get cooler, they slow down and seek shelter. In temperate climates, amphibians hibernate (remain inactive) during winter months. In hot, dry climates, amphibians go through estivation, a similar inactive period. While the soil is still moist from the rain, they dig themselves a foot or more into the ground, where they remain until the rains return. Only their nostrils remain open to the surface.

Common deciduous forest amphibians Amphibians common in temperate forests include spring peepers (tiny frogs that climb trees), spotted newts, Fowler's toads, and marble salamanders. The African bullfrog is common to dry forests in Africa and the Pipid toad in South America. The flying frog is found in moist forests in India. It has a web of skin on both sides that begins at the wrist and attaches to the ankle. This skin acts as a parachute and enables the frogs to glide from one branch to another.

Food Adult amphibians are usually carnivorous, feeding on insects, slugs, and worms. Salamanders that live in water suck their prey into their mouths. Those that live on land have long, sticky tongues to capture food. Amphibian larvae are mostly herbivorous (plant eaters), feeding on vegetation. Frogs and toads are omnivores (both plant and meat eating) feeding on algae, plants, and insects such as mosquitoes.

Reproduction Mating and egg-laying for amphibians must take place in water. Male sperm are deposited in the water, often right on top

Box turtles are common deciduous forest residents, enjoying insects and nearly all vegetable matter they find on the forest floor. IMAGE COPYRIGHT JAMIE WILSON, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

of the female's eggs. As the young develop into larvae and young adults, they have gills for breathing.

Reptiles Reptiles that live in deciduous forests include many species of snakes, lizards, and turtles. The body temperature of a reptile changes with the temperature of the surrounding environment. Early in the day, they expose as much of their bodies as possible to the sun for warmth. As temperatures climb, they begin to seek shade. During hot, dry periods, they must find shade or a hole in which to wait for cooler weather. During chilly nights, they become sluggish. In temperate climates, snakes may hibernate in burrows during the long winter.

Common deciduous forest reptiles Temperate forest reptiles in eastern North America include the five-lined skink, eastern box turtle, and garter snake. Reptiles found in dry tropical forests include the night adder, puff adder, Gabonan adder, and the agama lizard. Moist tropical forests are home to pythons and the calot lizard.

Food A lizard's diet varies, depending upon the species. Some have long tongues with sticky tips and specialize in insects. Many are carnivores that eat small mammals and birds. The water they need is usually obtained from the food they eat.

Blue jays are a familiar, and frequently noisy, deciduous forest resident. IMAGE COPYRIGHT BOB BLANCHARD, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

All snakes are carnivores. One large meal (such as a rabbit, rat, or bird) can last them days or weeks. Constrictors squeeze their prey to death, while other snakes kill their prey with venom (poison) injected through the snake's fangs.

Reproduction Reptile eggs are leathery and tough. Offspring are seldom cared for by the parents. Some females remain with their eggs, but most bury them in a hole and leave. The young are left to hatch by themselves. Once free of the eggs, the babies dig themselves out of the hole and begin life on their own.

Birds All forests have bird populations. Some species, such as the grosbeak, are migratory, which means they travel from one seasonal breeding place to another. During excessively cold or dry periods, most birds fly to more comfortable regions. Others, such as the blue jay, prefer to stay in the same area year-round.

Feathers protect birds not only from cold winters but from tropical heat. Air trapped between layers of feathers acts as insulation against both climates.

Common deciduous forest birds In temperate forests, common birds include screech owls, great horned owls, hummingbirds, woodpeckers, nuthatches, woodthrushes, American redstarts, hawks, blue jays, cardinals, scarlet tanagers, chickadees, and turkey vultures.

Wrens, falcons, weaverbirds, and chats are found in dry tropical forests. In the moist deciduous forests of Australia, currawongs build nests of sticks in the eucalyptus trees. Thrush are common in India.

Jay Most species of jays are found in the Northern Hemisphere but they are also common in South America, Eurasia, and Africa. Their feathers may be drab or brightly colored, such as those of the North American blue jay. Many have crests and long tail feathers. They eat both plant matter and insects, and some species eat the eggs of other birds.

Jays are known for their bold, aggressive behavior and loud, harsh voices. Gangs of jays often harass other birds and even humans.

Falcon Found all over the world, falcons are birds of prey. They are characterized by long, pointed wings and the ability to fly very fast. Some species fly to a high altitude and then dive on their prey, killing it with the

Falcons have exceptional vision and are adept flyers. IMAGE COPYRIGHT PETER BARRETT, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

powerful blow of their clenched talons. A peregrine falcon's dive can reach more than 200 miles (322 kilometers) per hour during an attack.

The sport of falconry (training falcons to hunt other animals) originated in the East with the earliest records dating back to 700 BC in China. Falconry was also popular in Japan, Mongolia, Korea, and Russia.

Food Birds are found in greater variety and numbers where there is an ample supply of seeds, berries, and insects. Different birds seek food in different layers of the forest. Orioles and tanagers, for example, hunt for food high in the canopy. The white-breasted nuthatch hunts for insects along the trunks of the trees, and towhees dig around on the ground. Some birds that live year-round in temperate climates such as chickadees and blue jays may hide seeds in holes in trees where they can find them during the cold months. This hiding of seeds is called caching.

Reproduction In dry tropical climates, such as that in most of Australia, birds adapt their breeding habits to periods of rainfall and breeding cycles may be far apart.

Birds are free to fly away from uncomfortable temperatures during the most of the year, but the breeding cycle dictates when they can travel. They must remain in the same spot from the time nest building begins until the fledgling birds can fly, a period of many weeks.

Raccoons eat a varied diet that includes berries, fruits, insects, small mammals, and fish. IMAGE COPYRIGHT MARKUS JABS, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Parents usually sit on the nest to protect the eggs from heat or cold. During very hot weather, the parents may stand over the nest to give the eggs or the nestlings shade.

Mammals Mammals are vertebrates that have hair and bear live young. Only a few large mammals, such as bear and deer, live in temperate deciduous forests. Several small mammals, including mice, squirrels, woodchucks, and foxes, make their homes there. During the cold winters, many mammals burrow underground or find some other kind of shelter. Squirrels, for example, build nests high in the forest canopy. Some mammals, like bears, hibernate. In dry tropical climates, small mammals, such as rodents, may estivate (be very inactive) during the dry season.

Common deciduous forest mammals Temperate forests are home to shrews, woodmice, gray foxes, chipmunks, ground squirrels, badgers, black bears, silver-haired bats, raccoons, opossums, weasels, cottontail rabbits, gray squirrels, skunks, flying squirrels, and bobcats.

Dry deciduous forests support grazing animals, such as zebras and gazelles, which feed on the grasses that grow beneath the widely spaced trees. In the moist deciduous forests of Australia, red and gray kangaroos browse on leafy foliage. Wombats, opossums, and koalas live among the trees. Tigers are common in the moist forests of Asia, as are elephants and buffalo.

Raccoon Raccoons are medium-sized furry mammals with stout bodies, short legs, and long, bushy tails. They are perhaps best known for the black "mask" around their eyes and their proficiency as burglars. They prefer living in the woods where they hunt rodents, birds and bird eggs, berries, fruit, and other plant matter. They also love corn, melons and other foods of civilized life, which makes them expert raiders of suburban gardens and garbage cans.

Raccoons live in dens made in hollow trees. This is where they spend the daylight hours, and they go out to hunt at night. They sleep more during cold seasons, but they do not hibernate. Intelligent and curious animals, raccoons are hunted for their fur and meat.

Tiger The tiger is one of the largest and strongest carnivores. They can grow more than 9 feet (2.7 meters) from nose to tail and weigh as much as 500 pounds (227 kilograms). They are found in the Asia wild, where they prey on hoofed animals, such as wild deer and pigs, as well as fish, birds, leopards and, occasionally, bears. Although tigers are only successful in one or two attacks out of twenty, they sustain themselves by their ability to eat up to 80 pounds (36 kilograms) in one sitting. Only 5,000 to 7,000 specimens of tigers exist. Their population has decreased by 95 percent since the turn of the twentieth century, mostly due to habitat destruction.

Nature's Johnny Appleseeds

Johnny Appleseed was the nickname of John Chapman (1774–1845), a man who traveled around North America planting apple trees. Some animals fulfill similar roles, although perhaps not on purpose. Squirrels and chipmunks, for example, prepare for the long winter by burying acorns and other nuts in the ground where they can dig them up later and eat them. They often forget where they buried them, and in the spring the nuts sprout and send up shoots. Thanks to the poor memories of squirrels and chipmunks, forests spread and grow.

Food Some mammals, such as mice, eat plants and insects. Others, like squirrels and hedgehogs, eat bird and reptile eggs and young. Many smaller mammals do not need to drink water as often because they obtain moisture from the food they eat.

Reproduction The young of mammals develop inside the mother's body. In this way they are protected from heat, cold, and predators. Mammals produce milk to feed their young. Those that live in dens must remain nearby until the young can survive on their own. In temperate forests, the young are usually born in the spring so they have many warm months ahead in which to grow strong.

Endangered species In Asia, South America, and Africa, all the big cats, including tigers, leopards, and cheetahs, are endangered as humans encroach on their habitats. In some parts of the United States and Canada, the timber wolf remains threatened. In Australia, the koala and some species of kangaroos are threatened, as is the elephant in Africa and Asia. In some areas the animals are overhunted; in others their habitats are disappearing.

Human Life

Humans are creatures of the forest. Until they learned to hunt, humans ate plant foods such as bark, nuts, and berries. The earliest records of humankind show that people and the great forests evolved together. As humans learned to hunt animals for food and clothing, they sought out the forests, which had plenty of animal life.

Impact of the deciduous forest on human life Forests have an important impact on the environment as a whole. From the earliest times, forests have offered food and shelter, a place to hide from predators, and many useful products.

Environmental cycles Trees, soil, animals, and other plants all interact to create a balance in the environment from which humans benefit. This balance is maintained in what can be described as cycles.

The oxygen cycle Plants and animals take in oxygen from the air and use it for their life processes. When animals and humans breathe, the oxygen they inhale is converted to carbon dioxide, which they exhale. This oxygen must be replaced, or life could not continue. Trees help replace oxygen during photosynthesis, when they release oxygen into the atmosphere through their leaves.

The carbon cycle Carbon dioxide is also necessary to life, but too much is harmful. During photosynthesis, trees and other plants remove carbon dioxide from the air. By doing so, they help maintain the oxygen/carbon dioxide balance in the atmosphere.

When trees die, the carbon in their tissues is returned to the soil. If decaying trees become part of Earth's crust, after millions of years, this carbon becomes oil and natural gas.

The water cycle Forests shade the snow, allowing it to remain in deep drifts. Root systems and fallen leaves help build an absorbent covering on the ground, allowing rain water and melting snow to soak into the soil and trickle down to feed underground streams and groundwater supplies.

Not only do forests help preserve water, but they also protect the land. Trees act as barriers, or walls, that help to reduce the strong forces of winds and rain. When forests are cut down, this barrier is removed and the topsoil is either blown away, or during heavy rains, the soil washes away. As a result, flooding is more common because there is no absorbent layer to soak up the rain. Since 1997, parts of India and Bangladesh have had severe flooding caused in part by the cutting of forests in the nearby Himalaya Mountains.

Trees take up water through their roots and use it for their own life processes. Extra moisture is released through their leaves back into the atmosphere, where it forms clouds and once again falls as rain or snow, continuing the water cycle.

The Nutrient cycle Trees get the mineral nutrients they need from the soil. Dissolved minerals are absorbed from the soil by the tree's roots and are sent upward throughout the tree. These mineral nutrients are used by the tree much like humans take vitamins. When the tree dies, these nutrients, which are still contained within parts of the tree, decompose and are returned to the soil. These nutrients are then available for other plants and animals to use.

Food Since the earliest times, forests have been home to game animals, such as deer, which supply meat for hunters and their families. Forests also supply fruits and seeds, as well as vegetation for livestock, and honey made by bees. Cranberries, gooseberries, strawberries, raspberries, huckleberries, and currants all grow in temperate woodlands.

Shelter During prehistoric times, humans lived in the forest because it offered protection from the weather and dangerous animals. People of developed countries who continue to live in forested areas usually do so because they enjoy nature's beauty. Some native tribes still live in forests, as their ancestors did many years ago.

Economic values Forests are important to the world economy. Many products used commercially are obtained from forests, such as wood, medicine, tannis, and dyes.

WORLD TRADE IN TIMBER PRODUCTS (PARTIAL LIST)

Country	Exports: tons (metric tons)	Imports: tons (metric tons)
United States	12,948 (11,744)	16,778 (15,218)
Canada	17,588 (15,952)	2,938 (2,665)
Great Britain	----	5,484 (4,974)
Russia	16,050 (14,577)	----
China	554 (493)	4,348 (3,944)
Japan	----	31,679 (28,733)
Indonesia	13,961 (12,663)	----
Sweden	4,403 (3,994)	2,023 (1,835)

Healing Saps and Gums

Gums and saps from certain trees have important commercial uses. For example, the sap of the spiny acacia, called gum arabic, was first used by the ancient Egyptians to make inks. It has been used in medicines, adhesives, and is still used in making watercolor paints. These helpful liquids, which usually ooze from wounds in a tree, are produced only by trees that are unhealthy because of dry weather or poor soil and have been infected by microorganisms or fungi. The sap or gum may help the tree heal itself.

Wood Trees produce one of two general types of wood: hardwood or softwood, based on the trees' cell wall structure. Hardwoods are usually produced by deciduous trees, such as oaks and elms. Most coniferous trees, such as pines, produce softwoods. These names can be confusing because some softwood trees, such as the yew, produce woods that are harder than many hardwoods. Some hardwoods, such as balsa, are softer than most softwoods.

Wood is used for fuel, building structures, and manufacturing other products, such as furniture and paper. Wood used for general construction is usually softwood. In order to conserve trees and reduce costs, some manufacturers have created engineered wood, which is composed of particles of several types of wood mixed with strong glues and preservatives. Engineered woods are very strong and can be used for many construction needs.

Hardwood from deciduous trees is more expensive because the trees grow slowly. It is used primarily for fine furniture and paneling. Most of this hardwood comes from forests in Europe. In the United States, the major commercial hardwoods are sugar maple, red oak, black walnut, and beech.

Farmland In temperate regions, the soil beneath a deciduous forest is often fertile. For this reason, forestland has often been cleared for agricultural purposes. As the United States was settled, most of the original deciduous forest in the East was cut down to accommodate farms and large plantations. After the land was exhausted and farming became centralized in the plains of the Midwest, the forests gradually grew back. Oaks, maples, and hickories now flourish in the same regions that supported their ancestors 400 years ago.

Medicines Since the earliest times, plants have been used for their healing properties. The ancient Greeks, for example, used extracts from willow bark to relieve pain, as did certain tribes of Native Americans. During the nineteenth century, scientists discovered the bark's pain-killing ingredient—salicylic acid. This ingredient is a component of the familiar pain-killing medicine, aspirin, made of acetylsalicylic acid.

Tannins and dyes Tannins are chemical substances found in the bark, roots, seeds, and leaves of many plants. These tannins can be extracted by boiling or soaking plant material. The extract is then used to cure leather, making it soft and supple. Trees used for tannins include oaks, chestnuts, and quebracho.

Dyes used to color fabrics can be obtained from oak, alder, birch, walnut, brazilwood, and logwood. Natural dyes are no longer commonly used commercially, since less expensive dyes can be produced from chemicals.

Recreation Many people feel the need to escape to natural surroundings on occasion. The beauty and quiet of deciduous forests draw many visitors for hiking, horseback riding, skiing, fishing, hunting, bird watching, or just sitting and listening to nature.

The World's Oldest Tree Species

The ginkgo (*Ginkgo biloba*), or maidenhair tree, is the only remaining survivor of a group of plants that thrived during the Permian period (260 million years ago). Essentially unchanged since prehistoric times, the ginkgo is a smooth-barked tree with fan-shaped leaves and few branches. Although it forms naked seeds, the ginkgo is deciduous; its leaves turn a golden color in fall and drop.

In China the ginkgo is sacred and is planted near temples. It is a popular ornamental plant in the temperate climates of Europe and North America. The seeds and leaves of the ginkgo are valued for their medicinal properties.

Impact of human life on the deciduous forest Just as the forest has had an effect on human life, human life has had an effect on the forest. About 10,000 years ago, forests covered about half of Earth's land surface. They now cover less than one-third. Nearly 2 billion tons (1.8 billion metric tons) of timber are cut from the world's forests each year. Most of the losses in forest cover occur in developing nations where wood is used for fuel and trees are cleared for farming. The rest of the crop is used commercially.

Use of plants and animals During the Middle Ages (500–1450) in Europe and the eighteenth and nineteenth centuries in America, it was thought that forests were indestructible. They seemed to go on forever. Eventually, the cutting of trees brought an end to many ancient forests. Only when they were left alone to regrow or were deliberately replanted, did the forests begin to recover.

In the United States, environmentalists are often in disagreement with logging companies over the cutting of old-growth forests. Trees are a renewable resource but old-growth trees may take more than 100 years to be replaced. Oftentimes, the logging companies replace the old trees with seedlings from other species that grow faster, and the original species are never

The Mighty Acorn

It is an old saying that "Mighty oaks from little acorns grow." Acorns are appreciated for more than just turning themselves into oak trees. Many animals use them for food, and, at various times in history, humans have pounded them into a nutritious flour. In recent years a new use has been found: a cure for polluted rivers.

Acorns contain acornic acid, which binds with poisons from heavy metals, such as uranium, allowing these pollutants to be removed from rivers and streams. An estimated 2.2 pounds (4.8 kilograms) of acorns can clean up 3.5 tons (3.9 metric tons) of water.

replanted. The companies sometimes replace only certain species, destroying the forest's diversity, along with plants and animals that depend on it.

Other threats to North American forests include mining operations that want to locate on public forest lands, and the cutting down of trees in order to develop land for homes and businesses.

Conservation laws in many states protect trees on public lands, while other laws protect forest creatures from being overhunted.

In tropical regions, forest land is being lost as populations grow and want the land for farms. Slash and burn agriculture is practiced when trees are cut and burned. The land is then used between one and five years for farming. When the land, which is usually poor, no longer supports crops, it is abandoned and another forest plot is cut down elsewhere. As a result, many animals and plants lose their habitats.

Quality of the environment Destruction of the forests does not just mean loss of their beauty and the products they provide. Soil quality declines. Some soil is washed away by rain, and the loss of plant life means the soil will not be built back up again.

Water quality and supply also suffers. With the loss of trees, rain does not seep into the soil and underground water reserves are not replaced. Soil that is washed away often ends up in streams and rivers. If the quantity of soil is large enough, fish may die.

Air quality is reduced when forests are destroyed. Not only do trees put oxygen back into the air, but soot and dust collect on their leaves. When it rains, the trapped soot and dust are washed to the ground where they enter the soil. In this way, trees help keep the air clean. When trees are cut down, the dust and soot remain, contributing to air pollution.

Carbon dioxide and other undesirable gases have built up in the atmosphere with the popularity of the automobile. Most scientists believe these gases are helping to raise the temperature of Earth's climate by forming an invisible layer in the atmosphere. This layer traps heat instead of letting it escape into the upper atmosphere. This is called the "greenhouse effect." Cutting down forests may be helping cause this global warming because they can no longer remove carbon dioxide from the air. If Earth

COMMON HARDWOODS

North America and Europe	Central and South America	Africa	Asia	Australia
Alder	Aromata	African oak	Aralia	Black bean
Ash	Balsa	African walnut	Bow wood	Cedar
Basswood	Bois gris	Comphorwood	Boxwood	Coconut palm
Beech	Bois lait	Canarium	Canarium	Gum
Birch	Brazilwood	Ebony	Cedar	Ironbark
Boxwood	Chilean laurel	Mahogany	Cinnamon	Peppermint
Cherry	Greenheart	Olive	Ebony	Silky oak
Chestnut	Lancewood	Teak	Elm	Tasmanian oak
Dogwood	Lignum vitae		Gum	Tea tree
Elm	Mahogany		Horse chestnut	Turpentine
Hickory	Pepper		Indian laurel	Walnut
Holly	Rosewood		Japanese alder	Wattle
Hornbeam	Satinwood		Japanese ash	
Lime	Snakewood		Japanese birch	
Magnolia	Teak		Japanese maple	
Maple	Tulipwood		Katsura	
Oak	Yokewood		Rosewood	
Olive			Sandalwood	
Pear			Teak	
Plane			Tree of Heaven	
Poplar			Walnut	
Sycamore			Willow	
Walnut				
Willow				

continues to grow warmer, many species of plants and animals could become extinct.

Air pollution is contributing to forest loss as well. Some forests take on an off-color, or sickly, appearance in polluted environments. Air pollution causes acid rain, which damages some types of trees. Acid rain occurs when certain compounds in polluted air mix with water vapor and fall to Earth in rain. When acid rain is absorbed into the soil, it can destroy nutrients and make the soil too acidic to support some species of trees. Forests in northern Europe, southern Canada, and the eastern United States have been damaged by acid rain.

Off-road vehicles, such as motorbikes and four-wheelers, tear up forest undergrowth, kill flowers, scare away animals, and destroy the peace of the forest.

Forest Management The U.S. National Forest Service was established in 1905 to protect forest resources. More than 193 million acres (78 million hectares) of land are now publicly owned. Most of this acreage is west of the Mississippi. Forests in the eastern half of the United States are managed by state programs. These forests may consist of land that can be used for logging and other commercial purposes; however, certain portions are kept for recreation and conservation.

Other nations, including Great Britain, Japan, China, and India, have established programs to conserve and replant forests.

Native peoples By 1950, native peoples in industrialized parts of the world had abandoned most of their tribal lands and customs. Many went to live in cities but some still live a traditional lifestyle. The Birhor of central India are one example. They live in the forests as nomadic hunter-gatherers and supplement their diet with rice that they trade for with forest products such as bark fiber rope.

Algonquin and Iroquois Tribes Until the European settlers forced them off their ancestral lands, many Native American tribes lived in the deciduous woodlands of the northeastern United States. They included tribes who spoke the Iroquois language—the Cayuga, Erie, Huron, Mohawk, Oneida, Onondaga, Seneca, Tuscarora, and Neutral; and those who spoke Algonquin—the Delaware, Fox, Illinois, Kickapoo, Mohican, Massachuset, Menominee, Miami, Mohegan, Ottawa, Pequot, Sauk, Shawnee, Shinnecock, and Wampanoag.

Long winters in those regions limited farming, so most foods were collected from the wild. These included fish, game, maple syrup, and wild rice.

Nearly all native groups who survived contact with European settlers were forced to move to reservations in Oklahoma during the early nineteenth century.

Ainu The Ainu are native peoples who live on Hokkaido, the northernmost island of Japan, and on the Russian island of Sakhalin in the North Pacific. Originally hunters and gatherers, the men used bow and arrow to hunt bear, deer, fox, otter, and other animals during the winter; in summer they fished. The women gathered roots, berries, mushrooms, and nuts and also did some farming. The men were skilled woodcarvers, and the women wove fabrics and did embroidery. Their chief musical instruments were the drum and flute.

At one time, the Ainu lived throughout the Japanese islands, but gradually, as the Japanese population has moved in and expanded, the Ainu have been pushed to their present territory. As of the last census in 1984, the population was only 24,381 people.

The Ainu are native people who live on the northernmost island of Japan. AP IMAGES.

The Food Web

The transfer of energy from organism to organism forms a series called a food chain. All the possible feeding relationships that exist in a biome make up its food web. In the deciduous forest, as elsewhere, the food web consists of producers, consumers, and decomposers. An analysis of the food web shows how energy is transferred within the biome.

Green plants are the primary producers in the forest. They produce organic materials from inorganic chemicals and outside sources of energy, primarily the sun. Trees and other plants turn energy into plant food.

Animals are consumers. Plant-eating animals, such as grasshoppers and mice, are primary consumers in the forest food web. Secondary consumers eat the plant-eaters. Tertiary consumers are predators, like owls, foxes, and tigers. They are carnivores. Humans fall into this category, but they are omnivores, which means they eat both plants and animals.

Decomposers feed on dead organic matter, and include fungi and animals like the turkey vulture. In moist environments, bacteria also help in decomposition. When fallen leaves from deciduous trees carpet the ground forming a thick layer, bacteria feed on the leaves and help decompose them into humus.

Spotlight on Deciduous Forests

Deciduous forests of Medieval Europe About 5,000 years ago, birch trees dominated the forests of the Northern Hemisphere. As the climate gradually became warmer other trees started to take over. By Medieval times (500–1450), many hardwood trees, such as beeches and long-lived oaks, ranged over much of central and western Europe north of the Alps and the Pyrenees Mountains, and eastward across Russia to the Ural Mountains. Oaks and beeches usually formed the canopy, with maples and birches in the secondary layer, and dogwoods, hawthorns, and hollies closer to the ground.

The forests were home to falcons, hawks, herons, owls, deer, wolves, boars, otters, squirrels, foxes, badgers, and other wild animals. Many of these were hunted; some for food and others to protect crops and domesticated animals.

The people who lived there depended on forests as a source of timber for building livestock houses, vines and leaves for feeding, and game animals for hunting. Bees, prized for their honey, were often kept within the forest, and the fruits and nuts of many trees, such as the hazel, were used as food. Pigs were kept in the forest where they could feed on acorns. Valued for these nuts, oaks were allowed to grow old. Wood was prized as fuel, not only as logs but as charcoal, which is created when wood is partially burned. Charcoal produces a very hot fire and was used in beer brewing and forging iron. Wood ash, a by-product of burning wood, was needed for making glass and soap. Wood was used to build boats, carts, furniture, and even shoes.

Open land was used for farming but as populations grew, more and more forests were cut down and used for planting crops. By the eleventh century, the heavy plow came into use. It worked the soil more efficiently than previous methods and increased the amount of land that could be used for agriculture.

Deciduous forests of Japan Japan is a series of islands, and deciduous forests cover at least half of the largest island, Honshu, and the lower-lying parts of southern Hokkaido.

Beeches are the dominant trees, but many other species are mixed in, including oaks, chestnuts, maples, and limes. Oaks and chestnuts are cultivated on privately owned tree plantations. Much of the land in Japan is intensely cultivated because it is a small country in terms of available land. This has led to the production of miniature trees that can be planted in small gardens.

The climate of Japan's deciduous forests is temperate but cool. Rain is plentiful, as is snow in winter. The stately beeches, which have bright green leaves in summer, turn a rich gold-brown in autumn.

Forests of Medieval Europe
Location: Northern and western Europe
Classification: Temperate

Deciduous forests of Japan
Location: Northern Japan
Classification: Temperate

Few trees are planted in Japan for timber. Most commercially grown trees, such as the beautiful Japanese maple and the flowering cherry, are sold for ornamental purposes.

Deciduous forests of China China is the third largest country in the world based on acreage, and its forested land stretches over many hundreds of thousands of square miles. In the north, the climate is cool temperate, while in the south the climate is warm temperate. Oak, ash, birch, and poplar forests predominate in the northeast. No single species predominates in the southeast, and even the canopy shows a mixture of trees, including oak, maple, poplar, boxwood, and sweetgum.

The world's first artificial forest was located in China, and is currently 115 million acres large (46 million hectares). It accounts for 26 percent of the world's artificial forests and covers 16.5 percent of China's land mass—more than double the 8.6 percent China had in 1950.

Deciduous forests of North America Deciduous forests are found in North America in portions of southern Canada, New England, the upper Midwest, the Appalachian region, along the Mississippi, and in the southeastern states.

When European settlers arrived in America in the 1600s, these forests were thick with oak, beech, and chestnut trees. Many trees were at least 100 feet (31 meters) tall and shaded a wide variety of other plants. Wild turkeys, passenger pigeons, moose, cougars, bison, beavers, otters, bears, and wolves were present. By 1970 most of the deciduous forests had been cut down, sacrificed to the building of houses and the need for farmland. Only in remote areas where the land was too steep to allow easy access did the original forest survive.

In some areas, deciduous forests are recovering. New England, for example, has more forest now than there was 100 years ago. Deciduous trees, such as sugar maple, birch, beech, and hemlock, mingle with coniferous forests. From Minnesota and Michigan eastward toward New England, the land is now being reclaimed by oak, beech, maple, aspen, and other species. In the southern and southeastern United States, the land was once covered primarily by deciduous trees, such as oaks, which were cut for timber and to clear the land for farms. Coniferous trees now predominate in some areas. If the land remains undisturbed, deciduous trees will once again take over.

Deciduous Forests of China
Location: Eastern China
Classification: Temperate

Deciduous Forests of North America
Location: Southern Canada and eastern United States
Classification: Temperate

Deciduous forests of Australia Only about 15 percent of the total area of Australia has enough rainfall to support forests. Its central region is primarily desert mixed with grassland, and its forests grow in bands on the outer fringes of the continent. Although most of these trees are evergreen, moist deciduous forests can be found along the north and northeast coasts. Along the southern edge of the continent are open woodlands and dry tropical forest mixed with grasslands.

In the more humid upland and coastal areas of southwestern and eastern Australia, eucalyptus, angophora, and sheoaks predominate, mixed with beeches in some areas and shrubs having leathery leaves. In the south, acacia, or wattle, trees are common.

Woodland animals are varied and include many poisonous snakes. One interesting species, the carpet snake, is not poisonous but suffocates its victims by wrapping itself around them. A climber, the carpet snake is often turned loose in barns by farmers who want it to catch rats and mice.

Forest birds include budgerigars, currawongs, honey-eaters, and laughing kookaburras.

Mammals are predominantly marsupials, such as wombats and kangaroos, that carry their young in a pouch. Kangaroos range through the open woodlands of eastern Australia.

The native peoples of Australia are the Aborigines, who live in dry regions.

Deciduous forests of Central India Central India, in the general area between the cities of Delhi and Nagpur, is a dry tropical region with dry and mixed deciduous forests. Trees found here include teak, mango, mohwa, jamun, gardenia, sal, and palm. Much of the area is grassland, and bamboo is common.

The region supports many parks and nature preserves, including Kanha Tiger Reserve and Taroba and Shivpuri National Parks.

Animals in this region include jays, peacocks, demoiselle cranes, wild boar, sambar and chital deer, gazelles, jackals, leopards, and tigers.

Forests account for only about 10 percent of India's land area, and forests are not accessible for commercial development. The government is attempting to increase the forested area by outlining three key goals—reduce soil erosion, supply wood product industries, and supply the needs of the rural population.

Deciduous forests of Australia
Location: Along the coastlines of the continent
Classification: Moist tropical and dry tropical

Deciduous forests of Central India
Location: Central India between Delhi and Nagpur
Classification: Dry tropical

Deciduous forests of Southern India Several regions at the southern tip of India support moist tropical deciduous forest and mixed forests with many evergreens. Trees include teak, ebony, and bejal. Except for areas devoted to the cultivation of teak, undergrowth tends to be thick. Open areas are covered by grasses and bamboo.

Several reserves and national parks are located here, including the Mudumalai Sanctuary, the Nagarhole Sanctuary, and the Bandipur Tiger Reserve.

The animal population is rich and varied. Termite nests can be seen along the roadways. Pythons, cobras, and monitor lizards are common. Birds include peacocks, parrots, pigeons, hornbills, and drongos. Giant squirrels, elephants, gaurs, lipped bears, leopards, and tigers also make their homes in the forest.

Deciduous forests of Tanzania and Kenya In Tanzania, the forest is called *miombo*. As of 2000, 41 percent of the Tanzanian land mass was covered in forests. Their trees are short with flat tops. During the dry season, which may last as long as seven months, the trees shed their leaves. Grasses and other plants die off, and the forest looks brown and scorched. When new leaves begin to appear, they signal the start of the rains, which give new life to the region.

Tree seedlings often develop large tap roots used to store water. During this time there is little development of the tree above the ground. Trees may take as long as seven years to grow more than 1 foot (30 centimeters) in height.

In Kenya, acacia woodlands are common, although baobab is predominant. Seasonal droughts cause vegetation to die. Many trees store water in tap roots or, like the baobab, in their trunks. A single baobab trunk can contain up to 25,000 gallons (94,625 liters) of water.

Common animals include the buffalo, elephant, leopard, lion, rhinoceros and wildebeest. Lions are the largest predator.

Deciduous forests of Southern India
Location: The tip of India, south of Bangalore
Classification: Moist tropical

Deciduous forests of Tanzania and Kenya
Location: Eastern Africa
Classification: Dry tropical

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Environmental Protection Agency, 401 M Street, SW, Washington, DC 20460, Phone: 202-260-2090, Internet: http://www.epa.gov

Friends of the Earth, 1717 Massachusetts Ave. NW, 300, Washington, DC 20036, Phone: 877-843-8687; Fax: 202-783-0444, Internet: http://www.foe.org

Global ReLeaf, American Forests, PO Box 2000, Washington, DC 20013, Phone: 202-737-1944, Internet: http://www.amfor.org

Greenpeace USA, 702 H Street NW, Washington, DC 20001, Phone: 202-462-1177, Internet: http://www.greenpeace.org

Izaak Walton League of America, 707 Conservation Lane, Gaithersburg MD, 20878, Phone: 301-548-0150, Internet: http://www.iwla.org

Sierra Club, 85 2nd Street, 2nd Fl., San Francisco, CA 94105, Phone: 415-977-5500; Fax: 415-977-5799, Internet: http://www.sierraclub.org

The Wilderness Society, 1615 M St. NW, Washington, DC 20036, Phone: 800-the-wild, Internet: http://www.wilderness.org

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Desert

All deserts have two things in common: they are dry, and they support little plant and animal life. If a region receives an average of fewer than 10 inches (25 centimeters) of rain each year, it is classified as a desert. Contrary to what most people believe, not all deserts are hot. Some deserts near the North and South Poles are so cold that all moisture is frozen—these are called polar deserts. Tropical desert areas are near the equator. Temperate desert areas are between the tropics and the North and South Poles.

True deserts cover about one-fifth of the world's land area. With the addition of polar deserts, the total rises to 30 percent. Another 25 percent of Earth's land surface possesses desertlike characteristics. In all, deserts constitute 33 million square miles (86 million square kilometers). Most deserts lie near the tropic of Cancer and the tropic of Capricorn, two lines of latitude about 25 degrees from the equator. The area between these two lines is called the Torrid Zone (*torrid* means very hot).

How Deserts Are Formed

Deserts are generally caused by the presence of dry air. The average humidity (moisture in the air) is between 10 and 30 percent. In some cases, mountain ranges prevent moisture-laden clouds from reaching the area. Mountains can cause heavy, moisture-filled clouds to rise into the colder atmosphere. There, the moisture condenses and falls in the form of rain, leaving the air free of moisture as it crosses the range. In other cases, certain wind patterns along the equator bring air in from dry regions. Cold-water ocean currents can cause moist air to drop its moisture over the ocean. The resulting dry air quickly evaporates (dries up) ground moisture along the coastal regions as it moves inland.

Deserts have always existed, even when glaciers covered large portions of Earth during the great Ice Ages. Although geological evidence is scarce,

WORDS TO KNOW

***Arroyo*:** The dry bed of a stream that flows only after rain; also called a wash or a *wadi*.

Butte: A small hill.

Deforestation: The cutting down of all the trees in a forest.

Desertification: The changing of fertile lands into deserts through destruction of vegetation (plant life) or depletion of soil nutrients. Topsoil and groundwater are eventually lost as well.

Dormant: A suspension of growing (plants) or activity (animals) when conditions are harsh.

Estivation: An inactive period experienced by some animals during very hot months.

Mesa: A flat topped hill.

Oasis (plural is oases): A fertile area in the desert having a water supply that enables trees and other plants to grow there.

***Wadi*:** The dry bed of a stream that flows after a rain; also called a wash, or an *arroyo*.

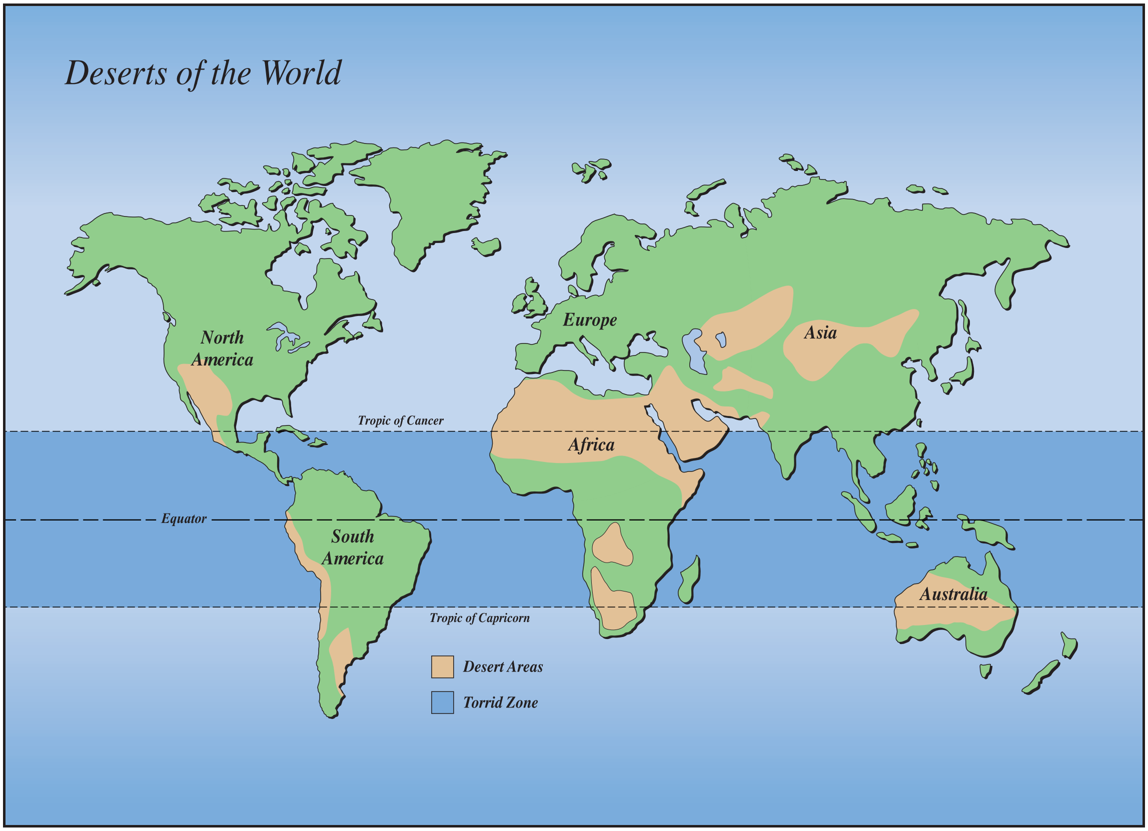
Xeriscaping: Landscaping method that uses drought tolerant plants and efficient watering techniques.

scientists tend to agree that some desert areas have always been present, but they were probably smaller than those of today. Fossils, the ancient remains of living organisms that have turned to stone, can reveal the climatic history of a region. For example, scientists believe that the Arabian Desert, which covers most of the Arabian Peninsula to the east of North Africa, once included wetlands because fossils of a small species of hippopotamus have been found there. In the Sahara Desert of North Africa, rock paintings made 5,000 years ago show pictures of elephants, giraffes, and herds of antelope that are no longer present.

Desertification (DES-aurt-ih-fih-KAY-shun; desert formation) occurs continuously, primarily on the edges of existing deserts. It is caused by a combination of droughts (rainless periods) and human activity such as deforestation (cutting down forests) or overgrazing of herd animals. When all the grass is used and rain is scarce, plants do not grow back. Without plants to hold the soil in place, wind blows away the smaller and finer particles of soil, exposing the less compacted layer of sand. This leaves a barren, unprotected surface. Eventually, even groundwater disappears.

Kinds of Deserts

Scientists measure a region's aridity (dryness) by comparing the amount of precipitation (rain, sleet, or snow) to the rate of evaporation.



Evaporation always exceeds precipitation. Deserts can be classified as hyperarid (less than 1 inch [2.5 centimeters] of rain per year); arid (up to 10 inches [25 centimeters] of rain per year); and semiarid (as much as 20 inches [50 centimeters] of rain per year, but are so hot that moisture evaporates rapidly). Most true deserts receive fewer than 4 inches (10 centimeters) of rain annually.

Except for those at the North and South Poles, which are special cases, deserts are classified as hot or cold. Daytime average temperatures in hot deserts are warm during all seasons of the year, usually above 65°F (18°C). Nighttime temperatures are chilly and sometimes go below freezing. Typical hot deserts include the Sahara and the Namib Desert of Namibia. Cold deserts have hot summers and cold winters. At least one month during the year the mean temperature is below 45°F (7°C). Cold deserts include Turkestan in Kazakhstan and Uzbekistan, Gobi (GOH-bee)

The oblong-shaped Ayers Rock is located in the Australian Desert. IMAGE COPYRIGHT RONALD SUMNERS, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

in China and Mongolia, and the Great Salt Lake Desert in Utah. These deserts usually get some precipitation in the form of snow.

Deserts can be further characterized by their appearance and plant life. They may be flat, mountainous, broken by gorges and ravines, or covered by a sea of sand. Plants may range from nearly invisible fungi to towering cacti and trees.

Climate

Although desert climates vary from very hot to very cold, they are always arid (dry).

Temperature In hot deserts, days are usually sunny and skies are cloudless. During the summer, daytime air temperatures between 105° and 110°F (43.8° and 46.8°C) are not unusual. A record air temperature of 136.4°F (62.6°C) was measured in the Sahara Desert, in a place called El Azizia, on September 13, 1922. The absence of vegetation exposes rocks and soil to the sun, which may cause ground temperatures in the hottest deserts to reach 170°F (77°C). Nights are much cooler. The lack of cloud cover allows heat to escape and the temperature may drop 25 degrees or more after the sun sets. At night, temperatures of 50°F (10°C) or less are common, and they may even drop below freezing.

The Sands of Time

When living things die, moisture in the air aids the bacteria that cause decay. Before long, tissues dissolve and eventually disappear. Desert air is so dry that decay does not take place or occurs extremely slowly. Instead, tissues dry out and shrink, turning an animal or human being into a mummy.

In ancient Egypt around 3000 BC, the dead were buried in shallow graves in the sand. The very dry conditions mummified the bodies, preserving them. Later, for those who could afford it, Egyptian burials became more complex. Internal organs were removed, and the bodies underwent special treatments designed to preserve them. They were then placed into tombs dug into rocky cliffs or, in the case of certain pharaohs (kings), placed within huge pyramids of stone. In most cases, bodies of the ancient Egyptians are so well preserved that much can still be learned about what they ate, how they lived, and what caused their deaths.

Graves discovered in the Takla Makan (TAHK-lah mah-KAN) Desert of China have also given scientists important information. (The name Takla Makan means "the place from which there is no return.") Well-preserved mummies as much as 3,800 years old have been found in the graves. The mummies have European features and some are dressed in fine woolens woven in tartan (plaid) patterns commonly used by the ancient Celts and Saxons of Northern Europe. Scientists believe these mummies were the first Europeans to enter China, which was officially closed to outsiders for thousands of years. Evidence exists that these people rode horses using saddles as early as 800 BC, and they may have introduced the wheel to China. Their descendants, who have intermarried with the Chinese, still live in the Takla Makan.

Winters in cold deserts at latitudes midway between the polar and equatorial regions can be bitter. In the Gobi Desert, for example, temperatures below freezing are common. Blizzards and violent winds often accompany the icy temperatures.

Precipitation Rainfall varies from desert to desert and from year to year. The driest deserts may receive no rainfall for several years, or as much as 17 inches (43 centimeters) in a single year. Rainfall may be spread out over many months or fall within a few hours. In the Atacama Desert of Chile, considered the world's driest desert, more than half an inch (1.3 centimeters) of rain fell in one shower after four years of drought. Such conditions often cause flash floods, which sweep vast quantities of mud, sand, and boulders through dry washes, gullies, and dry river beds (called *wadis* or *arroyos*). The water soon evaporates or disappears into the ground. The Atacama Desert is the site of the world's longest known drought; no rain fell for 400 years (from 1571 until 1971).

In coastal deserts, fog and mist may be common. Fog occurs when cold-water ocean currents cool the air and moisture condenses. The Atacama Desert lies in a depression behind mountains, so most of its precipitation is received in fog form.

Some deserts, such as the polar deserts, experience snow rather than rain or fog.

Geography of Deserts

The geography of deserts involves landforms, elevation, soil, mineral resources, and water resources.

Landforms Desert terrain may consist of mountains, a basin surrounded by mountains, or a high plain. Many desert areas were once lake beds that show the effect of erosion and soil deposits carried there by rivers. Wind

Sandstone formations are seen in Monument Valley, Utah. IMAGE COPYRIGHT SIGEN, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

helps shape the desert terrain by blowing great clouds of dust and sand that break down rock, sometimes sculpting it into strange and magnificent shapes. In the Australian Desert, unusual pinnacles (tall mountain shapes) of limestone rock, formed over thousands of years by the wind, stand on the desert floor. These limestone rock formations may be divided into two types. A mesa, the Spanish word for plateau, is a steep-sided, flat-topped hill. The mesa may be reduced to a butte (BYUT), the French word for hill or knoll, by erosion.

Sand dunes Bare rock, boulders, gravel, and large areas of sand appear in most desert landscapes. Vast expanses of sand dunes, sometimes called ergs, are not very common. Sand dunes make up less than 2 percent of deserts in North America, only 20 percent of the Sahara, and 20 percent of the Arabian Desert. The Empty Quarter (*Rub' al-Khali*) in the Arabian Desert is the largest sandy desert in the world, covering about 250,000 square miles (647,500 square kilometers).

Unless anchored by grass or other vegetation, sand dunes migrate constantly. Their rate of movement depends upon their size—smaller dunes move faster—and the speed of the wind. Some dunes may move over 100 feet (30 meters) in a year and can bury entire villages. In the Sahara, dunes created by strong winds can achieve heights of 1,000 feet (300 meters). Scientists estimate that dunes in the Namib Desert are the largest in the world.

Dunes take different shapes, depending upon how they lie in respect to prevailing winds. When the wind tends to blow in one direction, dunes often form ridges. The ridges may lie parallel to the wind forming seif (SAFE), or longitudinal dunes; or at right angles forming transverse dunes. Seif dunes are the largest, with some in the Sahara approaching 100 miles (160 kilometers) in length. At desert margins where there is less sand, dunes may assume crescent shapes having pointed ends. These are called barchan (bahr-KAN) dunes, and the wind blows in the direction of their "points." In the Sahara, stellar (star-shaped) dunes are commonly found. Stellar dunes form when the wind shifts often, blowing from several directions.

Disappearance of *Lady Be Good*

Becoming lost in the desert can often end in tragedy. In 1943, an American bomber, called *Lady Be Good*, went off course and crashed in the Sahara Desert. The surviving crew saw a line of hills in the distance and mistook them for the hills around the Mediterranean, where they hoped to find human settlements. At night they walked and they rested by day, covering 75 miles (120 kilometers) in a week. As it turned out, the hills were not those around the Mediterranean, and the crewmen were still 375 miles (600 kilometers) from the sea. The entire crew died from sun exposure and lack of food and water. Their bodies were not found until 1960—seventeen years later.

Soil Desert soils tend to be coarse, light colored, and high in mineral content. They contain little organic matter because there is little vegetation. If the area is a basin or a catch-all for flash-flood waters, mineral salts may be carried to the center where concentrations in the soil become heavy. If the area was once an inland sea, like the Kalahari (kah-lah-HAHR-ee) Desert of Botswana, eastern Namibia, and northern South Africa, exposed bottom sediments (matter deposited by water or wind) are very high in salt.

Most desert sand is made of tiny particles of the mineral quartz. Placed under pressure for long periods, grains of sand may stick together forming a type of rock called sandstone.

Some deserts have little soil, exposing bare, wind-polished, pebbly rock, called desert pavement. Rocks are often broken due to contraction and expansion caused by extreme temperature variations. Basin areas scoured by winds show surfaces of gravel and boulders, and on steep slopes, whipping winds may leave little soil.

Dust devils, columns of dust that spin over the desert landscape, are carried by whirlwinds. Dust storms can produce clouds thousands of feet high. In the Sahara, up to 200 million tons (180 million metric tons) of dust is created each year. Saharan dust has occasionally crossed the Atlantic to the United States. It has been known to travel as far north as Finland.

Two long-lasting chemical reactions affect desert rocks and soil. One, called desert varnish, gives rocks, sand, and gravel a dark sheen. Desert varnish is believed to be caused by the reaction between the moisture from overnight dew and minerals in the soil. The second reaction is the formation of duricrusts—hard, rocklike crusts that form on ridges when dew and minerals such as limestone combine, creating a type of cement.

Desert soils offer little help to plant life because they lack the nutrients provided by decaying vegetation and are easily blown away, exposing plant roots to the dry air. Some deep-rooted plants can exist on rock, where moisture accumulates in cracks. Other plants remain dormant during the driest periods, thriving and blooming after brief rains.

Soil reveals much about a desert's geological history. In Jordan, a Middle-Eastern country, the Black Desert takes its name from black basalt, a rock formed from volcanic lava.

Elevation Deserts exist at many altitudes. North American deserts are partly mountainous, but Death Valley, a large basin in California, is 282 feet (86 meters) below sea level at its lowest point. The main plateau of

The land is very flat in the Thar Desert. IMAGE COPYRIGHT CHRIS HOWEY, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

the Gobi is 3,000 feet (914 meters) above sea level, and the Sahara extends from 436 feet (130 meters) below to 10,712 feet (3,265 meters) above sea level. Temperature, plant, and animal life, are all influenced by elevation.

Mineral resources Valuable minerals like gold and oil (petroleum) are often found in desert regions. In the Great Sandy Desert of Australia, miners hunt for gold nuggets. "Black gold," as oil is often called, is found beneath the desert regions of the Middle East, where it formed over time from the sediment of prehistoric oceans. Iron ore is mined in portions of the Sahara. Borax—a white salt used in the manufacture of such products as glass and detergent—was once mined in Death Valley, California.

Water resources Water sources in the desert include underground reserves and surface water.

Groundwater In addition to occasional rainfall, deserts may have reserves of underground water. These reserves, often trapped in layers of porous rock called aquifers, were formed over thousands of years when rainwater seeped underground. Reserves close to the surface may create an oasis, a green, fertile haven where trees and smaller plants thrive. The presence of water may allow a completely different biome to form like an island in the desert.

People who live in the desert dig wells into aquifers and other underground water sources to irrigate crops and water their animals. As

WELL-KNOWN DESERTS OF THE WORLD

Name	Type	Location	Approximate Size
Arabian	Hot; extremely arid and arid	Arabian Peninsula	900,000 square miles (2,330,000 square kilometers)
Atacama	Hot; extremely arid and arid	Chile	70,000 square miles (181,300 square kilometers)
Australian	Hot; arid and semiarid	Australia	529,346 square miles (1,371,000 square kilometers)
Death Valley	Hot; arid	California (United States)	3,012 square miles (7,800 square kilometers)
Gobi	Cold; arid and semiarid	China, Mongolia	500,000 square miles (1,300,000 square kilometers)
Kalahari	Hot; arid	Southern Africa	10,038 square miles (260,000 square kilometers)
Mojave	Hot; arid	California and Nevada (United States)	25,000 square miles (65,000 square kilometers)
Namib	Hot; arid	Botswana, eastern Namibia, and northern South Africa	52,000 square miles (135,000 square kilometers)
Negev	Hot; arid	Israel	4,700 square miles (12,170 square kilometers)
Patagonian	Cold; arid	Argentina	260,000 square miles (673,000 square kilometers)
Sahara	Hot; extremely arid and arid	North Africa	35,600 square miles (92,200 square kilometers)
Thar	Hot; extremely arid	India and Pakistan	92,163 square miles (238,700 square kilometers)

desert populations grow, water sources shrink and cannot be replaced fast enough. There is a real danger that groundwater reserves will one day be depleted.

Surface water Water may be found in desert areas in the form of rivers or streams. Some streams form only after a rain, when water sweeps along a dry river bed in a torrent (violent stream) then quickly sinks into

A herd of wild horses run in the Mongolian desert. IMAGE COPYRIGHT PICHUGIN DMITRY, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

the ground or evaporates. Moisture sometimes remains under the surface, and plants can be seen growing along the path of streams.

Permanent rivers are found in desert regions. The Colorado River is one example. Over a million years ago, the Colorado River began cutting a path into the plateau of limestone and sandstone rock in northern Arizona, ultimately forming the Grand Canyon, which is 1.2 miles (1.9 kilometers) deep and 277 miles (446 kilometers) long. Perhaps the most famous desert river is the Nile, which bisects Egypt. Since ancient times, Nile floods have brought enough rich soil from countries farther south to turn Egypt's river valley into fertile country well known for its agricultural products, such as cotton.

Permanent lakes rarely occur in desert regions. Two exceptions are the Great Salt Lake of Utah, which is all that remains of what once was a great inland sea, and the Dead Sea of Israel and Jordan. The Dead Sea is actually a salt lake that was once part of the Mediterranean.

Plant Life

One of the most important characteristics of any biome is its plant life. Not only do plants provide food and shelter for animals, they recycle gases in the atmosphere and add beauty and color to the landscape. Deserts support many types of plants, although not in large numbers.

Algae, fungi, and lichens Algae (AL-jee), fungi (FUHN-ji), and lichens (LY-kens) do not fit neatly into either the plant or animal categories.

Algae Most algae are single-celled organisms; a few are multicellular. Like plants, nearly all algae have the ability to make their own food by means of photosynthesis (foh-toh-SIHN-thuh-sihs). Photosynthesis is the process by which plants use the energy from sunlight to change water and carbon dioxide into the sugars and starches they use for food. Other algae absorb nutrients from their surroundings. Although most algae are water plants, the bacteria known as blue-green algae do appear in the desert. They survive as spores during the long dry periods and return to life as soon as it rains. (Spores are single cells that have the ability to grow into a new organism.)

Fungi Fungi are commonly found in desert regions wherever other living organisms are found. Fungi cannot make their own food by means of photosynthesis. Some species, like molds and mushrooms, obtain nutrients from dead or decaying organic matter. They assist in the decomposition (breaking down) of this matter, releasing nutrients needed by other desert plants. Fungi that attach themselves to living plants are parasites. Parasites can be found wherever green plants live, and may weaken the host plant so that it eventually dies. Other parasitic fungi actually help their host absorb nutrients more effectively from the soil. All fungi reproduce by means of spores.

Lichens Lichens are actually combinations of algae and fungi living in cooperation. The fungi surround the algal cells. The algae obtain food for themselves and the fungi by means of photosynthesis. It is not known if the fungi aid the algal organisms, but they may provide them with protection and moisture.

Lichens are among the longest living organisms. Some lichens in polar deserts are believed to have survived at least 4,000 years. Although lichens grow slowly, they are very hardy and can live in barren places under extreme conditions, such as on bare desert rock or arctic ice. Crusty types colored gray, green, or orange, often cover desert rocks and soil. During very dry periods, they remain dormant. When it rains, they grow and make food.

Green plants Most green plants need several basic things to grow: light, air, water, warmth, and nutrients. In the desert, light, air, and warmth are abundant, although water is always scarce. The nutrients—primarily nitrogen, phosphorus, and potassium—obtained from soil may be in short supply.

Earth's Balancing Act

Many scientists recognize the many links among all life forms living on our planet. One biologist, James Lovelock, has theorized that life itself is responsible for changes in the land, water, and air. For example, until about 2 billion years ago, there was almost no oxygen in the atmosphere. Then blue-green bacteria, also called blue-green algae, began using energy from the sun for photosynthesis (a food-making process), which produces oxygen as a by-product. After enough blue-green algae and later plants got to work, the atmosphere eventually became, and is still maintained at, 21 percent oxygen, which is ideal for animal life. Lovelock believes that living things somehow work together in this way, instinctively providing a comfortable environment for themselves and one another.

To test his theory, Lovelock has produced a computer model. (Computer models enable scientists to more quickly study processes that take very long periods of actual time to show a result.) Suppose, for example, there are two species of flowers, one white and one dark blue. The white flowers reflect the sun's heat and can survive in warm climates. The dark blue flowers absorb heat and do better in cooler climates. According to Lovelock's model, the flowers help control the environment. The presence of blue flowers in a cool environment means heat is absorbed and the surrounding temperature is prevented from being too cool. The white flowers, on the other hand, reflect the heat and help keep a warm environment from being too warm.

Desert plants must protect against water loss and wilting, which can damage their cells. Large plants require strong fibers or thick, woody cell walls to hold them upright. Even smaller plants have a great number of these cells, which makes them fibrous and tough. Their leaves tend to be small and thick, with fewer surfaces exposed to the air. Outer leaf surfaces are often waxy to prevent water loss. Pores in the surface of green leaves allow the plant to take in carbon dioxide and release oxygen. The leaves of some desert plants may have grooves to protect their pores against the movement of hot, dry air. Other leaves curl up or develop a thick covering of tiny hairs for protection. Still others have adjusted to the dry environment by adapting the shape of their leaves. For, example cactus leaves are actually spines (needles). These spines have less surface area from which water can evaporate. As a result, more water is stored within the plant.

Common desert plants Several species of plants grow in the desert, including cacti, shrubs, trees, palms, and annuals.

Cacti Cactus plants originated in southern North America, Central America, and northern South America. Instead of leaves, a cactus has spines, which come in many forms from long, sharp spikes to soft hairs.

A Prickly Compass

The stems of the barrel cactus of the southwestern United States grow in a curve. The curve always points south because the cactus grows faster on its northern side, which is in the shade.

Photosynthesis takes place in the stems and trunk of the plant. Nectar, a sweet liquid that appeals to insects, birds, and bats, is produced in the often spectacular flowers.

One of the largest plants in the desert is the giant saguaro (sah-GWAH-roh) cactus. Its large central trunk can grow as tall as 65 feet (20 meters) and have a diameter of 2 feet (60 centimeters). Ninety percent of its weight is water, which it stores in its soft, spongy interior. During very dry conditions, as the plant uses up this stored water, the trunk shrinks in size.

Like many desert plants, the saguaro has a wide, shallow root system designed to cover a large area. After a long dry period, its roots can take up as much as 1 ton (1 metric ton) of water in 24 hours. The trunk expands as it absorbs and stores the new supply.

Pores run in deep grooves along the saguaro's stems. These pores open during the cooler nighttime hours to take in carbon dioxide and release oxygen. For protection from wind and animals, long, sharp spines run along the grooves. These spines reduce air movement, which conserves water and keeps grazing animals away.

Birds and bats love the nectar produced in saguaro flowers, and bats help to pollinate the saguaro. A bat's head fits the shape of the flowers almost perfectly. As the bat drinks the nectar, its head gets heavily dusted with pollen grains, which it then carries to the next plant.

Woody shrubs and trees Small, woody perennials that flourish in the desert climate include sagebrush, salt-brush, creosote, and mesquite (meh-SKEET). They have small leaves and wide-ranging root systems. Most shrubs have spines or thorns to protect them against grazing animals.

The mesquite is a tree with roots that may grow 80 feet (24 meters) deep, with most of the root system in the upper 3 feet (1 meter). The long roots find a constant supply of water and it remains green all year. The mesquite produces long seedpods with hard, waterproof coverings. When the pods are eaten by desert animals, the partially digested seeds pass out of the animal's body and begin to grow.

Joshua trees, a form of yucca plant, live for hundreds of years in the Mojave Desert of California. They can grow to 35 feet (11 meters) tall. Yuccas and treelike aloes store water in their leaves, not their stems. One

Several species of cactus including agave, candelabra, and cardon thrive in the desert climate. IMAGE COPYRIGHT DAVID M. SCHRADER, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

type of aloe, the kokerboom tree of southwest Africa, can survive several years without rain.

Palms Date palms, found at many oases in the Sahara and Arabian Deserts, can grow in soil with a high salt content. Only female trees produce dates, and only a few male trees are necessary for cross-pollination. The dates can be eaten raw, dried, or cooked and are an important food source for desert dwellers.

The Washingtonian fan palm is the largest palm in North America. Native to California, it requires a dependable supply of water to survive and sends out a thick web of tiny roots at its base. When its fronds (branches) die, they droop down around the trunk and form a "skirt,"

A Joshua tree is a type of yucca plant. IMAGE COPYRIGHT TERRY REIMINK, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

where animals like to live. The fan palm produces a datelike fruit that is eaten by many desert inhabitants.

Annuals Long grasses, such as alpha or esparto grass, often flourish in the desert after seasonal rains. Their stems can be used to make ropes, baskets, mats, and paper. Tufts of grasses sometimes become so entwined they form balls that drop their seeds as they spin across the landscape in the wind.

Almost every desert has its share of blooming annuals that add masses of color after a rain. Primroses and daisies adorn the California desert, while daisies, blue bindweed, dandelions, and red vetch beautify the Sahara.

Growing season The growing season in deserts is limited to the brief periods of rain that, in some cases, do not occur for several years. In some coastal deserts, certain plants absorb mist from the nearby ocean through their leaves. Where the soil is rich and rain is more regular and dependable, desert plants may flourish.

In cold deserts where real winters occur, plants are much like those in temperate climates. The portion above ground dies off, but the root system goes deep and is protected from freezing by layers of snow.

Deserts are home to both annuals and perennials. Annuals live only one year or one season, and they require at least a brief rainy period that occurs regularly. Their seeds seem to sprout and grow overnight into a sea of colorful, blossoming plants. This period of rapid growth may last only a few weeks. When the rains disappear, the plants die and the species

These palm trees are bearing hundreds of ripening dates. IMAGE COPYRIGHT ALBERT H. TEICH, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

withdraws into seed form, remaining dormant (inactive) until the next period of rain.

Unlike annuals, perennials live at least two years or two growing seasons, appearing to die in-between but reviving when conditions improve. Those that live many years must be strong and have several survival methods. As young plants, they devote most of their energy to developing a large root system to collect any available moisture. Plants are often many yards apart, because their roots require a large area of ground in order to find enough water. The above-ground portion of young perennials is small in comparison to the root system because their leaves do not have to compete for sunlight or air as they do for water. Some perennials are succulents (SUHK-yoo-lents), which are able to store water during long dry periods. Some, like the century plant, store water in their leaves, while others store it in their stems or in large roots.

Water supply Except for occasional rivers and oases, water in the desert comes from the brief rains. Plants may grow in greater numbers in arroyos or wadis where moisture may remain beneath the surface. In coastal deserts, some plants absorb moisture from fog and mists that condense on their leaves. In cold deserts, spring thaws provide water from melting snow.

Reproduction Pollination (the transfer of pollen from the male reproductive organs to the female reproductive organs of plants) is often a problem in deserts. The wind may carry pollen from one plant to another, but this

Termite mounds can get surprisingly tall, 6 to 9 feet (2 to 3 meters) is very common. IMAGE COPYRIGHT COLIN & LINDA MCKIE, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

method is not efficient because plants usually grow far apart. Insect pollination is rare because there are fewer insects than in other biomes. As a result, many plants have both male and female reproductive organs and pollinate themselves.

Endangered species Many desert plants, such as the candy cactus, saguaro cactus, and the silver dollar cactus, are threatened because of their popularity as house plants and for landscaping. They are available for sale in nurseries, but some people take them from the wild. Desert plants are sparse to begin with, so removal from their native home upsets the delicate balance of their reproduction.

Animal Life

All animals face the same problems in adapting to the desert. They must find shelter from daytime heat and nighttime cold, as well as food and water, which are often scarce. In spite of these extreme conditions, many animal species are represented in the desert environment, even some typically associated with temperate or wet surroundings.

Invertebrates Animals lacking backbones are called invertebrates. They include simple desert animals such as worms, and more complex animals such as the locust. Certain groups of invertebrates must spend part of their lives in water. These types are usually not found in deserts. One exception is the brine shrimp, an ancient species that lives in desert salt lakes. Other exceptions are certain species of worms, leeches, midges, and flies that live in the fresh water of oases and waterholes.

Most invertebrates are better adapted to desert life than vertebrates. Many have an exoskeleton (an external skeleton, or hard shell, made from a chemical substance called chitin [KY-tin]). Chitin is like armor and is usually waterproof. It protects against the heat of the desert sun, preventing its owner from drying out.

Common desert invertebrates Termites, spiders, locusts and scorpions are all invertebrates found in the desert.

Termites Termites, found all over the world, build the skyscrapers of the desert. Their mounds, often more than 6 feet (2 meters) tall, are erected over a vast underground system of tunnels. These tunnels go as deep as the groundwater, providing a water supply readily available to the termite colony. The mounds, which are made of dirt, decaying plants, and termite secretions that dry rock-hard in the sun, have many air ducts. As the sun warms the mounds, they grow very hot. The hot air inside the mounds rises, drawing cooler air through the tunnels, creating a type of air-conditioning system.

Termites eat plant foods, especially the cellulose (substance making up a plant's cell walls) found in woody plants.

Termites have an elaborate social structure. A single female—the queen—lays all the eggs and is tended to by workers. Soldier termites, equipped with huge jaws, guard the entrances to the mound. Soldiers cannot feed themselves, and the workers must tend to them, as well.

Living Juice Boxes

Honeypot ants, which live in Africa, Australia, and the Americas, take the business of food very seriously. They maintain herds of aphids, insects that suck the juices of plants and then secrete a sugar-rich "honey." Worker ants collect this honey and bring it back to the nest, where they feed it to a second group of workers. This second group takes in so much aphid honey that their stomachs swell and it is difficult for them to move. They then suspend themselves from the ceiling of the nest and wait. Later, when food becomes scarce, they spit the honey back up for other ants to eat. Some desert peoples like eating honeypot ants and seek out their nests.

Locusts Locusts are found in the deserts of northern Africa, the Middle East, India, and Pakistan. As members of the grasshopper family, they have wings and can fly, as well as leap, considerable distances. For years they live quietly, nibbling on plants and producing a modest number of young. Then, for reasons not completely understood, their numbers increase dramatically. Great armies of locusts suddenly emerge, hopping or flying through the desert in search of food. Eating every plant in sight, these swarms may travel thousands of miles before their feeding frenzy ends. In a short time, the hordes die off and locust life returns to normal. The devastated landscape they leave behind may take years to recover. The most destructive species, the desert locust, lives wherever the average rainfall is less than 8 inches (20 centimeters). A swarm may contain as many as 40 million to 80 million insects.

Food and water Many invertebrates are winged and can fly considerable distances in search of food. They eat plant foods or decaying animal matter. Some invertebrates are parasites, like the Guinea worm, that lurk at waterholes waiting for an unsuspecting animal to wander by.

Parasites attach themselves to the animal's body or are swallowed and invade the animal from the inside.

Arachnids (spiders and scorpions), which are carnivores (meat eaters), seem well suited to desert life. They prey on insects and, if they are large enough, small lizards, mice, and birds. Scorpions use their pinchers to catch prey, then inject it with venom (poison) from the stinger in their tails. Their venom can be lethal, even for large animals and humans. Arachnids do not usually drink water but get what they need from their prey.

Shelter Most desert spiders live on the ground rather than on webs, hiding in holes or under stones to escape the heat. The large, hairy camel spiders are nocturnal, which means they rest during the daytime hours and hunt at night.

Scorpions hunt at night to avoid the heat of the day, taking shelter beneath rocks or burying themselves in sand or loose gravel. Several American and Australian species dig burrows more than 3 feet (1 meter) below the surface.

Reproduction Some invertebrates, such as the scorpion, go through a mating ritual. Male and female scorpions appear to dance with their pinchers clasped together, as they do a two-step back and forth. After mating, the males hurry away to avoid being killed and eaten by the female.

Insects, the largest group of invertebrates, have a four-part life cycle that increases their ability to survive in an unfavorable environment. The first stage of this cycle is the egg. The egg's shell is usually tough and resistant to long dry spells. After a rain and during a period of plant growth, the egg hatches. The second stage is the larva, which may be divided into several stages between which there is a shedding of the outer covering, or skin, as the larva increases in size. Larvae have it the easiest of all in the desert, often being able to spend a portion of their life cycle below ground where it is cooler and more moist than on the surface. Some larvae store fat in their bodies and do not have to seek food. The third stage of development is the pupal stage. During this stage, the animal often lives inside a casing, in a resting state, which may offer as much protection as an egg. Finally, the adult emerges.

Amphibians Amphibians are vertebrates (animals with backbones) that usually spend part, if not most, of their lives in water. Unlikely as it seems, such animals can be found in a desert. Frogs and toads manage to survive in significant numbers in desert environments.

The short, active portion of their lives occurs during and immediately after the seasonal rains, when pools of water form. Mating, egg-laying, and young adulthood all take place in these pools. Offspring that survive into maturity leave the pools and take their chances on the desert floor, where they spend a few weeks feeding on both plants and insects. They must find shade or risk dying in the heat of the sun.

Avoiding Hot Sand

Several species of lizards have evolved methods for traveling over hot sand without burning their toes. The agamid lizard has long legs and keeps one foot raised and swinging in the breeze to cool it off while the other three support the animal. It does this in rotation, so that all its feet get an equal chance to cool off.

Common amphibians Frogs may spend up to ten months out of the year in their burrows, which are usually 3 feet (1 meter) under the desert floor. The Australian water frog can wait up to seven years for rain in a burrow made of its own shed skin. The Sonoran Desert toad is poisonous to predators and the largest toad in Arizona.

Food Frogs and toads feed on algae, plants, and freshwater crustaceans such as tiny shrimps that manage to survive in egg or spore form until brought to life by the rains. Frogs that eat the meat of crustaceans while they are tadpoles often become cannibals as they mature, eating their smaller, algae-eating brothers and sisters. If the rainy season is short, the cannibals have a better chance of survival because they have more food choices. If the rainy season lingers, the smaller tadpoles have a better chance because the cannibals cannot see their prey as well in muddy waters churned up by the rains, and the plant-eaters receive an increased supply of algae.

Shelter During the hottest, driest seasons, amphibians go through estivation (ess-tih-VAY-shun), an inactive period. While the soil is still moist from the rain, they dig themselves a foot or more into the ground. Only their nostrils remain open to the surface. Normally, their skin is moist and soft and helps them absorb oxygen. During estivation the skin hardens and forms a watertight casing. All the animal's bodily processes slow down to a minimum, and it remains in this state until the next rainfall, when it emerges. When water is scarce, Australian Aborigines (native peoples) dig up estivating frogs or toads and squeeze the animal's moisture into their mouths.

Reproduction Mating and egg-laying for amphibians takes place in water; the male's sperm is deposited in the water on top of the female's jellylike eggs. As the young develop into larvae and young adults, they often have gills and require a watery habitat. If there is not enough rain for pools of water to form, amphibian populations may not survive.

HOW TEMPERATURES GROW COOLER UNDERGROUND	
Burrowing animals escape the heat by going underground, where it can be up to twice as cool as above ground.	
Surface land temperature	165°F (74°C)
1 foot (31 centimeters) down	105°F (41°C)
2 feet (61 centimeters) down	95°F (36°C)
3 feet (91 centimeters) down	85°F (29°C)
4 feet (122 centimeters) down	83°F (28°C)

Reptiles Of all the animals, reptiles are perhaps most suited to living in the desert. Snakes, lizards, and some species of tortoises are the most common. The scaly, hard skin of reptiles prevents water loss, and their urine is almost solid, so no water is wasted.

Reptiles are cold-blooded, which means their body temperature changes with the temperature of the surrounding air. Early in the day, they expose as much of their bodies as possible to the sun for warmth. As the temperature climbs, they expose less and less of their bodies. During the hottest period of the day, they find shade or a hole in which to wait for cooler temperatures. During the chilly nights they become sluggish, because they do not have to use energy keeping their body temperatures up as do warm-blooded mammals and birds.

Besides being cold-blooded, some species of lizards have specially developed clear membranes in their lower eyelids that cover the entire eye and protect it from losing moisture.

Snakes have no legs. They move using special muscles that flex their flat belly scales forward and backward. Ridges on their scales grip the ground and pull them along. Some rattlesnakes, like the sidewinders of North American deserts, manage to move diagonally by coiling into a kind of S-shape, and propel themselves by pushing with the outside back portion of each S-shaped curve.

Common desert reptiles Snakes are less common in deserts than lizards. Common desert snakes include the gopher snake, horned viper, Gaboon viper, rattlesnake, and cobra. The Egyptian cobra can grow up to 8 feet (2.5 meters) long and is found in Africa. The Western diamondback rattlesnake, the most dangerous American snake, can grow to 6.5 feet (2 meters).

Common lizards include the gecko, the skink, the bearded dragon, the iguanid lizard, and the monitor lizard. The only two species of venomous lizards, the Gila monster and the bearded lizard, are related to the monitor. They are found in the southwestern United States and western Mexico.

Food and water The diet of lizards varies, depending upon the species. Some have long tongues with sticky tips good for catching insects.

Many are carnivores that eat small mammals and birds. The water they need is usually obtained from the food they eat. Geckos can survive long periods without food by living on stored fat.

While most lizards hunt food during the day, the Gila monster, found in the southwestern United States, looks for reptile eggs and baby animals after dark. Making the most of its opportunities, the lizard stuffs itself. During periods when food is scarce, its body draws on extra nutrients stored as fat in its tail, which can double in size after a big meal.

A Living Funnel

Most lizards obtain water from the food they eat. The thorny devil, a small lizard from Australia, is an exception. During the cool nights, dew condenses in the creases and folds of its skin. Most of these folds lead toward the lizard's mouth, and the lizard is able to lap up the moisture.

All snakes are carnivores, and one decent-sized meal will last them days or weeks. In the desert, they use their eyes to hunt during the cool nights when their prey is most active. Snakes cannot close their eyes because they have no eyelids. A transparent covering protects their eyes from the dry air, dust, and sand. Snakes often hunt underground and they have adapted to detecting ground vibrations. Many desert snakes bury themselves in the sand so that only their eyes and flickering tongues are visible. Some snakes kill their prey with venom (poison).

Although commonly thought of as jungle dwellers, boa constrictors and pythons (a species of constrictor) live in the desert. Constrictors strike their prey, hold it with a mouthful of tiny teeth, and then wrap their body around it like a coil. The prey suffocates and the constrictor swallows its meal whole, gradually working it into its stomach with its hinged lower jaw and strong throat muscles.

Shelter Lizards and snakes hide in the shade during the hottest hours of the day to escape the sun. Only a few make their own burrows. Most take over the abandoned burrows of other animals, find shelter in rock crevices, or bury themselves in the sand.

Desert tortoises obtain some shade from the sun with their thick outer shells. Most of the time they escape the heat of the day by retreating to burrows they dig. In the spring and autumn, when the days are not excessively warm, the tortoise ventures out during the day to forage for food. During the summer they forage for food at night when it is cooler, remaining in burrows during the day. In the winter, tortoises hibernate (become dormant) in a second burrow they have dug.

Reproduction The eggs of reptiles are leathery and tough and do not dry out easily. Some females remain with the eggs, but most bury

Secret Weapons

Rattlesnakes and other pit vipers have small pits on both sides of their face. These pits detect the body heat of prey, just like heat-seeking missiles. Pit vipers hunt at night, and their secret weapon allows them to find small animals hidden in the dark.

them in a hole. Offspring are seldom coddled and are left to hatch by themselves. Once free of the eggs, the offspring dig themselves out of the hole and begin life on their own.

Birds All deserts have bird populations. Tropical and subtropical deserts are visited twice each year by hundreds of species of migratory birds traveling from one seasonal breeding place to another. These migrators include small birds such as wheat-ears, as well as larger species such as storks and cranes. Some species know the route and where to find food or water. Others fly at night, when it is cool. Migrators are not true desert birds. They cannot survive for long periods in the desert as can birds for which the desert is home.

Birds have the highest body temperature of any animal—around 104°F (40°C). They do not need to lose body heat until the desert temperature is greater than their own. This makes desert life easier for them than for mammals, which must lose heat regularly during the warmest months, usually by panting or sweating.

Feathers protect birds not only from the cold in winter but from the sun and heat. Air trapped between layers of feathers acts as insulation. Birds do

This spitting cobra is ready to attack defending itself near its home in the Kalahari Desert. IMAGE COPYRIGHT LUCIAN COMAN, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

not sweat but, by flexing certain muscles, can make their feathers stand erect. This allows them to direct cooling breezes to their skin. Those having broad wing spans, such as eagles and buzzards, can soar at high altitudes and find cooler temperatures.

Common desert birds Common desert birds include ground birds and birds of prey.

Ground birds Ground birds are not hunters or scavengers (animals that eat decaying matter) but obtain most of their food from plants and insects. They have strong legs that enable them to dart around on the ground without tiring.

In Asia, Africa, Australia, and the Arabian Peninsula, families of thrushes, called chats, are common. Varieties of chats live at many different altitudes, including those over 13,000 feet (4,000 meters). They are found in both arid and semiarid regions, and their diets and habits vary according to their location.

Wrens are common in desert habitats all over the world. They eat insects, and species in North American deserts eat seeds and soft fruits. Cactus wrens, as their name implies, live among prickly desert plants where they build their nests among the spines.

A small desert bird that is a popular pet is the parakeet. Originally from Australia, parakeets live in huge flocks containing tens of thousands of birds. During years when food is plentiful, a flock may number in the millions. Parakeets prefer seeds and are nomads, often traveling from habitat to habitat in search of the seeds of annuals that bloom after a rainfall.

The largest ground birds found in deserts are members of the bustard family. The houbara bustard is found in the Sahara and the deserts of central Asia. It is about 2 feet (60 centimeters) tall and weighs as much as 7 pounds (3 kilograms). Houbaras depend primarily upon plants for food, but will eat invertebrates and small lizards. Houbaras can run fast—up to 25 miles (40 kilometers) per hour—and seldom fly. Other birds include the pale crag martin and the swallow.

Birds of prey Birds of prey are hunters and meat eaters. They soar high in the air on the lookout for small animals to eat. Their eyesight and

The Flying Sponge

The sandgrouse, found in the deserts of Africa and Asia, is a water-drinking bird. Most members of this species live near waterholes, except during nesting periods, when they may be forced to remain in an area experiencing drought (extreme dryness). Male sandgrouse have evolved an unusual method of overcoming this problem. They fly to the nearest waterhole, perhaps 20 miles (35 kilometers) away, and turn themselves into sponges. They wade into the water and let their special belly feathers absorb the liquid—as much as twenty times their own weight. Then they fly back to the nest where the nestlings drink by squeezing the water out with their beaks.

The Eyes Have It

The eyes of all birds are large in relation to their body size. Some of the largest are the eyes of owls, which take up about one-third of the space in the skull. Owl eyes are specially adapted to see better at night. They have more rods, the cells that are most sensitive to low light levels, and fewer cones, the cells sensitive to bright light. An owl's eyes are pear shaped and face forward, which gives the owl a kind of binocular vision and superior judgment of distances. An owl's eyes cannot turn in their sockets because of their size and shape. To look around, the owl must swivel its entire head.

hearing are usually very sensitive and enable them to see and hear creatures scurrying on the ground far below.

The roadrunner, found in the southwestern United States, can scurry over the desert floor for long stretches at speeds of about 13 miles (20 kilometers) per hour. Roadrunners are carnivores and are known to come running at the sound of a creature in trouble.

Several species of falcons live in semiarid regions; one of the true desert falcons is the prairie falcon of North America. Prairie falcons hunt for other birds such as larks and quail, and small mammals such as rabbits and prairie dogs. When food is scarce, they eat insects and reptiles. A falcon attacks its prey by diving at the head and trying to seize the head in its talons. Prairie falcons do not build their own nests. Instead, they move into the abandoned nests of other birds or use a hollow in a rock.

Owls live on the edges of deserts. The eagle owl is the largest, measuring 27 inches (68 centimeters) in length with a wingspan of over 6.5 feet (2 meters). They have the power to attack small deer. The smallest owl, the elf owl, hunts invertebrates, mainly insects. This owl is about 5 to 6 inches (12 to 15 centimeters) long and weighs 1.25 to 1.75 ounces (35 to 55 grams). Most owls hunt in the evening or at night when their extraordinary eyes and superior hearing allow them to find their prey.

The bird most often pictured in the desert is the vulture, waiting patiently while a creature dies of thirst. Most vultures are not really desert birds, although they do spend much time hunting in desert regions. They soar high in the air, circling and looking for carrion (dead animals), which their excellent eyesight allows them to easily see. When one bird spots a potential food source it begins to descend, and the other vultures follow.

Food and water Birds are found in greater variety and numbers around oases and waterholes where there is an ample supply of water, seeds, and insects. Some, like the Australian scarlet robin, often drink water. Birds that live in the desert itself are able to fly long distances in search of food or water. Some birds become nomads, following the rains from habitat to habitat. Birds usually require less than 10 percent of the amount of water needed by mammals. For this reason, many birds, like shrikes and some wheatears, can obtain enough moisture from the seeds, plants, and insects that they eat and do not need an additional water source. The same is true of vultures and birds of prey, which obtain water from the flesh of animals. Birds have kidneys that are very efficient in their ability to extract water, and their urine is not liquid but jellylike.

Commensalism

Sometimes animals are involved in relationships in which one animal is helped and the other is not affected. This is called commensalism. One example is a desert snake that takes over the abandoned burrow of a prairie dog.

Shelter During the hottest part of the day, most desert birds rest by roosting in the shade or in underground burrows. During excessively hot or dry periods, birds fly to more comfortable regions. It has been estimated that one-third of Australian birds are constantly on the move to escape the heat.

Many desert birds build nests in rock crevices, in abandoned burrows, or on the ground in the open because there are few trees in the desert. Those that build on the ground may put walls of pebbles around the nest that act as insulation and reduce the force of the wind.

Reproduction Except in Australia, desert birds appear to breed as other birds do—according to the seasons. In Australia, they adapt their breeding habits to periods of rainfall, and breeding cycles may be years apart.

Birds are free to fly away from the heat most of the year, but during the breeding cycle they must remain in the same spot from the time nest building begins until the young birds can fly. This is usually a period of many weeks.

Normally, the parents sit on the nest to protect the eggs from heat or cold. During very hot weather, the parents may stand over the nest to give the eggs or the nestlings shade.

Mammals Many mammals live in the desert. More than 70 species live in North American deserts alone. Among all of these species, only monkeys and apes are rarely seen.

Mammals must prevent the loss of moisture from their bodies in the desert. The urine and feces of many desert mammals are concentrated, containing only a small amount of water. Small desert mammals, such as rodents, do not sweat. They manage to lose enough heat through their skin. During the hottest times, they burrow underground. Some estivate in summer months.

No Need for Sunscreen

The naked mole rat, sometimes called the sand puppy, is an animal that seems poorly designed for desert life. It has no fur, just its wrinkly skin for protection, and it is almost blind. To make matters worse, unlike most mammals, it cannot maintain a steady body temperature. Its name gives a clue as to how it survives in the Sahara Desert; it burrows. Naked mole rats are tunneling experts, and a clan of rats will create an entire apartment complex of nurseries, storage chambers, and bedrooms. They dig so fast with their sharp buck teeth most predators cannot catch them and get just a face full of dirt for their trouble. The clan leader is always a female. She is the only one who breeds. Other females do not mature sexually until the queen dies or they decide to leave the den to create their own clan elsewhere.

Medium-sized mammals, such as rabbits and hares, do not burrow or estivate; but they will use another animal's burrow to escape from immediate danger. They have no sweat glands and cannot keep cool by sweating, although some heat escapes from their large ears. Hares and rabbits stay in whatever shade they can find during the hottest time of day. The quokka, a rabbitlike marsupial (a mammal that carries new offspring in a pouch) from Australia, copes with the heat by producing large amounts of saliva and licking itself. It is not known how the quokka makes up for this water loss.

Larger grazing animals, such as gazelles, can sweat, which helps them tolerate the heat. Some carnivores, such as coyotes, release body heat by panting (breathing rapidly through their mouths). This results in lost moisture. True desert dwellers, like the mongoose, the meerkat, and the hyena, avoid the midday heat by retiring to underground dens.

The Desert fox is one of the mammal residents of the desert. IMAGE COPYRIGHT MICHAEL SCHOFIELD, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Common desert mammals Other mammals commonly found in deserts include the kangaroo, the camel, and the hyena.

Kangaroos A well-known grazing animal of Australia is the red kangaroo. The kangaroo will hop long distances in search of food. Water is less of a problem as they get much of the moisture they need from grasses. They have efficient kidneys and produce a concentrated urine.

The kangaroo's strong legs allow them to move as fast as 20 miles (30 kilometers) an hour. Each hop can carry them as far as 25 feet (8 meters). Kangaroos are marsupials, which means that females carry their young, called a joey, in a pouch on their abdomen. Females with young in their pouches are seldom able to travel fast. If the female is in danger and the joey is too heavy, the mother will dump the young out in order to escape. This may seem cruel, but if she is caught the joey will die anyway. If she escapes, she will breed again.

Camels Camels are the mammals most people associate with the desert. The Bactrian camel has two humps and lives in the deserts of central Asia. The one-humped Arabian camel, called a dromedary, lives in the Arabian and Sahara Deserts. Camels are well adapted for desert life. They can travel almost 100 miles (160 kilometers) a day, for as long as four days, without drinking. When they do drink, they can take in more than 20 gallons (100 liters) in just a few minutes.

At one time it was believed that camels stored water in their humps. This is not true. The hump contains fat, which is used up during long journeys and may shrink in lean times. Camels have strong teeth and the membranes that line the insides of their mouths are tough, allowing them to eat almost anything that grows in the desert, even the thorniest plants. They can drink bitter, salty water that other animals cannot tolerate.

Camels have thick fur that molts (falls out) during the hottest seasons and is replaced by new, thinner hair. Camels can sweat to reduce body temperature, but their body temperature is not constant and varies depending upon surrounding air temperatures. Their eyes have long protective lashes, and their nostrils can be closed to keep out blowing sand. Their padded, two-toed feet are well insulated against the hot desert floor.

The Rabbit Plague

In the nineteenth century, English settlers introduced rabbits into the Australian Desert and grasslands. A few soon multiplied into half a billion strong. They ate everything growing in the pasturelands and then, when there was no more grass to supply moisture, the rabbits mobbed the water holes. Scientists got rid of vast numbers by introducing rabbit diseases in 1950. Some hardy animals survived and are still multiplying.

Packing it Away

Packrats are rodents that collect almost anything—seeds, bones, rocks—and store it away in their dens. Some of those dens need housecleaning so badly that, over the years, the stuff becomes glued together. Many generations of packrats often live in the same spot, and the piles can grow for thousands of years. The packrats' messy lifestyle may actually help scientists. When the burrows are studied, scientists can find out what an area looked like thousands of years ago.

Camels can no longer be considered wild animals. It is doubtful any wild groups still exist. They have been thoroughly domesticated (tamed) and are used by humans for transportation and other needs. Their ability to travel long distances and carry up to 600 pounds (270 kilograms) makes them useful.

Hyenas Hyenas are members of the dog family and have one of the strongest sets of jaws of any animal. They range over the deserts of Africa and Arabia, hunting in packs for antelope and other game, or stealing the meals of other carnivores. They also eat carrion and, occasionally, plant foods. Hyenas are not particularly fast, but they do not give up easily and may simply wear out their prey, which collapses beneath the snarling pack. Hyenas live as part of a clan in dens they dig themselves.

Food and water Some small mammals eat plant foods and insects; others, like the desert hedgehog, eat bird and reptile eggs and young. In Australia, a tiny mole no more than 8 inches (20 centimeters) long eats at least its own weight in insects and young lizards every day. Many small mammals do not need to drink water as often because they obtain moisture from the food they eat.

Large grazing animals need to drink and require a water source to replace the moisture lost in sweating. A few, such as the Arabian gazelle and the Nubian ibex, seldom drink water. They obtain what they need from the plants they eat. Grazing animals can travel to areas where rain has recently fallen. In temperate climates, most grazing animals live in large herds. The desert food supply will not support such numbers, and desert groups are usually very small.

Carnivores, such as mountain lions and coyotes, do not live in the deep desert but remain on the desert fringes where a supply of water is more readily found. Carnivores obtain much of their moisture requirements from the flesh of their prey, but they still need to drink.

Shelter Small mammals remain in burrows during the day. The air inside a burrow is up to five times more humid than the outside air. This helps the animal prevent moisture loss.

Medium-sized hares and rabbits do not live in burrows but seek shelter in the shade of plants or rocks and in shallow depressions. Grazing animals look for shade during the midday heat. Young animals may lie on the ground in the shade created by the adults.

Carnivores dig their own dens, which may consist of many tunnels to accommodate a family clan. The males mark their territories with scent, usually that of urine.

Reproduction Young mammals develop inside the mother's body where they are protected from heat, cold, and predators. The extra weight can make it difficult for the pregnant females themselves to escape danger. Female mammals produce milk to feed their young. In the desert this presents a problem in lost moisture. Those that live in dens must remain nearby until the young can survive on their own, making survival for both mother and young during drought conditions more difficult.

A wombat is a squirrel-like or rabbit-like mammal found in Australia. IMAGE COPYRIGHT TIMOTHY CRAIG LUBCKE, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Endangered species As in other biomes, many desert animal species are threatened.

The addax, a desert antelope with beautiful horns, has been greatly reduced in numbers by Saharan nomads who believe its stomach contents have healing powers. Its skin is valuable, for it is believed to have the power to ward off attacks from snakes and scorpions.

After World War II (1939–45), when dichlorodiphenyl-trichloroethane (DDT) and other dangerous pesticides were in common use, aplomado falcons shrank in number. These small falcons lived in desert areas of Mexico, Texas, and Arizona, but are no longer found north of Mexico. The poisons were used to kill grasshoppers that were devouring grasses and other vegetation. Grasshoppers are part of the falcons' diet, and as the birds ate the contaminated insects, the poison killed the falcons. The number of falcons will hopefully increase now that DDT is banned.

The California condor is one of the world's rarest birds. When early settlers slaughtered deer herds for food, they reduced the condor's food supply. Later, cattle ranchers set out poison baits to kill wolves and coyotes. The poison also killed the condors who ate the dead animals. California

The Web of Life: Natural Balance

Balance is important to every biome. Changes made by humans with even the best of intentions can create serious problems. During the nineteenth century, early settlers brought the American prickly pear cactus to Australia because they liked the plant's appearance. In America the prickly pear is a useful desert shrub, often serving as fencing for livestock. In Australia, where it had no natural enemies, it was a disaster. By 1925, prickly pear cacti covered more than 100,000 square miles (260,000 square kilometers) of the Queensland and Victoria provinces.

Nobody wanted the job of cutting down all those plants. Instead, a natural predator, a little moth that in caterpillar form loves to munch on prickly pears, was brought to Australia. Five years later, there were no more prickly pears.

condors are now protected. As a result of captive breeding in 2008 there were about 300 condors, with about half of those in captivity.

The beautiful spiral horns of the Arabian oryx are prized by hunters looking for trophies. By 1960 the Arabian oryxes were reduced to only about a dozen animals. In 1961 they became protected and several hundred were bred in zoos. After 1982 many of the zoo-bred animals were reintroduced into the wild.

Human Life

Human beings are able to adapt to many unfriendly environments. It is no surprise that they have learned to live in the desert and make it their home. Ten percent of the world's population lives on arid (dry) land; they include a large variety of native peoples of all races. This number is growing because most desert inhabitants live in developing countries with high rates of population growth.

Impact of the desert on human life Humans are able to maintain a safe body temperature in the desert by sweating. Under extreme heat, a human being may lose as much as 5 pints (3 liters) of moisture in an hour and up to 21 pints (12 liters) in a day. This water must be replaced or the person will die from dehydration. Dehydration occurs when tissues dry out, depleting the body of fluids that help keep it cool. Unlike the kidneys of many desert animals, human kidneys cannot concentrate urine to conserve water. The loss of salt through sweating is also a problem. Humans need a certain amount of salt to maintain energy production. If too much salt is lost, painful muscle cramps occur.

Humans can change very little physically to adapt to desert conditions, so they must change their behavior. This has been done in many ways, from the choice of lifestyle to the development of technologies such as irrigation (watering of crops).

Food and water Until the mid-1900s, many native desert dwellers were nomads—either hunter-gatherers, like the Bushmen of the Kalahari and Namib, or herders, like the Bedouin of the Middle East. They moved regularly, usually along an established route, in order to seek food and shelter for themselves or their herds of animals. Most nomads return year after year to the same areas within a given territory. They know when the rains usually come, where to find food or pastures, and where a water supply is located. By the late twentieth century less than 3 percent of desert peoples lived nomadic lives, having been driven from their lands by ranchers or mining companies looking for mineral, gas, and oil resources. Since 1950, many nomadic peoples have moved to cities where they often live in poverty.

Reverse Desertification

In some cases it might be possible to reverse desertification because nature fights back. Grasslands in Northern Uganda, Africa, had been lost when herds of cattle were allowed to overgraze the area. Then tsetse flies moved in and attacked the cattle. When the cattle herders moved to avoid the flies, the plants returned.

The diet of hunter-gatherers consists primarily of plant foods and game animals, although meat is usually scarce. Some, like the Aborigines of Australia, eat the grubs (larvae) of certain insects, which provide a source of protein.

Herding tribes depend primarily upon their animals for food, but they may also raise grains or trade for them. In the Sahara, dates from the date palm are an important food.

Many Native Americans found important uses for desert plants. The leatherplant, also called sangre de drago (blood of the dragon), contains a red juice used as a medicine for eye and gum diseases. Wine and jelly were made from the fruit of the saguaro cactus, the fruit of the prickly pear was made into jam, and ocotillo branches were useful as building materials.

Shelter The homes of hunter-gatherers tend to be camps, not houses. The Bushmen of the Kalahari, for example, make huts from tree branches and dry grass.

Traditionally, the nomadic tribes of the Sahara, whose shelters had to be portable, used tents made from the hides or hair of herd animals such as goats. The tents of the Bedouin are an example. Village houses in the desert are often made of mud bricks dried in the sun. The bricks do not need to be waterproof because there is so little rain.

In the desert country of Mongolia, desert dwellers commonly live in yurts—tentlike structures made from felt created from sheep's wool. The felt is stretched over a wood frame, and a hole at the top of the yurt allows smoke from cooking fires to escape.

Some Native Americans of the southwestern desert, such as the Hopi and Zuni tribes, built homes called pueblos from mud, wood, and stone.

The thick walls and small windows kept the interior cool. The Anasazi, who lived around 1100 AD, built their homes in the sides of cliffs. The homes were reached by ladders, which could be pulled up for defense. The Navajos made hogans—houses of logs and mud. Modern-day Native Americans live in the same kinds of homes as other Americans.

Clothing One advantage humans have over other animals is clothing, which is a substitute for fur. Unlike fur, clothing can be put on or taken off at will. Most traditional desert peoples wear layers of loose-fitting garments that protect the body from the heat. A naked person absorbs twice as much heat as a person in lightweight clothes. Loose clothing absorbs sweat and, as the air moves through, it produces a cooling effect. As a result, the person sweats less, conserving water. Many desert tribes, especially in the Middle East, have at least partially adopted western clothing styles.

The only desert peoples to go naked were the Bushmen of the Kalahari and the Aborigines of Australia. When nights were chilly they occasionally wore “blankets” made from bark, but more often their warmth came from a campfire. Those Bushmen and Aborigines who still live a traditional lifestyle continue to go without clothes.

Some kind of headgear is usually worn by people in the desert to shield their face from the sun and blowing sand. The Fulani, who live on the edge of the Sahara in West Africa, wear decorated hats made from plant fibers and leather.

Economy For traditional hunter-gatherers, possessions are almost meaningless. If they favor a particular stone for sitting on, they might carry it along. However, a stone, as well as other possessions, gets very heavy after a few miles. Their economy tends to be simple and little trading is done.

A century ago, desert herders were self-sufficient. Their wealth moved with them in the form of herd animals, jewelry, tents, and other possessions. Commerce usually involved selling goats, camels, or cattle. In the Middle East, the discovery of oil made important changes in the economy. In some cases, sweeping modernization made irrigation and food production more stable. Nomads settled in one spot and became farmers. In other cases, the wealth fell into the hands of a few people, while the large majority lived in poverty.

Impact of human life on the desert The fact that the desert is so unfriendly to human life has helped preserve it from those who could destroy its ecological balance.

The Hadzabe tribesmen in Tanzania are among the last hunter-gatherer peoples. IMAGE COPYRIGHT SEBASTIEN BUREL, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Use of plants and animals As long as traditional lifestyles remained in effect, the human impact on the desert was not severe. Desert dwellers understood the need to maintain balance between themselves and their environment. While animals and plants were used for food, they were not exploited (overused), and their numbers could recover. Since the introduction of firearms and the rapid growth of human populations, however, many plants and animals have become threatened.

Desertification, the deterioration of land until it becomes desertlike, continues in spite of efforts by conservationists (people who work to preserve the environment) to stop it. Several popular desert plants such as cacti, and animals such as lizards, are sold at high prices to collectors. Many of these species are threatened as a result.

Natural resources Overpopulation has diminished many natural resources. The digging of wells has caused the water table (the level of ground water) to drop in many desert regions. Supplies of oil and minerals are being removed from beneath the desert surface and cannot be replaced.

For thousands of years, crops have been grown in desert soil with the aid of irrigation (mechanical watering systems). Furrows were dug between rows of plants, and water pumped from wells was allowed to run along the furrows. In modern times, dams and machinery are used to control the rivers or pump groundwater for irrigation, allowing many

Xeriscaping

Green lawns and many popular trees and shrubs require constant watering in the summer. This puts a strain on water supplies. Some desert communities ask residents to forget the lawns and xeriscape instead. Xeriscaping is a kind of landscaping using desert plants that need less water.

former nomads to become settled farmers. To irrigate large cotton farms in the Kara Kum Desert of central Asia, water is brought from the Amu Darya River by means of a canal 500 miles (800 kilometers) long.

Irrigation must be controlled. If too much groundwater is pumped, it may be used up faster than it can be replaced. When the water table drops in regions near the ocean, the land may slump. Salt water may enter aquifers (underground layers of earth that collect water), destroying the fresh water. Another problem caused by irrigation is an accumulation of salt in the soil. All soils contain some salts and, if irrigation water is used without proper drainage, the salt builds up within the surface layers and prevents plant growth.

Quality of the environment People have impacted the desert environment in several ways. Drilling for oil and mining for other resources requires roads. The people who operate the drills need houses. Most of these changes have occurred along the Mediterranean in mineral-rich countries on the edges of the desert. However, the deep centers of deserts have usually not been disturbed. Roads remain tracks and have escaped being blacktopped.

The world's climate may be changing because of human activity. If so, the climate of the desert will change with unknown consequences to the plant and animal life.

Desert peoples The Bushmen and the Tuareg are two groups of desert peoples commonly found living in the desert.

Bushmen The Bushmen of the Kalahari and Namib Deserts of Africa live in clans consisting of several families. A clan's territory is about 400 square miles (1,036 square kilometers). Clans move according to the rains or the seasons, returning to familiar campgrounds year after year. Their territory includes good waterholes. Bushmen live off the land, eating berries, roots, and wild game. Plants, which make up the greatest share of their diet, are gathered by the women. Bushmen are expert trackers and use these skills to hunt game for food with bows and poisoned arrows. The meat is cut into strips and dried so that it will not spoil. Bushmen are not tall, ranging between 55 and 63 inches (140 and 160 centimeters) in height. This may be partially due to a diet deficient in some nutrients.

Overnight shelters built from grass and branches provide protection from the wind. In the winter, clans may break up into smaller groups and build stronger huts to keep out the rains. The Bushmen population numbers approximately 20,000. Probably fewer than half of those still live as hunter-gatherers.

Expert Trackers

The Bushmen and the Aborigines are excellent huntsmen and trackers. Bushmen can follow animal signs over the hardest ground and can distinguish the signs of one individual animal from those of another. During World War II (1939–45), when pilots whose planes had crashed were lost in the Australian deserts, Aborigines could find them by following footprints no one else could see.

The Tuareg The northern Tuareg of the Sahara depend upon the camel for their livelihood, grazing their animals on what little pasture exists on the desert fringes. Camels may be killed for meat or their milk used to make butter and cheese. They are also the primary means of transportation. Since the Tuareg are traders, camels are essential to carry goods such as cloth and dates.

The southern Tuareg tribes are more settled. As a result of modern technology that allows the digging of deep wells, the Tuareg have established cattle ranches on the edges of the Sahara. Unfortunately, the land is often overgrazed, and more territory is lost to the desert every year.

Tuareg men wear a characteristic blue veil wound into a turban (head covering) on their heads. Both men and women wear loose robes for protection against the sun. An indigo (blue) dye is used to color some clothing. The Tuareg have been known as the "blue men" because the dye often rubs off on the skin.

Homes are usually low tents made of animal hides dyed red. The tent roof is supported by poles and the sides are tied to the ground with ropes to keep out the wind and sand. During the hottest parts of the year, the Tuareg build a *zeriba,* a large, tall hut made from grasses attached to a wooden frame.

The Tuareg are known for their ability to fight. Before firearms were introduced during the eighteenth century, they made impressive weapons such as daggers and swords. They now prefer high-powered rifles. Historically, the Tuareg have had a tendency to raid other tribes, and wars between one tribe and another may last for years.

It is estimated that the Tuareg number as many as 1 million people. This figure is only approximate, since about 700,000 of the Tuareg are nomads and rarely remain in one place long enough for a reliable count to be made.

A Tuareg man draws water from a well, with help from his camel, to irrigate crops on his oasis plot. AP IMAGES.

The Food Web

The transfer of energy from organism to organism forms a series called a food chain. All the possible feeding relationships that exist in a biome make up its food web. In the desert, as elsewhere, the food web consists of producers, consumers, and decomposers. The following shows how these three types of organisms transfer energy to create the food web within the desert.

Green plants are the primary producers. They make organic materials from inorganic chemicals and outside sources of energy, primarily the sun. Desert annuals and hardy perennials, such as cacti and palms, turn energy into plant matter.

Animals are consumers. Plant-eating animals, such as locusts, gazelles, and rabbits, are primary consumers in the desert food web. Secondary consumers eat plant-eaters. They include the waterhole tadpoles that consume smaller, plant-eating family members. Tertiary consumers are meat-eating predators, like mongooses, owls, and coyotes. They will eat any prey small enough for them to kill. Humans, like the Bushmen, fall into this category. Humans are omnivores, which means they eat both plants and animals.

Decomposers feed on dead organic matter and include fungi and animals like the vulture. In moister environments, bacteria aid in decomposition, but they are less effective in the desert's dry climate.

Spotlight on Deserts

The Gobi Desert
Location: Mongolia and western China
Area: 500,000 square miles (1,300,000 square kilometers)
Classification: Cold; arid and semiarid

The Gobi Desert In the eastern part of central Asia, extending into Mongolia and western China, is the great Gobi Desert. It is part of a chain of deserts, including the Kara-Kum, the Kyzyl-Kum, the Takla Makan, the Alashan, and the Ordos. *Gobi* is a Mongolian word meaning "waterless place."

Surrounded by mountains—the Pamirs in the west, the Great Kingan in the east, the Altai, Khangai, and Yablonoi in the north, and the Nan

Hyenas and vultures are desert scavengers. IMAGE COPYRIGHT 7382489561, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Shan in the south—the Gobi is a high, barren, gravelly plain where few grasses grow. It is so flat that a person can see for miles in any direction.

Except for the polar deserts, the Gobi is the coldest because of its altitude—about 3,000 feet (900 meters) in the east and about 5,000 feet (1,500 meters) in the south and west. Arctic winds blow down from the north so that, in the winter, some areas become snow covered. Any rainfall occurs in the spring and fall. Temperatures average between 27°F (-3°C) in January to 86°F (30°C) in July.

Several rivers flow into the Gobi from the surrounding mountains, but the desert has no oases (waterholes). Dry river beds and signs of old lakes indicate that water once existed here. The only surface water that remains is alkaline (containing too many undesirable minerals). Fresh water is obtained primarily from wells.

The few trees found here are willow, elm, poplar, and birch. In general, the largest plants are the tamarisk bush and the saxoul. Grass, thorn, and scrub brush survive, and bush peas, saltbush, and camel sage are abundant. During the brief spring, annuals (plants that live only one season) flourish.

Few reptiles are present because they do not favor the cold winters, but several species of snakes live in the Gobi. Many birds, including sand grouse, bustards, eagles, hawks, and vultures, thrive here. Many of these are migrators (animals that have no permanent home). Small mammals include jerboas, hamsters, rats, and hedgehogs. Larger mammals include gazelles, sheep, and rare Mongolian wild horses.

The Mongolian people living in the Gobi include settled farmers, who cultivate grains on its fringes, and herders who prefer life on the windy plain. Herders tend to be nomads (wandering tribes) who raise horses, donkeys, camels, sheep, goats, cattle, and, in upland areas, yaks. The two groups often trade; the farmers provide grain and the herders supply meat. Since the 1940s, irrigation has been used to make cotton and wheat crops possible, and many nomadic peoples have settled on farms.

Famous Venetian explorer Marco Polo (1254–1324) reached the Gobi during his travels in the thirteenth century. Modern explorers, including archaeologists and anthropologists, still visit in search of dinosaur bones and eggs commonly found there. Such fossils are evidence that the Gobi was once a friendlier environment supporting diverse animal life.

The Thar Desert The Thar (TAHR) Desert (also called the Great Indian Desert) begins near the Arabian Sea and extends almost to the base of the Himalaya Mountains. It contains a variety of landforms and differing climates. It is considered an arid, lowland desert characterized by extreme temperature variations. January temperatures average 61°F (16°C), while June temperatures average 99°F (37°C).

The plain of the Thar slopes gently from more than 1,000 feet (305 meters) in the southeast to fewer than 300 feet (91 meters) in the northwest near the Indus River, broken only by areas of sand dunes—primarily seif (SAFE) dunes that run parallel to the wind. Some more or less permanent dunes may soar to heights of 200 feet (61 meters). Several salt lakes lie on the desert's margins. The salt covering the lake beds is mined and sold.

Rainfall is unreliable and drops to about 4 inches (100 millimeters) a year in the west. In the summer, the Thar benefits from seasonal monsoons (rainy periods) that arrive in July and August. During monsoon season, the largest salt lake may cover 90 square miles (35 square kilometers) and be 4 feet (1.22 meters) deep, only to disappear during the dry period.

Wheat and cotton have been grown on the irrigated Indus plain in the northeast since the 1930s, but most areas support only grass, scrub, jujube, and acacia, which are eaten by domesticated camels, cattle, goats, and sheep. Birds, such as the great bustard and quail, are found here. Wild

The Thar Desert
Location: India and Pakistan
Area: 77,000 square miles (200,000 square kilometers)
Classification: Cold; arid

mammals live in or on the fringes of the Thar, including hyenas, jackals, foxes, wild asses, and rabbits.

Nomads raise sheep, cattle, and camels. Villages are located in areas where grass will grow after a rain and support herds of livestock. Small industries are based on wool, camel hair, and leather.

About 5,000 years ago, the Indus Valley was home to the great Indus civilization. The decline and disappearance of this civilization is a mystery, but it may be partly due to climatic changes that caused the Thar to spread.

The Australian Desert About three-quarters of the Australian continent is desert or semiarid land, a mixture of stone, rock, sand, and clay. January temperatures average 79°F (26°C), and July temperatures average 53°F (12°C). The central region is a basin, the western area a high plateau. The Australian desert region is composed of six different deserts—the Simpson, the Great Victoria, the Sturt Stony, the Gibson, the Great Sandy, and the Tanami. They blend into one another and are part of the same whole.

The basin region is a flat land, where a visitor can gaze for miles without the view being interrupted by hills. This makes it a difficult place in which to navigate, for there are no landmarks. The terrain varies, changing from semiarid grassland to rocky stretches, to areas with sandy dunes. Strange, massive, solitary rock formations have spiritual meaning to the Aborigines, such as Ayers Rock or the Olgas.

The lowest point of the Australian Desert is near Lake Eyre, which lies 60 feet (18 meters) below sea level. The lake, situated close to sand dunes, is about 50 miles (80 kilometers) long and so salt-encrusted that during dry periods it appears white. It fills with water only once or twice during a ten-year period. When full, it supports abundant wildlife, including birds, frogs, and toads.

Mulga, a type of thorny acacia bush, and mallee, a species of eucalyptus, grow in the most arid regions of the Australian Desert. At the desert's edges, spinifex grass grows.

Australia is home to a number of animals found nowhere else in the world, but their ways of adapting to the desert are the same as animals elsewhere. Insects, such as locusts and termites; snakes, such as the bandy bandy and the brown snake; and lizards, such as the blue-tongued skink are commonly found in the Australian Desert. Birds include the emu, a large, flightless bird that resembles an ostrich, parrots, quail, cockatoos, and kookaburras.

The Australian Desert
Location: Australia
Area: 600,000 square miles (1,500,000 square kilometers)
Classification: Hot; arid and semiarid

Kangaroos are Australia's largest mammals. They prefer to live in grasslands but can travel long distances in the desert without water. Kangaroos are marsupials and carry their young in a pouch. Other marsupials unique to Australia are the wallaby and the wombat.

Until the middle of the twentieth century, most Aborigines of Australia still lived as hunter-gatherers. Traveling in small groups, or clans, they moved over an established territory. They gathered plant roots, bulbs, termites, and grubs; and hunted kangaroos and wallabies with spears and boomerangs. When young Aborigine men attained a certain age, they went on a "walkabout." During this time they had to leave their clan to wander in the desert, perhaps for years, learning about life and survival.

The Arabian Desert The Arabian Desert covers most of the Arabian Peninsula, from the coast of the Red Sea to the Persian Gulf. It measures 900,000 square miles (2,330,000 square kilometers). Except for fertile spots in the southeast and southwest, the peninsula is all desert. During prehistoric times, volcanic cones and craters formed along its western edge. On the eastern side, sedimentary rocks and prehistoric sea life formed the world's richest oilfields. Inside some of these same rocks are vast supplies of underground water, captured during ages past when the area included wetlands.

The desert plateau consists of bare rock, gravel, or sand having a characteristically golden color, with the exception of deep ravines in the south. Wind and occasional flooding has carved the rocks into fantastic shapes. The Empty Quarter—about one-third of the southern part of the peninsula—is a vast sea of sand dunes. Treacherous quicksand is found here, its particles so smooth they act like ballbearings, drawing unwary creatures below the surface to their deaths. Another area of dunes, the Great Nafud, is found farther north and contains so few waterholes even camels find it difficult to cross. Along the coasts, changing sea levels have resulted in large salt flats, some as much as 20 miles (30 kilometers) wide.

The Arabian Desert
Location: The Arabian Peninsula
Area: 900,000 square miles (2,300,000 square kilometers)
Classification: Hot; extremely arid

A monsoon season (rainy period) occurs along the southeast; rainfall elsewhere is only 1.4 inches (35 millimeters) per year. Flash floods are common during the infrequent rains, and hailstorms sometimes occur. Droughts may last several years. January temperatures average 65°F (18°C).

In the southern portion of the Arabian Desert annuals spread a colorful blanket over the soil right after a rain; otherwise hardy perennials are the most common plant life, including mimosas, acacias, and aloe. Oleanders and some species of roses also thrive. Few trees can survive. The tamarisk tree helps control drifting sand, and junipers grow in the southwest. Date palms grow almost everywhere except at high elevations, and coconut palms are found on the southern coast. Plants that can be cultivated with the aid of irrigation include alfalfa, wheat, barley, rice, cotton, and many fruits, including mangoes, melons, pomegranates, bananas, and grapes.

Swarms of locusts move over the land periodically, causing much destruction. Other common invertebrates include ticks, beetles, scorpions, and ants. Horned vipers and a special species of cobra make their home in the Arabian Desert, as do monitors and skinks. Ostriches are now extinct there, but eagles, vultures, and owls are common. Seabirds, such as pelicans, can be seen on the coasts. Wild mammals include the gazelle, oryx, ibex, hyena, wolf, jackal, fox, rabbit, and jerboa. The lion once lived there but has long been extinct in the area.

For centuries, the Arabian Desert has been home to nomadic tribes of Bedouin. The camel makes life in the desert possible for them. A camel's owner can live for months in the desert on the camel's milk. The camel is also used for meat, clothing, and muscle power, and its dung (solid waste) is burned for fuel. Domestic sheep and goats are raised, as well as donkeys and horses.

The Sahara Desert The Sahara Desert ranges across the upper third of Africa, from the Atlantic Ocean to the Red Sea, and is about 1,250 miles (2,000 kilometers) wide from north to south. It is the world's largest hot desert, covering an area of 3.5 million square miles (9 million square kilometers). Its landforms, which tend to have a golden color, range from rocky mountains and highlands (some as high as 10,712 feet [3,265 meters]) to stretches of gravel and vast sand dunes. Erosion has shaped the sandstone rocks in some areas into unusual shapes and deep, narrow canyons.

Millions of years ago, volcanic activity occurred here. The region was the site of shallow seas and lakes, which contributed to the vast reserves of oil deposits found there. Around 150 BC when the Romans controlled North Africa, the northern Sahara was a rich agricultural area. Over the centuries sand has claimed the once fertile landscape.

The Sahara is the hottest desert, with a mean annual temperature of 85°F (29°C). Nights are cool and occasionally fall below freezing in the winter months. Except along the southern fringe, rain is not dependable

The Sahara Desert
Location: North Africa
Area: 3,500,000 square miles (9,000,000 square kilometers)
Classification: Hot; extremely arid

and may be absent for as many as 10 years in succession. When it does rain, it tends to fall in sudden storms.

In some areas, such as the Tanezrouft region, nothing appears to grow. In other areas, annuals bloom after the unpredictable rains and provide food for camels and wild animals. At one time, the only perennial vegetation at oases were tamarisks and oleander bushes. The date palm has since been introduced and now citrus fruits, peaches, apricots, wheat, barley, and millet are all cultivated.

Animals such as gazelles, oryx, addax, foxes, badgers, and jackals live in the wild. Domesticated animals include camels, sheep, and goats.

Three main groups of people now live in the Sahara: the Tuareg, the Tibbu, and the Moors. Two-thirds of the population live at oases, where they depend upon irrigation and deep wells that tap underground water.

The Patagonian Desert Along the entire length of Argentina, between the Andes Mountains in the west and the Atlantic Ocean in the east, lies the Patagonian Desert, which is 300,000 square miles (777,000 square kilometers). It owes its existence to a cold ocean current and the Andes Mountains, both of which cause dry air to form. The terrain is a series of plateaus, some as high as 5,000 feet (900 meters) near the Andes, which slope toward the sea. Deep, wide valleys made by ancient rivers have created clifflike walls, but only a few streams remain. These are usually formed by melting snow from the Andes.

In some areas, the soil is alkaline or covered by salt deposits and does not support plant life. Elsewhere it is primarily gravel. Mineral resources, including coal, oil, and iron ore, have been found in several places but quantities are too small to be important.

Rainfall, which occurs in the summer, is usually less than 10 inches (25 centimeters) annually. Although arid, the Patagonian Desert does not experience extremes of temperature, primarily because it is so close to the ocean. Temperatures range from 45°F (7°C) to 78°F (26°C). During the colder months, subzero temperatures and snow are common. Mean annual temperatures range from 43° to 78°F (6° to 26°C). Winds of 70 miles (112 kilometers) per hour are not uncommon.

Plants, mostly saltbushes and other members of the amaranth family, cover 15 percent of the desert. In moister areas, cushion plants, shrubs, feather grass and meadow grass cover almost half the ground.

Many reptiles are found here, but small mammals are the most numerous animals. Rabbits and hares are widespread. The rhea, an

The Patagonian Desert
Location: Argentina
Area: 300,000 square miles (777,000 square kilometers)
Classification: Cold; arid

American ostrich, lives throughout the region. Other common animals are the mara and the guanaco, a llamalike animal prized for its long, fine hair. The guanaco was hunted almost to extinction because of the fine quality of its coat.

The most unusual animal of the Patagonian Desert is the armadillo. Its skin consists of plates of tough armor, including one that covers its face. It can travel very fast on its short legs and, when threatened, digs a hole to escape.

Patagonia means "big feet," and refers to the Tehuelche Indians when they were first seen by Portugese explorer Ferdinand Magellan (c. 1480–1521) in 1520. The Tehuelche were nomadic hunters whose size and vigor caused Europeans to consider them giants. After the Europeans introduced the Tehuelche to horses, their ability to seek new territory and intermarry with other tribes increased. By 1960, the race was virtually extinct. Modern settlements in and around the Patagonian Desert were established during the twentieth century after oil was discovered on the coast.

The Atacama Desert The Atacama Desert is a long, narrow, coastal desert 600 miles (965 kilometers) long, parallel to the coast of Chile. The Pacific Ocean lies to the west, where sheer cliffs about 1,475 feet (450 meters) high rise from the sea. Beyond these cliffs lies a barren valley that runs along the foothills of the Andes Mountains.

Cold ocean currents are responsible for the dry conditions that make the Atacama the world's driest desert. Droughts may persist for many years, and there is no dependable rainy season. Although it is classified as a hot desert, mean temperatures seldom exceed 68°F (20°C).

Much of the Atacama consists of salt flats over gravelly soil. Sand dunes have formed in a few areas. In the south, a raised plateau nearly 3,300 feet (1,006 meters) high and broken with volcanic cones takes on an otherworldly appearance. In the southeast, a plateau bordering the Andes reaches a height of 13,100 feet (4,000 meters).

The area is rich in boron, sodium nitrate, and other minerals, which contaminate any underground water, making it unusable both by plants and animals. Plant life consists primarily of coarse grasses, mesquite, and a few cacti.

Animal life is rare. The most commonly found animals are lizards, but even they are not numerous. The rather timid giant iguanas, some growing over 6 feet (2 meters) long and resembling dragons prowling, are

The Atacama Desert
Location: Chile and parts of Peru
Area: 54,000 square miles (140,000 square kilometers)
Classification: Hot; extremely arid

scavengers. Huge Andean condors that feed on carrion can be seen soaring overhead. Wherever cacti are found, cactus wrens feed and breed. Ovenbirds build their own little adobe (mud) huts instead of nests, and live in the less arid regions. The only mammals living in the Atacama are small rodents, such as the chinchilla, with guanaco and vicuña inhabiting higher elevations.

Indians may have lived in or on the fringes of the Atacama at one time; however, they may have been killed by European settlers during the eighteenth century. Those people who still live in the area are descendants of the European immigrants.

The Atacama was once important to the fertilizer industry for which sodium nitrate was mined. Another fertilizer, bird droppings called guano (GWAN-oh), was collected on the offshore islands, where seabirds would breed. In the 1920s synthetic fertilizers became popular, and the mining settlements in the Atacama were abandoned.

The Namib Desert A coastal desert, the Namib is part of the vast tableland (flat highland) of southern Africa. Although it borders the Kalahari Desert to the east, the two are very different. Some scientists do not consider the Kalahari a true desert, while the Namib certainly is one. The desert is dry, but not very hot, with temperatures between 66°–75°F (19°–24°C). It has been nick-named the world's oldest desert, dating back 55,000,000 years. The terrain is gravelly in the north, a rich area for gemstones, particularly diamonds. Sand prevails in the south, creating enormous dunes as much as 980 feet (300 meters) high in some areas.

Rain is rare and years may pass between showers. When rain does come, it creates flash floods and then disappears as quickly as it came. The winds that blow in from the Atlantic do not bring storms. Instead, dense fog rolls in almost nightly, creating very humid air.

Unusual life forms exist in the Namib, particularly in the southern dunes where plant life depends upon the fog and has evolved to draw moisture from it. The strange welwitschia plant is an example.

The Hartmann's zebra that lives in the Namib is able to sniff out small pools of water that may lie in gullies or dry stream beds. The zebras dig, sometimes 2 or 3 feet (0.6 or 1 meter), into the ground until the water is uncovered. The Namib is also inhabited by elephants, rhinos, giraffes, and lions.

Bushmen live principally in the Kalahari, but they occasionally frequent the Namib.

The Namib Desert
Location: Eastern Namibia
Area: 52,000 square miles (135,000 square kilometers)
Classification: Hot; arid

The Mojave Desert Deserts in North America are all part of the Great Basin, a vast territory stretching from just north of the Canadian border into parts of Mexico. In the north, cold semiarid deserts have formed, ringed by the Sierra Nevada and Rocky Mountains. Further south lie the hot deserts, the Mojave and the nearby Sonora Desert.

The Mojave Desert, named for the Mojave Indians who once lived along the Colorado River, consists of salt flats, barren mountains, deep ravines, high plateaus, and wide, windy plains of sand. Elevations range from 2,000 to 5,000 feet (600 to 1,500 meters), and it measures 25,000 square miles (65,000 square kilometers). During prehistoric times the Pacific Ocean covered the area until volcanic action built the mountain ranges, leaving saltpans and mudflats as the only remaining signs. The desert is rich in minerals. Borax, potash, salt, silver, and tungsten are mined here.

Annual rainfall is less than 5 inches (13 centimeters). Frost is common in the winter, and snow occasionally falls. One major river, the Mojave, crosses the desert, running underground for part of its length. Summer temperatures often rise above 100°F (38°C), and winter temperatures often drop below freezing.

Vegetation characteristic of North American deserts includes different species of cacti such as organ pipe, prickly pear, and saguaro. Although nothing grows on the salt flats, plants, such as the creosote bush, can find a foothold in other areas. Joshua trees are protected in the Joshua Tree National Park. On the highest mountains, piñon and juniper grow.

A wide variety of invertebrates, amphibians, reptiles, birds, and smaller mammals make a home in this region. The rare Mojave ground squirrel may spend nine months estivating (being dormant in hot weather) in its burrow. Larger mammals include the puma, jaguar, peccary, prong-horned antelope, and bighorn sheep.

Death Valley Death Valley is a basin in the Mojave Desert of which approximately 550 square miles (1,430 square kilometers) of the total 5,313 square miles (13,813 square kilometers) lie below sea level. Near its center is the lowest point in North America, 282 feet (86 meters) below sea level. Prehistoric salt flats exist in the lowest areas where nothing grows.

Death Valley is the hottest place on the continent. Average summer temperatures are 117°F (47°C) with a record temperature of 134°F (57°C) on July 10, 1913. Rainfall is seldom more than 2 inches (50 millimeters) per year. Many species of plants are found here. Annuals,

The Mojave Desert
Location: Southeastern California, Nevada, Arizona, Utah
Area: 25,000 square miles (65,000 square kilometers)
Classification: Hot; arid

Death Valley
Location: California
Area: 5,312 square miles (13,812 square kilometers)
Classification: Hot; arid

such as poppies, appear in late winter and early spring; perennials, such as cacti and mesquite, survive all year. Lizards, foxes, rats, mice, squirrels, coyotes, bighorn sheep, wild burros, and rabbits live here, as well as many birds, such as ravens.

The name Death Valley came from the numbers of gold-seekers who died there during the gold rush in the mid-1800s. Although gold, silver, lead, and copper have been mined in the area, Death Valley became known for borax (compound used as an antiseptic and cleanser), discovered in 1873 and brought out by mule teams. Mining ghost towns now draw tourists. Death Valley became a national monument in 1933 and a national park in 1994.

Walter Edward Scott (1872–1954), known as "Death Valley Scotty," was a cowboy in Buffalo Bill's Wild West Show. A mansion approximately 32,000 square feet (2,973 square meters) was built in 1927 by Albert Johnson, a wealthy Chicago executive, in the Grapevine Canyon of Death Valley. Johnson met Scott at one of his shows and the two become friends. Through their friendship, the ranch became known as Scotty's Castle, and is one of the most popular tourist attractions in Death Valley National Park.

The Antarctic Desert Polar deserts are like other deserts only in the dryness of the air. Here, all moisture is frozen. During the warmest season in the polar desert, temperatures never rise above 12.8°F (-3°C), with the mean temperature ranging from -30° to -4°F (-34° to -20°C). In the cold season, the mean temperature is -52.9°F (-47.2°C) and ranges between -94° and -40°F (-70° to -40°C).

Scientists know very little about the landforms in Antarctica because they are buried beneath such deep ice—over 14,000 feet (4,270 meters) deep in places. It is believed that the area is a series of islands connected by great ice sheets. Western Antarctica is mountainous, and eastern Antarctica is a plateau (high, flat land). It measures approximately 360,000 square miles (936,000 square kilometers). The Antarctic desert is the largest desert in the world, followed by the Sahara.

The Antarctic Desert
Location: Antarctica
Area: Approximately 360,000 square miles (936,000 square kilometers)
Classification: Polar

Tiny communities of microbes (microorganisms) have been found in the ice desert of Antarctica. During the summer, the sun warms little pockets of dirt and grit and turns them to slush. In the dim light, bacteria suspended in the slush can photosynthesize.

Plant growth is limited to the bordering tundra regions where lichens and mosses are the largest plant forms. Algae, yeasts, fungi, and bacteria are found in some areas. Grasses and a few other seed plants may grow on the fringes. The driest areas support no known plant life.

The only land animals are about 100 species of invertebrates, half of which appear to be parasites that live on birds and mammals. These include lice, mites, and ticks.

Seabirds, such as petrels and terns, frequent the coast where they feed on fish. The only true Antarctic bird is the penguin, and about eighteen species populate the area. Penguins live in large flocks and nest in the autumn, living on fish they catch in the coastal waters. They range in size from the fairy penguin, which is 16 inches (41 centimeters), to the emperor penguin, which is about 4 feet (1.2 meters) tall. Leopard seals, the largest of all seals, are 10 feet (3 meters) long and weigh 770 pounds (300 kilograms). They inhabit the Antarctic waters and are the natural predators of penguins.

Marine mammals, such as whales and seals, live in the coastal waters, but they do not enter desert areas. (Polar bears live only at the North Pole; they do not live in Antarctica.)

Temporary year-round human settlements were established in Antarctica around 1900, primarily for exploration purposes. Any industry is centered on the surrounding sea, primarily whaling and seal hunting.

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Chihuahuan Desert Research Institute, PO Box 905, Fort Davis, TX 79734, Phone: 432-364-2499; Fax: 432-364-2686, Internet: http://www.cdri.org

Desert Protective Council, Inc., PO Box 3635, San Diego, CA 92163, Phone: 619-342-5524, Internet: http://www.dpcinc.org/environ_issues.shtml

Environmental Defense Fund, 257 Park Ave. South, New York, NY 10010, Phone: 212-505-2100; Fax: 212-505-2375, Internet: http://www.edf.org

Environmental Protection Agency, 401 M Street, SW, Washington, DC 20460, Phone: 202-260-2090, Internet: http://www.epa.gov

Friends of the Earth, 1717 Massachusetts Ave. NW, 300, Washington, DC 20036-2002, Phone: 877-843-8687; Fax: 202-783-0444; Internet: http://www.foe.org

Greenpeace USA, 702 H Street NW, Washington, DC 20001, Phone: 202-462-1177; Fax: Internet: http://www.greenpeace.org

Sierra Club, 85 2nd Street, 2nd fl., San Francisco, CA 94105, Phone: 415-977-5500; Fax: 415-977-5799, Internet: http://www.sierraclub.org

World Wildlife Fund, 1250 24th Street NW, Washington, DC 20090-7180, Phone: 202-293-4800; Internet: http://www.wwf.org

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Grassland

A grassland is a biome in which the dominant plants are grasses rather than trees or tall shrubs. Often described as "seas of grass," grasslands cover about one fourth of Earth's surface. They are usually found in the interiors of every continent except Antarctica.

Although grasslands vary in climate and the type of plant and animal life they support, most have several things in common. They are covered with grasses, which may be of different heights and varieties. They are usually windy and dry for part of the year. They occur primarily on flat land or gently rolling hills, but a few are found on mountains where the environment is suitable. Grasslands are considered transition zones between deserts, which receive little rain, and forests, which get a lot of rain.

How Grasslands Develop

Grasslands develop as a result of changes in climate, changes in plant communities, and fires.

Climatic change Grasslands first appeared millions of years ago after mountains formed and caused climates to change. In North America, for example, the Rocky Mountains blocked moist air traveling across the continent from the Pacific Ocean, making the middle part of the continent drier. This caused trees to die and be replaced by grasses, which could adapt to the drier climate. The same process happened on other continents, allowing grasslands to form in places such as central Asia and South America. Grasslands throughout the world were fairly well established about 5 million years ago, covering more than 40 percent of Earth's surface.

Succession Grasslands also develop through a process called succession, a slow sequence of changes in a plant community. In dry areas, the growth of mosses and lichens (LY-kens) may be followed by the growth of leafy,

WORDS TO KNOW

Artificial grassland: A grassland created by humans.

Carnivore: A meat-eating plant or animal.

Estivation: An inactive period experienced by some animals during very hot months.

Herbivore: An animal that eats only plant matter.

Pampa: A tropical grassland found in South America.

Pantanal: A wet savanna that runs along the Upper Paraguay River in Brazil.

Puna: A high-altitude grassland in the Andes Montains of South America.

Scavenger: An animal that eats decaying matter.

Steppe: A temperate grassland found mostly in southeast Europe and Asia.

Veld: Temperate grassland in South Africa.

nonwoody plants. Gradually, the grasses, which are hardier plants, begin to take over and become the major form of plant life in the area.

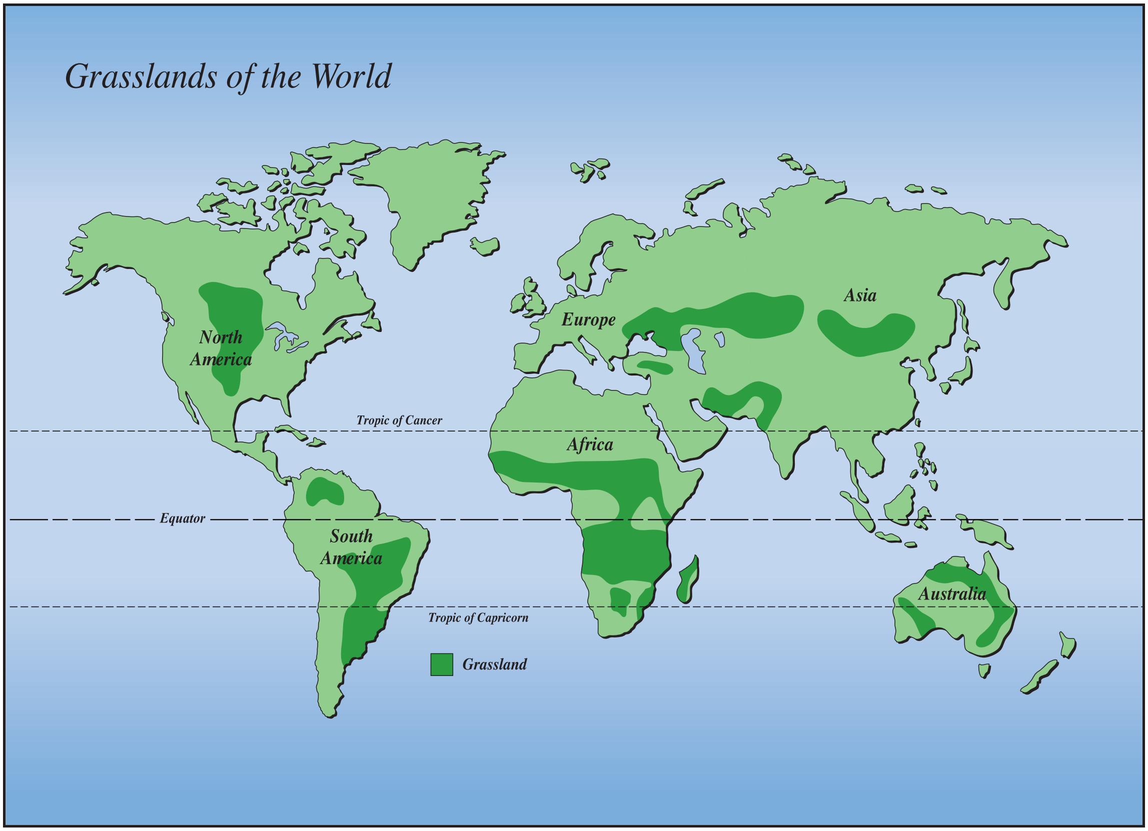
In ponds or other areas of still or slow-moving water, submerged plants like pondweed, grow beneath the water. Dead stems and leaves from these plants make the water thick, shallow, and slow moving. This dead matter forms a thick layer of organic material in which plants that must be anchored in soil, such as reeds and grasses, begin to grow. As this process continues, the pond fills with decaying plants until the water is gone and a grassland has developed.

Fires Fires help form and sustain grasslands. Most naturally occurring fires are started by lightning. Lightning strikes the ground, igniting dried grass. All vegetation (trees, shrubs, flowers) and grass are completely burned. The grass regrows because it has adapted to this dry environment and has a very deep root system and, often, underground stems. Fire helps to eliminate competition from trees, shrubs, and flowers for nutrients, water, and growing space, making it easier for grass to grow.

People may start fires that help establish grasslands. As far back as the Stone Age, hunters burned forests so that grasses would grow and attract the wild animals they relied on for food. Later, shepherds and herders burned brush and trees to encourage the growth of grasses for grazing.

Kinds of Grasslands

Grasslands may be classified as tropical, temperate, and upland grassland.



Tropical grassland Tropical grasslands, called savannas when they have scattered trees, are found in regions around the equator. Savannas are hot all year and have long dry seasons followed by very wet seasons. Savanna grasses vary across continents, depending on average rainfall. Thorn trees, for example, are found in North African savannas and can range from 13 to 50 feet (4 to 15 meters) in height. More trees grow in savannas than in any other type of grassland.

In Africa, Australia, South America, and India, savannas are transition zones between the rain forests and the deserts of the higher latitudes (distances north or south of the equator). In South America, the Llanos (YAH-nos) covers parts of northwestern Venezuela and northeastern Colombia, while larger and more wooded grasslands lie across southeastern Venezuela and southern Guyana. Brazilian grasslands include the Cerrado, a highland region, and the Pantanal, a wet savanna within the Cerrado. The Pantanal is the world's largest area of continental wetlands.

Carefully controlled fires in grasslands eliminates the competition from trees and other plants, making it easier for the grass to grow. IMAGE COPYRIGHT PHOTOSKY 4T COM, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Almost half of Africa, about 5,000,000 square miles (13,000,000 square kilometers), is covered with savanna, making it the world's largest tropical grassland. A well-known savanna in Tanzania is the Serengeti (sur-in-GEHT-ee) Plain. Savannas are also found in Australia and on India's Deccan Plateau.

Temperate grassland Temperate grasslands are those with moderate climates located farther from the equator. They have fewer trees than tropical grasslands and the grass is shorter.

Most savannas are tropical, but some occur in places with temperate climates, where they form borders between other grasslands and deciduous (trees that lose their leaves at the end of the growing season) forests. For example, oak savannas, 20 percent of which are tree covered, are found in midwestern states of the United States, such as Illinois, Indiana, Missouri, Kentucky, and Wisconsin. The major temperate grasslands include prairies, steppes, pampas, and velds.

Prairie The vast sweeping grasslands in North America are generally called prairies. The many different types of prairie grasses grow in a variety of textures and colors, which range from green to gold. These grasses vary in height but typically are 5 feet (1.5 meters) tall.

Three prairie regions are located east of the Rocky Mountains. The shortgrass prairie begins in the foothills of the Rockies and stretches east,

Big bluestem tallgrass prairie growing in the Homestead National Monument of America, Beatrice, Nebraska. IMAGE COPYRIGHT WELDON SCHLONEGER, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

where it merges with the mid-grass region of the Great Plains. The tallgrass prairie is easternmost, ending in Illinois.

Other prairie regions include the desert grassland of the southwestern United States, the intermountain grassland in the northwestern United States, and the central valley grassland in California. Within these prairie regions are subprairies—gravel prairies, hill prairies, sand prairies, and dry sand prairies. Gravel prairies grow on gravelly soil, while hill prairies are found in clearings on forested slopes. Sand prairies are characterized by sandy soils, and dry sand prairies are found on the crests of sand dunes.

Steppe *Steppe* is the Russian word for "grassy plain." A steppe is similar to a prairie, except that the grasses are shorter. Steppes are found primarily in southeastern Europe and Asia. One of the world's largest grasslands, the Eurasian steppe, stretches thousands of miles from Europe to China. Siberia is also home to steppes.

In general, there are two kinds of steppe: the meadow steppes of the North and the dry steppes of the South.

Pampas The pampas, which is Spanish for "plains," are temperate grasslands in South America. The land is flat and rolling and supports about twenty species of grasses that are tall and reedlike with silvery plumelike flowers. Many pampas grasses grow in tussocks (small clumps).

Veld In South Africa a temperate grassland is called a veld (FELT) or veldt, the Dutch word for "field." Velds are found at different elevations—

high, middle, and low. They are home to a large variety of vegetation. The highveld, for example, is dominated by red grasses that may be sweet or sour. The sweet grasses provide a good source of food for animals.

Upland grassland A few grasslands exist at high altitudes where it is too cold for trees to grow and only the hardiest of grasses survive. Upland grasslands include alpine meadows and alpine savannas. Alpine meadows are mountainous grasslands and occur in mountain ranges throughout the world. Alpine savannas occur in the tropics (the part of Earth's surface between the Tropic of Capricorn and the Tropic of Cancer, two lines of latitude above and below the equator). One example of alpine meadows is the *Puna* of the Andes Mountains of southeastern Peru and western Bolivia. Native and introduced grasses grow at elevations ranging from about 9,000 to 11,000 feet (2,800 to 3,850 meters). Forage grasses, on which grazing animals feed, grow at lower elevations.

Climate

Climate, especially rainfall and wind conditions, is the most important factor in grassland survival. Grasslands located deep in the interiors of continents in the Northern Hemisphere face extreme weather from tornadoes, droughts

Alpine meadows often have colorful flowers growing with the green grasses. IMAGE COPYRIGHT IGOR SMICHKOV, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

(dry periods), blizzards, and dust storms. Temperate grasslands in the Southern Hemisphere, such as the pampas in Argentina, are closer to the moderating effect of the oceans, which makes their climates less extreme.

The scarlet ibis lives on the Llanos, the tropical savanna found in Venezuela and northeastern Colombia. IMAGE COPYRIGHT RACHEAL GRAZIAS, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Temperature Since tropical grasslands are near the equator, their climate is warm all year. The winter is dry and the summer brings a short, but very wet, rainy season. The average summer temperature on a tropical savanna is above 80°F (26.6°C). Winter averages about 65°F (18°C).

Temperatures in temperate grasslands vary according to how far north or south of the equator they are located and how far inland from the oceans. In general, summers are hot and winters are cold. On the North American prairies, summer temperatures often reach 100°F (37.7°C). Prairies in Canada, which are farther from the equator, can be quite cold in winter, with the temperature often sinking to 14°F (-10°C).

Precipitation Precipitation (rain, snow, or sleet) is a key factor in determining the nature of a grassland, especially its soil and the type of plant life growing there. Grasslands typically receive 10 to 30 inches (25 to 76 centimeters) of rain every year; however, periods of drought are common. If rainfall decreases significantly over many years, grassland will become a desert. Likewise, an increase in rainfall over a long period of time encourages the growth of forests. Grasslands closer to the equator tend to have longer rainy seasons and a moister climate than grasslands farther from the equator.

Tropical savannas have what is called a monsoon climate, which means winds blow from different directions during different seasons. Winters are dry, and the dry period may last five to seven months. Summers, when the wind shifts direction, bring periods of heavy rain. Typical annual precipitation ranges from 25 to 60 inches (64 to 152 centimeters), but amounts vary depending on location. Grasslands in Australia, for example, receive fewer than 20 inches (50 centimeters) of

Wind turbines are powered by the frequent winds that cross the prairies. IMAGE COPYRIGHT INAKI ANTOÑANA PLAZA, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

rainfall in the east and 30 inches (76 centimeters) in the west. Grasslands in South America receive as many as 60 inches (150 centimeters).

Temperate grasslands generally receive less precipitation than tropical grasslands. They average between 12 to 40 inches (31 to 102 centimeters) per year, with much of the rain falling in the late spring and early summer.

Dry periods in both types of grasslands are important to their survival. For example, dry conditions promote fires, which is nature's way of encouraging new growth.

Wind Without trees to block the wind, it sweeps across grasslands at a high speed. In tropical grasslands, winds bring the soaking monsoon rains. Wind also helps to dry things out again because it aids evaporation. This reduction in moisture helps keep trees from growing and taking over the grassland. Wind plays a major role in spreading fires during the dry season.

Some grassland winds are so ferocious and well known that they have been given names. The buran is a strong northeasterly wind that blows over the steppes of Russia and Siberia, bringing blizzards in winter and hot dust in summer. The pampero of Argentina is a strong, cold wind that sweeps in from the Andes Mountains across the South American pampas. The warm, dry winter wind that blows over the Rocky Mountains in North America is called the chinook.

Geography of Grasslands

The geography of grasslands involves landforms, elevation, soil, and water sources.

Landforms The dominant feature of most grasslands is flat terrain or low, rolling hills. In African savannas, small hills called kopjes (KOPP-ees) are formed from rocks. Kopjes have their own type of vegetation and wildlife. In a land with few trees, kopjes provide shelter, shade, and protection for animals. The North American prairies often contain potholes, grass-filled depressions in the ground that fill with water after heavy rains.

Elevation Grasslands are found at many elevations. The South African veld, for example, is divided into zones based on elevation. The lowveld is

Twister!

Grasslands often lie in the path of violent windstorms called tornadoes. In a tornado, a huge column of air spins like a top at speeds of up to 300 miles (480 kilometers) per hour. Some have been recorded as spinning up to 500 miles (800 kilometers) per hour. Tornadoes are often called funnel-clouds because of their funnel-like shape. They are also called twisters because they spin.

While tornadoes occur in many countries around the world, they are most common in the grassland areas of the United States, especially in Kansas and Oklahoma, where few trees block the wind. As many as 1,000 tornadoes strike there every year. They develop during thunderstorms that form when warm tropical air hits cooler northern air and when the humidity is high and the air near the ground is unstable. Tornadoes travel a narrow path, usually about 600 feet (200 meters) wide, at an average speed of 40 miles (64 kilometers) per hour. Inside the center of the funnel cloud is a very strong updraft (an air current that moves upward). The updraft is so powerful it can lift heavy objects, like trees, cars, and even homes, into the air. Tornadoes can leave a path of destruction up to 15 miles (24 kilometers) long, often causing millions of dollars in damage and killing many people.

found between 500 and 2,000 feet (152 and 610 meters), the middle veld between 2,000 and 4,000 feet (610 and 1,219 meters), and the highveld between 4,000 and 6,000 feet (1,219 and 1,828 meters).

Colder grasslands are found at much higher elevations. The altiplano of the central Andes Mountains in Bolivia and Peru is about 12,000 feet (3,650 meters) above sea level.

Soil Grassland soil helps to determine what plants and animals can survive in an area.

Tropical savanna soils Soils in savannas are called "red earth" and are mostly sandy and dusty. Their red color comes from a high iron content. The long dry periods between the rainy seasons prevents dead plant matter from decomposing (breaking down) and releasing nutrients into savanna soil. This soil is not as rich as in other grasslands. Termites and other burrowing creatures turn the soil, helping air to circulate and water to reach lower levels.

Temperate grassland soils Temperate grassland soils are rich with humus, a dark, moist layer composed of decayed plant and animal matter and small grains of rock. Humus is rich in nutrients, such as nitrogen, that are vital to plant growth. It is spongy and able to store moisture.

The Role of Soil in the Food Web

Plants obtain some of their nutrients from the soil. These nutrients include minerals such as nitrogen and phosphorus, and acids such as carbonic and citric acids. Not all soils are the same and some contain a better balance of nutrients than others. Studies have shown that the quality of the soil in which a plant is grown can affect not only the plant itself, but also the creatures that eat the plant.

In a study at the University of Missouri, hay was grown on three plots of ground, all lacking nutrients. One plot (A) remained untreated. It produced about 1,700 pounds (3,740 kilograms) of hay per acre. Nitrogen fertilizer was added to the second plot (B), and it produced almost twice as much hay, about 3,200 pounds (7,040 kilograms) per acre. When the hay from both plots was fed to rabbits, the rabbits that ate hay from plot B did not grow as big as those fed hay from plot A. Although the nitrogen produced more plants per acre, those plants were not as nutritious for the rabbits.

A third plot (C) was given a balanced fertilizer to provide all the minerals the hay needed. This plot produced less hay than plot B, only 2,400 pounds (5,280 kilograms) per acre. However, when the rabbits ate it they grew twice as big as the rabbits that ate hay from plot B and 35 percent bigger than the rabbits that ate hay from plot A.

The three main types of temperate grassland soil are black earth, prairie soil, and chestnut soil.

Black earth In dry climates, there is not enough rain to wash the humus down into the soil, so it remains close to the top, producing "black earth." Called *chernozem* in Russian, black earth is an extremely fertile soil that provides excellent nutrition for crops like wheat and soybeans. Black earth is found on the steppes of Russia and central Asia, on the pampas of South America, in Australia, and on some North American prairies.

Prairie soil In moist climates with an average rainfall of 25 to 40 inches (64 to 102 centimeters), rain pushes humus deeper into the ground, producing brown prairie soils. These very fertile soils cover parts of eastern Europe and what is known as the Corn Belt in the United States. This belt runs through parts of Ohio, Indiana, Illinois, Iowa, Minnesota, South Dakota, Nebraska, Kansas, and Missouri. Prairie soils may be wet or dry and contain varying amounts of sand or gravel.

Chestnut soil Chestnut soils are found in the driest of the temperate grasslands, on parts of the South African veld, in the Argentine pampas, and on the high plains east of the Rocky Mountains. These soils are light or dark brown depending on their humus content, which makes them more or less fertile.

Water sources Rainy seasons in tropical grasslands create waterholes, swell rivers, and fill flood plains. Some tropical grasslands, like the Pantanal in Brazil, get so drenched they are under water for part of the year.

Ponds, lakes, streams, rivers, and marshes are found throughout temperate grasslands.

Plant Life

Grasslands support a wide variety of plant life, including more than 10,000 species of grasses worldwide. Grassland plants include algae (AL-jee), fungi (FUN-ji), lichens, and green plants.

Algae, fungi, and lichens It is generally recognized that algae, fungi, and lichens do not fit neatly into the plant or animal categories.

Algae Most algae are one-celled organisms too small to be seen by the naked eye. They make their food through photosynthesis (foh-toh-SIHN-thuh-sihs), the process by which plants use energy from the sun to change water and carbon dioxide from the air into sugars and starches they require for growth. Blue-green algae, also called blue-green bacteria, grow close to the ground in moist areas, often in mud after a rain. These algae help transform nitrogen in the soil so it can be absorbed by plants.

Fungi Fungi are plantlike organisms that cannot make their own food by means of photosynthesis. Instead, they grow on decaying organic matter or live as parasites (organisms that depend upon another organism for survival). Hundreds of species of fungi live in grassland soil and grow best in a damp environment. In the African savanna, for example, the termite-mound fungus grows on moist termite droppings. The fungi breaks down food matter in the droppings that the termites could not digest. This food matter is then re-eaten by the termites.

Lichens Lichens are combinations of algae and fungi. The alga produces food for both through photosynthesis. It is believed that the fungus protects the algae from dry conditions. Lichens found in grasslands grow close to the ground in moist environments.

Green plants Most green plants need several basic things to grow: light, air, water, warmth, and nutrients. In a grassland, more than half of all plant tissue—roots, stems, and rhizomes—lies underground. It is here that the plants absorb their nutrients, water, and oxygen. Savanna elephant grasses, for example, have roots that reach 10 feet (3 meters) deep.

Tough as Grass

Grass may not be as hard as nails, but it can be just as tough. It can survive drought, subzero temperatures, high winds, fires, mowing, and being trampled upon. Grass is able to grow again even after being severely damaged. Growing points on its stems and buds close to the ground can start new growth.

A tall, rough grass called slough (SLOO) grass grows along the edges of prairies close to water sources. Slough grass reaches about 9 feet (2.7 meters) in height. Nicknamed "ripgut," its stiff, razor-like leaves can cut a person's hands or an animal's mouth. While slough grass is not preferred for eating, its tough qualities make it useful for roof thatching.

Common green plants Grasses, sedges, and forbs are the most common green plants found on grasslands. A few scattered trees and shrubs also grow.

Grasses have round, hollow stems and long narrow leaves called blades. The blades grow from the base of the plant so that, when the grass is cut off at the top, it continues to grow. More than half of the grass tissue is underground, which helps the plants survive harsh weather. Some grasses, such as needle-and-thread grass, have adapted to prefer cooler rather than warmer climates.

Grasses are categorized primarily according to their height. The tallest grasses grow in tropical areas where rainfall is greater. Bamboo, one of the tallest and strongest grasses in the world, can be 180 feet (60 meters) tall. Bamboo grows quickly, sometimes at the rate of 3 feet (0.9 meter) a day. It is found throughout the tropics. A shorter species of bamboo grows in the southern United States.

Mixed-height grasses with flowering stems grow in temperate regions. On the North American prairies the grasses are categorized as shortgrass, mixed-grass, and tallgrass. Shortgrasses, which include grama grass and buffalo grass, grow to about 18 inches (45 centimeters) in height. Little bluestem, needlegrass, and foxtail barley, three mixed-grasses, grow to 3 feet (90 centimeters) tall. Tallgrasses, ranging from 3.3 to 10 feet (1 to 3 meters), include big bluestem, slough (SLOO) grass, cordgrass, and Indian grass.

Shorter grasses that grow in arid lowlands like the dry, southern Serengeti Plain, need less rainfall to survive. These include Rhodes grass and red oat grass. Most are less than 8 inches (20 centimeters) high.

Sedges are perennial, flowering herbs that closely resemble grasses. Found all over the world, they range in size from 0.4 inch to 16 feet (1 centimeter to 5 meters). They have solid, usually triangular, stems and grasslike green leaves arranged in three rows. Sedges prefer a damper environment than grasses and are often found on the edges of marshes, ponds, or other watery locations. The remote sedge, carnation sedge, and yellow nut sedge are common species.

African landscape with a beautiful Acacia tree, Hwange National Park, Zimbabwe, southern Africa. IMAGE COPYRIGHT ECOPRINT, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Forbs are flowering, broad-leaved plants without the woody stems of trees and shrubs. Wildflowers are prairie forbs and include blazing stars, sunflowers, purple coneflowers, bee balms, and shooting stars. Other North American forbs include gentian, milkweed, and fleabane. Forbs growing on the Russian steppes include anemones, red tulips, irises, and peonies.

Some temperate grasslands in drier regions support shrubs such as the mesquite and creosote bush. Along the wet edges of these grasslands, cottonwood, ash, and box elder can take root.

Baobabs and acacia trees thrive in the tropical savannas. Found in Africa and the Australian outback, the baobab has roots that go deep into the ground in search of water. It stores water in its thick trunk, which acts like a reservoir supplying water during the dry season. The African acacia produces as many as 20,000 seeds every year, ensuring that some will survive dry weather and grazing animals. As added protection for its survival, the acacia, known as a wattle in Australia, has long spines (like thorns) that are actually modified leaves. These spines keep grazing animals away and act as protection against drought, since they offer less surface area than normal leaves for moisture to evaporate.

Growing season The length of a grassland's growing season varies depending on precipitation and temperature. Growing seasons in tropical grasslands start when the rains come and end when the rains end.

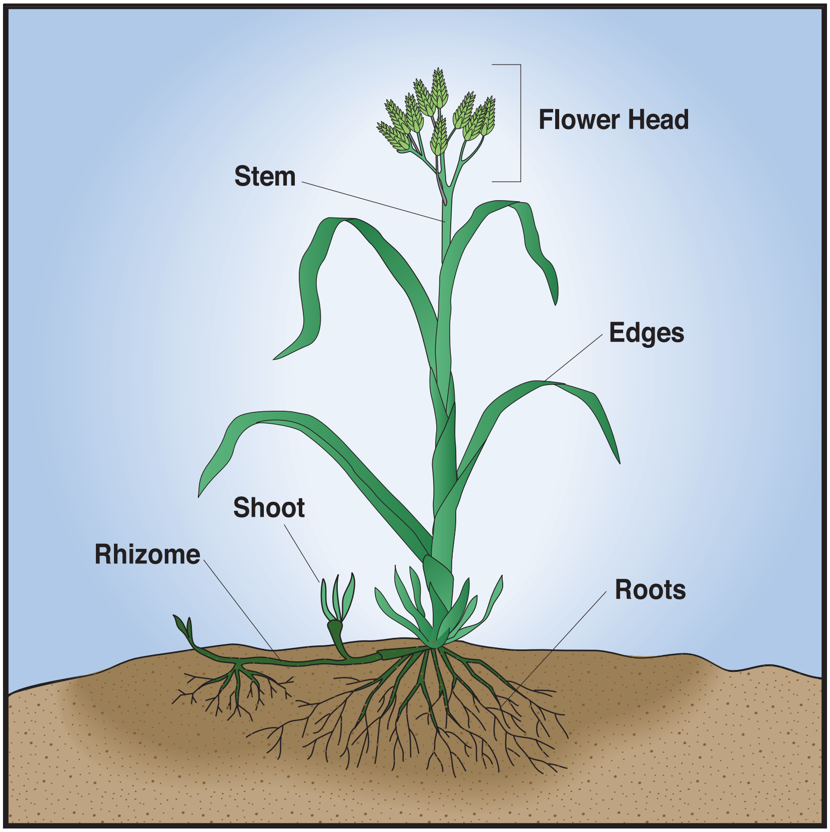


Illustration showing the parts of mixed-height grass. Since the blades of the grass grow from the base, the grass will continue to grow even after its top is cut off.

In temperate climates, the growing season lasts from 150 to 270 days and begins when the average temperature reaches about 50°F (10°C).

Reproduction Green plants reproduce by several methods. One is pollination, in which the pollen from the male reproductive part of a plant, called the stamen in flowering plants, is carried by wind or insects to the female reproductive part of a plant, called a pistil in flowering plants. Pollen-gathering insects distribute pollen at different times of the day according to when a plant's flower is open. Lilies, for example, are closed in the morning and evening, but open during midday when the weather is warmer and insects are more active.

Many species of perennial prairie grasses (those that live for two or more growing seasons) reproduce with the help of rhizomes, modified stems that spread out under the soil and form new plants. Rhizomes grow roots and produce leaves, stems, and flowers that grow upward and out of the soil.

Annual grasses (those that live only one year) produce seeds with thick outer shells. These shells protect the seeds, which are spread by the wind or by attaching themselves to passing animals.

Endangered species As grasslands become overrun by humans and animals, plants are endangered. Forbs are especially sensitive to abuse. When land is cultivated for crops or used for grazing animals, all of the native species in that area are destroyed.

Two endangered plants on the tallgrass prairies in North America are the leafy prairie clover and the prairie white-fringed orchid. The orchid is endangered because people dig it up to transplant into their home gardens and because pesticides accidentally kill the sphinx moth, an insect that pollinates the orchid.

Animal Life

Grassland animals range from very small aphids and worms to large African elephants. Different continents are home to different species.

Microorganisms Microorganisms are tiny animals that cannot be seen by the human eye except with the help of a microscope. Those found in grasslands are mainly protozoa and bacteria, which live in the root systems of grasses and help with decomposition. Some protozoa live in the intestines of termites and make it possible for the termite to digest the wood fibers they eat.

Invertebrates Invertebrates are animals that do not have a backbone. The invertebrate population of grasslands consists primarily of insects, such as dung (scarab) beetles, monarch butterflies, moths, and dragonflies.

Grubs, termites, and worms are invertebrates that play a key role in soil development. They churn the soil, allowing more oxygen and water to enter it. Worms rebuild the soil by digesting organic material and depositing this rich fertilizer in the ground.

Common grassland invertebrates Two common grassland invertebrates are termites and grasshoppers. Termites are insects that resemble ants. Most of the more than 2,000 species live in the tropics, although some are found in temperate areas. Termites live by the millions in highly social and organized communities in underground nests or in mounds having many chambers. Each termite has a role in the colony and is ranked as either royalty, nobility, soldier, or worker.

The Web of Life: Protecting House and Home

Certain species of African ants make their homes in the bullhorn acacia tree. Animals that might be a threat to the tree are driven away by the ants, which bite and sting. The presence of the ants stimulates the tree to form galls, a kind of tumor that grows on the branches. The galls have spikes that help keep hungry animals away from both the tree and the ants.

Grasshoppers are one of the most common invertebrates on the grasslands. IMAGE COPYRIGHT BRUCE MACQUEEN, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

On the African savanna, termites build huge brown mounds out of soil cemented with saliva or droppings, making the mounds rock hard. Termite mounds can be more than 25 feet (7.6 meters) high, 98 feet (30 meters) wide, and may last for decades.

Grasshoppers are one of the most common grassland insects. They are plant eaters with powerful hind legs that allow them to jump and wings that allow them to fly. All grasslands around the world face periodic swarms (large populations) of grasshoppers. The species that swarm are called locusts. In 1889, one of the largest swarms ever seen formed over the Red Sea in Northeast Africa and covered an area about 2,000 miles (3,200 kilometers) long, darkening the sky for days. Locusts may eat every plant in their path, including the stalks. When they are finished, all crops, as well as plants and shrubs, are destroyed.

Food Caterpillars and grasshoppers are among the insects that eat leafy vegetation. Grubs eat grass roots, while some insects are scavengers, feeding on what is left behind by larger animals. Two types of scavengers are the carrion beetle and the flesh fly, both of which live on the African savanna. The African scarab beetle is also a scavenger, feeding on animal droppings.

Reproduction The first stage of an invertebrate's life cycle is spent as an egg. When the egg hatches, the emerging creature is called a larva. The larva stage is divided into several stages between which there is a shedding of the outer skin as the larva increases in size. During the third, or the pupal stage, the insect lives in yet another protective casing, like a cocoon. In the final stage, the adult emerges.

The reproductive cycle of the sphinx moth of the African savanna follows the wet and dry seasons. Eggs are laid on vegetation during the rainy season. By the time the dry season arrives, the eggs have already hatched into caterpillars that have been feeding on leaves. After several molts (stages

Sphinx moths can be found in grassy areas. IMAGE COPYRIGHT C.L. TRIPLETT, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

where insects increase in size and shed their outer skin) they burrow into the soil, where they remain in pupal form until it rains again and they emerge as adult moths. The scarab beetle lays its eggs inside a ball of animal droppings. The young beetles feed on the droppings after they have hatched.

Amphibians Amphibians are vertebrates, animals with a backbone. Amphibians live at least part of their lives in water. Most are found in warm, moist regions and temperate zones where temperatures are seldom extreme.

Amphibians breathe through their skin, so they usually must remain close to water. Only moist skin can absorb oxygen, and if they are dry for too long they will die. On the African savanna, amphibians like the African bullfrog estivate (remain inactive) underground during the dry season. The termite frog estivates in a termite mound.

Common grassland amphibians The green toad is common to the steppes. Once it has become an adult, it is able to live out of water. Since the steppe climate can be extreme, the toad hibernates underground when the weather is too hot or too cold.

The small North American cricket frog lives in grasslands near ponds or streams. These frogs have brown or green skin covered with bumps. They grow to about 1.2 inches (3 centimeters) in length.

Food Amphibians eat insects and some small animals, using their long tongues to capture prey. Although they have teeth, amphibians do not chew but swallow their food whole. As larvae, they usually eat plants. Toads, for example, eat algae and water plants during the larval stage.

Reproduction Mating and egg laying for most amphibians takes place in water. Male sperm are deposited in the water on top of eggs laid by the female. The African running frog lays its eggs in puddles that form when the rainy season begins. As the offspring develop into larvae and young adults, they have gills, which means they must live in water. Once they mature, they breathe through lungs and live on land.

Most amphibians reach adulthood at three or four years, breeding for the first time about one year after they become adults.

Reptiles Reptiles are cold-blooded vertebrates that depend on the environment for warmth. They do not do well in extreme temperatures, either hot or cold. Reptiles are usually more active when temperatures become warmer. Many reptiles go through a period of hibernation in cold weather because they are so sensitive to the environment. Unlike amphibians, reptiles have waterproof skin, which allows them to move away from moist areas.

Common grassland reptiles The boomslang snake is common throughout the African savannas south of the Sahara Desert. Up to 6.5 feet (2 meters) in length, the boomslang is shy and highly poisonous. Its fangs are set in the rear of its upper jaw, and a bite causes excessive bleeding and death. The boomslang eats lizards, frogs, and sometimes birds and rodents. Other snakes include the python and the coral snake.

The agama lizard is also found on the African savannas. The male has a blue-orange body and red head. These bright colors help it to be visible to females and competing males. Each male lizard has its own territory and mates with several females. Adults are around 12 inches (30 centimeters) long.

The western box turtle is a land turtle found in the prairies of North America. Box turtles grow to about 8 inches (20 centimeters) in length and have a high, round shell. They eat both plants and animals, including berries, mushrooms, insects, and worms.

Food Most reptiles are carnivorous (meat-eating). For example, snakes consume their prey whole—and often alive—without chewing. It can often take an hour or more to swallow a large victim. Many snakes have fangs that are curved backward so their prey cannot escape.

Reproduction Most reptiles reproduce sexually, meaning the female egg is fertilized by the male sperm. Almost all species lay eggs. A rare few species bear live young.

Birds Hundreds of species of birds live on the grasslands. Many species must nest on the ground and perch on the grasses because there are so few trees.

Common grassland birds Representative of grassland birds are the ostrich, the prairie chicken, and the black hornbill.

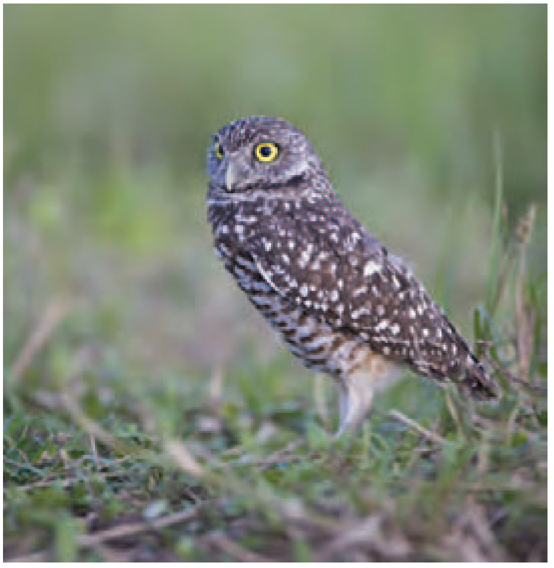
The ostrich is the largest and fastest bird in the world, weighing around 350 pounds (159 kilograms) and standing about 8 feet (2.4 meters) tall. Although it has wings, it cannot fly, but it is able to run at speeds up to 45 miles (72 kilometers) per hour. The ostrich is found on grasslands in parts of Africa and Southwest Asia. Males mate with several females, each of which typically lays twelve very large eggs in a nest built on the ground. In this species, the male and female take turns sitting on the eggs until they hatch.

Formerly one of the most familiar grassland birds in the United States is the greater prairie chicken, a species that has become quite rare. Found on tallgrass prairies, these birds live on the ground and eat seeds. Females lay about twelve eggs that hatch in fewer than forty-two days. The chicks can fly by the time they are two weeks old. The lesser prairie chicken is more common and can be found on short-grass prairies.

Black hornbills are large birds that walk along the African savanna in search of insects. They range from 12 to 47 inches (30 to 120 centimeters) in length and have large heads, thin necks, broad wings, and long tails. Hornbills nest in the grooves of large trees. The male builds the nest around the female and seals her inside with the eggs, passing food to her through a small opening. The female breaks out of the nest after the eggs hatch.

Hitchhiking on the Grassland

The bustard is a large, heavy, longlegged grassland bird found in Europe, Asia, and Africa. When the male strolls around looking for food, a small, reddish bird called a bee-eater hitches a ride on his back. As the bustard moves, it stirs up insects that are nabbed and eaten by the bee-eater.



The burrowing owl is one of the few ground-dwelling owls, and lives in dry areas with low vegetation. IMAGE COPYRIGHT BOB BLANCHARD, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

An Upside-Down Nest

African weaverbirds build some of the most complex and unusual nests in the world. Their globe-shaped nest is woven from savanna grasses and has its entrance hole at the bottom. With its entrance hidden, the nest is protected from predatory birds that might ordinarily swoop down into the nest to steal eggs or baby birds. The nests of many weaverbirds are hung together in trees, forming a community of "apartments" that resembles the thatched roof of a house when seen from a distance. Parent birds use the same nest every year, and young birds add their nests to their parents' structure.

Food Many grassland birds eat grains and seeds, which are readily available. Predatory (hunting) birds, like owls, hawks, and eagles, eat rodents and snakes, while others feed on insects. The green wood hoopoe eats butterflies or beetles. Tick birds, such as the groove-billed anis, eat ticks from the backs of large animals. Storks, vultures, and ravens are scavengers and dine on leftovers from a kill.

Reproduction All birds reproduce by laying eggs. Usually, the males must attract the attention of the females. Therefore, most males are more brightly colored than the females, and some sing or perform dancing rituals. For example, the greater prairie chicken inflates orange air sacs near its throat when beginning its mating call.

After mating, female birds lay their eggs in nests made out of many different materials and built in a variety of places. Many species, like the lark and bobolink, nest on the ground. The parent bird, usually the female, sits on the eggs to keep them warm until they hatch.

Ostriches live in groups of five to fifty birds, and are often seen traveling with zebras or other grazing animals. IMAGE COPYRIGHT ECOPRINT, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Mammals Mammals are warm-blooded vertebrates that are covered with at least some hair, bear live young, and produce their own milk. Hundreds of species of mammals live on grasslands around the world.

Grassland mammals Grassland mammals include prairie dogs and saigas. Saigas are endangered with a current population of about 40,000.

One of the most common North American prairie animals is the prairie dog. These small rodents weigh 1.5 to 3 pounds (0.7 to 1.4 kilograms) and live in prairie dog "towns" consisting of a network of underground tunnels. These tunnels provide a safe place to raise young, hibernate in winter, and hide from predators such as coyotes, snakes, and eagles. The many holes that lead into the tunnels can be found scattered over a wide area. The animals feed close by these holes and dart into them when danger is detected.

A male prairie dog mates with two or three females and protects the group, which lives in its own section of the town.

Getting the Most out of Every Meal

Many grasses are impossible for most mammals to digest. Some animals, like the bison, giraffe, and pronghorn antelope, are called ruminants and can eat tough grasses. These animals have a stomach with four chambers. After the grass is chewed and swallowed, it is stored in the first chamber, called the rumen, where microbes help break it down and soften it. Later, the animal brings the food back up into its mouth and chews it some more, a process called chewing cud. This cud is reswallowed and goes through all of the chambers of the stomach where it is completely digested. The four-chambered stomach probably helps grazing animals, which are always on the lookout for predators, eat large amounts very quickly and return to shelter where they can safely digest their meal.

Saigas are a type of antelope found on the steppes of Russia and Siberia. At only 2.5 feet (0.8 meter) tall, they must jump into the air to see above the grass when watching for predators. When threatened, they run away at speeds up to 50 miles (80 kilometers) per hour.

Saigas are plant-eaters that dine on forbs and grasses. Females often give birth to twins, which helps the survival of the species. Male saigas have a high mortality rate. Each year, more than half of the males starve to death.

Food Some mammals are herbivores (plant-eaters). Some herbivores, like the zebra, buffalo, wildebeest (WIHL-duh-beest), and antelope, are grazers. Grazers have front teeth that allow them to bite off grass close to the ground and back teeth to grind up the grass. Other herbivores, like giraffes and elephants, are browsers that nibble the leaves and bark of trees and shrubs.

Wildebeest and zebra graze in the Ngorongoro Crater in Tanzania. IMAGE COPYRIGHT VERA BOGAERTS, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

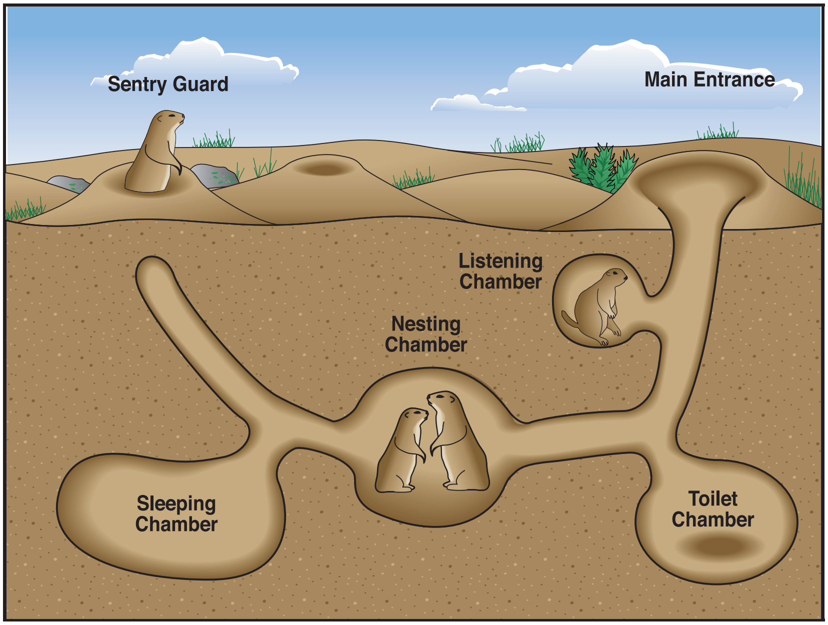
Other mammals, such as coyotes, lions, and cheetahs, are carnivores (meat-eaters). Jackals and hyenas are scavengers, meaning they eat the leftover carcasses and decaying meat from dead animals.

Reproduction Mammals give birth to live young that develop inside the mother's body. Some mammals are helpless at birth, like the hare, while others, like the zebra, are able to walk and even run almost immediately. The mother nurses the young with her own milk until they are old enough to find their own food.

Endangered species Many grassland animals are endangered because of overhunting, pollution, and the destruction of their habitats.

Before the end of the nineteenth century, there were as many as 400 million prairie dogs living in a single prairie dog town that stretched across North America. As grasslands were turned into farms, so many of these animals were killed that they faced extinction. Many national parks in the United States and Canada now protect prairie dogs.

Found in Africa and southern Asia, cheetahs are the fastest land animals in the world. With a small head, long legs, and a tail that helps them to keep their balance, cheetahs can run almost 60 miles (96 kilometers) per hour for short distances. Once hunted for their black-spotted fur, cheetahs are now protected. The major threat remaining for cheetahs is the loss of habitat, as more land is taken for farming and development.



An illustration of a prairie dog "town." The underground tunnls are used to raise the young, hibernate in the winter, and to hide from predators.

Many species of kangaroos are found in Australia and on neighboring islands such as New Zealand. A number of the larger species are endangered. Some are killed for hides (skins) and some for food. Kangaroos are grazing animals, and many are shot by ranchers and farmers who want their cattle to graze without competition.

North American pronghorn antelopes are found in Mexico and the western United States. In the nineteenth century, about 40 million pronghorns lived on the prairies of North America. In the early twentieth century, much grassland was destroyed for farming, and many pronghorns were killed for food and hides. There are fewer than 10,000 pronghorns left and they live in the state of Arizona. Conservation laws have provided protected areas, but the pronghorn still faces the threat of extinction because of shrinking habitats.

A similar fate occurred with the American bison. Prior to the expansion of the United States westward, there were about 30-60 million bison. Their number was reduced to only about 1,000 in the late nineteenth century. The herds have since increased to nearly 30,000 on protected lands. The purity of the species is threatened as many bison are cross-bred with cattle for commercial purposes.

The New Look of Lawns

Using grass for lawns began in France and England in the late eighteenth century. It became popular in the United States, first as a way for people to tame wild-looking plots, and eventually as a status symbol—the green yard with no weeds.

Lawns have a high environmental cost. Gas lawnmowers pollute the air, thousands of gallons of fresh water are used up in watering, and tons of pesticides (insect poisons) are applied every year. Unfortunately, these chemicals kill wildlife and endanger the health of people and pets.

Many communities encourage the use of native trees, shrubs, flowers, and grasses to replace the typical lawn. Native plants do not require the same amount of water and fertilizer necessary to maintain lawn grasses. They also return the landscape to its original beauty and protect the environment.

Human Life

Grasslands have been home to people around the world for thousands of years. Of all the flowering plants, none is more important to human life than grasses. Grasslands dominate the agricultural regions of every continent except Antarctica.

Impact of the grassland on human life Grasslands are essential to human life because of their role in food production and agriculture. Based on their usefulness to humans, there are six major types of grasses: grazing and forage grass, turfgrass, ornamental grass, cereal grass, sugarcane, and woody grass.

Food More than half of the world's population relies on grasses for food. About thirty-five species of grasses are grown for human and animal use. Many grasses are harvested for hay, to feed livestock. Grasses are also cultivated for their seeds, which are processed and eaten. These grasses include the cereal grains: wheat, oats, barley, rye, corn, millet, sorghum, and rice. Wheat and corn are grown all over the world, with large crops coming from the United States, China, and Russia. Oats and rye are the chief domestic crops from Russia and Europe. Cereal, bread, and pasta are common foods made from these grains. Some wild grass species, such as wild rice, are also harvested. Sugarcane is a type of grass, but it is not a cereal grass. Its sap is concentrated into sugar. The sprouts and shoots of bamboo, which is a woody grass, also provide food for humans.

Grassland animals, such as the American bison (commonly known as the buffalo), have been used for food since the earliest times. When the horse, another grassland animal, became domesticated (tamed), hunters could follow wild herds of bison as they migrated (moved from one area to another). Overhunting is one reason the American bison has become an endangered species.

Economic factors Many of the world's grasslands are used for farming and ranching and have great economic importance. Grazing and forage grasses are used for feeding cattle and other animals. Turfgrass is used to cover athletic fields, lawns, golf courses, and playgrounds. Turfgrasses include Kentucky blue grass, ryegrass, Bermuda grass, and buffalo grass. Ornamental (decorative) grasses, such as pampas grass and Chinese silvergrass, are used in parks and flower gardens. Sugarcane is used not only for sugar but also for making plastic and wallboard. Woody grasses, such as bamboo, can be used to make sturdy items including furniture and even houses. Fiber from the bark of the baobab tree is used for making rope and paper.

Grasslands are favorable sites for homes and cities because they tend to be relatively flat. Saskatoon in Saskatchewan, Canada, and Omaha, Nebraska, are both grassland cities.

Many grasslands offer mineral resources. Gold and diamonds are mined under the South African veld, while natural gas and petroleum are extracted from beneath the grasslands of Texas and Oklahoma.

Impact of human life on the grassland At one time grasslands were the largest single biome in the world, covering more than 40 percent of Earth's land surface. None of these native grasslands remain untouched by humans.

When the railways brought large numbers of colonists to remote regions during the nineteenth century, grasslands were rapidly taken over for farms and towns. The Trans-Siberian Railroad brought people onto the steppes of Siberia. Similarly, railways crossed North America, moving large numbers of people all across Canada and the United States.

Since that time, many grasslands have become artificial, or human-made. Some of the grasslands were created in areas once occupied by forests that had been cut down. Almost all of the grasslands in Europe are artificial and are used for grazing animals and growing grain.

Use of plants and animals Many native grassland plants are used for herbal medicines. The purple coneflower, for example, can be used to help heal wounds, and fleabane is used to repel insects. With the popularity of herbal remedies, many of these plants are being overharvested.

As more and more grassland is used for agriculture, native plants are destroyed leaving little food for wildlife. Trees are cut down and used for lumber or as fuel for cooking.

Grassland animals have also suffered from overuse. Mass slaughter and poaching of animals have nearly destroyed every major species of mammal and reptile and several species of birds in the South African veld.

After years of misuse, people have begun to restore prairies to their natural state. Here a refuge operations specialist at Squaw Creek National Wildlife Refuge works at clearing trees on a little over three acres of ground on the refuge. The refuge purchased the ground in the late 1980s and has been restoring the area to its original loess bluff prairie state. AP IMAGES.

Kruger National Park in South Africa is one of several protected areas in which some of these species survive.

Quality of the environment During the 1930s, serious misuse of grassland resulted in the great "Dust Bowl" in Oklahoma and Texas. Farmers failed to use soil conservation methods and, while plowing for crops, destroyed the grasses that held the soil in place. After a long, dry period, the crops died and sweeping winds blew the dry topsoil away. The dust drifted thousands of miles and rose as high as 30 feet (9 meters). It was so thick in the air that people became sick from inhaling it. Crops could no longer be grown in the ruined land. Many people went hungry and thousands were forced to move.

Erosion (wearing away of soil) is still a problem in grasslands. African savannas are being stripped of their natural vegetation so they can be used for agriculture. In the Sahel region of North Africa, more and more grassland is becoming desert each year.

Some farmers use irrigation techniques to overcome dry grassland conditions. However, when water is pumped from underground sources, these water supplies can be completely used up.

In certain grasslands, measures are being taken to overcome the negative impact of human interference. Irrigation ditches linking fields to nearby aboveground sources bring water to crops, and farmers plow in ways that help prevent erosion. Native vegetation is protected from cattle so that it has a chance to regrow.

Learn More About Life on the Grassland

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Native peoples Hunter-gatherers were living on the tropical grasslands of East Africa more than 40,000 years ago. About 10,000 years ago, these hunter-gatherers learned to cultivate the grasses and to domesticate animals, which allowed them to lead more settled lifestyles. Grasslands in some parts of the world continue to support tribes of people who live a traditional lifestyle.

Nomadic (wandering) hunters, herders, and shepherds once lived and roamed freely on temperate grasslands in North America. The Blackfoot, Teton Sioux, Cheyenne, and Comanche tribes followed the bison. Food, clothing, and shelter were all provided from the meat and skins of these animals. Some tribes, such as the Pawnee, Mandan, Hidatsa, and Arikara, were seminomadic and spent time planting and harvesting crops, especially corn, beans, and squash. By the nineteenth century European peoples began to move onto the world's grasslands, forcing the native peoples out of their traditional homes. Although some Native Americans still live on reservations (areas set aside for them to live), many have moved to large cities.

The Kazakh (also spelled Kazak) peoples live on the grasslands of Central Asia and parts of China. The Kazakh are nomads who raise sheep, cattle, goats, camels, and horses. Most still follow the traditional lifestyle, moving from one grassland to another when their animals need fresh pasture. Their food is primarily milk products and meat from their sheep. They live in portable, dome-shaped tents called yurts, which consist of a frame of poles covered with skins or wool felt. Many of their other needs are met with products from their animals: hides are made into clothing, horns are used for utensils, and horsehair is braided into rope.

African peoples still living on the grasslands include some tribes of Maasai found in the Great Rift Valley of southern Kenya and Tanzania. They are traditionally herders who move across the savannas with their cattle. Their cultural beliefs require them to live almost entirely off the

Yurts are dome-shaped, portable shelters used by the nomadic Kazakh. IMAGE COPYRIGHT MARC VAN VUREN, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

meat, blood, and milk provided by their livestock. Most Maasai are permitted to eat grains and vegetables when food is scarce, but warriors are not. Maasai villages, called kraals, consist of mud-dung houses for four to eight families surrounded by a large circular thornbush fence. As less and less grazing land is available for the Maasai, many are forced to give up their traditional lifestyle and make their living trying to farm.

The Food Web

The transfer of energy from organism to organism forms a series called a food chain. All the possible feeding relationships that exist in a biome make up its food web. On the grasslands, as elsewhere, the food web consists of producers, consumers, and decomposers. An analysis of the food web shows how energy is transferred within a biome.

Green plants are the primary producers in the grassland. They produce organic (matter derived from living organisms) materials from inorganic chemicals and outside sources of energy, primarily the sun.

Animals are consumers. Primary consumers eat plants and include grazing animals, such as zebras, bison, and antelopes. In the savannas, where trees are more common, tall plant-eaters, such as giraffes and elephants, browse on the leaves of trees or bushes.

Plant-eaters become food for predators, which are secondary consumers such as coyotes and lions. Tertiary consumers eat both primary and secondary consumers. They include leopards and eagles. Humans are omnivores, which means they eat both plants and animals.

Decomposers eat the decaying matter from dead plants and animals and help return nutrients to the environment. For example, small underground insects called springtails help decomposition by breaking down dead plants. This allows other organisms, like bacteria and fungi, to reach the decaying matter and decompose it further.

Barbed Wire and the End of the Old West

Before the end of the nineteenth century, the American West was an open range where ranchers could graze cattle freely and cowboys could drive large herds to market. As farmers began to settle in the area they needed to protect their crops and land from wandering cattle. Cattle often trampled wooden fences in an effort to get to food or water so a stronger barrier was necessary.

In 1874, Joseph F. Glidden invented a machine to manufacture barbed wire. Barbed wire was made out of two strands of wire twisted together from which sharp barbs protruded. The barbs caused pain and kept cattle from damaging the fence.

As the open range was cut up by fences, "range wars" developed between farmers and ranchers. By 1888, the farmers had won, and cattle ranchers were forced to keep their cattle on their own property. They began to use railway cattle cars rather than long cattle drives over open land to transport them to market.

Spotlight on Grasslands

The Llanos The Llanos (YAH-nos) is a tropical savanna found in Venezuela and northeastern Colombia. The Llanos is bordered by the Andes Mountains in the north and west, the Amazon and Guaviare Rivers to the south, and the lower Orinoco River to the east. At its highest elevation, the Llanos is about 1,000 feet (305 meters) above sea level, although some areas may be as a low as 200 to 300 feet (61 to 91 meters).

Typical of tropical grasslands, the Llanos is flooded for part of the year and dry for the rest. During the dry season, which lasts from December through April, fires often sweep the land. When the rains begin in May, lakes, lagoons, and marshes form. The area stays wet until November, when the dry cycle begins again. Annual precipitation ranges from 30 to 98 inches (76 to 160 centimeters). The annual average temperature is approximately 80°F (27°C).

Swamp grasses, sedges, and carpet grasses grow throughout the region, which is also home to the Llanos palm, the scrub oak, cassias, and the araguaney tree.

During the wet season, the great anaconda inhabits the areas around the rivers. The anaconda is the largest snake in the Americas, measuring 30 feet (9 meters) long. A type of constrictor, the anaconda wraps itself around its prey and squeezes it. The Orinoco crocodile, one of the most threatened reptiles in the world, lives along the edge of the river.

The Llanos
Location: Venezuela and northeastern Colombia in South America
Area: 220,000 square miles (570,000 square kilometers)
Classification: Savanna

Many species of birds live on the Llanos, including herons, storks, and ibises. The scarlet ibis, a large wading bird, has long legs and a long, slender, downward-curving bill used for searching in the mud for food. The jacana is a water bird whose long toes enable it to walk on the large floating leaves of water plants.

The capybara is the world's largest rodent, weighing about 100 pounds (45 kilograms). It eats grasses and aquatic herbs, which it finds both on land and in the water. The capybara is a favorite meal for both the anaconda and the Orinoco crocodile. The only wild animals with hooves that live on the Llanos are the white-tailed deer and the red brocket, a small deer with short, unbranched antlers.

The Llanos is home to the giant anteater and giant armadillo. A toothless animal that eats insects, but is especially fond of ants and termites, the giant anteater is 6 to 8 feet (1.8 to 2.4 meters) in length and weighs about 65 to 140 pounds (29 to 64 kilograms). The giant armadillo can weigh up to 100 pounds (45 kilograms) and is protected by a type of armor that covers its body from head to tail. In some species, the armor is in segments and is flexible. Unlike certain members of the armadillo family, the giant armadillo cannot roll into a ball to protect itself from predators. Instead, the giant armadillo quickly digs itself into the ground using the long claws on its front legs. Very shy and almost blind, it depends on its senses of smell and hearing. With its large claws, it rips apart insect nests in search of food but also eats roots and worms.

Serengeti National Park The name Serengeti is from a Maasai word meaning "endless plains." Serengeti National Park and Wildlife Refuge is located in north central Tanzania on a high plateau between the Ngorongoro highlands and the Kenya/Tanzania border. Stretching between Lake Victoria and Lake Eyasi, the park is best known for the millions of wild animals that live there.

The park contains a vast open grassland in the southern region, a large acacia savanna in the center, and wooded grasslands in the north. Within the Serengeti are kopjes (rocky hills) with their own unique biomes. Rivers, lakes, and swamps are scattered throughout the park, providing habitats for a variety of reptiles and birds.

Serengeti National Park
Location: North central Tanzania in Africa
Area: 5,700 square miles (14,763 square kilometers)
Classification: Savanna

Located in the tropics, the Serengeti is dry and warm. Yearly temperatures range from 59° to 77°F (15° to 25°C), and the coolest weather is from June to October. The major rainy season lasts from March to May, but shorter periods of rain occur in October and November. About 47 inches (120 centimeters) of rain fall near Lake Victoria and about 20 inches (51 centimeters) on the plains.

Elevations in the park range from 3,000 to 6,000 feet (920 to 1,850 meters).

Not many amphibians or reptiles inhabit grasslands. However, in 1992, a new species of tree frog was discovered in the Serengeti's rocky hills during the rainy season. This species is named *Hyperolius orkarkarri.*

More than 500 species of birds have been seen in the park. Common birds include starlings, ring-necked doves, and the barbet, a brightly colored bird with a large, strong bill with bristles at its base.

About thirty-five species of herbivores, such as wildebeests, zebras, giraffes, gazelles, topi, and konga, live here. Elephants began moving onto the Serengeti in the 1960s when human populations in the surrounding area increased, forcing them from their former homes. Carnivores include lions, cheetahs, hyenas, and leopards.

Land animals in the Serengeti migrate annually. The migration follows the pattern of the seasons and is led by the millions of wildebeests in the park. During the wet season, which lasts from December to May, herds graze on the southeastern plains. As the season progresses, they move west into woodland savanna and then north into the grasslands as their food and water supplies become scarce. When the dry season ends in November, the herds return to the rain-drenched southeastern plains, and the cycle begins again.

The Maasai were the first people to inhabit the Serengeti, arriving with their herds at the end of the nineteenth century. In the early twentieth century, Europeans and Americans arrived and began the wholesale killing of wild animals. The lion population was almost wiped out, but game reserves were established in the 1920s, and the entire area was made into a park in 1951. Although the Serengeti is one of the largest wildlife sanctuaries in the world, poachers (people who hunt or fish illegally) still pose a major threat. Elephants are killed for their ivory tusks and the black rhinoceros, which is almost extinct, is killed for its horn.

Wind Cave National Park
Location: South Dakota
Area: 28,292 acres (11,449 hectares)
Classification: Mixed-grass prairie

Wind Cave National Park Wind Cave National Park is located in South Dakota and borders the ponderosa pine forests of the Black Hills. It is home to a mixed-grass prairie that contains both tall grasses from the eastern prairies and short grasses from the high plains near the Rocky

Mountains. The park was established in 1903 to preserve its grasslands and its many limestone caverns.

The climate in the park is typical of a temperate grassland—warm in summer and cold in winter. The air that comes off the Rocky Mountains makes the park somewhat warmer and drier than the surrounding areas. In winter, temperatures range between 22° and 50°F (-5° and 10°C). Summer temperatures average 85°F (20°C). Some moisture comes from snow, which can accumulate as much as 30 inches (76 centimeters) in the winter.

Most of the vegetation in the prairie consists of grasses. When rainfall is more plentiful, the tall grasses dominate because they grow best in a moist environment. When there is less rain, the short grasses take over. Native tallgrass species include spikebent, redtop, big bluestem, and prairie sandreed. Native mixed-height grasses include slender wheatgrass, little bluestem, and Junegrass. Red three-awn, buffalo grass, and stink-grass are native short grasses. Other native vegetation includes forbs, such as small soapweed (a yucca plant), prairie clover, and Indian hemp dogbane.

Common amphibians that make this park their home include the blotched tiger salamander, the plains spadefoot toad, the upland chorus frog, and the Great Plains frog, which is easily identified by its many bumps. Reptiles found along the streams include the common snapping turtle, the wandering garter snake, and the prairie rattlesnake.

Hundreds of species of birds visit or make the park a permanent home. Permanent residents range from common finches to hawks, golden eagles, and prairie falcons.

Mammals frequently seen in the park are coyotes, prairie dogs, chipmunks, and elks. Bison, elk, and pronghorns were reintroduced to the park in 1913. There are sightings of coyote, mountain lions, and whitetail deer, but black bears, grizzly bears, and grey wolves are no longer found.

Manas National Park Manas National Park, located in the foothills of the Himalaya Mountains in India, is part forest and part grassland. It is home to a great variety of vegetation and wildlife. To the north is the country of Bhutan, to the south is North Kamrup, and forest preserves are to its east and west. The park includes part of Manas Reserve Forest and all of North Kamrup Reserve Forest. The Manas River runs through it. Manas was declared a wildlife sanctuary in 1928 and upgraded to a

Manas National Park
Location: Western Assam State in eastern India
Area: 125,000 acres (50,000 hectares)
Classification: Savanna

National Park in 1990. In 1992, it was recognized as a World Heritage Site in Danger because of heavy poaching and political unrest.

Much of the park is low-lying and flat, ranging in altitude from 100 to 361 feet (61 to 110 meters) above sea level. Summer is warm, lasting from April through June with a maximum temperature of 99°F (37°C). October through March is the chilly season with temperatures falling no lower than 51°F (11°C). The monsoon season lasts from May to September and is fairly warm. Annual rainfall, most of which falls during this season, is 131 inches (333 centimeters).

Many species of grasses and a variety of trees and shrubs are found in the park. In the northern forest region, evergreen and deciduous trees (trees that lose their leaves) grow. Tall, dense grasses used to manufacture paper are an important resource at these lower altitudes.

A few amphibian species and about 30 species of reptiles can be found in the park sanctuary. Reptiles include the vine snake, flying snake, Assam trinket snake, monitor lizard, and roofed turtle.

Hundreds of species of birds live in the park, including the great pied hornbill, the pied harrier, and the spot-billed pelican.

Elephants, hog deer, and tigers are among the more than fifty species of mammals in the sanctuary. The pigmy hog and the rare golden langur, a long-tailed monkey with bushy eyebrows and a chin tuft, rely on the park for their survival.

Eurasian steppes One of the world's largest temperate grasslands is the Eurasian steppe, which extends about 5,000 square miles (8,000 square kilometers) across Hungary, Ukraine, Central Asia, and Manchuria. The steppes are bisected (divided) by the Altai Mountains into the western steppe and the eastern steppe. The western steppe stretches from the mouth of the Danube River along the north shore of the Black Sea and across the lower Volga River. The eastern steppe continues to the Greater Khingan Mountain Range. The entire terrain is criss-crossed by rivers and streams.

In the summer, temperatures average 73°F (23°C) June through August. The winter is cold and the area is covered with as much as 4 inches (10 centimeters) of snow. Average winter temperatures from November to March are below freezing; temperatures average 29°F (-2°C). Annual rainfall for the steppes averages between 10 and 20 inches (25 and 51 centimeters).

Eurasian Steppes
Location: Hungary, Ukraine, Central Asia, Manchuria
Area: 5,000 square miles (8,000 square kilometers)
Classification: Steppe

The steppes contain some of the most fertile land in the world. Primarily made up of black earth (chernozem), steppe soil is excellent for crops. Most of Russia's grain, for example, is produced on the steppes.

Native steppe vegetation consists primarily of turf grasses, such as bluegrass, bunchgrass, feather grass, and fescue, as well as mosses and lichens. In the north where there is more moisture, wild tulips, irises, daisies, and sages grow. Fewer flowers grow in the drier southern region.

Common reptiles found on the Eurasian steppe include steppe vipers and whip snakes. Birds include larks, bustards, and kestrels. An unusual bird that comes to the steppes to mate is the demoiselle crane, famous for its mating dance. About 3 feet (0.9 meter) in height, this blue-gray bird is characterized by tufts of feathers on the sides of its head. Birds of prey include hawks, falcons, and eagles.

Burrowing animals, like marmots, steppe lemmings, and mole rats, do well on the open steppes. The spotted suslik, a ground squirrel, lives in underground colonies. Other mammals that live on the steppes include skunks, foxes, wolves, antelopes, muskrats, raccoons, beavers, and silver foxes. Saigas, at one time on the verge of extinction, have recovered and are now found almost everywhere throughout the regions.

For thousands of years people have lived on the steppes, beginning with hunter-gatherers in prehistoric times. Eventually the lifestyle changed to farming and, about 2000 BC, when the horse was domesticated, people began herding animals and moving from pasture to pasture. Conflict between tribes was common until the sixteenth century when the Russians conquered and colonized the area. A few small groups of nomads still make their home on the steppes.

Parts of the steppes are being preserved as national parks and wildlife refuges. For example, the Askaniya-Nova in the Ukraine works to protect endangered species. More than forty different mammals, including the onager (wild ass) and Przewalski's horse, have been introduced to the park.

Konza Prairie Preserve The Konza Prairie Preserve in Kansas is a tallgrass prairie, a rich environment that plays host to over 100 ecological research projects at any given time. In addition to grasslands, the Konza area contains streams and a deciduous forest. Wide expanses of tallgrass are broken up by natural depressions in the ground, such as prairie potholes. After the rain, these areas fill up and provide watering holes for animals.

The Konza climate is temperate, with warm, moist summers and cool, dry winters. Summer temperatures range from 80° to 100°F (27° to 38°C), while winter temperatures can be as low as 10°F (-12°C). Annual average rainfall is 32 inches (81 centimeters).

The most common grass on the Konza is big bluestem. Other grasses include Indian grass, switchgrass, and little bluestem. Forbs such as asters and sunflowers are abundant, while sedges are less common. Many prairie plants once used by Native Americans for food and medicine still grow in the Konza, including wild nodding onion, wild plum, prairie turnip, and prairie parsley.

Of the many different insect species found on the Konza, June beetles, dung beetles, lappet moths, butterflies, and grasshoppers are perhaps the most common.

Few amphibians live on this prairie since there are no natural ponds. Depressions that fill with water and artificial ponds originally built to provide water for livestock do provide homes for some species of frogs, toads, and salamanders. The bullfrog is the most common.

Reptiles roaming the Konza include the western box turtle and the collared lizard. The most common reptile is the Great Plains skink, a type of lizard that can detach its tail when attacked and leave it wriggling on the ground to confuse the predator. A new tail grows in quickly.

The open prairie is home to birds that nest on the ground, such as meadowlarks and mourning doves. Cowbirds have an unusual adaptation to life on the open prairie: they lay their eggs in the nests of other birds, who raise the cowbird babies with their own.

Mammals living in the preserve include a large bison herd and small groups of deer. Many rodents live here, with deer mice being the most plentiful. Voles and shrews, some of the smallest mammals in the world, also make the preserve their home.

The Konza Preserve is as a conservation partnership. Most of it is owned by The Nature Conservancy (an organization that establishes private nature sanctuaries in order to preserve plants, animals, and natural communities) and serves as an outdoor research laboratory run by the Division of Biology at Kansas State University. The area was chosen by the National Science Foundation as a long-term ecological research site.

Konza Prairie Preserve
Location: Riley and Geary Counties in Kansas
Area: 8,616 acres (3,487 hectares)
Classification: Tallgrass prairie

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Friends of the Earth, 1717 Massachusetts Ave. NW, 300, Washington, DC 20036-2002, Phone: 877-843-8687; Fax: 202-783-0444; Internet: http://www.foe.org.

Greenpeace USA, 702 H Street NW, Washington, DC 20001, Phone: 202-462-1177; Internet: http://www.greenpeace.org.

Nature Conservancy, Worldwide Office, 4245 North Fairfax Drive, Arlington, VA 22203-1606, Phone: 800-628-6860; Internet: http://www.nature.org.

Sierra Club, 85 2^{nd} Street, 2^{nd} Fl., San Francisco, CA 94105, Phone: 415-977-5500; Fax: 415-977-5799, Internet: http://www.sierraclub.org.

World Meteorological Organization, 7bis, avenue de la Paix Case postale No. 23000, CH-1211 Geneva 2, Switzerland, Phone: 41(0) 22 7308111; Fax: 41(0) 22 7308181, Internet: http://www.wmo.ch.

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Lake and Pond

Lakes and ponds are inland bodies of water. Ponds tend to be shallow and small, and most do not have names. Lakes vary greatly in size and most do have names. Lake Superior, for example, which lies between Canada and the United States, has the greatest surface area of any freshwater lake in the world—31,800 square miles (82,362 square kilometers). Lake Baikal in southern Siberia is the deepest at 1 mile (1.6 kilometers). Baikal holds the most water even though its surface area is less than half that of Lake Superior. Ponds and lakes differ in overall water temperature. Ponds have a uniform temperature throughout, but a lake has two distinct layers: an upper layer affected by air temperature, and deeper water that may be either warmer or colder than the upper layer, depending upon the season.

Less than 1 percent of all the water on Earth is held in lakes and ponds. Even so, the amount is considerable. In North America alone, there are at least 1.5 million ponds, totaling as much as 2 million acres (808,000 hectares) of water. Both lakes and ponds tend to be more numerous in the northern hemisphere and in mountain regions. There are relatively few in South America, for instance, but the northern areas of Canada are a large network of lakes and ponds.

How Lakes and Ponds Develop

All lakes and ponds have a life cycle that begins when they are formed and ends when they are filled in with plant life.

Formation Both lakes and ponds usually form when water collects in undrained depressions, or basins, in the ground and any outlet, such as a stream, does not drain them completely. The source of the water may be precipitation (rain, sleet, and snow), a river, a stream, a spring, or a melting glacier. In any case, there must be enough water to keep the depression

WORDS TO KNOW

Epilimnion: The layer of cold or warm water closest to the surface of a large lake.

Euphotic zone: The zone in a lake where sunlight can reach.

Eutrophication: Loss of oxygen in a lake or pond because increased plant growth has blocked sunlight.

Herbivore: An animal that eats only plant matter.

Hypolimnion: The layer of cold or warm water closest to the bottom of a large lake.

Kettle: A large pit created by a glacier that fills with water and becomes a pond or lake.

Parasite: An organism that depends upon another organism for its food or other needs.

Profundal zone: The zone in a lake where no more than 1 percent of sunlight can penetrate.

Sediments: Small, solid particles of rock, minerals, or decaying matter carried by wind or water.

Seiche: A wave that forms during an earthquake or when a persistant wind pushes the water toward the downward end of a lake.

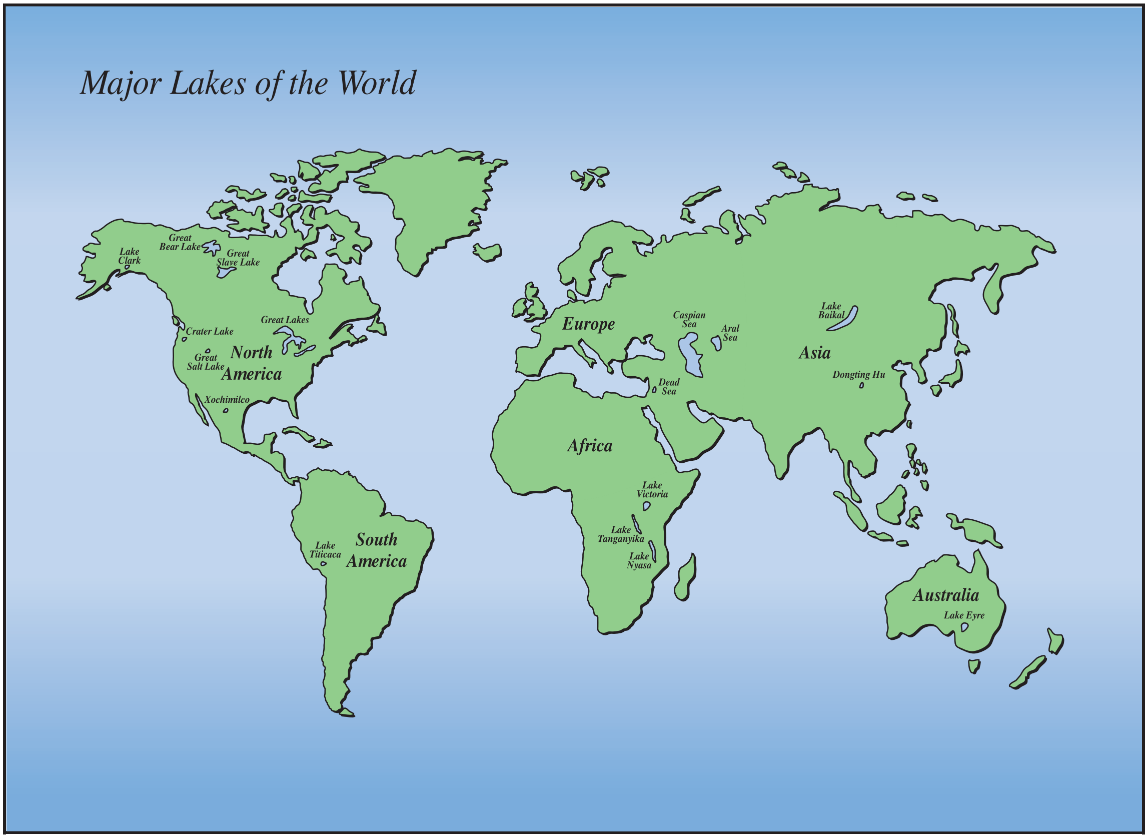
Soda lake: A lake that contains more than 0.1 ounce of soda per quart (3 grams per liter) of water.

filled. In very dry regions, ponds or lakes may form during a rainy season and then disappear when the dry season returns.

Depressions that become ponds and lakes may be created by natural forces, animals, people, and even the wind. Most are made by glacial, volcanic, tectonic (crustal plate movement), or riverine action, and by sinkholes and barriers.

Glacial action During the Ice Ages, starting 2 million years ago, glaciers (gigantic slow-moving rivers of ice) gouged depressions in the land. Many of these depressions filled with water, creating lakes and ponds. Examples include lakes in Canada, the northern United States, Finland, and parts of Sweden. Glaciers on the tops of mountains, such as in Glacier National Park in Montana, still produce lakes by means of the same process, and most mountain lakes originated in this way. Berg Lake in Canada gets its name from the icebergs that break off a glacier sitting along its shoreline. Glacial basins tend to be shallow and rimmed by rocky shorelines.

When glaciers melt, they sometimes leave pits, called kettles, which fill with the meltwater and become ponds, lakes, or wetlands. Prairie regions in North America have many of these kettles, also called prairie potholes.



Volcanic action The craters of extinct or inactive volcanoes often contain lakes. One example is Crater Lake in Oregon. The walls of laval rock surrounding this lake rise to 1,932 feet (589 meters) above its surface. Lakes in craters often contain islands. Some of these islands are cones of ash and lava created when the volcano went through another active period. The largest crater lake in the world is Lake Toba in Sumatra, although it is undergoing changes due to earthquake activity.

Tectonic action Tectonic action refers to movement of Earth's crust during earthquakes. Earth's crust is always in motion causing some pieces to push against one another and others to pull apart. During earthquakes, great cracks may form in the ground. When water fills these cracks, it forms lakes. Examples of lakes created by tectonic action include Lake Tahoe in California and Lake Baikal in Siberia.

Wizard Island is a small volcanic cone in Crater Lake, which is in a crater of an extinct volcano in southern Oregon. IMAGE COPYRIGHT BRYAN BRAZIL, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Riverine action During floods, rivers may overflow their banks, creating shallow floodplain lakes. The Amazon River in Brazil, for example, frequently becomes flooded and thousands of lakes form along its great length. Winding rivers often create oxbow lakes during floods. The river jumps its banks and changes course. The abandoned section, which is curved, or bow shaped, becomes a lake.

Sinkholes Sinkholes are formed when the underlying rock is limestone and a source of water, such as an underground river, dissolves the limestone. The ground overhead collapses, leaving a pit. If the pit fills with water, a lake or pond is formed. Sinkhole lakes may be 50 feet (15 meters) or more deep. Several sinkhole pools, called Silver Springs, are located in northern Florida.

Barriers Barriers of sand, gravel, mud, rock, lava, and glacial debris can dam up a river or stream, and the area behind the dam fills with water. This type of lake is often short lived because the movement and pressure of the water soon cuts through the debris and the lake is drained.

Succession Lakes and ponds are not permanent, even though some lakes may exist for thousands of years. A volcano or tectonic action, for example, may change the structure of the underlying rock, causing the water to drain away. Streams or other sources that feed the lake may change course or dry up, or the climate may change, yielding little precipitation. Most lakes and

The Killer Lakes

In the Cameroon highlands of West Africa is a series of beautiful but deadly lakes that are responsible for killing nearly 2,000 people during the 1980s. Rolling hills covered in tall grasses and lush vegetation are characteristics of this region, and the soil is so rich that many farming communities of the Bantu and Fulani tribes have located there. Legends of the Bantu and Fulani tell of strange floods that destroyed villages and of spirit women who live in the lakes and pull people to their deaths. There is some truth to these legends.

In 1984 the police in a nearby village were told about people dying on the road near Lake Monoun. When they went to investigate, they saw a smokelike cloud drifting outward from the lake that left seventeen people dead in its wake. Lake Monoun and its sister lakes are pools that formed in the craters of inactive volcanoes. It was determined that a small earthquake had shaken up the lower depths of the lake where carbon dioxide gas was suspended like bubbles in a can of soda. All at once these deep waters were forced upward to where the pressure was less, and the gas was released into the air. In high concentrations, carbon dioxide is deadly, as it was in this case when it suffocated everyone in its path.

Before the mystery was solved and the information was made available, similar clouds had erupted from other lakes in the region, taking many lives.

ponds begin to transform as soon as they are created because they gradually fill with sediments (particles of soil and other matter) and dead plant and animal matter. This ecological process is called succession.

Succession usually follows the same pattern. As sediments fill the bottom of the pond or lake, shore plants, such as reeds and grasses, can gain a foothold and grow. Gradually, they begin to move in toward the center of the lake. The increased waste from dead stems and leaves makes the water thick, shallow, and slow moving. Eventually, shrubs and then trees, such as willows, begin to grow. The open water continues to shrink until the area becomes a wetland. As succession continues, the wetland disappears and is replaced by dry ground.

The speed with which succession takes place varies, depending upon the kinds of sediments and the death rate of plants in the region. A small pond can disappear in fewer than 100 years; a lake takes much longer, perhaps several thousand years.

Kinds of Lakes and Ponds

Lakes and ponds can be classified in many ways. One of the most common ways is by chemical composition. They may contain fresh water, salt water, or soda water.

Water Down Under

Groundwater is what its name implies—water beneath the ground. Over time, water from ponds, lakes, and rain or snow trickles down through the earth and collects between layers of rock. When someone digs a well, the water that fills the well is groundwater.

A spring occurs when groundwater breaks through to the surface. Springs may feed lakes, ponds, and natural wetlands. The world's largest reported spring is Ras-el-Ain in Syria, with an average yield of 10,200 gallons (38,700 liters) per second. The largest spring in the United States is Silver Springs in Florida, which averages 6,100 gallons (23,000 liters) per second.

Freshwater lakes and ponds The water in freshwater lakes is relatively pure. It contains many dissolved minerals and salts at very low concentrations. Freshwater lakes tend to be located in temperate or cold regions, and they support much plant and animal life.

Saltwater lakes and ponds The salt found in salt lakes and ponds may be sodium chloride, which is ordinary table salt, or it may include a combination of other types, including magnesium salt. The Great Salt Lake in Utah contains sodium chloride, whereas the Dead Sea between Israel and Jordan contains a combination of salts.

These salts usually enter the water as it dissolves the surrounding rock, or they are carried in by streams. Salt lakes occur primarily in dry climates where evaporation is sped up and the concentration of salt is able to build.

Salt lakes contain at least 0.1 ounce (3 grams) of salt per quart (liter) of water. The minimum amount produces water less salty than seawater, but the concentration in some lakes makes them much saltier than the ocean. The Dead Sea, which has the highest salt content of any lake on Earth, is nine times saltier than ocean water. When these bodies of water dry up, they leave behind a crust of salt, sometimes referred to as white alkali.

Soda lakes and ponds Soda (alkali) lakes and ponds contain minerals that are usually produced in hot, volcanic springs. The primary mineral is sodium bicarbonate, which is similar to baking soda. Lake Natron in Tanzania is an example of a soda lake. Like salt lakes, soda lakes usually occur in hot climates. The water in Lake Natron evaporates quickly under midday temperatures as high as 140°F (60°C), but it is fed by geysers (volcanic springs) that help maintain its size.

To be classified as a soda lake, a lake must contain more than 0.1 ounce (3 grams) of soda per quart (liter) of water. The soda in Lake Natron is so concentrated that in places it is thick and hard enough to walk on. Natron's water kills almost all plant and animal life and can burn human skin seriously enough to require surgery.

The Water Column

The water column refers to the water in a lake or pond, exclusive of its bed or shoreline.

Composition The water in a pond or lake may be fresh, salty, or alkaline; it may be clear or cloudy; it may be polluted or clean. Its characteristics are determined by where it comes from and the nature of its bed or basin. For example, if a river flowing into a lake carries a large quantity of sediment with it, the water in the lake will be muddy.

Zones Different parts of a lake or pond may have different features and support different kinds of plants and animals. These different parts are called zones. Zones may be determined by temperature, vegetation, or light penetration.

Zones determined by temperature Ponds and small lakes often have a uniform temperature throughout because they are relatively shallow. The water in large lakes may form layers based on water temperature. This difference in

Pond Inspiration

Many books have been written about ponds, but few compare to *Walden* by Henry David Thoreau (1817–1862). Thoreau, a famous American writer, wrote his book after living two years beside Walden Pond, a small body of water near Boston, Massachusetts.

Born in 1817, Thoreau was an artist whose own life became the material for his book. In a society rapidly growing more urban and industrial, he believed in the wholeness of nature and in a life of principle. In 1845 he sought solitude and simple living beside Walden Pond, where he could think, write, and discover "the great facts of his existence." He built a small cabin and did some farming. The journals he kept became the basis for his book, which he published in 1854.

The importance of *Walden* and Thoreau's other works were not appreciated during his lifetime. These records of what was basically a spiritual journey are now among the world's finest writings.

Fishermen rowing their boat in Lake Baikal in Siberia, Russia. Lake Bailkal is the deepest lake in the world. IMAGE COPYRIGHT VOVA POMORTZEFF, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Geysers

Deep within Earth is a core of molten rock that, in places, is close enough to the surface to heat groundwater and turn it into steam. When this steam builds up, it forces its way to the surface in a gush of water and vapor called a geyser (GY-zuhr).

Geysers and hot springs usually occur in regions where volcanoes were or are active, and some, such as Old Faithful in Yellowstone National Park, erupt with clocklike regularity. Pools of hot mineral-rich mud may form in the same region. These naturally hot springs and pools were used by humans as early as 190 BC for their healing properties.

Since 1900, scientists have experimented with tapping the heat within Earth for use as a power source. Called geothermal (jee-oh-THUR-muhl) energy, it can be used to drive engines and heat water. In Iceland, many homes and greenhouses are heated using geothermal energy.

temperature prevents the waters from mixing well. In temperate climates (those with warm summers and cold winters) these layers occur seasonally.

In the summer the heat of the sun and the warmth of the air create an upper layer of warm, circulating water called the epilimnion (eh-pih-LIHM-nee-uhn). The colder water, which is heavier and noncirculating, sinks to the bottom where it forms a layer called the hypolimnion (HIGH-poh-lihm-nee-uhn). The zone in between is called the thermocline.

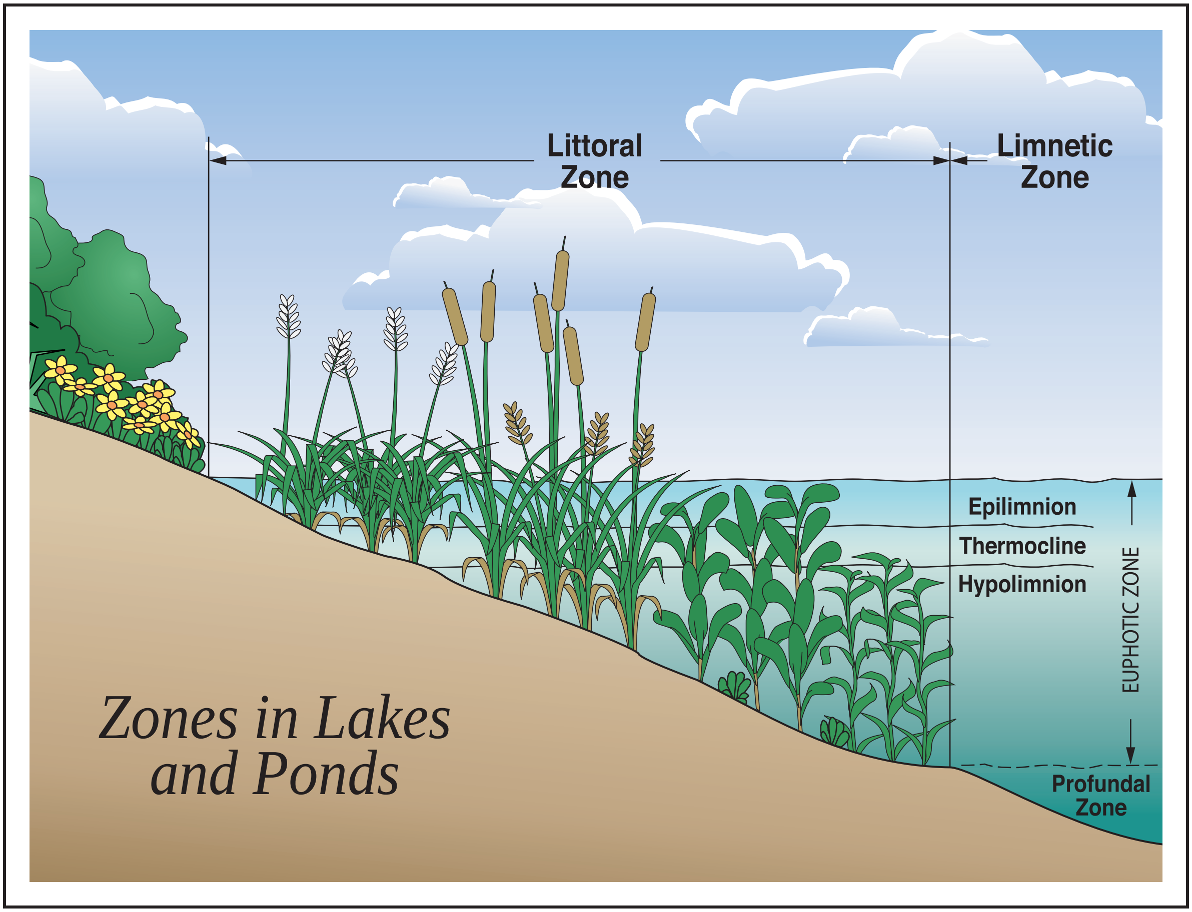
In the autumn, heat in the epilimnion is lost as cooler weather moves in, and the lake achieves about the same temperature throughout. In winter, the epilimnion is exposed to the cold air temperatures and may freeze, forming a layer of ice, while the hypolimnion remains comparatively warm. The layers do not mix again until the spring when the ice thaws.

Zones determined by vegetation Along the edges of a pond or lake, areas of vegetation run somewhat parallel (in the same direction) to the shoreline. Here the soil is marshy and wet. The area where shallow water begins to appear around the roots of plants marks the beginning of the littoral zone. This zone is the area near the shore where plants are rooted at the bottom and light penetrates down to the sediment. This zone supports a large variety of animal life. The width of the littoral zone may vary from a few feet to a few miles.

The limnetic zone is the deeper, central region characterized by open water and no vegetation.

Zones determined by light penetration Deep lakes may be divided into zones based on light penetration. The upper, or euphotic (yoo-FOH-tik) zone is exposed to sunlight and supports the most life. In clear lakes this zone may reach as deep as 165 feet (50 meters). In muddy lakes, the euphotic zones may only be 20 inches (51 centimeters) deep.

The lower, or profundal (proh-FUN-duhl) zone receives no more than 1 percent of sunlight. No plants grow here, although animals frequent this zone.



Circulation Water in a lake is usually in motion, forming both waves and currents.

Waves Waves are rhythmic rising and falling movements in the water. Although waves make the water appear as if it is moving forward, forward movement is actually very small. Most surface waves are caused by wind. Their size is due to the speed of the wind, the length of time the wind has been blowing, and the distance over which it travels. As these influences grow stronger, the waves grow larger.

A seiche (SAYSH) is a wave that forms during an earthquake or when a persistent wind forces the water toward the downwind end of the lake. When the wind ceases, the water flows back and forth from one end of the lake to the other in a rocking motion.

Waves collapse on the shoreline because the water at the bottom of them is slowed by friction as it rolls along the shore. The top water then outruns the bottom and topples over. IMAGE COPYRIGHT ALEXANDER KOLOMIETZ, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Currents Currents are the steady flow of water in a certain direction. Surface currents are caused by persistent winds, the position of landmasses, and water temperature variations.

Winds tend to follow a regular pattern. They generally occur in the same place and blow in the same direction, and the movement of water follows this pattern. When a current meets a landmass, such as an island, it is deflected and forced to flow in a new direction.

Both horizontal and vertical currents below the surface occur when seasonal temperature changes cause layers of water (the epilimnion and hypolimnion) to form. As the layers take shape or break up, the water turns over (warmer water rises and the cooler water sinks). Most freshwater lakes turn over at least once a year and some twice. In salt and soda lakes, the heating and cooling of the upper layer is not strong enough to cause the water to turn over.

Effect of the water column on climate and atmosphere The climate surrounding a pond or lake depends upon where the lake or pond is located. If it is located in a desert country, such as Iran, the climate will be hot and dry. If it sits on top of a mountain in the northern hemisphere, the climate will be cold. Ponds in temperate climates are often affected by seasonal changes. A small pond may completely dry up in summer, or

THE WORLD'S LARGEST LAKES

Lake	Location	Surface Area		Depth	
		Square Miles	Square Kilometers	Feet	Meters
Caspian Sea*	Azerbaijan, Kazakhstan, Turkmenistan, Iran, Russia	144,000	373,000	3,264	995
Lake Superior	Canada, United States	31,820	82,732	1,333	406
Lake Victoria	Kenya, Tanzania, Uganda	26,828	69,484	270	82
Lake Huron	Canada, United States	23,000	59,600	750	229
Lake Michigan	United States	22,300	57,757	923	281
Aral Sea*	Kazakhstan, Uzbekistan	15,500	40,100	177	54
Lake Tanganyika	Burundi, Zambia, Tanzania, Zaire	12,700	32,893	4,708	435
Lake Baikal	Siberia	12,162	31,494	5,315	620
Great Bear Lake	Canada	12,096	31,328	1,299	396
Lake Nyos	Tanzania, Mozambique, Malawi, Cameroon	11,100	28,749	2,300	701

***Saltwater lakes**

freeze to the bottom in winter. Severe spring floods may destroy shoreline plants including the homes and feeding grounds of many animals.

The presence of a large lake can itself create some climatic differences. A large body of water absorbs and retains heat from the sun. In the winter, this stored heat is released into the atmosphere helping to keep winter temperatures around the lake warmer. In summer, when the water temperature is cooler than the air temperature, winds off the lake help cool the nearby region. This is known as the lake-effect. The climate of Chicago, which is located on the shores of Lake Michigan, benefits in this way.

The water in lakes and ponds is partly responsible for the precipitation (rain, sleet, or snow) that falls on land. The water evaporates in the heat of the sun, forms clouds, and falls elsewhere. Large lakes can even influence storms. In winter, for example, as air flows over a lake, it picks up moisture. When the warmer, moister air meets the colder, drier air over land, it produces lake-effect snow. Towns along the eastern shore of Lake Ontario regularly receive 118-157 inches (300-400 centimeters) of snow a year for this reason.

Bodies of water help regulate the levels of different gases in the atmosphere, such as oxygen and carbon dioxide. Too much carbon dioxide in the atmosphere contributes to warmer global temperatures. The presence of ponds and lakes helps moderate such undesirable changes by absorbing some carbon dioxide.

Geography of Lakes and Ponds

The geography of lakes and ponds involves the process of erosion (wearing away) and deposition (dep-oh-ZIH-shun; setting down), which helps determine the different types of shoreline surfaces and landforms.

Erosion and deposition As waves slap against a shoreline they compress (squeeze) the air trapped in the cracks in rocks. As the waves retreat, the air pressure within the rocks is suddenly released. This process of pressure and release widens the cracks and weakens the rocks, causing them to eventually break apart. Waves created by storms in a large lake can be high and forceful. In places where wave action is strong, the water stirs up particles of rock and sand from the lake bed throwing them against the shoreline. As a result, particles in the water produce a cutting action, eroding the shoreline even further.

Some of the chunks and particles eroded from a shoreline may sink to the lake bed. Others may be carried by currents farther along the shore and deposited where there is shelter from the wind and the wave action is less severe. Erosion and deposition can change the geography of a shoreline over time.

Shoreline surfaces The general shape of the shoreline is usually determined by the shape of the surrounding landscape. If the lake or pond is on a flat plain, the shoreline will be broad and level. If it is located in the mountains, the shoreline is likely to be steep and rocky. Beaches that develop along rocky shorelines usually consist of pebbles and larger stones, as the waves carry away finer particles.

Movement of Earth's crust during an earthquake may have given the shoreline a folded appearance. Huge boulders and rocks or piles of gravel and sand may indicate that a glacier once moved across the region. The presence of a river may mean a large quantity of sedimentary deposits on the lake bed or the shoreline near the river mouth. Sandy shores are constantly changing, depending upon the movement of the wind, water, and sand. Some sandy shores may be steep while others have a gentle slope.

Landforms Landforms include cliffs and rock formations; beaches and dunes; spits, bars, and shoals; deltas; and islands.

Cliffs and rock formations Where highlands meet the edge of a lake, cliffs sometimes occur. Waves pounding the cliffs gradually eat into their base, creating a hollowed-out notch. The overhang of the notch may collapse and fall, creating a platform of rubble.

Many shorelines consist of both hard and soft rock. Wave action erodes the soft rock first, sometimes sculpting beautiful shapes, such as arches, along the shore. Caves may be gradually carved into the sides of cliffs, or headlands may be created. A headland is a large arm of land made of hard rock that juts out from shore after softer rock on either side has been eroded away.

Beaches and dunes Beaches are nearly level stretches of land along the water's edge. They may be covered by sand or stones. Sand is small particles of rock, less than 0.08 inches (2 millimeters) in diameter. It may be white, golden, brown, or black, depending upon the color of the original rock. Yellow sand usually comes from quartz and black sand from volcanic rock. White sand may have been formed from limestone.

Putting a Nuisance to Work

A water hyacinth is an aquatic plant that lives in ponds, quiet streams, and ditches. Water hyacinths have large violet flowers that float on top of the water, and some species have long, trailing, feathery roots. In the wrong place, these roots can clog otherwise navigable watercourses and irrigation ditches, which makes the plant a nuisance. The water hyacinth may be able to make up for this annoying tendency with another important characteristic: it can absorb large amounts of pollutants. Researchers are experimenting with using the hyacinth in water-treatment systems and sewage-disposal plants.

Sand is carried by water and wind. When enough sand has been heaped up to create a ridge or hill, it is called a dune. Individual dunes often travel, as the wind changes their position and shape. They tend to shift less if grasses and other plants take root in them and help hold them in place.

Spits, bars, and shoals A spit is a long narrow point or strip of deposited sand, mud, or gravel that extends into the water. A bar is an underwater ridge of sand or gravel formed by currents that extends across a channel. Shoals are areas where enough sediments have accumulated that the water is very shallow. Shoals and bars make navigation dangerous for boats.

Deltas Where rivers meet a lake, huge amounts of silt (a type of very small soil particle) can be carried by river currents from far away and deposited in the lake along the shoreline. Large rivers can dump so much silt that islands of mud build up forming a fan-shaped area called a delta. The finer debris that does not settle as quickly may drift around the lake, making the water cloudy.

Large rivers deposit silt as the water slows down, entering a lake. This causes mud to build up, creating islands in a fan shape. IMAGE COPYRIGHT MIRCEA BEZERGHEANU, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Islands Islands are landmasses completely surrounded by water. In lake basins dug out by glaciers, islands may be formed from large piles of debris created when the glacier moved across the area. In crater lakes, islands may have formed from secondary cones that developed when the volcano became active again. Other islands may have been created when the water surrounded a high point of land, cutting it off from the shore on all sides.

Basins Basins of ponds or lakes slope gently from the shore down to the center, where the water is deepest. Basins are usually covered with sediments. Some sediments are formed by waste products and dead tissues of plants and animals. Others consist of clay, stone, and other minerals.

Elevation Lakes occur at all altitudes. For example, Lake Titicaca, which lies between Bolivia and Peru, is 12,500 feet (3,810 meters) above sea level, while the Sea of Galilee, located between Israel and Jordan, is 695 feet (212 meters) below sea level. (Sea level refers to the average height of the surface of the sea.)

Plant Life

Most lake and pond plants live in the waters around the shoreline. They include microscopic, one-celled organisms; plants commonly referred to as seaweed; and many other types of grasses and flowering plants.

The water offers support to plants. Even a small tree on land requires a tough, woody stem to hold it erect, but underwater plants do not require woody portions because the water helps to hold them upright. Their stems are soft and flexible, allowing them to move with the current without breaking.

Plants in and around a lake or pond may be classified as submergent, floating aquatic (water), or emergent, according to their relationship with the water.

A submergent plant grows beneath the water. Even its leaves are below the surface. Submergents include milfoil, pondweed, and bladderwort, an insect-eating plant.

Floating aquatics float on the water's surface. Some, such as the water hyacinth, water lettuce, and duckweed have no roots anchored in the bottom soil. Others, such as water lilies and pondweed, have leaves that float on the surface, stems that are underwater, and roots that anchor them to the bottom.

Water lilies and lily pads are common lake and water plants. COPYRIGHT © 2006 KELLY A. QUIN.

An emergent plant grows partly in and partly out of the water. The roots are usually underwater, but the stems and leaves are at least partially exposed to air. They have narrow, broad leaves, and some even produce flowers. Emergents include reeds, rushes, grasses, cattails, and water plantain.

Plants and plantlike organisms that live in lakes and ponds can be divided into four main groups: algae (AL-jee), fungi (FUN-ji), lichens (LY-kens), and green plants.

Algae Most lake and pond plants are algae. (It is generally recognized that algae do not fit neatly into the plant category.) Algae inhabit even the salt and soda lakes that are unfriendly to other life forms.

Some forms of algae are so tiny they cannot be seen without the help of a microscope. Other species, like many seaweeds, are larger and remain anchored to the bed of the lake or pond.

Growing season Algae contain chlorophyll, a green substance used to turn energy from the sun into food. As long as light is available, algae can grow. Growth is often seasonal. In some areas, such as the northern hemisphere, the most growth occurs during the summer when the sun is more directly overhead. In temperate (moderate) zones, growth peaks in the spring but continues throughout the summer. In regions near the equator, no growth peaks occur. Instead, growth is steady throughout the year.

Food Most algae have the ability to make their own food by means of photosynthesis (foh-toh-SIN-thih-sihs). Photosynthesis is the process by which plants use light energy to change water and carbon dioxide from the air into the sugars and starches they use for food. A by-product of photosynthesis is oxygen, which combines with water and enables aquatic animals, such as fish, to breathe. These types of algae grow in the euphotic, or sunlit zone where light is available for photosynthesis. Other types absorb nutrients from their surroundings.

Algae require other nutrients that must be found in the water, such as nitrogen, phosphorus, and silicon. In some lakes, when deeper waters rise during different seasons and mix with shallower waters, more of these nutrients are brought to the surface. Algal growth increases when nitrogen and phosphorus are added to a body of water by sewage or by runoffs from farmland.

Reproduction Algae reproduce in one of three ways. Some split into two or more parts, each part becoming a new, separate plant. Others form spores (single cells that have the ability to grow into a new organism). A few reproduce sexually, during which cells from two different plants unite and a new plant is created.

Common lake and pond algae Two types of algae are commonly found in lakes and ponds: phytoplankton and macrophytic algae.

Phytoplankton float on the surface of the water, always within the sunlit zone. Two forms of phytoplankton, diatoms and dinoflagellates (dee-noh-FLAJ-uh-lates), are the most common. Diatoms have simple, geometric shapes and hard, glasslike cell walls. They can live in colder regions and even within arctic ice. Dinoflagellates have two whiplike attachments that make a swirling motion. They often live in tropical regions (regions around the equator).

Macrophytic algae (*macro* means large) usually grow attached to the bottom of the lake or pond and are submergents.

Fungi As with algae, fungi and lichens do not fit neatly into the plant category. Fungi are plantlike organisms that cannot make their own food by means of photosynthesis. Instead, they grow on decaying organic (derived from living organisms) matter or live as parasites on a host. A parasite is an organism that depends upon another organism for its food or other needs. Fungi grow best in a damp environment, which makes the edges of lakes and ponds a favorable home. Common fungi include mushrooms, rusts, and puffballs.

Lichens Lichens are combinations of algae and fungi that tend to grow on rocks and other smooth surfaces. The algae produces food for both itself and the fungus by means of photosynthesis. In turn, it is believed the fungus protects the algae from dry conditions.

Green plants Hydrophytes are green plants found growing in the water or in very wet places where the soil is saturated (soaked with water). They

Waterproof Roofing

Reeds have been used for thousands of years as a building material. During the Middle Ages (500–1500) in England, for example, people used reeds to make thatched roofs for their houses. The reeds are bundled tightly together and, when put in place, keep out both rain and cold. If made by a skilled worker with reeds of good quality, a thatched roof will remain waterproof for up to forty years.

Mexico's Floating Gardens

The Aztecs, the original settlers of Mexico, built rafts that they floated on Lake Xochimilco (soh-chee-MEEL-koh), which lies about 12 miles (19 kilometers) southeast of Mexico City. The rafts were used to grow flowers, vegetables, and fruits. But because the lake was shallow, the rafts soon became rooted in the water. Eventually a city formed, and today Xochimilco is famous for these permanent floating gardens.

are similar to plants that grow on dry land and are found along the shoreline of lakes and ponds. Sedges are an example. They have roots adapted to this environment. Large beds of these plants slow the movement of water and help prevent erosion of the shoreline. Some water animals use them for food and hiding places.

Mesophytes such as reeds, need moist, but not saturated soil. They occupy the emergent zone between the water-covered area and dry land. The plants that grow on the dry shore are called xerophytes. They are able to survive with little moisture and are more typical of dry, arid lands.

Most green plants need several basic things to grow: light, air, water, warmth, and nutrients. Light and water are in plentiful supply near a lake or pond. Nutrients, primarily nitrogen, phosphorus, and potassium, are usually obtained from the soil. Some soils are lower in these nutrients. They may also be low in oxygen so many lake and pond plants have special tissues with air pockets that help them to breathe.

Common lake and pond green plants Typical green plants found around lakes and ponds include water lilies, pondweed, and duckweed.

Water lilies are found in both temperate and tropical regions. They have large, nearly circular leaves that float on the water and beautiful white, yellow, pink, red, scarlet, blue, or purple flowers that float or are supported by stems above the water's surface. Ancient peoples considered the water lily a symbol of immortality because it arose from dried-up pond beds after the return of the rains.

Pondweeds usually have both floating and submerged leaves, although some species are completely submerged. The flowers appear above the water on spikes and bear a nutlike fruit. Pondweeds are important food plants for ducks.

Growing season Climate and precipitation affect the length of the growing season. Warmer temperatures and moisture usually signify the beginning of growth. In regions that are cold or receive little rainfall, the growing season is short. Growing conditions are also affected by the amount of moisture in the soil, which ranges from saturated to dry.

Reproduction Green plants reproduce by several methods. One is pollination, in which the pollen from the male reproductive part of a plant, called the stamen in flowering plants, is carried by wind or insects to the female reproductive part of a plant, called a pistil in flowering plants. Pollen-gathering insects distribute pollen at different times of the day according to when a plant's flower is open. Water lilies, for example, which are closed in the morning and evening, open during midday when the weather is warmer and insects are more active. Instead of pollination, some shoreline plants grow rhizomes, which are stems that spread out under water or soil and form new plants. Reed mace and common reeds develop underground rhizomes.

Duckweeds are small water plants that may be the size of a grain of rice that float on the surface during spring and summer. During the growing seasons the plants produce an excess of starch that weighs them down, so that by autumn they sink to the bottom. The starch keeps them alive throughout the cold months, and in the spring they float to the surface again.

Snowy white egret looks for fish in Florida wetland marsh pond covered with duckweed. IMAGE COPYRIGHT FLORIDASTOCK, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Endangered species Changes in the habitat, such as succession, pollution, and new weather patterns, endanger lake and pond plants. Lakes and ponds are endangered by people who collect the pond plants, and who use insecticides (insect poisons) and herbicides (plant poisons) on farms and gardens. These poisons contaminate nearby rivers and streams, which then contaminate the lake or pond. Herbicides in particular are harmful to plant life. Other threats include fertilizer runoff from nearby farms. Saw grass, for example, struggles to survive in water polluted by fertilizer.

Animal Life

Freshwater lakes and ponds support many species of aquatic and land animals. Some aquatic animals swim freely in the water; others live along the bottom. Many land animals, such as opossums, raccoons, and deer, visit lakes and ponds for food and water.

Water Walkers

What allows some insects, such as the water strider, to skate along the surface of the water without sinking? A water strider is so small that its body is extremely light. Within a lake or pond, each molecule of water has similar molecules attracting it uniformly in every direction. At the water's surface, these molecules crowd together to produce what is called surface tension. If a creature or an object is small and light enough, these tightly packed molecules will support its weight. A steel sewing needle, for example, can float on water if it is gently lowered to rest on the surface.

Few species of animals live in the waters of salt and soda lakes. Those that do provide food for birds and other animals. Ducks and wading birds feed on the microscopic brine shrimp that flourish in these lakes. These types of lakes are usually found in desert areas and they may be the only source of food for many miles.

Microorganisms Microorganisms cannot be seen by the human eye without the use of a microscope. Those found in ponds and lakes include transparent daphnia, creatures that catch food with the hairs on their legs; rotifers that sweep algae into their mouths with swirling hair-like fibers; and bacteria. Bacteria make up a large portion of the microscopic organisms found in lakes and ponds. They aid in the decomposition (breaking down) of dead organisms. Bacteria tend to exist in great numbers near the shoreline where larger organisms are found.

Invertebrates Invertebrates are animals without a backbone. They range from simple worms to more complex animals such as insects and crabs.

Many species of insects live in lakes and ponds. Some, like the diving beetle, spend their entire lives in the water. Others, like mosquitoes, live in the water as larvae but are able to breathe air through small tubes attached at the end of their bodies. They leave the water when they become adults. Another type of insects, like backswimmers, have gills, just like fish, which enable them to obtain oxygen from the water.

Crustaceans, such as shrimp, and mollusks, such as mussels, are invertebrates with a hard outer shell that often inhabit lakes and ponds. One species, the brine shrimp, favors salt and soda lakes where it is able to filter out the harmful minerals.

Leeches feed on blood, and as they feed they produce a blood-thinning chemical called hirudin. Hirudin is used for medical purposes, and about 26,000 pounds (57,200 kilograms) of leeches are caught each year commercially. Their numbers have diminished as a result.

Common lake and pond invertebrates Invertebrates common to lakes and ponds include fisher spiders, leeches, and dragonflies.

Water spiders can stay suspended over water, aided by the air bubbles under their feet. IMAGE COPYRIGHT BASEL101658, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Fisher spiders are predators that feed on insects and tadpoles. The fisher's body is covered with hairs that help distribute its weight and allow it to walk on water. If the spider is submerged, the hairs trap a coating of air so the animal can remain underwater for a long period of time and still breathe.

Leeches are slick, flat parasites that live on the blood of other animals. Some attack fish, and others attack snails, reptiles, and mammals, including humans. Turtles, for example, often have a ring of leeches around their eyes and necks. As it feeds, the body of the leech swells with blood. Many species feed only occasionally because they can store food in their digestive systems.

Dragonfly nymphs, the youthful form of the adult insect, are among a lake or pond's dominant carnivores (meat eaters). They will eat anything smaller than themselves, including fish, snails, and other insects. Some stalk their prey; others lie in wait and nab it as it passes. The nymph grasps the victim with its lower lip and pulls it into its mouth.

Food Some insects feed underwater as well as on the surface. They may be either plant eaters, meat eaters, or scavengers that eat decaying matter. The giant water bug is a 3-inch-long (76-millimeter-long) predator that grasps fish, frogs, and other insects in its powerful legs, paralyzes them with injections of poison, and sucks out their body fluids.

The diets of other invertebrates also vary. Some snails are plant feeders that eat algae, whereas crabs are often omnivorous, eating both plants and animals.

Reproduction Most invertebrates that are insects have a four-part life cycle. The first stage is spent as an egg. The second stage is the larva, which may actually be divided into several stages as the larva increases in size and sheds layers of the outer skin. The third stage is the pupal stage, during which the insect lives in yet another protective casing. The pupal stage is the final stage of development before emerging as an adult.

Amphibians Amphibians, including frogs, toads, newts, and salamanders, are vertebrates, which means they have a backbone. Amphibians live at least part of their lives in water. They must usually remain close to a

Bullfrogs are the largest North American frog. IMAGE COPYRIGHT PAUL S. WOLF, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

water source because they breathe through their skin, and only moist skin can absorb oxygen. If they are dry for too long, they will die.

Amphibians are cold-blooded animals, which means their body temperatures are about the same temperature as their environment. They need the warmth they get from the sun in order to be active. As temperatures grow cooler, they slow down and seek shelter. In cold or temperate regions, some amphibians hibernate (remain inactive) and dig themselves into the mud. When the weather gets too hot, they go through a similar period of inactivity called estivation.

Common lake and pond amphibians The most common lake and pond amphibians are salamanders, newts, frogs, and toads. They can be found all over the world, primarily in fresh water.

The bullfrog is the largest North American frog. Its body measures 8 inches (20 centimeters) in length and its legs another 10 inches (25 centimeters). Long legs enable it to leap 15 feet (4.6 meters). A bullfrog spends most of its time floating in the water or diving to the bottom in search of food. It eats insects, crayfish, smaller frogs, small birds, and small mammals.

Food In their larval form, amphibians are usually herbivorous (plant eating). Adults are usually carnivorous, feeding on insects, slugs, and worms. Those that live part of their lives on land have long, sticky tongues with which they capture food.

Reproduction Most amphibians lay jellylike eggs in the water. Depending on the species, frogs can lay as many as 50,000 eggs, which float beneath the water's surface. Frog eggs hatch into tadpoles (larvae) that can swim, and breathe through gills. Spotted newts hatch in the water and live there as larvae, developing gills. Later, they lose their gills and live for a time on dry land. Two or three years later, they return to the water where they live the remainder of their lives.

Reptiles Reptiles are cold-blooded vertebrates that depend on the temperature of their environment for warmth. They are more active when the weather and water temperature become warmer. Many species of reptiles, including snakes, lizards, turtles, alligators, and crocodiles, live in temperate and tropical lakes.

Many reptiles go through a period of hibernation in cold weather because they are so sensitive to the temperature of the environment. Turtles, for example, bury themselves in the mud. They barely breathe and their energy comes from stored body fat. When the weather becomes very hot and dry, some reptiles go through estivation, another inactive period similar to hibernation.

Common lake and pond reptiles Two well-known lake and pond reptiles are the grass snake and the painted turtle.

The grass snake is found in Europe, western Asia, and North Africa. Averaging a length of about 28-47 inches (70-120 centimeters), its diet consists primarily of frogs, newts, and fish. Although they do not spend all of their time in water, grass snakes are good swimmers and obtain most of their food from lakes and ponds.

The painted turtle usually lives in shallow, muddy, freshwaters of North America. It grows to between 3.5 and 10 inches (9 and 25 centimeters) and can be identified by the red and yellow markings on their dark colored shell.

Food All snakes are carnivores. Many that live around lakes and ponds, including the banded water snake, eat frogs, small fish, and crayfish. The pond turtle is an omnivore. When it is young it feeds on insects, crustaceans, mollusks, and tadpoles. Adult turtles eat primarily wetland plants.

Reproduction The shells of lizard, alligator, and turtle eggs are either hard or rubbery, depending upon the species, and do not dry out easily. Most species bury their eggs in warm ground, which helps them hatch. The eggs of a few lizards and snakes remain inside the female's body until they hatch, and the females give birth to live young.

The Monster of Loch Ness

Since the Middle Ages (500–1500), people have reported seeing a huge, serpentlike monster swimming in Loch Ness, a deep lake (754 feet; 230 meters) in northern Scotland, and the largest lake in Great Britain. The first recorded sighting was made in 565 when Saint Columba came upon the burial of a man said to have been bitten to death by the monster. According to one account, Saint Columba himself saw the creature.

In 1933, the monster, referred to as Nessie, attracted the attention of the news media when a man and woman driving by the lake noticed a great commotion of water in the middle, and for several minutes they watched "an enormous animal rolling and plunging." The incident was widely reported.

Since then, many people have tried to find evidence of the creature using such equipment as sonar (sound vibration technology) and even a submarine. In 1972 and 1975, an American expedition sponsored by the Academy of Applied Science obtained startling underwater time-lapse pictures that some researchers believe show a large animal swimming submerged in Loch Ness. A 1987 British expedition failed to confirm the presence of such a creature, and most scientists do not believe Nessie exists.

Crocodiles and alligators keep their eggs warm by laying them in nests, which can be simple holes in the ground or constructions above the ground made from leaves and branches.

Fish Fish are cold-blooded vertebrates. Lakes and ponds support two basic types. The first grouping are parasites and include lampreys, which attach themselves with suckers to other animals and suck their blood for food. The second grouping, the bony fishes, are the most numerous. They use fins for swimming and gills for breathing. Some fish can survive in polluted waters. Others, such as some African and Asian species of catfish, can breathe air and may live for a short time on land.

Many species of fish, such as sticklebacks, swim in schools. A school is a group of fish that swim together in a coordinated manner. The purpose of a school is to discourage predators. Also, the more eyes watching, the more likely it is that a predator will be seen before it can strike.

In the winter, most lakes freeze only on the surface. This surface ice helps insulate the deeper water by trapping the warmth, and allowing fish down below to survive. The ice is comparatively thin, so light can still reach submerged plants and they can photosynthesize, which helps put oxygen into the water, enabling the fish to breathe.

Common lake and pond fish Typical lake and pond fish include the pike and the carp.

Pike are long, narrow, streamlined fish that live in shallow lakes and large ponds. They may grow as large as 80 pounds (36 kilograms), depending on the size of their habitat. The largest type of pike is the muskellunge, which is found in North American waters. Other species live in Europe and Russia.

Pike are predators and hide among water plants where their striped and spotted bodies blend in with the surroundings. They move swiftly and catch prey in their sharp teeth. When young, they feed on insects and worms, but large adults will attack water birds and small mammals.

Carp prefer warm, weedy water and are found across Europe, North America, South America, and parts of Asia, Africa, Australia, and New Zealand. The world's largest known carp, the giant Siamese carp, weighed 265 pounds (120 kilograms) and was caught in the lakes of Thailand.

Carp are resistant to pollution and can survive where other fish die. When young, they eat insect larvae and crustaceans. As adults, they eat invertebrates and aquatic plants.

Food Some fish eat plants while others depend upon insects, worms, and crustaceans (shellfish). Larger fish often eat smaller fish, and a few species feed on carrion (dead bodies). Most fish specialize in what they eat. Bluegills, for example, feed on insect larvae, and pumpkinseed fish eat snails. Some fish feed on the surface, and others seek food in deep water.

Reproduction Most fish lay eggs. Many species abandon the eggs once they are laid. Others build nests and care for the new offspring. Still others carry the eggs with them until they hatch, usually in a special body cavity, or in their mouths.

Birds Many different species of birds live on or near lakes and ponds. These include many varieties of wading birds, waterfowl, and shore birds. Most visit lakes or ponds in search of food, and certain species use them as nesting places.

Common lake and pond birds Birds found around lakes and ponds can be grouped as wading birds, shore birds, waterfowl, or birds of prey.

Wading birds, such as herons, have long legs for wading through shallow water. They have wide feet, long necks, and long bills that are used for nabbing fish, snakes, and other food. Herons are common in

Swans are well adapted for swimming because their feet are close to the rear of their bodies, and their feet are webbed. IMAGE COPYRIGHT OTMAR SMIT, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

North America, Europe, and Australia, and there are about 100 species worldwide.

Shore birds, such as the plover or the sandpiper, feed and nest along the banks of lakes and ponds. They prefer shallow water. The ruddy turnstone, a stocky shore bird with orange legs, is named for its habit of overturning pebbles and shells in search of food.

Waterfowl are birds that spends most of their time on water, especially swimming birds such as ducks, geese, or swans. Their feet are close to the rear of their bodies, and the skin between their toes is webbed. This is good for swimming but awkward for walking and causes them to waddle. Their bills are designed for grabbing the vegetation, such as sedges and grasses, on which they feed. There are approximately 150 species of these types of birds.

The fish eagles, which are birds of prey, hunt exclusively in freshwater. The bald eagle, the national bird of the United States, occasionally hunts for fish, as do kingfishers and osprey.

Food Nearly all birds must visit a source of fresh water each day to drink, and many feed on aquatic vegetation or the animals that live in lakes and ponds. An adaptation of birds to aquatic life is their beaks, or bills. Some beaks, like that of the kingfisher, are shaped like daggers for stabbing prey such as frogs and fish. Others have a slender bill, like the least sandpiper, designed to probe through the mud in search of food, such as insect larvae and small mollusks.

Reproduction All birds reproduce by laying eggs. Male birds are typically brightly colored to attract the attention of females. After mating, female birds lay their eggs in a variety of places and in nests made out of many different materials. Different species of birds lay varying numbers of eggs. The mute swan lays five to seven eggs, which hatch in about thirty-six days. One parent usually sits on the nest to keep the eggs warm.

Moose feed on twigs, bark, and saplings, as well as aquatic plants. IMAGE COPYRIGHT CALEB FOSTER, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Mammals Mammals are warm-blooded vertebrates covered with at least some hair, they bear live young, and nurse with the mother's milk. Aquatic mammals, such as muskrats, have waterproof fur and partially webbed toes for better swimming. Other mammals, such as raccoons, often visit lakes and ponds for food or water but spend little time in the water.

Common lake and pond mammals Although many mammals visit lakes and ponds for food and water, some species spend most of their time in the water. These include muskrats, otters, water shrews, water voles, beavers, and, in summer, even moose.

The water vole is a mouselike rodent that is not a good swimmer but an excellent diver. It lives in burrows dug in the bank of a lake or pond. It eats mainly reeds, sedges, and other shoreline plants, as well as acorns and beechnuts. Nuts are usually stored for use in winter because the vole does not hibernate. The water vole is found in Europe and parts of Russia, Siberia, Asia Minor, and Iran.

At about 4 feet (1.3 meters) long, the beaver can weigh as much as 65 pounds (30 kilograms). The long, reddish-brown fur of the beaver is warm and waterproof, allowing it to swim in icy water. The toes on the hind feet are webbed for swimming, and its tail is shaped like a flat paddle, which helps it maneuver through the water. The front feet resemble small hands, enabling the beaver to carry things. Its large front teeth allow it to cut down trees and other vegetation. Beavers feed mainly on bark from aspen, willow, poplar, birch, and maple trees.

Beavers are social animals who live and work in groups. They live in lodges, a network of tunnels and burrows deep within log structures

Beavers are very industrious animals, and can be seen working on their dams that they use for shelter. IMAGE COPYRIGHT JOSEPH DIGRAZIA, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

called beaver dams. Beavers build these dams by cutting down small trees with their sharp teeth. They then pile logs and sticks across small rivers and streams, damming them up and creating ponds. The lodge usually has an underwater entrance and air holes for ventilation.

The North American beaver once ranged over the continent from Mexico to Arctic regions. It was widely hunted for its fur and for a liquid called castorium, produced in the beaver's musk glands and used in perfume. As a result, beaver numbers are now greatly reduced, and it is confined largely to northern wooded regions. Beavers were once common throughout northern Europe but are virtually extinct there, except in some parts of Scandinavia, Germany, and Siberia.

The moose is the largest member of the deer family. The largest on record weighed 1,166 pounds (528 kilograms). Moose antlers may span more than 6 feet (2 meters). They feed on twigs, bark, and saplings in winter, and they spend many hours in lakes and ponds in warm weather where they eat aquatic vegetation. They will even submerge completely to get at the roots of water plants.

Moose are found in wooded regions of North America. In other countries they are called elk (a close relative) and may be found in Norway, Sweden, Russia, and northern China.

Food Certain aquatic mammals, like the otter, are carnivores, eating rabbits, birds, and fish. Muskrats are omnivores, and they eat both animals, such as mussels, and plants, such as cattails. Beavers are herbivorous and eat trees, weeds, and other plants.

Reproduction Mammals give birth to live young that have developed inside the mother's body. Some mammals are helpless at birth, while others are able to walk and even run almost immediately. Many are born with fur and with their eyes and ears open. Others, like the muskrat, are born hairless and blind.

Endangered species As lakes and ponds are filled in or polluted, many species of migratory birds are threatened because they can no longer use them for finding food or as nesting areas. Their numbers decline as a result.

Prehistoric Lake Cabins

During several prehistoric periods, early humans often built homes and villages near the waters of a lake or a marsh. Probably in anticipation of flooding, the homes were built on platforms or artificial mounds. The most famous platform lake dwellings are those of the late Neolithic and early Bronze Ages (approximately 6,000 years ago) found in Switzerland, France, and northern Italy. One village contained about ninety circular huts constructed of close-set vertical timbers. Individual homes called crannogs were built on artificial mounds or islands in certain parts of Ireland and Scotland.

Human Life

Since prehistoric times, lakes and ponds have played an important role in the lives of the people who lived in the surrounding region.

Impact of lakes and ponds on human life People use lakes and ponds for water and food, for recreation and building sites, for transportation, and for industrial purposes.

Water Many lakes, such as Lake Michigan, are sources of drinking water, as well as water for such things as bathing, laundry, and power generation for nearby communities. The world's use of water has tripled since 1950 and in the United States alone, each person uses an average of 130 gallons of fresh water each day. In developed countries, about half the supply is used by industry. In less wealthy countries, 90 percent is used for crops and irrigation.

Food The fish and plants in lakes and ponds are often a source of food for humans. Most fish used for food come from the ocean, but commercially important freshwater fish include catfish, lake trout, bass, perch, and whitefish. Some aquatic plant species, such as water chestnuts and watercress, are also popular foods. Farmers often use aquatic plants, such as marsh grass and sedges, for feeding livestock.

Recreation and building sites Lakes and ponds are popular sites for sport fishing, swimming, boating, and nature appreciation. During

Hook, Line, and Sinker

Ever since the first humans tried to snatch minnows (tiny fish) from a pond, fishing has not only been a source of food, but also a popular sport. Ancient Egyptian drawings show fishing scenes, and the sport is mentioned in writings from China, Greece, Rome, and the Middle East.

In the United States alone, about 36.5 million freshwater fishing licenses are issued each year. The largest freshwater sport fish is the white sturgeon. Other popular freshwater fish include black bass, various types of trout, sunfish, crappies, salmon, perch, pike, muskies, sturgeon, and shad.

warm months, many lakes are crowded with vacationers, and in urban areas their shorelines have become popular sites on which to build homes. Artificial lakes or ponds may be created to add beauty and wildlife to a residential area.

Transportation Large lakes, such as the Great Lakes in North America, provide water transportation. The Great Lakes were a way for settlers to travel to the interior of the North American continent. They are still important to commercial vessels and even ocean-going ships, because they are linked to the ocean by the St. Lawrence Seaway. Smaller lakes may be important for local boat traffic.

Other resources Lake and pond plant materials can be used for building. Reeds are used for huts in Egypt and in stilt houses in Indonesia. Sediments, such as clay and mud, may be used to manufacture bricks.

Lake and pond fish provide more than just food, yielding such products as fish oils, fish meal, fertilizers, and glue.

Shoreline properties are popular places for people to live and relax. IMAGE COPYRIGHT THOMAS BARRAT, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

The water in lakes and ponds may be used to cool power stations and for other industrial purposes. Some industries have used lakes and ponds as dumpsites for industrial chemicals causing serious environmental damage.

Impact of human life on lakes and ponds The important role of lakes and ponds for plant and animal communities, for human life, and for the environment has not always been appreciated. Many ponds have been drained to eliminate mosquitoes and prevent diseases, to increase land for farming, and to make room for development. The water in others has been carelessly used for irrigation or industrial purposes.

Water supply Although all water on Earth is in constant circulation through evaporation and precipitation, some regions may have a limited supply. As populations grow, the supply diminishes even more. In some regions, forests are cut down and replaced by farms. Since trees help conserve underground water, much of this water may be lost. Ponds gradually disappear because they are often supplied by groundwater, springs, and lakes.

Irrigation practices can cause damage, especially in desert regions, because there is not enough precipitation to replace the water used to water crops. The Aral Sea, a large lake in Central Asia has shrunk to half its original surface area because so much water has been removed to irrigate farms in the area.

Use of plants and animals Many freshwater lakes used for recreation have been overfished, and attempts to stock the lakes with commercially raised fish are not always successful. Overfishing is often more serious in lakes where the local population depends upon fish for their daily food. The fish are rarely restocked and their numbers never recover.

Overdevelopment People may wish to live near a lake or pond for its beauty and a sense of being close to nature, but overdevelopment can destroy the very things they are seeking. Overdevelopment results in erosion of the shoreline and loss of the scenic value. Instead of blue water and trees, residents look out on cars and concrete.

Quality of the environment Pollution by communities, industries, shipping, and poor farming practices has led to poisoning of water and changes in its temperatures. Several environmental problems, including accelerated eutrophication (YOU-troh-fih-kay-shun; becoming over enriched with nutrients) and acid rain, are issues that affect the quality of water in lakes and ponds.

Lakes of the Poets

The Lake District in northwestern England is a region of mountains, lakes, and waterfalls famous not only for its beauty but also for the many great poets it inspired. William Wordsworth (1770–1850), Samuel Taylor Coleridge (1772–1834), and Robert Southey (1774–1843) all lived in the district.

The Lake District National Park, established in 1951, covers an area of 866 square miles (2,243 square kilometers) and takes in England's largest lakes and highest mountains, including Scafell Pike. Lakes include Lake Windermere, Ullswater, Bassenthwaite Lake, Derwent Water, and Coniston Water.

Eutrophication occurs when fertilizers, especially nitrogen and phosphorus, used in farming get into lakes and ponds, spurring a greatly increased growth of algae. These algae form a thick mat on the water's surface and block the sunlight, causing submerged plants to die. As the dead plants decay, oxygen in the water decreases. Water with little oxygen cannot support most plants and animals. Some of the world's major lakes, such as Lake Geneva in Switzerland, suffer from eutrophication. Eutrophication results in the lake becoming a wetland (an area where the soil is saturated with water for most of the year).

Acid rain is a type of air pollution dangerous to lakes and ponds. It forms when industrial pollutants, such as sulfur or nitrogen, combine with moisture in the atmosphere to form sulfuric or nitric acids. These acids can be carried long distances by the wind before they fall, either as dry deposits or as rain or snow. Acid rain can damage both plant and animal life. It is especially devastating to amphibians such as salamanders because their skin is so thin and permeable (able to pass through). The pollutants from acid rain pass right through the skin and enter into their bodies.

The Ramsar Convention The U.S. Department of the Interior, the U.S. Fish and Wildlife Service, and many environmental groups are working to preserve lakes and ponds and to create new ones. The Convention on Internationally Important Wetlands was signed by representatives of many nations in Ramsar, Iran, in 1971. Commonly known as the Ramsar Convention, it is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.

Native peoples Humans have always lived near lakes and ponds because they provide a source of food and fresh water. Two groups that continue to depend on lakes for their survival are the Turkana in Kenya and native peoples of the Andes Mountains in South America.

The Turkana The Turkana people live along the shores of Lake Rudolf in Kenya, renamed Lake Turkana. It covers an area of 2,433 square miles (6,405 square kilometers) and supports many fish species.

The Turkana did not always depend upon the lake for their livelihood. Until the 1960s they were nomads and raised herds of camels, goats, and cattle that they used for milk and blood, their primary foods.

In the 1960s a severe drought (extremely dry period) struck the region and many animals died, causing famine among the Turkana. The people turned to fishing and discovered Lake Turkana to be a rich source of large Nile perch and a smaller fish called tilapia. This discovery changed the Turkana's lifestyle. They began to catch fish for food, some of which they sold in nearby towns and cities.

The Turkana are having to change their lifestyle again, because Lake Turkana is shrinking, becoming more saline (salty), and has been overfished. The region gets less rainfall than before, and at least one of the rivers that feed the lake has dried up. Many Turkana have gone back to raising animals, although this cannot be a permanent solution because the drier climate has reduced grazing land.

Island People of Lake Titicaca Lake Titicaca (tee-tee-KAH-kah) is the highest navigable lake on Earth at 12,580 feet (3,834 meters). It is located in the Andes Mountains, on the border between Bolivia and Peru in South America. The Native American people who live there are descendants of the ancient and powerful Inca Empire, and the lake has

In Lake Titicaca in Peru, reeds grow together, forming floating islands that people live on.

IMAGE COPYRIGHT JOEL BLIT, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

been a center of their lives for 2,000 years. The Incas believed the lake was the origin of human life. The lake contains forty-one islands, the largest is Isla del Sol (Sun Island).

A species of reed called totora grows in the lake and forms floating islands on which the people live. They use the reeds to build boats and huts and to make baskets, which they sell. They use submerged plants, called yacco, to feed their cattle that graze along the shore. Around 1930, non-native fish, trout and mackerel, were introduced to the lake, reducing the number of native species of karachi and boga.

The Food Web

The transfer of energy from organism to organism forms a series called a food chain. All the possible feeding relationships that exist in a biome make up its food web. In lakes and ponds, as elsewhere, the food web consists of producers, consumers, and decomposers. These three types of organisms transfer energy within the biome.

Algae and plants are the primary producers in lakes and ponds. They produce organic materials from inorganic chemicals and outside sources of energy, primarily the sun.

Animals are consumers. Those that eat only plants, such as snails, are primary consumers in the lake or pond food web. Secondary consumers, such as certain fish, eat the plant-eaters. Tertiary consumers are the predators, like turtles and snakes. Humans fall into the predator category. Humans are omnivores, which means they eat both plants and animals.

Decomposers feed on dead, organic matter. These organisms convert dead organisms to simpler substances. Decomposers include insect larvae and bacteria.

Harmful to the lake or pond food web is the concentration of pollutants and dangerous organisms. They become trapped in sediments where certain life forms feed on them. These life forms are fed upon by other life forms, and at each step in the chain the pollutant becomes more concentrated. Finally, when humans and other large mammals eat fish, ducks, or other animals contaminated with pollutants, they are in danger of serious illness. The same is true of diseases such as cholera, hepatitis, and typhoid, which can survive and accumulate in certain aquatic animals and then be passed on to people who eat these animals.

Spotlight on Lakes and Ponds

Lake Baikal Lake Baikal is the largest lake on Earth by volume, 5,521 cubic miles (23,015 cubic kilometers). It contains 20 percent of the world's fresh water and 80 percent of the fresh water in Russia and Siberia. It is also the world's deepest lake, reaching 5,712 feet (1,740 meters), with a layer of accumulated sediment on its floor adding another 5 miles (8 kilometers) of depth. Although Baikal has the largest surface area of any lake in Europe or Asia, it is small in comparison to the area covered by the Great Lakes in North America. More than 300 rivers flow into Lake Baikal, but only one, the Angara, flows out.

Lake Baikal formed during a shifting of the Earth's crust 25 million years ago, making it the world's oldest freshwater lake. Earthquake activity continues in the region, and some scientists think that the Asian continent is splitting apart at this point. If so, Baikal may actually be a "baby" ocean. This theory is supported by the 1990 discovery of hot water springs bubbling up through the floor, a feature usually found in mid-ocean.

Many storms develop over the surface of Baikal because it is so large; often whipping up waves higher than 15 feet (4.6 meters). The lake has a moderating effect on local weather. Its water temperature is cold, never climbing to more than 63°F (17°C) in summer. From January to May the lake is frozen to a depth of 3 feet (1 meters).

Baikal's water has few minerals. The presence of unique miniature crustaceans (shrimp and crab) that consume the millions of phytoplankton help to keep the lake very clear and blue. It is often called the blue pearl of Siberia.

Of the 1,500 known animal species and 700 plant species found in Baikal, two-thirds are found nowhere else on Earth. Most of these unique species are found in its deepest waters where light never penetrates and water temperature remains at about 32°F (0°C) for the year. Most of the creatures have little eyesight or are blind. One species of fish, the golomyanka, has no scales and contains so much oil in its body that it is translucent. The nerpa seal, one of only two species of freshwater seals, lives in Baikal. These seals feed primarily on fish, which feed on freshwater shrimp, which are being harmed by pollution. Thus, the seals' food supply is threatened.

At one time, Baikal was one of the cleanest lakes in the world and a popular summer resort. In the 1960s industrial waste began to threaten its

Lake Baikal
Location: Siberia
Area: 12,160 square miles (31,494 square kilometers)
Classification: Fresh

purity. By the 1980s, the government had placed severe restrictions on activities that were polluting Baikal. In 1996, the area was deemed a UNESCO World Heritage site, meeting all four criteria: geological significance, biological-evolutionary importance, natural beauty, and outstanding importance for conservation.

The Great Lakes The Great Lakes are a group of five freshwater lakes—Superior, Michigan, Huron, Erie, and Ontario—that lie along the border between the United States and Canada. Of the five lakes, Lake Superior is the largest and deepest. It covers a surface area of 31,800 square miles (82,362 square kilometers) and is, at its lowest point, 1,333 feet (406 meters) deep. The lakes are linked together by rivers and channels to create a waterway 2,342 miles (3,747 kilometers) long. Taken together, they comprise the largest surface area of fresh water in the world and the second largest in volume, 5,439 cubic miles (22,684 cubic kilometers).

The Great Lakes began to form about 60,000 years ago when glaciers moved across North America covering the region with ice. The weight of this ice depressed Earth's crust by as much as 1,500 feet (456 meters), and the movement of the ice carved out large basins in the rock. Glacial meltwater, combined with precipitation, gradually filled the basins, forming the lakes.

The lakes help moderate temperatures in the region, producing milder winters and cooler summers. In winter, the presence of the lakes contributes moisture to the air that helps produce lake-effect blizzards. Buffalo, New York, for example, receives an average 93 inches (236 centimeters) of snow a year. Sudden and severe storms are common. The Great Lakes Storm of 1913, often called the white hurricane, claimed eight large freighters and 235 lives.

In 1700, the Great Lakes supported many species of fish such as lake trout, sturgeon, and whitefish. By the end of the nineteenth century populations were greatly reduced, not only because of heavy fishing, but because of human tampering with the lakes' many tributaries (rivers and streams that feed lakes). Dams and destruction of surrounding forests destroyed spawning habitat. Ocean fish such as the alewife and the sea lamprey, which normally only lay their eggs in fresh water, have become permanent residents, competing for food with native species. In the 1960s, scientists introduced trout, coho salmon, and other predators that feed on lampreys, to help reduce the undesirable populations.

The Great Lakes
Location: North America
Area: 94,950 square miles (245,919 square kilometers)
Classification: Fresh

The sturgeon, which may be 6 feet (1.8 meters) in length, is prized for its meat and caviar. They have been overfished and are rarely found.

Connected by channels or canals, the lakes are navigable from Duluth, Minnesota, in the west to the eastern shore of Lake Ontario. Ocean-going vessels from the Atlantic Ocean can use the lakes by entering through the St. Lawrence Seaway. In 2002, 162 million tons (147 million metric tons) of dry bulk, such as iron ore, stone, coal, and salt, was moved on the lakes.

Fertilizer and farm runoff that has entered the lakes has increased the level of nutrients. This encourages rapid growth of phytoplankton and other plants, which make the lakes age faster. Industrial chemicals, such as dioxin and mercury, and other pollutants have destroyed the purity of the water, leading to destruction of plant and animal life.

Great Salt Lake The Great Salt Lake lies between the Great Salt Lake Desert and the Wasatch Mountains in northwestern Utah. Most of the region is arid (dry). Approximately 4,200 feet (1,280 meters) above sea level, the lake was formed by glacier action. The Great Salt Lake is a remnant of a prehistoric freshwater lake ten times larger than it is now. Its size fluctuates, as does its depth, depending upon rates of evaporation.

The lake is fish free but some species of algae and a few invertebrates, such as brine shrimp and brine (alkali) flies, live in the lake. Many birds, including gulls, pelicans, blue herons, cormorants, and terns, nest on the lake's islets (tiny islands).

The Great Salt Lake is three to five times more saline (salty) than the ocean. Salts found in the lake include sodium chloride (table salt), and thousands of tons of this salt have been removed over the years for commercial purposes. The lake is used for recreation and has several beaches as well as a yacht harbor. Salt Lake City is built to the southeast and named for the lake.

Mono Lake Mono Lake lies in the shadow of the Sierra Nevada Mountains and was described by American writer Mark Twain (1835–1910) as "solemn, silent, sailless ... the lovely tenant of the loneliest spot on Earth." At least 700,000 years old, Mono was created by glaciers. All the water that enters it eventually evaporates, and for centuries it remained about the same size. Since 1941, many of the streams that normally feed it have been diverted to provide water for the city of Los Angeles. As a result, Mono Lake is shrinking, and the concentration of its minerals is

Great Salt Lake
Location: Salt Lake City, Utah
Area: 2,450 square miles (6,345 square kilometers)
Classification: Salt

Mono Lake
Location: Eastern California
Area: 60 square miles (155 square kilometers)
Classification: Soda/salt

increasing. More than 25 square miles (65 square kilometers) of mineral-encrusted lake bottom have been exposed. Winds, picking up alkaline dust, create thick clouds thousands of feet (meters) in the air.

Mono's salinity (saltiness) is only three times greater than that of the oceans; however, its alkalinity is 80 times greater. Dissolved carbonates give it a bitter taste and create weird towers of mineral deposits, called tufa towers, that are exposed along the shoreline as the lake recedes.

Blue-green algae, brine shrimp, and brine (alkali) flies are among the few life forms Mono Lake supports. There are no other animals to eat the flies and shrimp, so they multiply unchecked. As many as 4,000 flies have been counted in a single square foot (.09 meter) of shoreline, and 50,000 brine shrimp have been found in a cubic yard (cubic meter) of lake water. The flies and shrimp attract many species of birds, including gulls, grebes, phalaropes, and ducks.

Lake Victoria Lake Victoria, also called Victoria Nyanza, is the largest lake in Africa and the second largest freshwater lake in the world. Its coastline is more than 2,000 miles (3,220 kilometers) long, and it lies at an altitude of 3,720 feet (1,134 meters) above sea level. Its greatest depth is 270 feet (82 meters).

Victoria's basin was created by tectonic (earthquake) activity, and the shoreline is marked by steep cliffs, rocky headlands, swamps, and a river delta. Ukerewe and the Ssese Archipelago are its most important islands, all of which are densely wooded. The islands have become a popular destination for tourists.

The surrounding area has a large population, most of which are Bantu-speaking tribes. Boat building and fishing are important occupations. The introduction of Nile perch and Nile tilapia in the 1930s has caused at least 200 other species of fish to become extinct or near extinction. Lake Victoria yields about 550,000 tons (500,000 metric tons) of fish a year. This predominately includes Nile perch, Nile tilapia, and sardinelike dagaa.

A primary source of the Nile River, Lake Victoria was named for British monarch Queen Victoria (1837–1901) by British explorer John Hanning Speke (1827–1864), who first reached the lake in 1858. Alan Moorhead's books, *The White Nile* and *The Blue Nile*, and a British film titled *Mountains of the Moon*, tell of Speke's explorations.

Lake Victoria
Location: Africa, primarily within Uganda and Tanzania and bordering on Kenya
Area: 26,828 square miles (69,484 square kilometers)
Classification: Fresh

Caspian Sea The Caspian Sea is the world's largest lake in terms of surface area. It is bordered by Russia, Azerbaijan, Kazakhstan, Turkmenistan, and Iran. Lying 94 feet (28 meters) below sea level, its depth reaches 3,360 feet (1,024 meters) in the south. The depth in the northern portion of the sea is only 16 feet (5 meters). Its size fluctuates over time and, until 1977, the lake was shrinking.

The Caspian's basin was formed by both earthquake and glacier activity. Once part of an ocean, much of the surrounding region is covered by greenish clay ocean deposits. Its water is three times less salty than the ocean. The Ural and Volga rivers supply freshwater to the sea, diluting the salt content.

Average winter temperatures in the region are 14°F (-10°C) in the north and 50°F (10°C) in the south. In summer, the average is 79°F (26°C). Precipitation is light with only about 8 inches (20 centimeters) annually. In the shallower northern portion, ice forms during the winter months.

Over 400 species of fish live in the Caspian, including sturgeon, herring, pike, catfish, and carp. The sturgeon, comprising seven species in the sea, are fished for caviar. The Caspian seal, a freshwater seal, also makes its home here.

The lake is important to the economies of the surrounding regions, especially that of Russia and Iran. Many fish are taken from its waters and it is used for transportation. Fluctuations in its size and depth have reduced both the numbers of fish caught and the usefulness of its ports. Large oil fields extend beneath the lake, and there is considerable offshore production.

Lake Titicaca Located in the Andes Mountains at an altitude of 12,500 feet (3,810 meters), Lake Titicaca is the world's highest lake that can be used by large ships.

The presence of the lake moderates the local climate so that crops, such as corn, barley, quinoa (KEEN-wah), and potatoes, which are not usually grown at such high altitudes, can be raised there.

Only two species of fish, killifish, and catfish, inhabit the lake naturally. Trout were introduced in 1939.

The shores of the lake are densely populated by descendents of the Inca Indians. Modern steamboats and traditional Inca reed boats connect villages along the shoreline.

Caspian Sea
Location: On the border between Europe and Asia
Area: 144,000 square miles (373,000 square kilometers)
Classification: Salt

Lake Titicaca
Location: South America, between Bolivia and Peru
Area: 3,200 square miles (8,300 square kilometers)
Classification: Fresh

Dead Sea The Dead Sea, a salt lake in the Middle East's Jordan Trench, has a shoreline located on the lowest point on Earth's surface—about 1,300 feet (396 meters) below sea level. At its deepest point, the lake descends to 2,300 feet (701 meters). Its basin was created by earthquake action, and at one time it was part of the Mediterranean Sea. Highlands border it to the east and west.

The region has a desert climate with warm, dry winters and hot, dry summers. Only about 4 inches (10 centimeters) of rain fall each year. The Dead Sea is fed by rivers but evaporates at the rate of about 55 inches (140 centimeters) each year. About nine times as salty as the ocean, its water is so dense that swimmers cannot sink and nothing grows there.

Minerals, such as potash (used in fertilizer), are mined from the lake, as are its salts. Muds from the shores of the sea are famous for their healing and rejuvenating effects.

The lake is a part of biblical history and figures in the stories of Abraham, Lot, David, Solomon, and the defenders of Masada. The first Dead Sea Scrolls (ancient Jewish manuscripts dating as far back as 350 BC) were found at Qumran on the northeastern shore.

Lake Clark Lake Clark in southern Alaska is located about 125 miles (200 kilometers) southwest of Anchorage. It is part of Lake Clark National Park and Preserve, which is a mountainous region with two active volcanoes—Iliamna (10,016 feet/3,053 meters) and Redoubt (10,197 feet/3,108 meters). Gases are frequently seen venting out of Mount Iliamna, but there have been no recent eruptions. Mount Redoubt last erupted in 1966 and 1989.

Lake Clark is of glacial origin, and dozens of long valley glaciers, hundreds of waterfalls, and other glacial lakes are present in the park.

Lake Clark is the spawning ground for red salmon, and bald eagles and peregrine falcons live in the park year-round. The lake contains five different mammals: harbor seals, beluga whales, Stellar sea lions, and harbor porpoises. Large animals native to the park include grizzly bears, brown bears, wolves, lynxes, Dall sheep, moose, and caribou. The Dall sheep are the only wild sheep in the world with a white coat.

Crater Lake Crater Lake, the deepest lake in the United States, is located in Crater Lake National Park in the Cascade Mountains of Oregon. The lake occupies the crater of an extinct volcano called Mount Mazama and lies at an altitude of 6,176 feet (1,882 meters). It is surrounded by lava

Dead Sea
Location: Between Israel and Jordan
Area: 405 square miles (1,049 square kilometers)
Classification: Salt

Lake Clark
Location: Alaska
Area: 110 square miles (286 square kilometers)
Classification: Fresh

Crater Lake
Location: Southern Oregon
Area: 20 square miles (52 square kilometers)
Classification: Fresh

walls as high as 2,000 feet (610 meters), and its depth is 1,943 feet (592 meters). Along the lake's western shore is Wizard Island, a small volcanic cone. Some geologists believe the volcano is not really extinct but only temporarily inactive.

Originally named Deep Blue Lake, Crater Lake glows intensely blue when the sun shines on it. Precipitation filled the lake and continues to maintain it. An average 44 feet (13.5 meters) of winter snow maintains the lake's water supply.

The surrounding area is heavily forested with lodgepole, ponderosa, and sugar pines, and white and Douglas firs. At higher elevations, stands of pine and fir are broken by meadows of wildflowers.

Eagles, hawks, owls, beavers, bears, mountain lions, and deer are common animals in the area.

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Canadian Lakes Loon Survey, PO Box 160, Port Rowan, ON, Canada N0E 1M0; Internet: http://www.bsc-eoc.org/cllsmain.html

Environmental Defense Fund, 257 Park Ave. South, New York, NY 10010, Phone: 212-505-2100; Fax: 212-505-2375; Internet: http://www.edf.org

Envirolink, P.O. Box 8102, Pittsburgh, PA 15217; Internet: http://www.envirolink.org

Environmental Protection Agency, 401 M Street, SW, Washington, DC 20460, Phone: 202-260-2090; Internet: http://www.epa.gov

Freshwater Foundation, 2500 Shadywood Rd., Navarre, MN 55331, Phone: 612-471-9773; Fax: 612-471-7685; Internet: http://www.envirolink.org/resource.html?itemid=601&catid=5

Friends of the Earth, 1717 Massachusetts Ave. NW, 300, Washington, DC 20036-2002, Phone: 877-843-8687; Fax: 202-783-0444; Internet: http://www.foe.org

Greenpeace USA, 702 H Street NW, Washington, DC 20001, Phone: 202-462-1177; Internet: http://www.greenpeace.org

International Joint Commission, 1250 23rd Street NW, Suite 100, Washington, DC 20440, Phone: 202-736-9024; Fax: 202-467-0746, Internet: http://www.ijc.org

Izaak Walton League of America, 707 Conservation Lane, Gathersburg, MD 20878, Phone: 301-548-0150; Internet: http://www.iwla.org/

North American Lake Management Society, PO Box 5443, Madison, WI 53705-0443, Phone: 608-233-2836; Fax: 608-233-3186, Internet: http://www.nalms.org

Project Wet, 1001 West Oak, Suite 210, Bozeman, MT 59717, Phone: 866-337-5486; Fax: 406-522-0394; Internet: http://projectwet.org

Sierra Club, 85 2nd Street, 2nd fl., San Francisco, CA 94105, Phone: 415-977-5500; Fax: 415-977-5799, Internet: http://www.sierraclub.org

World Wildlife Fund, 1250 24th Street NW, Washington, DC 20090-7180, Phone: 202-293-4800; Internet: http://www.wwf.org

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Ocean

The oceans are great interconnected bodies of salt water that cover 71 percent of Earth's surface, a total of 139,400,000 square miles (361,100,000 square kilometers). They contain 97 percent of all the water on Earth, a total volume of 329,000,000 cubic miles (1,327,000,000 cubic kilometers).

Oceanography, the science of the oceans, officially started in the 1870s when the British ship *Challenger* began its career of oceanic exploration. The findings of this expedition took twenty years to analyze and are published in fifty thick volumes. Another research vessel, the *Meteor,* equipped with electronic equipment, began exploration in 1925 and discovered great mountains and trenches on the sea floor. Only since the 1930s have people entered the deeper regions. The deepest spot, the Mariana Trench in the Pacific Ocean, was not reached until 1960. New information continues to be discovered all the time about how oceans work and what lives in them.

How the Oceans were Formed

There are three main reasons why water covers so much of our planet. First, millions of years ago as Earth was forming, many active volcanoes released water vapor into the atmosphere in the form of steam. Second, Earth's gravity did not allow the water vapor to escape into space. It collected, along with other gases, to form clouds. Third, as Earth cooled, the moisture in those clouds condensed (turned from vapor to water), falling to Earth as rain. The rain filled the low areas in Earth's crust, and the cooler temperatures allowed much of this water to remain in liquid form. Over time, enough water accumulated to create a great ocean. If all of these factors had not been at work over 200 million years ago, our Earth might be dry, barren, and lifeless much like the moon.

WORDS TO KNOW

Bathypelagic zone: An oceanic zone based on depth that ranges from 3,300 to 13,000 feet (1,000 to 3,000 meters).

Coriolis Effect: An effect on wind and current direction caused by Earth's rotation.

Epigelagic zone: An oceanic zone based on depth that reaches down to 650 feet (200 meters).

Fast ice: Ice formed on the surface of the ocean between pack ice and land.

Hadal zone: An oceanic zone based on depth that reaches from 20,000 to 35,630 feet (6,000 to 10,860 meters).

Littoral zone: The area along the shoreline that is exposed to the air during low tide; also called intertidal zone.

Mesopelagic zone: An oceanic zone based on depth that ranges from 650 to 3,300 feet (200 to 1,000 meters).

Neap tides: High tides that are lower and low tides that are higher than normal when the Earth, sun, and moon form a right angle.

Neritic zone: That portion of the ocean that lies over the continental shelves.

Pack ice: A mass of large pieces of floating ice that have come together on an open ocean.

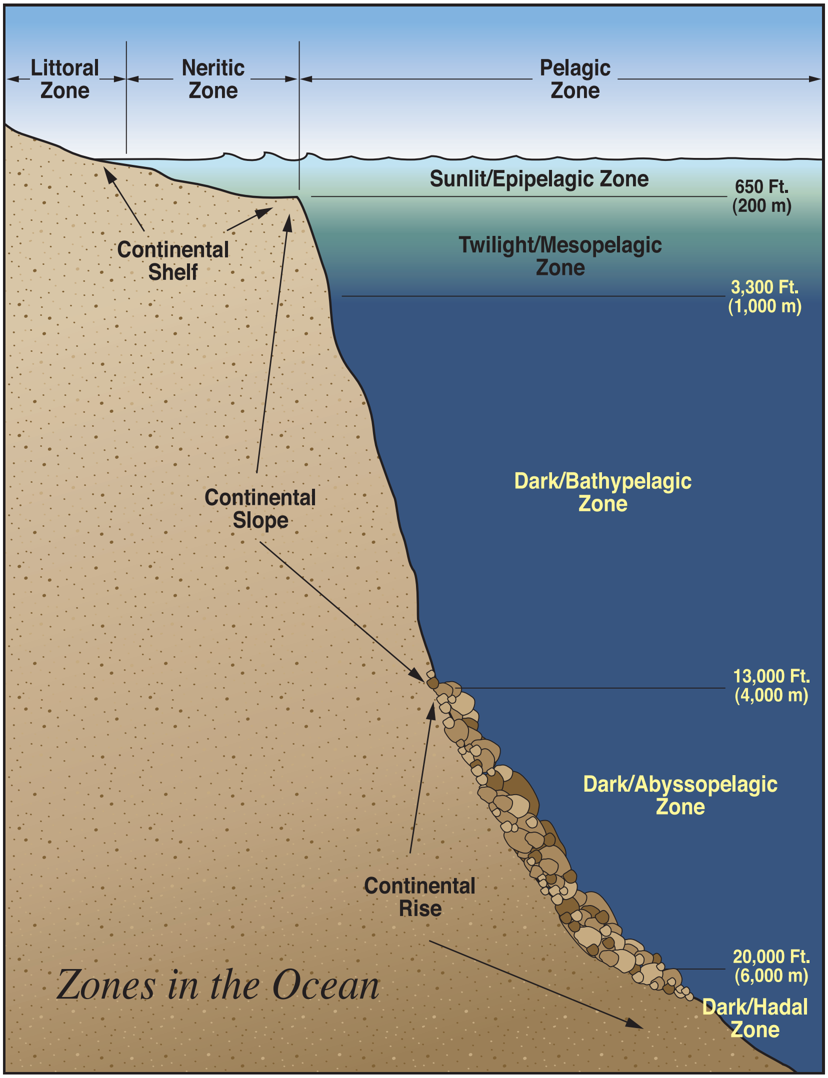
Spring tides: High tides that are higher and low tides that are lower than normal because the Earth, sun, and moon are in line with one another.

Thermocline: Area of the ocean's water column, beginning at about 1,000 feet (300 meters), in which the temperature changes very slowly.

Scientists named the original great ocean Panthalassa (pan-thah-LAHS-uh). More than 220 million years ago, only one large continent existed in this vast, primitive ocean. This land mass was named Pangaea (pan-GEE-uh). As time passed, Pangaea began to pull apart, and the ocean flowed into the spaces created between the land masses.

The breakup of Pangaea was caused by heat forces welling up from deep within Earth. Earthquakes split the ocean floor, creating fracture zones, or faults. Magma (molten rock) from below Earth's crust flowed into the fractures. As the magma cooled, it solidified, creating basins and ridges. After millions of years of repeated earthquakes and welling up of magma, the upper parts of Earth's crust were pushed farther apart. About 50 million years ago, the continents and the oceans took the basic shapes and positions of their current location.

The sea floor is still spreading at a rate of about 2 inches (5 centimeters) a year. This means the shapes of the continents and oceans are still changing.



Major Oceans and Adjoining Regions

All the oceans considered together are called the World Ocean. The World Ocean is divided by the continents into three major oceans; the Atlantic, the Pacific, and the Indian. The Atlantic lies to the east of North and South America, and the Pacific lies to the west. The Indian Ocean lies to the south of India, Pakistan, and Iran. Some scientists consider the water

> **Goodbye, Baja**
>
> About 6 million years ago Baja (BAH-hah), California, split away from Mexico to form the Gulf of California. This splitting continues, and Baja is moving westward at a rate of about 2.5 inches (6 centimeters) a year.

surrounding the North Pole as a fourth ocean, the Arctic; most consider it part of the Atlantic.

The Pacific Ocean is the world's largest at 59,000,000 square miles (153,000,000 square kilometers). The next in size is the Atlantic at 32,000,000 square miles (83,000,000 square kilometers). The smallest of the three is the Indian Ocean at 26,000,000 square miles (67,000,000 square kilometers). The Atlantic is divided into North Atlantic and South Atlantic regions, and the Pacific into North Pacific and South Pacific.

The terms ocean and sea are often used interchangeably. However, an ocean is generally larger and deeper than a sea, and the physical features along its floor may be different. Seas are either contained within a larger ocean or connected to it by means of a channel. For example, the Sargasso, the Mediterranean, and the Caribbean Seas are all part of the Atlantic Ocean.

Even smaller bodies of water, called gulfs and bays, lie along the oceans' margins. A gulf is partly surrounded by land and it usually joins the ocean by means of a strait, which is a narrow, shallow channel. The Gulf of Mexico lies at the point where the Atlantic curves in between Mexico and Florida. It connects to the Atlantic by the Straits of Florida. A bay is partly enclosed by land, but it joins the ocean by means of a wide mouth or opening. The Bay of Bengal, which lies between India and Myanmar, is an example.

The Water Column

The water in an ocean, exclusive of the sea bed or other landforms, is referred to as the water column. The average depth of the World Ocean's water column is 12,175 feet (3,711 meters).

The term sea level refers to the average height of the sea when it is halfway between high and low tides and all wave motion is smoothed out. Sea level changes over time. Between 1930 and 1950, sea level along the east coast of the United States rose about 0.25 inches (1 centimeter) per year.

Ocean composition Every element known on Earth can be found in the ocean. Ocean water is 3.5 percent dissolved salts by weight, including primarily chloride, sodium, sulfur (sulfate), magnesium, calcium, and

SEAS, GULFS, AND BAYS OF THE OCEANS		
Atlantic Ocean	**Indian Ocean**	**Pacific Ocean**
Baltic Sea	Andaman Sea	Bering Sea
Barents Sea	Arabian Sea	Celebes Sea
Mediterranean Sea	Phillipine Sea	Coral Sea
Black Sea	Red Sea	East China Sea
Norwegian Sea	Sea of Okhotsk	Java Sea
Sargasso Sea	Sea of Japan	
North Sea	South China Sea	
Scotia Sea	Timor Sea	
Weddell Sea	Yellow Sea	
Greenland Sea	Gulf of Aden	
Gulf of Guinea	Gulf of California	
Gulf of St. Lawrence	Bay of Bengal	
Labrador Sea	Great Australian Bight (bay)	
Baffin Bay		
Hudson		

potassium. The measure of these salts determines the ocean's salinity (saltiness). One cubic mile (4.1 cubic kilometers) of sea water contains enough salt to cover all the continents with a layer 500 feet (153 meters) deep. These salts make sea water heavier than fresh water.

Most of the oceans' salts come from the weathering of rocks and the materials released by volcanoes. The level of saltiness has been increased by millions of years of evaporation and precipitation (rain, snow, and sleet) cycles. The water closest to the surface is usually less salty because of rainfall and fresh water flowing in from rivers. One of the saltiest bodies of water is the Red Sea, which receives little fresh water from rivers. One of the least salty is the Baltic Sea, which receives inflow from many rivers.

Water temperature The temperature of the oceans varies. In general, temperature changes are greatest near the surface where the heat of the sun is absorbed. In the warmest regions, this occurs to depths of 500 to 1,000 feet (152 to 305 meters). Near the equator, the average surface temperature is about 77°F (25°C). The warmest surface water is found in

Taking the Salt from Sea Water

Water, water, everywhere, and all the boards did shrink;

Water, water, everywhere, nor any drop to drink.

The mariners (sailors) in Samuel Taylor Coleridge's (1772–1834) "Rime of the Ancient Mariner," were in trouble because they were out of fresh water. Sea water is not safe to drink because its high salt content causes illness and, eventually, death. In some areas with few fresh water sources, the salt can be removed from ocean water. This is process is called desalination.

There are several methods for desalination. In one method, the water is heated until it evaporates. As the water vapor condenses, it is collected as fresh water and the salts are left behind. In a second method, an electric current is passed through the water. The salts collect on strips of metal called electrodes. In a third method, the water is frozen and the salt crystals are separated from the ice crystals. The ice crystals are then melted back to water.

the Pacific Ocean. In February, off the coast of Australia, the surface temperature is about 81°F (27°C).

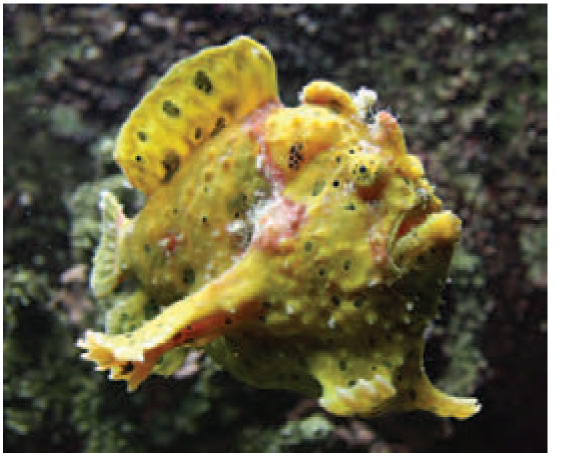
The average surface temperature of the ocean near the poles is about –28°F (–2°C). Sea water grows colder more slowly than fresh water because of its salt content. In the Arctic, the water column is permanently covered with ice. Pack ice (a mass of large pieces of floating ice that have come together) forms on open water. Fast ice is ice formed between pack ice and the land.

The range of annual temperatures on land can vary more than 100°F (47°C). In the ocean, temperatures vary only about 15°F (7°C) annually. Most of the ocean (about 95 percent) is so deep it is unaffected by the sun and seasonal changes. At a depth of about 1,650 feet (500 meters) begins an area called the thermocline, where temperatures change very slowly. Close to the ocean floor, the average water temperature is between 32° and 41°F (0° and 5°C) throughout the World Ocean.

Zones in the ocean Different parts of the ocean have different features, and different kinds of creatures live in them. These different parts are called zones. Some zones are determined by the amount of light that reaches them. Others are based on depth and the life forms present. The different zones overlap and interact with one another.

Zones determined by light penetration The surface waters of the ocean receive enough light to support photosynthesis in plants. Photosynthesis is the process by which plants use the energy from sunlight to change water and carbon dioxide (from the air) into the sugars and starches they use for food. These surface waters are called the sunlit zone, which reaches down as far as 660 feet (200 meters) below the surface.

The next level is the twilight zone, which ranges from 660 to 3,000 feet (200 to 914 meters). Only blue light can filter down to this level, where it is too dark for plant life, but where at least 850 species of fish make their



Frogfish are dark-zone fish. IMAGE COPYRIGHT TILL VON AU, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

home. These twilight dwellers have large eyes and often travel to the sunlit zone at night to feed.

In the deepest region of the oceans, from 3,000 to 36,163 feet (914 to 11,022 meters), there is no light. This is called the dark zone. It is not known if any fish that live here travel upward at night, but their eyes are usually tiny and many are blind.

Zones determined by depth Based on depth, the zone closest to the surface of the sea is called the epipelagic zone. It reaches down to 660 feet (200 meters) and corresponds to the sunlit zone. The next zone is the mesopelagic zone, and it corresponds to the twilight zone. It ranges from 660 to 3,000 feet (200 to 914 meters). The zones of darkness follow. First is the bathypelagic zone, which covers from 3,000 to 9,843 feet (914 to 3,000 meters). Then comes the abyssopelagic zone, ranging from 9,843 to 19,685 feet (3,000 to 6,000 meters). At the very bottom is the hadal zone. It reaches from 19,685 feet (6,000 meters) to the very bottom of the Mariana Trench, the deepest spot on Earth at 35,840 feet (10,924 meters).

Zones determined by sea life The entire water column of the ocean is a vast ecosystem (an environment in which all organisms living within are dependent on other living and nonliving organisms for survival and continued growth) called the pelagic zone. Most life forms that live in it are concentrated near the surface where light is available. The neritic zone is the portion of the ocean that lies over the continental shelves (extensions of the continent that taper gently into the sea). The littoral zone refers to the area along the shoreline that is exposed to the air during part of the day as tides flow in and out.

Ocean circulation The oceans are constantly, restlessly moving. This movement takes the form of tides, waves, surface currents, vertical currents, and eddies and rings.

Tides Tides are rhythmic movements of the oceans that cause a change in the surface level of the water, noticeable particularly along the shoreline. When the water level rises, it is called high tide. When it recedes (drops), it is called low tide. Some tides, such as those in the Mediterranean Sea, are barely measurable. In the Bay of Fundy in Nova

Melting Ice

The great icecap over the North Pole has shrunk in size during different prehistoric periods, adding its water to the oceans. This added water has raised sea level as much as 660 feet (200 meters). During cooler periods the icecap has always been restored to an even larger size.

Scotia, the difference between high and low tide may be as much as 52 feet (16 meters). High and low tides occur in a particular place at least once during each period of 24 hours and 51 minutes.

Tides are caused by a combination of the gravitational pull of the sun and moon, and Earth's rotation. The gravitational pull from the sun or moon causes the water to bulge outward. At the same time, the centrifugal force created by Earth's rotation causes another bulge to occur on the opposite side of Earth. These areas experience high tides. Water is pulled from the areas in between, and those areas experience low tides.

When the Earth, sun, and moon are lined up, the gravitational pull is stronger. Then, high tides are higher and low tides are lower than normal. These are called spring tides. When the Earth, sun, and moon form a right angle, the gravitational pull is weaker. This causes high tides to be lower and low tides to be higher than normal. These are called neap tides.

Wind-driven surface waves Waves are rhythmic rising and falling movements of the water. Although waves make the water appear as if it is moving forward, forward movement is actually very small. Most surface waves are caused by wind. Their size is due to the speed of the wind, the length of time it has been blowing, and the distance over which it has traveled. As these influences grow stronger, the waves grow larger, and storm waves can produce waves over 100 feet (31 meters) high. When the ocean's surface can absorb no more energy, instead of growing in size, the waves collapse. Hurricanes, with wind speeds of 106 miles per hour (170 kilometers per hour), rarely raise waves higher than 43 feet (13 meters).

Once set in motion, waves can move for long distances. Over time, they become more regular in appearance and direction, forming a swell. By studying the movement of the swell, experienced ocean travelers can determine where a distant storm has occurred.

In shallow areas, such as along a shoreline, the bottom of a wave is slowed down by friction as it moves against the sea floor. The top of the wave is not slowed down by friction and moves faster than the bottom. When the top finally gets ahead of the bottom, the wave tumbles over on itself and collapses causing a breaker and sending a mass of swirling, bubbling foam tumbling onto the shore.

Tsunamis A type of surface wave called a tsunami (soo-NAH-mee) is caused by undersea earthquakes. When the ocean floor moves during the quake, its vibrations create a powerful wave that travels to the surface. The tsunami is barely noticeable in mid-ocean, but as it approaches bays, channels, or sloping shorelines, its power is concentrated. Suddenly its height increases, sometimes forming a towering crest that can reach a height of 200 feet (61 meters) as it crashes onto the land. A tsunami that struck eleven countries bordering the Indian Ocean in 2004 was 50 feet (15 meters) high and killed over 130,000 people.

Most tsunamis do not create walls of water but appear as sudden upwellings (rising of the water level). They are seldom just one wave. A dozen or more that vary in strength often travel in succession. Tsunamis can move as fast as an airplane—440 miles (700 kilometers) per hour—and can travel thousands of miles from their source before sweeping onto the land. As they recede back to sea, they make a loud sucking noise.

When tsunamis strike inhabited areas, they can destroy entire towns and kill many people. Some people drown as the wave washes inland; others are pulled out to sea when the tsunami recedes. Hawaii is very vulnerable to tsunamis because of its position in a Pacific region known for frequent volcanic activity and earthquakes. The Pacific Ocean experiences, on average, two life-threatening tsunamis each year. They are monitored by the Pacific Tsunamis Warning Center (PTWC).

Surface currents Currents are the flow of water in a certain direction. They can be both large and strong. For example, the Gulf Stream, a current that lies off the eastern coast of the United States, and the Kuroshio (koo-ROH-shee-oh) near Japan, travel at 2.5 to 4.5 miles per hour (4 to 7 kilometers per hour). Usually, surface currents do not extend deeper than a few hundred yards (183 meters). The Florida Current and the Gulf Stream extend to depths of 6,560 feet (2,000

Storm at Sea

The large and usually violent tropical cyclones that form over oceans are called hurricanes in the Atlantic and eastern Pacific, and typhoons in the western Pacific. Their wind speeds are at least 75 miles (120 kilometers) per hour and may reach 180 miles (300 kilometers) per hour. A single storm may cover an area up to 2,000 miles (3,200 kilometers) in diameter and release up to 10 inches (25 centimeters) of rain a day.

Hurricanes and typhoons require very moist air to supply their energy, and only very warm air contains enough moisture. As a result, they only form over water at temperatures of at least 80°F (27°C). As they move over cooler regions, their power diminishes and they break up.

The forceful, rotating winds created by tropical storms cause much damage, especially when they reach land, as do the waves that batter the shoreline. Many people lose their lives each year in tropical storms. After 1944, airplanes were used to help spot and keep track of these storms. Weather satellites in orbit around Earth now monitor their growth and movement.

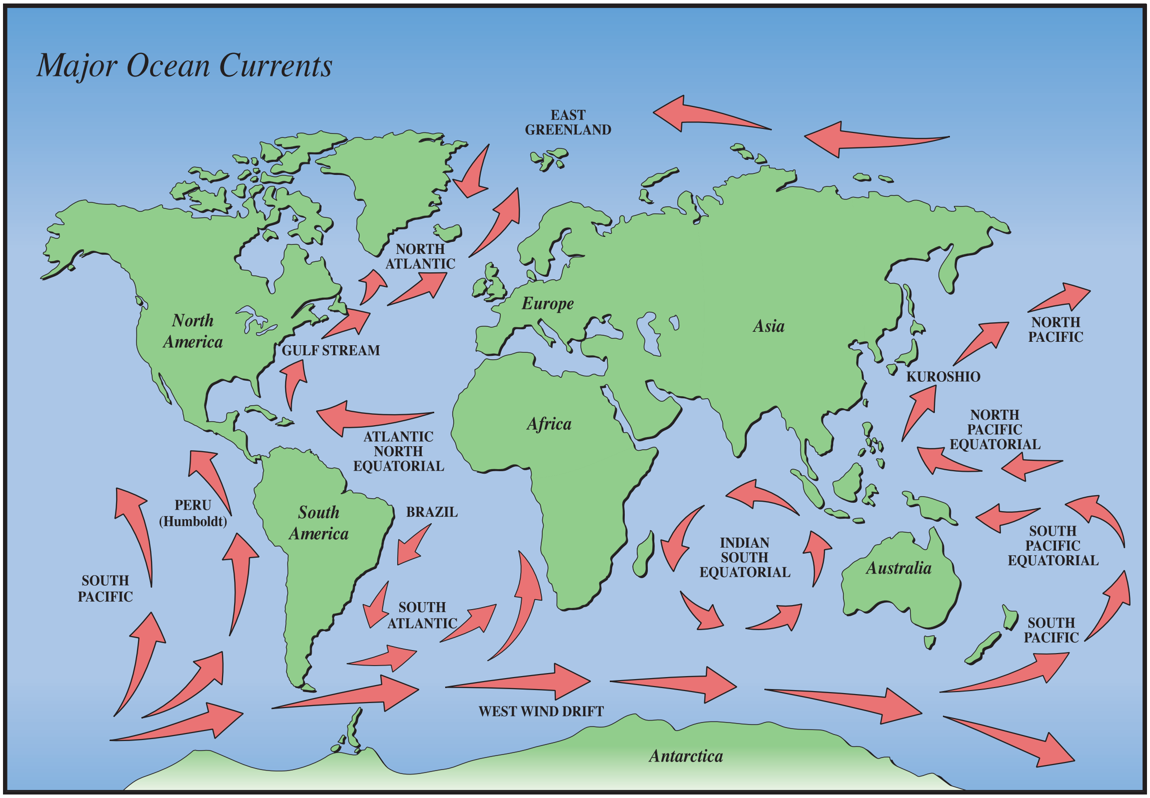
The Sea State Scale

The heights of waves are measured on the sea state scale in number values from zero to nine. A sea state of zero means calm, smooth water. A sea state of nine means waves over 45 feet (14 meters) high.

meters). They are caused by the wind, the rotation of Earth, and the position of continental landmasses. They contain about 10 percent of the World Ocean water.

Effects of wind Winds directly affect only the upper zone of the ocean down to about 660 feet (200 meters). The currents created by the wind may reach depths of more than 3,000 feet (914 meters). Wind-driven currents move horizontally (parallel to Earth's surface).

Winds over the oceans tend to follow a regular pattern, generally occurring in the same place and blowing in the same direction. At the equator are the doldrums, very light winds that create little water movement. Both north and south of the equator to about 30° latitude are the trade



winds, which blow primarily east. (Latitude is a distance north or south of Earth's equator, measured in degrees.) At about 60° latitude are the westerlies. Near the poles, the polar easterlies occur. These three wind patterns create three basic systems of ocean currents: the equatorial system, the subtropical gyre (JYR), and the subpolar gyre. (A gyre is a circular or spiral motion.)

The Coriolis effect The rotation of Earth influences the patterns of the wind and the ocean's currents. This is called the Coriolis (kohr-ee-OH-lus) Effect. In the Northern Hemisphere, the Coriolis Effect causes air masses moving south to veer westward. Just the opposite happens in the Southern Hemisphere. Air masses moving north veer eastward. Currents north of the equator move in a clockwise direction. Currents south of the equator move counterclockwise. The Coriolis Effect is greater near the poles and causes the currents on the western sides of ocean basins to be stronger than those on the eastern sides.

Currents that develop from Coriolis forces are usually permanent. They include the West Wind Drift, the North Equatorial Current, and the South Equatorial Current.

Effect of landmasses Currents are affected by the presence of obstacles such as the continents and large islands. In the North Pacific, for example, currents moving west are deflected northward by Asia and southward by Australia. The same currents then move east until North and South America send them back toward the equator.

Vertical currents Upward and downward movements occur in the ocean. These vertical currents are primarily the result of differences in water temperature and salinity.

At the North and South Poles, the surface water often freezes, due to its lower salt content. As a result, the salts become more concentrated in the water below the surface, causing this water to remain unfrozen and become heavier. This heavy, cold water then sinks and travels along the ocean floor toward the equator. At the same time, near the equator, the sun warms the surface water, which travels toward the poles. As this cycle repeats itself, the water is continually circulating. Warm surface water flows toward the poles, cools, sinks, and flows back toward the equator. Vertical currents help limit the depth of horizontal currents.

Tides of Fire

In 1964, an earthquake struck Alaska, causing great damage. A pipeline carrying oil was broken and the oil caught fire. A tsunami three stories high followed the quake, surging inland. Because oil floats on water, the burning oil was carried overland in a tide of fire. The fires reached the railroad yards, where the iron tracks soon glowed red from the heat. More tsunamis followed and flowed over the tracks. The sudden cooling made the tracks rise up and curl like giant snakes

Ben Franklin Speeds the Mail

In 1770, Benjamin Franklin (1706–1790) was postmaster general for the American colonies. At that time, the colonies depended upon sailing ships to carry the mail back and forth between England and America. A constant complaint from postal customers was that mail going east to England always arrived weeks sooner than mail moving west to the colonies. Puzzled, Franklin decided to investigate.

Franklin's cousin, Timothy Folger, was a ship's captain. He told Franklin about the presence of the Gulf Stream. He explained that when they traveled to England, the ships moved with the current, which added to their speed. When they returned to America, they had to fight the current, which slowed them down.

Luckily, the Gulf Stream was only about 62 miles (100 kilometers) wide. Franklin believed it could be avoided and mapped a new route. He named the current the Gulf Stream because it flowed out of the Gulf of Mexico.

In some coastal areas, strong wind-driven currents carry warm surface water away. An upwelling of cold water from the deep ocean occurs to fill the space. This is more common along the western sides of the continents. These upwellings bring many nutrients from the ocean floor to the surface.

Eddies or rings Eddies or rings are whirlpools that move in a circular motion against the flow of a main surface current. Eddies are probably caused when the speed and intensity of a current increases to such a point that the current becomes unstable. The eddy allows the excess speed and intensity to be distributed into the surrounding water.

Effect of the water column on climate and atmosphere The World Ocean is responsible for much of the precipitation (moisture) that falls on land. Ocean water evaporates in the heat of the sun, forms clouds, and falls elsewhere in the form of rain, sleet, or snow.

The ocean absorbs and retains some of the sun's heat. In the winter, this heat is released into the atmosphere, helping to keep winter temperatures warmer inland. In summer, when the water temperature is cooler than the air temperature, winds off the ocean help cool coastal areas.

Pools of warmer or cooler water within the ocean influence storms in the atmosphere. The *El Niño* flow of warmer water, which affects the storm systems in North and South America, is an example. This warm current causes changes in winds and air pressure, bringing severe storms and droughts (very dry periods). How *El Niño's* effect comes about is still not clearly understood.

The oceans help regulate the levels of different gases in the atmosphere, such as oxygen and carbon dioxide. About one-half of the carbon dioxide that is produced by burning forest fires and other causes is captured by the oceans. Too much carbon dioxide in the atmosphere contributes to warmer global temperatures. The ocean's presence helps moderate such undesirable changes.

Geography of the Ocean Floor

The ocean floor is that area of Earth's crust covered by ocean water. It is divided into the continental margins and the deep-sea basins.

Continental margins

The continental margin is the part of the seafloor at the edges of the continents and major islands where, just beyond the shoreline, it tapers gently into the deep sea. The continental margin includes the continental shelf, the continental slope, and the continental rise.

Continental shelf The continental shelf is that part of the margin that begins at the shoreline. It is flat and its width varies. Off the coast of Texas the shelf is 125 miles (200 kilometers) wide. The continental shelf is usually less than 660 feet (200 meters) below sea level. It receives much rich sediment (soil and other particles) from rivers that flow to the sea and, being in the sunlit zone, it supports many forms of ocean life.

Continental slope At the end of the continental shelf there is a steep drop. This is the continental slope, which descends to depths of 10,000 to 13,000 feet (3,000 to 4,000 meters) and ranges from 12 to 60 miles (20 to 100 kilometers) in width. In many places, the slope is cut by deep underwater canyons that may have been formed by prehistoric rivers.

Continental rise Beyond the continental slope is the continental rise, where sediments drifting down from the continental shelf collect. These deposits may extend as far as 600 miles (914 kilometers) into the ocean where the deep-sea basin begins.

Deep-sea basins

The deep-sea basins begin at the edge of the continental rise. These vast, deep basins in the ocean floor contain underwater mountain ranges (ridges), volcanoes, deep trenches, and wide plains.

The mid-ocean ridge A long chain of submerged (underwater) mountains called the mid-ocean ridge runs through the World Ocean. This ridge was formed when rifts (cracks) were created in the sea floor by earthquakes and volcanic action. Hot lava seeped or poured out of these cracks, spreading apart the sea floor. As the seafloor spread, it buckled, forcing Earth's crust upward and forming a chain of mountains about 40,000 miles (65,000 kilometers) long. This ridge was discovered at different locations by different scientists who did not realize it was one chain and who gave it different names, such as mid-Atlantic ridge or West Chile Rise.

LANDFORMS OF THE OCEAN'S BASINS

Atlantic Ocean Basin	Indian Ocean Basin	Pacific Ocean Basin
Falklands Escarpment	Central Indian Ridge	Aleutian Trench
Mid-Atlantic Ridge	Java Trench	East Pacific Rise
Puerto Rico Trench	Ninetyeast Ridge	Emperor Seamount Chain
Sandwich Trench		Hawaiian Ridge
Scotia Ridge		Japan Trench
Walvis Ridge		Kermadec-Tonga Trench
		Kuril Trench
		Mariana Trench
		Peru-Chili Trench
		Philippine Trench
		West Chile Trench

The mid-ocean ridge usually rises 0.6 to 1.8 miles (1 to 3 kilometers) above the surrounding sea floor. Those peaks that break the surface of the water form volcanic islands. Iceland is an example. The highest submerged mountain is 29,520 feet (8,997 meters) and is found between Samoa and New Zealand.

Deep valleys often cut into the mid-ocean ridge, and are frequently the site of volcanic and earthquake activity.

Seamounts Some isolated volcanoes that do not reach the surface of the ocean, called seamounts, form alongside the mid-ocean ridge but are separate from it. Seamounts have steep slopes and may be as high as 13,000 feet (5,000 meters).

Smokers On the deep ocean floor in highly volcanic zones, jets of hot water (up to 716°F [380°C]), called smokers, have been discovered. These water jets are composed of ordinary seawater that enters clefts (splits) in hot volcanic rock where it heats up, expands, and escapes. In its passage through the rock, the hot water absorbs large quantities of dissolved minerals that make it look cloudy and smokelike as it reenters the surrounding ocean. Sometimes the dissolved minerals are deposited around the vents (openings) through which it is expelled, forming hollow black chimneys as high as 33 feet (10 meters).

Oceanic islands rise from the ocean floor, often as the result of volcanic activity. IMAGE COPYRIGHT SPECTA, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Trenches As the sea floor spreads, it meets the edges of the continents, which resist its movement. This results in an area of extreme pressure called a subduction zone. In the subduction zone, this enormous pressure forces the expanding sea floor down and under the continental margin, often causing a deep, V-shaped trench to form. The greatest depths in the oceans are found in these trenches, and the deepest trenches are located in the Pacific. The Mariana Trench is the deepest at 35,840 feet (10,924 meters).

Ocean trenches are much deeper than any valley on the continents. The Grand Canyon in Arizona, for example, is about 1 mile (1.6 kilometers) deep. The Mariana Trench in the Pacific is about 6.8 miles (11 kilometers) deep. If Mt. Everest, the tallest mountain on Earth, could be put into the Mariana Trench, more than 6,800 feet (2,073 meters) of ocean would still cover it.

Islands and atolls Continental islands were once part of a nearby continent. As the continent drifted, the island broke away. These islands may include hills and mountains similar to those on the continent.

Oceanic islands are those that rise from the deep-sea floor. Volcanoes, some of which are still active, formed most of the islands. At first, volcanic islands lack any form of life except possibly bacteria. Seeds and plant spores (single cells that grow into a new organism) arrive on the

> ### The Newborn Island, Surtsey
>
> In 1963, a baby island was born off the coast of Iceland. It has been named Surtsey. The product of an underwater volcano, Surtsey was formed of cooled magma. A similar island may be forming on the seabed southeast of Hawaii.

wind or are carried there by ocean waves or visiting animals. Gradually, an ecosystem tailored to each particular island is formed.

Atolls are ring-shaped coral reefs that have formed around a lagoon. A coral reef is created by small, soft, jellylike animals called corals. Corals attach themselves to hard surfaces and build a shell-like external skeleton. Many corals live together in colonies. Young corals build their skeletons next to or on top of older skeletons. Over hundreds, thousands, or millions of years, a wall, or reef, of these skeletons is formed. The mountain peak in the center gradually sinks or is washed away and only the reef remains.

Abyssal plains Abyssal plains are the vast flat areas where light does not penetrate. They make up the largest portion of the ocean floor. The abyssal plain is deepest in the Pacific Ocean at 20,000 feet (6,098 meters) and shallowest in the Atlantic Ocean at 10,000 feet (3,048 meters).

Where the ocean floor remains uncovered by sediment, a hard rock called basalt is visible. Elsewhere, the floor is covered by sediments that have drifted down from the continental margins, from volcanic activity, from dead marine life, from coal-burning ships, and even from dust carried by the wind and deposited on the water's surface. These sediments build up until they create a flat surface.

Sediments are of two types. Those formed from the waste products and dead tissues of plants and animals are called ooze. Usually, ooze is found only in temperate (having moderate temperatures) and tropical (hot and humid) regions where it may become hundreds of yards (meters) thick. Other sediments are usually red clay. About 1 inch (2.5 centimeters) of red clay is deposited on the ocean floor every 2,500 years. In parts of the ocean floor, the sediment layer is more than 3,000 feet (7,000 meters) thick.

Plant Life

Plants that live in the sea are surrounded by water at all times. For this reason, they have no need to develop the special tissues and organs for conserving water that are needed by plants on land. Seaweeds, for example, use their rootlike structures called holdfasts to anchor them in one spot. They do not use them to draw water from the soil.

The Web of Life: Alien Algae

In 1984, an alien was discovered in the Mediterranean Sea. Although probably not from outer space, its origin remains unknown and it is gradually taking over. It is a species of green algae that usually grows only in aquariums. Somehow it found its way into the sea where it grows aggressively with no natural enemies. It is smothering anything from the beach to a depth of about 150 feet (46 meters). It has no scientific name, but some researchers believe it is derived from *Caulerpa taxifolia*. Others are in favor of calling it *C. Godzilla* for obvious reasons.

This species reproduces by fragmentation; small pieces that break off grow into new plants. Any attempt to dig it up or mow it down fails, because millions of potentially new plants are created in the process. Pesticides are too toxic and dangerous for wildlife. The only hope for saving the Mediterranean from the algae seems to be the use of bio-controls (natural means of controlling pests). Scientists are searching for an animal, such as a snail or slug that will eat the algae. Bio-controls can cause other problems. Sometimes the new animal turns up its nose at the pest plant and eats other, more desirable plants. Then, instead of one problem, there are two. Until a remedy is found, many countries, including the United States, are prohibiting the importation of this type of algae for use in aquariums.

The water offers support to ocean plants. Giant underwater plants do not require tough woody stems like land plants to remain upright; the water holds them up. Instead, sea plants have soft and flexible stems, allowing them to move with the current without breaking.

Many species of plants live in the oceans; however, all species are not found in all oceans. Species of plants found in the Indian Ocean, for example, are seldom found in the Atlantic. Most plants live along the continental margins and shoreline, not in mid-ocean.

Ocean plants can be divided into two main groups: plantlike algae (AL-jee) and green plants.

Algae It is generally recognized that algae do not fit neatly into the plant category, but they have some characteristics similar to true plants.

Algae are found extensively in the oceans. Most algae have the ability to make their own food by means of photosynthesis (foh-toh-SIN-thih-sihs). Others absorb nutrients from their surroundings.

The types of algae commonly called seaweed resemble green plants, but they have no true leaves, stems, or roots. Some are so tiny they cannot be seen with the naked eye. Others are massive and live in vast underwater forests. Many algae, such as kelp, have soft, jellylike cell surfaces. Other types, such as diatoms, form shells, scales, or stony coverings.

Seaweed provides nutrition and also homes for many animals living in the ocean. IMAGE COPYRIGHT GRAEME KNOX, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Some algae float freely in the water, allowing it to carry them from place to place. These are called plankton (a Greek word meaning "wanderers"). Kelp anchors itself to the sea floor, and belongs to the benthic species. (Benthos in Greek means "seafloor.")

Common algae Phytoplankton are tiny plants that usually cannot be seen without the aid of a microscope. They float on the water's surface, always within the sunlit zone, and are found near the coast and in mid-ocean. They are responsible for about 90 percent of the photosynthesis carried out in the oceans, helping to supply Earth's atmosphere with oxygen as a result.

Two forms of phytoplankton are the most common, diatoms and dinoflagellates (dee-noh-FLAJ-uh-lates). Diatoms have simple, geometric shapes and hard, glasslike cell walls. They live in colder regions and even within Arctic ice. Dinoflagellates have two whiplike attachments that make a swirling motion to help them move through the water. They live in tropical zones (regions around the equator).

Growing season Both land and sea plants contain chlorophyll, the green pigment in which they turn energy from the sun into food. As long as light is available, ocean plants can grow, even in the Arctic. In some algae, the green of chlorophyll is masked by orange-colored pigments, giving them a red or brown color.

Food Most algae grow in the sunlit zone where light is available for photosynthesis. Algae require other nutrients that must be found in the water, such as nitrogen, phosphorus, and silicon. In certain regions, upwelling of deep ocean waters during different seasons brings more of these nutrients to the surface. This results in greater numbers of algae during those times. These increases are called algal blooms. When the upwelling ceases, their numbers decrease.

Nitrogen and phosphorus are in the shortest supply in most oceans, which limits plant growth. When these elements are added to a body of water by sewage or by runoffs from farmland, there is a sudden burst of algae growth in these regions.

Reproduction Algae may reproduce in one of three ways. Some split into two or more parts, each part becoming a new, separate organism. Others produce spores. A few reproduce sexually; cells from two different plants unite to create a new plant.

Green plants Green plants do not grow in mid-ocean. Instead, various types of seagrasses live in protected areas along the continental shelf where their roots can find soil and nutrients. Some marine animals use them for food and for hiding places.

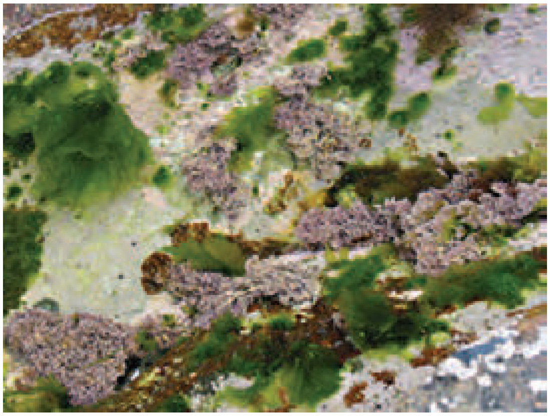
The Colors of Kelp

Kelp must absorb sunlight in order for photosynthesis to take place. For this reason, kelp are found in the sunlit zone in fairly shallow water. Different species are found at different depths, and these species vary in color. This color difference is due to the filtering effect of the water. As sunlight penetrates deeper, different colors in it are filtered out. Near the surface, kelp is green. Farther down, the brown varieties grow. Red and blue species are found where there is the least amount of light.

Animal Life

The oceans swarm with life and are the largest animal habitats on Earth. More life forms are found in the oceans than in tropical rain forests. Most species live along the continental margins. Some of those enter mid-ocean regions when they migrate to different areas in search of food or for breeding purposes. The numbers that live in mid-ocean permanently are fewer. The Gulf Stream, for example, supports so few species it is almost like a desert.

Living organisms must maintain a balance of body fluids and salt levels in their blood. Animals that live in the sea have developed ways to cope with its high salinity. Naked animals or those with thin skins or shells usually have high levels of salt in their blood and do not need to expel any excess. Others, such as most fish, have special organs that remove the extra salt from their bodies and release it into the water.



Small plants thrive in the ocean, providing food and protection for fish and small invertebrates.

IMAGE COPYRIGHT STEPHEN KRAUSSE, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

The water offers support to marine (ocean) animals as it does to plants. For example, giant whales could not exist on land because of their body weight. The effect of gravity would be too great. But ocean water allows them to float and swim effortlessly. Many marine animals have special chambers in their bodies that allow them to adjust their buoyancy (BOY-un-see; ability to float) so that they can change their depth. Some, such as seals, have fins to make swimming easier. Others, such as octopi, forcefully eject water in a kind of jet stream to help them move.

Distribution of animals in the oceans depends primarily on the food supply. Tropical seas, which are rich in nutrients, have many more life

Tidepools form at the edge of the ocean. During low tide, they are small ponds, separated from the ocean, but when they tide comes in, they are covered by the ocean again. IMAGE COPYRIGHT LEV RADIN, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

forms than polar seas. The lack of sudden temperature changes in the oceans makes the environment comfortable for most marine animals.

Marine animals may be classified as microorganisms, vertebrates, and invertebrates. They are also classified according to their range of movement. Plankton drift in the currents and include both microorganisms and larger animals such as jellyfish. Many plankton move upward and downward in the water column by regulating the amount of gas, oil, or salt within their bodies. (Production of gas or oil and removal of salt causes the organism to rise; the reverse causes it to sink.) Many larger animals spend part of their young lives as plankton. Crabs, which float with the current in their larval (immature) form, are an example. Larger animals that swim without the help of currents, such as fish and whales, are called nekton. Benthos are animals that live on the ocean floor. These include snails, clams, and bottom-dwelling fish.

Microorganisms Microorganisms cannot be seen with the human eye without the aid of a microscope. Most microorganisms are zooplankton (tiny animals that drift with the current). They include foraminiferans, radiolarians, acantharians, and ciliates, as well as the larvae or hatchlings of animals that will grow much larger in their adult form.

Bacteria Until 1998, it was believed that bacteria appeared in the ocean only where other organisms were decomposing (decaying). Scientists now agree that bacteria are found throughout the ocean and make up much of the dissolved matter in the mid-ocean water column. As such, they provide food for microscopic animals. Bacteria help decompose the dead bodies of larger organisms, and for that reason their numbers increase near the coastlines where the larger organisms are found.

Bacteria are found in the sediment on the dark ocean bottom and around the waterjet smokers created by deep-sea volcanic vents. These deep-sea bacteria obtain food and oxygen by means of chemosynthesis (kee-moh-SIHN-thuh-sihs), a process in which the organism creates food using chemical nutrients as the energy source instead of sunlight. The bacteria live in cooperation with animals unique to this region, providing them with important nutrients.

Food Some zooplankton eat phytoplankton and are preyed upon by other carnivorous zooplankton, such as arrow worms. Krill are shrimplike zooplankton that play an important part in the food web of the ocean. They feed upon plant-eating zooplankton and are eaten in turn by larger fish and mammals. The largest mammals of all, the great whales, consume tons of krill each day.

The Red Tide

Some species of dinoflagellates are poisonous. When enough of them are present, they color the water red, creating what is called red tide. Their toxic secretions kill many fish, and even humans are not immune. When the poison is released into the air by waves breaking on shore, people can develop irritation in their mouth and lungs.

Ocean waters allow octopus and other sea creatures to swim effortlessly. IMAGE COPYRIGHT LAVIGNE HERVE, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Invertebrates Animals without backbones are called invertebrates. Many species are found in the oceans. Crustaceans, invertebrates with hard outer shells such as lobsters and clams, are probably the most numerous and diverse group.

Common invertebrates Invertebrates found in the oceans range from planktonic jellyfish to benthic worms and crabs.

Most crustaceans swim freely in the upper waters. Some, like the barnacle, attach themselves permanently to solid surfaces. Clams typically live in shallow water. At least one species has been found on the deep ocean floor near smokers where they have adapted to the warm, sulfur-rich water.

Squid live along coastlines and in mid-ocean, in surface and deep waters. They can exist as plankton, drifting along with the current, or use

Sea anemone look like plants but they are actually invertebrates. IMAGE COPYRIGHT VIRGINIA GOSSMAN, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

a form of jet propulsion by squirting water in a forceful stream from a tube near their heads.

Giant tubeworms grow up to 8 feet (2.4 meters) long and live in clusters around deep-sea smokers. These worms have neither a mouth nor a digestive system. They survive because of bacteria that live around them and produce the nutrients they need by chemosynthesis.

Food Invertebrates may eat phytoplankton, zooplankton, or both. Some eat plants or larger animals. The sea anemone uses its stinging tentacles to paralyze shrimp and small fish that swim past. Other invertebrates, including lobsters and crayfish, roam along the ocean floor to feed on dead organisms. A species of hadal zone spider has no eyes and feeds by sticking a long tube into worms and other soft creatures and sucking out body juices.

Reproduction Marine invertebrates reproduce in one of three ways:

- Eggs are laid and fertilized externally. A parent watches over the young in the early stages, and offspring number in the hundreds.
- Fertilization is internal. A parent cares for the young in the early stages, and offspring number in the thousands.
- Fertilization is external. The young are not cared for, and offspring number in the millions. Survival depends upon the absence of predators and the direction of currents.

Reptiles Reptiles are vertebrates (animals having backbones). The body temperatures of reptiles changes with the temperature of their surroundings. In cold temperatures, they become sluggish, so they do not have to waste energy keeping their body temperatures up as do most mammals and birds.

The two types of reptiles found in the oceans are sea turtles and sea snakes. Sea turtles can be distinguished from land turtles by their paddle-shaped limbs called flippers, which enable them to swim. The largest marine turtle, the Atlantic leatherback, may weigh as much as 2.2 tons (2,020 kilograms) and measure 9 feet (3 meters) from the tip of one flipper to another. Sea turtles have glands around their eyes that remove excess salt from their bodies. This process makes them appear to cry.

Sea turtles are found in all of the world's oceans except the Arctic Ocean. IMAGE COPYRIGHT STEPHEN STRATHDEE, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

At least thirty-two species of snakes live in tropical oceans, and all of these are found in regions around Australia and New Guinea. They look much like land snakes, having long bodies, some of which attain 9 feet (3 meters) in length. Unlike land snakes, they have salt glands that help them maintain a body fluid balance. Their tails are paddle shaped, which helps them move through the water, and some species are able to close their nostrils, which enables them to dive and remain submerged for hours. Sometimes, colonies of thousands can be seen floating on the surface of the water, basking in the sun.

Food Reptiles can survive for a long time without eating. When food is obtained they often eat large amounts. Turtles are omnivorous (eating both plants and animals). They eat soft plant foods as well as small invertebrates such as snails and worms. Turtles have no teeth. Instead, the sharp, horny edges of their jaws are used to shred food enough to swallow it.

Sea snakes are carnivorous (meat-eaters), feeding primarily on fish, including eels, that they find along the ocean floor in rocky crevices. They first bite their prey, injecting it with poison so it cannot escape.

Common reptiles Green sea turtles are typical of oceanic reptiles. They are migrators, traveling as far as 1,250 miles (2,000 kilometers) to return to a particular breeding area where they lay their eggs. Analysis of their brain structure suggests that they have a keen sense of smell and a built-in sense of direction that guide them to their particular breeding grounds. One green turtle was observed to travel 300 miles (480 kilometers) in ten days, which indicates it was moving quite quickly. Green sea turtles and the other six species of sea turtles are endangered.

Sea snakes are all venomous. The most dangerous is the beaded sea snake since just three drops of its venom can kill nine people. Very few human deaths occur from sea snake bites because the creatures are afraid of humans.

Reproduction Both snakes and turtles lay eggs, and some types of snakes bear live young. Turtles lay their eggs in a hole on a sandy shore, which they then cover. After the nest is finished, the female abandons it and seems to take no interest in the offspring. Six weeks later, the eggs hatch and the young turtles run for the water and disappear into the ocean.

Some species of sea snakes come to shore during breeding season and lay their eggs on land. The remainder bear live young at sea.

The Sneaky Shark

The cookie-cutter shark, a dwarf species named because it bites a round, cookie-shaped chunk of flesh out of bigger animals, uses a sneaky method of attracting prey, The cookie-cutter's underside glows, except for a large spot beneath its jaw. The ability to glow helps it blend in with the light filtering down from above. To another predator, the dark spot beneath its jaw may appear to be a smaller, innocent-looking fish. When a tuna or swordfish comes along, it spies the dark spot and thinks lunch is at hand. But when the big fish rushes upward for a bite, the cookie-cutter shark is the one that gets the meal.

Fish The oceans are home to about 14,700 kinds of fish, about 60 percent of all fish species on Earth. Fish are primarily cold-blooded (temperature varies with the surroundings) vertebrates having gills and fins. The gills are used to draw in water from which oxygen is extracted. The fins are the equivalent to arms and legs and are used to help propel the fish through the water.

Mackerel sharks and tuna are examples of warm-bodied fish. They have a special system of blood circulation that allows them to keep their body temperature as much as 21°F (12°C) above the water temperature. This extra warmth gives them more muscle power and thus more speed.

Fish vary in size from the tiny goby of the Philippines that measures less than 0.5 inch (1 centimeter) in length to the giant whaleshark that can grow as long as 60 feet (18 meters). Most fish have long, streamlined bodies built to move swiftly through the water, but shapes vary greatly. Manta rays, for example, are flat and round. Seahorses are narrow and swim with their bodies in a vertical (upright) position.

Most fish species live in the sunlit zone. Approximately 855 species live in the twilight zone, including the hatchetfish, the dragonfish, the lanternfish, the lancet fish, and the viperfish. These fish often have large, upward-angled eyes designed to see in the murky depths. They may have rows of light organs on their undersides, which help them blend in with the more well-lit waters above them or help them attract mates. The light from these organs is produced by either bacteria or chemical reactions they produce themselves. Some species have stretchy bodies, huge jaws, and fanglike teeth that enable them to take in and digest prey as large or even larger than themselves. These features may help them survive in a region where food is scarce.

Fish living in the dark zone include the gulper eel, the anglerfish, the whalefish, and the tripod fish. Most are white and small and either have no eyes or have tiny eyes that are blind. They, too, may have stretchy bodies and huge mouths. Few have light organs, perhaps because these would not be very useful around other blind fish. Many twilight and dark-zone fish have sensory hairs on their bodies that detect motion or changes in water pressure. Some can also detect odors.

Common fish Typical mid-ocean fish include sharks and tunas. There are about 330 species of sharks. Most of these live in coastal waters. Only six species favor the mid-ocean. These include the crocodile, the whale, the blue, the shortfin mako, the oceanic whitetip, and the silvertip. Some live and travel alone; others move about in schools (large gatherings of fish). They are present in all oceans except the Antarctic. Sharks are most abundant in tropical and subtropical waters. They vary in size and behavior and are relatively free of disease. With the exception of other sharks, they have few enemies.

Some deep-ocean sharks must remain in constant movement in order to breathe. Their forward motion forces water through their gills from which they extract oxygen. Other species with more ordinary respiratory (breathing) systems can float or rest on the ocean bottom. Most sharks move leisurely, but some species are very fast. The blue shark can attain speeds of up to 40 miles (64 kilometers) per hour. A shark's sensitive eyes can see well in dim light, which enables some species to hunt in the twilight zone. They have a highly developed sense of smell and can sense movement vibrations in the water, which makes it easy for them to find prey.

All sharks are carnivorous. The rare whale shark, the largest fish in the ocean at more than 50 feet (15 meters), feeds only on small fish and plankton. The real predator is the great white, which averages 20 feet (6 meters) in length but may grow much larger. The diet of a shark includes almost every animal in the oceans, including other sharks. During feeding frenzies, large numbers of sharks attack the same prey, tearing it to pieces. In their haste to eat they may rip into one another, and any unlucky wounded shark is eaten along with the rest of the meal. Sharks often go without food for long periods, during which time oil stored in their livers helps sustain them.

Compared to some other species of fish, sharks do not produce large numbers of young. They may have as few as two or almost one hundred. Some species lay eggs, while in others, the young develop much as mammals do inside the female and are born alive. Development of the egg or embryo (baby) may take from a few months to two years,

Grey reef sharks frequent the waters near islands and coral reefs. IMAGE COPYRIGHT IAN SCOTT, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

depending on the species. The parents do not care for their young, which are completely developed at birth.

As humans probe farther into the oceans, they encounter sharks more frequently. Six species are known to attack humans: great whites, tigers, bulls, makos, hammerheads, and oceanic whitetips. In 2005 only about 58 unprovoked attacks occurred, and only a few were fatal. Most mid-ocean sharks live too far offshore to present much of a threat.

Tunas live in both temperate and tropical oceans; usually in the surface waters. They tend to be large fish, although their size varies from species to species. The largest species, the bluefin, may grow to more than 14 feet (4.2 meters) in length and weigh more than 1,400 pounds (680 kilograms). Their dark blue-green and silver coloring helps disguise them from predators. They are migrators and travel long distances in search of food and for breeding purposes. Skipjack tunas have been observed to travel as far as 16,000 miles (256,000 kilometers).

Like some species of sharks, tunas must be in constant motion in order to breathe. They are warm-bodied fish, which means their circulatory system enables them to maintain a body temperature warmer than that of the surrounding water. This gives them more power; they are fast swimmers, traveling at more than 30 miles (48 kilometers) per hour. Since their energy demands are great, they require a lot of food. They primarily eat other fish and squid.

Tunas are in great demand commercially as food for humans. For example, a bluefin tuna, which is endangered, can be worth as much as $60,000. To prevent overfishing, international agreements have been made to limit the number that can be caught and the areas where tuna fishing is allowed.

Food Most fish live near the continental margins where food is readily available. Some are plant eaters whose diets are primarily phytoplankton, algae, or sea grasses. Fish that must swim in search of prey have more streamlined bodies than those that burrow into the bottom sediments for it.

Fish that live primarily in the twilight zone often travel to the sunlit zone at night to feed. Their large eyes aid them in finding prey, which may not be able to see as well under low-light conditions. They often use a light organ to lure prey.

Fish that live in the deepest regions must depend on food that falls from above, such as particles of zooplankton or the dead bodies of other animals. Strict carnivores are rare in the dark zone, perhaps because there is too little prey. Many dark-zone fish have bodies that stretch to accommodate large meals when they can find them. Although most dark-zone fish are not luminous, the anglerfish has a light organ used to lure prey. This organ is positioned over its mouth like the bait on the end of a fishing pole. Another fish, drawn by the light to investigate, is snapped up for a meal. Some species of dark-zone fish travel at night to higher levels for food, but they do not travel as far as fish living in the twilight zone.

Reproduction Most fish lay eggs, although many, such as certain species of sharks, bear live young. Some, such as the Atlantic herring, abandon their eggs once they are laid. Others build nests and care for the new offspring. Still others carry the eggs with them until they hatch, usually in a special body cavity or in their mouths.

Certain marine fish, such as sturgeons and Pacific salmon, are actually born in freshwater rivers but spend most of their lives at sea, often traveling thousands of miles. Years later they return to the river where they were born. There, they breed and then die. Atlantic freshwater eels leave American and European rivers to breed in the Sargasso Sea, where they, too, die. By some inherited means of guidance, their young return to those same rivers, and the cycle is repeated.

Male anglerfish, a dark-zone species, are dwarfs. Before the breeding season, the male bites into the skin of the female, and their circulatory systems become joined so that the male receives his nutrients from the female's blood. (The circulatory system includes the heart, blood vessels, and lymphatics that carry blood and lymph throughout the body.) This may help assure that males and females can find one another at the appropriate time in this sparsely populated region. Some dark-zone fish are hermaphroditic. This means the reproductive organs of both sexes are present in one individual fish, and true mating is not necessary.

Seabirds Most seabirds remain near land where they can nest during breeding season. A few species are known to travel great distances over the oceans in search of food and spend most of their lives doing so. The Arctic tern, for example, is the greatest long-distance migrator of all, traveling up to 20,000 miles (32,000 kilometers). These species are classified as

Albatrosses feed on fish, krill, and squid, often spending much of their lives flying over the open ocean. IMAGE COPYRIGHT ARMIN ROSE, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

oceanic birds. Many seabirds have adapted to marine environments by means of webbed feet and special glands for removing excess salt from their blood.

Common seabirds Many seabirds remain near the coastline and spend much of their time on land. A few species, such as the albatross, petrel, and tern are oceanic birds.

Albatrosses are wanderers, spending much of their lives over the open ocean. Some appear to follow established routes; others follow the wind. Albatrosses are very large birds with long, narrow wings that may span up to 12 feet (3.5 meters) from tip to tip. In 1998, a black-footed Laysan albatross was observed to have traveled 25,135 miles (40,216 kilometers) in seventy-nine days. Albatrosses sleep on the ocean's surface, drink seawater, and feed on small fish and squid. Some species are scavengers and follow ships at sea, eating the garbage thrown overboard. Although they mate for life, the mated pair normally live thousands of miles apart and come together on land only during the breeding season.

Petrels, like albatrosses, spend most of their lives at sea. One species, called storm petrels, were once believed by sailors to signal the coming of bad weather. Storm petrels feed on plankton floating on the surface of the ocean. Some diving petrels can swim after prey underwater. Larger species eat carrion (dead animals). Like albatrosses, petrels come to land only to breed.

Terns plunge dive into the ocean to catch small fish. These sea birds encounter more hours of daylight each year than any other creature thanks to their migration patterns.

Food All seabirds are carnivorous. Most eat fish, squid, or krill, and they live where the food they prefer is in ready supply. Several species, such as cormorants and diving petrels, hunt underwater, using their wings to swim. Other species, such as gannets, spot their prey from high above and then dive-bomb into the water, bringing their catch to the surface to eat. Some, like gulls, swoop down on fish swimming close to the surface.

Reproduction Seabirds tend to nest on islands where there are few land-dwelling predators. Some nest in huge colonies on the ground, others dig burrows, and still others prefer ledges on a cliff. Like other birds, seabirds lay eggs and remain on the nest until the young are able to

Manatees are also known as sea cows and they spend their time grazing in shallow waters. IMAGE COPYRIGHT WAYNE JOHNSON, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

leave on their own. Some live in one area and migrate to another for breeding. The Arctic tern, for example, spends the winter months in Antarctica, then travels halfway around the globe to breed during the summer in the Arctic Circle.

Marine mammals The three most important mammals that are truly marine are whales, porpoises, and sea cows. They must remain in the water at all times. Other mammals, including seals and sea otters, spend much of their time in the water but are able to live on land, and do so especially at breeding time.

Common marine mammals Whales and their cousins, porpoises and dolphins, are the primary deep-ocean mammals. Whales are found in all the world's oceans, including the Antarctic. Most species migrate, some traveling as much as 14,000 miles (22,400 kilometers) during one breeding season. Their paths usually follow ocean currents and may depend upon available food supplies and water temperature. Most species travel in schools. Smaller species may live as long as thirty years. The larger species may live to be 100 years old.

Whales fall into two categories: toothed whales and baleen whales. Instead of teeth, baleen whales have a row of bony, fringed plates they use to filter plankton from the water. Baleen whales include the gray, the humpback, and the blue whale. Blue whales are the largest animal known to have lived. They grow to lengths of 100 feet (30 meters) and may weigh as much as 200 tons (180 metric tons). Toothed whales include killer, beluga, and sperm whales. These are all predators, feeding mainly on fish and squid.

A layer of dense fat, called blubber, surrounds the whale's body directly under its skin. Whales are warm blooded and the main purpose of this fatty layer may be to help them maintain body temperature. Some species, such as the sperm whale, may dive to depths of more than 3,300 feet (1,006 meters) and stay underwater for up to an hour, but whales must return to the surface to breathe. The blowhole on the top of a whale's head is actually the nostril. The spout, which looks like a stream of water the whale shoots in the air through its blowhole, is actually exhaled air. This exhaled air is usually warmer than the outside atmosphere and its moisture quickly condenses and looks like steam.

Whales occasionally jump out of the water, landing again with a huge splash. This is called breaching. The reason for it is unknown, but it may have something to do with the fact that they are very social animals. Almost all species of whales produce sounds such as whistles, squeals, and clicks. These sounds may have much to do with social behavior, and there is little doubt that they express certain emotional states such as fear or hunger.

Food The sea cow is the only plant-eating mammal that truly lives in the sea. Most marine mammals are carnivorous. Some, like the baleen

Whales are one of the few truly marine mammals. These are Beluga whales. IMAGE COPYRIGHT MARTIN TILLER, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

whales, feed primarily on zooplankton, especially krill. Others, like the porpoise, feed on fish and invertebrates such as squid and even clams or oysters.

Reproduction Like other mammals, marine mammals bear live young. Most have only one offspring at a time. The young are nursed with milk produced by the mother's body until they are able to find food on their own.

DIVING ABILITIES OF DIFFERENT ANIMALS*

Sperm whale	5,280 feet (1,609 meters)
Weddell seal	1,968 feet (600 meters)
Blue whale	1,000 feet (305 meters)
Penguin	800 feet (244 meters)
Human with aqualung	260 feet (79 meters)
Porpoise	164 feet (50 meters)

*These are distances that have been actually measured, depths may be much greater in some cases.

Endangered species At one time sharks were plentiful; however, reduction in their food supply from commercial fishing and a growing interest in the sharks themselves for human food have reduced their numbers.

Most seabirds tend to be unafraid. Many are threatened by humans who use them for food or feathers when they come to land. On the open ocean, thousands are caught accidentally each year in fishing nets. Others suffer from pollution, pesticides, and the results of oil spills, which destroy the waterproofing effect of their feathers. The albatross population alone has declined 40 percent in the past thirty years.

Until the twentieth century and the introduction of factory whaling ships, the great whales were numerous. Beginning around 1864 and ending in the 1970s, commercial whaling reduced the numbers of many coastal species. In 1986, a number of nations suspended commercial whaling in order to allow populations to increase. Since then, a few countries allow limited hunting locally for food. The North Atlantic right whale, protected since the 1930s, has fewer than 500 specimens remaining.

The bluefin tuna has decreased to 10 percent of its population since 1975.

Human Life

People do not live in the ocean environment for long periods of time, but the oceans have had an effect on all human life. Human life has its effect on the oceans too.

Impact of the ocean on human life Without the oceans, there would be no life on Earth. Not only did the first life forms originate there, but

Sea Serpent Sightings

For centuries, people have wondered if strange, gigantic creatures lay hidden in the unexplored regions of the sea. Every now and then, someone reports seeing what they think is a sea serpent. So far, the sightings that could be checked have turned out to be creatures already known. For example, a sea serpent that was reportedly washed up on the California coast turned out to be the remains of a beached whale. Sharks or other predators had eaten part of the whale, and its skin was twisted in such a way that it appeared to have a very long neck. Large regions of the ocean are still unexplored, and gigantic animals may yet remain to be discovered. The larva of an enormous eel has been found in the Pacific, for example. If its parent ever turns up, it might just be the legendary sea serpent.

the oceans help sustain all life forms. Oceans regulate gases in the atmosphere, and the phytoplankton that grows in them provide oxygen. The oceans influence weather and help moderate temperature; they are largely responsible for the rain, sleet, and snow that fall on land. They are also a source of food, water, energy, minerals, and metals.

Food and water Since prehistoric times, humans have depended upon the oceans for food, primarily fish. Some fish, such as orange roughy, are caught in deep waters, but most primary fishing areas are over the continental margins where the waters support more sea life.

To make up for the shortage of certain species of fish, fish farming has become popular. In fish farms, fish eggs are hatched and the young fish are fed and protected until they can be released into the ocean or sold for food. A few sea fish, such as salmon, are grown successfully in farms but their flesh lacks the high levels of nutrients found in wild salmon.

Algae are used for food and to make food products. Certain varieties of kelp are popular in Japan, where they are cultivated in sea farms and used as a vegetable. In the United States, algae are used primarily as thickeners in ice creams and puddings.

Sea salt is another food item taken from the oceans. Sea water isolated in shallow ponds along the shoreline is allowed to evaporate until a crust of crystals forms. The crystals are then collected, processed, and packaged.

Sea water is desalted and used by some desert countries for drinking and irrigation (a method of supplying water to dry land). This process, called desalination, is expensive and not very efficient. Only wealthy countries can afford to do it.

Energy Millions of years ago, sediments from dead animal and plant life (fossils) formed on the ocean floor. Time, heat, and pressure from overlying rock have worked to turn these sediments into fossil fuels, primarily gas and oil. To obtain these resources, oil rigs (large platforms standing well above sea level but anchored to the sea bed) are built. From these platforms, drilling is done into the rock, releasing the gas and oil,

Fossil fuels such as oil can be found beneath the ocean floor. Large platforms, anchored on the sea bed, are built to mount drilling equipment to retrieve these resources. IMAGE COPYRIGHT ARTHUR EUGENE PRESTON, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

which are then pumped to shore through pipelines. Most gas and oil deposits have been obtained from offshore rigs. As these deposits are used up, ways of acquiring deposits in the deep sea are being explored.

Ocean surface waters absorb large quantities of solar energy (energy from the sun). A process known as Ocean Thermal Energy Conversion has been used to capture some of that energy for human use. Conversion plants are located in Hawaii and other tropical islands. Producing usable energy from ocean currents, waves, and tides is also being explored.

Minerals and Metals Minerals and metals are other important oceanic resources. Rocks, sand, and gravel dredged from the sea floor, especially in the North Sea and the Sea of Japan, are used in construction. Bottom deposits of manganese, iron, nickel, and copper have been found in the deep ocean, but so far, extracting them is expensive and poses environmental problems. Some minerals, such as sulfur, can be pumped as liquids from beneath the ocean floor.

Transportation Since the first humans ventured out on the oceans in ships, the oceans have provided transportation routes. At least 40,000 years ago, people made the journey from Southeast Asia to Australia and New Guinea. Since then, seagoing routes have been used for trade, expansion, travel, and war.

Impact of human life on the oceans The World Ocean surrounds us, so what one country does to it affects all countries. If one country overfishes a species of fish, other countries may suffer.

Wrecks at Sea

Since people first began to travel on the open sea, there have been shipwrecks. Some areas, such as the Bermuda Triangle in the Atlantic, are famous for the number of ships lost in them.

The sea helps preserve wooden ships by covering them with sediment so that wood-eating animals that might attack them are kept away. Metal ships, however, rust easily in seawater. Animals, such as corals, grow on the outside of the ship, and others, such as fish and octopi, may use the interior for shelter.

The most famous wrecked ship is the *Titanic*, which sank in 1912 on its first voyage. The *Titanic* was supposedly unsinkable because it contained many water-tight compartments that should have kept it afloat. It struck an enormous iceberg and sank in less than three hours. Of the 2,228 people on board, 1,523 died.

Use of plants and animals After World War II (1939–45) the technology of commercial fishing improved, and a growing population increased the demand for fish as a food source. Major food species such as herring, cod, haddock, sardines, and anchovies, had been greatly reduced. Marine fishing reached an all-time high in 1989, at about 98 million tons (89 million tonnes). Regulations now limit fishing for these species. Some scientists believe that by monitoring the number of fish in a certain species, and by adding more species of those used for human food, no species should be threatened with extinction.

Fish farms are a means of helping maintain certain species of commercially popular fish. Pacific salmon are raised in hatcheries (fish farms) in the United States and Norway; oysters are raised in the United States; and shrimp farms can be found in Mexico, Ecuador, and Taiwan. Japan has greatly increased its catch of fish by building artificial reefs along its coastline. These reefs attract algae, which in turn attract fish and other sea animals.

The great whales were hunted for centuries by people of many countries for their meat, which was used for food; their fat, which was used for oil and in making soap; and for other body parts, which were ground into animal feed or used to make such items as brushes. Whales are now protected, but some scientists believe certain species will never recover from their losses and may still face extinction.

The Stellar sea cow, which looked like a giant walrus, weighed up to 11 tons (10 metric tons) and was hunted into extinction in the 1700s.

Many sea plants and animals are popular as souvenirs or art objects. When seashells from dead animals are taken, no harm is usually done. However, many shells available commercially are taken from living animals and the animals are left to die.

Marine parks and reserves have been set up all over the world to protect endangered species. They include the Shiprock Aquatic Reserve in Australia and the Hervey Bay Marine Park in California. Species on the endangered lists include the leatherback sea turtle, humpback whale, green sea turtle, and the bowhead whale.

Natural resources Large quantities of natural resources, such as oil and minerals, can be found in the oceans or beneath the ocean floor. These resources have not been used up because they are still too difficult or too expensive to obtain. As methods improve that may change.

Quality of the environment For centuries, the oceans have been used as a garbage dump. Six million tons (5,442,000 metric tons) of litter are dumped into them each year from ships alone, while sewage and industrial wastes come from coastal cities. Discarded items, such as plastic bags and old fishing nets, pose a hazard for the animals that get caught in them. Oil spills from tanker ships carrying oil from one country to another are dangerous, as is oil from oil refineries and pipelines. Efforts by concerned nations have begun to correct some of these problems. In 1972, an agreement to prohibit dumping of toxic (poisonous) materials in open seas was signed by ninety-nine nations.

At one time, radioactive nuclear wastes, which are extremely toxic, were dumped into the ocean. The Irish Sea, where this occurred, is the most radioactive sea in the world. Dumping of nuclear waste is now banned. Some countries have begun to study the deepest areas of the sea as potential disposal sites for extremely dangerous wastes, such as waste from nuclear reactors. Whether this can be done successfully without harm to the ocean environment, and ultimately to humans, remains to be seen.

The God of the Sea

To the ancient Greeks, Poseidon was the god of the sea. It was believed that he lived beneath the oceans's depths and controlled the fate of those who ventured out upon the waters. Poseidon could summon tsunamis, which is how he brought down the ancient kingdom of Crete, home of the fearful mythical Minotaur who was half man, half bull.

Ocean exploration Humans have explored the surface of the seas since ancient times, going as far as their craft and their courage would take them. By 3200 BC the Egyptians had invented sails and were traveling by sea to different countries for trading purposes. The ocean depths are another matter; humans can go only so deep without special equipment.

During the 1600s, diving bells were designed that allowed divers to go as deep as 60 feet (18 meters). Lead-lined wooden barrels filled with air were lowered periodically to the bell and a leather tube was used to connect them with the divers. In the 1700s, compressed air (air forced into a metal container) and the development of metal helmets and flexible

The Seven Seas

Centuries ago, people spoke of "sailing the seven seas." The seas in question were those considered navigable at the time: the Atlantic, Pacific, Indian, and Arctic Oceans; the Mediterranean and Caribbean Seas; and the Gulf of Mexico. Now scientists only speak of three major oceans, the Atlantic, Pacific, and Indian. The remainder of the original seven are considered part of the Atlantic.

diving suits made exploration easier. In 1943, Jacques Cousteau and Emile Gagnan made diving to a depth of 165 feet (50 meters) possible by perfecting the automatic aqualung. (An aqualung provides compressed air through a mouthpiece.) Diving deeper has proven difficult. The dark, the cold, and the high pressure created by the weight of the water overhead limit what humans can do without special pressurized suits and protective vehicles.

In 1960, the bathyscaphe (BATH-uh-skafe) *Trieste,* operated by the U.S. Navy, descended almost 6.8 miles (11 kilometers) into the Mariana Trench in the Pacific. A bathyscaphe is a small, submersible (underwater) vehicle that can accommodate several people and is able to withstand the extreme pressures of the deep ocean—more than 16,000 pounds (110,240 kilopascals) per square inch. Other manned submersibles, including the U.S. *Alvin*, the French *Nautile*, the Japanese *Shinkai 6500*, and the Russian *Mir I* and *Mir II*, have reached depths of 3.7 miles (6 kilometers) and have greatly added to our knowledge about the ocean floor. In 1996, the Japanese submersible *Kaiko* collected the first samples of sediment from the Challenger Deep, the lowest part of the Mariana Trench.

Safety and other considerations make manned exploration of the oceans difficult. For these reasons, remotely operated vehicles are often used for unmanned exploration. Some vehicles are about the size of a small car. They are attached by cables to a "mother" ship and may be equipped with video cameras, mechanical arms, and sensors that measure temperature, salinity, and other water conditions. New models are expected to go as deep as 13,120 feet (4,000 meters) and have cameras that can operate without lights. These newer models are not able to go as deep as previous models, like the *Trieste,* but they are more sophisticated and are meant for more elaborate studies.

Much exploration has been made using sonar equipment. Sonar is the use of sound waves to detect objects. Single pulses of sound are sent out by a machine at regular intervals and as the sound pulses are reflected back a "picture" is obtained of the surrounding area. Sonar has helped researchers map the mountains and valleys of the ocean floor.

The Food Web

The transfer of energy from organism to organism forms a series called a food chain. All the possible feeding relationships that exist in a biome make up its food web. In the ocean, as elsewhere, the food web consists of producers, consumers, and decomposers. These three types of organisms transfer energy within the oceanic environment.

Phytoplankton are the primary producers in the oceans. They produce organic materials from inorganic chemicals and outside sources of energy, primarily the sun.

Zooplankton and other animals are consumers. Zooplankton that eat only plants are primary consumers in the oceanic food web. Secondary consumers eat the plant-eaters. They include the baleen whale and zooplankton that eat other zooplankton. Tertiary consumers are the predators, like tunas and sharks. Humans are also tertiary consumers called omnivores, organisms that eat both plants and animals.

Decomposers feed on dead organic matter and include lobsters and large petrels. Bacteria help in decomposition.

Harmful to the oceanic food web is the concentration of pollutants and dangerous organisms. It was once thought that the ocean would dilute harmful chemicals, but just the opposite is true. They become trapped in sediments where life forms feed. These life forms are fed upon by larger organisms, and at each step in the food chain the pollutant becomes more concentrated. When humans eat contaminated sea animals, they are in danger of serious illness. The same is true of diseases such as cholera, hepatitis, and typhoid, which can survive and accumulate in certain sea animals and then be passed on to people.

Spotlight on Oceans

The Indian Ocean The Indian Ocean is the third largest in the world and covers about 20 percent of Earth's water surface. Its volume is estimated to be about 62,780,380 cubic miles (261,590,400 cubic kilometers).

The Indian Ocean contains many islands. During the prehistoric breakup of the continents, small pieces of continent were left behind in the Indian Ocean as undersea plateaus (high, level land areas). Some of these plateaus rise above the water and form islands, such as the Laccadives. Many other islands, such as Mauritius, are volcanic in origin. On the ocean's eastern border lie the islands of Indonesia; on the western

The Indian Ocean
Location: South of India, Pakistan, and Iran; east of Africa; west of Australia; north of the Antarctic Sea
Area: 28,000,000 square miles (73,000,000 square kilometers)
Average Depth: 12,760 feet (3,890 meters)

border lie Madagascar, Zanzibar, the Comoros, the Seychelles, the Maldives, and the Nicobar Islands. To the south are the Crozets and the Kerguelen. Coral reefs (undersea walls made from coral skeletons) can be found in areas of the ocean located in the tropics.

Running through the center of the Indian Ocean's floor is part of the mid-ocean ridge in the form of an upside-down Y. Many peaks in this mountain chain are about 6,560 feet (2,000 meters) high. All along the chain are active volcanoes; earthquakes constantly occur, causing spreading of the sea floor. The Indian Ocean basin is expanding at a rate of about 1 inch (2.5 centimeters) each year.

The Java Trench is the only known trench in the Indian Ocean. It lies south of Indonesia and, at its lowest point, is 4.5 miles (7 kilometers) deep. To the north of the trench is another string of volcanoes, the most famous of which is Krakatoa, which exploded so violently in 1883 that it could be heard 1,860 miles (3,000 kilometers) away.

Several major rivers flow into the Indian Ocean bringing large quantities of sediment. These include the Indus and Ganges in India and the Zambesi in southern Africa. Over thousands of years, these sediment layers have formed vast fans that spread out over the nearby ocean floor.

Climatic conditions over most of the Indian Ocean are tropical. In its warmest part, the Arabian Sea, surface waters can reach 86°F (30°C). Near the Antarctic Sea, the temperature can drop to less than 54°F (12°C). Average annual rainfall is about 40 inches (102 centimeters). In the ocean's northern reaches, rainfall is affected by the monsoons (rainy seasons) that drench the Asian continent. In the southern portion, trade winds blow from the southeast all year long.

Two major currents occur in the Indian Ocean. In the southwest, the Agulhas flows between Africa and Madagascar. At the equator, the North Equatorial Current occurs in the winter and flows west.

Where the Indian Ocean meets the Pacific Ocean in the region of the Philippines, marine life is very rich. In the open ocean marine life is scarce because the waters of the Indian Ocean are warm, and growth of phytoplankton is limited. As a result, the creatures that feed on phytoplankton are limited.

Among the species of invertebrate plankton that live in the Indian Ocean is the sea wasp jellyfish. Its poisonous sting produces large welts. A person with many stings can die in minutes. Crabs, lobsters, oysters, squid, and giant clams are found here.

The Indian Ocean supports many species of seabirds, especially around the shoreline where food is plentiful. The most common birds are noddies, boobies, terns, frigate birds, storm petrels, and albatrosses.

Species of mid-ocean fish include sharks, flying fish, tunas, marlins, and sunfish. The coelacanth, a species of fish surviving from prehistoric times, has been found off the Comoros Islands, where it is now protected.

Whales are plentiful in the Indian Ocean, especially in the cooler southern waters where food is abundant. Much of the Indian Ocean is now a protected area for whales. Other mammals include fur seals, elephant seals, and, in northern portions, sea cows. Sea cows have become endangered because they are easily caught in nets and killed for their meat and hides.

Commercial fishing in the Indian Ocean is limited to local needs. Over the centuries, the ocean's greatest value has been for trade transport. Since the discovery of large oil deposits in the Middle East, it has been key to the shipment of petroleum extracted along the Persian Gulf.

The first Westerner to explore the Indian Ocean was Vasco da Gama (c. 1460–1524) of Portugal. In May 1498, da Gama reached India and, for the next century, Portugal claimed this ocean as part of its empire. The ocean was so vast that no one nation controlled the surrounding lands until England in the early 1800s. After World War II (1939–45), England withdrew from the area. Gradually, India, Russia, and the United States have become major influences. Countries bordering the ocean want it declared a peaceful zone where all people may travel the waters freely and safely.

The Sargasso Sea The Sargasso (sar-GAS-oh) Sea is a clear, saucer-shaped area of water near the island of Bermuda in the Atlantic. It is formed by two main opposing ocean currents, the Gulf Stream to the north, and the North Equatorial Current to the south. Its waters are warm and, because of the action of the currents, they slowly revolve clockwise above much colder Atlantic depths. This rotation causes the water in the center to rise, and the level of the Sargasso is about 3 feet (1 meter) higher than the water surrounding it.

The name Sargasso comes from Sargassum, the type of brown algae that grows there in abundance. The algae are plankton, and they possess clusters of gas-filled chambers resembling grapes at the bases of their fronds that keep them afloat. Huge masses of the algae drift on the surface of the sea. These algae reproduce when pieces break off the main

The Saragasso Sea
Location: Western North Atlantic
Area: 2,000,000 square miles (5,200,000 square kilometers)
Average Depth: 3 miles (4.8 kilometers)

organism and begin to grow. Every piece can potentially grow into a new organism.

Many animals live in the Sargasso Sea that are ordinarily not found in mid-ocean because of the plentiful algae. Some animals, like tubeworms, attach themselves to the algae and sift the water for tiny organisms they use for food. Crabs, shrimp, and snails roam everywhere over the fronds. The leptocephalus (lep-TOH-sef-a-LOS) eel migrates to the Sargasso to breed but otherwise lives in freshwater rivers thousands of miles away.

Permanent species of fish include the sargassum fish, which lives only in the Sargasso. Its scientific name means "the actor;" an appropriate name because it spends its life pretending to be a sea weed frond. Its body has black and yellow-green blotches to match the algae. It has a pair of fins with fingerlike projections that allow it to attach to a frond and drift as the frond does. When it stalks its prey, it climbs over the weeds. One of its fingerlike projections resembles a bit of food, which it dangles in front of its mouth waiting for another fish to take the "bait."

Italian explorer Christopher Columbus (1451–1506) reported on the Sargasso after his first voyage to the "Indies," and he claimed to have found evidence of other voyagers there. It is possible that the Carthaginians, who lived in the city of Carthage on the North coast of Africa during ancient times, may have reached the Sargasso as early as 530 BC. Legends tell of ships being trapped in the weeds, but that likely never happened. Instead, ships set adrift may have been carried here because of the rotating current, and this may be the source of the myth.

The Black Sea The Black Sea is the world's largest inland body of water. It qualifies as a sea because it remains connected to the Sea of Marmara, the Aegean Sea, and finally to the Mediterranean Sea by means of the Bosporus Strait. Large European rivers including the Dnieper, the Danube, the Dniester, and the Don flow into it. The fresh water they bring makes it less salty than most seas.

The Black Sea
Location: North of Turkey, south of Russia and the Ukraine
Area: 162,000 square miles (419,580 square kilometers)
Average Depth: 3,826 feet (1,166 meters)

Two currents flow through the 19-mile (30-kilometer) -long Bosporus Strait. A rapid surface current carries water from the Black Sea toward the Aegean and eventually into the Mediterranean. Beneath this current, a strong undercurrent travels in the opposite direction, bringing waters from the Mediterranean into the Black Sea. These currents create very choppy waters and help create the Black Sea's unusual environment.

The water column in the Black Sea is layered. Salt water coming from the Mediterranean enters at a deep level and continues to sink. Fresh water from the rivers flows into the shallow coastal areas. Fresh water is lighter than salt water, so it floats on top of the salt water. The two layers mix very little. The bottom layer, which consists of almost 90 percent of the water column, receives little oxygen creating a dead zone. Nothing lives at the bottom of the Black Sea except a few species of bacteria. A form of sulfur dissolved in the deep water gives it the odor of rotten eggs.

The upper layer supports abundant life forms. About 300 species of algae live in the upper layer to a depth of about 65 feet (20 meters). These plants provide food for zooplankton, mollusks, and other sea life. Many kinds of fish live in the upper layer, including anchovies, bluefish, turbot, and sturgeon. The largest mammals in the Black Sea are dolphins. More than 1 million dolphins once lived there, but their numbers were greatly reduced by commercial fishing. Some countries have begun programs to protect the dolphins and other endangered species.

Countries surrounding the Black Sea once depended upon it financially for fish. Overfishing, the use of pesticides, industrial pollution, diversion of river waters for irrigation, and nuclear contamination from the Chernobyl reactor explosion in 1986 have caused fish populations to decrease. Lack of fresh river water has resulted in an increase in the size of the dead zone, which may eventually take over the entire Black Sea. If that happens, nothing will be able to live in it except bacteria.

In Greek legend, the Black Sea was the body of water on which Jason and the Argonauts sailed in search of the Golden Fleece. For centuries, the Black Sea was considered unfriendly for sailors because of its sudden storms and strong currents. These dark storms and heavy threatening fogs may have been what earned the sea its name.

The Pacific Ocean The Pacific Ocean is the world's largest ocean. Waters in its northern and southern halves seldom mix. In the north it is linked to the Arctic Sea by means of the Bering Strait. In the south it is bordered by the Antarctic Sea. Its volume is about 154,960,672 cubic miles (643,375,552 cubic kilometers).

The mid-ocean ridge cuts through the Pacific basin from Japan to Antarctica and attains a height of 13,000 feet (3,962 meters) in some places. Trenches along the continents often exceed 26,000 feet (7,925 meters) in depth. Deeper trenches are found along strings of islands, such as the Aleutians and the Philippines. The deepest trench in the world, the Mariana, is found in the Pacific near the Mariana Islands.

The Pacific Ocean
Location: West of North and South America; east of Asia and Australia
Area: 64,000,000 square miles (1,666,000,000 square kilometers)
Average Depth: 12,700 feet (3,870 meters)

Islands are numerous in the Pacific, and most have been created by volcanoes. The famed "Ring of Fire," an area of intense volcanic activity is found in the region of Indonesia. Islands near the equator usually have coral reefs.

Around the equator, the trade winds maintain a permanent current moving from east to west. As this current turns northward around the island of Japan, it is called the Kuroshio (koo-ROH-shee-oh) current. Like the Gulf Stream in the Atlantic, the Kuroshio is a strong, intense current.

The areas of the Pacific most abundant with plant and animal life are in the far north and far south where icy water circulating upward from the sea floor brings nutrients to the surface. Millions of tons of phytoplankton and zooplankton drift upon the waters in spring and summer, providing food for baleen (toothless) whales and basking sharks, as well as smaller animals. Species from one area seldom inhabit the other.

The Pacific is home to one of the most dangerous of the invertebrates, the little blue-ringed octopus, whose sting is highly poisonous and usually deadly. Another invertebrate, the Pacific lobster, lacks claws and uses its antennae instead for defense.

Several species of sharks and rays are found only in the Pacific. The Port Jackson shark eats primarily clams and other mollusks, using its powerful jaws to crack the shells. This particular shark has a long history; its form has remained unchanged for the past 150 million years. More than twenty species of whales, porpoises, and dolphins live only in the Pacific. In the southern regions, leopard and fur seals can be found.

More than 40 percent of commercial catches of fish with fins, such as anchovies and tuna, come from the Pacific. Other Pacific resources with commercial importance include offshore deposits of iron ore near Japan, and tin near Southeast Asia.

The Atlantic Ocean The Atlantic Ocean contains about 25 percent of all the water in the World Ocean. Its volume is 73,902,416 cubic miles (307,902,776 cubic kilometers).

Although its waters are typically less salty than those of the Pacific, its northern portion is the warmest and saltiest area in the World Ocean. This is due, in part, to water flowing into it from the Mediterranean. Its circulation is limited because the northern portion is hemmed in by continents, and because its waters do not readily mix with those of the Arctic Ocean to the north. Currents are stronger than in the southern Atlantic.

The Atlantic Ocean
Location: East of North and South America, west of Europe and Africa
Area: 33,000,000 square miles (86,000,000 square kilometers)
Average Depth: 12,100 feet (3,688 meters)

The mid-ocean ridge forms an S-shape in the Atlantic basin and divides it into two parallel sections. Some peaks along the ridge form islands, such as the Azores. Its deepest trench is the Puerto Rico with a depth of 28,232 feet (8,605 meters).

The most familiar Atlantic current is the Gulf Stream, which flows along the eastern coast of North America. A number of currents in the North Atlantic form a clockwise gyre. In the South Atlantic, currents form a counterclockwise gyre.

The Atlantic is geologically young, and its bottom-dwelling animals are descendants of animals that migrated there from other oceans. As a result, the numbers of bottom-dwelling species are few. In its equatorial and temperate regions, nektonic and planktonic animals are abundant. Many ocean travelers, such as sharks, whales, and sea turtles, cross the southern regions when they migrate.

Atlantic resources include diamonds found off the southwest coast of Africa, sand and gravel off the coast of northwest Europe, and oil and gas in the Caribbean and North Sea regions. Fish taken commercially from the Atlantic include salmon, lobster, shrimp, crabs, sardines, and anchovies.

The science of oceanography began in the northern Atlantic, and many theories about oceans are based on studies made there. The northern portion of the Atlantic differs from its southern portion and from the Indian and Pacific Oceans, so these generalizations cannot be automatically accepted.

The Antarctic Ocean The Antarctic Ocean is sometimes called the Southern Ocean. It encircles the continent of Antarctica, and in winter ice forms over more than 50 percent of the ocean's surface. Glaciers break free of the continent periodically and drift seaward to join floating ice shelves.

In the north, the mid-ocean ridge borders the Antarctic basin. The basin itself reaches a depth of about 18,400 feet (5,600 meters).

Currents in the Antarctic Ocean flow from west to east and the water is turbulent (rough). The area is windy and usually cloud covered.

The amount of daylight varies dramatically at the south pole. In winter, it is dark almost all of the time, and light almost all of the time in summer. Growth of phytoplankton is limited to spring and summer seasons.

The most important zooplankton is krill, which is food for baleen whales, seals, sea birds, fish, and squid. Among invertebrates, squid are

The Antarctic Ocean
Location: Surrounding the continent of Antarctica
Area: 12,451,000 square miles (32,249,000 square kilometers)
Average Depth: 12,238 feet (3,730 meters)

common and play an important part in the food web. They are eaten by sperm whales and albatrosses.

Most fish in the Antarctic are bottom-dwellers, where they tend to live on or near the continental margins. Many, such as the Antarctic cod, contain a kind of antifreeze in their body fluids that allows them to live at temperatures below freezing.

Sea birds, such as penguins, breed on the continent. The Adelie penguin is the most numerous. Breeding colonies are usually densely packed because ice-free land is limited.

Among mammals, baleen whales, toothed whales, and seals thrive there. Overhunting in the area has threatened many species, especially the blue whale, and it is not known if some of these species will survive. In 1982, the Convention for the Conservation of Antarctic Marine Living Resources was agreed to by concerned nations in order to better regulate fishing in the Antarctic Ocean.

The Red Sea The Red Sea lies in the heart of the Middle East and is surrounded by desert. In the south it is connected to the Gulf of Aden and the Indian Ocean by means of the Straits of Bab el Mandeb. In the north, it is linked to the Mediterranean Sea by means of the Gulf of Aqaba and the Gulf of Suez.

The Red Sea started to form 40 million years ago when the area that is now Saudi Arabia broke away from the continent of Africa. The sea floor here is still spreading at a rate of 0.5 inch (1 centimeter) per year, and scientists consider the Red Sea a “baby” ocean that will, after about 200 million years, be as large as the current Atlantic Ocean.

The presence of surrounding desert lands causes a high degree of evaporation in the Red Sea making its water very salty. No fresh water is added because no rivers drain into it. Another source of its saltiness is the presence of hot salty pools approximately 1.3 miles (2.1 kilometers) below its surface. It is believed that the salt in these pools comes from sediments found in some parts of the Red Sea. These sediments are rich in iron, manganese, zinc, and copper, and may prove very valuable when methods for mining them become practical.

In summer, winds come from the northwest and currents flow toward the Gulf of Aden. In winter, a southeasterly wind causes the surface currents to flow in the opposite direction.

The Red Sea
Location: East of Egypt, Sudan, and Ethiopia; west of Saudi Arabia and Yemen
Area: 169,000 square miles (437,700 square kilometers)
Average Depth: 1,730 feet (524 meters)

Normally, the Red Sea is a bluish-green color. However, it is heavily populated by orange colored algae that turn reddish-brown when they die. This may be why it was named the Red Sea.

Over 400 species of corals are found here. As the corals form reefs, they attract the types of fish that thrive in those areas. The largest fish that live in the Red Sea are whale sharks. Manta rays are also common. Other fish include snappers, grouper, parrotfish, and sardines.

Animals found in the Red Sea are important to human life. Sea cucumbers, a sausage-shaped invertebrate, are common. They are a Far Eastern delicacy making them commercially important, as are prawns, a type of tropical shrimp. Pearls from oysters in the Red Sea are famous for their high quality. Mother-of-pearl, taken from the shell of another sea animal, the mollusk, is used to make shirt buttons and other decorations.

The process of desalting ocean water to produce fresh water is becoming more common in countries bordering the Red Sea. There are eighteen desalination factories along the Saudia Arabian border. These factories remove salt from water to make it drinkable.

The Red Sea has been important for transportation since at least 2000 BC. Until 1869, the only access to the Red Sea was from the south; it was closed at its northern end until the Suez Canal was constructed by the British. The Suez Canal is a long channel that allows the waters of the Red Sea to mix with those of the Mediterranean. Ships going through the canal can reach the Indian Ocean without traveling all the way around the continent of Africa, a great savings of time and distance.

The Red Sea is made famous from the Bible because God gave Moses the power to part its waters. Moses was then able to lead the Israelites across the sea floor during their escape from bondage in Egypt.

The Mediterranean Sea The Mediterranean Sea is the world's largest inland sea. It lies between the continents of Europe and Africa. It is connected to the Atlantic in the west by the Straits of Gibraltar and to the Red Sea in the east by the Suez Canal. To the north, it joins the Aegean and Black Seas, which are also inland seas.

The Mediterranean is bisected by a submarine ridge into eastern and western basins. Many of its islands were formed by volcanoes, some of which are still active. The region has many earthquakes. Its greatest depth, 16,814 feet (5,125 meters), is in the Matapan Trench.

The climate around the Mediterranean is warm and wet in the winter and hot and dry in the summer. Surface water temperatures range from

The Mediterranean Sea
Location: Between Europe and North Africa
Area: 1,145,000 square miles (2,965,500 square kilometers)
Average Depth: 4,902 feet (1,494 meters)

about 41°F (5°C) in the north during the winter to 88°F (31°C) in the south during the summer. Many rivers flow into the Mediterranean, the largest of which is the Nile River of Egypt, but its water is very salty because of continual evaporation.

The warm water means less phytoplankton, and less phytoplankton means fewer animal species in general. The sea varies in temperature, salinity, and depth from place to place, and a variety of plant and animal life can be found. Invertebrates include crabs, lobsters, shrimp, oysters, mussels, clams, and squids. More than 400 species of fish are found there including bass, flounder, tuna, sharks, and mackerel.

Since ancient times, the Mediterranean has been a source of fish for people living in the surrounding countries. However, the catches are not large enough to be commercially important worldwide. Of greater economic importance is the discovery of oil and gas deposits beneath the sea floor.

The Mediterranean suffers from pollution as a result of industrial and municipal wastes dumped along the European coast. Oil tankers travel its waters and oil spills add to the problem. Efforts are being made to repair the damage.

The Mediterranean has been historically important since the Egyptian people began to explore it as early as 3000 BC. In later millennia, Crete, Greece, and Anatolia began to use it for trade and for ships of war. Between 300 BC and 100 AD, Rome ruled the sea. After the fall of Rome in 476 AD, the Arabs, Germans, Slavs, and Ottoman Turks each took a turn holding sway over the area. During the 1700s, the discovery of new sea routes to India around Africa made the Mediterranean less important for travel and commerce.

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Environmental Defense Fund, 257 Park Ave. South, New York, NY 10010, Phone: 212-505-7100; Fax: 212-505-2375, Internet: http://www.edf.org.

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Friends of the Earth, 1717 Massachusetts Ave. NW, 300, Washington, DC 20036-2002, Phone: 877-843-8687; Fax: 202-783-0444; Internet: http://www.foe.org.

Greenpeace USA, 702 H Street NW, Washington, DC 20001, Phone: 202-462-1177; Fax: Internet: http://www.greenpeace.org.

Sierra Club, 85 2nd Street, 2nd fl., San Francisco, CA 94105, Phone: 415-977-5500; Fax: 415-977-5799, Internet: http://www.sierraclub.org.

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Rain Forest

A tree is a woody plant with a single, strong trunk and many branches that lives year after year. A large group of trees covering at least 25 percent of the area where the tops of the trees, called crowns, interlock to form an enclosure, or canopy, at maturity make up what is called a forest. The term rain forest is used to refer to any forest in tropical or semitropical regions. (Tropical regions are those around the equator.) Rain forests occur in a few regions with temperate (moderate) climates.

Tropical rain forests, also called jungles, are located for the most part in the belt between the tropics of Cancer and Capricorn. The term jungle usually indicates a disturbed, tangled, tropical rain forest with vines and other distinct plant and animal life. Plenty of rain and warm temperatures year-round support constant plant growth and great diversity of species. It is estimated that there are up to 260 different kinds of trees per square mile of rain forest. Trees that would normally lose their leaves during the autumn season in cooler climates retain them for several years (some trees for up to sixteen years), becoming evergreens because there are no cold and warm seasons. Rain forests cover only about 7 percent of Earth's surface, or 4.4 million square miles (11.5 million square kilometers) of land.

Tropical evergreen rain forests occur in four main regions:

- The Americas and the Caribbean
- Africa and Eastern Madagascar
- India and Malaysia
- Australia

How Rain Forests Develop

The first forests evolved during Earth's prehistoric past. Since then, all forests have developed in essentially the same way, by means of a process called succession.

WORDS TO KNOW

Angiosperms: Trees that bear flowers and produce seeds inside a fruit; deciduous and rain forest trees are usually angiosperms.

Clear-cutting: The cutting down of every tree in a selected area.

Elfin forest: The upper cloud forest at about 10,000 feet (3,000 meters) which has trees that tend to be smaller, and twisted.

Emergents: The trees that stand taller than surrounding trees.

Epiphytes: Plants that grow on other plants with their roots exposed to the air. Sometimes called "air" plants.

Forbs: A category of flowering, broadleaved plants other than grasses that lack woody stems.

Gymnosperms: Trees that produce seeds that are often collected together into cones; most conifers are gymnosperms.

Rhizomes: Plant stems that spread out underground and grow into a new plant that breaks above the surface of the soil or water.

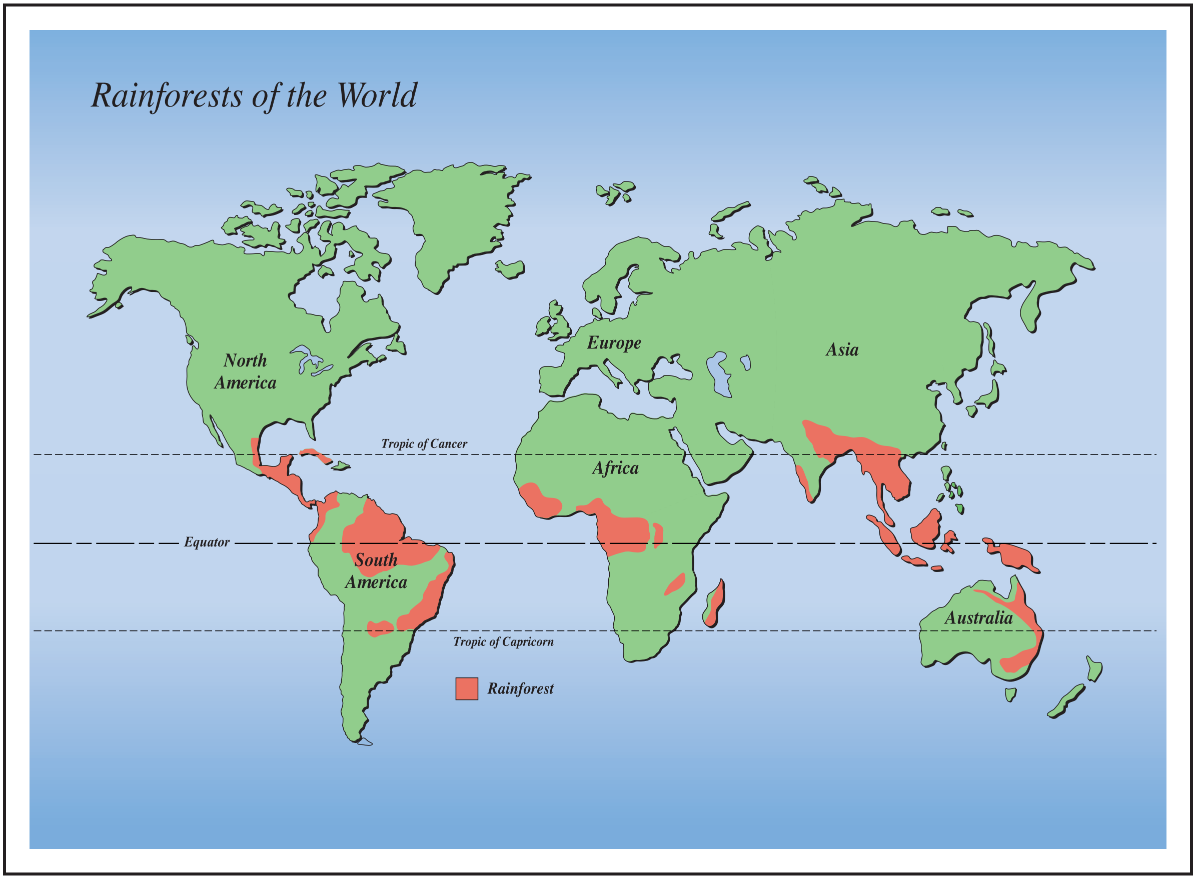
Tannins: Chemical substances found in the bark, roots, seeds, and leaves of many plants and used to soften leather.

Understory: A layer of shorter, shade-tolerant trees that grow under the forest canopy.

The first forests The first forests were very different from those found today. They were mostly composed of huge ferns and clubmosses; there were no flowers to speak of. Flowering plants developed only 65 to 145 million years ago during the Cretaceous period. Among the first to evolve were the ancestors of modern water lilies. Present day rain forests began developing shortly after the flowering plants.

Succession Trees compete with one another for sunlight, water, and nutrients, thus a forest is constantly changing. The process by which one type of plant or tree is gradually replaced by others is called succession. Succession can occur naturally when different species of trees become dominant as time progresses and the environment changes. It can also occur from natural disasters, such as forest fires.

Primary succession Primary succession of some forests in North America usually begins on bare soil or sand where no plants grew before. When the right amount of sunlight, moisture, and air temperatures is present, seeds begin to germinate (grow). These first plants are usually made up of the grasses and forbs (a nonwoody broad-leaved plant) type. They continue to grow and eventually form meadows. Over time, and as conditions change,



other plants begin to grow such as shrubs and trees, which become dominant and replace or take over where the grasses and forbs originally grew.

As primary succession continues, "pioneer" trees that are tall and sun-loving quickly take over the meadow. They change the environment by making shade. Trees with broader leaves that prefer some protection from the sun can then take root. If conditions are right, a mixed forest of sun-loving and shade-loving trees may continue for many years. Eventually, more changes occur.

The climax forest Seedlings from pioneer trees do not grow well in shade; therefore, new pioneer trees do not grow. As the mature trees begin to die from old age, disease, and other causes, the broad-leaved trees become dominant. The shade from these broad-leaved trees can be too dense even for their own seedlings. As a result, seedlings from trees

One view in the Monteverde Cloud Forest in Costa Rica. IMAGE COPYRIGHT STEFFEN FOERSTER PHOTOGRAPHY, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

that prefer heavy shade begin to thrive and eventually dominate the forest. These trees produce such deep shade that only trees or plants that can survive in complete shade will succeed there. When this happens, the result is a climax forest.

Few true climax forests actually exist because other changes take place that interfere with a forest's stability. Fires, floods, high winds, and people can all destroy a single tree to acres of trees. Glaciers can mow them down; volcanoes can smother them with ash or molten rock or knock them over with explosive force. Then the process of succession starts over.

Secondary succession When the land has been stripped of trees, in some areas it will eventually be covered with them again if left alone. This is called secondary succession and can take place more quickly than primary succession. Seeds from other forests in neighboring regions are blown by the wind or carried by animals to the site. The seeds take root, seedlings sprout, and the process begins again.

Kinds of Rain Forests

Tropical evergreen rain forests can be classified into three main types: lowland, montane, and cloud.

Lowland wet forest Lowland wet forests thrive close to the equator where rainfall is heavy, at elevations from sea level up to 4,000 feet (1,200 meters). They occur widely in the Asian tropics, in South America near the Amazon, and in Africa. Vegetation is wide and varied in these forests, having as many as 2,000 different species of trees. The largest lowland wet forest is currently located in Brazil (commonly known as *Selva*, the Spanish word for forest). Studies show that the Amazon forest may contain up to 120 different species in one acre of forest.

Montane rain forest The true montane, or mountain, rain forests begin where lowland wet forests leave off; about 4,000 feet above sea level.

There are lower and upper montane forests at lower and higher altitudes respectively. The average temperature is 66°F (19°C), and oak and laurel trees are predominant. At higher altitudes (upper montane) the cooler weather is favored by coniferous trees and myrtles. Montane forests can be found in Africa, Papau New Guinea, and South America.

Cloud forest Cloud forests, such as those in Costa Rica, grow on mountains but usually at altitudes higher than 5,000 feet (1,500 meters). Their name comes from the fact that low-lying clouds form around them, shrouding them in mist. At about 10,000 feet (3,000 meters), the upper cloud forest is known as the elfin forest. The trees, including some species of pines, tend to be stunted and more twisted than those at lower elevations. Mosses, ferns, and lichens are abundant throughout this forest.

Climate

The climate of a tropical rain forest is warm and humid all year long. Average annual temperatures are between 68° and 84°F (20° and 29°C), and the temperature never drops below 64°F (18°C). There is almost no seasonal temperature change because the difference between the coldest and warmest months is only 3°F (1°C).

Rainfall varies throughout the tropics, with some areas receiving as little as 60 inches (1.5 meters) annually, and others twice that amount. Dry seasons occur, especially in monsoon climates. Some precipitation (rain) falls almost every day. It may come in a thunderous downpour or in a misty shower. In general, humidity is very high, and days are often cloudy.

Geography of Rain Forests

The geography of rain forests varies, depending upon location, and includes landforms, elevation, soil, and water resources.

Landforms The terrain over which lowland forests grow features valleys, rolling hills, old river basins, and level areas. Montane forests develop in mountainous regions, as do cloud forests. Tropical mountains tend to be volcanic in origin, and their slopes are often gentle rather than steep and craggy (rugged and uneven).

Elevation Rain forests grow at almost all elevations, from sea level to about 10,000 feet (3,000 meters). The greatest share of rain forested area exists at

Cecropia trees grow in the lower canopy layer of the rainforest and can grow six feet in height each year. IMAGE COPYRIGHT DR. MORLEY READ, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

elevations below 4,000 feet (1,200 meters), in what are known as lowland wet forests.

Soil Rain forest soil tends to be red or yellow in color and low in nutrients because the vast number of plants quickly absorb its valuable minerals. Decaying vegetation continually enriches the topsoil, which is the most fertile soil near the surface. For this reason, tree roots are more likely to remain near the surface. In forests where the shade is dense, few smaller plants may grow and the topsoil layer is even richer. Where the ground is rocky and not much soil is present, trees may develop stiltlike projections from their trunks that help anchor them to the ground.

The presence of volcanoes increases the richness of soil in Indonesia and parts of Central and South America. Volcanic ash contains many minerals and adds nutrients to the soil.

Water resources In tropical regions, rivers and streams are often the primary water resources. Daily rainfall not only helps maintain them, but can also cause them to flood.

Plant Life

Most forests contain a mixture of many different species of trees, and rain forests contain the most species. Both coniferous (cone-bearing) and nonconiferous evergreen trees exist within their boundaries. Exploration of most rain forests is challenging for humans so many of these species are yet to be named.

The trees and smaller plants in a rain forest grow to different heights, forming layers. The crowns of tall trees create a canopy, or roof, over the rest of the vegetation that averages 120 feet (37 meters) above the ground. The very tallest trees, called emergents, pop through the canopy like lonely towers, some as tall as 200 feet (61 meters). Trees help support one another because they grow so close together. Beneath the canopy grows at least one more layer of shorter, shade-tolerant trees, which cover heights of 30 to 65 feet (10 to 20 meters). This shorter layer is called the understory. The next layer, about 16 feet (3 meters) off the ground, is composed of tree seedlings, a few small shrubs, and a few flowering plants. The very lowest layer consists of small plants, like mosses, that live atop the soil.

Non-tree plants that grow in the rain forest are often either climbers, epiphytes (EPP-ih-fites), or parasites. Climbers have roots in the ground, but use hooklike tendrils to climb up the trunks and along the limbs of trees in order to reach the canopy where there is light. Epiphytes, or "air" plants, store water in their fleshy stems and leaves. They also grow on trees and other plants, especially in the canopy, but their roots are exposed to the air. These plants absorb the nutrients they need from rain and forest debris. Parasites attach themselves to other plants and trees, but they manage to do without light and take their nourishment from their host.

Rotten Flower

The Rafflesia (rah-FLEA-e-ah) plant of Malaysia is a parasite. Its seeds burrow beneath the bark of another plant and invade it with hairlike strands that absorb nutrients. Eventually a flower bud emerges, but the bud has no stem or leaves. About nine months later, this bud produces a spectacular bloom that measures as much as 3 feet (1 meter) in diameter and 37 pounds (81 kilograms). It is the largest known flower in the world. The Rafflesia is not content to be just a parasite with a big, unattractive flower. It also produces one of the worst fragrances imaginable, the smell of rotting meat. The Rafflesia's goal is to attract flies with this fragrance in hopes that they will carry its pollen to a Rafflesia in the next forest.

Plant life within the rain forests includes not only trees but also algae (AL-jee), fungi (FUHN-ji), lichens (LY-kens) and green plants.

Algae, fungi, and lichens Algae, fungi, and lichens do not fit neatly into either the plant or animal category.

Algae Most algae are single-celled organisms, although quite a few are multicellular. Most algae have the ability to make their own food in a process called photosynthesis (foh-toh-SIHN-thuh-sis). During this process they use the energy from sunlight to change water and carbon dioxide into the sugars and starches they use for food. Other algae absorb nutrients from their surroundings.

Although most algae are water plants, green and blue-green algae do appear in the rain forest where they encrust the leaves of trees. This blocks the sunlight from the trees' leaves, but the green-blue algae may aid the tree in obtaining nutrients, such as nitrogen, from the atmosphere.

Fungi Unlike algae, fungi cannot make their own food by photosynthesis. Some fungi, like molds and mushrooms, obtain nutrients from dead or decaying organic matter (material derived from living organisms). They assist in the decomposition (breaking down) of this matter and in releasing the nutrients needed by plants back into the soil.

Other fungi are parasites. Fungi reproduce by means of spores, which are usually single cells that have the ability to grow into a new organism.

Fungi prefer moist, dim environments, and they thrive on the shadowy forest floor. Some, like the marasmius, grow directly on the litter of plant matter, while others protrude from the trunks of trees. Another type of fungi, the mycorrhizae, live in the soil and surround the roots of most rain forest trees. They absorb energy from the tree and help the tree's roots absorb nutrients from the soil.

Lichens Lichens are actually combinations of algae and fungi that live in cooperation. Fungi surround algae cells, and the algae obtain food for themselves and the fungi by means of photosynthesis. It is not known if fungi aid algal organisms, but it is believed that fungi may provide moisture for the algae.

Lichens often appear on rocks and other bare woodland surfaces. Some grow on the leaves of lowland trees, while others favor the cooler cloud forests and dangle from the limbs of trees. Lichens are common in all types of forests and seem able to survive most climatic conditions.

Green plants other than trees Most green plants need several basic things to grow: sunlight, air, water, warmth, and nutrients. In the rain forest, water and warmth are abundant. However, nutrients such as nitrogen, phosphorus, and potassium, which are typically obtained from the soil, may not be in large supply. Light can be scarce because the thick forest canopy obscures the forest floor, and may block sunlight. The lack of seasons means that the canopy is in full leaf all year long. For this reason, most rain forest plants grow in the canopy of the forest. Those that do grow on the ground often have very large leaves that provide more surface area to be exposed to the scarce amount of light.

Common rain forest green plants Common rain forest plants include rattans, pitcher plants, ferns, African violets, nasturtiums, Spanish mosses, orchids, lianas, urn plants, hibiscus shrubs, and bamboo.

Liana Lianas are climbers found in rain forests throughout the world. Their roots can be large and tough, but they do not develop a thick trunk. Instead, they depend entirely on trees for support. Once they reach the canopy, they drape themselves among the branches and develop leaves, branches, flowers, and fruits. Often they send out "feeding," or aerial (AIR-ee-yuhl), roots that dangle in midair and absorb nutrients.

A common liana is the strangler fig, which begins as an epiphyte that sends long roots down to the ground. These roots grow branches that

Chocoholic Heaven

In the rain forests of Central and South America grows the cocoa, or cacao, tree. The seeds of this delightful tree produce chocolate. Initially, the roasted seeds were used by the Aztecs to make a hot drink flavored with vanilla and spices. In 1502, Italian explorer Christopher Columbus (1451–1506) brought the cocoa "beans" back to Spain, where the same drink was made but with sugar. Over the next 100 years, the use of cocoa spread to other parts of Europe and, by 1657, solid chocolate had been developed in France. Around 1700, the English improved hot chocolate by adding milk, and by 1850, manufacturing processes made sweet eating-chocolate possible. By 1876, its popularity had spread throughout the world.

Cocoa trees are raised on farms in Central and South America and portions of western Africa. In 1977, 1,653,000 tons (1,500,000 metric tons) of cocoa seeds were produced, and 20 percent of all the exports went to the United States. However, Americans consume only about 10 pounds (4.5 kilograms) of chocolate per person annually. The largest consumers are the Swiss, who eat 21 pounds (9.5 kilograms) per person each year.

Although the names are sometimes confused, the cocoa tree is not the source of the drug cocaine. Cocaine comes from the coca shrub, an unrelated plant.

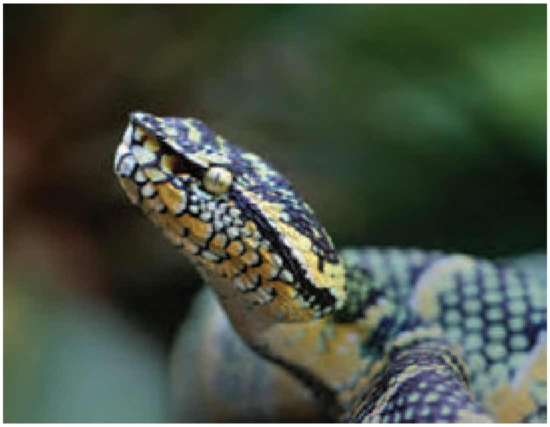
surround the host tree, blocking the light. Eventually, the host dies and decays, leaving a hollow ring of stranglers.

Urn plant Urn plants are epiphytes found in Central and South America that belong to the pineapple family. The plant's overlapping leaves form an urn, or cup, which collects rainwater and any dead plant matter that falls into it. Little hairs on the leaf surface absorb the water and dissolved minerals. Urn plants provide homes for many aquatic (water) insects and even frogs.

Hibiscus Hibiscus shrubs grow on the ground around the edges of the forest where they can obtain light. In Africa, they quickly attain heights of up to 7 feet (2 meters). Their large, colorful flowers are bell shaped and may be scarlet, pink, yellow, or white.

Bamboo Bamboo is a woody grass that can grow as tall as a tree. Dense forests of bamboo are found in Asia and Central Africa where plants may reach 130 feet (40 meters) in height. Bamboo tends to grow in thick, tightly packed clumps. Flowering occurs several years later, after which the plant dies. There are 480 species of bamboo. Its uses vary from food to instrument to paper.

Growing season It is always growing season in the tropical rain forest. At any given time, at least one species will be flowering.



The viper snake has a prehensile tail, aiding its ability to move among the tree branches. They rarely venture down to the ground. IMAGE COPYRIGHT SNOWLEOPARD1, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Reproduction Most green plants are seed plants, and most seed plants are flowering plants that reproduce by means of pollination. Pollination involves the transport of pollen from the stamen, the male part of the flower, to the pistil, the female part of the flower where seeds develop, by visiting animals or the wind. The seed's hard outer covering protects it while it waits for moisture and light to stimulate its growth.

Instead of pollination, some plants reproduce by means of rhizomes—long, rootlike stems that spread out below ground. These stems develop their own root systems and send up sprouts that develop into new plants.

Rain forest trees Most trees have a single strong stem, or trunk. This single trunk gives them an advantage over smaller woody plants in that most of their growth is directed upward. Some large rain forest trees develop buttresses, winglike thickenings of the lower trunk that give tall trees extra support.

As a tree grows, its trunk is thickened with a new layer, or ring, of conducting tissues that carry water and nutrients from the roots to the branches. As the tree ages, the tissues from the center outward become hardened to produce a sturdy core. In cooler climates, the rings are formed seasonally and, when a tree is cut down, its age can be determined by how many rings are present. In the rain forest there are no seasons, so rings do not form regularly and cannot be used to accurately estimate a tree's age. Other methods are used to determine the age of rain forest trees, such as measuring the increase in the tree's circumference during a year and dividing that number into its total girth (size). Based on these calculations, one species in Malaysia may be 1,000 years old, a baby compared to the 4,900-year-old bristlecone pine of North America, but unusually old for the rain forest, where most trees only live 100 to 300 years.

Rain forest trees seldom exceed 200 feet (61 meters) in height, although the tualang of Malaysia has been recorded at 260 feet (80 meters). It is a common misconception that the world's tallest trees grow in the rain forests. The tallest trees grow in drier, more temperate climates.

The leaves of rain forest trees are often waxy and develop a "drip tip;" a long, narrow point that allows rain to run off easily.

Rainforests are full of thousands of different plant and animal species, many which may not have been discovered yet. IMAGE COPYRIGHT STEFFEN FOERSTER PHOTOGRAPHY, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Common rain forest trees Common rain forest trees include black ebony, cinchona, mahogany, and mango.

Black ebony Found in the rain forest of Africa, the black ebony tree is almost white in color, but its heartwood is black and extremely hard. Valued for its heaviness, color, and durability, ebony heartwood is considered a precious wood. It has been commonly used to make the black chord keys on a piano.

Cinchona The cinchona (sing-KOH-nah) is native to Central and South America where it is found in lower montane rain forests. Its flowers grow in white, pink, and yellow clusters and its bark is an important source of several medicines, including quinine (KWY-nine), a treatment for malaria. During the 1800s, cinchona seeds were brought to Java in Indonesia, where the trees are still raised commercially.

Mahogany The term mahogany is applied to almost 200 species of trees with reddish-brown wood, winged seeds, and small, greenish-yellow flowers. The first trees given the name are native to the West Indies, but the most commercially important mahoganies come from Central and South America. They are used in fine furniture and paneling. African and Philippine mahogany are also economically important.

Mango The mango tree was originally discovered in East India. In its wild state, it produces a fibrous fruit that tastes like turpentine. In some species, this fruit is poisonous. Cultivated trees produce a delicious fruit that is enjoyed throughout the world. In the fifth century BC the mango was brought to Malaysia and eastern Asia. In India, the mango tree is sacred, believed to be a symbol of love and having the potential to grant wishes. The tree can reach heights of about 90 feet (27 meters) and is popular for its dense shade.

Growing season Trees are woody perennial plants, which means they live more than one year, or growing season. When temperatures are warm year-round and rainfall is constant, as they are in the rain forest, trees become evergreen and grow almost continuously. Some rain forest trees shed their leaves periodically for a short time; however, this shedding is not simultaneous, even among trees of the same species.

Many rain forest trees do not bear fruit every year and thus do not regenerate readily. Seeds that lie on the forest floor may remain dormant (inactive) for many years. Those that sprout grow very slowly after the nutrients stored in the seeds are used up. If a tree falls and creates a gap in the canopy allowing sunlight to enter, these seedlings make up for lost time. They grow quickly toward the light and soon the gap is closed again.

Reproduction In general, trees are divided into two groups according to how they bear their seeds. Gymnosperms produce seeds inside cones. Most conifers, like the pine, are gymnosperms. Angiosperms have flowers and produce their seeds inside fruits. Broad-leaved trees, such as maples, are usually angiosperms. Some species of gymnosperms are found in rain forests, but most rain forest trees are angiosperms.

The seedlings of some rain forest trees do not develop large amounts of chlorophyll, the substance in leaves that gives them their green color, until they reach light in the canopy. The leaves of these young trees are often red, blue, purple, or white instead of green.

Endangered species Vast areas of rain forest have been destroyed by uncontrolled logging and clearing of the land for farms. From 2000 to 2005, tens of thousands of miles of rain forest in Brazil were lost due to deforestation. In more mountainous regions, such as Papua New Guinea, the land is less useful for farming and huge tracts of rain forest still remain untouched.

Many individual plants are threatened as the forest is destroyed. The African violet, for example, which is commonly cultivated as a house plant, is found in only a few forests in Tanzania, where it is rapidly disappearing.

Animal Life

Animal life in the rain forest is as diverse as its plant life because the warm temperatures and plentiful moisture aid survival. Most animals live in the trees, especially high in the canopy.

The Web of Life: Biotic Potential

The highest rate of reproduction under ideal conditions is a population's biotic potential. For most creatures, this potential is enormous. A single bacterium, for example, could set off a chain reaction of births that would cover our planet within thirty-six days.

What keeps bacteria, as well as mosquitoes, frogs, and alligators reaching their full biotic potential? The answer is that, while creatures are determined to reproduce, life is not easy. Each life form is opposed by limiting factors that keep population growth in check. Cold temperatures, for example, kill mosquitoes. A shortage of mosquitoes starves frogs. A shortage of frogs keeps alligators hungry, preventing them from reproducing more quickly and taking over the world.

Microorganisms Microorganisms, like their name suggests, can not be seen without the aid of a microscope. Bacteria are microorganisms that are always present in forest soil. They help decompose dead plant and animal matter. They grow quickly in the warm, humid rain forest environment where they feed on the leaves, twigs, and other matter that falls from the canopy.

Invertebrates Animals without backbones are called invertebrates. They include simple animals such as insects and worms, and more complex animals such as the click beetle or the trapdoor spider. Certain groups of invertebrates, like mosquitoes, must spend part of their lives in water. In general, these types are not found in the trees, but in streams or in pools of rainwater. The humid rain forest is an ideal environment for many soft-bodied invertebrates, such as leeches, because there is little danger of drying out.

Common rain forest invertebrates In addition to bacteria, invertebrates remain the least known variety of life in the rain forest. Among those that have been identified are the Hercules beetle, the forest termite, the orchid bee, the Queen Alexandra's birdwing butterfly, the postman butterfly, the blue hunting wasp and the army ant.

Postman butterfly The postman butterfly lives in jungles of Central America. In its larval state as a spiny caterpillar, it is a voracious eater with a preference for the passionflower vine. The adult butterfly feeds on this vine's protein-rich pollen and nectar. The added protein gives it a longer lifespan than most butterflies, usually from six to nine months. The passionflower is a highly poisonous plant, so female butterflies lay their eggs on its youngest leaves, which contain less poison. As the larvae grow, they gradually absorb some of the poison and become immune to it.

The Web of Life: How Ants Help to Make Rain

Seventy-five percent of the rain that falls on the rain forests is recycled. It evaporates and creates clouds that protect the forest from too much sun. Many creatures help in this process. For example, the forests of the Amazon are home to vast armies of ants. Ants produce formic acid, which they use for defense and as a means of communication. They spray approximately 200,000 tons (181,400 metric tons) of formic acid into the air each year. This formic acid makes the rain that falls in the area slightly acidic and promotes the decay of dead wood. As the wood decays, bacteria are released into the atmosphere, where ice crystals tend to form around them. The ice crystals fall as rain, and the cycle continues.

Blue hunting wasp The blue hunting wasp prefers dining on crickets, which it hunts by flying low over the forest floor. It grips a victim in its powerful jaws and then paralyzes it with its stinger. Female wasps drag the paralyzed victim into a burrow and then lay their eggs on it so their larvae have food when they hatch.

Army ant Army ants are some of the most feared residents of the rain forest because they travel in huge colonies of up to 20 million individuals. The army's number demands that food be plentiful. The army usually empties an area of insects, small lizards, and snakes, leaving them no choice but to continue moving. They take shelter at night by linking themselves together with their strong legs beneath the fallen leaves and trees. When they are on the march, worker ants carry any developing larvae with them.

Food Many invertebrates eat plants or decaying animal matter. The larvae of insects, such as caterpillars, are the primary leaf eaters. Weevils drill holes and lay their eggs in nuts, which their larvae use for food. Bees gather pollen and

The Postman butterfly is one of the pollinators of flowers in the rain forest. IMAGE COPYRIGHT TIM ZUROWSKI, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

nectar from flowers, as do butterflies and moths. The arachnids (spiders), which are carnivores (meat eaters), prey on insects and sometimes, if the spiders are big enough, small lizards, mice, and birds.

The Spiny bush cricket is native to the rainforests of Central and South America. IMAGE COPYRIGHT DR. MORLEY READ, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Reproduction Most invertebrates have a four-part life cycle. The first stage of this cycle is spent as an egg. The eggshell is usually tough and resistant to long dry spells in tropical climates. After a rain, and during a period of plant growth, the egg hatches. The second stage is the larva, which may be divided into several stages between which there is a shedding of the outer skin as the larva increases in size. Larvae often spend their stage below ground where it is cooler and moister than on the surface. The pupal, or third stage, is spent hibernating within a casing, like a cocoon. In the fourth and final stage, the animal emerges from this casing as an adult.

Amphibians Amphibians are vertebrates (animals with a backbone) that usually spend part, if not most, of their lives in water. Frogs, toads, and salamanders are all amphibians. They live in significant numbers in rain forests where humid conditions are ideal. Amphibians are cold-blooded, which means their bodies are about the same temperature as their environment. In the rain forest they can be active year-round because the temperature is always warm.

Amphibians breathe through their skin, and only moist skin can absorb oxygen so they must usually remain close to a water source. Mating, egg-laying, and young-adulthood all take place in ponds, lakes, or pools of rainwater. When they mature, amphibians leave the pools for dry land where they feed on both plants and insects.

Common rain forest amphibians Amphibians commonly found in rain forests include tree frogs and poison arrow frogs.

Tree frog Eighty percent of frogs and toads live in tropical forests. Some, such as the fringe limb tree frog, may leap out of a tree to escape a predator. Webs of skin between their limbs act like parachutes, enabling them to glide from one branch to another. Other species of tree frogs have suction pads on their toes that secrete a sticky mucus, enabling the frog to cling to tree trunks and branches.

Tree frogs, such as this red-eyed tree frog, are common in the rain forest. Many tree frogs have suction cups on their feet to help them cling to smooth surfaces. IMAGE COPYRIGHT SNOWLEOPARD1, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Poison arrow frog Poison arrow frogs are usually brightly colored. This color warns potential predators that to bite the frog may mean death. One ounce of poison from the kokai frog can kill up to 100,000 average size humans. These frogs, abundant in South America, are used by the local people, who tip their arrows and darts in the poison (hence the frogs' name).

Food Most adult amphibians are carnivorous, feeding on insects, slugs, and worms. Salamanders that live in the water suck their prey into their mouths. Those that live on land have long, sticky tongues to capture food. Salamander larvae are mostly herbivorous, feeding on vegetation. Frogs and toads feed on algae, plants, and insects such as mosquitoes.

Reproduction Mating and egg-laying for amphibians must take place in water because male sperm are deposited in the water and must be able to swim to the eggs in order to penetrate them. Some amphibians lay their eggs in the cups of plants where water has collected and where insect larvae may grow. As the young develop into larvae and young adults, they often have gills for breathing. They, too, require a watery habitat.

Reptiles Reptiles that live in rain forests include snakes and lizards. Since a reptile's body temperature changes with the temperature of the surrounding air, the warm, humid rain forest is a comfortable environment for them.

Many rain forest reptiles are capable of camouflage (KAH-mah-flahj), or protective coloration. Their skins are often patterned or colored to resemble the forest background in which they live, and they may be able to alter their coloration to a darker or lighter shade. Many reptiles living in the forest canopy have a prehensile (grasping) tail to help them climb and may prevent falls. Rain forest reptiles may have grasping claws to ensure a firm, steady hold as they climb through the trees.

The Emerald tree boa is one of many breeds of snake that thrive in the warmth and humidity of the rain forest. IMAGE COPYRIGHT HOWARD SANDLER, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Common rain forest reptiles Common rain forest snakes include the vine snake of West Africa, the bushmaster and fer-de-lance of Central and South America, the gaboon viper of Asia, and many tree snakes. Lizards include the Jesus Christ lizard of Central America, the crested water dragon of Asia, Parson's chameleon of Africa, and the Komodo dragon of Indonesia.

Chameleon The chameleon (kuh-MEEL-yuhn) lizard is an expert at camouflage. A resident of the canopy, it can change its coloration to resemble that of the leaves, and it may even tremble slightly to mimic leaves swaying in a breeze. Its feet and tail are perfect for grabbing hold of tree limbs, and its long, sticky tongue flicks out with amazing speed to catch the insects that make up its diet.

Tree snake Many species of tree snakes are found in rain forests. The emerald tree boa of the Amazon is not poisonous, and kills its prey with by squeezing it. Pythons, anacondas, and cobras are found in the rain forest. Pythons can be found in Africa and Australia, cobras in Africa and Asia, and the anaconda in South America.

Komodo dragon The Komodo dragon, the world's largest lizard, is found in Indonesia, especially on Komodo Island for which it is named. Komodo dragons can measure up to 10 feet (3 meters) in length and weigh up to 366 pounds (166 kilograms). Komodo dragons are carnivores and eat animals as large as buffalo or as small as geckos and other insects. They have long, sharp claws and jagged teeth that enable them to tear meat from their prey. In 1992, komodo dragons hatched at the Smithsonian Zoo, the first of their kind to ever have been bred outside of Indonesia.

Food A lizard's diet varies, depending upon the species. Some have long tongues with sticky tips for catching insects, while others eat small mammals and birds. The water they need is usually obtained from the food they eat.

All snakes are carnivores, and one good meal will last them for days or weeks. Some snakes kill their prey with venom (poison) injected through their fangs.

Reproduction Most reptiles lay eggs. Some females remain with the eggs, others bury them in a hole and abandon them leaving the young

Green Mansions

The South American rain forest provided the setting for *Green Mansions*, a novel by British author W. H. Hudson (1841–1922) that was written in 1904. It is a fantasy love story about Rima, a strange half-bird, half-human character who lives in the forest and cannot leave it. A statue of Rima was erected in 1925 in the bird sanctuary at Hyde Park in London, England.

to hatch by themselves. Snakes that live in the canopy often bear live young. They produce fewer babies, but the babies, being mobile, have a better chance of survival.

Birds All rain forests have large bird populations. Most do not need the protection of camouflage, having only to compete with bats, and their feathers are usually brilliantly colored. Their songs vary from the scream of the eagle to the haunting warble of many smaller birds. Bower birds and pittas seem to be able to "throw" their voices like ventriloquists.

Rain forest birds have developed short, broad wings that do not require much room for flying because the vegetation is so dense. Some species, such as toucans and parrots, have feet adapted to climbing.

Common rain forest birds Common birds of the rain forests include toucans, hummingbirds, birds of paradise, jacamars, eagles, parrots, and junglefowl.

Harpy eagle Harpy eagles live high in the forest canopies of Central and South America, often sitting in one of the emergent trees where their sharp eyes can spot prey. Harpies do not soar high above, but move from tree to tree in short flights. Their large nests are built of sticks, leaves, and fur about 165 feet (50 meters) above the ground. Females produce two eggs. Harpies like to catch monkeys or sloths in their huge talons, and, if their victim attempts to cling to a tree, they are strong enough to wrench the victim free.

Parrot Parrots are brightly colored birds with a loud, harsh call. There are 328 species of parrots, including the commonly known parakeets, macaws, and cockatoos. They tend to be social and roost in large groups. Their feet are strong enough to make it possible for them to hang upside down from a branch for long periods. Their nests are usually in holes in trees, where the female sits on the eggs, and the male brings her food. Preferring to eat seeds, parrots use their tongues to position a seed at the front of the strong, hooked beak and then crack the seed apart. Parrots, well know for their ability to mimic humans, are popular and desirable pets.

Junglefowl The junglefowl of Asia is the ancestor of the chicken and, as such, has affected human life more than any other bird. Male junglefowl crow like roosters and have a red comb. In the wild, they are very aggressive; much of this behavior has been bred out of the domesticated species over the years. They live primarily on the forest floor where they feed on seeds, fruits, berries, and insects. They are good runners, but their flight is weak.

Food Rain forest birds may fly considerable distances in search of trees bearing fruit. Different birds seek food in different layers of the forest. Parrots, for example, hunt for seeds in the canopy and insects along the trunks of the trees, while pittas dig around on the ground for snails and ants.

Reproduction Birds reproduce by laying eggs, for which many species build a nest. Some, such as the macaw, prefer to use a hole in a tree. Females usually sit on the eggs until the young birds hatch. The female hornbill of Southeast Asia walls herself into a hole with mud and other materials and the male feeds her until the young can leave the nest. Both parents of most species usually feed their young until they are able to fly. Some young birds, such as the hoatzin of the Amazon region, are uniquely adapted to life in the forest. The hoatzin chicks have two claws on each wing, enabling them to climb through the branches.

Wild Blue and gold macaws live high in the trees in the rainforests of Mexico, Central and South America. IMAGE COPYRIGHT JANPRCHAL, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Mammals Mammals of all kinds live in the rain forest, from the monkeys that swing from the tops of its trees to the shrews that scamper about the jungle floor.

Common rain forest mammals Rain forest mammals include monkeys, antelopes, coatis, bats, sloths, okapis, gorillas, and jaguars.

Bat Bats are the only mammals truly capable of flight, which they do primarily at night. During the day, they sleep hanging upside-down from branches or holes in trees. Some species are very social and roost in groups of 100 or more. At night they leave their roosts to seek food. A rain forest bat's diet is either insects or flower nectar and fruits. Many trees are dependent upon them as an aid in pollination.

The God of the Air

The quetzal, or resplendent trogon, of the mountain jungles of Central America has some of the most colorful plumage of any bird. To the Mayas and Aztecs, the quetzal's emerald and crimson feathers symbolized spring vegetation. They used its tail feathers in religious ceremonies and worshiped the bird as a god of the air. The beautiful quetzal is the national emblem of Guatemala, and its name is given to a unit of Guatemalan currency.

Sloth Sloths are slow-moving creatures with large claws that spend their lives hanging upside-down from tree limbs in Central and South America. Adults are only about 2 feet (0.6 meters) long, and the claws by which they grip the trees measure about 3 inches (8 centimeters). Sloths are so well adapted to their life upside-down that even their hair grows that way, from stomach to spine. They are herbivores that almost never leave the trees because, on the ground, a sloth cannot stand or walk but rather drags itself around with its claws.

Okapi The okapi, a short-necked relative of the giraffe that lives in the rain forest of eastern Congo, was not discovered by European explorers until 1901. It feeds on understory vegetation, such as shrubs and leaves. The coat is purplish brown, with black and white stripes on the upper legs and buttocks. Okapis are unusual in that females are larger than males.

Sloths eat leaves almost exclusively and rarely venture to the ground to move to a different tree. IMAGE COPYRIGHT ALVARO PANTOJA, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Gorilla Gorillas are found only in Africa, where there are three species: the western lowland gorilla, the mountain gorilla, and the eastern lowland gorilla. These types vary slightly in physical characteristics, such as color.

The gorilla is the world's largest living primate (group of animals including apes, monkeys, and humans). Males may be as tall as 6 feet (1.8 meters) and weigh between 300 and 400 pounds (135 and 180 kilograms). Gorillas live in groups and rarely change locations if they can help it. They spend most of their day, apart from a midday rest period, foraging for food, primarily nuts, berries, fruits, and leaves.

World's Smallest Mammal

The world's smallest mammal is only 1 inch (2.5 centimeters) long, about the size of a bumblebee. It was first catalogued by researchers in 1974. It may have been overlooked until then because it only comes out at night and might have been mistaken for an extremely large mosquito. This little mammal is the Kitti's hog-nosed bat, and it lives in the rain forests of Thailand.

Jaguar The largest cat in the western hemisphere, jaguars are found mostly in South America. A male jaguar may be 6 feet (1.8 meters) in length with a 2-foot (0.6-meter) -long tail, and may weigh more than 300 pounds (135 kilograms). It has a tan coat and is spotted like a leopard, though some are completely black or white. Jaguars feed on both small and large animals. They hunt mostly on the ground, but they are agile (skilled) climbers and swimmers.

Food Small mammals, such as the fawn-footed melomys (a type of rodent), often eat plants and insects. Herbivores (plant-eaters), including the agouti, the paca, and the royal antelope, feed on leaf buds and fruit. Cats, such as the palm civet, the ocelot, and the servaline genet, are carnivores (meat-eaters). Many mammals, such as the orangutan, are omnivores, which means they eat both plant and animal foods.

Reproduction The young of mammals develop inside the mother's body, where they are protected from predators. Mammals produce milk to feed their young and must remain nearby until the young can survive on their own.

The Okapi live in the rainforests of central Africa. They were discovered by scientists in the 1900s. IMAGE COPYRIGHT STEFFEN FOERSTER PHOTOGRAPHY, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Gorillas are one of the many endangered species of the rain forest. IMAGE COPYRIGHT PICHUGIN DMITRY] 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Endangered species The list of endangered rain forest animals is long. Many species of parrots are endangered, especially in Central and South America, because they are sought by animal dealers to sell as pets or because their habitat is disappearing. An example is the Spix's macaw, found in Brazil. In 1999, only one bird remained alive in the wild. Concentrated efforts to bring the bird out of near extinction resulted in sixty birds living in captivity. Reintroducing them to the wild has been difficult. Biologists are attempting to send females into the wild in hopes that they will mate with the lone male.

Orangutans and gorillas are in danger because they require deep forest cover and their habitat is rapidly disappearing. For some, their only hope of preservation seems to be zoos and wildlife sanctuaries. Many rain forest cats are also endangered because they have been hunted extensively for their skins. Although many are now protected, their numbers are so low there may not be enough animals left for successful breeding.

Only five species of rhinoceros remain in the world. They are protected, but remain threatened by poachers who kill them for their horns, and by the loss of their habitat. Rhinos live in Africa, India, and Southeast Asia. Although their senses of smell and hearing are well developed, they can not see very well, making them susceptible to attack from both humans and forest predators.

Human Life

Humans are creatures of the forest. Until they learned to hunt, humans gathered their food and made their dwellings among the trees of the forests.

Rain Forest Cousins

Chimpanzees are great apes, the closest living relatives to the human species. They resemble humans in some important ways, including their use of tools. Some chimp populations in western Africa use stone and wooden hammers to break open nuts. In eastern Africa, chimps have been observed to stick plant stems into termite nests to drive the termites out so they can eat them, and during a heavy rain they use leafy tree branches as umbrellas.

Impact of the rain forest on human life Forests have an important impact on the environment as a whole. From the earliest times, forests have provided humans with food and shelter, a place to hide from predators, and many useful products.

Environmental cycles Trees, soil, animals, and other plants all interact to create a balance in the environment from which humans benefit. This balance is maintained in what can be described as cycles.

The oxygen cycle Plants and animals take in oxygen from the air and use it for their life processes. This oxygen must be replaced, or life on Earth could not continue. Animals breathe in (inhale) oxygen and breathe out (exhale) carbon dioxide. Trees convert this carbon dioxide into oxygen during photosynthesis, releasing the oxygen into the atmosphere through their leaves.

The Sumatran orangutan is a critically endangered resident of the rain forest. IMAGE COPYRIGHT MICHAEL STEDEN, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

The carbon cycle Carbon dioxide is necessary to life, although too much is harmful. During photosynthesis, trees pull carbon dioxide from the air. This helps maintain the oxygen/carbon dioxide balance in the atmosphere. When trees die, the carbon in their tissues is returned to the soil. Decaying trees become part of Earth's crust, and after millions of years, this carbon is converted into oil and natural gas.

The water cycle The root systems and fallen leaves of trees help build an absorbent covering on the forest floor that allows rain water to trickle down into the soil to feed streams and groundwater. In this way, forests help conserve water and protect the soil from erosion caused by heavy rain. When forests are cut down, the soil washes away and flooding is more common. For example, heavy rainfall in Indonesia has caused severe flooding, in part due to tree removal. Trees take up some of this rain water through their roots and use it for their own life processes. Extra moisture is released through their leaves back into the atmosphere, where it helps to form clouds.

The nutrient cycle Trees get the mineral nutrients they need from the soil. Dissolved minerals are absorbed from the soil by the tree's roots and are sent upward throughout the tree. These mineral nutrients are used by the tree much like humans take vitamins. When the tree dies, these nutrients, which are still contained within parts of the tree, decompose. They are then returned to the soil making them available for other plants and animals.

Food Forests are the home of game animals, such as birds, that provide meat for hunters and their families. Forests also supply fruits, nuts, seeds, and berries, as well as vegetation for livestock. Vanilla, for example, is made from the seed pod of a type of orchid found in Central and South American rain forests; nutmeg and cloves come from Asian rain forests; coffee beans are native to Africa and are products of Central America along with cocoa beans; and starfruits grow in Asia. It is estimated that rain forests contain more than 3,000 species of edible fruits and vegetables, and only about 200 of these have been cultivated for commercial use. With correct management these species might yet provide more food varieties for both humans and animals.

Shelter During prehistoric times, humans lived in the forest because it offered protection. Today trees can provide building materials. Trunks are cut into planks or used as poles, while fronds (branches) and grasses can be cut for thatch and used to make huts or roofs for wooden structures.

Economic values Forests are important to the world economy. Many products used commercially, such as wood, medicines, tannins, dyes, oils, and resins (sap) are obtained from forests. Forest land is also important to the farm and tourist industries.

Wood Trees produce one of two general types of wood, hardwood or softwood, based on the tree's cell wall structure. Hardwoods are usually produced by angiosperms, such as the mahogany tree, while most coniferous trees, such as pines, produce softwoods. These names can be confusing because some softwood trees, such as the yew, produce woods that are harder than many hardwoods. Some hardwoods, such as balsa, are softer than most softwoods.

Wood is used for fuel, building structures, and manufacturing other products, such as furniture and paper. Wood used for general construction is usually softwood. In order to conserve trees and reduce costs, some manufacturers have created engineered wood composed of particles of several types of wood combined with strong glues and preservatives. Engineered woods are very strong and can be used for many construction needs.

In an effort to preserve the natural forests, plantations are developed to supply the world's demands for wood. India, South America, and Africa combined have 102,000 square miles (264,178 square kilometers) of tree plantations.

Farmland Although rain forest land is poor for farming, more and more of it is being cleared for that purpose. It supports crops for a few years, and then it is used for cattle pasture. When its nutrients are completely exhausted it is abandoned.

Medicines Since the earliest times, plants have been used for their healing properties. It is estimated that at least 70 percent of cancer fighting plants are tropical plants from the rain forest. Quinine, from the cinchona tree, is used to fight malaria.

Coffee—The World's Most Valuable Agricultural Product

In the mid-1990s, imports of coffee beans to the United States totaled $1.5 billion each year. The United States is the world's largest importer, and the average American drinks about 27 gallons (102 liters) of coffee annually.

Coffee trees grow in montane forests, and coffee beans are the roasted seeds of the tree. The birthplace of coffee was probably Ethiopia, the tree's native environment. Its use was first developed by the Arabs, and it did not arrive in Europe until the sixteenth century where it was introduced as a medical potion. Coffee became popular as a beverage around 1652.Coffee plantations were soon established in Indonesia, the West Indies, and Brazil, and coffee cultivation became important to colonial economies. Latin America and Africa produce most of the world's coffee; Central and South America grow about 60 percent of the world's total production.

Deadly Traveler on the Kinshasa Highway

The Kinshasa Highway crosses central Africa, linking remote areas to airports in the large cities of Nairobi and Mombasa, both in Kenya. Any traveler starting from deep inside the rain forest who reaches one of those airports is within 24 hours of every other place on Earth. During the 1970s one traveler made such a journey, a journey of deadly consequence.

The traveler was HIV, the human immunodeficiency virus, and by 2007, only twenty-five years after its emergence from the rain forest, it had infected 40 million people worldwide. Already 25 million people have died of AIDS (acquired immune deficiency syndrome), which appears to be caused by HIV.

For millennia, potentially deadly bacteria and viruses have remained undisturbed in the rain forests. If humans caught them, villages were so remote and travel so slow that infected people seldom lived long enough to reach large populated areas where the disease could spread unchecked. As humans penetrate farther into the rain forest and destroy the natural balance that often keeps disease carriers under control, more and more problems are being created. The latest cause for concern is the hemorrhagic fever viruses, such as *Ebola zaire*, another rain forest resident, which is even more deadly than HIV.

Tannins, dyes, oils, and resins Tannins are chemical substances found in the bark, roots, seeds, and leaves of many plants. It is used to cure leather, making it soft and supple. Dyes used to color fabrics can be obtained from the bark or leaves of such trees as the brazilwood. Palm oil and coconut oil are used as cooking ingredients. Resins, or saps, are used in paints and other products. Chicle is a resin from the sapodilla tree used in chewing gum, and natural rubber is made from the resin of the South American rubber tree.

Tourism Rain forests have become popular with tourists who are interested in hunting, nature study, and environmental issues (ecotourism). Some tropical countries have found it economically desirable to set aside large tracts of forest for tourism.

Impact of human life on the rain forest While forests have had a positive effect on human life, human life has had a mostly negative impact on forests. Nearly 60,000 square miles (155,399 square kilometers) of forest are cleared each year. Most of the forest loss has occurred in developing nations where wood is used for fuel and trees are cleared for farming. A large number of trees are also lost each year to commercial use.

Rain Forest Explorers

When Europeans first encountered the rain forest, they saw it from a position at its edge, where light could penetrate and foliage ran rampant. The forest soon gained a reputation for being impenetrable, and the first men who ventured into it had remarkable courage. Many were seekers of knowledge about the world; others had a hunger for riches that they believed they would find in the jungle.

At first, valuable goods were the primary target. The Portuguese penetrated Africa by means of its rivers but gained little knowledge of the interior. Few who entered it, such as Portuguese explorer Vallarte in 1448, came back alive. The first European to explore the rain forests of the Amazon in South America was Francisco de Orellana who went in search of cinnamon trees and gold in 1541.

In the 1700s, scientific curiosity became the primary motive for exploration. Between 1799 and 1803, Alexander Baron von Humboldt and Aime Bonpland explored thousands of miles of South America in order to study plant and animal life. During the nineteenth century, journalist Henry Morton Stanley (1841–1904) made a dangerous voyage the length of the Congo River in Africa. Prince Maximilian of Wied-Neuwied, Henry Walter Bates, Alfred Russel Wallace, Jules Crevaux, and, in the twentieth century, Theodore Roosevelt (1858–1919), Percy Fawcett, and Michael Rockefeller also undertook journeys into unexplored regions.

Use of plants and animals Rain forests are disappearing at alarming rates each year, especially the montane forests. Much forestland is being lost as populations grow and want the land for farms and cattle pasture. Slash and burn agriculture is a routine procedure in which trees are cut and burned. When the land will no longer support crops, it is abandoned and additional forest is cut down somewhere else. As a result, many animals and plants are permanently losing their habitats.

Our ability to harvest trees for wood is greater than the forest's ability to regenerate. Mechanical harvesting with huge machines makes clear-cutting (cutting down every tree in an area) cheaper and more efficient than selecting only certain trees for harvesting. Replanting may not be done, or a fast-growing species may be replanted rather than the original species. The original species may never grow back. Clear-cutting endangers wildlife by destroying natural habitats.

Quality of the environment Destruction of the forests does not mean just loss of their beauty and the products they provide. Water quality suffers because the trees are gone and rain no longer seeps into the soil. Instead, it runs off and underground water reserves are not

A Penan woman holds her child, deep within Sarawak's rainforest in Malaysian Borneo. The Penan are among the world's isolated communities. They hunt wild pigs and deer with spears and blow darts, and pick wild fruits from the lush bush. AP IMAGES.

replaced. Topsoil is eroded away and often ends up in streams and rivers. If the quantity of soil is large enough, fish may die.

Air quality is also reduced by the destruction of forests. Trees not only put oxygen back into the air, but soot and dust floating in the air often collect on their leaves and are washed to the ground when it rains. When the trees are cut down, the dust and soot remain in the air as air pollution.

With the popularity of the automobile, carbon dioxide and other undesirable gases have built up in the atmosphere. Most scientists believe these gases are helping raise the temperature of Earth's climate (the greenhouse effect). Forests help remove carbon dioxide from the air, so cutting them down may be a factor in global warming. If Earth grows warmer, many species of plants and animals could become extinct.

Forest management Most rain forests grow in developing countries that need forest resources for economic reasons. Since 1945, more than 50 percent of the world's rain forests have been cut down and cleared away. Some countries have realized that they must use their resources wisely, and conservation efforts are under way. Malaysia and Uganda, for example, are making better use of trees that were formerly wasted, and replanting programs have begun in Gabon and Zambia.

Native peoples Native people have been found in all the major rain forests of the world. They include the Yanomami of South America, the Asanti and Bambuti of Africa, the Andaman of Asia, the Aeta of the Phillipines, the Penan of Borneo, and the Aborigines of Australia.

In general, forest dwellers are hunter-gatherers who make few changes to the forest environment. Changes other people are making may destroy their way of life.

Yanomami The Yanomami tribe, comprised of four smaller tribes, are scattered across Brazil and Venezuela. Only about 20,000 of them remain, as their population has decreased by over 10 percent in the last twenty years. The Yanomami live in villages as few as 40 residents to as many as 300 people. Trade and marriage keep the villages in contact with one another; sometimes peacefully and other times not. They seldom leave the forest, as it provides them with all they need to survive. Huts are built from timber and vine and food is either grown or hunted.

Asante The Asante (sometimes referred to as Ashanti) of Africa make their home in Togo and the Ivory Coast. Like many native tribes, they began as forest dwellers. Loss of their home due to the clearing of the forest has caused some to move to nearby towns. Farming is their main livelihood. They export plantains, bananas, yams, and other staples to the local market.

Although mostly a peaceful tribe, the Asante have their share of war and strife. In the seventeenth century, firearm trade caused a power struggle in which the Asante prevailed. Then in the nineteenth century, they fought the British seeking an independent government from the Republic of Ghana. This battle was lost, but the Asante were allowed to live in peace, and they now number over 600,000 people.

Andaman The Andaman tribe is the only tribe of natives that never learned to make fire. They waited for fire to naturally occur, such as lightning fires, and then were careful to preserve the fire as long as possible.

Located on the Andaman and Nicobar islands in the Bay of Bengal, they survive by hunting, and their diet consists of no plants or vegetables. As islanders, they seek out iron from nearby shipwrecks and use it to make their weapons.

The Food Web

The transfer of energy from organism to organism forms a series called a food chain. All the possible feeding relationships that exist in a biome make up its food web. In the rain forest, as elsewhere, the food web consists of producers, consumers, and decomposers. An analysis of the food web shows how energy is transferred within the biome.

Green plants are the primary producers in the forest. They produce organic materials from inorganic chemicals and outside sources of energy, primarily the Sun. Trees and other plants turn energy into plant matter.

Animals are consumers. Plant-eating animals, such as certain insects and mice, are the primary consumers in the rain forest food web. Secondary consumers, such as anteaters, eat the plant-eaters. Tertiary consumers are the predators, like owls and leopards. Some, such as orangutans and humans, are omnivores.

Decomposers feed on dead organic matter and include fungi and animals like the vulture. In the moist rain forest, bacteria aid decomposition. When leaves fall to the ground, bacteria feed on the leaves and speed up the decomposition process.

Spotlight on the Rain Forests

Rain forests of South America More than half of all the world's rain forests are located in South America. The South American region contains all three types—lowland, montane, and cloud forest—and is dominated by the great Amazon River and its tributaries. The forests of South America claim 2.7 million square miles (7 million square kilometers). The region on the northwest coast of Colombia is not well explored, in contrast to the much-explored forests of northern Brazil. Bordering Paraguay is the Mato Grosso forest. Cloud forests occur in the mountains of Venezuela, Brazil, Peru, and Guyana.

Annual rainfall is more than 236 inches (600 centimeters), which makes this one of the wettest places in the world.

An estimated 70,000 species of plants can be found in South American rain forests, which includes about 2,500 species of trees. Some trees, such as mahogany and rubber trees, have gained worldwide commercial importance.

No one knows how many species of insects live in the South American rain forest because so many remain to be identified or even discovered. Among those that have been catalogued include the malachite butterfly and the postman butterfly.

More than half of the world's species of birds make their home in the Amazon basin. A few are migratory but most live in the rain forest year-round. They have the short, broad wings of true jungle birds and range in size from the large-billed toucan to the tiny hummingbird.

Comparatively speaking, this area supports few mammals. They tend to be small and shy and include deer, pacas, agoutis, capybaras, anteaters, tapirs, jaguars, bats, and many species of monkeys, including spider monkeys, woolly monkeys, and capuchins.

In the 1970s, a network of highways was constructed through the Brazilian rain forest in an attempt to develop the land for farming and provide access to mineral and timber resources. This has proved

Rain forests of South America
Location: Brazil, Bolivia, Peru, Ecuador, Colombia, Venezuela, Guyana, Surinam, and French Guiana

disastrous. Rain forest soil is poor; after a few years farms are abandoned and more land is cleared. In addition, roads are often impassable from January to July, during the season of heaviest rain and severe flooding.

Rain forests of Central America Before the sixteenth century, the small countries of Central America were covered by rain forest. Forests now cover only about 196,000 square miles (507,000 square kilometers) of land. Some forests are protected, such as the Monteverde Cloud Forest Reserve in Costa Rica.

Like the South American forests, the Central American forests are rich in diversity, claiming to have 43,000 to 48,000 different species; 20,000 to 25,000 of these are not found anywhere else in the world. Flowering plants include the hotlips, the brown violet-ear, and many species of orchids. Trees include the massive guanacaste and the Gunnera.

Paper wasps, red-kneed tarantulas, tiger moths, false-leaf katydids, golden beetles, termites, land snails, and sally lightfoot crabs are among the invertebrates that live here. Frogs and toads are exist in great numbers. While some depend on camouflage, others are brightly colored or patterned. Boa constrictors and iguanas are representative of reptiles. Bird life is extremely varied, and Panama supports more species than the whole of North America. Some birds are migratory, spending only the winter months here. Mammals include howler monkeys, tapirs, peccaries, deer, and jaguars.

For more than 3,000 years, Central America was home to the great Aztec and Maya civilizations. The Aztec were centered in Mexico and the Maya in Belize and Guatemala. They were primarily agricultural peoples and had developed methods of irrigating (watering) and fertilizing crops such as corn, beans, and squash. These civilizations also developed forms of writing, books, maps, astronomy, and a very accurate calendar. But by 1521, Hernán Cortés (1485–1547) of Spain had conquered the Aztecs, and by 1550 the Mayans were also overcome and their great civilizations destroyed.

Rain forests of Africa The lowland wet forest lines the West African coast, from Senegal to the Congo. Montane forest is found in central south Africa. The total area is much smaller than covered by rain forest in South America or Southeast Asia. Here the forest measures about 780,000 square miles (2.02 million square kilometers), or one third of the continent.

The climate in Africa is warm and wet, and annual rainfall is greater than 60 inches (1.5 meters). This helps to support plant and animal life,

Rain forests of Central America
Location: Parts of Mexico, Panama, Costa Rica, Nicaragua, Honduras, Guatemala, and Belize

Rain forests of Africa
Location: Zaire, Congo, Cameroon, Gabon, Nigeria, Liberia, Sierra Leone, Ivory Coast

including the African mahogany, obeche, and ebony trees. African forests are also home to many flowering plants. One, called the "flame of the forest" or the "flamboyant tree" yields huge scarlet flowers. Animals commonly found in the African forest include gorillas, bats, monkeys, apes, and many others.

Rain forests of Madagascar Rain forest in Madagascar covers the east side of the island along the coast. Rainfall is about 139 inches (353 centimeters) annually. The island is vulnerable to storms at sea and much damage occurs periodically.

Vegetation is dense and of the montane variety. Trees include traveler trees and palms. Ferns, lianas, and epiphytes dominate the understory.

Invertebrates include grasshoppers, termites, cockroaches, mosquitoes, moths, and butterflies. Reptiles include chameleons, geckos, and lizards. Birds are numerous and include guinea fowls, herons, flamingoes, and owls. At one time, Madagascar was part of Africa, and animal life in both places has similar origins. The current island broke away from Africa some 50 million years ago. As a result, the animals in Madagascar developed in isolation, creating a home to many unique species. These include many species of chameleon, the mesite, the lemur, the tenrec, and the fossa.

Rain forests of Southeast Asia Tropical forests in Asia can be found in Bhutan, Myanmar, Bangladesh, India, the Malay peninsula, Indonesia, and the Philippines. Together, it covers 864,000 square miles (12.2 million square kilometers) of land. Within that, 566,000 square miles (1.47 million square kilometers) is covered in lowland wet forest.

In terms of tree species, the rain forests of Asia differ from others in that they support coniferous trees. The dipterocarps is a large family of hardwoods bearing winged fruits. It dominates these forests. Examples of dipterocarps include the *Shorea* and *Dipterocarpus* species. Other trees include kapoks, palms, and even pines. Smaller plants include mosses, ferns, rattans, ginger, orchids, and ant plants.

Asian forests are rich in fruit, such as breadfruit, jackfruit, and durian. Jackfruit is one of the largest fruits in the world, with some species weighing up to 55 pounds (25 kilograms). Durian has a

Rain forests of Madagascar
Location: Madagascar Island, off the east coast of Africa

Rain forests of Southeast Asia
Location: Malayasia, Indonesia, the Philippines, Thailand, Cambodia, Laos, and Vietnam

very distinct, unpleasant odor, but is popular among the natives of Asia.

Mammals are well represented and include rats, squirrels, tigers, elephants, rhinoceroses, tapirs, wild pigs, leopards, deer, antelopes, marbled cats, and many species of monkeys and their relatives.

Rain forests of New Guinea The eastern half of New Guinea, Papau New Guinea, is an independent country, while the western half, Irian Jaya, belongs to Indonesia. As a whole, the island boasts that 77 percent of its lands are mostly lowland wet forests. Ranges of mountains run through the center of the island, the tallest peak is 16,535 feet (5,040 meters) high. Much of this region is unexplored. Steep gorges and rolling valleys punctuate the mountains.

Rainfall is heavy and, on the north coast, totals about 100 inches (254 centimeters) annually. Lowland temperatures remain at about 80°F (27°C) throughout the year.

The forest is rich with kamamere, lancewood, New Guinea basewood, and walnut. Moretan bay pines and klinki pines can be found at higher altitudes in the montane forest. The klinki pine is the tallest tree in all of the tropical forests in the world, measuring 292 feet (89 meters) tall.

Constant rain removes nutrients from the soil, and most inland soils are poor. In regions around volcanoes soil quality improves. In the montane forests, dead vegetation several feet thick often covers the ground.

Animal life resembles that found in Australia, especially the mammals. Ants, cockroaches, sand flies, butterflies, mosquitoes, and giant snails are representative of invertebrates, and the island is home to many snakes, most of them poisonous. Other reptiles include lizards, tortoises, and crocodiles. Birds are similar to those found in Malaysia and Australia; the cassowary and the bird of paradise are examples. Many mammals are found here, all of which are marsupials (mammals that carry their young in a pouch) except for the spiny anteater, the bat, and non-native rodents. An example of a marsupial is the tree kangaroo.

Native peoples depend upon agriculture, and the rain forest is gradually being cut down to accommodate farms. Crocodile farming is common for the sale of their skins.

Rain forests of New Guinea
Location: Pacific Ocean, north of Australia

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Environmental Defense Fund, 257 Park Ave. South, New York, NY 10010, Phone: 212-505-2100; Fax: 212-505-2375, Internet: http://www.edf.org.

Environmental Protection Agency, 401 M Street, SW, Washington, DC 20460, Phone: 202-260-2090, Internet: http://www.epa.gov.

Friends of the Earth, 1717 Massachusetts Ave. NW, 300, Washington, DC 20036, Phone: 877-843-8687; Fax: 202-783-0444, Internet: http://www.foe.org.

Greenpeace USA, 702 H Street NW, Washington, DC 20001, Phone: 202-462-1177, Internet: http://www.greenpeace.org.

Rainforest Alliance, 665 Broadway, Suite 500, New York, NY 10012, Phone: 888-MY-EARTH; Fax: 212-677-1900, Internet: http://www.rainforest-alliance.org.

Sierra Club, 85 2nd Street, 2nd fl., San Francisco, CA 94105, Phone: 415-977-5500; Fax: 415-977-5799, Internet: http://www.sierraclub.org.

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River and Stream

A river is a natural flow of running water that follows a well-defined, permanent path, usually within a valley. A stream (also called a brook or a creek) is a natural flow of water that follows a more temporary path that is usually not in a valley. The term stream is often used to mean any natural flow of water, including rivers. Although some rivers are larger than some streams, size is not a distinguishing factor.

The origin of a river or stream is called its source. If its source consists of many smaller streams coming from the same region, they are called headwaters. Its channel is the path along which it flows, and its banks are its boundaries, the sloping land along each edge between which the water flows. The point where a stream or river empties into a lake, a larger river, or an ocean, is its mouth. When one stream or river flows into another, usually larger, stream or river, and adds its flow, it is considered a tributary of the larger river. Many tributaries make up a river system. The vast Amazon system in South America, for example, is fed by at least 1,000 tributaries.

The world's longest river is the Nile in eastern Africa. It begins in Ethiopia and travels 4,000 miles (6,437 kilometers) into Egypt, where it discharges its waters into the Mediterranean Sea. The river system that obtains water from the largest area, 2,722,000 square miles (7,077,200 kilometers), is that of the Amazon. The Amazon River transports the largest volume (20 percent) of all the water in all the rivers of the world.

How Rivers and Streams Develop

Rivers and streams are part of Earth's hydrologic cycle. The hydrologic cycle describes the manner in which molecules of water evaporate, condense and form clouds, and return to Earth as precipitation (rain, sleet, or snow). Rivers pass through several stages of development.

WORDS TO KNOW

Arroyo: The dry bed of a stream that flows only after rain; also called a wash or a *wadi.*

Erosion: Wearing away of the land.

Headwaters: The source of a river or stream.

Oxbow lake: A curved lake formed when a river abandons one of its bends.

Rhizomes: Plant stems that spread out underground and grow into a new plant that breaks above the surface of the soil or water.

Riffle: A stretch of rapid, shallow, or choppy water usually caused by an obstruction, such as a large rock.

Rill: Tiny gully caused by flowing water.

Tributary: A river or stream that flows into another river or stream.

Wadi: The dry bed of a stream that flows only after rain; also called a wash or an *arroyo.*

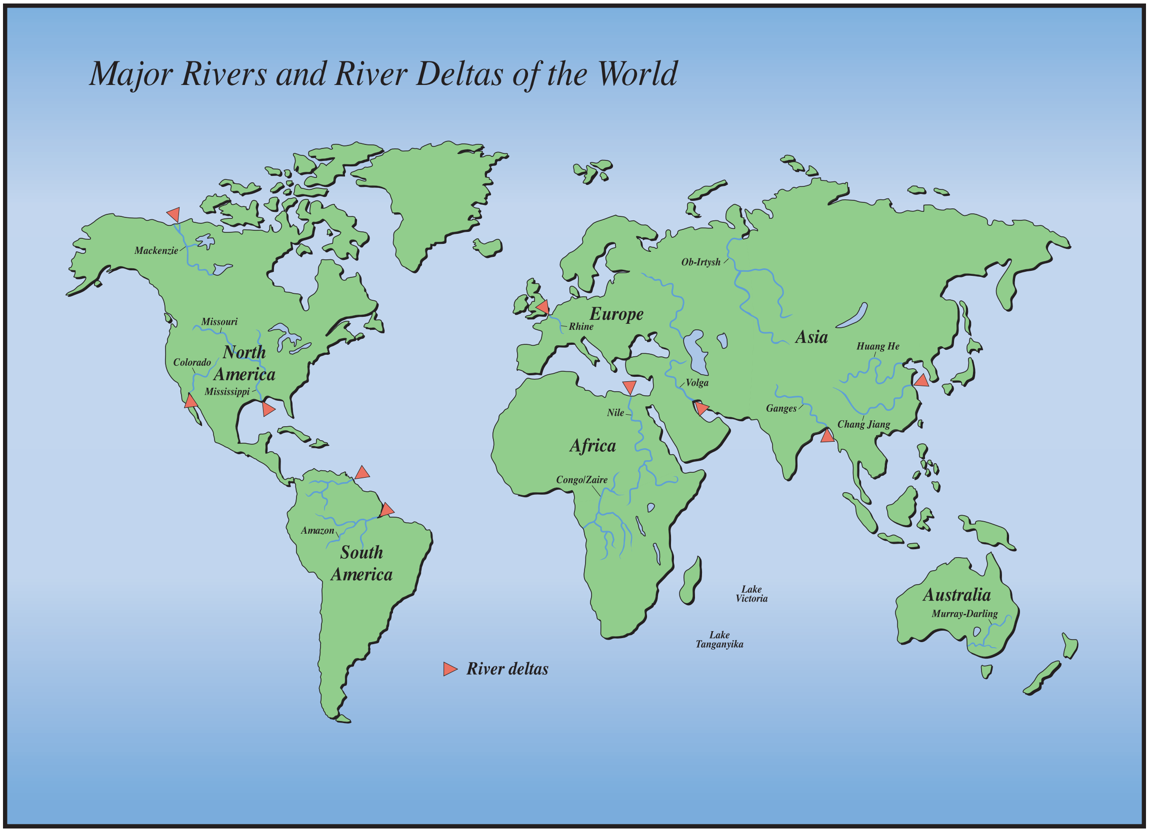
Formation Rivers and streams owe their existence to precipitation, lakes, and groundwater, combined with gravity and a sloping terrain.

When rain falls on the land, often the soil cannot absorb it all. Much of rain runs off and travels downhill with the aid of gravity, creating rills (tiny gullies). Many of these rills may meet at some point and their waters run together to form bigger gullies until all this water reaches a valley or gouges out its own large channel. When enough water is available to maintain a steady ongoing flow, a stream or river results. Gravity and the pressure of the flowing water cause the river to travel until it is either blocked, in which case the water backs up and forms a lake, or empties into an existing lake or ocean.

Most of the precipitation that feeds streams and rivers comes from runoff. Precipitation may also be stored as ice in glaciers in arctic regions or on mountaintops. As the glaciers melt, they nourish streams, and the streams feed rivers. The Rhine River in Germany, for example, obtains much of its water from the Rheinwaldhorn Glacier in the Swiss Alps.

A lake can be a source of river water. If the land slopes away from the lake at some point and the water level is high enough for it to overflow, a river or stream may form.

Another source of river water is groundwater. Groundwater is water that has seeped beneath Earth's surface where it becomes trapped in layers of rock called aquifers. The Ogallala Aquifer, the largest aquifer in North America, under the Great Plains in the United States is an example. When

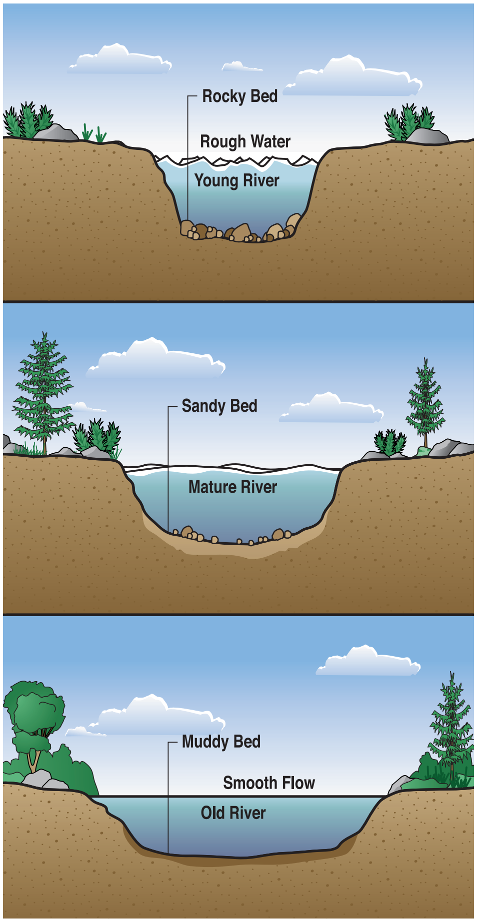


an aquifer is full, its water escapes to the surface, either by seeping directly into a river or stream bed or by forming a spring (an outpouring of water), which may then become a river's source. As much as 30 percent of the world's freshwater comes from groundwater. It is estimated that groundwater supplies about half of the water in the Mississippi River. In contrast, river water may seep into the ground and fill an aquifer, as the Colorado River does as it travels through Arizona, Nevada, and California.

Stages of development Rivers are said to age not in terms of how long they have existed but in terms of their development as they travel across the land. They are young, mature, or old. Some rivers, such as the Mississippi, may be in all three stages of development at one time.

Young rivers usually occur in highland or mountainous regions and have narrow, rocky channels with many boulders. The water may form

Stages in River Development



waterfalls or foam and gurgle as it rushes over the rocks. Young rivers have few tributaries.

Mature rivers are those that have reached flat land as their tributaries pour more water into them. They often become flooded during periods of heavy rain or snowmelt. Their beds tend to be muddy rather than rocky because of the sediment (particles of sand or soil) carried into them by swift-flowing streams, and the valleys through which they flow are usually fairly broad. Few waterfalls occur on mature rivers, but they may have many bends or loops as they curl across the land looking for the lowest level to follow.

A river is old near its mouth, where layers of sediment build up over time. Here, the land is wide and flat, and the water travels more smoothly than in young and mature rivers.

Kinds of Rivers and Streams

Rivers and streams can be classified according to their degree of permanence, the shape of their channels, and their branching network.

Degree of permanence Permanent streams and rivers flow all year long. Enough water is available to keep them from drying up completely, even during a long, dry spell. Most large rivers are permanent.

Intermittent streams and rivers are seasonal. They occur only during the rainy season or in the spring after the snow melts. Rivers and streams in desert regions tend to be intermittent, where they are also called wadis or arroyos.

Interrupted streams and rivers flow above ground in some places and then disappear from sight as they dip down under sand and gravel to flow underground in other places. The Santa Fe River in Florida is an example of an interrupted river.

During the wet season, this dry river bed could be a flowing stream. IMAGE COPYRIGHT LINDA ARMSTRONG, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Channel shape The material over which a stream or river flows, and the force of the water as it travels determine the shape of the channel, which can be straight, braided, or meandering.

Straight streams or rivers flow in a straight line. This type is very rare because flowing water tends to trace a weaving path. Straight streams that do occur tend to have rocky channels.

Braided streams or rivers, such as the Platte River in Nebraska, consist of a network of interconnecting channels broken by islands or ridges of sediment, primarily mud, sand, or gravel. Braided streams often occur in highland regions and have a steep slope.

Meandering streams or rivers wind snakelike through relatively flat countryside. Meandering streams tend to have low slopes and soft channels of silt (soil) or clay. The Menderes River in Turkey meanders, and the term, which means to wander aimlessly, is derived from its name.

Branching network Rivers do not usually originate from a single spot but are the result of a branching network that resembles the branches on a tree. The smallest streams or branches that do not have tributaries are called first-order streams. If two first-order streams join to form a new stream, the new stream is considered a second-order stream. When two second-order streams join, they form a third-order stream, and so on. This system of ordering was developed by an American engineer, Robert E. Horton (1875–1945) in 1945. A very large river the size of the

Architects of the Underground

In areas where large deposits of limestone and other soft rock are found, underground rivers may create vast networks of caves. The best example is Mammoth Cave in Kentucky, which has large chambers and underground passageways on five levels that wind back and forth for a total length of 365 miles (587 kilometers). Several underground rivers and streams still flow through the cave, including Echo River, on which tour boats were once operated. The beautiful caverns and rock formations carved by the rivers have been given intriguing names, such as King Solomon's Temple, the Pillars of Hercules, and the Giant's Chamber. Ancient Native American tribes once used the caves, and their mummified bodies have been found there.

Mississippi is usually considered a tenth-order stream. The Amazon River is rated a twelfth- or thirteenth-order stream.

The Water Column

The water column refers to the water in a river or stream, exclusive of its channel (path) or banks. All of the world's rivers and streams combined contain less than 1 percent of all the water on Earth. Most water is held in the oceans.

Composition Rivers and streams carry fresh water, but this water may be clear or cloudy, polluted or clean. Its characteristics are determined by where it originates and the nature of its channel.

As the water moves across the land, particles of rock, soil, and decaying plant or animal matter, called sediment, become suspended in it. If a river carries a large quantity of sediment, it will be muddy. The smaller the amount of sediment, the clearer the water.

River water reacts chemically with the rocks in its channel and dissolves some of the minerals they contain, called salts. These dissolved

This is the braided Rakaia River in Canterbury, New Zealand. IMAGE COPYRIGHT CHRIS HELLYAR, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

salts give the water its taste and make it "hard." Rivers and streams carry large amounts of these salts. The Niagara River, which lies on the border between the state of New York and Ontario, Canada, carries an average of 60 tons (54 metric tons) of dissolved mineral salts per minute as it pours over Niagara Falls, giving the water a green color.

Mark Twain

Samuel Clemens (1835–1910), a famous American author, wrote under the name Mark Twain. The word twain means "two fathoms deep" (a fathom is about 6 feet [2 meters]). It was one of the terms shouted by crewmen on Mississippi river boats who were measuring the river's depth to help the captain know if the boat could pass through that part of the channel. Clemens himself worked for a time as a steamboat pilot, and many of his stories have to do with the river. His river adventures are chronicled in *Life on the Mississippi* and *The Adventures of Huckleberry Finn*.

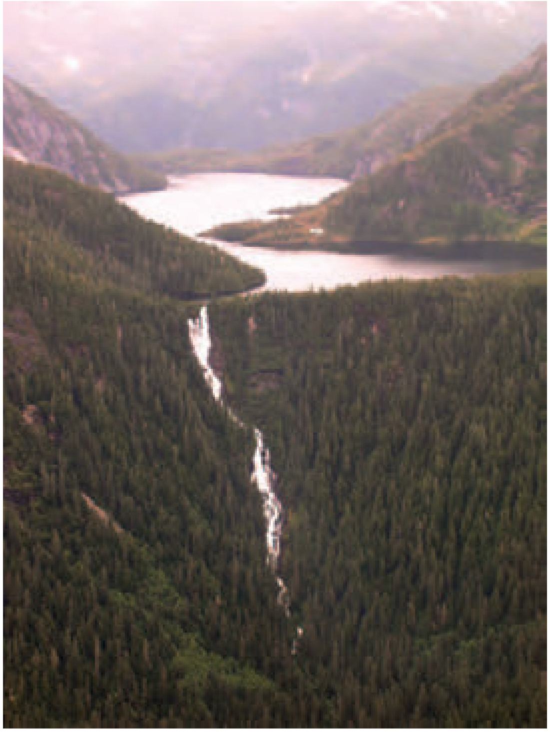
Circulation Water in a river or stream is almost always in motion. The direction from which it comes is called upstream, and the direction toward which it flows is called downstream. If you paddle upstream, you ascend the river. If you paddle downstream, you descend.

Velocity Rivers and streams acquire their initial energy from their elevation. Their waters are always falling downhill toward their ultimate goal, sea level (the average level of the surface of the sea). The fastest velocities (speeds) occur at waterfalls. The water flowing over Niagara Falls has been clocked at 68 miles (109 kilometers) per hour. Most rivers and streams seldom exceed 10 miles (1.6 kilometers) per hour, and the average speed is 2 to 4 miles (3.2 to 6.4 kilometers) per hour.

Although gravity helps get things started, gushing mountain streams actually move more slowly than large, broad, mature rivers. This happens because friction (resistance to motion when one object rubs against another) caused by water molecules rubbing against the channel and banks decreases downstream where the channel is usually smoother and less rocky. Where the river is wider, deeper, and the volume of water is greater, a smaller percentage of water molecules is exposed to friction.

The water at different locations or levels in the same section of river may move at varying speeds. The velocity is fastest in the middle and just below the surface. Movement slows down with depth and along the banks because friction increases. Along the very bottom of the channel is the boundary layer, a layer of water only 0.1 inch (0.25 centimeter) deep, where friction has stopped the flow completely.

Wave and current Waves are rhythmic rising and falling movements in the water. Surface waves are caused by wind blowing across a river's surface. Winds tend to follow a regular pattern. They occur



This high altitude lake in the Misty Fjords National Monument and Wilderness in Ketchikan, Alaska, gives the water energy as it cascades into lower terrain. COPYRIGHT © 2003 KELLY A. QUIN.

in the same place and blow in the same direction, and the movement of waves follows this pattern.

The current is the steady flow of the water in a particular direction, usually from upstream to downstream. River currents can be influenced by the slope and composition of the channel and the position of landmasses. When a current travels down a very steep slope, it may gain speed and force. When it meets a landmass, such as an island, it may be deflected and turn in a new direction.

An eddy is a current that moves against the regular current, usually in a circular, or whirlpool, motion. A riffle is a stretch of rapid, shallow, or choppy water that alternates with a quiet pool. A riffle is usually caused as the current flows over stones or gravel. A quiet pool is a deep, still area of water.

Discharge A river's discharge is the amount of water that flows out of it over a given period of time into another river, a lake, or the ocean. All of the world's rivers and streams combined discharge a total of 28,000,000,000 gallons (106,000,000,000 liters) of water every day. If all this water were to flow out over the land, it would cover the land to a depth of 9 inches (25 centimeters).

Discharge is usually measured by multiplying the river's width at the surface by its average depth times its velocity. The Amazon, which empties into the Atlantic Ocean, discharges more water than any other river—more than 52,834,410 gallons per second (199,999,999 liters per second).

Tidal bores Tidal bores are surges of ocean water caused when ridges of sand direct the ocean's flow back into a narrow river channel, sometimes as a single wave. Most tidal bores are harmless. The Tsientang River in China, however, has bore speeds of 18 to 25 miles (29 to 40 kilometers) per hour.

Floods Floods are caused when more water enters the river than its channel can hold. The result is increased discharge and high water levels.

Most rivers overflow their banks every two to three years, but the amount of overflow is usually moderate. Depending on the river's origins and location, flooding is caused by melting snow, melting glaciers, or heavy rainfall, and sometimes by all three. Rivers supplied by snow or glaciers ordinarily produce only moderate flooding because snow and glaciers melt slowly and the extra water does not enter the river all at once. When heavy rainfall is added the discharge may be enormous. Rain in a location upstream may cause a flood downstream in a region that received no rain at all because rivers are so long.

Yukon Gold Rush

Between 1860 and 1910, people stampeded to the Yukon Territory of Canada in search of gold. They found it not only in the ground, but also in the sediments of rivers, especially the Klondike, the Lewes, the Stewart, and the lower Yukon. These sediments were scooped up into a flat pan and sloshed with water in an effort to separate bits of rock and other debris from the shining gold particles. It is estimated that about $100 million in gold was taken from the Yukon Territory during that time.

The seriousness of a flood is measured by comparing the river's average annual discharge rate to the rate during the flood. The Huang He (Yellow) River in China, for example, has a discharge rate of 88,286 to 158,916 cubic feet (2,500 to 4,500 cubic meters) per second. During a flood in 1958, its rate increased to 812,237 cubic feet (23,000 cubic meters). The flood covered 34,000 square miles (88,060 square kilometers) and killed 1 million people. The worst flood to occur in the United States was in 1993,

Most rivers overflow their banks every few years. Here is a flooded parkland at Henley on Thames during the UK floods of summer 2007. IMAGE COPYRIGHT PETER ELVIDGE, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Amazon River Name Origin

The first European to explore the Amazon and its basin was Francisco de Orellana of Spain (c. 1511–1546). In 1541, he made a seventeen-month trip from the foot of the Andes Mountains in the west to the mouth of the Amazon River in the east. The journey was difficult and involved many battles with the native peoples. At times food was scarce and he and his men had to eat toads and snakes. This lack of food may partly explain why de Orellana thought they had been attacked by a band of female warriors resembling the famous Amazons of Greek legends. Other explorers failed to encounter these hostile females, but de Orellana had named the river in their honor, and the name stuck.

along the middle and lower portions of the Mississippi River. Killing 487 people, the flood caused $15 billion in property damage.

In very dry regions, a river or stream may dry up completely for several weeks or months. During a sudden rainstorm, the channel may not be large enough to contain the amount of water, and a flash flood may occur. Flash floods are dangerous because they happen very suddenly. This wall of water brings down everything it reaches.

Effect on climate and atmosphere The climate of a stream or river depends upon its location as it travels over land. In general, if it passes through a desert area, such as Northern Africa, the climate will be hot and dry. If it begins on top of a mountain in the Northern Hemisphere, the climate will be cold. Rivers and streams in temperate (moderate) climates are often affected by seasonal changes. In these areas, small streams or rivers may dry up in summer or develop a layer of ice in winter.

The presence of a large river can create some climatic differences. In summer, evaporation may create more moisture in the air. When the water temperature is cooler than the air temperature, winds off the river can help cool the nearby region. The water in rivers and streams is partly responsible for the precipitation that falls on land. The water evaporates in the heat of the sun, forms clouds, and falls elsewhere.

Geography of Rivers and Streams

Rivers and streams are strong forces in shaping the landscape through which they flow. As the current moves against the channel and banks, water and the particles of sediment the river carries wear away the surface with a cutting action called erosion (ee-ROH-zuhn).

The faster a river flows, the faster it wears the land away and the more sediment it bears. Some of the eroded chunks and particles may sink to the bottom. Others are carried along and, as the river slows down, are dropped farther downstream. Erosion (wearing away) and deposition (dep-oh-ZIH-shun; layering) make many changes over time.

Waterfalls, such as these on the Tahquamenon River in Michigan, occur when a river or stream falls over a cliff or erodes the channel to such an extent that a steep drop occurs. COPYRIGHT © 2006 KELLY A. QUIN.

The drainage basin A river or stream obtains runoff from an area of land called its drainage basin, or watershed. The drainage basin can be extremely large. The Mississippi-Missouri river system, for example, has as its drainage basin the entire area between the Appalachian Mountains in the east and the Rocky Mountains in the west. The world's largest drainage basin is that of the Amazon, which measures 2,700,000 square miles (7,000,000 square kilometers).

Channel and banks The channel of a river or stream slopes down to the center where it is deepest. The bottom of the channel is called its bed. Channel beds may be rocky or covered with gravel, pebbles, or mud. Some river bed sediments are formed from the waste products and dead tissues of animals and plants. Others usually consist of clay, stone, and other minerals.

The general shape of the banks is partly determined by the general shape of the surrounding land. If the river runs through a plain, then its banks will be broad and level. If it occurs in the mountains, then its banks may be steep and rocky.

As water rushes through the channel of a young river, erosion tends to scour it out and make it deeper. Young river valleys are often narrow and steep sided. As the river matures and velocity and volume increase, width tends to increase more than depth. A mature valley tends to have a gentle slope, and an old valley may be almost flat.

MAJOR RIVER SYSTEMS

Name	Location	Length (mi./km.)	Basin Area (sq. mi./sq. km.)
Nile	North Africa	4,157 / 6,651	1,100,000/2,860,000
Amazon	South America	3,915 / 6,437	2,722,000/7,077,200
Mississippi-Missouri	North America	3,860 / 6,176	1,243,700/3,233,620
Ob-Irtysh	Siberia	3,461 / 5,538	959,500/1,919,000
Yangtze	China	3,434 / 5,494	756,500/1,919,000
Murray-Darling	Australia	3,371 / 5,394	414,253/1,077,058
Yenisei-Angara	Siberia	3,100 / 4,960	1,003,000/2,607,800
Zaire-Congo	Africa	2,716 / 4,346	1,425,000/3,705,000

Moderate periodic flooding is a major cause of changes in bank shape. Although large floods cause more erosion, they do not occur often enough to make drastic or permanent changes.

Landforms Landforms created by rivers and streams include floodplains and levees; wetlands; canyons and gorges; rapids and waterfalls; spits, bars, and shoals; and deltas and estuaries.

Floodplains and levees When a stream carrying a large quantity of sediment flows into another stream or out over a plain, it slows down and its sediments settle to the bottom. These sediments (called alluvium [a-LOO-VEE-um]) often spread out in a fan shape, creating an alluvial fan. When this occurs frequently, the result may be a floodplain. A floodplain is a flat region with soil enriched by river sediments and usually makes good farmland.

Very silty rivers may create high banks of sediments called levees. The levees of the Mississippi River are several yards (meters) high in places.

Wetlands Sometimes a river may change its path during a flood. The current may seek out a new path or, as the flood waters recede, sediments prevent the water in a loop or bend from rejoining the rest of the river. Here, a wetland, such as a marsh or swamp, or an oxbow lake may form. Oxbow lakes have a curved shape, which gives a clue to the origin of their name. (An oxbow is a U-shaped piece that loops around an ox's neck, and is part of the harness.)

Canyons and gorges Many riverbanks consist of both hard and soft rock. Moving water erodes the soft rock first, sometimes sculpturing strange shapes. In regions where much of the rock is soft, rivers and streams may cut deep canyons (long, narrow valleys between high cliffs) and gorges (deep, narrow passes). The Gooseneck Canyon in Utah was cut into the soft limestone of the region by the San Juan River over millions of years. The distance from the top of the canyon to the river is now 1,500 feet (456 meters).

This magnificent waterfall is in the Yellowstone National Park. IMAGE COPYRIGHT GSK, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Caves may be gradually carved into the sides of cliffs by erosion. In large rivers, headlands may be created. A headland is an arm of land made of hard rock that juts out from the bank into the water after softer rock has been eroded away.

Rapids and waterfalls When fast-moving water erodes softer rock downstream, gradually cutting away the bed in some places and creating many short drops, rapids may form. Rapids are often called "white water" because of the foam created when the rushing water hits the exposed bands of rock. The Salmon River in Idaho flows through steep canyons and has many rapids. Its rapids are so dangerous to travelers that it has been nicknamed the "River of No Return."

When a river or stream falls over a cliff or erodes the channel to such an extent that a steep drop occurs, it creates a waterfall. The world's highest waterfall is Angel Falls on the Rio Churun in southeastern Venezuela. Its greatest drop is 3,212 feet (979 meters). Victoria Falls, on the Zambezi River between Zimbabwe and Zambia, is considered one of the Seven Natural Wonders of the World. It is the world's largest falls at nearly 4,400 feet (5,577 meters) wide. Africans call it *Mosi-oa-tunya,* the "smoke that thunders."

Where a waterfall strikes the valley below, it gouges out a deep basin called the plunge pool. Eventually, it erodes the lip of rock over which it flows. As erosion continues over time, the waterfall slowly moves upstream. Niagara Falls, for example, is being cut back at a rate of 3 feet (1 kilometer) a year.

Spits, bars, and shoals A spit is a long, narrow point of deposited sand, mud, or gravel that extends into the water. A bar is an underwater

Fast moving water erodes softer rock downstream, creating many short drops, called rapids. IMAGE COPYRIGHT ANDREW MCDONOUGH, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

ridge of sand or gravel, formed by currents, that extends across a channel or the inside bank of a curve. Shoals are areas where enough sediments have accumulated that the water is very shallow and dangerous for navigation.

Deltas and estuaries Where rivers meet a lake or ocean, huge amounts of silt can be deposited along the shoreline. Large rivers can dump so much silt that islands of mud build up, eventually forming a triangle-shaped area called a delta. The finer debris that does not settle as quickly may drift around, making the water cloudy. The Nile River in Egypt and the Ganges (GANN-jeez) in India both have large deltas. The Ganges Delta is 220 miles (350 kilometers) wide and covers 25 percent of India's territory, making it the largest delta in the world.

When a river traveling through lowlands meets the ocean in a semi-enclosed channel or bay, the area is called an estuary. The water in an estuary is brackish—a mixture of fresh and salt water. In these gently sloping areas, river sediments collect and muddy shores form. Chesapeake

A spit is a long narrow point of deposited sand, mud, or gravel that extends into the water. COPYRIGHT © 2006 KELLY A. QUIN.

Bay, along the Atlantic Coast of Maryland, is the largest estuary in the United States. Estuaries are often sites for harbors because they can serve both river and ocean travel.

Elevation Rivers and streams occur at all altitudes. Their altitude changes over their length because they usually begin in highlands or mountains and move to lower elevations. The headwaters of the Ganges River in India, for example, start from an ice cave in the Himalaya Mountains at an elevation of 10,300 feet (16,480 meters). A thousand miles (1,600 kilometers) from its mouth, the Ganges is only about 600 feet (180 meters) above sea level, and 0 feet (0 meters) at its mouth where it enters the Bay of Bengal.

Plant Life

Few plants can root and grow in running water. Most plants that live in rivers and streams are found along the banks or in quiet pools where the environment is similar to that of a lake or pond. Plants with floating leaves do not do well in fast-moving streams because the current pulls the leaves under. When rooted plants gain a foothold and manage to reproduce, they can grow so numerous that they slow the flow of water and can even cause flooding.

River and stream plants may be classified as submergent, floating aquatic (water), or emergent according to their relationship with the water.

A submergent plant grows beneath the water; even its leaves lie below the surface. Submergents include the New Zealand pygmyweed, tape grass, and water violet.

Floating aquatics float on the water's surface. Some, such as duckweed, have no roots. Others, such as the water lily, have leaves that float on the surface, stems that are underwater, and roots that are anchored to the bottom.

An emergent plant grows partly in and partly out of the water. The roots are usually underwater, but the stems and leaves are at least partially exposed to air. They have narrow, broad leaves, and some even produce flowers. Emergents include reeds, rushes, grasses, cattails, and sedges.

Plants that live in rivers and streams can be divided into four main groups: bacteria; algae (AL-jee); fungi (FUHN-ji) and lichens (LY-kens); and green plants.

Algae Most submergent plants are algae. (It is generally recognized that not all algae fit neatly into the plant category.) Some forms of algae are so tiny they cannot be seen without the help of a microscope. These, like spirogyra, sometimes float on the water in slow-moving rivers or coat the surface of rocks, other plants, and river debris. Other species, such as blanket weed, are larger and remain anchored to the riverbed in quiet pools.

Most algae have the ability to make their own food by photosynthesis (foh-toh-SIN-thih-sihs), the process by which plants use energy from sunlight to change water and carbon dioxide from the air into the sugars and starches they use for food. A by-product of photosynthesis is oxygen, which combines with the water and enables aquatic animals, such as fish, to breathe. Algae require other nutrients that must be found in the water, such as nitrogen, phosphorus, and silicon. Algal growth increases when nitrogen and phosphorus are added to a stream by sewage or by runoff from fertilized farmland.

Common river and stream algae Phytoplankton float on the surface of the water. Two types of phytoplankton, diatoms and dinoflagellates (dee-noh-FLAJ-uh-lates), are the most common. Diatoms have simple, geometric shapes and hard, glasslike cell walls. They live in colder regions and even within arctic ice. Dinoflagellates have two whiplike attachments that make a swirling motion. They live in tropical regions (regions around the equator).

Macrophytic algae are not as common in fast-moving water, but some filamentous species can be found growing on stable surfaces.

Growing season Algae contain chlorophyll, a green pigment used during photosynthesis. As long as light is available, algae can grow. Growth is often seasonal. In some areas, such as the Northern Hemisphere, most growth occurs during the summer months when the sun is more directly overhead. In temperate zones, growth peaks in the spring but continues throughout the summer. In regions near the equator, no growth peaks occur since it is warm year round. As a result, growth is steady throughout the year.

Reproduction Algae may reproduce in one of three ways. Some split into two or more parts, each part becoming a new, separate plant. Others form spores (single cells that have the ability to grow into a new organism), and a few reproduce sexually, during which cells from two different plants unite to create a new plant.

Fungi and lichens As with algae, it is generally recognized that fungi and lichens do not fit neatly into the plant category. Fungi are plantlike organisms that cannot make their own food by means of photosynthesis. Instead, they grow on decaying organic (material derived from living organisms) matter or live as parasites (organisms that depend upon other organisms for food or other needs) on a host. Fungi grow best in a damp environment and are often found along riverbanks. Common fungi include mushrooms, rusts, and puffballs.

Lichens are combinations of algae and fungi that tend to grow on rocks and other smooth surfaces. The alga produces the food for both itself and the fungus by means of photosynthesis. The fungi may provide moisture for the algae. One of the most common lichens found near streams is called reindeer moss, which prefers the solid surfaces of rocks.

Green plants Most green plants need several basic things to grow: light, air, water, warmth, and nutrients. Near a stream, light and water are in plentiful supply. Nutrients, primarily nitrogen, phosphorus, and potassium, are usually obtained from the soil. Some soils are lower in these nutrients. They may also be low in oxygen. These deficiencies may help limit the kinds of plants that can grow in an area.

The true green plants found growing in the water along the banks of rivers and streams are similar to those that grow on dry land. Unlike algae, they have roots and some, like the eelgrass, may even bloom underwater.

Large beds of green plants slow the movement of water and help prevent erosion. Some water animals use green plants for food and for hiding places. Plants that occupy the emergent zone between the water-covered area and dry land, such as sallows (European species of willows) and sedges, need moist, but not saturated, soil.

Common river and stream green plants Common plants found in and around rivers and streams include willow moss, water lily, pondweed, duckweed, aquatic buttercup, great pond sedge, water plantain, water lettuce, mosquito fern, water soldier, bur reed, marsh horsetail, reed mace, mare's tail, greater spearwort, flowering rush, water forget-me-not, St. John's wort, alder, and weeping willow.

Growing season Climate and the amount of precipitation both affect the length of the growing season. Warmer temperatures and moisture usually signify the beginning of growth. In regions that are colder or receive little rainfall, the growing season is short. Growing conditions are also affected by the amount of moisture in the soil, which can range from saturated, during flooding or a rainy season, to dry.

Reproduction Green plants reproduce by several methods. One is pollination, in which the pollen from the male reproductive part (called a stamen in flowering plants) of a plant is carried by wind or insects to the female reproductive part (called a pistil in flowering plants). Water lilies, for example, are closed in the morning and evening, but open during midday when the weather is warmer and insects are more active and more likely to visit. Some shoreline plants, like sweet flag, reproduce by sending out rhizomes (RY-zohms), which are stems that spread out under water or soil and form new plants. Reed mace and common reeds reproduce by this means.

Endangered species Changes in the habitat, such as pollution and the presence of dams, endanger river and stream plants. Plants are also endangered by people who collect them, and by the use of fertilizers and herbicides (poisons used to control weeds), which enter the water as runoff from farms.

The papyrus plant in Egypt, for example, is endangered because of the Aswan High Dam. The dam traps Nile water in its reservoir upstream, and the swamps and ponds that form the habitat for papyrus are disappearing.

Animal Life

In addition to the land animals that visit for food and water, rivers and streams support many species of aquatic animals. Some swim freely in the water, while others live along the muddy bottom. Some prefer life in midstream or on rocks beneath a fast-moving flow; others seek the shallows or quiet pools. Shallows are often warm and exposed to sunlight, but animals that prefer cool shady spots can find them along the banks beneath overhanging trees. Many river and stream animals are adapted to life under high-speed conditions. Salmon and trout, for example, are torpedo-shaped and can swim against the current more easily than other fish. Some, like torrent beetles and stonefly larvae, have low-slung or flattened bodies that enable them to cling to rocks without being washed away.

Water quality often determines which species will be supported in a particular river or stream. Temperature, velocity, oxygen content, mineral content, and muddiness are all factors. Cold-water trout, for example, prefer cool, shady streams, while snails require calcium-rich waters in order to build their shells. Estuaries are a combination of both salt- and freshwater environments. They are home to species especially adapted to those conditions.

Microorganisms Microorganisms cannot be seen by the human eye without the use of a microscope. Those found in rivers and streams include the transparent stentor. The larvae of animals whose adult forms may be larger, such as dragonflies, worms, and frogs, may spend some time as microorganisms living in the water.

Bacteria Bacteria are microorganisms found throughout rivers and streams and make up much of the dissolved matter in the water column. They provide food for smaller animals and help decompose (break down) the dead bodies of larger organisms. For those reasons, their numbers increase along the banks where the most life is found.

Invertebrates Invertebrates are animals without a backbone. They range from simple flatworms to more complex animals such as spiders and snails.

Many species of insects live in rivers and streams. Some, like the diving beetle, spend their entire lives in the water. Others, like black flies, live in the water while young but leave it when they become adults.

River Blindness

In tropical Africa, South America, and Central America, a round worm causes a disease in humans called river blindness. The worm is introduced by the black fly, which thrives around fast-moving rivers. The fly carries the larvae of the worm and spreads them to humans in its bite. The larvae burrow under the skin and spread throughout the body, eventually reaching the eyes. In some African villages, 15 percent of the people are infected.

Mollusks, such as freshwater mussels, are invertebrates with a hard outer shell that often inhabit rivers.

Common river and stream invertebrates Common invertebrates found in rivers and streams include diving beetles, mayflies, water fleas, torrent beetles, stoneflies, dobsonflies, water boatmen, water striders, whirligig beetles, black flies, fisher spiders, water scorpions, water sticks, leeches, flatworms, snails, freshwater clams, freshwater mussels, raft spiders, caddisflies, and freshwater crayfish.

Food Insects may feed underwater as well as on the surface. They may be herbivores (plant eaters), carnivores (meat eaters), or scavengers that eat decaying matter.

The diets of invertebrates other than insects varies. Some snails are plant feeders that eat algae, while freshwater crabs are often omnivorous, eating both plants and animals.

Reproduction Most invertebrates are insects, which have a four-part life cycle. The first stage is spent as an egg. The second stage is the larva. It may be divided into several stages between which there is a shedding of the outer skin casing. A caterpillar is an example of an invertebrate in the larval stage. The third stage is the pupal stage, during which the insect lives in yet another protective casing, like a cocoon. Finally, the adult breaks through the casing and emerges.

For some insects, their entire life cycle is centered on breeding. Mayflies, for example, live for an entire year in streams as larvae. After they shed the larval casing, they breed, lay eggs, and die; all within a day or two. If enough mayflies survive the larval stage, the numbers of dead adults can be enormous. On one occasion, a snowplow had to be used to remove a layer of mayflies several feet thick from a bridge across the Mississippi.

Raft spiders live along the edges of slow-moving rivers where they are able to run across the water's surface in search of insect prey. Bristles on their feet help distribute their weight so they do not sink. Raft spiders can be identified by two yellow stripes running the length of their bodies.

Adult caddisflies are creatures that come out only at night, rarely feed, and live for only a couple of days. The larvae of caddisflies use stones, sand, shells, and other items to build a protective shell around themselves. The only opening is a hole at the front through which the larva's head emerges to feed. Some larvae eat algae, and others build nets to catch food carried by the current.

The 540 species of freshwater crayfish are found in rivers on all continental landmasses except Africa. The crayfish is related to the lobster and needs mineral-rich waters to build its protective shell. Species range from 1 inch to 16 inches (2.5 to 40 centimeters) in length. They seek shelter under stones in the stream bed or may even burrow into it, sometimes as far as 20 feet (6 meters) down. They catch prey, such as small fish, with their large pincer claws. Some blind, albino (colorless) species live in underground rivers.

Spotted newts hatch from eggs in the water, and then live part of their adult lives on land. IMAGE COPYRIGHT STEPHEN BONK, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Amphibians Amphibians, including frogs, toads, newts, and salamanders, are vertebrates, which means they have a backbone. Amphibians live at least part of their lives in water. They must usually remain close to a water source because they breathe through their skin, and only moist skin can absorb oxygen. If they are dry for too long, they will die.

Amphibians are cold-blooded animals, which means their body temperatures are about the same temperature as their environment. As temperatures grow cooler, they slow down and seek shelter in order to be comfortable. In cold or temperate regions, some amphibians hibernate (remain inactive), digging themselves into the mud. When the weather gets too hot, many go through another similar period of inactivity called estivation.

Common river and stream amphibians The most common amphibians found in rivers and streams all over the world are salamanders, frogs, toads, and newts.

The palmate newt lives on land for part of the year where it hunts at night for worms and other small animals. In spring it returns to the water where it breeds and lays eggs. Most newts lay eggs one at a time and attach them to water plants. Some species even wrap each egg in a leaf for protection.

Walking on Water

The Jesus Christ lizard, or basilisk, of Central America got its name from its ability to walk on water. Scales and a flap of skin on its hind toes increase the surface area of its feet and enable it to scamper on the water's surface. Being lightweight also helps.

Another water-walker, or one that appears to be, is the jacarana, or lily trotter, bird of the tropics. Jacaranas have extremely long toes that distribute their weight over the surface, but they are actually walking on the floating leaves of water plants.

Food In their larval form, amphibians are usually herbivorous, while the adults are usually carnivorous, feeding on insects, slugs, and worms. Those that live part of their lives on land have long, sticky tongues with which they capture their food.

Reproduction Most amphibians lay jelly-like eggs in the water. Frogs, depending on the species, can lay up to as many as 50,000 eggs, which float beneath the water's surface. After being fertilized by the sperm of male frogs, the eggs hatch into tadpoles (larvae) and require a water habitat as they swim and breathe through gills. When the tadpole turns into a frog, it develops lungs and can live on land.

Spotted newts hatch in the water and live there as larvae, even developing gills. Later, they lose their gills and live for a time on dry land. Two or three years later, they return to the water where they live the remainder of their lives.

Some amphibians, like the common frog, prefer quiet water for breeding. Others, like the large hellbender salamander, seek rushing streams.

Reptiles Reptiles are cold-blooded vertebrates that depend upon the environment for warmth. They are more active when the weather and water temperature become warmer. Many species of reptiles, including snakes, lizards, turtles, alligators, and crocodiles, live in temperate and tropical rivers and streams. All are air-breathing animals, with lungs instead of gills, which have adapted to life in the water. The Southeast Asian fishing snake, for example, can close its nostrils while swimming submerged.

Many reptiles go through a period of hibernation in cold weather because they are so sensitive to the environment. Turtles, for example, bury themselves in the mud. They barely breathe and their energy comes from stored body fat. At the other extreme, when the weather becomes very hot and dry, some reptiles go through estivation.

Common river and stream reptiles Common reptiles found in rivers and streams include the water moccasin, the viperine water snake, the eastern water dragon, the soft-shelled turtle, the matamata turtle, the

Crocodiles are fierce predators that spend time both in and out of the water. IMAGE COPYRIGHT JOSHUA HAVIV, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

yellow-bellied terrapin, the snapping turtle, the anaconda, and the crocodile.

The anaconda of South American rivers is the world's largest snake, some individuals attain lengths of more than 33 feet (10 meters). Although they are excellent swimmers and prefer to hunt along the edges of rivers and swamps, they can also climb trees. Anacondas are constrictors, killing their prey by coiling their body around it and squeezing it. Their young are born alive in the water.

Crocodiles hunt at twilight in tropical rivers. During the day they bask in the sun at the river's edge. As the light dims, they seek their prey. Some, such as the New Guinea crocodile, eat just fish. Most other species eat a variety of foods. They swallow smaller prey whole, but larger animals are dragged underwater where they drown and are torn apart and eaten.

Food All snakes are carnivores. Water snakes eat frogs, small fish, and crayfish. Some species of turtles are omnivores.

Reproduction The eggs of lizards and turtles have either hard or rubbery shells and do not dry out easily. Most are buried in warm ground, which helps them hatch. The eggs of a few species of lizards and snakes are held inside the female's body, and the babies are born alive.

Crocodiles keep their eggs warm in nests that can be simple holes in the ground or constructions above the ground made from leaves and branches.

Fish Like amphibians and reptiles, fish are cold-blooded vertebrates. There are two types of freshwater fish. The first type, the parasites, which include some species of lampreys, attach themselves with suckers to other animals and suck their blood for food. The second type, which eat plant foods or catch prey, are the most numerous. They use fins for swimming and breathe with gills.

Many species of fish, such as archer fish, swim in schools. A school is a group of fish that swim together in a coordinated manner to discourage predators.

Food Some fish, such as the grass carp, eat plants while others, such as bluegills, depend upon insects, worms, and shellfish. Larger fish, such as the sturgeon, often eat smaller fish, and a few species feed

A predatory fish of South America, the piranha feeds on other fish or foods that fall into the water. A school of piranhas will quickly devour large animals. IMAGE COPYRIGHT DMITRIJS MIHEJEVS, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

on carrion (dead animals). Most fish specialize in what they eat and where they find their food. Some feed on the surface, and others seek food in deep water. Some prefer rushing streams and others calm pools. The arawana of Southeast Asian rivers has a large, upward-pointing mouth that helps it feed on the surface.

Common river and stream fish Typical fish found in rivers and streams include the roach, rudd, tench, bream, perch, gudgeon, carp, bitterling, African knifefish, elephant fish, hatchetfish, shovel-nosed sturgeon, white sturgeon, paddlefish, freshwater shark, arapaima, stickleback, piranha, catfish, salmon, and trout.

Piranhas (purr-AN̂-ahs) are predatory fish of South America, known for their several rows of sharp, triangular teeth. They usually feed on other fish, or fruits and seeds that fall into the water. They become particularly dangerous during the dry season when the water level drops and fish gather together in schools. A school of piranhas can attack and devour large animals, including humans.

Many species of catfish inhabit rivers worldwide. Some tropical varieties can climb out of the water and walk overland from one river or stream to another. They range in size from the small species that live in mountain streams, to those that live in the Danube River in Europe and grow to a length of 13 feet (4 meters) and a weight of 400 pounds (180 kilograms).

Catfish got their name from the long feelers around the mouth that resemble cats' whiskers. They have poisonous spines along the fins that can cause painful injuries. Catfish adapted to life in fast-moving streams have fins with suckers or large, fleshy lips that help them cling to rocks and even climb. Bullheads, a species of catfish, have flattened bodies, which enables them to squeeze under stones and resist the current. Some freshwater catfish communicate with each other through grunting and clicking sounds.

Salmon live in both fresh and salt water. The young hatch in fast-moving rivers and streams, where they live for about the first three years of their lives. They then migrate to the sea where they live for up to four years, feeding on small fish and shellfish. When it comes time to breed, they return to the river of their birth, swimming upstream. Salmon are called *anadromous* fish, which is Greek for "running upward." After breeding, they die; their decaying bodies provide an injection of nutrients to their birth area.

Shocking River Residents

There are lots of good reasons to not swim in tropical rivers, and one is to avoid an electric shock. The African catfish and the Amazonian eel are two tropical river residents that produce their own electricity and use it as a weapon.

The body of an electric eel functions like a chemical battery. Thousands of electricity-producing cells are stacked in columns and oriented in the same direction. When the eel sights something tasty, a nerve impulse from the eel's brain triggers the flow of electric current from its tail, through the water, toward its head. When the eel touches its prey, the circuit is interrupted and the current flows into the body of the victim, stunning it. An adult eel can produce 600 volts of electricity, which is enough to knock out an animal the size of a horse or a human.

In general, trout are found in oxygen-rich, cool, fast-moving streams with beds of gravel. They are carnivorous, feeding on insects, freshwater shrimp, and clams. Some species also prey on other fish. Rainbow trout, which originated in North America, have a silver belly and an iridescent stripe along the side. The Aurora trout, a subspecies of the brook trout, is a spectacularly colored fish. They are native to two small lakes in Ontario, Canada. In the 1960s, the Aurora trout was almost driven to extinction due to acid rain. The lakes were treated with lime to decrease the acidity of their waters and the trout was reintroduced.

Reproduction Most fish lay eggs, and many species abandon the eggs once they are laid. Others build nests and care for the new offspring until they hatch. The male stickleback lures several females to his nest where they lay their eggs. He then fertilizes the eggs and guards them until they hatch. Still other species, such as certain catfish, carry the eggs with them until they hatch, usually in a special body cavity or even in their mouths.

The Fish that can Climb Ladders

In order to breed, Atlantic salmon return from the sea to rivers along the Atlantic and Pacific coasts where they first hatched. Most of these rivers have been dammed in places, preventing the fish from continuing on their journey upstream. To aid them, some states have built "fish ladders," water-covered steps alongside the dams that allow the fish to jump from one level to the next as they would over a natural waterfall. In spite of this technological aid, the numbers of salmon continue to decline, as do the numbers of animals who depend upon the salmon for food.

Birds Birds are vertebrates, and many different species live near rivers and streams. These include many varieties of wading birds, waterfowl, and shore birds. Most visit in search of food, and certain species use riverbanks as nesting places.

Most aquatic birds prefer quiet waters, but a few are specially adapted for the speed and turbulence of life upstream. One example is the torrent duck of the Andes Mountains in South America. Built like an ordinary duck in most respects, it has a longer tail to help it steer when swimming in fast currents, and claws on its webbed feet that allow it to cling to rocks.

Common river and stream birds Birds found around rivers and streams include mergansers, warbles, reed buntings, ospreys, sunbitterns, finfoots, egrets, and wood ducks. Kingfishers, herons, fish eagles, ibises, grebes, and cranes are the few bird species that spend their entire lives around freshwater habitats. They fall into four basic categories: wading birds, shorebirds, waterfowl, and birds of prey.

Wading birds, such as herons, have long legs and wide feet for wading through shallow water. They have long necks and bills necessary for nabbing food. There are approximately 100 species of heron.

Shorebirds, such as the sandpiper, feed and nest along the banks and prefer shallow water. Some, like the godwit, have long, slender, upturned bills that help them sift through mud in search of food. Other birds, like the ruddy turnstone, have bills that are curved to one side, which helps them to overturn pebbles. The red knot is an example of a shorebird that has specialized bill cells that are pressure sensitive, allowing them to detect shellfish buried beneath the sand.

Waterfowl are birds that spend most of their time on water, such as ducks, geese, and swans. Their flattened bills are designed for grabbing vegetation, such as sedges and grasses, on which they feed. Waterfowl are strong fliers and swimmers. Of the 150 species, most prefer freshwater environments. Migrating waterfowl play a major role in dispersing small aquatic organisms that attach to their feet or feathers.

Osprey and fish eagles are birds of prey that only hunt in freshwater. Other birds of prey include gulls, terns, and stilts.

Wading birds have long legs and wide feet for walking through shallow water, and long necks and bills for grabbing food. IMAGE COPYRIGHT EVGENY V. KAN, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Food Nearly all birds must visit a source of fresh water each day to drink, and many feed on aquatic vegetation or the animals that live in the water. The dipper can actually walk underwater in search of small animal prey.

One of the adaptations of birds to aquatic life is their beak, or bill. Some are shaped like daggers for stabbing prey such as frogs and fish; others are designed to root through mud in search of food. Water-dwelling birds spend much time preening their feathers because they depend on their feathers to keep them dry.

Reproduction All birds reproduce by laying eggs. Male birds are often brightly colored to attract the attention of females. After mating, female birds lay their eggs in a variety of places and in nests made out of many different materials. One parent usually sits on the nest to keep the eggs warm while the other searches for food.

Mammals Mammals are warm-blooded vertebrates covered with at least some hair, that bear live young and nurse their young with milk. Aquatic mammals, such as the muskrat, often have fur that is waterproof. They may have webbed toes for better swimming. The toes of the duck-billed platypus of Australia, for example, are webbed.

Food Certain aquatic mammals are carnivores. The water shrew, for example, eats insects, worms, and frogs. Others, like muskrats, are omnivores, while beavers are herbivores.

What Am I?

The duck-billed platypus, which is found in Australian rivers, appears to be a cross between a reptile, a duck, a beaver, and an otter. It has a ducklike beak, webbed feet, and lays eggs. It also has dense fur and a flat, beaverlike tail, and suckles its young with milk. The platypus is a good swimmer and dines on the river's insect population. Officially, the platypus is a mammal and cousin to the anteater. Some scientists believe that the species originated during the evolution of reptiles into mammals.

Reproduction Mammals give birth to live young that have developed inside the mother's body. Some mammals, such as otters, are helpless at birth, while others, like dolphins, are able to walk or swim immediately. Many are born with fur and with their eyes and ears open. Others, like baby muskrats, are born hairless and blind. Mammals feed their young with milk produced by the mother.

Common river and stream mammals Mammals found in and around rivers and streams include manatees (sea cows), capybaras (large rodents), tapirs, minks, water shrews, beavers, dolphins, otters, and hippopotami.

Of the five recognized species of freshwater dolphins, four live in rivers. River dolphins are found in the Ganges, Indes, Amazon, and Yangtze rivers. They are almost blind and find their way through muddy waters by sending out sound waves that bounce off obstacles to warn them of what's ahead and help them find the fish on which they feed. Like their saltwater cousins, freshwater dolphins are considered intelligent and some fishermen use them to herd schools of fish into waters where they are more easily caught. They differ from their marine cousins in that they are slower swimmers and have larger heads.

Dolphins produce a single calf that is capable of swimming and breathing within the first minutes of its life. Some mothers have been observed guiding the calf to the surface, as if to help it reach air. River dolphins are threatened by hunting, entanglement in fishing nets, and pollution.

Of the thirteen species of otters, twelve are found in freshwater. River otters have webbed feet and strong tails that make them good swimmers. Their thick, water repellent fur coasts keep them warm and dry. They feed on frogs, birds, fish, and small mammals. Their eyes, ears, and nostrils are placed high on their heads, which enables them to look sharply around while swimming. They dig dens into the riverbank where they care for their young until the young are able to live on their own. Otters are playful animals and spend much of their time at acrobatic games. Weasels, skunks, and badgers are relatives of the otter that are found in rivers and streams.

River otters spend most of their time on land, but are excellent swimmers. They eat fish and other aquatic organisms. IMAGE COPYRIGHT JOHN WILLIAMS, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

The name hippopotamus means "river horse" in Greek, and, although hippos look ungainly, they are fast both in the water and on land. They graze on vegetation on land at night and spend their days dozing in the muddy waters of African rivers. Adult males may reach a length of 16 feet (5 meters) and weigh as much as 4 tons (3.6 metric tons). Their skin is nearly hairless, and the eyes and nostrils protrude so that they are above the water even when the rest of their body is submerged. There are two species of hippo. The larger, common species is widespread in Central Africa. The scarcer, pigmy hippo is restricted to Western Africa.

Endangered species Seven types of salmon and two species of trout are on the endangered list in the northwestern United States. The Topeka shiner and the Arkansas River shiner are threatened in the central United States and the snail darter in Tennessee. As rivers and streams become polluted, many species of birds, such as the fish eagle, have become threatened. Birds cannot use the polluted waters for food or as nesting areas, which causes their numbers to decline.

At one time hippos were found in almost all African rivers. As the human population has grown, their habitat has shrunk and they are now found in only a few rivers. The Amazonian manatee, the only species of freshwater manatee, is now protected against hunters, who kill it for its meat.

River of Death

In Greek mythology, the River Styx traveled through the underworld, the land of the dead. The water of that river was supposedly so poisonous that it would dissolve any vessel used to carry it except one made from a horse's hoof. An ancient account claims that Alexander the Great (356–323 BC), king of Macedon, was poisoned by Styx water. There may be a bit of truth in the claim; some experts believe he died of a bacterial infection caught by drinking water from the Euphrates River, which carried raw sewage out of the ancient city of Babylon in what is now southern Iraq.

Human Life

Rivers have always been intimately connected to human life, and river valleys have been the birthplaces of the world's great civilizations. The Nile River is the scene of the oldest and perhaps the most remarkable of ancient civilizations, Egypt. The Nile's yearly floods brought rich sediments to the soil, and the people learned to divert the floodwaters for agriculture and drain the swamps. Chinese civilization got its start in the lower valley of the Huang He, where many floods and extreme weather forced people to develop the technology necessary for life to continue successfully there. In the valley of the Tigris and Euphrates rivers, Sumerian civilization developed as people fought to clear jungle swamps and manage floodwaters. The same was true of the Indus civilization, which arose in the valleys of the Ganges and Indus rivers in India and Pakistan. While rivers offered opportunities for water and transportation, they also presented challenges that inspired people to excel in order to survive.

Impact of rivers and streams on human life People use rivers and streams for water and food; boundaries, transportation, and trade; recreation and building sites; and creating hydroelectric power.

Water and food Many rivers and streams are sources of drinking water and for such things as bathing and laundry. In developed countries, about half the freshwater supply is used by industry. In less wealthy countries, up to 90 percent is used for irrigation (watering) of crops. The earliest irrigation systems were built on the banks of the Nile River about 6,500 years ago. Pumping systems and waterwheels soon followed. About 642,473,992 acres (260,000,000 hectares) of land is now irrigated worldwide.

The fish and plants in rivers and streams are often a source of food for humans. Although most fish used for food come from the ocean, commercially important freshwater fish include trout and salmon. Farmers often use aquatic plants, such as marsh grass, reeds, and sedges, for feeding livestock.

Boundaries, transportation, and trade Throughout history, rivers have acted as boundaries. If they were too big or too fast to cross easily, they limited overland travel. During exploration of the American West, for example, wide rivers like the Missouri meant that travelers had to build a boat or raft or find a spot where the channel was narrow and the water shallower, so that horses could swim across.

Rivers can act as boundaries between two different territories. Many countries use rivers to help define their borders. The Rio Grande separates Texas from Mexico, and the Congo in Africa divides the Democratic Republic of the Congo and Zaire.

Rivers have always provided a means of transportation and trade. Cities built at the edge of rivers could import or export goods upstream or downstream or even to sea more easily and less expensively than cities reachable only by land routes. An example is the Mackenzie River of Canada's Northwest Territories, which flows into the Arctic Ocean. Early European settlements, such as Fort Good Hope, were built along its shores as part of the fur trade. It is now used to transport petroleum and uranium ore.

Swan Song for the Thames

Even before 1800, the Thames (TEMS) River in England was polluted by chemicals and other materials used in manufacturing. With the invention of flush toilets, things got much worse. Where did the sewers empty out? In the Thames. The fish suffocated to death and swans and other waterbirds left for a healthier part of town. Until the 1950s, the Thames was considered one of the most polluted rivers on the planet.

Public protest finally grew so loud that things began to change. Strict regulations were created to limit what could be dumped into the water. Sewage-treatment plants were improved, and special equipment was installed in some locations to mix the water with oxygen. Before long, the river began to recover. Within thirty years, pollution had been reduced by 90 percent, and oxygen content rose to healthy levels. The fish returned, and so did aquatic plants. Even the swans moved back.

Many rivers are still important routes for bulk cargo, such as coal. The Chang Jiang River in China, for example, is navigable by ocean-going freighters for 680 miles (1,090 kilometers) inland and the St. Lawrence Seaway between the United States and Canada for about 2,300 miles (3,800 kilometers).

Recreation and building sites Streams and even some rivers are popular for sport fishing and boating, but pollution makes most of them undesirable for swimming. In urban regions, the areas along riverbanks have become popular sites on which to build homes. Some rivers and streams may be diverted to create artificial lakes or ponds in order to add beauty and wildlife to a residential area.

Hydroelectric power and other resources When river waters rush over the blades of a turbine (energy-producing engine), the blades turn rapidly. The rapid turning can be used to produce electricity. This form of electricity, called hydroelectric power, can provide heat and light for many people. Worldwide, about 15 percent of electricity is produced by hydroelectric power plants, such as Hoover Dam on the Colorado River in Nevada and Grand Coulee Dam on the Columbia River in Washington.

Plant materials found along rivers and streams can be used for building. Reeds are used for huts in Egypt and stilt houses in Indonesia. River sediments, such as clay and mud, are used to produce bricks.

Fish are used for more than just food. They yield such products as fish oils, fishmeal, fertilizers, and glue. Other animals may be introduced into rivers to help control problems. The Amazonian manatee, for example, was placed in reservoirs because they eat the river plants that were clogging the turbines of hydroelectric plants.

The water in rivers and streams may be used to cool power stations and for other industrial purposes. Unfortunately, some industries have used them as dumpsites for industrial chemicals.

Saving the Salmon

Saving threatened species of animals usually requires sacrifices on the part of humans who live in the region. When seven species of salmon that breed in the Columbia and Willamette Rivers in the northwestern United States were put on the endangered list in 1999, people living in Seattle, Washington, Portland, Oregon, and other communities agreed to:

- limit logging and move that activity back from riverbanks to decrease erosion
- recycle water used for golf courses and limit the use of fertilizers on golf greens
- redesign some hydroelectric dams and remove others to allow the salmon to reach their breeding grounds
- keep domestic cattle away from rivers, reduce the cattle population, and treat animal waste before it is used as a fertilizer
- limit washing of cars
- limit use of pesticides and herbicides
- build environmentally friendly sewage treatment plants
- limit salmon fishing
- enact new pollution controls for industry

Impact of human life on rivers and streams Initially, the effect of human life on rivers and streams was small. As the human population has grown, abuses have increased, and many rivers and streams resemble open sewers.

Each year a conservation group called American Rivers, publishes a list of the most endangered American rivers. Those endangered in 2007 were:

- Santa Fe River in New Mexico
- San Mateo Creek in California
- Iowa River in Iowa
- Upper Delaware River in New York

- White Salmon River in Washington
- Neches River in Texas
- Kinnickinnic River in Wisconsin
- Neuse River in North Carolina
- Lee Creek in Arkansas and Oklahoma
- Chuitna River in Alaska

Water supply Although all water on Earth is in constant circulation, some regions may have a limited supply. As populations grow, the supply diminishes even more. Forests, for example, are cut down and replaced by farms. Because trees help conserve underground water, much of this water is being lost. Rivers and streams are often linked to groundwater, so they gradually disappear as well.

Irrigation practices can cause damage, especially in desert regions, because there is not enough precipitation to replace the water that is used from the rivers and streams.

Use of plants and animals The distribution of many popular species of fish has been affected by changes made to rivers and streams in Europe and America. The giant catfish, the Atlantic salmon, the Danube salmon, the sturgeon, the beluga sturgeon, and many others are now found in only a few rivers.

Overdevelopment People may wish to live near a stream or river for its beauty and a sense of being close to nature, but overdevelopment can result in erosion, loss of wildlife, and the scenic value. Removal of trees during housing development can cause ground water to disappear and deprive the river or stream of its source. Large tracts of homes and areas covered by concrete can prevent rain from soaking into the ground. Instead, the runoff enters rivers and streams, causing flooding.

Quality of the environment Pollution by communities, industries, shipping, and poor farming practices has led to poisoning of water and changes in its temperature, as well as loss of animal habitats.

The most common form of river pollution is domestic sewage. If there is enough oxygen in the water, bacteria can break the sewage down

The Rock Breaker

Henry Morton Stanley (1841–1904) was given the nickname "rock breaker" for his ability to overcome difficulties. An illegitimate child, Stanley spent part of his young life in a workhouse in Wales, the country of his birth, where he was routinely mistreated. At the age of fifteen he ran away to America where a kindly merchant adopted him and turned his life in a new direction.

Stanley served as a soldier in the American Civil War, as a seaman in merchant ships, and most importantly as a journalist. In 1869, he was commissioned by the New York Herald to travel to Africa to find David Livingstone (1813–1873), a British explorer who was missing. Stanley succeeded, and together he and Livingstone explored Lake Tanganyika in eastern Africa. After Livingstone died, Stanley carried on his explorations, eventually tracing the route of the Congo River and helping to found the Congo Free State. He described his dangerous journey in the book titled *Through the Dark Continent*, which was published in 1878.

The African Queen

A mixture of comedy, adventure, and romance, *The African Queen* is a classic film about two people during World War I (1914–18) who take an ancient, ramshackle boat up a treacherous river in Africa in hopes of finding and destroying an enemy ship. They encounter rapids, leeches, hippos, and other river dangers during the wild ride to their destination. The film starred Katharine Hepburn and Humphrey Bogart and won the Academy Award in 1951. It was based on the book of the same name by British author C. S. Forester (1899–1966).

quickly. Problems occur when the volume of sewage is so large and bacteria use up so much oxygen that plants and animals cannot survive. Additionally, this process results in the formation of ammonia, which is poisonous to most animals. Sewage fungus, a combination of bacteria and molds, may grow on the surface of the water.

Another source of river pollution is industrial chemicals and heavy metals, which may dissolve in the water or remain as solids. Enormous quantities of these materials poison animals, clog gills in fish, and bury the riverbed in sediments. Industries are responsible for dumping heated water (thermal pollution) into rivers, raising their temperature and killing many species of plants and animals that require a cooler environment.

Shipping can cause pollution. Ships discharge waste into the water or develop leaks and spills that threaten the water's purity and destroy wildlife.

Eutrophication (yoo-troh-fih-KAY-shun) occurs when fertilizers used in farming get into rivers and streams, spurring a greatly increased growth of algae in slow-moving waters. These plants form a thick mat on the surface and block the sunlight, causing submerged plants to die. As the dead plants decay, oxygen in the water is used up, killing fish and other plant life.

Flood control Flooding nourishes the soil in floodplains, creates natural wetlands, and supports wildlife. Floods can also be destructive and dangerous to human life. For this reason, efforts have long been made to control floods using dams and artificial levees. Many of these changes have not only harmed wildlife, they have sometimes caused more problems than they have helped. The Aswan High Dam in Egypt is an example. Completed in 1970, the dam is 2.5 miles (4 kilometers) in length and rises 364 feet (111 meters) above the Nile riverbed. The dam was built in order to irrigate desert regions. However, dissolved salts have built up in the irrigated areas and increased the saltiness of the Nile itself. The Nile used to carried vast amounts of sediments to the Mediterranean. With their reduction, the sardine fishery in the eastern Mediterranean has been destroyed. The dam has increased erosion in the Nile waterway and in the delta region.

Giants of the River

The last part of the twentieth century has seen the building of colossal dams designed to bring hydroelectric power and flood control to undeveloped countries.

As of 1999, the world's largest was the Itaipu Dam on the Parana River between Brazil and Paraguay in South America. Completed in 1991 at a cost of over $20 billion, it has eighteen huge turbines that generate as much as 12,600 megawatts of electricity. (By comparison, the largest dam in the United States, the Grand Coulee, outputs only 9,700 megawatts.) Over 30,000 workers took sixteen years to create the 4.8-mile- (7.6-kilometer-) long, 500-foot- (152-meter-) high structure, using enough concrete to build eight medium-sized cities. Its reservoir covers 870 square miles (2,262 square kilometers), and thousands of farm families had to be relocated. The presence of the reservoir has caused some cooling of the local climate, which endangers wheat and other commercial crops, but the dam produces clean, renewable energy and creates thousands of jobs.

Soon to overtake the Itaipu in scope and power production is the Three Gorges Dam on the Chang Jiang (Yangtze) River of China. With its twenty-six turbines, the Three Gorges is expected to output 18,200 megawatts of electricity—as much as eighteen nuclear plants—and help bring prosperity to central China. At a projected cost of $75 billion, the dam is scheduled for completion in 2010 and will be 610 feet (187 meters) high and 6,864 feet (2,092 meters) wide. Its reservoir will be 370 miles long (592 kilometers), filling the towering limestone canyons along the river's route. As many as fourteen towns will be drowned and nearly two million people relocated. There is opposition to the dam because it will kill many aquatic animals and destroy ecosystems and valuable archaeological sites. On the other hand, it is hoped that the dam will end the disastrous flooding common to the Chang Jiang, which has killed as many as 300,000 people during the past century alone.

Other giant dams in progress include the Ataturk Dam on the Euphrates River in Turkey and the Sardar Sarovar in India, part of a proposed thirty-dam project on the Narmada River.

In Quebec, Canada, many people are opposing the James Bay Project, a proposed hydroelectric dam that will alter the region. People are beginning to wonder if it may be wiser to allow rivers to flow unobstructed.

Wild and Scenic Rivers Act In 1968, the U.S. Congress passed the Wild and Scenic Rivers Act, which established a program to study and protect free-flowing rivers. The act prohibits building hydroelectric or other water development projects on certain rivers. In order to qualify for protection, a river must be undammed and have at least one outstanding resource, such as a wildlife habitat or historic feature. As of 2007, 130 rivers fall under the Act's protection, including the Klamath River in California and the Rio Grande in Texas.

North American River Explorers

During the great period of world exploration, from about 1400 to 1900, most inland travel was accomplished by means of rivers. The journeys of Europeans into the North American wilderness are no exception. Jacques Cartier (1491–1557), a Frenchman, was the first. Beginning in 1534, he traveled down the St. Lawrence River to the present location of Montreal, Quebec. In 1673, French explorers Louis Jolliet (1645–1700) and Jacques Marquette (1637–1675) traveled down the Mississippi River to where it joins the Arkansas River, then returned via the Illinois River to Lake Michigan. Alexander Mackenzie (1764–1820) from Scotland, descended the Mackenzie River from Great Slave Lake in the Northwest Territories of Canada to the Arctic Ocean in 1789.

Native peoples Rivers have always attracted human settlements, and most rivers and streams have probably played a part in the lives of people native to the region. In the United States, for example, the Great Plains between the Rocky Mountains and the Mississippi River was the home of many Native American tribes, including the Arapaho, Blackfoot, Cheyenne, Crow, Iowa, Pawnee, and Sioux. Bison (buffalo) were the primary source of meat, but the rivers and streams provided fish and other edibles, as well as water, and villages were often located alongside them. Rafts and dugout canoes made from logs, and more sophisticated craft covered with skins or birchbark, were used for river travel.

Since 1940, native peoples who still live a traditional lifestyle are usually found in undeveloped countries, and most of those have been touched by the modern world in some way. The Jivaro of Ecuador and Peru are an example. They live in the tropical forests and depend upon the rivers of that region—the Tigre, Pastaza, Morona, Alto Moranon, and Santiago—for fish and a means of travel.

The Food Web

The transfer of energy from organism to organism forms a series called a food chain. All of the possible feeding relationships that exist in a biome make up its food web. In rivers and streams, as elsewhere, the food web consists of producers, consumers, and decomposers. These three types of organisms transfer energy within the biome.

Algae are primary producers in rivers and streams. They produce organic materials from inorganic chemicals and outside sources of energy, primarily the sun.

Animals are consumers. Those that eat only plants, such as snails, are primary consumers in the river or stream food web. Secondary consumers, such as carp, eat the plant-eaters. Tertiary consumers are predators, like otters and anacondas, that eat second-order consumers. Humans are omnivores, meaning they eat both plants and animals.

Decomposers, which feed on dead organic matter, include some fly larvae. Bacteria play an important part in decomposition.

Extremely damaging to the river or stream food web is the concentration of pollutants and dangerous organisms that become trapped in sediments where life forms feed on them. These life forms are fed upon by other life forms and, at each step in the chain, the pollutant becomes more concentrated. Finally, when humans eat fish, ducks, or other river wildlife contaminated with the pollutants, they are in danger of serious illness. The same is true of diseases such as cholera, hepatitis, and typhoid, which can survive and accumulate in certain aquatic animals. These diseases can then be passed on to people who eat the animals.

Spotlight on Rivers and Streams

The Amazon Of all the rivers in the world, the Amazon carries the greatest volume of water (one-fifth of all river water) and has the largest drainage basin (5 percent of the world's total land area). In 1994, researchers claimed to have discovered its true source as the Ucayli River, and, if they are right, that may make the Amazon the world's longest river, surpassing even the Nile. Its discharge—up to 7,000,000 cubic feet (196,000 cubic meters) per second—is so strong that it carries fresh water 200 miles (320 kilometers) into the Atlantic Ocean.

More than 1,000 streams make up the Amazon's tributaries, at least 200 of which are major rivers in their own right. They include the Tapajos, the Purus, the Jurua, the Javari, the Rio Negro, the Madeira, the Japura, and the Tigre. The main stream originates in glacier-fed lakes in the Andes Mountains of Peru, only 100 miles (160 kilometers) from the Pacific Ocean, and travels across the continent to empty into the Atlantic.

Average velocity of the Amazon is about 1.5 miles (2.4 kilometers) per hour, although velocity increases greatly at flood times. During a flood, the height of the river may increase as much as 50 feet (15 meters). At its mouth, a 12-foot (3.6-meter) high tidal bore occasionally travels upstream at about 15 miles (24 kilometers) an hour with a force that can uproot trees growing along the river's banks.

The Amazon receives up to 8 feet (2.4 meters) of annual rainfall, which causes it to overflow its banks for up to 30 miles (48 kilometers).

Amazon River
Location: Brazil and Peru in South America
Length: 3,915 miles (6,437 kilometers)
Discharge Basin: 2,722,000 square miles (7,077,200 square kilometers)

This vast floodplain is underwater for several months each year, and many channels and oxbow lakes form. In Obidos, Brazil, its depth is about 300 feet (91 meters). The maximum width of its permanent bed is 10 miles (16 kilometers). The width of its mouth is 360 miles (580 kilometers). No delta has formed because the 3,000,000 tons (2,721,554 metric tons) of sediment discharged daily are carried northward by ocean currents and deposited along the coast of French Guiana.

The Amazon basin supports the largest area of rain forest in the world and the greatest plant and animal diversity, with about one million species. Plants, such as cassava, tonka beans, guava, and calabash, are found here. Trees include palms, myrtles, laurels, acacias, and rosewoods.

The Amazon region hosts more than two million species of insects. The number of Amazon fish species has been estimated at 1,500, more than 18 percent of the world's known species. A few, such as the piaraucu, are commercially important. Most streams are home to piranhas, sting rays, and giant catfish.

Turtles and giant constrictor snakes represent reptiles. Birds live among the trees, and some, such as the fish eagle, hunt food in the river. Mammals include the capybara. The giant otter, which can grow to more than 6 feet (1.8 meters), is heavily hunted and almost extinct. It is only found in the Amazon.

Most human inhabitants of the Amazon basin have been Indians, such as the Jivaro and the Yanomamo, but the area has never been heavily populated. The soil is poor and not really suitable for farming, although huge tracts of forest are being destroyed for agricultural purposes. The river itself has been used for transportation and trading since the earliest times, and ocean-going vessels can travel as far as 1,000 miles (1,600 kilometers) upstream to Manaus, a city in northern Brazil.

Nile River
Location: Egypt, Burundi, Rwanda, Uganda, Ethiopia, Kenya, Tanzania, and Sudan in Africa
Length: 4,160 miles (6,695 kilometers)
Discharge Basin: 1,100,000 square miles (2,860,000 square kilometers)

The Nile The Nile is the longest river in the world, at a length of 4,160 miles (6,695 kilometers). Its main tributaries are the White Nile, which has its headwaters in Burundi, and the Blue Nile, which rises in the highlands of western Ethiopia. Lake Albert, Lake Victoria, and Lake Tana all contribute water. The Blue Nile and the White Nile join together at Khartoum in Sudan and continue north into southern Egypt. Six stretches of rapids and waterfalls break its flow, ending at Aswan. Between Aswan and the Mediterranean Sea, the river creates a wide, rich floodplain that has been cultivated for more than 3,000 years. The Nile delta lies north of Cairo, a 100-mile- (160-kilometer-) long stretch of rich silt deposits cut by many streams. This area provides almost all of Egypt's food crops, and cotton, one of the country's major exports.

Precipitation varies along the Nile's length, but most of its basin receives no rain from November to March. At Khartoum, 5 inches (12.7 centimeters) of rain falls annually, but Cairo receives only 1 inch (2.5 centimeters). The far south receives 79 inches (200 centimeters) of rain each year. Before the Aswan High Dam was completed in 1970, heavy rains in the south caused floods. The floods were vital to agriculture in the region, but they often caused serious damage. The dam prevents flooding, but holds back the silt, so the land has to be fertilized by other means. The dam has also led to erosion of the delta.

Grasslands and tropical forests occur where the river passes through Ethiopia and eastern Africa. Papyrus, water lettuce, sedges, and water hyacinth grow in and around the river. Farther north, drier conditions prevail and support only acacia and scrub. Beyond that, the Nile passes through true desert. In Egypt, desert land along the Nile is irrigated and cultivated.

The river supports fish, snakes, turtles, crocodiles, and lizards. In its southern waters, hippopotami can be found.

About 3100 BC, the ancient Egyptian civilization began on the banks of the Nile and was totally dependent upon the river both for water and for the sediments that enriched the soil. Lower Egypt, which was centered around the delta, was fertile and green. Upper Egypt was hot and dry, and the band of land suited for farming was only a few miles wide. Crops of all kinds were grown, and cattle, goats, pigs, and sheep were pastured. The river provided fish and waterfowl, and papyrus and other reeds and grasses were turned into fibers for baskets, boats, and paper. River mud was used to make bricks and, over time, the Egyptians developed great architectural skill, creating the magnificent pyramids that still stand.

Almost 97 percent of Egypt's population still lives in the Nile valley and delta. Fishers and farmers live in the irrigated north and in southern regions where rainfall is adequate. In northern Sudan, nomads raise cattle and camels. More arid (dry) regions are extremely dependent upon the river for their economy. The Aswan High Dam produces electricity and has increased irrigated land by 30 percent.

Huang He (Yellow) River
Location: China
Length: 2,901 miles (4,641 kilometers)
Discharge Basin: 486,000 square miles (1,263,600 square kilometers)

The Huang He (Yellow River) The Huang He (wang HO) or Hwang Ho, which is Chinese for Yellow River, is the second longest river in China and flows eastward from the Kunlun Mountains through the central plains to the Yellow Sea. Its waters are clear in the upper regions, but as it passes through Shanxi and Shanxi provinces, it picks up large quantities of sediments—1,600,000,000 tons (1,440,000 metric tons) annually—that give it its yellow color and, therefore, its name. These sediments made the Huang He's delta the fastest growing in the world. By the 1990s, dam construction, particularly Sanmen Gorge in the Henan Province, is causing the delta to erode.

Average precipitation in the Huang He basin is about 16 inches (40 centimeters) a year, and average annual discharge is 11 cubic miles (49 cubic kilometers). Rainfall varies greatly. In winter and early summer, the river is at its low point. In spring and late summer, water levels are high, sometimes as much as 70 feet (21 meters) above its banks, and severe flooding is common. The Huang He has overflowed its dikes (retaining walls) hundreds of times in the past 3,000 years, causing so much damage and so many deaths that it has been referred to as "China's Sorrow." In an attempt to control flooding, artificial embankments have been created along 1,120 miles (1,800 kilometers) of the river's length.

Much of the Huang He basin is grassland. Cattail marshes are home to many geese, ducks, and swans. Carp and catfish live in the river itself.

China's great civilization, dating from at least as early as 2000 BC, probably began in the Huang He basin. The basin supports a population of more than 120 million people. In many places, the current of the Huang He is so swift and the channel so shallow that it is of little use for navigation, but the floodplain is developed for agriculture.

The Chang Jiang (Yangtze) The Chang Jiang (zhang jee-ANG), also spelled Yangtze, is the longest river in China at 3,915 miles (6,300 kilometers). It crosses the central region from east to west, where it flows into the East China Sea near Shanghai. Its headwaters are in the Tibetan highlands at elevations of about 18,000 feet (5,480 meters), and its course makes many bends. Below Wan-hsien it travels about 200 miles (320 kilometers) through spectacular gorges and deep canyons where rapids form. In the region of the gorges, the river is 500 feet (152 meters) deep, making it the world's deepest. During summer floods, the water in this region can rise 200 feet (61 meters) and travel at velocities faster than 13 miles (21 kilometers) per hour. Boats are often towed through the gorges by large gangs of men on shore using 0.5-mile-long (0.8-kilometer-long) ropes made from bamboo.

Chang Jiang (Yangtze) River
Location: China
Length: 3,915 miles (6,300 kilometers)
Discharge Basin: 756,498 square miles (1,966,895 square kilometers)

Until 1957, there was only one bridge across the Chang Jiang, near Wuhan. Here, the river forms a vast floodplain, and flooding often occurs in summer. Since that time sixteen other bridges have been built. In 1998, the worst flood in forty-four years caused 3,004 deaths and twenty billion dollars (U.S.) in damages. More than fourteen million people were left homeless.

Precipitation averages 24 inches (60 centimeters) annually. Average discharge into the sea is 1,010,000 cubic feet (28,600 cubic meters) per second, and 250,000,000 tons (336,796,185 metric tons) of sediment is deposited annually.

Deciduous forests cover those areas of the basin that are not cultivated for farming. About 70 percent of China's rice crop is grown in the Chang Jiang basin, and about 300 million people live in the region.

The Chang Jiang River has been home to the giant paddlefish, which may now be extinct. The rare Chang Jiang river dolphin was declared extinct in 2006, due to pollution, dam construction, hunting, and depletion of its food supply. Animal life varies along its length and includes thrushes, pheasants, and antelopes.

The Chang Jiang is important commercially. The volume of transportation is greater than all the other waterways of China combined. About 25,000 miles (40,000 kilometers) of main river and tributaries can be navigated by small craft, and ocean-going ships can reach Wuhan, a city in central China. Five of China's largest cities—Shanghai, Wuhan, Chongqing, Chengdu, and Nanjin—are on or near the Chang Jiang system.

The river is considered ideal for generating hydroelectric power, and the gigantic Three Gorges Dam, which began construction in 1994, is predicted to provide at least 15 percent of China's electricity needs. The dam will also help control flooding, but many scenic areas will be permanently covered by its reservoir. Thousands of people are being forced to relocate, and some scientists believe the dam will have undesirable effects on the environment after it is completed around 2010. Once completed, the dam will be the world's largest at 6,864 feet (2,092 meters) wide and 610 feet (186 meters) high.

Ganges (Ganga) River
Location: India and Bangladesh
Length: 1,557 miles (2,491 kilometers)
Discharge Basin: 188,800 square miles (490,880 square kilometers)

The Ganges (Ganga) The Ganges (GANN-jeez) crosses northern India and then flows south through the provinces of Uttar Pradesh, Bihar, West Bengal, and finally Bangladesh. Its headwaters are the Alaknanda and Bagirathi Rivers, which begin in the Himalaya Mountains. Its delta begins 200 miles (320 kilometers) from the sea, where it joins with the Jumna River to form the Padma and then flows into the Bay of Bengal, where it discharges more sediment into the sea than any other river system.

The flow of water in the Ganges varies with the seasons, but the changes are seldom violent. It travels through dry plains, drawing water from several tributaries such as the Jumna, Gogra, Gandak, Kasi, and Brahmaputra. In the last 1,000 miles (1,600 kilometers), flow is sluggish. Floods are common, especially in the delta region where tropical storms and tidal waves (giant waves associated with earthquakes) occur. During one such storm in 1970, about one million people were killed.

Forests grow on the Gangetic plain. Where rainfall is heavy, evergreens predominate. Carp are found in the river, as are geese and ducks. Mammals include tigers, deer, and wild dogs, but reptiles are more numerous, especially crocodiles, lizards, and snakes. The endangered Bengal tiger makes its home in the Ganges Delta, as does the Indian python and the Asian elephant.

Changing water levels limit the use of the Ganges for large vessels. In the delta region, many places are accessible only by small watercraft. Soils here are rich and fertile, but in the north the land is too high for irrigation unless power equipment is used. Crops include rice, wheat, sugar, cotton, and oil seed, which support 500 million people.

To those of the Hindu faith, the Ganges is holy, and many places along its shore, such as Varanasi (Benares), Allahabad, and Hardwar, have religious significance. Many people go on pilgrimages (religious journeys) to visit these places. Hindus believe that bathing in the Ganges is religiously purifying, and thousands flock to its banks each day. The river is polluted by human sewage, fertilizer runoff, and industrial wastes. In 1985, efforts were begun to clean up the river and are ongoing.

One of the world's earliest civilizations, the Indus, began in the neighboring Indus River valley and spread into the Ganges valley. One of the most well-known archaeological sites is Mohenjo-Daro, beside the Indus River.

Indus River
Location: Tibet, India, and Pakistan
Length: 1,800 miles (2,880 kilometers)
Discharge Basin: 372,000 square miles (967,200 square kilometers)

The Indus The Indus (INN-duhs) River begins in Tibet, travels through part of northern India, and completes its course in Pakistan. Its headwaters are formed by meltwater in the Himalaya Mountains and the Karakoram Range, where its flow is turbulent, unnavigable, and prone to flooding, especially in the summer months. When it leaves the mountains and enters the dry Punjab plains of Pakistan, it broadens and picks up sediments.

The major tributaries of the Indus are the five rivers of the Punjab: the Sutlej, Chenab, Jhelum, Ravi, and Beas. Its delta begins at Thatta and enters the Arabian Sea 70 miles (110 kilometers) farther south, where the river splits into several channels.

Rainfall in the Indus Valley ranges from 5 to 20 inches (13 to 51 centimeters) annually. The Indus is used for irrigation in the drier regions.

Desert vegetation predominates and includes thorn forests and many shrubs. Grasses do not thrive here. Indus baril, Indus gurua, Rita catfish, and snakehead fish are common fish. Sarus cranes and bearded vultures frequent the area, as do crocodiles and cobras. Mammals include deer and wolves.

The Punjab plain is Pakistan's richest farming region, where wheat, corn, rice, millet, dates, and other fruits are grown. Large dams have been built on the river to provide hydroelectric power and water for irrigation. Use of the Indus has been disputed by India and Pakistan as they have tried to determine their borders.

The cities of the great Indus civilization, Harappa and Mohenjo-Daro, were built in the Indus valley around 2500 BC. The civilization appears to have declined gradually. It is believed that barbarian nomads of the Eurasian high plains invaded the region and destroyed what was left of this civilization.

The Colorado The Colorado River is created by rain and melting snow in the mountains of central Colorado, Wyoming, and Utah. Its main tributaries are the Gunnison, the Dolores, the Green, the San Juan, the Little Colorado, the Gila, and the Virgin. As it travels south and southwest through Utah, Arizona, and Nevada, it creates the magnificent Grand Canyon, cutting deeper into the rock each year. The canyon is 218 miles (349 kilometers) long and, in one spot, 18 miles (29 kilometers) wide and 5,249 feet (1,600 meters) deep. At its mouth, the Colorado empties into the Gulf of California on the Pacific coast.

Discharge rates vary from 3,000 cubic feet (84 cubic meters) per second when water levels are low to 125,000 cubic feet (3,540 cubic meters) per second at flood times.

Colorado River
Location: Colorado, Arizona, Utah, Nevada, and California
Length: 1,440 miles (2,304 kilometers)
Discharge Basin: 244,000 square miles (634,400 square kilometers)

Much of the region is treeless and desertlike, and plants include those that tolerate semiarid conditions. Desert birds and waterfowl are common. Mammals include deer and bears.

The Colorado is one of the most valuable rivers in the world in terms of irrigation and power. The river is prone to flooding, but Hoover Dam and its reservoir (storage area), Lake Mead, have helped prevent disasters. Hoover Dam is the first multipurpose dam, providing both flood control and power generation. The Los Angeles-San Diego region receives much of its water from the Colorado, and arguments have ensued among neighboring states as to how the water should be divided. Environmental concerns have slowed further development of river resources.

Until the Spanish arrived in 1540 and gave the Colorado its present name, which means "red color," the Colorado basin was the home of several Native American tribes, including the Pueblo and the Navajo.

The Congo (Zaire) The Congo, or Zaire (zy-EER), River is the second longest in Africa. During the fifteenth century, Europeans called it the Zaire, a corruption of a Bantu word meaning "river." Later, the name was changed to Congo after the great African kingdom of Kongo located near its mouth. It is now known by both names.

The Congo's headwaters are in Kabalo, in the Democratic Republic of the Congo (DRC). It travels north across the country of Zaire, turns west, and then angles southwest, forming the border between Zaire and Congo. Its mouth, where it empties into the Atlantic Ocean, is in Angola.

The Congo's discharge basin is the second largest in the world. It draws water from tributaries in the Central African Republic, Cameroon, Congo, Angola, Zaire, and northern Zambia. Some of its tributaries include the Chambezi, Lualaba, Luvua, Lukuga, Chenal, Ubangi, Sangha, and Kwa. Along its course it forms many lakes, such as Bangweulu, Mweru, and Malebo Pool. Rapids, waterfalls, gorges, and a narrow channel, are found along its length.

The river straddles the equator, passing through the great rain forest of Zaire, which keeps it supplied with rainfall all year long. The Congo basin has uniform average annual rainfall of 90 inches (229 centimeters).

Annual volume of discharge of the Congo River is second only to that of the Amazon. Its force is so great that brownish-colored Congo waters can still be distinguished for more than 300 miles (480 kilometers) out to sea. During prehistoric times its flow cut a submarine canyon as deep as 4,000 feet (1,220 meters) into what is now the ocean floor.

Congo (Zaire) River
Location: Zambia, Zaire, Congo, and Angola
Length: 2,716 miles (4,346 kilometers)
Discharge Basin: 1,425,000 square miles (3,705,000 square kilometers)

In the northern and southern parts of its basin it passes through grasslands (savannas) where trees are scattered. In Zaire and along the Zaire-Congo border, dense rain forest occupies the basin. The Congo River basin contains the second largest rain forest in the world, second to the Amazon rain forest.

Vegetation in the central basin is abundant and diverse. Huge rain forest trees draped with clinging vines line its banks. In the southern regions, acacias are common. In the highlands, bamboo, heather, and giant senecio are found. Cultivation and burning have altered the vegetation along much of the Congo's length, and many non-native plants, such as cassava, citrus, and maize have been introduced.

At least 686 species of fish have been identified in Congo waters, 80 percent of which are found nowhere else in the world. Among the best known is the lungfish, which can live in oxygen-depleted water. Mammals typical of grasslands, such as lions and zebras, are found in the northern and southern regions, while gorillas and rhinoceroses are found in the rain forests. Elephants and leopards are common throughout.

The first people to inhabit the Congo were the Pygmy. Most native peoples who live along the Congo catch its fish. Some are also farmers. Many peoples, such as the Bobangi and the Teke, use the river for trade. The river is important as a source of hydroelectric power but the area's economy has not yet been able to take full advantage of its potential.

In the late nineteenth century, many European explorers, such as David Livingstone (1813–1873) and Henry Morton Stanley (1841–1904), penetrated the African interior by traveling on the Congo.

The Tigris and Euphrates The Tigris (TY-grihs) river flows though southeastern Turkey and Iraq. Above Basra in southern Iraq, it joins the Euphrates (yoo-FRAY-teez) to form the Shatt-al-Arab, which empties into the Persian Gulf.

The Tigris-Euphrates basin is a hot, dry plain with daytime temperatures as high as 120°F (49°C). Average annual rainfall is only 8 inches (20 centimeters), and it falls seasonally, from November to March. The Euphrates floods twice during the year, the largest occurring in April and May, and creates marshy regions along its banks.

Desert vegetation, such as thorn and scrub, predominate. Bats, jackels, and wildcats are common mammals, but reptiles are more numerous, particularly snakes and lizards. Many fish live in the river, including the Tigris salmon.

Tigris and Euphrates River
Location: Turkey, Syria, and Iraq
Length: Tigris 1,181 miles (1,890 kilometers); Euphrates 1,740 miles (2,784 kilometers)
Discharge Basin: Tigris 145,000 square miles (377,000 square kilometers); Euphrates 295,000 square miles (767,000 square kilometers)

Both rivers are used for irrigation, and two major reservoirs are located on the Euphrates where farmers raise cereal grains and dates and the nomadic tribes raise livestock. The Tigris provides irrigation waters for the cultivation of wheat, barley, millet, and rice.

The Tigris-Euphrates basin was the birthplace of the great Sumerian civilization, which dates back to at least 3000 BC in what was then Mesopotamia. The Sumerians dug canals along the Tigris, and Nineveh, the capital of ancient Assyria, was located there.

The Mississippi The Mississippi is the second longest river in the United States, and its name in the Algonquian language means "father of waters." Its headwaters are in Minnesota, and its drainage basin includes at least part of thirty-one states and covers about 40 percent of the country. As it flows south, it forms the boundary between Minnesota, Iowa, Missouri, Arkansas, and Louisiana on the west and Wisconsin, Illinois, Kentucky, Tennessee, and Mississippi on the east.

Fed by Lake Itasca, a glacial lake, the upper Mississippi forms rapids where it joins the Minnesota River. Further south it is lined by high bluffs, and below Cairo, Illinois, it becomes an old stream, meandering through flat floodplains between natural levees.

Its most important tributaries are the Illinois, the Chippewa, the Black, the Wisconsin, the Saint Croix, the Iowa, the Des Moines, the Ohio, the Arkansas, the Red, and the Missouri Rivers. The mouth of the Mississippi is at the Gulf of Mexico where its delta covers a region 9,872 square miles (25,568 square kilometers) in area, and about 79,935,000 tons (72,515,812 metric tons) of sediments are deposited each year.

The river travels the length of the United States and precipitation varies from 40 to 60 inches (102 to 152 centimeters). The southern section of the river is prone to severe flooding, and in 1927 Cairo, Illinois, remained flooded for 153 consecutive days. Artificial levees, meander cutoffs, flood outlets, and upstream reservoirs have been built since that time to try to contain floodwaters. The river flooded again in 1993, covering 14,000,000 acres (5,500,000 hectares) and causing fifty deaths.

Willow, oak, and pine trees are common, as are many species of grasses and aquatic plants. Fish include catfish and paddlefish. Cranes, ducks, and other waterfowl frequent the river, as do turtles, muskrats, and deer.

Ocean-going ships can travel upstream to Baton Rouge, Louisiana. Smaller ships can travel through 15,000 miles (24,150 kilometers) of the

Mississippi River
Location: Minnesota, Iowa, Missouri, Arkansas, Louisiana, Wisconsin, Illinois, Kentucky, Tennessee, and Mississippi
Length: 2,348 miles (3,757 kilometers)
Discharge Basin: 1,243,700 square miles (3,233,620 square kilometers)

entire river system, and use of the river for transportation is increasing. Cargo consists mainly of midwestern grain and petroleum products from the Gulf of Mexico. More than 460,000,000 tons (420,000,000 metric tons) of freight are transported on the Mississippi each year.

Native peoples who once lived along the river were the Ojibwa, the Winnebago, the Fox, the Sauk, the Choctaw, the Chickasaw, the Natchez, and the Alabama. The first European to reach the river inland was Hernando de Soto (c. 1496–1542) in 1541. In 1673, Jacques Marquette (1637–1675) and Louis Jolliet (1645–1700) explored the northern regions. The river system enabled Europeans to settle the central United States, and it was an important transportation route during the Civil War.

The Missouri The Missouri is the longest river in the United States and the largest tributary of the Mississippi. Its headwaters are the Jefferson, Gallatin, and Madison Rivers in Montana, and it travels through North and South Dakota to finally join the Mississippi in St. Louis, Missouri. Its own tributaries include the Little Missouri, the Cheyenne, the White, the Niobrara, the James, the Big Sioux, the Platte, and the Kansas rivers. Its drainage basin includes parts of Canada.

In Montana and North and South Dakota, it passes through high plains where the soil is poor. Farther south it enters the humid grain belt and the drier grasslands where cattle graze. The soil is rich along is southern stretches, although erosion is heavy. The river carries so much sediment that is nicknamed is "Big Muddy."

Precipation ranges from 20 to 40 inches (51 to 102 centimeters) annually. The river's average discharge is about 64,000 cubic feet (1,810 cubic meters) per second. Flood season is from April to June, and the federal government has built dams and reservoirs to help control flooding, provide irrigation, and make the river navigable.

Natural vegetation in the Missouri basin consists primarily of grasses. Fish include bass and trout. Mammals such as deer and coyotes can be found in this region.

Native peoples who lived in the region include the Cheyenne, the Crow, the Mandan, the Pawnee, and the Sioux. French explores Jacques Marquette (1637–1675) and Louis Jolliet (1645–1700) explored the region by 1673. By 1843 farmers had begun to settle in the Missouri valley. Today, the Missouri is important to traffic in bulk freight such as grain, coal, steel, petroleum, and cement.

Missouri River
Location: Montana, North Dakota, South Dakota, Nebraska, Iowa, and Missouri
Length: 2,466 miles (3,946 kilometers)
Discharge Basin: 529,000 square miles (1,375,400 square kilometers)

The Volga The Volga is the longest river in Europe. Its headwaters are in the hills north of Moscow, Russia, and it empties into the Caspian Sea, which lies on Russia's southern border. It has more than 200 tributaries, the most important of which is the Kama, Oka, Vetluga, and Sura rivers The Volga delta covers more than 34,000 square miles (86,000 square kilometers).

Melting snow and summer rains are the Volga's main source of water. Annual precipitation averages 20 inches (50 centimeters) in the north and 12 inches (30 centimeters) in the south. Spring flooding is controlled by several dams and reservoirs.

The Volga passes through forested land and forms several lakes in the north. Below that it enters a flat, swampy basin bordered by low hills. Its southern section curves around mountains and finally enters a broad floodplain.

Willow, pine, and birch are common trees. River fish include sturgeon, perch, pike, and carp. Mammals include deer, beavers, and foxes. The Volga delta, with a length of 99 miles (160 kilometers), is Europe's largest estuary and the only place in Russia where pelicans, flamingo, and lotuses may be found.

Although almost all of the Volga is navigable, ice covers most of the length of the river for three months. The river carries about 50 percent of Russia's river freight, including timber, petroleum, coal, salt, farm equipment, construction materials, fish, and fertilizers.

Volga River
Location: Russia
Length: 2,292 miles (3,667 kilometers)
Discharge Basin: 532,800 square miles (1,385,280 square kilometers)

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American Rivers, 1101 14th Street NW, Suite 1400, Washington, DC 20005, Phone: 202-347-7550; Fax: 202-347-9240, Internet: http://www.americanrivers.org.

Environmental Defense Fund, 257 Park Ave. South, New York, NY 10010, Phone: 212-505-2100; Fax: 212-505-2375; Internet: http://www.edf.org.

Envirolink, P.O. Box 8102, Pittsburgh, PA 15217; Internet: http://www.envirolink.org.

Environmental Protection Agency, 401 M Street, SW, Washington, DC 20460, Phone: 202-260-2090; Internet: http://www.epa.gov.

The Freshwater Society, 2500 Shadywood Rd., Navarre, MN 55331, Phone: 952-471-9773; Fax: 952-471-7685; Internet: http://www.freshwater.org.

Friends of the Earth, 1717 Massachusetts Ave. NW, 300, Washington, DC 20036-2002, Phone: 877-843-8687; Fax: 202-783-0444; Internet: http://www.foe.org.

Greenpeace USA, 702 H Street NW, Washington, DC 20001, Phone: 202-462-1177; Internet: http://www.greenpeace.org.

Global Rivers Environmental Education Network (GREEN), 2120 W. 33rd Avenue, Denver, CO 80211; Internet: http://www.earthforce.org/green.

Izaak Walton League of America, 707 Conservation Lane, Gathersburg, MD 20878, Phone: 301-548-0150; Internet: http://www.iwla.org/.

Project Wet, 1001 West Oak, Suite 210, Bozeman, MT 59717, Phone: 866-337-5486; Fax: 406-522-0394; Internet: http://projectwet.org.

Sierra Club, 85 2nd Street, 2nd Fl., San Francisco, CA 94105, Phone: 415-977-5500; Fax: 415-977-5799, Internet: http://www.sierraclub.org.

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Seashore

The seashore, also called the coastline, shoreline, or beach, is the portion of a continent or island where the land and sea meet. The seashore includes the area covered by water during high tide and exposed to air during low tide, the area splashed by waves but never under water, and the area just beyond the shore that is always under water. (The tides are the rhythmic rising and falling of the sea.) Seashores vary greatly in appearance, from flat, sandy, and washed by gentle waves to storm-battered and rocky or bounded by tall cliffs.

How the Seashore is Formed

Seashores were first created when the continents and islands of Earth were formed. Since then, many changes have occurred. Some happened during prehistoric times and others are still taking place.

Movement of Earth's crust The underlying structure of the shoreline depends upon the shape of the land where it meets the ocean and the type of rock of which it is a part. Earthquakes and volcanoes during prehistoric times may have helped form many shorelines. An earthquake, for example, caused part of the California shoreline to sink. The sunken area became what is now San Francisco Bay and a new shoreline was created. In regions like northern California, where earthquakes and volcanoes still occur, the shoreline may undergo many more changes in the future.

Glaciers During prehistoric times, glaciers (giant, slow-moving rivers of ice) may have altered the shape of the seashore by cutting into it and leaving deep valleys behind when they retreated. Glaciers created the fjords (fee-OHRDS; long, narrow arms of the ocean stretching inland) of Scandinavia, Greenland, Alaska, British Columbia, and New Zealand. They also created the U-shaped valleys along the coastline of southern

WORDS TO KNOW

Estuary: The place where a river traveling through lowlands meets the ocean in a semi-enclosed area.

Intertidal zone: The seashore zone covered with water during high tide and dry during low tide; also called the mitermle, or the littoral, zone.

Littoral zone: The area along the shoreline that is exposed to the air during low tide; also called intertidal zone.

Longshore currents: Currents that move along a shoreline.

Neap tides: High tides that are lower and low tides that are higher than normal when the Earth, sun, and moon form a right angle.

Rip currents: Strong, dangerous currents caused when normal currents moving toward shore are deflected away from it through a narrow channel; also called riptides.

Spring tides: High tides that are higher and low tides that are lower than normal because the Earth, sun, and moon are in line with one another.

Sublittoral zone: The seashore's lower zone, which is underwater at all times, even during low tide.

Submergent plant: A plant that grows entirely beneath the water.

Supralittoral zone: The seashore's upper zone, which is never underwater, although it may be frequently sprayed by breaking waves; also called the splash zone.

Tidal bore: A surge of ocean water caused when ridges of sand direct the ocean's flow into a narrow river channel, sometimes as a single wave.

Tsunami: A huge wave or upwelling of water caused by undersea earthquakes that grows to great heights as it approaches shore.

Chile. In polar regions, glaciers are still at work, carving deep channels as they inch toward the sea.

Glaciers continue to alter the shape of shores by cutting into them, and leaving valleys behind when they retreat. COPYRIGHT © 2003 KELLY A. QUIN.

The presence of a glacier weighs the land down, causing it to sink. About 10,000 years ago when many glaciers receded, some coastlines rose up, and areas once under water were now above it. In some places, such as Scandinavia, the coastlines are rising as much as 0.4 inch (10 millimeters) a year even though the glaciers have been gone for thousands of years.

Changes in sea level Sea level refers to the average height of the sea when it is halfway between high and low tides. Sea level changes over time. For example, when the Ice Ages ended and glaciers began to melt into the ocean, the

Locked in the Ice

Exploration of remote areas, such as Antarctica, demanded people with courage and endurance. Ernest Shackleton (1874–1922), a British explorer, had those characteristics and made several expeditions to Antarctica in the early 1900s. His most remarkable, and almost fatal, journey was made in 1914 with twenty-seven other men on board a small ship called *The Endurance*, a name that would prove prophetic.

The Endurance became trapped in drifting ice in the Weddell Sea (part of the Antarctic Ocean) during one of the coldest winters in memory. The explorers had come prepared to spend the winter, if necessary, but the weather did not get warm enough the following spring to free the ship. The ice crushed its forward section, and the ship sank in November 1915. By then the men had begun to kill penguins and their own sled dogs for food.

They managed to save three small boats and, for seven days, used them to travel to an uninhabited island. All were starved and exhausted, but taking no time to rest on the island, Shackleton and five of the strongest men set out again in one of the boats to seek aid. They finally found it on South Georgia Island farther north. Shackleton turned around and went back to rescue the others. The first three tries were unsuccessful, but he succeeded on the fourth attempt. Everyone survived because of Shackleton's courage and endurance.

level of the water rose. Some areas that were once exposed to the air were now covered permanently by water and new shorelines were created.

Sea level is still changing. For the past 100 years, it has risen about 0.08 inch (2 millimeters) per year. As the water creeps higher, more of the existing shoreline becomes submerged. Low-lying coastal areas in Texas and Louisiana have already been flooded.

Offshore barriers The presence of a barrier island, reef (an underwater wall made of rocks, sand, or coral), or other offshore landmass running parallel to the shore may affect a seashore's formation. It does this by reducing the effects of wind and water. Deposits of sediment (particles of matter) are allowed to accumulate because the force of the waves is lessened.

Coral reefs are created in tropical regions by small, soft, jellylike animals called corals and algae that trap hard calcium carbonate. Corals attach themselves to hard surfaces and build a shell-like external skeleton. Many corals live together in colonies, the younger building their skeletons next to or on top of older skeletons. Gradually, over hundreds, thousands, or millions of years, a reef of these skeletons is formed. Because reefs slow the movement of the water, sediments sometimes lodge in the reef allowing plants to take root. As the plants die and decay, a layer of soil is created. Eventually, the shoreline may extend, and even trees may grow.

SEASHORE PARKS AND RESERVES OF THE WORLD (PARTIAL LIST)

Name	Location	Square miles (square kilometers)	Features
Aldabra Islands Nature Reserve	Seychelles (Africa)	60 (156)	Protects giant tortoise and other animals
Bako National Park	Sarawak	10 (26)	Bays and caves; forest; wild pigs, deer, monkeys, birds
Cape Le Grand National Park	Australia	124 (321)	Beach; coostal plants
Easter Island National Park (Rapa Nui)	Chile	63 (163)	Protects vegetation and animals
Elat Gulf Coral Reef Reserve	Israel	0.5 (1.3)	Coral reefs with tropical fish
Eldey Nature Reserve	Iceland	0.006 (0.015)	Gannet breeding area
Franklin D. Roosevelt National Park	Uruguay	58 (150.8)	Sand dunes, pines
Ise-Shima	Japan	201 (522.6)	Forested coastline; pearl farms
Kong Karls Land Reserve	Norway	200 (520)	Arctic islands, polar bears
Kranji Reserve	Singapore	0.08 (0.21)	Mangrove marsh
Kyzylagach	Azerbaijan	363 (943.8)	Coastal reed and salt marshes; flamingos, bustards
Pembrokeshire Coast	Great Britain	225 (585)	Rocky coast; island birds
Prince Edward Island	Canada (Gulf of St. Lawrence)	7 (18.2)	Forested coastline; many small mammals
Rikuchu Kaigan	Japan	45 (117)	Cliffs, islands, and beaches; forests; birds
Skallingen	Denmark	12 (31.2)	Dunes, marshes
St. Lucia	Natal (Africa)	190 (494)	Estuary on False Bay; hippopatoami and birds
Westhoek Nature Reserve	Belgium	1.3 (3.4)	Sand dunes, marine plants
Yala National Park	Sri Lanka	91 (236.6)	Lagoons, rocky hills

The Bordering Sea

The oceans are constantly, restlessly moving. This movement takes place in the water column (the water in the ocean exclusive of the sea bed or other landforms) in the form of tides, waves, and currents; all of which affect the shoreline.

Tides Tides are rhythmic movements of the oceans that cause a change in the surface level of the water. When the water level rises, it is called high tide. When it falls, it is called low tide. Along some shorelines, the tides are barely measurable. In other areas the difference between high and low tide may be several feet (meters). High and low tides occur in a particular place at least once during each period of 24 hours and 51 minutes.

Tides are caused by a combination of the gravitational pull of the sun and moon and Earth's rotation. The sun or moon pulls on the water, causing it to bulge outward. At the same time, the centrifugal force (movement from the center) created by Earth's rotation causes another bulge on the opposite side of Earth. Both of these areas experience high tides. At the same time, water is pulled from the areas in between, and those areas experience low tides.

When the Earth, sun, and moon are lined up, the gravitational pull is strongest. At these times, high tides are higher and low tides are lower than normal. These are called spring tides. When the Earth, sun, and moon form a right angle and the gravitational pull is weakest, high tides are lower and low tides are higher than normal. These are called neap tides.

Tidal bores are surges of tidal waters caused when ridges of sand block the flow of ocean water and direct it into a narrow channel, sometimes as a single wave. Most tidal bores are harmless, but the bore that enters the Tsientang River in China sometimes reaches 15 feet (4.5 meters) in height and travels 25 feet (7.5 meters) per second.

Waves Waves are rhythmic rising and falling movements in the water. Most surface waves are caused by wind. Their size is due to the speed of the wind, the length of time it has been blowing, and the distance over which it has traveled. A breaker is a wave that collapses on a shoreline in a mass of foam. As it rolls in from the ocean, the bottom of the wave is slowed by friction as it drags along the sea floor. The top then outruns it and topples over, landing on the shore.

The Beaches at Normandy

Beaches have often been used by invading armies to conquer the neighboring region. During World War II (1939–45), the beaches of the province of Normandy, France, were the site of an important strike against Nazi Germany. Germany had conquered France earlier in the war and much of their power in that country was concentrated in Normandy, which bordered the English channel and was only a short distance from England, which the Nazis hoped to conquer.

On D-Day, June 6, 1944, in an effort to recapture France, the Allies (Britain, Canada, Poland, France, and the United States) struck the beaches at Normandy. The beaches, named Utah, Omaha, Gold, Sword, and Juno, stretch about 50 miles (80 kilometers) along the coast between Cherbourg and LeHavre. The slope of the beaches is gentle and a wide expanse of shore is exposed at low tide. The date for the invasion was selected based on the tides, the weather, the presence of moonlight, and other conditions.

The Germans, who expected trouble, were unaware of the exact invasion point and had fifty infantry and ten tank divisions spread out over France and neighboring countries. To distract the Germans, British-based aircraft bombed rail lines, bridges and airfields on French soil for two months before D-Day. The night before, paratroops were dropped inland to interfere with enemy communications. Naval guns pounded German gun nests on shore.

In the early daylight at low tide on June 6, in rough seas, about 5,000 Allied ships approached the Normandy coastline. The British and Canadians moved in efficiently at Gold, Juno, and Sword beaches and the Americans at Utah Beach. But at Omaha Beach, the central point of the landings, American troops encountered heavy German gunfire, and many men were killed. Within five days, sixteen Allied divisions had landed in Normandy. By August, Paris had been freed, and it was the beginning of the end of Nazi rule in Europe.

A realistic account of the Normandy invasion can be viewed in Stephen Spielberg's 1998 Academy-Award-winning film *Saving Private Ryan.*

Waves can be extremely powerful. Storm waves can even hurl large rocks high into the air. So many rocks have broken the beacon at the lighthouse at Tillamook Rock, Oregon, that the beacon—133 feet (40.5 meters) above the water—is now enclosed in a steel grating.

One dangerous type of wave, called a tsunami (soo-NAH-mee), is caused mainly by undersea earthquakes. When the ocean floor moves during the quake, its vibrations create a powerful wave that travels to the surface. When tsunamis strike coastal areas, they can destroy entire towns and kill many people.

Currents Currents are the flow of the water in a certain direction. Most currents are caused by the wind, the rotation of Earth, and the position of continental landmasses. A longshore current is one that runs along a shoreline. Rip currents, or riptides, are strong, dangerous currents that occur when currents moving toward shore are deflected away from it through a narrow channel.

Upward and downward movement also occurs in the ocean. Vertical currents are primarily the result of differences in the temperature and salinity (level of salts) of the water. In some coastal areas, strong wind-driven currents carry warm surface water away. Then an upwelling (rising) of cold water from the deep ocean occurs to fill the space. This is more common along the western sides of continents. These upwellings bring many nutrients from the ocean floor to the surface, encouraging a wide variety of marine (ocean) life.

The Silver Dragon

High tides arrive at most shorelines gradually. In locations where tapering coastlines face a large ocean, however, the volume of the tide is focused very narrowly and its force increases. When such a tide meets a river flowing into the sea, a steep wave forms, forcing itself up the river and far inland. This wave is called a tidal bore.

The world's largest tidal bore is called the Silver Dragon, and it occurs once a month where the South China Sea invades the Quiantang River of China. Reaching heights of 20 feet (6 meters) or more, the Silver Dragon rushes over an area 5 miles (8 kilometers) wide.

Other large bores occur on the Amazon River in South America, on the Petitcodiac where it meets the Bay of Fundy in Canada, on the Hooghly in India where it flows into the Bay of Bengal, and on the Severn in England.

Zones in the Seashore

The seashore can be divided into zones based on relationships to the ocean, particularly the tides.

The seashore's lowest zone is underwater at all times, even during low tide. This lower zone is called the sublittoral zone. It is a marine environment.

The intertidal zone (called the middle, or littoral, zone) is covered during high tide and exposed during low tide. This is the harshest of all seashore environments, since any animal or plant that lives here must be able to tolerate being submerged for part of the day and exposed to the air and sun for the rest.

The upper zone is never underwater and may be frequently sprayed by breaking waves. It is often referred to as the splash or supralittoral zone. Conditions here are similar to other dry-land areas.

Climate

The climate of a particular seashore depends upon its location. In general, if the shoreline is part of a desert country, such as Saudi Arabia, the climate will be hot and dry. If it is part of a country in the frozen north,

Hurricane winds originate at sea, but their forceful rotating winds cause extensive damage, both from the winds of up to 180 miles per hour (300 kilometers per hour), and the huge waves that batter the shoreline. IMAGE COPYRIGHT KONOVALIKOV ANDREY, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

such as Siberia, the climate will be cold. The presence of the ocean can create some climatic differences.

The ocean absorbs and retains some of the sun's heat. In the winter, the warmer water releases heat into the colder atmosphere, helping to keep temperatures warmer inland. In summer, when the water temperature is cooler than the air temperature, winds off the ocean help cool coastal areas.

Other effects of the ocean on climate result primarily from moderating ocean currents and storms at sea.

Moderating currents Ocean currents may be warm or cold, depending upon where they started. The presence of a current can moderate the weather along a particular coastline. For example, the North Atlantic Drift is a warm current that originates in regions farther south. As it flows around the coast of Scotland, it warms the air temperature enough that palm trees will grow there. As it travels farther north along the coast of Norway, it keeps the water above freezing so that Norway's ports are open all winter, even though they are above the Arctic Circle.

Storms at sea Seashores are vulnerable to storms that originate at sea and produce strong winds and high waves. Hurricanes and typhoons are violent tropical storms that form over the oceans. Their wind speeds can reach 75 to 200 miles (120 to 322 kilometers) per hour. Their forceful, rotating winds cause much damage when they reach land, as do the waves that batter the shoreline.

The worst coastal weather in the world is in the North Atlantic where the climate is cooler and the force of the waves has been measured at 6,000 pounds per square foot (13,200 kilograms per square meter). Driven by gale-force winds, waves along these coastlines have been known to be very destructive.

Geography of the Seashore

The geography of the seashore is affected by the process of erosion (wearing away) and deposition (dep-oh-ZIH-shun; setting down), which helps determine the different types of surface and landforms found at the seashore.

Erosion and deposition As waves crash against a shoreline, they compress (squeeze) the air trapped in cracks in rocks. As the waves retreat, the pressure is suddenly released. This process of pressure and release widens the cracks and weakens the rock, causing it to eventually break apart. Some waves, especially those created by storms, are very high and forceful. In places where wave action is strong, the waves pick up particles of rock and sand and throw them against the shoreline with a crashing motion. This produces a cutting action.

Some of the chunks and particles eroded from a shoreline may then be carried out to sea by waves. The particles sink and become deposited on the ocean floor. Other particles may be carried by longshore currents farther along the coast and deposited where there is shelter from the wind, and the wave action is not as severe. Even boulders may be carried by this means.

In the Path of the Great Waves

Over 2.8 million people have been killed by tsunamis (giant waves) during the past twenty years. One in every three tsunamis occurs off the coast of Chile, and that country experiences 40 percent of all the damage caused worldwide.

In 1964, an earthquake struck Alaska, causing great damage and breaking a pipeline carrying oil. The oil caught fire. Then a tsunami three stories tall followed the quake and, picking up the burning oil, carried it overland in a tide of fire. The fires reached the railroad yards, where the steel tracks soon glowed red from the heat. When more tsunamis followed and flowed over the tracks, the sudden cooling made the tracks rise up and curl like snakes.

Shoreline surfaces Seashore surfaces are classified as rocky, sandy, or muddy, depending upon their composition (makeup).

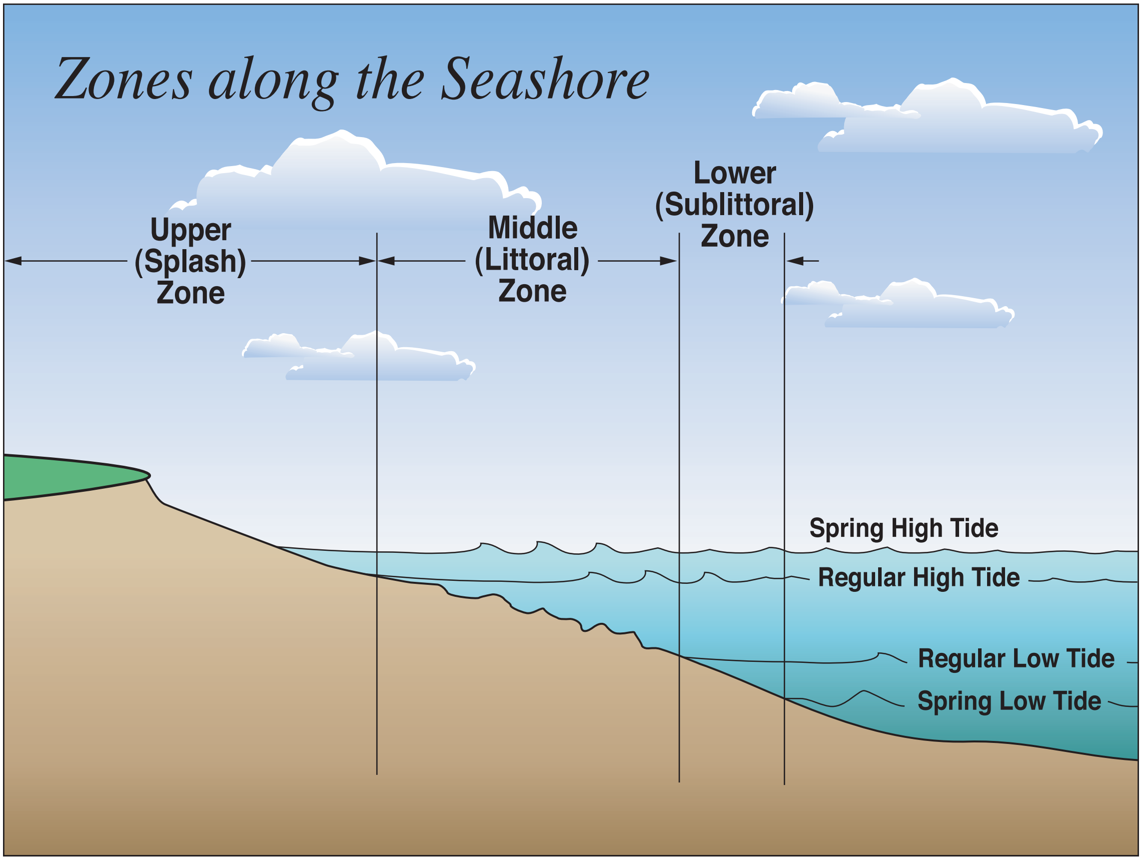
Rocky shores may consist of vertical cliffs, sloping shores, platforms, and boulder-covered areas. Vertical cliffs have no protection from the waves. On shores covered by boulders, spaces among the stones are protected, and pools of water, called tide pools, may form in them.

Beaches along rocky shorelines usually consist of pebbles and larger stones. The waves carry away the finer particles.

Sandy shores make up about 75 percent of the world's seashores that are not ice-covered. They are constantly changing, depending upon the movement of the wind, the water, and the sand.

Some sandy shores form a steep slope down to the sea. On this type of shoreline, the waves break directly on the beach. Cycles of erosion and deposition are more extreme and have a greater effect on the shape of the shoreline. The greater the force of the waves, the steeper the slope, and the larger the sand particles.

Sandy shores that slope gently down to the sea are usually protected in some way from the full force of the water. A reef, for example, may have



formed some distance from shore. As a result, the waves that reach the beach are gentle, erosion is slow, and sand particles are finer.

The texture of the sand helps determine what the beach will be like. Fine sand packs down and produces a smooth, gentle slope. Coarse sand allows the waves to sink in and move the particles around, producing a steep surface.

An estuary is where a river, traveling through lowlands, meets the ocean in a semi-enclosed channel or bay. In these gently sloping areas, river sediments (soil and silt) collect, and muddy shores form. Water in an estuary is brackish, a mixture of fresh and saltwater.

Estuaries are semi-enclosed by land, which usually protects them from the full force of ocean waves. High tide may bring in a new supply

Lighthouses are found on some seashores, built to guide boats into ports and docks, or away from dangerous waters. COPYRIGHT © 2006 KELLY A. QUIN.

of seawater and the water becomes more salty. During low tide, fresh water from the river dominates. After a rain washes soil into the river, the water carried into the estuary may be cloudy from the added sediments.

Landforms Landforms found at the seashore include cliffs and rock formations; beaches and dunes; deltas; spits and bars; and certain types of saltwater wetlands.

Cliffs and rock formations High cliffs usually occur when highlands meet the sea. Pounding waves may gradually eat into the base of the cliffs, eroding the rock and creating a hollowed-out notch. Eventually, the overhang collapses and falls onto the beach, creating a platform of rock and soil.

Many coastlines consist of both hard and soft rock. Wave action erodes the soft rock first, sometimes sculpting strange and beautiful shapes, such as arches. Caves may be carved into the sides of cliffs, or headlands may be created. A headland is a large arm of land made of hard rock that juts out from the beach into the ocean after softer rock has been cut away.

Beaches and dunes Beaches are almost-level stretches of land along the water's edge. They may be covered by sand or stones. Sand is small particles of rock less than 0.08 inch (2 millimeters) in diameter. It may be white, golden, brown, or black, depending upon the color of the original rock. Yellow sand usually comes from quartz and black sand from volcanic

Once grasses take root in dunes, the dunes are less likely to travel with the wind and change their position and shape. COPYRIGHT © 2006 KELLY A. QUIN.

rock. White or pink sand may have been formed from limestone, seashells, or coral particles.

Sand is carried not only by water but also by wind. When enough sand has been heaped up to create a ridge or hill, it is called a dune. Dunes range from 15 to 40 feet (4.6 to 12.2 meters) in height, and a few may become 75 feet (23 meters) tall. Individual dunes often travel, as the wind changes their position and shape. They tend to shift less if grasses take root in them and help hold them in place.

Deltas In estuaries, where rivers meet the sea, huge amounts of silt (very small particles of soil) carried from far inland by the river are deposited in the ocean along the shoreline. Large rivers can dump so much silt that islands of mud build up, forming a fan-shaped area called a delta. In regions where Earth's crust is thin, the weight of these sediments may cause the shoreline to sink. Huge deltas have formed at the mouths (where a river empties into a larger river or ocean) of the Mississippi River in the United States and the Nile River in Egypt.

Spits and bars A spit is a long, narrow point of deposited sand, mud, or gravel that extends into the ocean. In an estuary, a spit may reach up into the river's mouth.

A bar is an underwater ridge of sand or gravel formed by tides or currents that extends across the mouth of a bay (an area of the ocean partly enclosed by land). If the bar closes off the bay completely, the water trapped behind the bar is called a lagoon. A tombolo is a bar that forms between the beach and an island, linking them together.

Saltwater wetlands Saltwater wetlands are portions of land covered or soaked by ocean water often and long enough to support plants adapted for life under those conditions.

A swamp is a type of wetland dominated by trees. A saltwater swamp is formed by the movement of the ocean tides. When the tide is low, flat places in the swamp are not under water.

Marshes are wetlands dominated by non-woody plants such as grasses, reeds, rushes, and sedges. Saltwater marshes are found in low, flat, poorly drained coastal areas. They are especially common in deltas, along low-lying seacoasts, and in estuaries. Saltwater marshes are greatly affected by the tides, which raise or lower the water level on a daily basis. A saltwater marsh may have tidal creeks, tidal pools, and mud flats.

The Legendary Lusca

Along the shores of the Bahama Islands, in the depths of the beautiful blue waters of the Caribbean Sea, lives the legendary Lusca, a creature that is supposedly half shark and half octopus. The Lusca draws people and even boats into its lair and, afterwards, like a rather rude dinner companion, it signals its satisfaction with a sudden upwelling "burp" of water.

Although not really a sea monster, the Lusca can be a bit tricky to get to know. A Lusca is not a creature at all, but an underwater cave carved out of the limestone that lies under the Bahama Islands. As sea levels rise and fall, these caves fill with water. When rainwater mixes with the seawater, their different densities (weights) cause whirlpools. These whirlpools account for people being drawn down into the caves and for the sudden burps of water. These extreme conditions often churn up sediments, making the caves dangerous for divers who, in the resulting dimness, may not be able to find their way out again.

Plant Life

Seashore plants include many kinds of seagrasses and some species of trees. The types of plants that grow in a particular region are determined by climate and the kind of shoreline surface—rocky, sandy, or muddy. Some sandy or muddy shores do not support plants because the soil is frequently disturbed.

Plants that live in the lower (sublittoral) zone along the seashore are always surrounded by water. Most have not developed the special tissues and organs for conserving water that are needed by plants on land. The surrounding water offers support to these plants, helping to hold them upright. Their stems are soft and flexible, allowing them to move with the currents without breaking.

Plants that live in the intertidal (littoral) zone are very hardy because they are exposed to the air for part of the day and are underwater for part of the day. Plants in the upper (supralittoral), or splash, zone have adapted to life on land. However, they must be tolerant of salty conditions.

The Web of Life: Seashore Succession

Life exists everywhere on our planet, even in the most remote, unfriendly places. Often, one life form leads the way for others because its presence in the habitat causes changes. Soon, other life forms move in, some to eat the first inhabitants, others because the habitat is now more comfortable for them. This process of succession occurs regularly along the seashore in some surprising ways.

Suppose a new boat is tied to the end of a pier. Within minutes, life forms will have begun to build colonies on its hull. Within an hour, bacteria will attach themselves to any surface below the water line. Phytoplankton and zooplankton come next, usually within the first day. By the second or third day, hydroids and bryozoa, tiny but more complex animals, move in too. If the boat is not moved, barnacles and larger algae will have attached themselves to its hull by the end of the week and the other animals will have been greatly reduced in number. Eventually, mussels will move in, crowding everybody else out.

Algae, fungi, and lichens Most marine plants are algae, and many algae are green plants. However, it is generally recognized that algae do not fit neatly into the plant category. Most algae have the ability to make their own food by means of photosynthesis (foh-toh-SIHN-thih-sihs), the process by which plants use the energy from sunlight to change water and carbon dioxide into the sugars and starches they use for food. Algae require other nutrients they obtain from the water. In certain regions, upwelling of deep ocean waters during different seasons brings more of these nutrients to the surface. This results in sudden increases in the numbers of algae. Increases also occur when nutrients are added to a body of water by sewage, or by runoffs from fertilized farmland.

Some forms of algae, called phytoplankton (fy-toh-PLANK-tuhn), are so tiny they cannot be seen without the help of a microscope. They float freely in the water, allowing it to carry them from place to place. Other larger species, often referred to as seaweeds, may be anchored to the seafloor.

Fungi (FUHN-ji) cannot make their own food by means of photosynthesis. Some, like molds, obtain nutrients from dead or decaying organic matter. They assist in the decomposition (breaking down) of this matter and release many nutrients needed by other plants. Others are parasites and attach themselves to, and feed on, other living organisms.

Lichens are combinations of algae and fungi that live in cooperation; the fungi surround the algal cells, and the algae obtain food for themselves and the fungi by means of photosynthesis. Lichens prefer the upper zones of the seashore, surviving dryness by soaking up water during high tide.

Common algae Two types of algae commonly found along the seashore include phytoplankton and seaweeds. Diatoms and dinoflagellates (DI-noh-FLAJ-uh-lates) are the most common types of phytoplankton.

Seaweeds are forms of green, brown, and red algae that grow primarily along rocky seashores. Green algae prefer the upper zone where they are exposed to sunlight and fresh water from rain. Brown algae prefer the middle zone and shallow water. They absorb sunlight readily and are tough enough to endure the action of waves and tides. Red algae live in tide pools or offshore waters, as do the large forms of brown algae, called kelps.

Seaweeds are different from land plants in that they do not produce flowers, seeds, or fruits. They lack root systems because they do not need roots to draw water from the soil. Instead, they have rootlike holdfasts that anchor them to rocks. They are seldom found on sandy shorelines because there are no rocks for anchorage.

The type of shoreline determines the species of seaweeds that will grow there. Different species prefer different zones along the same shoreline. Some are better adapted to dry conditions than others. Some species, for example, have a thick layer of slime that prevents water loss, while others have a layer of tissue that retains water.

Growing season Algae contain chlorophyll, a green pigment used to turn energy from the Sun into food. As long as light is available, algae can grow. In some species, the green color of the chlorophyll is masked by orange-colored compounds, giving the algae a red or brown color.

The growth of ocean plants is often seasonal. In northern regions, the most growth occurs during the summer. In temperate (moderate) zones, growth peaks in the spring but continues throughout the summer. In regions near the equator, growth is steady throughout the year.

Reproduction Algae may reproduce in one of three ways. Some split into two or more parts; each part becoming a new, separate plant. Others form spores (single cells that have the ability to grow into a new organism). A few reproduce sexually, during which cells from two different plants unite to form a new plant.

Fungi and lichens usually reproduce by means of spores. Lichens can reproduce when soredia (algal cells surrounded by a few strands of fungus) break off and form new lichens wherever they land.

Green plants Green plants have roots, stems, leaves, and often flowers. Most green plants need several basic things to grow: light, air, water, warmth, and nutrients. Like algae, green plants depend upon photosynthesis for food. The nutrients, primarily nitrogen, phosphorus, and potassium, are obtained from the soil. These minerals may not be in large supply. In some seashores along dry, desert coasts, plants have evolved that can absorb mist from the nearby ocean through their leaves. The mist provides enough water for them to survive.

Green plants grow in all seashore zones. Those that grow in the lower zone are sea plants, and those that grow in the upper zone are land plants.

Common green plants Green plants found along the seashore include seagrasses, such as eelgrass, turtlegrass, and paddleweed. These plants live in the lower zone but are similar to land grasses. They have roots, and they bloom underwater. Beds of seagrass occur in sandy or muddy shores in calm areas protected from currents, such as in lagoons or behind reefs. They attract a wide variety of grazing marine animals. These grasses help slow the movement of the water and prevent erosion of the shoreline.

The high salt content of the seawater in the intertidal zone makes it hard for land plants to adapt. Grasses such as marsh grass, cord grass, and salt hay grass thrive here. In salt marshes, glassswort and sea lavender are found.

Sand dunes are too dry to support much plant life, but there are many species of plants that grow on dunes. These include sandwort, beach pea, marram grass, yellow horn poppy, beach morning glory, and sea oats. Sea oats grow a long taproot (main root) that may extend more than 6 feet (1.8 meters) into the sand to reach water. Dunes may support trees, such as pine and fir, if the soil is stable and freshwater is available.

Mangrove trees grow in estuaries in tropical zones where the shoreline is muddy. Some are small, shrublike plants; others are tall and produce large forests. Mangroves have two root systems. One is used to anchor them in the muddy bottom. The other is exposed to the air from which it pulls oxygen because the soil in mangrove swamps is usually low in oxygen.

Growing season The growing season depends upon where the seashore is located. Near the equator, growth continues throughout the year. In northern regions, there is a spurt of growth during the summer. In moderate climates, growth begins in the spring and continues throughout the summer.

Reproduction Green plants often depend upon the wind and insects to carry pollen from the male part of a flower, called a stamen, to the female part of a flower, called a pistil, for reproduction. This process is called pollination. Others send out stems from which new plants sprout.

Endangered species Coastlines are popular places for people to live, but plants can suffer when their natural habitat is disturbed. Algae and seagrasses can be destroyed by polluted water. Dune grasses are easily trampled by beachgoers or destroyed by dune buggies and other off-road vehicles. When visitors pick flowering plants, they limit the plants' ability to reproduce. Many mangrove forests are being reduced due to erosion of the deltas.

Bursting at the Seams

Crabs, like other crustaceans, have a hard outer shell. This shell does not grow as the crab grows. Any crab that outgrows its current shell has to get rid of it fast or feel the pinch. This shedding of the shell is called molting.

Molting is caused by hormones, chemical messengers in the crab's body that help split the shell so the crab can climb out. While it runs around shell-less, the crab is in greater danger from predators. Eventually, its skin hardens and soon it has a new, ready-made suit of armor.

Animal Life

The kinds of animals that live along a particular shoreline are determined by zone (upper, intertidal, or lower) and the type of surface (rocky, sandy, or muddy). This is true of different species of the same animal. Hermit crabs, for example, live comfortably in the lower and intertidal zones of rocky shores, whereas mudcrabs prefer muddy estuaries.

Lower zone animals, including sea anemones, shrimp, and small fish, are underwater almost all of the time. Upper zone animals, such as ghost crabs, prefer dry conditions and live on land. The middle, or intertidal, zone along rocky shores supports the most life-forms, in spite of its being the harshest zone of all. Cockles, barnacles, clams, sea urchins, and fish are all found in this zone. Some, such as clams, survive during low tide when they are exposed to air by closing their shells to keep from drying out. Their shells also help them survive battering by the waves. Others find shelter in small pools where water collects in depressions and among rocks when the tide goes out, remaining there until high tide returns.

On depositional (sandy or muddy) shores, animals are constantly shifted around by the motion of water because there is nothing on which to anchor themselves. Many burrowing animals, such as clams and lugworms, survive by digging into the sand. They often have siphons (tubes) through which they can draw in oxygenated water and food.

Life on eroding shores is even harder; animals must attach themselves firmly to rocks or be washed away by the battering waves. The crevices of the rocks are homes to soft-bodied animals such as sea anemones. Dark caves found on many rocky shorelines provide a place where many sea creatures may take shelter.

Microorganisms Seashores are home to many kinds of microscopic animals. Most microorganisms are zooplankton (tiny animals that drift

A hermit crab moves on a sandy beach in Mozambique, southern Africa. They search the shallow water for food. IMAGE COPYRIGHT ECOPRINT, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

with the current) that live on the surface of the sea. They include protozoa, nematodes (worms), and the larvae or hatchlings of animals that will grow much larger in their adult form. Some zooplankton eat phytoplankton and, in turn, are preyed upon by other carnivorous (meat-eating) zooplankton.

Bacteria Bacteria are found in every zone along the shore and provide food for microscopic animal forms. They also help decay the dead bodies of larger organisms.

Much of the water that washes up on a beach sinks downward again and the sand or gravel acts as a filter. Particles of matter suspended in the water become trapped between the grains of sand. These particles become food for the bacteria that consume them and then release other nutrients into the water.

Invertebrates Animals without backbones are called invertebrates. Many species are found along the seashore. Crustaceans and mollusks, invertebrates that usually have hard outer shells, are well adapted to the intertidal zone because their shells help prevent them from drying out during low tide. Soft-bodied animals, such as sea anemones and small octopi, prefer rocky shores where they can hide in rock crevices and survive low tide in rock pools.

Periwinkles are a kind of snail that live on the rocky shores, they mostly eat algae. IMAGE COPYRIGHT VAIDE SESKAUSKIENE, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Sand dunes are home to many insects, such as wasps, ants, grasshoppers, and beetles. Some insects and spiders burrow into the sand during the heat of the day and hunt for food at night.

Common seashore invertebrates Tiny crustaceans called sand hoppers, or beach fleas, live on sandy beaches where they can hop several feet (1 meter) in one jump even though they are only 0.6 inch (1.5 centimeters) long. They are not real fleas and do not bite humans or other animals but live on seaweed and dead matter.

On rocky shores, many species of periwinkles are common. Periwinkles are snails that come in several colors, including brown, yellow, and blue. They eat algae and can live many days without water. A periwinkle has a hinged door in its shell that it can shut, keeping moisture locked inside.

On muddy shores, mangrove forests are often homes for oysters and barnacles, which attach themselves to the trunks and roots of trees. Snails and crabs are common in saltwater marshes.

Food Invertebrates may eat phytoplankton, zooplankton, or both. Mollusks draw seawater in through their siphons and filter out the tiny creatures, which they then consume. Some invertebrates eat plants or larger animals. Starfish, for example, dine on mollusks.

Reproduction Most invertebrates are insects, which have a four-part life cycle. The first stage is spent as an egg. The second stage is the larva. It may be divided into several stages between which there is a

Plastic is not a Nutrient

Sea turtles love to snack on jellyfish. Unfortunately, plastic bags puffed with air resemble jellyfish and a sea turtle that can not distinguish between the two, can die. Plastic bags cannot be digested and moved through the animal's body; the bags and other plastic garbage block an animal's digestive tract. Dolphins, seals, whales, and other animals are also in danger from plastics. A gallon-sized plastic milk bottle, a plastic float, a garbage bag, and other items were found wedged in the digestive tract of a dead sperm whale.

shedding of the outer skin casing. A caterpillar is an example of an invertebrate in the larval stage. The third stage is the pupal stage, during which the insect lives in yet another protective casing, like a cocoon. Finally, the adult breaks through the casing and emerges. In most cases, the young are not cared for by the parents. Survival often depends on the absence of predators.

The marine iguana lives both on land and in the sea. IMAGE COPYRIGHT VOVA POMORTZEFF, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Reptiles Reptiles, such as lizards and snakes, are cold-blooded vertebrates. Only one species of lizard, the marine iguana, lives both in the sea and on the seashore. Pine lizards may be found in dry areas on sandy beaches where pitch pines grow. Some species of snakes, such as the hognose snake, live among sand dunes on sandy shorelines, preferring the dry conditions found there. Fowler's toads can be found on upper beaches. A saltwater crocodile makes its home in the waters of Southeast Asia, where it lives along muddy seashores near the mouths of rivers. A notable reptile at the seashore is the sea turtle.

Common seashore reptiles Sea turtles can be distinguished from land turtles by their flippers, which enable them to swim, and by their tolerance for salt water. Green sea turtles are migrators, traveling as far as 1,300 miles (2,094 kilometers) to return to a particular breeding area where they lay their eggs.

The saltwater, or estuarine, crocodile lives in northern Australia and in the region stretching from the east coast of India to the Philippines. It is one of the largest species of crocodiles; average males grow 17 feet (5 meters) long. Most crocodiles float on the surface of the water close to the shoreline where they wait for prey to wander past. The saltwater crocodile is also known to swim out to sea.

Food Turtles eat soft plants, as well as small invertebrates such as snails and worms. Turtles have no teeth. Instead, they use the sharp, horny edges of their jaws to shred the food enough so they can swallow it.

Sand dune snakes are carnivorous and catch mice and other small prey. They also eat the eggs of nesting shorebirds. Saltwater crocodiles are carnivorous and feed primarily on fish and turtles. They have been known to attack and eat humans.

Reproduction Both snakes and turtles lay eggs. Turtles lay theirs in holes on a sandy shore, which they then cover over with sand. After the nest is finished, the female abandons it, taking no interest in her offspring. Six weeks later the eggs hatch and the young turtles make a run for the ocean and swim away.

Fish Fish are primarily cold-blooded vertebrates (dependent on the environment for warmth) having gills and fins. Gills are used to draw in water from which oxygen is extracted. Fins are used to help propel the fish through the water.

Most fish found along the seashore are smaller varieties that can live in shallow water or in tide pools. They are dull in color to match the sand or gravel background. Some have suckers (suction cups) on their undersides that allow them to cling to rocks so they will not be washed away. The exception is the flounder, which can grow to be quite large and spends its entire life in the shallow pools of water on the beach.

Schools of barracuda cruise the shorelines. They are voracious predators. IMAGE COPYRIGHT SERGEY POPOV V, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Common seashore fish Flatfish live in shallow water on sandy shorelines. They begin life looking like other fish; however, as they mature, they lie on one side and become flattened. The eye on the bottom side migrates to the top until both eyes are looking upward.

Mudskippers are small amphibious (am-FIB-ee-yuhs) fish that live along muddy shores, especially near mangrove forests. Amphibious means that they can live either on land or in water. When the tide is in, mudskippers swim and breathe underwater. When the tide is out, they breathe air and use their fins to hop among the tree roots.

Other shoreline fish include spiny dogfish, which are a species of shark, common anchovies, killifish, northern pipefish, bluefish, northern barracuda, striped bass, cowfish, four-eyed butterfly fish, northern sea robins, barred sea perch, and kelp greenlings.

Food Some fish, such as the clingfish of Chile, attach themselves with suckers to rocks and scrape off any animals or plants on which they feed before letting the waves carry them back out to sea. Predatory fish, such as some sculpin species, may lie in wait in rock pools until the tide brings in their prey. Most shoreline fish are slow swimmers that feed on other slow-moving creatures, such as shrimp.

Reproduction Fish reproduce by laying eggs. Some build nests and care for the new offspring, while others carry the eggs with them until they hatch, usually in a special body cavity or in their mouths. For example, female seahorses lay their eggs in a pouch on the underside of the male, who then carries the eggs until they hatch.

Some fish, such as the Atlantic menhaden, live in deep waters for most of the year. During breeding season, they appear in large numbers in shallower shoreline waters where they lay their eggs.

Birds Birds are vertebrates. Most seabirds remain near land where they can nest during breeding season. Many have adapted to marine environments by means of webbed feet for swimming and special glands for removing excess salt from their blood.

Shorebirds, such as oystercatchers and gulls, feed or nest along the coast and prefer hunting in shallow water. Their feet are usually webbed and most migrate. Lesser golden plovers, for example, spend their winters in South America and their summers in the Arctic. During their travels, they may stop to rest on the eastern coast of the United States.

Common seashore birds include pelicans and gulls, who feed from the shallow waters. IMAGE COPYRIGHT MICHELLE RADIN, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Wading birds, such as the American avocet, are often found along muddy shores. They have long legs, wide feet, long necks, and long bills that are useful for nabbing fish and other food.

Waterfowl are birds that spend most of their time on water, such as ducks. Their legs are positioned closer to the rear of their bodies, which is good for swimming, but awkward for walking. As a result, they waddle as they walk. Their bills are designed for grabbing vegetation, such as grasses, on which they feed.

Farther inland, common land birds, such as red-winged blackbirds, may live among dune grasses where they hunt for insects.

Food All birds that live along the seashore are carnivorous. Most eat fish, squid, or zooplankton, and they live where food is plentiful. Several species, such as eiders, dive to the bottom of shallow water where they feed on shrimp, worms, or crabs. Other species, such as sanderlings, dash into the water as waves retreat in order to grab prey before it has a chance to get away. Some, like gulls, are scavengers that eat dead matter other creatures have discarded.

Reproduction Sea and shorebirds usually nest on land. Some nest in huge colonies on the ground, others dig burrows, and still others, like the kittiwakes, prefer ledges on a cliff. Like ordinary land birds, they lay

The oystercatcher is an example of a shorebird. They have strong beaks for prying open shells. IMAGE COPYRIGHT GRAEME KNOX, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

eggs and remain with the nest until the young are able to survive on their own. Some live and feed in one area and migrate to another for breeding. Birds that nest on sandy shores tend to lay speckled or blotchy eggs in beige and brown colors that blend in with the sand and pebbles in order to protect the eggs from predators.

Common seashore birds Birds that live along the seashore include gulls, plovers, pelicans, boobies, puffins, ruddy turnstones, sandpipers, sanderlings, and penguins. There are only a few true sea ducks, including the eider and the scoters.

Mammals Mammals are warm-blooded vertebrates that have at least some hair and bear live young nursed with the mother's milk. Few mammals live permanently along the seashore. Those that do, such as mice, are small and prefer dry areas out of reach of the tide. Many land mammals, such as skunks, rats, foxes and raccoons, may visit the shoreline at night in search of food. They prefer low tide, when mussels, oysters, worms, and tide pool animals are exposed and easy to find.

Food Many mammals are carnivorous. Raccoons, for example, hunt crabs, shrimp, and turtle eggs. Sea otters eat mussels and other invertebrates, using rocks and other "tools" to break the shells. Some mammals, such as mice, are omnivorous, which means they eat both plants and animals, such as insects. Herbivores, like rabbits, eat only plants.

Reproduction Mammals bear live young. Most have only one offspring at a time, but rodents, such as mice, have large families. The young are nursed with milk produced by the mother until they are able to find food on their own. This is true whether the mammal spends some of its time in the water or all of its time on shore.

Common seashore mammals Sandy beaches are home to cottontail rabbits, voles, and mice. Rocky shores in some regions provide breeding and socializing areas for seals and walruses. Sea otters are found along rocky coastlines. Muskrats are common along muddy shores that have marshy areas.

Endangered species All species of sea turtles are endangered. Sea turtles lay their eggs on beaches which make the eggs easily hunted and/or destroyed. The eggs are a popular food in many parts of the world, as

Sea otters inhabit coastlines, eating invertebrates such as this crab. IMAGE COPYRIGHT KIM WORRELL, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

are the turtles themselves. Turtles are also threatened by pollution, which can destroy their food supply.

In certain areas, other animals are endangered, including the starlet sea anemone, the osprey, the Eskimo curlew, the Dalmatian pelican, and the West Indian manatee.

Human Life

In times past, the oceans were the only transportation route between the eastern and western hemispheres. The oceans have always been important for fish and other food resources. For these reasons, people have usually lived within an easy distance of the seashore. More than one third of the world's population still lives in or around cities located on the coast. By 2025, it is expected that two out of three people will live within 62 miles (100 kilometers) of a seashore.

Impact of the seashore on human life People have always lived along the seashore, so it has had an important effect on human life.

Food Various species of seaweed are used by people as food and in food preparations. Humans eat many of the animals found along shorelines, including crabs, mussels, clams, oysters, shrimp, fish, turtles, and turtle eggs. Anchovies, tiny fish that live in shallow coastal waters, are one of the most important commercial fishes.

Fish farming, the raising of fish for commercial purposes, is an important industry of the coastlines.

Harbors Many of the world's great cities, such as New York, San Francisco, Hong Kong, Tokyo, and London, are harbor cities. From these harbors, millions of tons of goods are shipped around the world, which has an important effect on the world economy. Many factories are built near harbors in order to keep transportation costs low. Passenger ships and ferries use these harbors to carry people from place to place.

Energy The ocean is a source of energy. The energy in the tides, for example, can be harnessed to produce electrical power. The first tidal power station was developed in an estuary in France in 1966. Turbines (engines with fanlike blades) are built into a dam that spans the estuary. As the tides flow in and out of the estuary, they turn the turbine blades. Plans have been made to build a similar station on the estuary of the Severn River in England.

Other types of power stations may be located by the sea because seawater is used to cool the machinery.

Minerals and metals Minerals and metals are other important resources of coastlines. Rocks, sand, and gravel dredged from the sea bottom, especially off the coasts of England and Japan, are used in the construction of roads and buildings. Along the Namibian coast of southwest Africa, diamonds are mined.

Recreation Beaches, sandy beaches in particular, attract millions of visitors each year. Huge hotels, resorts, and amusement parks have been built along coastlines where people can enjoy sailing, swimming, fishing, walking, camping, and lying in the sun.

Impact of human life on the seashore While the benefits that coastlines have brought to human life are many, human life has brought many impacts to the seashores.

Use of plants and animals After World War II (1939–45), the technology of commercial fishing improved and a growing population increased the demand for fish as a food source. By the 1970s, major food species, including anchovies and certain shellfish, had been greatly reduced.

Fish farms have helped maintain certain species of commercially popular fish. Shellfish, such as oysters, mussels, scallops, and clams, are

Surf's Up!

Next to swimming and sunbathing, surfing is probably the best-known beach activity. Surfing involves being carried on the sloping portion of a wave as it moves toward shore. It is especially popular along the coasts of Hawaii, California, New Zealand, Australia, South Africa, Puerto Rico, Peru, Great Britain, and Brazil, where wave conditions are the most favorable.

For body surfing, a person swims toward shore, matching the speed of a particular wave. The swimmer then stiffens the body in order to provide a flat surface that will glide on the front of the wave and carry him or her to shore. To surf using a board, the person lies on the board and paddles until the board is going as fast as the chosen wave. The person then stands up and rides the wave toward shore.

Surfboards weigh between 24 and 40 pounds (11 and 18 kilograms) and are 6 to 12 feet (1.8 to 3.7 meters) long. Surfing requires good balance, timing, and coordination because boards can reach speeds of 35 miles (56 kilometers) per hour.

Surfing originated in Hawaii, where it was used by nobility as part of a religious ceremony. In 1920, Duke Kahanamoku of Hawaii, the Olympic swimming champion, formed the first surfing club and almost single-handedly made the sport popular.

the most commonly farmed. Crabs, lobsters, shrimp, salmon, trout, and tilapia are farm raised, but to a lesser extent. The output of fish farms (aquaculture) from 1990 to 2002 increased at a rate of 10 percent per year, producing 38,000,000 tons (34,473,020 metric tons) in 2002.

Other sea plants and animals have been taken as souvenirs or art objects, reducing their numbers. When seashells are taken from dead animals, no harm is usually done. However, many shells available commercially are taken from living animals and the animals are left to die.

Preventing natural changes Homes and other structures built along coastlines are threatened when storms, erosion, and other natural processes change the seashore. Sometimes, people try to work against nature by building walls and other barriers to protect these structures. Often, these efforts make the problems worse. As the natural shape of a shoreline is changed, waves may become stronger and do even more damage.

Changes made by humans to protect one shoreline may cause unexpected, undesirable changes in another. Walls built to prevent the sand from being washed away from beaches at Ocean City, Maryland, for example, kept that sand from naturally rebuilding the beaches on

Humans can change the appearance of shorelines when using it for housing, ports, and recreation. IMAGE COPYRIGHT NATALIA BELOTELOVA, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Assateague Island to the south. The erosion rate averages 10 feet (3 meters) per year since the walls were built. So far about 9 miles (15 kilometers) of the inlet have been affected.

Overdevelopment Use of the land for harbors, recreation, and housing has changed the appearance of many shorelines. The popularity of beaches has caused many to become crowded with so many people and buildings that wildlife has either been destroyed or frightened away. In many places, the coastline has lost its natural beauty and has become just another part of a big city.

Dune buggies, dirt bikes, and other recreational vehicles destroy plants and scare animals. Hikers can destroy vegetation, and even well-meaning people who wish only to observe nature can frighten animals or upset the natural rhythms of their lives.

Quality of the environment In 2006, there were 25,643 occasions when beaches were closed and swim advisories were in effect in the United States because the water was polluted. Most ocean pollution caused by humans is concentrated along the seashore. Sewage and industrial wastes are dumped from coastal cities, adding metals and chemicals to the water. Discarded items, such as plastic bags and food wrappers, pose health hazards for both animals and people.

Insecticides (insect poisons) and herbicides (weed poisons) reach the oceans when the rain washes them from fields and they are carried by rivers to the sea. These poisons often enter the food chain and become concentrated in the bodies of some organisms. Fertilizers and human sewage are also a problem. They cause phytoplankton to reproduce rapidly. When the plants die, their decaying bodies feed bacteria. The bacteria reproduce and use up the oxygen in the water, and other organisms, such as fish, soon die.

Industrial accidents and waste are other problems. It is estimated that 1,435 people died and thousands were paralyzed when they ate fish contaminated with mercury, a metallic element used at a nearby factory at Minamata Bay in Kyushu, Japan in 1953. Oil spills from tanker ships are another danger, as is oil from oil refineries, pipelines, and offshore oil wells. Power plants and some industries often dump warm water into the oceans, causing thermal (heat) pollution. Organisms that require cooler water are killed by the increase in the water temperature.

Agriculture, construction, and the removal of trees digs up the soil. The rain then washes the soil into streams and rivers. Eventually, it enters the ocean to collect as sediment in coastal areas. Some organisms that cannot survive in heavy sediment, such as clams, die. Organisms that inhabited preagricultural, preconstruction, and forested areas also die.

Pollution can travel, so that problems caused by one country may damage the shoreline environment in another.

World's Worst Oil Spill

Oil spills are especially hazardous to coastlines. The oil is carried ashore by ocean waves and tides, but when the water retreats back to the sea, the oil remains. Thick deposits stick to the shoreline and coat the plants and animals that live there. Oil mats the feathers of birds and the fur of swimming animals leaving the creatures unable to keep warm, and causing many to die of the cold.

The world's worst oil spill took place in 1989 when the ship *Exxon Valdez* was wrecked in Prince William Sound, Alaska. Eleven million gallons (42 million liters) of oil were spilled. Over time, the oil spread out, covering 10,000 square miles (25,900 square kilometers) of ocean and 1,200 miles (1,940 kilometers) of coastline. It is estimated that as many as 6,000 otters, whales, dolphins, and seals, and 645,000 birds died. Three nearby national parks and three national wildlife refuges were also affected.

Native peoples In most parts of the world, people often settled near coastlines where fish were plentiful and the ocean offered a means of transportation. Since the mid-twentieth century, desirable seashore locations have been taken over by tourists and non-native residents. Few native peoples have continued to live traditional lifestyles. Many have gone to live in cities or adopted more contemporary ways of life. Among those that have tried to maintain important elements of their traditional cultures are the Samoans and Native American tribes of the northwest coast.

Kon-Tiki

Norwegian explorer Thor Heyerdahl (1914–2002) was convinced that ancient peoples once sailed across 4,300 miles (6,900 kilometers) of the Pacific Ocean from Peru and colonized Polynesia. To test his theory, he set out with a crew of six people to duplicate the feat in 1947. The expedition lasted 101 days and was carried out on a large raft called the *Kon-Tiki*.

Named for a legendary Inca Sun-god, the *Kon-Tiki* was patterned after sailing rafts used by the ancient Incas, native peoples who lived in what is now Peru. The raft measured 45 feet (13.7 meters) long in the center and tapered to 30 feet (9.1 meters) at the sides. No metal was used. Instead, the nine thick balsa logs were tied together with hemp rope. Two masts supported a large rectangular sail, and a bamboo cabin was built in the center for shelter.

On April 28, 1947, the raft was set adrift 50 miles (80 kilometers) off the coast of Peru. Ninety-three days later, the *Kon-Tiki* sailed past the island of Puka Puka, which lies east of Tahiti. On August 7, 1947, after the *Kon-Tiki* crashed into a reef in the Tuamoto Archipelago, the voyage was finished, but Heyerdahl had proved his point. The *Kon-Tiki* is now in a museum in Oslo, Norway. Heyerdahl wrote about the voyage in his book, *Kon-Tiki*.

Samoans The Samoa Islands lie in the Pacific Ocean southwest of Hawaii. The largest island, Savai'i, has an area of only 659 square miles (1,707 square kilometers), so the seashore is easily accessible and an important part of everyone's life.

The people of Samoa are Polynesian and closely related to the native people of Hawaii and New Zealand. Although the islands have felt the influence of Europe and then America since 1722, traditional Samoan culture has remained very important.

The Samoan economy is based on agriculture. Crops include corn, beans, watermelons, bananas, and pineapples. Fish have always been an important food source for local families, but fishing was not commercially important until 1953 when a tuna cannery was built in the town of Pago Pago.

Native Americans of the Northwest Coast The Columbia and Fraser Rivers in North America open into the Pacific Ocean, and each year millions of Pacific salmon return to those rivers to breed. This ample supply of fish led many native peoples to settle there, including the Tlingit, Haida, Tsimshian, Kwakiutl, Nootka, and Salish. The area proved rich in other wildlife as well. Mussels, clams, oysters, candlefish, herring, halibut, and sea lions were available from the sea. The land provided food, such as

Two Haida war canoes paddle up Gastieau Channel near Juneau, Alaska in June 1998, from Ketchikan, Alaska, to take part in Celebration '98, a biennial celebration of Native culture, dance and song. AP IMAGES.

moose, mountain sheep and goats, deer, and many small animals, as well as roots and berries.

Products of the seashore, such as shells, dried fish, fish oil, and the dugout canoes built for transportation were considered a source of wealth. Religious beliefs were based on mythical ancestors whose images were carved on totem poles, boats, masks, and houses.

By 1900, traditional ways of life were disappearing, but the people remained on or near their ancient lands. Many now work in forestry. Some groups are restoring native customs, and there is interest in a return to arts-and-crafts production.

The Food Web

The transfer of energy from organism to organism forms a series called a food chain. All the possible feeding relationships that exist in a biome make up its food web. Along the seashore, as elsewhere, the food web consists of producers, consumers, and decomposers. These three types of organisms transfer energy within the seashore environment.

Phytoplankton are among the primary producers along the lower zone of the seashore. They produce organic (derived from living organisms) materials from inorganic chemicals and outside sources of energy, primarily the Sun. Other primary producers include seagrasses and plants that live in the upper zone.

Zooplankton and other animals are consumers. Animals that eat only plants are primary consumers. Secondary consumers eat the plant-eaters.

Puffins are chunky birds with large bills. They shed the colorful outer parts of their bills after the mating season, leaving a smaller and duller beak. IMAGE COPYRIGHT TOM CURTIS, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

They include zooplankton that eat other zooplankton. Tertiary consumers are the predators, like starfish and mice that eat the second-order consumers. Some, such as mice and humans, are omnivores, organisms that eat both plants and animals.

Decomposers feed on dead organic matter and include some insects and species of crabs. Bacteria also help in decomposition.

A serious threat to the seashore food web is the concentration of pollutants and dangerous organisms that become trapped in sediments where organisms lower on the food chain feed. These life-forms become food for consumers higher on the food chain, and at each step in the food chain the pollutant becomes more concentrated. Finally, when humans eat contaminated sea animals, they are in danger of serious illness. The same process is true of diseases such as cholera, hepatitis, and typhoid, which can survive and accumulate in certain sea animals, and are then passed on to people who eat those animals.

Spotlight on Seashores

Point Reyes National Seashore

Location: Pacific coast of California, north of San Francisco
Area: 64,546 acres (25,818 hectares)

Point Reyes National Seashore Point Reyes National Seashore is part of a large peninsula (arm of land) extending off California into the Pacific Ocean. Its broad beaches are backed by tall cliffs and forested hills and valleys.

The shoreline along the California coast was carved by volcanoes and earthquakes, and earthquakes are still common. During the 1906 earthquake that struck San Francisco, the Point Reyes peninsula moved more than 16 feet (5 meters) to the northwest. Shifting sands, islands, and steep underwater cliffs are all found in the region.

Wave action is strong and has carved the offshore rocks into rugged shapes. Rip currents and a pounding surf make swimming dangerous in some places. In sheltered areas, quiet bays and lagoons have formed, which are enclosed by sand dunes and grass-covered lowlands.

Sea stars, horseshoe crabs, and other invertebrates live along the shore, and Point Reyes is popular with seabirds, sea otters, and sea lions. Migrating gray whales can often be seen passing in the distance.

Padre Island National Seashore Padre Island National Seashore is located on a barrier island that stretches about 110 miles (177 kilometers) along the coast of Texas in the Gulf of Mexico. Padre Island borders the Laguna Madre, a shallow lagoon. The park consists of sandy beaches and dunes as high as 40 feet (12 meters).

Many waterfowl winter on the island. Other birds include herons, terns, egrets, brown pelicans, and white pelicans. Since the mid-1980s, scientists have been bringing eggs from endangered sea turtles here to help rebuild the population.

The island is uninhabited by people and is the largest undeveloped beach remaining in the United States (exclusive of Alaska and Hawaii).

Virgin Islands National Park Virgin Islands National Park occupies about over 7,000 acres (2,833 hectares) of St. John, the smallest of the three main Virgin Islands, and takes in many tiny islands offshore. Many caves and grottoes are found along the shoreline.

The park's white sandy beaches are backed by steep mountains and valleys covered with tropical forests. The highest point of land is Bordeaux Peak at 1,277 feet (389 meters). Mangrove forests grow along the shore, while a number of coral reefs support tropical fish and other marine creatures such as sea urchins offshore. The only native mammals living within the park are bats.

Pre-Columbian Indians once lived here, and relics of their culture can be found. For two centuries, the islands were a base for pirates, and some people believe that buried treasure may still be hidden in the region.

Acadia National Park Acadia National Park in Maine includes parts of Mt. Desert Island, Isle au Haut, Schoodic Peninsula, and several smaller islands. It is a rugged, rocky shoreline backed by mountains. Coniferous forests grow close to the water. Mt. Desert Island features Cadillac Mountain, which is 1,530 feet (466 meters) high.

More than 10,000 years ago, the shoreline was much further out than it is now. For that reason, the region is often called the drowned coast. Its cliffs were once inland mountains, and the park includes a fjord called Somes Sound. Some areas show the rubble left by glaciers.

Padre Island National Seashore
Location: Coast of Texas, along the Gulf of Mexico
Area: 133,918 acres (53,567 hectares)

Virgin Islands National Park
Location: Caribbean Sea, east of Puerto Rico
Area: 7,000 acres (2,833 hectares)

Acadia National Park
Location: Atlantic coast of Maine
Area: 41,634 acres (16,653 hectares)

Wave action of the North Atlantic is strong here, and huge blocks of granite have been dislodged from the cliffs and lie along the shore. Anemone Cave, a large cavern 89 feet (27 meters) deep, has been carved into the solid rock by wave action. In sheltered areas, small bays and coves have formed.

The intertidal zone has many tide pools and is home to a host of creatures, including sea stars, periwinkles, anemones, sea urchins, and crabs. Seabirds, such as gulls, guillemots, and ducks are common.

Cape Hatteras National Seashore Cape Hatteras National Seashore in North Carolina is a chain of low, narrow, barrier islands, including Bodie, Hatteras, and Ocracoke. At some points the islands are as much as 30 miles (48 kilometers) off the North Carolina coast. The seashore area has 70 miles (110 kilometers) of beaches, dunes, and salt marshes and is a wildlife refuge.

Cape Hatteras National Seashore is known for severe storms. Off the Cape, which is a promontory (arm of land) on Hatteras Island, cold northern currents meet the warmer Gulf Stream as it moves through the Atlantic. Their collision breeds stormy conditions. Diamond Shoals, a region of shallow water, has been called the "graveyard of the Atlantic" because so many ships have been wrecked there. Their remains are still visible from the shore.

The Cape has had a lighthouse since 1803. The present lighthouse, which is the tallest in the continental United States at 191 feet (58 meters), has been in operation since 1870. Years of severe weather, including hurricanes, threatened to destroy it and it was finally moved inland.

Cape Hatteras National Seashore
Location: Atlantic coast of North Carolina
Area: 30,350 acres (12,282 hectares)

Rhine River Delta
Location: North Atlantic coast of the Netherlands
Area: Approximately 900 square miles (2,340 square kilometers)

Rhine River Delta The Rhine River Delta in the Netherlands is a vast area connecting the Rhine River with the North Sea. Centuries ago, it was marshy and dotted with small islands. Storms often swept in from the North Sea, and the land was frequently flooded.

Drawn by the plentiful supply of fish, the Dutch began living on the islands in the Rhine River Delta around 450 BC. They built hills of earth on which to live during flood times. In the twelfth century, special walls called dikes were constructed to keep out the sea. Later, Dutch soldiers fighting in Middle Eastern lands learned a trick from the Arabs who used windmills to pump water for growing crops. The Dutch figured the same process could be used in reverse to drain the land. Soon, the Dutch had built dikes around the marshy areas and used windmills to pump the water out into the ocean. By the 1700s, the Netherlands had 10,000 windmills. In later years, steam-driven pumps replaced the windmills, which have become a symbol of the Netherlands and are popular among tourists.

In 1919, work began to reclaim a freshwater lake, called the Zuider Zee, that had been invaded by the sea. A dam was completed in 1932 that allowed the seawater to drain, reclaiming 407,724 acres (165,000 hectares) of land. By 1937, the lake was fresh again and was renamed Ijsselmeer.

A winter storm in 1953 hit and destroyed many dikes along the coast, killing hundreds of people when the land was flooded. The Dutch built more dams across the delta to prevent such an accident from repeating. The project was finished in 1986, closing all the estuaries in the area except two that are used for shipping. Protected by dikes, dams, and pumps, the Rhine Delta's fertile soil is now valuable farmland. About 25 percent of the Netherlands is below sea level during high tide. The lowest spot, 22 feet (6.7 meters) below sea level, lies to the northeast of Rotterdam.

Fjords of Western Norway Usually found in northern regions along mountainous coasts, fjords are valleys eroded by glaciers. When the glaciers retreated or melted, the ocean poured in, creating long, narrow, deep arms of water that project inland. The fjords of western Norway have high, steep walls; often rising to 3,280 feet (1,000 meters). The crowns of these surrounding cliffs may be heavily forested. Cascading waterfalls sometimes drop from great heights, adding to the spectacular scenery.

The depth of the fjords depends upon how much erosion took place below sea level. The deepest along western Norway is the Sognefjord at 4,291 feet (1,304 meters). Inland, some fjords end in glaciers, from which huge chunks of ice break off creating icebergs.

Fjords are not always penetrated by cold ocean water and are usually ice free in the winter, except along the coast where the water may be more shallow and freezes more rapidly. Gales (high winds) are frequent on the western coast.

Inland fjord valleys are rich in vegetation, especially coniferous trees, lowland birches, and aspens. The coast attracts large numbers of food fishes, such as cod, herring, mackerel, and sprat. Woodcocks and migratory birds, as well as lemmings, hares, red foxes, and reindeer, are common.

Fjords of Western Norway
Location: North Atlantic coast of Norway
Individual Length: As much as 114 miles (182 kilometers)

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American Oceans Campaign, 2501 M Street, NW Suite 300, Washington D.C. 20037-1311, Phone: 202-833-3900, Fax: 202-833-2070, Internet: http://www.oceana.org.

Center for Marine Conservation, 1725 De Sales St. NW, Suite 600, Washington, DC 20036, Phone: 202-429-5609 Internet: http://www.cmc-ocean.org.

Coast Alliance, P.O. Box 505, Sandy Hook, Highlands, NJ 07732, Phone: 732-291-0055, Internet: http://www.coastalliance.org.

Environmental Defense Fund, 257 Park Ave. South, New York, NY 10010, Phone: 212-505-2100; Fax: 212-505-2375; Internet: http://www.edf.org.

Envirolink, P.O. Box 8102, Pittsburgh, PA 15217; Internet: http://www.envirolink.org.

Environmental Protection Agency, 401 M Street, SW, Washington, DC 20460, Phone: 202-260-2090; Internet: http://www.epa.gov.

Friends of the Earth, 1717 Massachusetts Ave. NW, 300, Washington, DC 20036-2002, Phone: 877-843-8687; Fax: 202-783-0444; Internet: http://www.foe.org.

Greenpeace USA, 702 H Street NW, Washington D.C. 20001, Phone: 202-462-1177; Internet: http://www.greenpeace.org.

Olympic Coast Alliance, P.O. Box 573 Olympia, WA 98501, Phone: 360-705-1549, Internet: http://www.olympiccoast.org.

Sierra Club, 85 2nd Street, 2nd fl., San Francisco, CA 94105, Phone: 415-977-5500; Fax: 415-977-5799, Internet: http://www.sierraclub.org.

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Tundra

In the northern lands close to the Arctic, and on the upper slopes of high mountains all over the world, a unique biome called the tundra is found. The word tundra comes from a Finnish word *tunturia*, which means barren land. In this cold, dry, windy region where trees cannot grow, the often bare and rocky ground supports only hardy, low-growing plants, such as mosses, sedges, heaths, and plantlike lichens (LY-kens), which give it a greenish-brown color. During the brief spring and summer, flowers burst into bloom with the warmth of the sun, dotting the landscape with color.

Tundra covers about 20 percent of Earth's surface. Almost all tundra is located in the Northern Hemisphere (the half of Earth above the equator); small areas do exist in Antarctica in the Southern Hemisphere. Antarctica is much colder than the Arctic and the ground is usually covered by ice. Conditions are seldom right for tundra to form there.

The tundra is not an environment with high biodiversity. (An area with high biodiversity supports a wide variety of plants and animals.) Only a few species of plants and animals live in the tundra, but those few, such as lichens and mosquitoes, are found in great numbers.

The tundra may seem bleak and unfriendly, but it can be a place of eerie beauty, especially in the Arctic during the winter. Winter nights last for weeks and are often lit up by the blue, red, and green colors of the Aurora Borealis, or northern lights. The Aurora Borealis occurs when energy-charged particles from the sun enter Earth's atmosphere and create flashes of light. The Arctic is called the Land of the Midnight Sun because, during the summer, the sun never sets below the horizon and daylight lasts for twenty-four hours.

WORDS TO KNOW

Hypothermia: A lowering of the body temperature that can result in death.

Peat: A type of soil formed from slightly decomposed plants and animals.

Permafrost: Permanently frozen topsoil found in northern regions.

Pingos: Small hills formed when groundwater freezes.

Rhizomes: Plant stems that spread out underground and grow into a new plant that breaks above the surface of the soil or water.

Soredia: Algae cells with a few strands of fungus around them.

Thermokarst: Shallow lakes in the Arctic tundra formed by melting permafrost; also called thaw lakes.

Tussocks: Small clumps of vegetation found in marshy tundra areas.

How Tundra Develops

Tundra forms primarily because of climate. In the Arctic, winters are long and cold, and summers are short and cool. This allows limited plant growth. On high mountains, tundra forms when the location is right to produce the necessary climate.

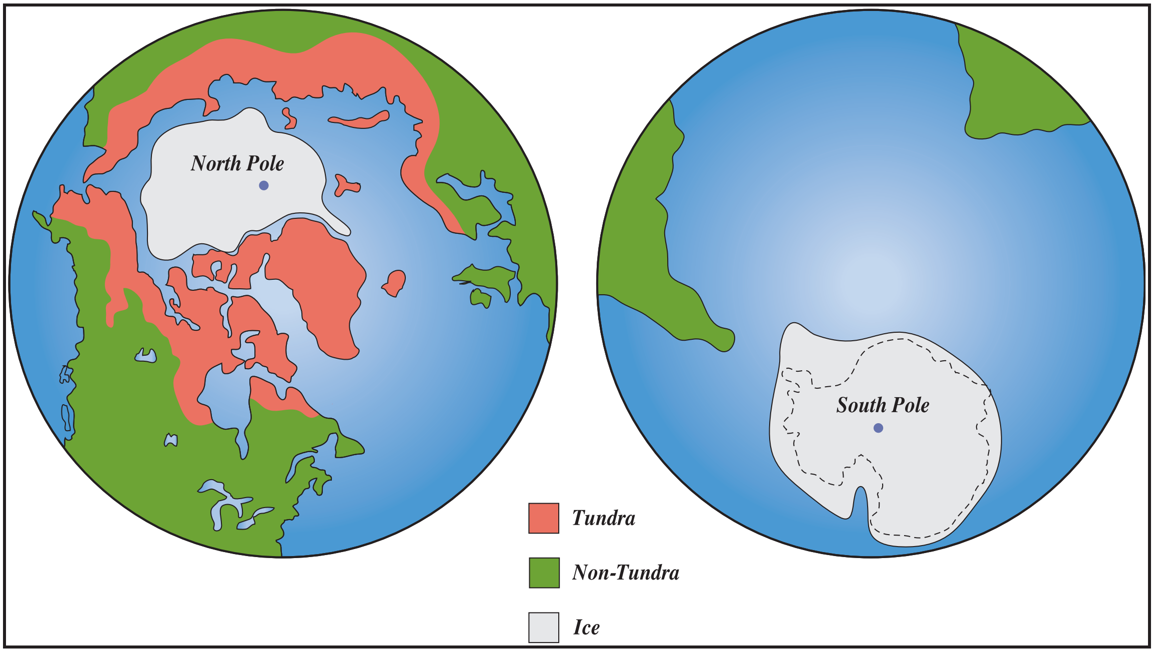
The lack of soil in a tundra region may be due to erosion (wearing away) from wind and rain. During the Ice Ages more than 10,000 years ago, glaciers scraped away any soil, leaving only bare rock.

Kinds of Tundras

There are two types of tundra: Arctic and alpine. Arctic tundra is found near the Arctic Circle. Alpine tundra forms on mountaintops where the proper conditions exist.

Arctic tundra Several characteristics are typical of Arctic tundra. One is the polar climate, which has an average July temperature of not more than 50°F (10°C). Arctic tundra is far from the equator. Sunlight hits Earth here at an angle and must pass through more atmosphere. This means the sunlight that reaches the soil contains less energy per square foot (square meter) than at the equator.

Another characteristic of the Arctic tundra is a deep layer of permanently frozen ground called permafrost. Generally, fewer than 18 inches (45 centimeters) of tundra soil thaws during the cool summer. Below that the ground remains frozen. Water from melting snow cannot drain into



the frozen ground, and little evaporates in the cool summer air. As a result, the water becomes trapped on the surface.

Arctic tundra is found on all three northern continents close to or above the Arctic Circle and near the Arctic Ocean. In Asia, Arctic tundra is found in the part of Russia known as Siberia. In Europe, it is found in northern Scandinavia, which includes the countries of Norway, Sweden, and Finland. In North America, Arctic tundra is found in northern Alaska and Canada. Some Arctic tundra is located on islands, such as Greenland and Iceland.

Alpine tundra Alpine tundra is found at the tops of mountains above the timberline, the point above which trees cannot grow. The timberline and tundra are found at different elevations (heights) in different mountain ranges. The farther the mountains are from the equator, the lower the elevation needed for tundra to form.

Compared to Arctic tundra, alpine tundra gets more rain and its soil drains better because of the sloping terrain. It also gets more sunlight because it is found at lower latitudes (a distance north or south of the equator, measured in degrees) where day and night are more equal in

Storms on the Sun

The Aurora Borealis, or Northern Lights, occur when there are "storms" on the sun. These storms shoot out streams of energy-charged particles called electrons. When the electrons enter Earth's atmosphere and collide with each other, a flash of light occurs. The magnificent Aurora Borealis is created when billions of these collisions occur at the same time.

length than in the Arctic. Usually, there is no lower layer of permafrost in alpine tundra.

Alpine tundra is found in the Rocky, Cascade, and Sierra Mountains in North America, the Andes Mountains in South America, the Alps and Pyrenees in Europe, and the Himalayas in Asia.

Climate

Both Arctic and alpine tundra have very cold climates. Variations in temperature ranges may occur because of location. Arctic tundra located high above sea level (the average height of the sea) has a colder climate. If tundra is found near the coast, ocean currents can affect the temperature. For example, the North Atlantic Drift, a warm ocean current, warms the coast of northern Scandinavia. The coast of northeastern Canada is colder due to the influence of the Labrador Current, an icy current that mixes with the warmer waters. Arctic tundra is windy, with winds ranging between 30 to 60 miles (48 to 97 kilometers) per hour.

Unlike Arctic tundra, alpine tundra has a more moderate climate that varies with latitude and altitude. The farther away from the equator, the colder the temperature becomes. The higher the altitude, the colder and

Elk can be seen on the alpine tundra. IMAGE COPYRIGHT GEORGE BURBA, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

windier the climate. At 15,000 feet (4,500 meters) above sea level, the climate changes as much as if it were located 10° latitude farther north. High altitude also means that the atmosphere is thin, which results in little oxygen present in the air.

Arctic Heat Wave

Sometimes the weather can become quite warm during summer on the Canadian tundra, warm enough for people to swim in the Arctic Ocean. In 1989 the temperature rose above 90°F (32°C) at Coppermine in the Northwest Territories. These temperature increases are caused by warmer water brought into the Arctic Ocean by northward-moving currents, such as the Irminger current. This current is a branch of the Gulf Stream, which is a warm ocean current that begins in the Gulf of Mexico.

Temperature The Arctic tundra is one of the driest and coldest biomes on Earth. It is generally described as a cold desert. January temperatures average from –4° to –22°F (–20° to –30°C). In Siberia, an extremely cold area in north central Asia, winter temperatures may drop to –40°F (–30°C) or lower. Scandinavian tundra is relatively warm, and the winter temperatures may average 18°F (–8°C). Average arctic temperatures in summer range from 38° to 50°F (3.3° to 10°C). Although daytime temperatures above 90°F (32°C) have been recorded, normally the average does not rise much above 50°F (10°C) because temperatures drop significantly in the evenings.

Antarctica's small tundra region is even colder, with an average annual inland temperature of –70°F (–56°C).

Alpine tundra is cold, but temperatures are more moderate than in the Arctic. Elevation affects the temperature in an alpine tundra, and mountains have been described as "open windows letting the heat out." Scientists estimate that for every 1,000 feet (305 meters) in height, the temperature drops 3.6°F (–15.8°C).

Winter temperatures in an alpine tundra rarely fall below 0°F (–18°C) and summers are cool. The average annual temperature in the Peruvian mountains seldom falls below 50°F (10°C). On Alaskan mountains, temperatures in January average about 8°F (–13°C) and almost 47°F (8°C) in July.

Precipitation Arctic tundra is similar to a cold desert in that it receives little precipitation (rain, snow, or sleet), usually fewer than 10 inches (25 centimeters) annually. Most precipitation falls as snow in winter.

Alpine tundra receives more rain than Arctic tundra, but the water runs rapidly off the mountain slope, leaving any dry soil to blow away in the wind.

Geography of Tundras

The excessively cold temperatures affect the geography of the tundra.

Landforms In Arctic tundra, water trapped in the top layer of soil does strange things to the landscape. The water freezes each winter, and the ice melts each summer. When water freezes, it expands (takes up more space). When ice melts, it contracts (shrinks). This yearly expansion and contraction cracks and breaks rocks, creating hills, valleys, and other physical features.

A pingo is a small circular or oval hill formed when a pool of water under the ground freezes and forces the soil up and out. The hill may grow a few inches taller every year. Some pingos are as high as 300 feet (90 meters) and more than half a mile (800 meters) wide. Stone circles are formed by piles of rocks that have been moved into a more or less circular shape by the expansion of freezing water.

Polygons are cracks in the ground that take on geometric shapes because of the freezing and thawing action. If the soil is rocky, the rocks can be pushed up through the cracks, making the geometric shapes even more distinct.

Irregularly shaped ridges, called hummocks or hammocks, are formed when large blocks of ice meet and one slides over the top of the other. When the ice melts, the ground is uneven. Their heights range from 65 to 100 feet (20 to 30 meters).

Areas of bare, rock-covered ground on alpine tundra are called fell-fields. They are often formed when rock and soil slide down a slope.

Elevation Most of the low, rolling plains of the Arctic tundra are located about 1,000 feet (300 meters) above sea level, whereas alpine tundra is found high on mountains above the tree line. In northern latitudes, close to the Arctic Circle, arctic tundra may begin at about 4,000 feet (1,200 meters) above sea level. In more southern mountains, alpine tundra usually begins around 12,000 feet (3,657 meters) above sea level.

Soil The soil in Arctic tundra has two layers. The surface layer is called the active layer because it freezes in winter and thaws when the weather warms up. This layer is shallow, its depth ranging from about 10 inches to 3 feet (25 centimeters to 1 meter). About 15 percent of the active layer is well drained because it is located on stony or gravelly material, on slopes,

Permafrost lake in tundra above the Arctic Circle in Canada. IMAGE COPYRIGHT OKSANAPERKINS, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

and in elevated areas. The remaining 85 percent of the active layer is usually poorly drained and remains wet.

The lower, or inactive, layer of soil stays frozen throughout the year and is called permafrost. Permafrost prevents the water captured in the active layer of soil from draining away. Made of such materials as gravel, bedrock, clay, or silt, permafrost reaches depths of 300 to almost 2,000 feet (90 to 609 meters). In Russia on the Taimyr Peninsula, permafrost goes very deep, reaching 1,968 feet (600 meters), whereas permafrost on tundra near Barrow, Alaska, descends to only 984 feet (300 meters).

Tundra soil is generally poor in nutrients, such as nitrogen and phosphorous. In some areas where animal droppings are plentiful and fertilize the soil, vegetation is lush. Near the southern edge of the Arctic tundra, for example, the soil can be boggy. Bog soil contains little oxygen, is acidic, and is low in nutrients and minerals.

Treasures in the Ice

The remains of plants and animals millions of years old have been discovered in tundra permafrost. Tree stumps found on Canadian tundra could still be burned for fuel.

The bodies of many mammoths have been perfectly preserved in the Siberian tundra. These large animals, now extinct, are related to modern-day elephants. In the early 1900s, a mammoth was discovered with its head sticking out of a bank of the Berezovka River. Although wolves had eaten part of his head, its tongue and part of its mouth were still preserved. In its mouth, between its teeth, were the remains of the sedge and buttercups it had been eating. Both of these plants still grow on the tundra.

Alpine tundra rarely has a permafrost layer, but the soil does freeze and thaw as in the Arctic. When permafrost does occur in alpine tundra, it is at higher elevations where temperatures are colder and in areas where mud, rock, and snow slides are common.

Similar to arctic soil, alpine soil is stratified (arranged in layers). Alpine soil has good drainage because of the sloping terrain. However, fierce winds may dry it out and blow it away. Some alpine regions are covered with material so weathered and thin it cannot be classified as soil.

Water sources Melting snow in Arctic tundra has nowhere to go since it cannot sink into the ground, and temperatures never get warm enough for it to evaporate. As a result, in summer the tundra is covered with marshes, lakes, bogs, and streams. Marshes are a type of wetland characterized by poorly drained soil and plant life dominated

by nonwoody plants. Bogs are a type of wetland that has wet, spongy, acidic soil, called peat.

Thermokarst, or thaw lakes, are shallow bodies of water unique to Arctic tundra and formed by melting ground ice. Permanent rivers flow into tundra, like the Mackenzie and Yukon rivers in Alaska, and the Lena, Ob, and Yenisei in Siberia. These rivers are partially or completely covered by ice for about six months of the year.

In alpine tundra, water from melting snow and glaciers usually runs off the slopes. In areas where depressions in the ground occur, ponds and marshes form. Mountain streams, which flow during the five warm months of the year, are formed by surface runoff and from springs.

Nature's Hothouses

Since the tundra growing season is so short, some plants get a head start by making use of hothouses formed by the sun. Darker colors absorb more heat, so the sun melts some snow close to the dark soil. This forms small caves in the snow. The floor is the soil and the roof is a dome of snow that remains frozen. Poppies and saxifrages grow well in these miniature hothouses because the air inside is warmer than the outside air.

Plant Life

Permafrost and the yearly freezing and thawing, break up plant roots and make it impossible for trees and other tall plants to survive on Arctic tundra. Plant growth in the alpine tundra is also affected by freezing and thawing. The sloping terrain, exposure to more light, and the lesser amount of moisture available affect the kinds of plants that grow in mountainous alpine tundra.

Despite the harsh conditions, about 1,700 kinds of plants grow on tundra, including sedges, reindeer mosses, liverworts, and grasses. The 400 varieties of flowers found add a wide range of colors.

Algae, fungi, and lichens It is generally recognized that algae (AL-jee), fungi (FUHN-ji), and lichens do not fit neatly into the plant category.

Algae Algae play an important role in the tundra. Most species have the ability to make their own food by means of photosynthesis (foh-toh-SIHN-thuh-sihs); the process by which plants use the energy from sunlight to change water and carbon dioxide from the air into sugars and starches. Other species of algae absorb nutrients from their surroundings. In the Arctic, algae are found in the ocean and wetland areas. In alpine tundra, algae grow on unmelted snow. These algae have a red pigment.

Algae may reproduce in one of three ways. Some split into two or more parts, with each part becoming a new, separate plant. Others form spores (single cells that have the ability to grow into a new organism). A few reproduce sexually, during which male and female cells unite to create a new plant.

Fungi Fungi are plantlike organisms that cannot make their own food by means of photosynthesis; instead they grow on decaying organic (derived from living organisms) matter or live as parasites on a host. Fungi are decomposer organisms that, together with bacteria, are responsible for the decay and decomposition of organic matter. One of the most important roles of fungi in tundra is formation of lichens.

Fungi form spores to reproduce. These spores are carried from one location to another on the air or by animals.

Lichens Lichens are the most common tundra plant, with about 2,500 species growing in Arctic and alpine regions. Lichens are combinations of algae and fungi living in cooperation. The fungi surround the algae cells. The algae obtain food for themselves and the fungi by means of photosynthesis. It is not known if the fungi aid the algae organisms, but they may provide them with protection and moisture. In harsher climates, lichens are often the only vegetation to survive. They have no root system so they can grow on bare rock, adding beauty to the tundra with their colors of orange, red, green, white, black, and gray.

Despite the short growing season, lichens thrive in their harsh environment. They freeze in winter, but continue to grow in spring. Lichens often live for hundreds of years, although growth is slow.

Like algae, lichens can reproduce in several ways. If a spore from a fungus lands near an alga these two different organisms can join together to form a new lichen. Lichens can also reproduce by means of soredia (algal cells surrounded by a few strands of fungus). When soredia break off and are carried away by wind or water they form new lichens wherever they land.

Reindeer lichen, also called reindeer moss, is one of the most common tundra plants. It provides a key source of food for Arctic plant-eating animals like caribou and reindeer. Another common type of lichen, called the British soldier, has a tall stalk with a red cap on top, which makes it resemble its namesake.

Green plants Most green plants need several basic things to grow: light, air, water, warmth, and nutrients. Light, air, and water provide almost all of their needs. The remaining nutrients, primarily nitrogen, phosphorus, and potassium, are obtained from the soil. While water is plentiful for tundra plants, warmth, which brings on the growing season, is available for only a short period of time.

Plants in the tundra grow low to the ground. This helps them stay warm and protected from the high winds. Since the tundra receives little precipitation, many plants have nearly invisible hairs on their leaves, stems, and flowers that reduce moisture loss. Their roots form a dense mat just under the surface of the ground enabling them to quickly draw moisture from melting snow and store it in their leaves. Many plants grow in a tight clump, which helps traps heat. Tussocks are thick clumps of plants, such as cotton grass, that grow to about 1 foot (30 centimeters) in height and are found in marshy areas.

Cozy Flowers

Some tundra insects find warmth and shelter by hiding inside flowers. Inside a buttercup, for example, the temperature can be 40°F (4°C) warmer than the outside air. During the day, these flowers lean toward the sun, following its path to get as much heat as possible. For that reason, they are called heliotropes, which means "to turn toward the sun."

Some alpine plants have deeper roots that help prevent soil erosion. Many alpine plants have red leaves because of a coloring matter called anthocyanin. This special pigment protects plants from the dangers of ultraviolet radiation (a form of harmful light within the sun's rays). Twice as much ultraviolet radiation reaches alpine tundra than regions at sea level because of the high elevation.

Common green plants Typical flowering plants on Arctic tundra include Arctic lupine, yellow poppy, saxifrage, Arctic campion, Lapland rhododendron, buttercup, campanula, and barberry. The Labrador tea, a hardy evergreen, is very common. Non-grass perennials, called forbs, lie dormant all winter with their growth buds protected underground.

The rosette plant is well-designed to survive in harsh Arctic weather. This type of plant forms rings of leaves around a central growth bud. The leaves protect the fragile bud and help to trap insulating snow in winter and dew during the dry growing season.

Examples of alpine tundra plants include sorrel, saxifrage buttercup, plane leaf, tufted hair grass, alpine bluegrass, and alpine sandwort. The alpine azalea is a member of the heath family called a cushion plant. Cushion plants grow in groups, tightly clumped together, so the plants on the outer edge can protect the ones in the middle. At the lower edges of alpine tundra grow Krummholz, dwarf trees kept small by the cold, icy, windy environment.

The small area of tundra located on the Antarctic Peninsula is home to the only two flowering plants found on that continent, pearlwort and hair grass.

Labrador tea, a hardy evergreen, is common on the tundra. IMAGE COPYRIGHT MASLOV DMITRY, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Growing season The growing season on tundra is short, lasting from six to ten weeks in June, July, and August. In the Arctic, during those weeks the sun shines almost all day. As a result, plants must make the most of the opportunity for growth.

Green plants may be annuals or perennials. Annuals live only one year or one growing season. Perennials live at least two years or two growing seasons. The above ground portion of perennials often appears to die in winter, while the roots remain dormant underground. The plant returns to "life" in the spring when the weather becomes warmer. Most tundra plants are perennials that can flower quickly and take advantage of the short growing season.

Reproduction Perennials reproduce and spread by forming seeds. Some plants are self-pollinating, which means that the male and female reproductive cells come from the same plant. Most perennials need pollen from another plant. This process is aided by insects attracted to the colors of the flowers and that travel between flowering plants transferring the pollen from the male reproductive part of a plant, called the stamen, to the female reproductive part of another plant, called the pistil. Strong winds help scatter the fertilized seeds.

Some plants in the more northern, colder Arctic tundra reproduce by budding and division rather than by flowering since the growing season is short. In budding, a new plant develops from any part of the parent. In division, a piece of the parent plant breaks off and develops into a new plant. Forbs reproduce in this way. Mountain sorrel reproduces through rhizomes (RY-zohmz), rootlike stems that spread out under the soil and form new plants.

Endangered species Tundra plants are very fragile. In the Arctic, traffic during construction of the Alaskan oil pipeline that began in the 1970s damaged the tundra, which did not recover until long after construction had ended. In alpine tundra, beautiful plants are endangered because people pick them or step on them. Their short growing season makes it difficult for them to be easily replaced.

The Penland alpine fen mustard, a small perennial with white flowers found on the Rocky Mountain tundra in Colorado, grows on wetlands fed by melting snowfields. This little plant is endangered because mining and off-road vehicles, which leave tracks in the soil, divert the flow of water away from its habitat.

Heather and lichen vegetation. IMAGE COPYRIGHT VERA BOGAERTS, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Animal Life

The tundra is a permanent home to only a few species of animals because of its harsh environment. Birds, caribou, and red deer, for example, spend only the summers there. The Antarctic tundra has the fewest animals.

For tundra animals, size is an important factor in preventing heat loss. When an animal's appendages (arms, legs, tails, ears) are small, they lose less heat. The Arctic fox, for example, has small ears, short legs, and a short tail. This means there is less area from which body heat can escape.

Microorganisms Microorganisms are small organisms, such as a protozoan or bacterium, that cannot be seen with the human eye. Bacteria live in the active layer of tundra soil and help decompose dead plants and animals.

Invertebrates Invertebrates are animals that do not have a backbone. Clams, mussels, snails, crabs, and shrimp are invertebrates found in marshy areas. The primary invertebrate population of tundra consists of a few species of insects that are present in large numbers. There are more mosquitoes on the Arctic tundra, for example, than anywhere else on Earth, because the wet summers provide perfect breeding conditions. As many as one million mosquitoes can be found in an area 1 square yard (0.8 square meter). Springtails are the dominant organism of tundra soil. Populations can reach in excess of several billion per acre (0.405 hectare).

Arctic insects are darker in color than insects elsewhere, which is better for absorbing heat from the sun. They also have more hair to help them conserve heat and energy. Many tundra insects do not have wings.

Arctic tundra moss and berries turn red and green in autumn. IMAGE COPYRIGHT FLORIDASTOCK, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Some scientists believe this helps them conserve energy. Others believe it is because they would not be able to fly in the strong winds. The springtail, for example, has a springlike appendage on its stomach. It hits the ground with this spring and then bounces to a new location, much like a person can on a pogo stick. Those that can fly, stay close to the ground so they do not get blown away.

Common invertebrates Two common tundra insects are the aphid and the midge. Aphids, also called plant lice, feed on the sap from willows, saxifrages, sedges, and other plants. Most aphids are wingless females. During the warmer weather, the females produce live young, which are also all females, without mating. In the fall, they give birth to a generation that includes both males and females. After mating, the females of this generation lay eggs that hatch in the spring to start new colonies.

Midges are small insects with two sets of wings. One set is for flying and the other for balance. Unlike the mosquito, midges do not bite. They are so numerous that their mating swarms are said to look like tornado clouds and can obstruct the vision of any animal they encounter. Midge larvae live in watery areas and feed on algae and dead matter. Midges can grow very old, some living as long as six years.

While Arctic tundra is infamous for its mosquito population, alpine tundra is known for butterflies and biting flies. In the small area of tundra in Antarctica, spiderlike mites and wingless springtails are found. The largest animal living here is the midge, which is half an inch (1.27 centimeters) long.

Food Some insects eat plants and some eat other insects or animals. Male mosquitoes, for example, feed on plant juices, while females feed on the blood of animals and humans. During the summer, plenty of water is available in Arctic tundra because the surface water cannot sink into the frozen ground. In alpine tundra, surface water and streams are sources of water.

Mosquito Antifreeze

Mosquitoes can keep themselves from freezing in winter the same way people keep their cars from freezing—with antifreeze. Some mosquitoes replace the water in their bodies with a chemical called glycerol. Their bodies are able to manufacture glycerol from other substances such as fat. With this protection, they can spend the winter under the snow and live to bite again the following summer.

Reproduction The first part of an insect's life cycle is spent as an egg. The second stage is the larva, the immature or young stage of a developing insect. This second part of the life cycle may be divided into several steps between which the developing insect grows larger and sheds an outer skin casing. Some larvae store fat in their bodies and do not need to seek food. During the third, or pupal, stage, the insect's casing offers as much protection as an egg. Finally, in the last stage, the adult emerges. These stages can occur quickly or take up to several years. In the colder tundra regions the process is slow. The midge, for example, takes two years to complete its life cycle in tundra, but only six months in warmer climates.

In order to mate, some wingless, female insects in tundra emit a scent into the air that attracts males, who can fly. In species where both males and females fly, the insects swarm in great numbers. Some males are able to recognize females by the vibrations given off by the beating of their wings. In some species of Arctic insects, like the caddis fly and midge, males are few. Females carry all the necessary genetic information and reproduce without having to mate with a male. The eggs are stimulated to develop by chemical means rather than by male sperm.

Amphibians Amphibians, such as salamanders and frogs are vertebrates (animals with a backbone) that live at least part of their lives in water. Most amphibians are found in warm, moist, freshwater environments and in temperate zones (areas in which temperatures are seldom extreme). Only a few amphibians live in Arctic tundra and none are usually found in alpine tundra.

Common amphibians The Siberian salamander is the only salamander found in the tundra. This hardy creature spends winter frozen in the permafrost in Russia and has been found alive at depths of almost 50 feet (14 meters).

The Hudson Bay toad lives in Arctic tundra in North America. The wood frog, which is common in Alaska, is sometimes found on the tundra as well.

Food Amphibians use their long tongues to capture prey. Even though they have teeth they do not chew, but swallow their food whole.

Bumblebee Heating System

Arctic bumblebees are able to produce their own heat. They vibrate their wing muscles so fast that they actually warm their bodies. When enough bees get together, this combined body heat is able to warm their nests to 86°F (30°C).

As larvae, amphibians eat mostly plants, such as algae, or tiny water animals. Adults eat insects, worms, and other amphibians or small animals.

Reproduction Mating and egg-laying for most amphibians takes place in water. Male sperm are usually deposited in the water and must swim to the eggs, which are encased in a jellylike substance. Here the sperm penetrate the eggs. As the young develop into larvae and young adults, they often have gills and require a watery habitat. Once they mature, they develop lungs and can live on land. Salamanders often have internal fertilization in which male sperm penetrate the eggs while they are still in the female.

Some amphibian females carry their eggs inside their bodies until they hatch. Certain species lay eggs and protect them until they hatch. Others lay eggs and abandon them.

Most amphibians reach maturity at three or four years. They breed for the first time about one year after they become adults.

Reptiles Reptiles are cold-blooded vertebrates, such as lizards and snakes. Cold-blooded animals are unable to regulate internal body temperature and depend on their environment for warmth. They are usually most active when the weather is warm. No reptiles do well in extreme temperatures, either hot or cold. Many hibernate (remain inactive) during the winter.

Common reptiles The viviparous lizard in Europe and the garter snake in North America live on the tundra borders. Only one reptile, the European viper, lives north of the Arctic Circle on the Scandinavian tundra.

The European viper is a highly venomous (poisonous) snake found only in Europe, Asia, and Africa. It grows to an average length of 19 to 23 inches (50 to 60 centimeters), but some may attain 31 inches (80 centimeters). It eats small vertebrates, such as rats or mice, and sometimes birds. The viper paralyzes or kills its prey by injecting it with venom.

This viper tolerates cold better than any other member of the viper family. It is able to move at temperatures as low as 37°F (3°C) and cannot thrive in weather much warmer than 93°F (34°C). During the coldest parts of winter it hibernates, hiding from 6 to 19 inches (15 to 50

The viviparous lizard lives on the tundra borders. IMAGE COPYRIGHT VOLKOV ILYA, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

centimeters) underground in areas that are moist, like rock crevices or rodent dens.

Food Most reptiles are carnivorous (meat-eating). Snakes consume their prey whole and often alive without chewing, taking an hour or more to swallow a large victim. Many have teeth that are curved backward so their prey cannot escape.

Reproduction Most reptiles reproduce sexually with the male depositing sperm in the body of the female, and their young come from eggs. Reptiles in tundra give birth to live young that have developed inside eggs contained in the mother's body, which protects them from the cold.

Fish Fish are cold-blooded vertebrates that live in water. They have fins for swimming and breathe through gills. Some tundra fish, like the Arctic char, spend their entire lives in tundra lakes and streams. Others, like the salmon, live in the ocean, returning to tundra streams to breed.

Common fish The Arctic char, a relative of the salmon, is found in both the sea and polar lakes in Arctic tundra. Char are dark colored with light spots and blend in with their environment. Their size ranges from 2 to 10 pounds (0.9 to 4.5 kilograms). Those that live in the sea swim up the rivers of the Arctic tundra to freshwater lakes where they lay their eggs.

Graylings, another relative of the salmon, live in tundra streams. Pike and trout spend some time in tundra.

Reproduction Fish reproduce by laying eggs. Usually, the female releases eggs and the male releases sperm and fertilization takes place in the water. The eggs can cling to rocks or float on the water's surface. Some species dig depressions in the ground under the water and deposit eggs there.

Salmon spend three to five years at sea before they return to the same stream where they were born to spawn (reproduce). When spawning is complete, they die.

Birds Birds are vertebrates. Hundreds of species of birds visit Arctic and alpine tundra, but few stay all year long. The snowy owl, the raven, the willow ptarmigan (TAHR-mah-guhn), and the rock ptarmigan are permanent residents of the Arctic. One of the only species of birds found in both the Arctic and alpine areas is the water pipit.

Many species of birds migrate to the Arctic tundra to breed. They fly south in winter and return to the tundra in summer with their mates to build nests and lay their eggs.

Common birds Water birds that migrate to the Arctic tundra include geese, ducks, and even a few swans. The Arctic tern makes the

The water pipit is the only species of bird found in both the Arctic and alpine tundras. IMAGE COPYRIGHT CARLOS ARRANZ, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

The Ptarmigan is one of the few permanent residents of the Arctic. IMAGE COPYRIGHT TTPHOTO, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

longest journey, flying from Antarctica in a round trip of at least 25,000 miles (40,000 kilometers).

Birds that summer on Arctic tundra include gulls, plovers, redpolls, buntings, loons, warblers, red phalaropes, and skuas. Some of these birds eat insects, which are plentiful during the summer. The skua and the gyrfalcon are predators that eat other birds and small animals.

Alpine tundra is home to many birds. Some species of hawks, eagles, and falcons live above the tree line and eat small mammals, such as rodents and hares, or smaller birds. Wall-creepers eat insects and may move lower down the mountain in winter. Alpine cloughs, wall-creepers, and accentors stay close to the ground to avoid the winds. Some finches remain at higher elevations all year.

The ptarmigan is a brownish-colored grouse with feathered legs and feet. It is one of the few birds that spends nearly all year on the tundra, both in Arctic and alpine regions. Its feathers grow very dense and turn white during the winter. Sometimes ptarmigans sleep in the snow in order to preserve body heat, which is more easily lost out in the open. The ptarmigan is a plant-eater and, in very severe winter weather, travels below the timberline in search of food.

Food The marshy areas of tundra provide plenty of water for all animals, and many birds feed on water insects. Plant material, shellfish, and carrion are other sources of food. The golden eagle feeds on small mammals, usually rabbits. It will also eat other birds and carrion.

The Monster of the Mountains

The Sherpa people of Nepal believe they share their mountain home with a creature even larger than the yak—the Yeti, or abominable snowman. A yak can weigh up to 2,200 pounds (1,000 kilograms), which would make a Yeti huge. Many footprints have been found and a number of Sherpa claim to have seen one, yet no Yeti, dead or alive, has ever been proven to exist.

Reproduction All birds reproduce by laying eggs. Usually, male birds must attract the attention of females by singing, displaying feathers, or stomping their feet. After they mate and the female lays her eggs, she sits on them to keep them warm until they hatch. Two species of Arctic swimming birds, the red phalaropes and the northern phalaropes, reverse these roles. The female shows off to attract the attention of the male. After they mate, she usually lays four eggs. The male sits on them until they hatch and then he cares for the young.

Some birds, like the least sandpiper, take advantage of the short breeding season by rotating parental duties. After the female lays the eggs, the male mates with one other female and then returns to the nest of the first female to take care of the young. This frees the female to mate again with another male, ensuring that enough young birds will be born to survive the cold weather.

Many birds, like the ruddy turnstone, shelter along rocky coasts and shores. Their nests are hidden in depressions in the ground, called scrapes, that they line with tundra grasses.

Mammals Mammals are warm-blooded vertebrates (having a backbone). They maintain a consistent body temperature, are covered with at least some hair, and bear live young that are nursed with milk.

In a barren land such as tundra, animals that live there all year long must be very clever in seeking shelter from both predators and the cold. Mammals adapt in several ways. Many, like the Arctic fox, grow a thick, insulating cover of fur, which not only keeps them warm, but also helps to camouflage them. Their coats turn white in winter and brown in summer so that they blend in with the environment making it hard for predators to see them. Most mammals accumulate deposits of fat under their skins, which insulates them and provides a source of nourishment when food is scarce. Some mammals, like the Alaskan marmot and the Arctic ground squirrel, wait out the cold by hibernating until the weather turns warm.

Alpine mammals must adapt to mountain living as well as the cold. Ibexes, for example, have soft pads on their feet that act like suction cups to help them grip the steep rocks. Since there is less oxygen high in the mountains, the yak and mountain goat have developed large hearts and lungs and have more red blood cells (which absorb oxygen) than would be found in similar animals living closer to sea level. These features allow their bodies to use oxygen more effectively. Alpine mammals often seek shelter in forests below the tundra or in rock caves underground. Yaks and musk oxen can withstand the worst cold the tundra has to offer.

The Arctic fox is found in both alpine and arctic tundras. IMAGE COPYRIGHT SAM CHADWICK, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Common mammals About forty-eight species of land mammals live on tundra. Large Arctic mammals include musk oxen, caribou, barren-ground grizzly bears, wolves, and polar bears. Smaller Arctic mammals include hares, lemmings, and squirrels. Large alpine mammals include mountain goats, wild sheep, ibexes, red deer, and snow leopards. Pikas, marmots, chinchillas, hares, and viscachas are among the smaller alpine mammals.

Food Mammals are either meat-eaters or plant-eaters. Musk oxen and caribou are among the tundra's plant-eaters. Reindeer lichen, is the bulk of the caribou's diet. Other vegetarians include lemmings, hares, and squirrels.

The barren-ground grizzly and the polar bear are primarily meat-eaters, feeding on seals, birds, and fish. The polar bear supplements its diet with seaweed and grass. Wolves eat hares, musk oxen, and caribou. Foxes eat lemmings, stoats, ptarmigans, and hares.

Reproduction Mammals give birth to live young that have developed inside the mother's body. All young are nursed with milk produced by the mother and must remain close to her until they are able to find their own food. Some mammals, like lemmings, are helpless at birth, while others, like caribou, are able to walk and even run almost immediately. Some are even born with fur, and with their eyes open.

Polar bears give birth in dens under the snow in the Arctic tundra. Caribou calves are born in the open as the animals migrate north in spring to their tundra feeding grounds. Musk oxen are also born on open tundra.

Caribou Caribou are migratory herd animals that spend their summers in the Arctic and their winters in the forest on the edge of tundra. Their winter coat is long and thick to protect them from freezing. Their hooves are wide and flat for easy movement over the snow and ice.

Caribou is a Native American word that means "wandering one." Caribou migrate farther than any other land animal, some traveling over

Lemmings on the March

Lemmings are small plant-eating mammals related to field mice. During winter they live in the shelter of burrows in the snow, feeding on seeds and plants. In years when there is a good food supply, lemmings reproduce rapidly. One female may give birth four or five times a year and have six to ten offspring at a time. After three to five good years the tundra is swarming with lemmings. Before long, there is not enough food for all of them. Suddenly, small groups of lemmings begin to run north.

As the lemmings run, they are joined by more and more of their fellow creatures until thousands are on the march. They cross mountains and rivers, never stopping to eat. Many starve to death along the way and many more are eaten by predators.

When the survivors reach the Arctic Ocean they jump in the water. Some scientists say it is an attempt to cross it, some say it is to get food. The tundra seems empty, but the lemmings that stayed behind soon repopulate it.

1,200 miles (2,000 kilometers) each year. They are found in Alaska, the Yukon, and the Northwest Territories of Canada.

In summer, caribou feed on birch leaves and grasses. In the winter they feed on lichens, a staple in their diet, and any remaining twigs or tree buds.

Caribou give birth to their young on the Arctic tundra, usually in the same area the herd has used for many years. After only three days, a calf is strong enough to travel with the adults.

Pika The pika is a small, short-legged animal that resembles a cross between a guinea pig and a rabbit. An adult pika weighs about 5 ounces (140 grams), has rounded ears, a stocky body, and almost no tail. Pika's have sharp, curved claws to help it climb on rocks, and the pads of their feet have thick fur to ensure stable footing when they leap from rock to rock. Protected against the cold by its thick fur, a pika can remain active all winter.

Pikas have two sets of upper teeth, one behind the other. These teeth are sharp and used for tearing the plants they eat for food. They produce two different types of droppings. One is a special, jellylike pellet the animal eats to gain extra nutrients that may not have been absorbed the first time the food went through its digestive tract. The second is a normal solid pellet of unneeded waste matter.

Pikas are found in rocky areas, usually at high altitudes. Colonies are formed around large boulders or rock slides where vegetation can be found nearby. They collect plant materials in the summer and make "haystacks," which are their winter food stores. These haystacks consist of their chief food-plant, the avens, a member of the rose family.

Male and female pikas mark an area in which they live all year. They have two to six young in a litter and produce two litters every summer. Females generally do not leave their territories, but the males roam in search of food.

Pikas are most common in Asia, especially northeast Siberia, but a few species are found in Arctic tundra and alpine tundra in Alaska.

Musk oxen When winter comes to the Arctic tundra, most animals head for shelter. Some go south while others go underground. Musk oxen do neither. Their thick coats keep them warm in the worst Arctic weather, and they remain on the open tundra all winter long, foraging under the snow for plants to eat. In spring, musk oxen shed their warm undercoat, called qiviut. This hair is highly prized by local women who gather it as it is shed each year to knit it into garments, such as scarves, to be worn or sold.

The Warmest Coat on the Tundra

The chinchilla is a small South American rodent that lives high in the Andes Mountains. It has one of the warmest coats found in nature, a beautiful blue-gray fur. Usually, a mammal grows only one hair per pore, but chinchillas have as many as sixty hairs growing in each pore. As a result, their fur is extremely thick and soft, keeping the chinchilla warm in the cold, even during the freezing alpine nights.

Wolves Wolves live together in familylike packs of five to twenty members on both Arctic and alpine tundra. They are sociable animals, which helps the pack remain together. Each pack is led by a male and female called the alpha (lead) pair. These two wolves produce the yearly litter and other members of the pack help care for the pups. Pack members may watch the young so the mother can join in a hunt. When a kill is made, a wolf can store partially digested meat in its stomach. This is then regurgitated (vomited) and fed to the pups or is shared with a nursing mother.

Endangered species Overhunting and overfishing are two of the most common reasons animals in tundra are endangered. Their habitats are also being disrupted as more people move into the area. Some animals, like the snow leopard and the chinchilla, are rarely seen in the wild, but are raised in captivity in zoos or on fur farms.

The Eskimo curlew is a dark-colored shorebird with a long, downward-curving bill. At one time, the nesting grounds of the curlew were on Arctic tundra of Alaska and Canada and on the coast of the Chukotka Peninsula in Siberia. The bird is endangered because of unrestricted hunting. Its habitats have been destroyed as land is cultivated for farming and used for grazing herds. Scientists do not know

Pikas are mammals found in the rocky tundra regions of Asia, especially Siberia. IMAGE COPYRIGHT SERG ZASTAVKIN, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

The polar bear is rapidly becoming a symbol of global warming because of the thinning of sea ice, which endangers their survival. IMAGE COPYRIGHT FLORIDASTOCK, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

the location of its current breeding grounds. The Eskimo curlew is close to extinction, if not extinct already.

Caribou in Greenland and the Peary Caribou in the Canadian Arctic are two groups whose numbers are low. Caribou are affected by predators such as wolves and hunters, as well as changes in their habitats, including the building of natural gas pipelines that cut across their migration routes.

Human Life

Few people live on Arctic tundra; those who do are spread all around the polar region. Most people who live in areas of alpine tundra make their homes below the timberline. In some areas, people live below the timberline in winter and move onto the tundra in summer. The Kohistani people of Pakistan, for example, move from 2,000 feet (600 meters) in winter to 14,000 feet (4,300 meters) in summer. Swiss farmers move their goats to the tundra to graze during summer. While there, the farmers raise some crops and make butter and cheese.

Although some native peoples continue to live a traditional way of life, most tundra peoples have adopted more modern lifestyles.

Impact of the tundra on human life Arctic tundra is harsh land, and life is shaped by the bitter cold. For humans, a few minutes' exposure to the cold can lead to frostbite and the possible loss of fingers, toes, noses, or ears. Longer exposure can lead to hypothermia (a lowering of the body temperature) and death.

There is very little people can do to physically adapt to tundra conditions, instead, they must change their behavior. This is done by living a lifestyle in which nature is respected, people are creative, and nothing is wasted. For example, when the Inuit peoples of North America kill a caribou for food, they use the skin for tents, bedding, and clothes. Harpoons are fashioned from the antlers, and needles and other tools are made from the bones. Thread for sewing is made from the animal's tendons.

Food Unlike people in more temperate and fertile biomes where the growing season is much longer, the people of the Arctic tundra do not rely on growing grains for food. They find their food by hunting and gathering. Some peoples, such as the Sami, who live in Scandinavia and

Russia, survive by herding animals. Their diet consists primarily of meat from caribou and freshwater fish like char. The ocean is another source of food, and they hunt whales, walruses, and seals. Berries and herbs supplement the diet, and leaves are used for medicine. The traditional diet may be supplemented by canned goods shipped in during the summer months.

Alpine tundra dwellers hunt wild mountain animals for food, such as sheep, goats, and red deer. They also use domesticated llamas and yaks as food sources. South American Indians raise llamas for milk. In the milder alpine climate crops such as barley and potatoes are grown.

Shelter Traditionally, people of the tundra have built their homes from the materials at hand, mainly frozen blocks of snow, pieces of sod, animal skins, or stone. The Sherpas of the Himalayas build their houses of stone, making very thick walls. They live on top of the yak stables so that the warmth given off by the animals helps warm the home.

Clothing Tundra dwellers wear layers of clothing during the cold weather. If traditional, these clothes are made from the skins of animals. Caribou skin is a favorite choice because it is very warm yet light. During winter, two pairs of pants are worn. The inside pair is made with the animal hair facing in for warmth. The outside pair is made with the hair facing outward to provide waterproofing.

People on the tundra may wear parkas, which are jackets with hoods. The lining of the hood is usually wolf or wolverine hair. Sealskin is desirable for boots because it is waterproof. Bird skin lines the boots to make them warm. Moss, which is very absorbent, may be dried out and used for baby diapers.

Economic factors For traditional hunter-gatherers, possessions are almost meaningless. They do not have traditional jobs or seek to gain wealth. They spend their time finding the food they need and making clothing, weapons, and tools. In the past, reindeer herders were totally self-sufficient, getting food, clothing, and shelter from their herds. After World War II (1939–1945) the economy of many tundra regions changed.

Many minerals have been discovered in Arctic tundra. Coal, iron, nickel, gold, tin, and aluminum are found in eastern European countries

The Wheels that Dug Lakes

The tundra environment is very fragile and its ability to restore itself is limited. When a construction truck or bulldozer drives on the tundra during the summer it leaves ruts in the ground. When the sun hits these ruts it causes the permafrost to melt, which then causes erosion, and the ruts get bigger. Each summer more of the exposed permafrost melts and eventually the rut turns into a gully. During World War II (1939–1945), heavy trucks were driven on the tundra, leaving large ruts behind. The areas of permafrost that melted because of these ruts have grown so large over the years that some of them are now lakes.

Minerals have been found in the tundra. Gold was mined from this tunnel around Salmon Glacier, Hyder, Alaska. IMAGE COPYRIGHT NATALIA BRATSLAVSKY, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

such as Russia. Lead and zinc are mined in Greenland and gold in Canada. The largest mining activity on the tundra is drilling for natural gas and oil. Oil found on tundra changed the economy of Western nations, who no longer need to rely so heavily on the Middle East for their oil supplies. The discovery of oil and the need to build a pipeline to move it brought many non-native people to the Alaskan tundra. The creation of jobs was a boost to the economy of the countries that provided the work force.

After World War II, the Arctic tundra was the site of military activity. In North America, the United States built a series of radar stations from Alaska to Greenland called the Distant Early Warning (DEW) Line. This brought new residents and new jobs to the area.

Impact of human life on the tundra Due to its relative isolation, either in the far north or high in the mountains, the tundra biome has not been affected as much by the presence of humans as have many other biomes. Its harsh environment has helped keep people away, but this is changing.

Use of plants and animals When native peoples use plants and animals only for their own food and necessary materials, wildlife populations remain stable. When people hunt with guns for commercial reasons, more animals are killed than are born. In the 1800s and throughout much of the 1900s, tundra animals were overhunted. Musk oxen were almost wiped out when their meat was sold to sailors on whaling ships. The skins were traded and baby musk oxen were sold to zoos. Caribou were so severely overhunted that their herds were reduced by 90 percent.

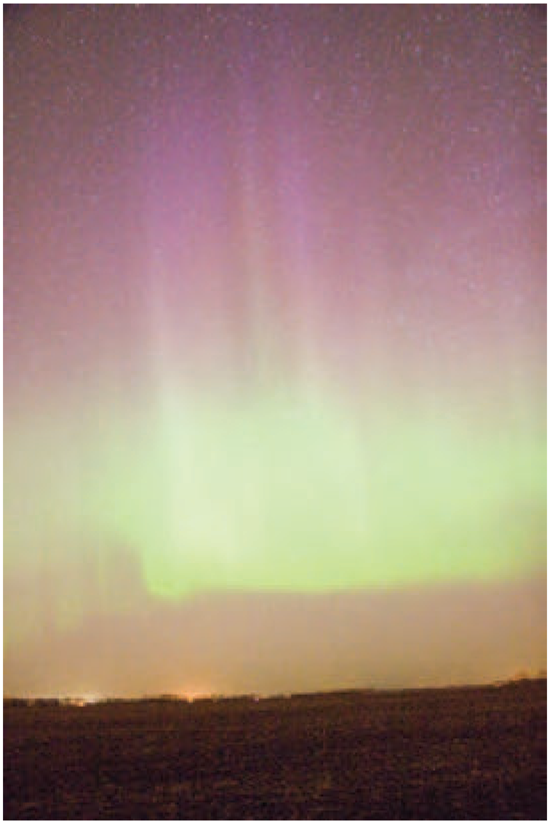
Many countries have since set limits on the number of tundra animals that can be killed each year, including caribou, musk oxen, and polar bears.

Quality of the environment The quality of the Arctic tundra environment has been threatened by the effects of mining, the use of pesticides, and air pollution.

Effects of mining Mining and drilling operations pollute the air, lakes, and rivers, and damage the land. In Russia, the land around some nickel mines has become so polluted that all the plants have died. With no plant life to anchor it, the soil has washed away. Delicate plants are trampled as roads, airstrips, and houses are constructed. These plants take years to grow back, and some never recover. When mines are abandoned, the old equipment and debris may be left behind, becoming eyesores.

Animals will not go near mining and drilling operations because of the noise and activity. This may cut them off from familiar food and water sources. The Alaskan pipeline, for example, was built across the caribou migration route. In order to correct this problem, the pipeline has been raised like an overpass so they can walk underneath, but the road beside the pipeline may be a problem. Scientists do not know what long-range effects these human-made additions will have on the animals.

The increasing number of people moving to the tundra to work in mining operations has created a need for houses, towns, and additional roads to bring in supplies. Getting rid of waste is a serious problem. The cold weather prevents decomposition of garbage and it cannot be buried in the frozen ground. The choices are to ship it out, which is very expensive, or create above-ground garbage dumps, which destroy the landscape.



The Aurora Borealis, or Northern Lights. IMAGE COPYRIGHT STEPHEN KIERS, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Use of pesticides Pesticides (poisons) affect tundra wildlife. A migratory bird such as a goose may eat plants sprayed with pesticides in the United States, where it spends the winter. When it returns to the Arctic in summer, a predator such as a fox may kill it. The fox and her young eat the goose. A falcon or polar bear might eat one of the young foxes. In this way, the pesticide contaminates a number of animals.

Peregrine falcons and polar bears have been especially affected by pesticide use. Some pesticides make falcon eggs soft, causing them to break open before the chick has fully matured. Pesticides that have built up in the bodies of polar bears after they have eaten a number of contaminated animals can, ultimately, kill them.

Air pollution The quality of the environment is affected by what happens outside the tundra. Air pollution may travel to the tundra from

Travel on the Tundra

People who live on the tundra use cars, airplanes, and snowmobiles, but methods of travel were not always so modern. Hunter-gatherers walked. Herders walked or rode their animals. The Laplanders rode in carts or sleighs pulled by reindeer. The Inuit invented a type of sled pulled by dogs, usually huskies. In summer, when the ice melted, the Inuit traveled in boats called kayaks, which could be made from seal-skin spread over animal bones or wood.

thousands of miles away. In 1986, a nuclear reactor blew up at the Chernobyl power station in Prypìyat, near Kiev in the Ukraine. Nuclear waste was carried on air currents all over Europe and landed on plants in the tundra. When it reached Lapland tundra, reindeer ate the contaminated plants, got sick, and had to be destroyed.

Air pollution has also affected the ozone layer. Ozone is a chemical that forms naturally high up in Earth's atmosphere. Ozone helps to protect Earth from the harmful ultraviolet rays in sunlight. Pollution destroys the ozone, without which people, animals, and plants can suffer severe burns and develop cancers. The density of the ozone layer over the Arctic has been changing since the 1970s and is now reduced.

The change in the ozone layer may be impacting the world's climate. Carbon dioxide and other gases build up in Earth's atmosphere, preventing heat from escaping. Called global warming, this may cause a change in temperature, melt glaciers, and cause the level of the sea to rise. Permafrost may begin thawing, which would cause flooding and erosion, changing the landscape. Animal and plant life would be affected as habitats change.

Native peoples Alpine tundra is home to the South American Indians who live in the Andes Mountains in Colombia, Ecuador, Peru, Bolivia, Chile, and Argentina. The Himalayan Mountains in Nepal are home to the Sherpas.

Arctic tundra dwellers include the Aleuts, Lapps, and Sami of Scandinavia and Russia, the Chukchi of eastern Siberia, and the Inuit of North America.

Traditionally, the Inuit of the Arctic tundra build snow houses (called igloos) when they need a temporary home while hunting. More permanent homes are built of bones and stones, with moss for roofing. The bladder of a seal or walrus is stretched across a hole in the wall to serve as a window. Platforms for sleeping are built up off the ground and lined with sealskin. Homemade lamps made of soapstone burn seal and whale blubber, giving off both heat and light.

Hunters of seals, whales, and caribou, the Inuit people have been impacted by the presence of military stations in the north. Many native peoples have taken jobs building, and later rebuilding, these stations.

A Dangerous Chill

The wind chill factor is the combination of cold temperature and strong wind that makes the effect of cold weather on the body worse than the temperature indicates. For example, if the temperature is 20°F (–6°C) and a 20 mile- (32-kilometer-) per-hour wind is blowing, the temperature will feel like –10°F (–23°C). In the Arctic, wind chill factors are so severe that bare flesh can freeze within 30 seconds.

The Food Web

The transfer of energy from organism to organism forms a food chain. All the possible feeding relationships that exist in a biome make up its food web. In the tundra, as elsewhere, the food web consists of producers, consumers, and decomposers. An analysis of the food web shows how energy is transferred within the tundra.

Green plants are the primary producers in the tundra. They produce organic materials from inorganic chemicals and outside sources of energy, like the sun. Tundra annuals and hardy perennials, such as buttercups and dwarf willows, turn the sun's energy into plant matter through photosynthesis.

Animals are consumers. Plant-eating animals, such as certain insects, caribou, reindeer, mountain goats, pikas, marmots, waterfowl, and lemmings, are primary consumers in the tundra food web. These animals become food for secondary consumers, which include predators such as spiders, wolves, and foxes. Tertiary consumers, such as grizzly bears and humans, eat other secondary consumers. Some tertiary consumers are omnivores, meaning they eat both plants and animals.

Decomposer organisms, like bacteria and fungi, eat decaying matter from dead plants and animals and release their nutrients back into the environment. Decaying matter in soils provides nutrition for flowering plants and grasses, as well as for the fungi and bacteria themselves.

Spotlight on Tundras

Niwot Ridge Niwot Ridge, an area of alpine tundra, is located about 22 miles (35 kilometers) west of Boulder, Colorado, and more than 9,843 feet (3,000 meters) above sea level. The ridge and the adjoining Green Lakes Valley cover approximately 3.8 square miles (10 square kilometers). Runoff from the mountains feeds the Colorado and Mississippi Rivers.

Niwot Ridge
Location: Rocky Mountains west of Boulder, Colorado
Area: 3.8 square miles (10 square kilometers)
Classification: Alpine tundra

Alpine tundra in the Rocky Mountains generally begins forming from 4,000 to 10,000 feet (1,219 to 3,048 meters) above sea level. Since its elevation is fairly high, Niwot Ridge is characterized by low temperatures throughout the year. The annual mean temperature is 5°F (–3.7°C). Temperatures in January average about 8°F (–13°C) and in July about 47°F (8°C).

This tundra is surrounded by subalpine forest at the lower elevations. Where the forest and tundra meet, subalpine meadows and patches of krummholz (dwarf trees) exist. Other physical features include a cirque glacier, the Arikaree, which is a U-shaped glacier with its open end facing down the valley. Talus slopes formed by the accumulation of rock fragments are also found here.

Some areas are snow covered. Strong winds that occasionally reach 170 miles (273 kilometers) per hour blow snow from other areas, leaving them bare. Meltwater (water melted from ice or snow) is found only where there is snow. Although precipitation in summer is uneven, yellow, pink, and purple flowers color the tundra in warm months. Plants include snow buttercup, old-man-of-the-mountain, Parry's primrose, and shooting stars.

Many birds live on this tundra only in summer. These include the water pipit, horned lark, and white-crowned sparrow. The only year-round resident is the white-tailed ptarmigan.

Thirty-two species of mammals live on Niwot Ridge. Small plant-eating mammals include deer mice, voles, golden-mantled ground squirrels, pikas, yellow-bellied marmots, snowshoe hares, and porcupines. Badgers and weasels are seen from time to time.

Many scientists and students work in the area studying the weather, analyzing the soil, and observing plant and animal life. Niwot Ridge is designated as a Biosphere Reserve by the United Nations' Educational, Scientific, and Cultural Organization (UNESCO) and an Experimental Ecology Reserve by the United States Department of Agriculture (USDA) Forest Service.

The ridge is part of Roosevelt National Forest. When visitors are allowed on the tundra, they are encouraged to use the trails designated for this purpose because even one footprint can damage the fragile landscape.

Bering Tundra
Location: Seward Peninsula, Alaska
Area: 23,400 square miles (60,610 square kilometers)
Classification: Arctic tundra

Bering Tundra The Bering Tundra is a western extension of the arctic coastal plain, a broad lowland in western Alaska between Kotzebue and Norton Sound. It is located on the Seward Peninsula on the American side of the former Bering Land Bridge (a narrow strip of land with water on both sides that at one time connected two continents) and is usually in the form of snow.

The Bering Tundra has cold winters and cool summers. Although summer temperatures in a polar climate rarely exceed 50°F (10°C), a high of 90°F (32°C) in summer has been recorded here. In winter, the low has reached –70°F (–57°C). Annual precipitation averages 17 inches (43 centimeters).

Thousands of shallow lakes and marshes (wetlands with poorly drained soil and nonwoody plants) are found along the coast. Two large rivers, the lower Yukon and the Kuskokwim, flow out of the province to the southwest. The terrain on the peninsula varies from lava fields to hot springs to tundra.

Much of the tundra is less than 1,000 feet (305 meters) above sea level. Some small mountain groups range from 2,500 to 3,500 feet (762 to 1,067 meters) high. The highest point is Mount Osborn, which reaches a height of 4,714 feet (1,436 meters).

Permafrost lies under most of the area and the active layer of soil is considered young and undeveloped. Despite permafrost and a growing season that can be as short as two weeks, there is still a wide variety of vegetation.

Species of dwarf trees, like birch, border the tundra. Birch, willow, and alder thickets are found between shoreline and forest. The lower Yukon and Kuskokwim Valleys are dominated by white spruce and cottonwood. Typical tundra plants include sedges, lichens, mosses, and cottongrass tussocks. Labrador tea, cinquefoil, and brightly colored forbs also grow in the region.

The coast provides habitats for migrating waterfowl and shore birds. Other bird species include ospreys, falcons, grouse, ravens, golden eagles, and various hawks and owls.

Mammals living in the tundra include musk oxen, brown and black bears, wolves, wolverines, coyotes, and a large herd of moose. Snowshoe hares, red foxes, lynxes, beavers, and squirrels summer here. Polar bears, walruses, and arctic foxes are sometimes seen along the northern coast of the Bering Sea.

Caribou migrate every summer to the tundra to give birth to their calves. They sometimes mix with domestic caribou, causing the native Eskimo herders to lose many of their animals, which join the wild herds.

An Inupiat Eskimo settlement of about 170 people is located in Wales on the western tip of the Seward Peninsula. Fewer than 60 miles (96 kilometers) from Siberia, Wales is one of the Alaskan settlements closest to Russia. Here, and in other places on the peninsula, native hunter-gatherers still live off the land. They are faced with the challenge of adapting to changes caused by development, especially by the exploitation of natural resources such as oil.

During the early twentieth century, thousands of non-native people came to Alaska in search of gold. As a result, more than a million dollars in gold was taken from the peninsula.

Kola Peninsula Murmansk is a province in northwestern Russia on the Kola Peninsula, a peak of high land that juts out into the ocean between the Barents and White Seas. Most of the peninsula lies across the Arctic Circle. It extends about 190 miles (305 kilometers) from north to south, and 250 miles (400 kilometers) from east to west. Elevations in the peninsula's Khibiny Mountains reach 3,907 feet (1,191 meters), and Arctic tundra covers the northern areas.

The largest town is the ice-free port of Murmansk, on the eastern shore, with a population of more than one million people. Fishing is the main occupation along the coast, but mining is the most important part of the economy.

Many minerals are found on the peninsula, including the world's largest deposits of apatite, a mineral rich in phosphorus and used for fertilizer production. Nephelinite (a source of aluminum), zirconium, iron, and nickel are also mined here.

Bogs (wetlands with wet, spongy, acidic soil) are widespread and form in areas where the soil is saturated by water. Since summer meltwater cannot drain into the permafrost and temperatures are too cool for evaporation, conditions are ideal for bog formation.

Despite problems with permafrost and thin, poorly developed topsoil, the peninsula has been called a botanical garden. Mosses, lichens, and dwarf Arctic birch cover most of the region. A forested area in the south has birch, spruce, and pine. Other typical tundra vegetation include lichens, Lapp rhododendrons, Arctic willows, and white mountain avens, a yellow-flowered member of the rose family.

Bird life typical to the tundra includes Siberian jays, Siberian titmice, grouse, and ptarmigans. Migrating seabirds include eider ducks, skuas, gulls, and Atlantic puffins. Lemmings, beavers, otters, and brown bears

Kola Peninsula
Location: Murmansk Oblast Province, northern Russia
Area: 40,000 square miles (100,000 square kilometers)
Classification: Arctic tundra

are common mammals, and thousands of reindeer migrate to the tundra in summer.

In the interior, a few thousand Sami are engaged in reindeer herding, which was the basis of their economy until the twentieth century. Families lived in tents and migrated with their herds. This way of life is disappearing as families now have permanent homes and only the herders move with the reindeer.

The deepest hole ever created by humankind is in the Kola Peninsula. The drilling experiment taken on by the Russians in 1962 through 1994, in order to investigate Earth's crust, ended with a hole 7 miles (12 kilometers) deep.

The western part of Kandalaksha Bay and the area south of Murmansk are wildlife reserves. No visitors are allowed in these areas. They are headquarters only for scientific research.

Northeastern Svalbard Nature Reserve The Svalbard Reserve is one of the largest and most important nature reserves in Norway. The area became protected by the Norwegian government in 1973 and includes North East Land, Kvit Island, Kong Karls Land, smaller adjoining islands, and the surrounding territorial waters. North East Land, the largest part of northeastern Svalbard, is covered by glaciers and ice caps all year long. *Svalbard* means "the land with the cold coast."

Arctic tundra covers the reserve, which is characterized by high winds, extremely cold temperatures, and permafrost that reaches depths of 1,640 feet (500 meters). Only the upper 6 to 10 feet (1.8 to 3 meters) of ground thaw in the summer, making it impossible for trees or plants with deep roots to grow.

In most Arctic climates winters are extremely severe and summers are short and cool. A branch of the warm ocean current called the North Atlantic Drift, moderates the climate here. Temperatures range from 59°F (15°C) in the summer to –40°F (–40°C) in the winter.

The growing season is very short, lasting only a few weeks in the summer. Plant life is typical for Arctic tundra and includes more than 150 species of plants. There are many lichens and mosses, and tiny polar willows and dwarf birches grow along the tundra borders.

Almost twenty species of birds nest on the islands. These include murres, which are diving shorebirds with stocky bodies, short tails, wings, and webbed feet. Several types of gulls, ptarmigans, arctic terns, and

Northeastern Svalbard Nature Reserve
Location: Svalbard Islands, Norway
Area: 7,350 square miles (19,030 square kilometers)
Classification: Arctic tundra

phalaropes also nest here. Two species of ptarmigan, the rock ptarmigan and the willow ptarmigan, are the only birds that live here year round.

There are fewer species of mammals than birds in the area. Polar bears, Arctic foxes, reindeer, and musk oxen live in the reserve. Polar bears in this region eat only meat; seals are a big part of their diet. Not native to the reserve, the musk ox was imported from Greenland in 1929.

Since trapping is an important economic activity, land game, such as foxes, reindeer, and bears, is protected by law so it does not become endangered by overhunting. Hunters once lived on the tundra, but very few spend the winter there. Most live in permanent communities at lower elevations. Svalbard's economy depends upon industrial operations and coal mining.

Tromsø University in Norway, in cooperation with the University of Alaska, runs a Northern Lights research station in the reserve.

Katmai National Park and Preserve The Katmai National Park and Preserve is located on the northeast coast of the Alaska Peninsula, along Shelikof Strait. The northern part of the park is Alpine tundra. Moving south, the terrain changes to forests, which line the bays and fjords (narrow inlets or arms of the sea bordered by steep cliffs).

Katmai tundra begins at a relatively low elevation, around 2,000 to 2,300 feet (600 to 700 meters) above sea level. The highest peaks in the park reach 7,585 feet (2,312 meters).

The climate is cold and windy with harsh winters; short, cool, summers with constant winds. In Katmai, the average summer temperature is 60°F (15.5°C). In winter there are only about six hours of sunlight each day.

The terrain in this park includes glaciers, waterfalls, and mountains. The Valley of Ten Thousand Smokes, where thousands of steam vents once came through the valley floor, was formed in 1912 when the Novarupta Volcano erupted violently. Only a few active vents remain.

Forests of blue spruces, alders, and willows border the tundra. Higher up, heaths, mountain avens (a member of the rose family), and bearberries grow.

Mammals include brown bears, wolves, foxes, moose, and caribou. The park is home to the largest population of protected brown bears in the world. The Alaskan brown bear, also known as the grizzly bear, is the world's largest carnivore and feeds on red salmon that spawn in the area.

Katmai National Park and Preserve
Location: Alaska
Area: 5,806 square miles (15,038 square kilometers)
Classification: Alpine tundra

People do not live here permanently because it is too inhospitable, but many visitors come to camp.

Taymyr Taymyr (also spelled Taimyr or Tajmyr) is a province located in northeastern central Russia. Mostly Arctic tundra, it extends from the Taymyr Peninsula south to the northern edge of the Central Siberian Plateau. The area includes the Severnaya Zemlya archipelago (a group of many islands) in the high Arctic.

The climate in Taymyr is exceptionally severe, with prolonged, bitter winters. The average temperature in January is –22°F (–30°C) and in July from 35° to 55°F (2° to 13°C). There are few sunny days. Precipitation ranges from 4 to 14 inches (11 to 35 centimeters) annually.

The region has a variety of landforms, including mountains, lowlands, and plateaus (raised, flat-surfaced areas). The mountains of Byrrang are at an elevation of 3,760 feet (1,146 meters). In the Arctic, plateaus of ice can be as thick as 4,900 feet (1,500 meters). This ice was formed when glaciers covered much of the Arctic more than 10,000 years ago. The Plateau of Plutoran has an elevation of 4,399 feet (1,341 meters).

A variety of minerals are found in Taymyr, including complex ores such as copper, nickel, platinum, gold, and coal. Gas is also mined.

The soil in Taymyr is typical tundra soil. The active layer of topsoil above the permafrost thaws in summer and freezes in winter. Bogs are widespread and form in areas where the soil is saturated with water. Since summer meltwater cannot drain into the permafrost and temperatures are too cool for evaporation, conditions are ideal for bog formation.

Although the growing season is only a few weeks long, plants take advantage of the long hours of daylight during the short summer months. Most of the area is covered with mosses, sedges, rushes, and some grasses. Lichens grow on the hillsides and bilberries, a type of blueberry, grow in clusters. Many flowering plants provide color. On the edge of the tundra, dwarf willows and birch trees grow.

Taymyr is the summer home for the red-breasted goose, which is a threatened species. Steller's eider, a large sea duck, is found on the peninsula. The mammal population includes reindeer, sable, wolf, fox, and white hare. Polar bears live farther north.

Few people live above the Arctic circle. Those that do include Russians, Dolgans, Nenets, Ukrainians, and Nganasans. Their chief economic activities are hunting, reindeer herding, fishing, and fur farming. Animals whose fur is used for clothing, such as the sable, are raised domestically

Taymyr
Location: North Central Russia
Area: 332,850 square miles (862,100 square kilometers)
Classification: Arctic tundra

rather than trapped in the wild. Only two cities are located in Taymyr province, the capital, Dudinka, and the port of Dikson. Their combined population is estimated at about 55,000.

Many traditional native lifestyles are slowly dying out. The Dolgan, for example, were primarily reindeer herders and lived a nomadic lifestyle for the last several hundred years. Since the 1970s their lifestyle has become less nomadic. Now they rely on gardening as well as hunting for food.

The Russian government established the Great Arctic Reserve in 1993 on the Arctic tundra for shorebird conservation and research. This area is the breeding zone for many shorebirds who summer in Africa or along the Atlantic coasts of Europe.

Gaspé The Gaspé (Gas-PAY) Peninsula lies in eastern Quebec, Canada. The forests and alpine tundra extend east-northeastward for 150 miles (240 kilometers) from the Matapédia River into the Gulf of St. Lawrence. The name Gaspé is from the Mi'kmaq Indian word *gespeg*, which means "land's end."

The tundra covers 24 percent of Quebec and lies in the Chic-Choc, or Shickshock, Mountains, which are part of the Appalachian range. They are the highest in Quebec, with Mount Jacques Cartier rising to 4,160 feet (1,268 meters). The tundra on the Gaspé Peninsula begins around 3,280 feet (1,000 meters) above sea level.

Gaspé lies between a humid continental climate and a subarctic climate. Continental climates are warmed somewhat in summer as tropical air moves north. In winter the cold polar air moves south. Gaspé faces severe winters, which have kept the population sparse. Temperatures can range from lows of –11°to 14°F (–10° to –24°C) in January to highs of 52° to 68°F (11° to 20°C) in July.

The land is crisscrossed by a number of rivers, and the peninsula is surrounded on three sides by the St. Lawrence River and the Gulf of St. Lawrence. A coniferous (evergreen) forest separates the province's deciduous (trees that loose their leaves at the end of each growing season) forests to the south from the subarctic and tundra areas where no trees grow.

Arctic-alpine plants that grow along the cliffs of the peninsula include lichens, mosses, sedges, grasses, and other low woody and leafy plants. On the edges of the tundra maples, yellow birches, white spruces, and balsam firs grow.

Gaspé
Location: Eastern Quebec, Canada
Area: 11,390 square miles (29,500 square kilometers)
Classification: Alpine tundra

Many seabirds are found along the cliffs, including black-legged kittiwakes, double-crested cormorants, black guillemots, and razorbills. This is the only area of Quebec where caribou, moose, and white-tailed deer are found. Other mammals include foxes, lynxes, black bears, beavers, Arctic hares, and porcupines.

People do not live in this alpine tundra. It is a place for visitors and research only. The rest of the peninsula is sparsely populated, with about one-fifth of the people earning a living through agriculture. In summer months, many tourists visit the peninsula and support the economy. Lumbering, mining, and fishing are the major economic activities. Minerals mined in the area are copper, lead, and zinc.

The Mi'kmaq (also spelled Micmac) people have inhabited the Gaspé Peninsula for thousands of years. They were one of eight major tribes who comprised the Woodland First Nations peoples. Traditionally, they were a seasonally nomadic people, hunting moose, caribou, and small game in winter and fishing in summer. Their winter homes were conical (cone-shape) wigwams covered with birch bark or animal skins. In summer, they lived in open-air, oblong wigwams. Homes were portable and easy to put up or move. Travel was by canoe, toboggan, or snowshoe. Some of the Mi'kmaq still live on Gaspé, but many have migrated to the United States.

The Gaspésian Provincial Park is a large conservation area covering much of the peninsula. Another park, Forillon National Park, covers 93 square miles (240 square kilometers) at the northeastern tip of the peninsula.

Arctic National Wildlife Refuge The Arctic National Wildlife Refuge in Alaska is one of the largest wildlife refuges in the world. To the north is the Arctic Ocean and to the south is Porcupine River. The refuge extends east to west more than 200 miles (322 kilometers) from the Trans-Alaska pipeline corridor to Canada, and almost 200 miles north to south from the Beaufort Sea to the Yukon Flats National Wildlife Refuge. It supports both Arctic and alpine tundra.

The Brooks Range, with peaks as high as 9,000 feet (2,743 meters), extends from east to west through the refuge. The Brooks Range is the highest mountain range within the Arctic Circle and is the northernmost extension of the Rocky Mountains in northern Alaska.

Winter on the refuge is long, and snow usually covers the ground at least nine months of the year. The average winter temperature here is

Arctic National Wildlife Refuge
Location: Alaska
Area: 19,000,000 acres (7,600,000 hectares)
Classification: Arctic and alpine tundra

below 0°F (below –17°C). The wind chill factor makes the temperature feel like –100°F (–73°C) to exposed skin. In summer, the temperature averages 50°F (10°C). Annual precipitation ranges from 4 to 16 inches (10 to 40 centimeters).

Besides two tundra zones, the refuge includes barren mountains, forests, shrub thickets, and wetlands. The alpine tundra is crisscrossed by braided rivers and streams, with clusters of shallow, freshwater lakes and marshes.

The Arctic National Wildlife Refuge contains the greatest variety of plant and animal life of any conservation area within the Arctic Circle. Even though the growing season can be as short as two weeks, the continuous summer daylight helps plants grow rapidly. Reindeer moss, sedges, and flowering plants are common. Spruces, poplars, birches, and willow trees grow in areas surrounding the tundra.

More than 180 species of birds have been observed here. Peregrine falcons are common in the refuge as are rock ptarmigans, grebes, snow geese, plovers, and sandpipers.

Thirty-six species of land mammals live here, including all three species of North American bears (black, brown, and polar). Smaller mammals include lynxes, wolverines, lemmings, Arctic hares, and wolves.

In the summer, tens of thousands of caribou give birth to and raise their calves on the tundra. These caribou migrate south in winter to northeastern Alaska and the northern Yukon, almost 1,000 miles (1,609 kilometers), farther than any other land animal. Even though their winter habitat is milder than their tundra breeding grounds, they still face Arctic weather. The caribou can dig through snow almost 2 feet (60 centimeters) deep to reach food, which consists of lichens, sedges, and grasses. The refuge protects most of the calving grounds for the Porcupine caribou herd, the second largest herd in Alaska, which numbers about 180,000 animals. It also protects a large part of their migration routes.

Dall sheep live in the refuge all year, mostly in the tundra. They stay close to rocky outcrops and cliffs where they are safe from predators that include wolves, golden eagles, bears, and humans. Dall sheep eat grasses, sedges, broad-leaved plants, and dwarf willows. In winter, when these foods are scarce, they eat lichens.

The area is home to several groups of native peoples and is the site of controversy over oil development. Kaktovik, an Inupiat Eskimo village, borders the refuge on the north side. The Inupiat have incorporated and, along with the government, own part of Alaska. The Gwich'in, another native group, are one of the few who have not incorporated and choose to maintain their reservation status and a subsistence lifestyle in their nine villages.

The Inupiat see the value of oil development in the area. It provides jobs and supports schools and community improvements. The Gwich'in see it as endangering the fragile tundra environment and disturbing migration routes and breeding places for the caribou.

Huascaran National Park Huascaran (hwa-SCAH-run) National Park is a place of biological diversity. Situated in the Andes Mountains in Peru, the landscape is dominated by mountain peaks, glaciers, lakes, and alpine tundra. It became a national park in 1975 and a World Heritage Site in 1985. The Quechua (QWAY-chwah) people live near the park and maintain a traditional lifestyle.

Alpine tundra, characterized by cold winds, is found on mountains above the timberline. The lower portion of the mountain is covered by tropical rain forest.

The snowcapped peak of Mount Huascaran, the highest mountain in Peru, rises to an elevation of 22,205 feet (6,768 meters) above sea level. The climate varies, with temperatures getting colder and rainfall decreasing as the elevation increases. The tundra climate has an average annual temperature below 50°F (10°C).

Much of Huascaran National Park is covered with permanent ice and snow. A permanent snowline begins between 14,700 and 16,400 feet (4,480 and 5,000 meters). Just below the tundra is the *puna*, an area of alpine grasslands with no trees. Below that is the *tierra fria*, the cool land, where most of the people live. This area has forest and land suitable for growing wheat and potatoes.

Vegetation is typical of alpine tundra in other parts of the world. Mosses and lichens grow on bare rocks. Short flowering plants and grasses, cushion plants, and sedges are common.

The South American, or Andean, condor nests on the cliffs in the high tundra. A member of the vulture family, it is one of the largest flying birds in the world with a wing span of about 10 feet (3 meters). The condor is carnivorous and feeds on dead animals.

Mammals in the Andes are different from those in other alpine tundra. The llama, alpaca, vicuña, and guanaco are native to this part of the world. Although they are all relatives of the camel, they have no hump. The vicuña is an endangered species hunted for its fleece, from

Huascaran National Park
Location: Peru
Area: 840,000 acres (340,000 hectares)
Classification: Alpine tundra

which some of the world's finest wool is made. The chinchilla, a small rodent common here, was hunted almost to extinction for its fur.

South American Indians living near the Huascaran Park are the Quechua and the Aymara, who have adapted to cold, high-altitude living. They have larger lungs and hearts, and their blood contains more red blood cells, allowing it to hold more oxygen. This makes it easier for them to live and work in the thin atmosphere of the mountains. They are also able to walk barefoot on icy rocks. These native peoples lead isolated lives as herders and farmers. Women make clothes and blankets to sell at market, spinning their own wool and weaving fabrics.

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Center for Environmental Education, Center for Marine Conservation, 1725 De Sales St. NW, Suite 500, Washington, DC 20036

Environmental Defense Fund, 257 Park Ave. South, New York, NY 10010, Phone: 800-684-3322; Fax: 212-505-2375, Internet: http://www.edf.org.

Environmental Network, 4618 Henry Street, Pittsburgh, PA 15213, Internet: http://www.envirolink.org.

Environmental Protection Agency, 401 M Street, SW, Washington, DC 20460, Phone: 202-260-2090, Internet: http://www.epa.gov.

Friends of the Earth, 1025 Vermont Ave. NW, Ste. 300, Washington, DC 20003, Phone: 202-783-7400; Fax: 202-783-0444.

Greenpeace USA, 1436 U Street NW, Washington, DC 20009, Phone: 202-462-1177; Fax: 202-462-4507, Internet: http://www.greenpeaceusa.org.

Nature Conservancy, 1815 N. Lynn Street, Arlington, VA 22209, Phone: 703-841-5300; Fax: 703-841-1283, Internet: http://www.tnc.org.

Sierra Club, 85 2nd Street, 2nd Floor, San Francisco, CA 94105, Phone: 415-977-5500; Fax: 415-977-5799, Internet: http://www.sierraclub.org.

World Wildlife Fund, 1250 24th Street NW, Washington, DC 20037, Phone: 202-293-4800; Fax: 202-229-9211, Internet: http://www.wwf.org.

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Wetland

Wetlands are areas covered or soaked by ground or surface water often enough and long enough to support special types of plants that have adapted for life under such conditions. Wetlands occur where the water table (the level of groundwater) is at or near the surface of the land, or where the land is covered by shallow surface water (usually no deeper than about 6 feet [1.8 meters]). They form the area between places that are always wet, such as ponds, and places that are always dry, like forests and grasslands.

Many wetlands are not constantly wet, experiencing what is called a wet/dry cycle. Some are wet for only part of the year, like those that are drenched during heavy seasonal rains. Some have no standing water but, because they are near the water table, their soil remains saturated (soaked with water). Others may dry out completely for long periods, sometimes years.

Wetlands are among the world's most productive environments with high biodiversity (a large variety of life forms). Only rain forests and coral reefs have more biodiversity.

Wetlands are found all over the world, in every climate from the frozen landscape of Alaska to the hot zones near the equator, except Antarctica. In the continental United States, there are about 110,000,000 acres (44,500,000 hectares) of natural wetland, and some types are found in every state. Alaska contains about 175,000,000 acres (71,000,000 hectares) of wetlands.

How Wetlands Develop

Wetlands have a life cycle that begins with their formation and may involve many changes over time.

Formation Many wetlands were formed when glaciers retreated after the last ice age, about 10,000 years ago. Some of the glaciers left depressions

WORDS TO KNOW

Arroyo: The dry bed of a stream that flows only after rain; also called a wash or a *wadi*.

Biodiverse: Term used to describe an environment that supports a wide variety of plants and animals.

Bio-indicators: Plants or animals whose health is used to indicate the general health of their environment.

Dambo: Small marsh found in Africa.

Fen: A bog that lies at or below sea level and is fed by mineral-rich groundwater.

Hydric soil: Soil that contains a lot of water but little oxygen.

Hydrophytes: Plants that are adapted to grow in water or very wet soil.

Kettle: A large pit created by a glacier that fills with water and becomes a pond or lake.

Peat: A type of soil formed from slightly decomposed plants and animals.

Pocosin: An upland swamp whose only source of water is rain.

Prairie potholes: Small marshes no more than a few feet deep.

Submergent plant: A plant that grows entirely beneath the water.

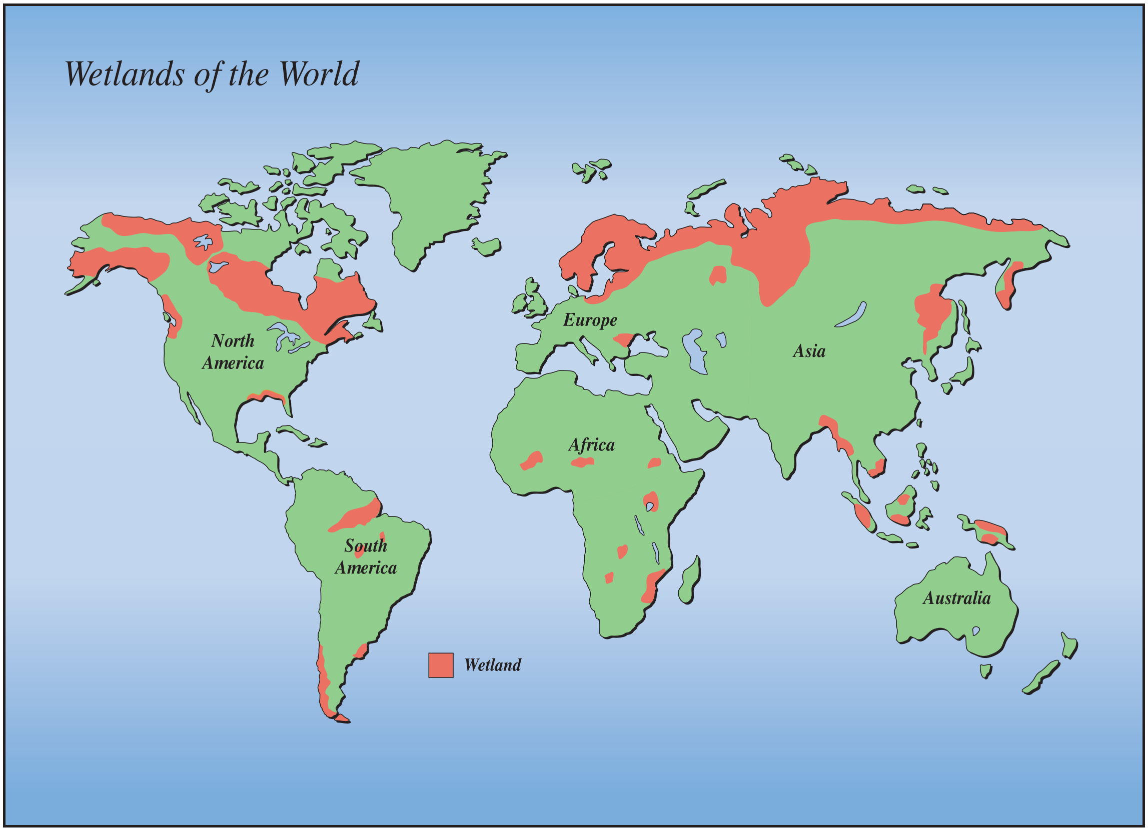
Wadi: The dry bed of a stream that flows only after rain; also called a wash or an *arroyo.*

in the ground, called kettles, which were perfect places for water to gather. In some places, buried ice melted to form kettle lakes that eventually turned into wetlands.

Wetlands are formed by overflowing river banks and changes in sea level (the average height of the sea) that leave behind waterlogged areas. Some wetlands are formed with help from beavers making dams that cause rivers or streams to back up and flood the surrounding area. Landslides or centuries of heavy winds may change the terrain or carve out depressions in the ground where water then collects.

Climate plays a key role in the formation of wetlands. Lots of rain and little drainage, for example, can cause the ground to become waterlogged.

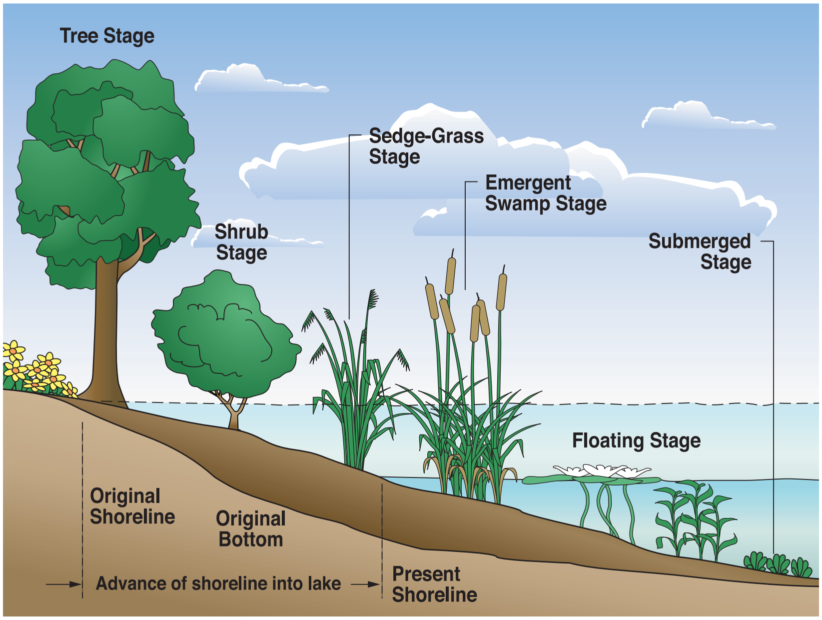
Succession Wetlands are constantly changing as their plant and animal life changes. This process is called succession. For example, one type of floating plant, such as pondweed, begins to fill up a pond or lake. The waste from these plants, such as dead stems and leaves, makes the water thick, shallow, and slower moving. As a result, plants that must be



anchored in soil, such as reeds and grasses, can grow. As waste matter continues to accumulate, the pond gradually becomes wetland. As succession continues, the wetland eventually disappears and is replaced by dry ground.

Kinds of Wetlands

The three main types of wetlands are swamps, marshes, and peatlands. They can be identified by size, soil type, plant populations, and the type and amount of water they hold. Some wetlands located inland are fresh water, while coastal wetlands may be fresh or salt water. Many areas contain several different types of wetlands. The Great Dismal Swamp in Virginia, contains both peat bogs and freshwater swamps.



Swamp A swamp is a wetland characterized by poorly drained soil and plant life dominated by trees. Swamp soil is usually saturated for most of the year. The water can range from 1 inch (2.5 centimeters) to more than 1 foot (30 centimeters) deep.

Because swamp ground is constantly waterlogged, trees and plants that grow must be able to tolerate having their root systems wet for long periods of time. The water is stagnant (without movement) and the dead plant matter that settles on the bottom receives little oxygen. Without oxygen, the dead matter cannot fully decay. This gives the swamp its characteristic brown water and unpleasant smell.

Swamps are usually found in low-lying areas near rivers or along coastal areas. They get water from the overflow of the river or from ocean tides. Inland swamps always contain fresh water, but coastal swamps may contain either fresh or salt water.

In the eastern United States, some swamps, called pocosins, form in upland areas. The term *pocosin* comes from the Algonquin phrase meaning “swamp on a hill.” Rain is usually their only source of water, meaning the soil is low in minerals and nutrients that come from ground water. Drainage is poor in pocosins and the saturated soil is acidic (high in acids). In this environment, decomposition (breaking down) of waste is slow, and decaying matter accumulates over time. Sometimes pocosins are flooded by slow-moving streams.

Freshwater swamp Freshwater swamps develop near the edges of lakes and next to rivers that overflow their banks. Partly decayed plant matter and stagnant water soon create swamp conditions. The Everglades in Florida, the Okefenokee Swamp in Georgia, and the Great Dismal Swamp in North Carolina and Virginia, are examples.

Saltwater swamp A saltwater swamp is formed by the ebbing (receding) and flowing of the ocean tides. (Tides are a rhythmic rising and lowering of the oceans caused by the gravitational pull of the sun and moon.) When the tide is low, flat areas of the swamp are not under water. Saltwater swamps can be found in New Guinea, Indonesia, Kenya, Zaire, along the Mekong River in Vietnam, and along the Ganges River in India.

In some low-lying coastal areas regularly flooded with sea water, mangrove swamps develop. A mangrove swamp is a coastal, saltwater wetland found in tropical and subtropical climates such as southern Florida and Puerto Rico. (Tropical and subtropical climates are found in areas close to the equator and are characterized by warm weather.) The mangrove swamp supports salt-loving shrubs and trees such as the mangrove, from which it takes its name. Few other woody plants grow there because of the high salt content.

Marsh Marshes are the most common type of wetland. They are dominated by nonwoody plants such as grasses, reeds, rushes, and sedges. Some marshes are so thickly covered with vegetation they look like fields of grass.

Marshes are usually found in temperate climates where summers are hot and winters are cold. They often form at the mouths of rivers (the point where a river enters into a larger river or ocean), especially those having large deposits of soil and sand, called deltas. They also form in flat areas frequently covered by shallow fresh or salt water.

Freshwater marsh Freshwater marshes are the most common of the world's temperate wetlands. Some receive no rain, and most are found along the edges of lakes and rivers or where groundwater, streams, or springs cause flooding. The Camargue in the Rhône Delta in southern France is an example. Different types of freshwater marshes include prairie potholes, riparian areas, wet meadows, and washes.

The Great egret makes its home in the marshy areas of wetlands where its long legs are ideal for wading in the shallow waters. IMAGE COPYRIGHT GLEN JONES, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Prairie potholes are small marshes found by the millions throughout the north central area of the United States and south central Canada. Usually no more than a few feet deep, they may cover as much as 10,000 acres (4,000 hectares). Prairie potholes are important to migratory waterfowl as places to rest, feed, and nest. In Africa, these small marshes are called dambos. In North America it is estimated that two-thirds of all waterfowl are hatched in prairie potholes.

Wet meadows are freshwater marshes that frequently become dry. They look like grasslands but the soil is saturated. They are common in temperate and tropical regions around the world, including the midwestern and southeastern United States. Their dominant plants are sedges, flowering plants that resemble grass.

Riparian wetlands are marshes found along rivers and streams. They range in width from a few feet (meters) to as much as 12 miles (20 kilometers). Smaller riparian wetlands are common in the western United States. Larger ones are located along large rivers, such as the Amazon in South America. Riparian wetlands are unique from others in that the vegetation and life forms found immediately adjacent to the river or streams differ from those of the surrounding area, usually a forest. This marked contrast produces a diversity and enhances the benefits for wildlife, both in food (grasses and sedges) and in shelter (shrubs and trees) in a relatively small place.

Mangrove tree, here seen at low tide. IMAGE COPYRIGHT ECOPRINT, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

A wash is a dry streambed that becomes a wetland only after a rain. Washes are found in dry plains and deserts. The plant life they support usually has a short growing season and disappears during dry periods. In North Africa and Saudi Arabia washes are called *wadis.* In the American west they are called *arroyos.*

Saltwater marsh Saltwater marshes, also called salt marshes, are found in low, flat, poorly drained coastal areas. They are often flooded by salt water or brackish water (a mixture of both fresh and salt water). Saltwater marshes are especially common in deltas, along low seacoasts, and in estuaries (arms or inlets of the sea where the salty tide washes in and meets the freshwater current of a river). They can be found in New Zealand, in the Arctic, and along the Atlantic, Pacific, Alaskan, and Gulf coasts.

Saltwater marshes are greatly affected by tides, which raise and lower the water level on a daily basis. A saltwater marsh may have tidal creeks, tidal pools, and mud flats, each of which has its own ecosystem (a network of organisms that have adapted to a particular environment).

The high salt content of the sea water in the marsh makes it hard for plants to adapt. Grasses such as marsh grass, cord grass, salt hay grass, and the grasslike needlerush thrive here.

Peatland Peatlands are wetlands in which peat has formed. Peat is a type of soil made up of the partially decayed remains of dead plants, such as

Cranberries grow in bogs in the cooler parts of the northern hemisphere. IMAGE COPYRIGHT LIJUAN GUO, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

sphagnum moss and even trees. In peatlands, dead plant matter is produced and deposited at a greater rate than it decomposes. Over time, sometimes over thousands of years, a layer of this plant matter is formed that may be as deep as 40 feet (12 meters). Several conditions are necessary for peat to form. The soil must be acidic, waterlogged from frequent rains, and low in oxygen and nutrients. The bacteria responsible for decomposing plant matter cannot thrive under these conditions, resulting in accumulation of the layers of partially decayed plant matter.

Peatlands cover three percent of Earth's land and freshwater surface area. Peatlands are located in colder, northern climates and in the tropics. They can be found in Russia (mainly Siberia), China, Scandinavia, northern Europe, England, Ireland, Canada, and the northern United States.

The types of peatlands are temperate bogs, fens, and tropical tree bogs.

Temperate bog Ninety percent of peatlands are found in northern temperate climates where they are called bogs. Bogs have a soft, spongy, acidic soil that retains moisture, which comes primarily from rainwater. Some bogs have taken as long as 9,000 years to develop and are sources of peat that can be burned as fuel.

Temperate bogs have been described as soft, floating carpets. The carpet is made mostly of sphagnum moss, which can be red, orange, brown, or green and may grow as long as 12 inches (30 centimeters). Sphagnum moss can grow in an acidic environment. It holds fresh rainwater in which other bog plants can grow. The high concentration of sphagnum moss has led other bog plants to develop unusual adaptations for obtaining nutrients. For example, the bog myrtle forms a partnership with the bacteria in its roots to get extra nitrogen. Other plants that grow in bogs include grasses, small shrubs such as leatherleaf, flowering plants such as heather, and poison sumac. Some rare wildflowers, such as the lady slipper orchid and the Venus flytrap, are found in bogs.

Most bogs lie in depressed areas of ground. Some, called raised bogs, grow upward and are about 10 feet (3 meters) higher than the surrounding area.

Blanket bogs are shallow and spread out like a blanket. They form in areas with relatively high levels of annual rainfall. Their average depth is 8 feet (2.6 meters). Blanket bogs are found mainly on lowlands in western Ireland and in mountain areas. After a heavy rainfall, bogs located on steep slopes can wash down like a huge landslide of jelly and cover cattle, farms, and even villages.

Nature's Diapers

Sphagnum moss, which is found in bogs, can absorb many times its weight in water. At one time, certain Native Americans dried this moss and used it as diapers for their babies.

Fen When a peatland is less acidic and is fed by mineral-rich groundwater, it is called a fen. Plants characteristic of fens are grasses, sedges, and reeds rather than sphagnum moss, and the soil does not become as acidic as in a bog. Less peat accumulates in a fen and it becomes only about 6 feet (2 meters) thick. As plant matter accumulates in a fen over time, it may form a raised bog.

Tropical tree bog Bogs found in tropical climates are called tree bogs. These bogs produce peat from decaying trees rather than from sphagnum moss. The trees most commonly found in these bogs are broad-leaved evergreens. Temperatures are warmer than in temperate regions, causing decay to occur more rapidly. As a result, not as much peat develops. The only source of water is rain.

Tropical tree bogs can be found in South America, Malaysia, Africa, and Indonesia.

Climate

Unlike some other biomes, wetlands do not have a characteristic climate. They exist in polar, temperate, and tropical zones, but not usually in deserts. They are very sensitive to changes in climate, such as a decrease in precipitation (rain, sleet, or snow). The amount of precipitation and changes in temperature affect the growth rate of wetland plants. Some wetlands are seasonal, which means they are dry for one or more seasons of the year.

Temperature Temperatures vary greatly depending on the location of the wetland. Many of the world's wetlands are in temperate zones (midway between the North and South Poles and the equator). In these zones, summers are warm and winters are cold, but temperatures are not extreme. Wetlands found in the tropic zone, which is around the equator, are always warm. Temperatures in wetlands on the Arabian

Peninsula, for example, can reach 122°F (50°C). In northeastern Siberia, which has a polar climate, wetland temperatures can be as cold as –60°F (–51°C).

Rainfall The amount of rainfall a wetland receives depends upon its location. The average rainfall for wetlands in Wales, Scotland, and western Ireland is about 59 inches (150 centimeters) per year. Wetlands in Southeast Asia, where heavy rains occur, can receive up to 200 inches (500 centimeters). In the northern areas of North America, wetlands exist where as little as 6 inches (15 centimeters) of rain fall each year.

Geography of Wetlands

The geography of wetlands involves landforms, elevation, and soil.

Landforms Landforms found in wetlands depend upon location, soil characteristics, weather, water chemistry, dominant plants, and human interference. Their physical features are often short-lived, especially if they are near floodplains or rivers, which can cause abrupt changes. Wetlands usually form in a basin where the ground is depressed, or along rivers and the edges of lakes.

A view of the wetlands and woods near Ocean City in Maryland. IMAGE COPYRIGHT ANDREW F. KAZMIERSKI, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Elevation Wetlands are found at many elevations (the height of an area in relation to sea level). Some wetlands in the Rocky Mountains in North America, for example, are at an elevation of 10,000 feet (3,048 meters).

Elevation is used to help classify some wetlands in Ireland. Bogs that are less than 656 feet (200 meters) above sea level are called Atlantic blanket bogs. Those that are more than 656 feet (200 meters) above sea level are called mountain blanket bogs.

Soil An important characteristic of a wetland is its soil. Soil composition helps to determine the type of wetland and what plants and animals can survive in it. Almost all wetland soils are at least periodically saturated.

Wetland soils are hydric. This means they contain a lot of water but little oxygen. Only plants that that can adapt to these wet soils live in wetlands. The nutrients in the soil often depend upon the water supply. If the water source is primarily rain, the wetland soils do not receive as many minerals as those fed by groundwater. Soil in floodplains is very rich and full of nutrients, including potassium, magnesium, calcium, and phosphorus.

In some bogs associated with forests, decaying plant matter fully decomposes and is combined with sediments to form muck. This type of soil is dark and sticky. To be classified as muck, soil must contain not less than 20 percent organic (derived from living organisms) matter.

Plant Life

An important characteristic of any biome is its plant life or lack of plant life. More than 5,000 species of plants live in or near wetlands. Wetlands have high biological productivity (the rate at which life forms grow in a certain period of time). The higher its plant productivity, the more animal life a wetland can support. The kinds of plants found in a wetland are determined by several factors, especially the type of soil and the quantity of water.

Some plants, called hydrophytes, grow only in water or extremely wet soil. Sedges are an example. Mesophytes, such as reeds, need moist but not saturated soil. When a wetland dries up,

Pitcher plants are carnivorous. An insect crawls into the "pitcher" and cannot crawl back up. The plant digests the insect. IMAGE COPYRIGHT CHERYL CASEY, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

A Useful Nuisance

People often grumble about the water hyacinth because it multiplies and spreads quickly in open water. The plants become so thick that boats have a hard time moving through them. The water hyacinth has an important use, though. It absorbs and neutralizes many pollutants that would otherwise contaminate the water. It also has a high nutrient content, which makes it a good fertilizer.

the area may fill with plants called xerophytes. These are plants adapted to life in dry habitats and can survive where other wetland plants would wilt.

A submergent plant grows beneath the water and is found in deep marshes and ponds. Even its leaves are below the surface. Submergents include milfoil, pondweed, and bladderwort, an insect-eating plant.

Found in deep marshes, floating aquatics float on the water's surface. Some, like duckweed, have free-floating roots. Others, including water lilies, water lettuce, and water hyacinths, have leaves that float on the surface, stems that are underwater, and roots that are anchored to the bottom.

An emergent plant grows partly in and partly out of the water. The roots are usually under water, but the stems and leaves are at least partially exposed to air. They have narrow, broad leaves, and some produce flowers. Emergents include reeds, rushes, grasses, cattails, and water plantain.

Algae, fungi, and lichens It is generally recognized that algae (AL-jee), fungi (FUHN-ji), and lichens (LY-kens) do not fit neatly into the plant category.

Algae Most algae are one-celled organisms too small to be seen by the naked eye. They make their food by a process called photosynthesis (foh-toh-SIHN-thuh-sihs). Photosynthesis is the process by which plants use the energy from sunlight to change water and carbon dioxide from the air into the sugars and starches they need. Some wetland algae drift on the surface of the water, forming a kind of scum. Others attach themselves to weeds or stones. Some grow on the shells of turtles or inside plants or animals. Microscopic algae that can be found in saltwater marshes include diatoms and green flagellates (FLAJ-uh-lates). Desmids are a type of green algae found in bogs.

Fungi Fungi are plantlike organisms that cannot make their own food by means of photosynthesis; instead, they grow on decaying organic matter or live as parasites (organisms that depend upon another organism for food or other needs).

Fungi grow best in a damp environment, which makes wetlands a favorable home. Common wetland fungi include mushrooms, rusts, and puffballs.

Lichens Lichens are combinations of algae and fungi. The alga produces food for both itself and the fungi by means of photosynthesis. It is believed the fungus absorbs moisture from the air and provides shade. One of the most common wetland lichens is reindeer moss, an important food source for northern animals such as caribou.

The Hat Thrower

An unusual fungus called a hat thrower grows on dung (animal waste) deposited in wetlands. The fungus forms a tiny black bulb that looks like a hat. The hat explodes under pressure and pieces get thrown outward from the fungus and attach to other plants. When an animal eats those plants, the hat thrower passes through its digestive system. When the animal defecates, a new fungus grows on the pile of dung.

Green plants Most green plants have several basic requirements: light, air, water, warmth, and nutrients. In a wetland, light and water are in plentiful supply. Nutrients, primarily nitrogen, phosphorus, and potassium, are obtained from the soil. Some wetland soils are lower in these nutrients and low in oxygen. As a result, many wetland plants have special tissues with air pockets that help them survive.

Water lilies and wild grasses grow are common wetland plants. IMAGE COPYRIGHT DANISH KHAN, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Trees that grow in swamps, such as the mangrove and bald cypress, have shallow roots. Due to the lack of oxygen in the soil, the roots remain near the surface. Other trees found in mild climates include willows and alders. Palms are found in warm climates.

Wetland plants are classified as submergents, floating aquatics, or emergents, according to their relationship with water.

Common green plants Common wetland green plants include mangrove trees, insectivorous plants, reeds, rushes, and sedges.

Trees that live in wetlands must tolerate having their roots wet for a long period of time. One of the best examples of this is the mangrove tree, which grows in tropical and subtropical saltwater swamps. Mangroves have done so well adapting to wetland conditions that there are more than 34,000,000 acres (14,000,000 hectares) of them in the world. One of the largest mangrove forests is the Sundarban Forest in Bangladesh. Mangroves can also be found in southern Florida and other tropical and subtropical areas.

Attack of the Killer Plant

Insectivorous (insect-eating) plants, such as the sundew, the pitcher plant, and the Venus flytrap, need nitrogen to survive. These plants live in bog areas where the soil is acidic and nitrogen and phosphorus are not readily available. In order to obtain the proper nutrition, they trap insects, dissolve them, and absorb their nutrients, which include these essential nutrients.

The Venus flytrap, for example, has toothed "jaws" at the end of its leaves. These jaws spring shut when an insect in search of nectar touches the sensitive hairs inside. The plant eats the insect by dissolving it with digestive juices and absorbing it through its leaves. After the insect has been digested, the plant opens its jaws again and waits for the next victim.

Venus flytraps are found in the marshy coasts of North and South Carolina. These plants grow only under certain conditions and are popular houseplants. As a result, they sometimes have been overharvested.

Some non-tropical mangroves have special membranes that reduce the entry of salt into their systems. Mangroves get some of their oxygen from pores in their roots, the largest portions of which are above ground, and from small gaps in their bark.

Mangrove flowers are pollinated by the wind, insects, birds, or bats. The seedlings begin to grow while they are still attached to the parent tree. Seedlings germinate (grow) within the fruit that contains them. The root, or roots, of the maturing seedling then break through the outer wall of the fruit. When the seedling reaches a mature enough stage, it is released from the parent plant, floats on the water, and then settles in mud, where it establishes roots and begins to grow.

Two common peatland plants eat insects. The sundew eats ants by catching them in a sticky liquid on its leaves. It then releases chemicals that break down the ant's body so the plant can absorb the nutrients. The pitcher plant gets its name from the shape of its leaf, which looks like a pitcher. If an insect crawls down the leaf it cannot crawl back up because the leaves have downward pointing hairs and are too slippery. It is then digested by chemicals in the plant.

A reed is a type of grass with tall, feathery flowers, with round, hollow stems, and long, flat, narrow straplike leaves. Rushes and sedges are grasslike, but they are not true grasses. Rushes have round, solid stems and narrow, rigid leaves. Sedges have solid, triangular stems.

Reed mace and common reeds play a key role in wetland succession. They reproduce widely through their rhizomes (underground stems). As the plants spread out, they push aside other plants and quickly choke up a pond, slowing the water's movement and trapping dead plant matter. As this matter accumulates, the pond fills up and becomes a marsh.

Growing season Climate and precipitation effect the length of the growing season in a wetland. Warmer temperatures and moisture usually signify the beginning of growth. In regions that are colder or receive little rainfall, the growing season is short. Growing conditions are affected by the amount of moisture in the soil, which ranges from saturated to dry. Although many wetland plants die during dry periods, their seeds remain in the soil all winter and sprout in the spring.

Reproduction Green wetland plants reproduce by several methods. One is pollination, in which the pollen from a flowering plant's male reproductive part, called the stamen, is carried by wind or insects to the flowering plant's female reproductive part, called the pistil. Water lilies, for example, are closed in the morning and evening, but open during midday when the weather is warmer and insects are more active. It is usually at this time that the insects pick up the pollen and transfer it from the stamen to the pistil, allowing pollination to occur.

Some wetland plants send out rhizomes, which are stems that spread out under water or soil and form new plants. Reed mace and common reeds are examples.

Endangered species One-third of the endangered plants in North America are dependent upon wetlands for their survival. As of January 2008, there were 1,046 endangered and 305 threatened plants in the United States protected under the U.S. Endangered Species Act.

Changes in the habitat, such as succession, pollution, and new weather patterns, endanger wetland plants. They are also endangered by people who collect them. Rare species of orchids are an example, as is the Venus flytrap, which has become a popular houseplant and has been overharvested. Peat moss is overharvested because it is popular as fuel, packaging material, and in gardens.

Animal Life

Wetlands have been called "biological supermarkets." Besides animals that live there permanently, many nonwetland animals, such as opossums, raccoons, and skunks, visit for food and water. Wetlands provide shelter for mammals such as minks, moose, and muskrats. Wetland conditions make it necessary for the animals that live there permanently to adapt in special ways.

Microorganisms Microorganisms cannot be seen by the human eye. Those found in wetlands include protozoa and bacteria. Protozoa are single-celled animal-like protists that feed on bacteria and other microorganisms. Other protozoa are parasites that live on aquatic plants, on damp ground, or inside animals or plants. Protozoa are not capable of

The Persistent Marsh

For more than 2,000 years popes, emperors, and government officials tried to drain the Pontine Marshes where malaria-carrying mosquitoes like to live. Located in south-central Italy, the marshes are bordered by the Tyrrhenian Sea, the Lepini Mountains, and the Alban Hills.

All attempts to completely drain the marshes failed. The area survived and about 300 square miles (777 square kilometers) of the original marsh is now a national park with native vegetation intact. With the help of water from the marsh, the area is now one of the most agriculturally productive in Italy. Crops grown in the area include sugar beets, fruits, grains, and vegetables. Livestock is also raised here.

photosynthesis. Bacteria are also single-celled; most cannot make their own food and must obtain it from the environment. Blue-green bacteria are plantlike, photosynthetic algae that can make their own food.

Some protozoa cause malaria, a disease characterized by chills, fever, and sweating. Mosquitoes carry malaria and spread the disease to humans. Malaria is found in temperate, subtropical, and tropical regions. Spread of the disease has been greatly reduced due to the use of pesticides to kill mosquitoes, but it remains a problem in parts of Africa and southeastern Asia.

Invertebrates Invertebrates are animals without a backbone. They range from simple sponges to complex animals like insects, snails, and crabs.

Thousands of species of insects have adapted to life in wetlands. Some spend their entire lives in the water. Others live in the water while young, but leave it when they become adults. Still other insects have gills, just like fish, which enable them to obtain oxygen from the water; and some breathe air. For example, the diving beetle traps air in the hairs on its body or under its wings, which helps it to float. Water spiders create bubbles of air under the water in which they feed and lay eggs. The water spider even hibernates under water. When the weather gets cold, it constructs an air bubble in deep water and remains there until spring.

Some invertebrates, such as crabs, survive in wetlands by creating watertight holes in the mud or sand and hide there during high tide. Other species, like the African mangrove snail, feed in the mud and sand when the tide is low. When the tide comes in the snail climbs the mangrove trees to keep from drowning.

Common invertebrates Perhaps the most well-known and unpopular wetland invertebrate is the mosquito. Mosquitoes breed in shallow wetland waters. In their larval form, they have tubes in their abdomens that stick out of the water, allowing them to breathe. Larvae are often eaten by frogs, fish, and aquatic insects. Those that survive face being eaten by bats, sprayed with pesticides, and swatted by humans. In spite of these hazardous conditions, mosquitoes in large numbers are responsible for diseases in both humans and animals.

Food Insects may feed underwater as well as on the surface. The milkweed beetle feeds on insects found on wetland plants, while the diving beetle's diet includes tadpoles and small fish. The dragonfly larva eats tiny floating organisms and water fleas. The larva of a certain species of caddisfly weaves a silk net under the water in which to catch floating algae.

Some snails are plant feeders, while others eat the eggs and larvae of other invertebrates, or even decaying matter. Crabs are often omnivorous, meaning they eat both plants and animals.

Reproduction Most invertebrates are insects, which have a four-part life cycle. The first stage is the egg. The second stage is the larva, which may be divided into several steps as the insect increases in size, between which there is a shedding of the outer casing or skin. The third stage is the pupal stage, during which the insect lives in yet another protective casing. Finally, the adult emerges. Some wetland dragonflies lay their eggs in the tissues of submerged plants. The insects remain in the water as larvae. As they mature, they move to dry land.

The Marsh Treader

The marsh treader is an insect that can be found walking very slowly across the surface of marsh water. It has a long, skinny body about 0.3 inches (8 millimeters) in length. Its legs are as fine as threads and its body is covered with velvety hairs. As it moves across the water, it searches for food. Mosquito larvae are its favorite meal.

Amphibians More than 190 species of amphibians are found in wetlands. Amphibians are vertebrates, which means they have a backbone. There are two kinds of amphibians, those with tails, like salamanders and newts, and those without tails, like toads and frogs.

Amphibians live at least part of their lives in water and are found in primarily freshwater environments. Most are found in warm, moist regions and in a few temperate zones. Because amphibians breathe through their skin, they must remain close to water so they can stay moist. Only moist skin can absorb oxygen. If they are dry for too long they will die. Their lower layer of skin, called the dermis, helps them to stay moist by producing mucous, a thick fluid that moistens and protects the body.

Amphibians are cold-blooded animals, which means their body temperature is about the same temperature as their environment. They need warmth and energy from the sun in order to be active. As temperatures grow cooler, they slow down and seek shelter. In cold or temperate

The Salamander that Never Grows Up

The axolotl, a type of salamander found in freshwater wetlands in Mexico and the western United States, spends its entire life as a tadpole. It can reach a size of 10 inches (25 centimeters) and is able to reproduce, but it never matures, so it never leaves the water. Scientists have determined that the diet of these salamanders is lacking the chemical iodine, which is in short supply in many parts of the world. This shortage is the reason why iodized table salt is used in most homes. Iodine has been added as an essential nutrient.

regions, some amphibians hibernate (become inactive) during the winter, hiding in mud or trees. When the weather gets too hot, they go through another period of inactivity called estivation.

Common amphibians The most common wetland amphibians are salamanders, frogs, and toads. Frogs and toads are found all over the world, at all altitudes, and in both fresh and salt water.

Frog A frog spends half its life in the water and half out of it. Frogs can lay up to 3,000 eggs, which float beneath the water's surface. The eggs hatch into tadpoles (larvae), which swim and breathe through gills, like those on a fish. The larvae feed on small plants and animals in the water. As they mature, legs and lungs develop, which they will need on land.

Adult frogs feed mainly on insects, especially mosquitoes, but bullfrogs have been known to eat birds and snakes. In the food web they, in turn, become meals for herons, raccoons, and other wetland animals.

Frogs are considered bio-indicators. This means that when many frogs are sick their entire environment may be in trouble. If they disappear from a habitat or if they do not sing, the area may be polluted and its resources may be dwindling. Frogs are totally absent from some wetlands in the United States, indicating their environment was no longer a healthy place for them to live.

Food In their larval form, amphibians are usually herbivorous (plant-eating). Adult amphibians are usually carnivorous (meat-eating), feeding on insects, slugs, and worms. Salamanders that live in the water suck prey into their mouths. Those that live on land have long, sticky tongues that capture food.

Reproduction Most frogs and toads lay many tiny eggs. Some are held together in a jellylike substance. As the female lays her eggs in the water, the male releases sperm, which is carried to the eggs by the water. Most salamanders and newts lay eggs that have been fertilized internally (within the female).

Reptiles Reptiles are cold-blooded vertebrates that depend on the environment for warmth. Thousands of species of reptiles live in the temperate and tropical wetlands of the world. They include snakes, lizards, turtles, and crocodiles. Reptiles are more active when the weather and water temperature become warmer. Unlike amphibians, reptiles have skin that is waterproof, so they do not dry out. This allows them more freedom to move away from the wet areas.

Because they are so sensitive to their environment, reptiles often go through a period of hibernation in cold weather. Turtles bury themselves in the wetland mud. They barely breathe, and their energy comes from stored body fat. When the weather warms in spring, they come out of hibernation and become active. At the other extreme, when the weather becomes very hot and dry, some reptiles go through estivation, another inactive period.

Common reptiles Two well-known and dangerous wetland reptiles are the crocodile and the cottonmouth snake.

A young American alligator swims in the Everglades National Park in Florida. IMAGE COPYRIGHT IOFOTO] 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

The Web of Life: Keystone Species

Species interact with one another in many ways. Those that play an important role in the survival of others are called keystone species. In the wetlands, a keystone species is the alligator, which lives in southern marshes such as the Florida Everglades.

Wetlands often dry up if rainfall is low. Alligators then dig holes with their powerful tails and bodies. Water collects in these holes and helps alligators, as well as birds, fish, frogs, turtles, and other marsh animals, survive during dry periods.

Crocodile Crocodiles are found in warmer parts of North and South America, Africa, Australia, and Southeast Asia. They have inhabited Earth for more than 170,000,000 years. Their long survival may be due in part to the fact that they will eat almost anything or anyone. Crocodiles are responsible for killing at least ten humans every day in Africa, and a large crocodile will attack a 4,000-pound (1,816-kilogram) adult rhinoceros if given the chance. A crocodile's teeth are rounded and made for holding, not cutting, and it first tries to swallow its prey whole. If the prey is too large, the crocodile pulls it underwater and stashes it where it can decay. When the meat is soft, the crocodile rips off a piece at a time.

The largest living crocodile officially recorded was 20.3 feet (6.2 meters) long. A crocodile continues to grow throughout its life, reaching average ages of 60-70 years; the oldest known crocodile was 115 years old. Their speed out of the water over short distances may be more than 35 miles (56 kilometers) per hour. By contrast, a very fast human may run 25 miles (40 kilometers) per hour over the same distance.

Cottonmouth snake The cottonmouth snake inhabits marshes and swamps in the south and southeastern United States. A thick-bodied snake, it spends most of its life in or near water. It is active at night, when it preys on amphibians, fish, snakes, and birds. Its venom is extremely poisonous.

Food Some wetland reptiles, such as the dice snake, are carnivores that eat frogs, small fish, and crayfish. The pond turtle, which inhabits tropical swamps, is an omnivore. When it is young it feeds on insects, crustaceans, mollusks, and tadpoles. As an adult, it eats primarily wetland plants.

Reproduction The eggs of lizards, alligators, and turtles are either hard or rubbery and do not dry out easily. Most are buried in the warm ground, which helps them hatch. In a few species of lizards and snakes the young develop inside the female's body until birth.

The dice snake lays it eggs on land, close to the water. Crocodiles and alligators keep eggs in warm nests, which can be simple holes in the ground or constructions above the ground made from leaves and branches.

Fish Like amphibians and reptiles, fish are cold-blooded vertebrates. They use fins for swimming and gills for breathing. Two-thirds of all fish used for human food depend on wetlands during some part of their lives. Most commercial game fish breed and raise their young in marshes and estuaries. When the wetlands are not healthy, the fish die, and the commercial and recreational fishing industries suffer.

Common fish Fish that commonly rely on coastal wetlands are striped bass, sea trout, African lungfish, mudskippers, and flounder. Brackish marshes, which contain both salt and fresh water, support sole, sardines, and common mackerel.

African lungfish The African lungfish, which lives in pools surrounded by swampland, has adapted to the wet/dry cycle of wetlands. When there is plenty of water, the fish breathes through its gills. In the dry season, when the water disappears, the fish burrows into the mud and seals itself into a moist cocoon, breathing through special pouches on its underside. It can remain inactive in its cocoon for months or even years.

Mudskipper Also well adapted to life in the wetland is the mudskipper, found in coastal areas of Bangladesh. This fish usually lives out of the water on exposed mud at low tides. Mudskippers breathe air through membranes at the back of their throats. Enlarged gill chambers hold a lot of water to help them remain on land for long periods. They keep water in their mouths, which they swish over their eyes and skin to help them stay wet. They feed on crabs that are easily caught during low tide.

Food Some fish eat plants while others depend upon insects, worms, crustaceans, or smaller fish. Some fish may simply grab an insect from the surface of the water or use a more elaborate scheme. The archerfish, for example, has grooves in the top of its mouth that lets it spit water at its prey. The force of the spit knocks the insect off its perch and into the water, where it is quickly eaten. Archerfish are found in the swamps of southeast Asia.

Reproduction Fish that breed in wetlands include flounder, sea trout, striped bass, and carp. Some European carp live in rivers and move to the floodplains during spawning (breeding) season. Others live in the ocean and spawn in mudflats, marshes, or mangrove swamps.

Birds Many different species of birds live in or near wetlands. These include many varieties of wading birds, waterfowl, shore birds, and perching birds. One of the special adaptations of birds to wetlands is their bill. Some bills, like those of the egret, are shaped like daggers for

A heron walks the marshy water of the Bolsa Chica Wetlands in Huntington Beach, California. AP IMAGES.

stabbing prey such as frogs and fish. Other bills, like those of the spoonbill, are designed to root through mud in search of food.

Wetlands provide a variety of hiding places where birds can build nests and protect their young. Dense underbrush or hollows in the ground are good hiding places, especially when nests are made from reeds, flowers, and grasses, which help them blend into their surroundings. Wood ducks build their nests in hollow cavities in trees lining the wetland shores.

Common birds Birds found in wetland environments can be grouped as wading birds, shorebirds, waterfowl, and perching birds.

Wading birds Wading birds, such as herons and egrets, have long legs for wading through the shallow water. They have wide feet, long necks, and long bills that are used for nabbing fish, snakes, and other food. Herons and egrets are the most common in freshwater marshes of North America. The great blue heron stands 4 feet (1.2 meters) tall. This is the tallest recorded wading bird in North America.

Shorebirds Shorebirds feed or nest along the banks of wetlands and prefer shallow water. Their feet are adapted for moving in water, and some have long, widely spread toes to prevent them from sinking in the mud.

The bills of shorebirds are designed to help them find food. The ruddy turnstone, for example, has a short, flattened, upturned bill, which helps it sift through mud or overturn pebbles and shells. A favorite food of the oystercatcher is the mussel. Each young oystercatcher learns from its parents a technique for opening the mussel shells to get at the meat. Some birds hammer a hole in the shell with their bills, and others prop the shells at an angle so they can pry them open. It may take the birds several years of practice to get the technique just right.

There are more than 200 species of shorebirds dependent on wetland habitats. These include sandpipers, which are found in marshes, wet woodlands, and on inland ponds, lakes, and rivers.

Waterfowl Waterfowl are birds that spend most of the time on water, such as ducks, geese, and swans. Their legs are closer to the rear of their bodies than those of most birds, which is good for swimming, but awkward for walking. Their bills are designed for grabbing wetland vegetation, such as sedges and grasses, on which they feed.

Perching birds Perching birds can be found living along wetland areas where food and shelter are readily available. They are land birds, with feet designed for perching. Their feet usually have three long toes in the front and one in the back. The barred owl is commonly found in swamps, while red-winged blackbirds live in cattail marshes. Bogs are home to golden plovers, skylarks, and meadow pipits.

Food Plants and small animals in wetlands provide a ready food source for birds. Some birds feed on vegetation, while others are predatory. The marsh harrier, for example, feeds on mussels, small fish, or insects and their larvae. Herons and egrets feed on fish, frogs, and snakes.

Reproduction All birds reproduce by laying eggs. Most male birds are brightly colored and sing to attract the attention of females. After mating, female birds lay their eggs in nests made out of many different materials. These nests may be found in a variety of places throughout the wetland area. Different species of birds lay varying numbers of eggs. The tufted duck, for example, lays six to fourteen eggs that hatch in less than a month. The ducklings begin to swim within days.

The Duck that Saved Wetlands

The Federal Duck Stamp Program began in 1934 when the U.S. Congress passed the Migratory Bird Hunting Stamp Act. The act required waterfowl hunters to purchase and carry Federal Duck Stamps that are attached to a hunting license or other document. The money was used to buy or lease waterfowl habitats from their owners and designate them as restricted areas. This helped save millions of acres of wetlands.

Over the years, efforts have also included saving wetland species that were declining in numbers, such as wood ducks, canvasback ducks, and pintail ducks. The program helps endangered species that rely on wetlands for food and shelter.

Anyone can own Federal Duck Stamps. State, international, and junior stamps are available. A duck stamp provides free admission to all National Wildlife Refuges where entrance fees are charged. To learn more about the duck stamps and to see pictures of them, visit http://www.nationalwildlife.com.

Mammals Mammals are warm-blooded vertebrates that are covered with at least some hair and bear live young nursed with milk. Aquatic mammals, such as muskrats, have waterproof fur that helps them blend into their surroundings and webbed toes for better swimming. Some of these mammals live permanently in wetlands and others, such as raccoons, visit for food, water, and shelter during part of their lives.

Common mammals American beavers are well-adapted to the wetland environment. They have webbed feet for powerful swimming

Wetlands are ideal for water birds such as the Black-bellied whistling duck. IMAGE COPYRIGHT FLORIDASTOCK, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

and warm, waterproof fur. Other mammals found in wetlands include the mink, the water shrew, and the Australian platypus. The sitatunga, a type of antelope, lives near swamps in central and east Africa. It feeds on emergent wetland plants.

Red deer Although peatlands generally do not support many species of animals, red deer live in the bogs. At 5 feet (1.5 meters) tall, it is the largest land mammal found in Ireland. It can be seen rolling in the peat in order to get rid of parasites and insects.

Muskrat Muskrats resemble beavers. They are heavy-bodied rodents about 12 inches (30 centimeters) long, not including the long tail. They are native to North America and common to marshes all over the country. Their hind feet are webbed for swimming and they can often be seen floating on the water's surface. Marsh plants such as sedges, reeds, and the roots of water plants provide most of their diet.

Muskrats build dome-shaped houses in water. They pile up mud, cattails, and other plants until the mound rises above the water's surface. Tunnels lead into the mound where one or more rooms are hollowed out above the water's surface.

These mammals are hunted for their fur, which is brown and consists of soft underfur and a dense coat. They are also sold as food, often labeled as "marsh rabbit."

Food Some aquatic mammals, like the otter, are carnivores, eating rabbits, birds, and fish. Muskrats are omnivores, eating both animals, such as mussels, and plants, such as cattails. Beavers are herbivorous and eat trees, weeds, and other plants.

Reproduction Mammals give birth to live young that have developed inside the female's body. Some mammals are helpless at birth while others are able to walk and even run immediately. Some are born with fur and with their eyes and ears open. Others, like the muskrat, are born hairless and blind. After about three weeks young muskrats are able to see and swim.

Endangered species Over half of the endangered or threatened fish and other wildlife in the United States (about 240 species altogether) rely partly on wetlands for food, water, shelter, or a place to reproduce. Over one-third of these live only in wetlands.

In North America, endangered species include the whooping crane and the manatee. The whooping crane lives in coastal swamps and feeds on roots and small reptiles. It has been threatened by hunting, pollution, and dredging (dragging a net along the bottom of a body of water to gather shellfish or plant specimens).

The manatee is a slow-moving, seal-like animal. Manatees live in shallow coastal wetlands in the Caribbean, the Amazon, and Africa. They have become endangered because of overhunting, being caught and strangled in fishing nets, or being killed by boat propellers. Pollution has disrupted their habitats and food sources.

In Ireland, the Greenland white-fronted goose, which relies on bogs for feeding and breeding, is endangered because many bogs have disappeared.

The Swimming Rabbit

The North American swamp rabbit has broad, flat feet so that it can move easily over wet, marshy soil. It can swim, and often escapes danger by staying submerged with only the tip of its nose exposed to the air in order to breathe.

Muskrats are residents of marshy areas throughout most of North America. IMAGE COPYRIGHT JUDY CRAWFORD, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Human Life

After 13000 BC, wetlands played an important role in early civilizations. For prehistoric communities throughout the world they provided food, water, and materials for clothing, shelter, and tools. Wetlands are able to reveal many of these ancient civilizations' secrets to scientists. Bodies of animals and humans, and artifacts (objects made by humans, including tools, weapons, jars, and clothing) have been well preserved in some wetlands and give information about how ancient people lived. Evidence of these ancient communities has been found in bogs. Conditions in bogs are excellent for preserving artifacts and bodies.

Impact of wetlands on human life Wetlands have had an affect on the supply of food and water, on shelter, and on other resources.

The Bog People

Organic materials in peat bogs absorb and hold large amounts of water like a sponge. Bog soils are extremely acidic and have little oxygen. Because of these factors, decomposition takes place very slowly. Entire trees, animals, and even human bodies have been preserved for centuries.

The remains of more than 2,000 humans have been found in bogs, primarily in northwestern Europe. The bodies are in various stages of preservation, from skeletons to those with flesh intact. Sometimes only body parts such as heads or limbs are found. Often the skin has darkened and the hair has turned red from peat acids. The bodies found in Europe range in age from about 1,500 to 3,000 years old. The body of a woman, known as the Koelbjerg Woman, was found in Denmark and is believed to be 10,000 years old.

Many of these people appear to have died violent deaths. Perhaps they were killed as a punishment for a crime or were the victims of human sacrifice. Their deaths may have taken place at the bog because it was so isolated.

At a bog in Windover, Florida, 160 bodies have been found that are about 7,000 years old. Buried with them are food, tools, clothes, and weapons. Many of these items were made from wetland plants and from the bones of wetland animals.

Food and water Wetlands are a source of water for drinking and crops. Areas near wetlands continue to provide food in a variety of ways for tribal cultures in Asia and Africa and for urban peoples elsewhere. Since wetlands are a habitat for much wildlife, hunting and fishing are common there.

Cattle can be raised near wetlands because water and grazing land are available. Crops such as sorghum (a cereal grain native to Africa and Asia) are commonly grown in wetland areas. Grain sorghums, such as milo, kafir, and durra, have adapted to the extremes of the wet/dry cycle of the wetland and are among the most drought-tolerant grains. Millions of people in China, India, and Africa rely on sorghum as a food staple. In the United States, sorghum is used mostly as livestock feed.

Besides sorghum, American farmers use wetland plants, such as marsh grass, reeds, and sedges, for feeding livestock. Wetlands are an excellent place to grow rice, which is a major food source for much of the world's population.

Shelter Materials for dwellings are available from wetland sources. Roofs made from reeds are used on huts in Egypt and in stilt houses in Indonesia to keep the occupants cool and dry. A tightly woven reed roof can last for forty years. House frames are constructed from the timber of mangrove, and palm trees. Wetland sediments, such as clay and mud, may be used to produce bricks that are used for walls.

Houses Without Walls

The Seminoles, a Native American people who once lived in the Florida Everglades, built homes with no walls. Called a chikee, the home was built on a platform, had a log framework, and a thatched reed roof. The absence of walls provided ventilation in the warm climate.

Other resources Wetlands provide other resources that humans rely on besides building materials. For example, dried peat is used in homes for heat and to fuel electric generators in countries such as Ireland, where coal is scarce. Peat is a source of protein for livestock feed, and chemically processed peat is used as a base for polishes and waxes. In horticulture, peat moss is used as ground cover, a soil conditioner, and a growing medium. Peat is also found in medicinal baths and cosmetics.

There are at least 120 distinct medicinal substances derived (made) from wetland plants. Wetland soils are sources of gravel and phosphate. Phosphate is used as a raw material for making fertilizers, chemicals, and other commercial products.

Wetlands prevent loss of human life and property during floods because they absorb and store water. The riparian wetlands along the Mississippi River once stored sixty days of floodwater. Since most of these wetlands have been filled or drained, they now only store twelve days of floodwater.

Impact of humans on wetlands The important role of the wetland for plant and animal communities and for the environment in general has not always been understood. For more than 2,000 years, people in different countries have been draining wetlands to get rid of mosquitoes and disease, to increase land for farming, and to make room for development. By 1990, more than half of the wetlands in the United States were destroyed.

As the value of wetlands becomes more recognized, government agencies, such as the U.S. Department of the Interior and U.S. Fish and Wildlife Service, as well as environmental groups, are working to preserve existing wetlands and to create new ones. In 1989, U.S. president George Bush, asked that the United States work toward the goal of no net loss of wetlands. This means that if a natural wetland is destroyed by development, an artificial one must be built to replace it. As of July 1998, there were 97,000,000 acres (39,000,000 hectares) of artificial wetlands in the United States. In 1998, the Clinton administration issued an

An Earth-Friendly Architect

Architect James Cutler of Seattle, Washington, believes that the environment should be preserved when designing and building houses. He has gone to extremes to save the landscape, including building houses on stilts and placing sidewalks over the tops of forests. Cutler designed a home for Microsoft Chairman Bill Gates, where he reestablished wetlands on the property.

Reeds are harvested and bundled to be used on thatched roofs. IMAGE COPYRIGHT MARTIN WALL, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

initiative calling for a net gain of 100,000 acres (40,500 hectares) of wetlands per year beginning in 2005.

The Convention on Internationally Important Wetlands was signed by representatives of many nations in Ramsar, Iran, in 1971. Commonly known as the Ramsar Convention, it is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.

Use of plants and animals When animals and plants are overharvested they may become endangered. Overharvesting means they are used up and destroyed at a faster rate than they can reproduce. When this happens, wetland, timber, fuel, medicines, and sources of food for humans and animals are all lost.

Use of natural resources The two primary resources found in wetlands are water and peat. Wetlands often act as part of the groundwater system. When they are lost, the supply of drinking water may be affected.

It takes ten years to form less than half an inch of peat, and its overuse has caused significant peatland losses. Western European peat mining companies are rapidly using up local areas of peat and expanding their mining operations into eastern European countries. All natural peatlands in the Netherlands have been destroyed. Switzerland and Germany each have only 1,250 acres (500 hectares) of peatland remaining.

Quality of the environment Wetlands are endangered by industrial and municipal (city) contaminants, by the accumulation of toxic chemicals, and from acid rain.

Acid rain is a type of air pollution especially dangerous to wetlands. It forms when industrial pollutants such as sulfur or nitrogen combine with moisture in the atmosphere and form sulfuric or nitric acids. These acids can be carried long distances by the wind before they fall either as dry deposits or in the form of rain or snow. Acid rain can significantly damage both plant and animal life. It is especially devastating to wetland amphibians such as salamanders, because it prevents their eggs from maturing.

Mining for minerals near a wetland can have a negative impact on the biome. Mercury, a poisonous liquid metal used in gold mining operations, often contaminates wetlands close to the mines. Mining operations also require large amounts of water, and nearby wetlands may be drained.

The world's climate may be growing warmer because of human activity. As polar ice caps melt, there is a rise in sea level. As this happens, more salt water floods into coastal wetlands and increases the salinity not only of the wetlands, but of rivers, bays, and water supplies beneath the ground. As these habitats change, animal and plant life are affected, and some wetlands may be destroyed.

Adopt A Wetland

Both the federal government and individual states are working to protect wetlands. Some states sponsor "Adopt a Wetland" programs, in which groups of people agree to help support their local wetlands in a variety of ways, such as picking up litter. For information about adopting a wetland, contact the U. S. Environmental Protection Agency, Public Information Center, (202) 260-7756 or (202) 260-2080.

Artificial wetlands Artificial wetlands are those created by humans. Creating a wetland is very difficult; all the right conditions need to be met, including a water source and nutrient rich soil that contains a lot of water but not much oxygen. In Arizona, there are twenty-six artificial wetlands operational with twenty-four others under construction or awaiting approval.

An artificial wetland that works well and is extremely valuable worldwide is a rice paddy. A rice paddy is simply a field that is flooded for the purpose of growing rice, a food staple for about three billion people—nearly one half of the world's population. Some are flooded naturally, by monsoon (tropical) rains or overflowing rivers. Others are flooded by irrigation (watering). Mud dams and waterwheels are built to bring in and hold the water level at approximately 4 to 6 inches (10 to 15 centimeters) while the rice grows. Ninety percent of rice paddies are in Asia, especially China and India. Some rice is also grown in Europe and the United States.

Artificial wetlands are found on the Arabian Peninsula where they are used for water storage and sewage treatment. Other human-made wetlands have been created as winter homes for migrating waterfowl.

Marshes Clean Up Messes

A lot of contaminants seep into the environment every day from oil spills, sewage treatment plants, industrial waste, and old mines. In some areas, phytoremediation (fi-toh-rih-mee-dee-AY-shun) is being used to clean up these messes. (*Phyto* is a Greek word for plant and *remediation* means to make things right.) Phytoremediation uses plants to absorb pollutants.

One type of phytoremediation involves creating an artificial marsh containing cattails and water lilies. These wetland plants are able to absorb some water pollutants. Poplar trees can clean up water polluted with oil, and sunflowers are used to help clean up radioactive materials in the soil. Sunflowers are used near the Chernobyl nuclear power station in Pryp'yat near Kiev in the Ukraine. The power station exploded in 1986, releasing radioactive waste into the environment.

Many varieties of rice grow well in shallow water. IMAGE COPYRIGHT JAPONKA, 2007. USED UNDER LICENSE FROM SHUTTERSTOCK.COM.

Native peoples The Marsh Arabs of Iraq and the Nilotic peoples of Africa live in or near wetlands that provide almost all of the resources they need.

Marsh Arabs of Iraq The Mesopotamian wetland lies between the Tigris and Euphrates Rivers in southern Iraq. At almost 8,000 square miles (20,000 square kilometers), it is one of the largest wetlands in the world. The Marsh Arabs, or Ma'dan, have lived there for more than 6,000 years. The water there is clean, calm, and fairly shallow—about 8 feet (2.4 meters) deep.

The Marsh Arabs' houses are made of reeds and built on islands that they make. To construct the islands, they create a fence from reeds and partially submerge it. Then they fill the area inside the fence with cut rushes, add layers of mud, and stamp it all down. When the pile reaches the water's surface, they fold the top of the fence onto the pile and add more reeds to finish it. The completed island is big enough not only for the family to build a house and live on, but for their cattle as well.

Isolation from the outside world has allowed the Marsh Arabs' way of life to remain the same for hundreds of years. Daily life consists of fishing, buffalo herding, and growing rice. Reeds are gathered every day to feed the buffalo. Transportation from house to house or to other villages is by means of small canoes called *mashhufs.*

Survival of the Marsh Arabs is threatened by irrigation practices, which have drawn water from their wetlands. Some of the marshes have already been drained for agricultural use and oil exploration.

Nilotic Peoples Nilotic peoples live near the Nile River or in the Nile Valley in Africa. Two Nilotic tribes, the Dinka and the Nuer, live in southern Sudan. This area is a rich floodplain, and during the wet season, from July through October, the people live on high ground in permanent villages. From December through April, when the floodwater recedes, they move to the floodplains. There, the Dinka build temporary villages along the banks of the Nile River. Their homes, made from reeds and grasses, are circular at the base and come to a point at the top, much like a teepee. Their neighboring tribe, the Nuer, lives in a similar fashion but in the marsh, savanna (grassland), and swamp areas.

Madan, or Marsh Arab, children play in water canals that still are left in what is now mostly dry land in Qurnah, southern Iraq. AP IMAGES.

Wetland grasses and plants grow in the floodplain after the waters recede. The grasses provide food for cattle and attract wildlife, which is often hunted for food. Nilotic tribes fish, hunt, and grow some grains. The Dinka use their cattle for meat and milk, but the Nuer eat cattle only during religious ceremonies. For them, cattle represent wealth and are used for bridal dowries (gifts) and to sell. Animal hides are made into clothing and bedding, and dried cattle dung (waste) is used for fuel.

The Food Web

The transfer of energy from organism to organism forms a series called a food chain. All the possible feeding relationships that exist in a biome make up its food web. In the wetland, as elsewhere, the food web consists of producers, consumers, and decomposers. These three types of organisms transfer energy within the wetland environment.

At the bottom of the food chain are the producers, such as photosynthesizing plants and algae, which use energy from the sun to produce sugars and starch from carbon dioxide and water. The shallow wetland water lets in lots of sunlight, which helps these organisms grow.

Primary producers are eaten by primary consumers such as the larval forms of frogs and toads, and larger animals such as shrimp and snails. Other primary consumers, such as small aquatic insects, shellfish, and small fish, feed on plant materials.

Primary consumers are food for predators such as larger fish, reptiles, amphibians, birds, and mammals, which are called secondary consumers. Tertiary consumers are the predators, such as owls, coyotes, and humans, that prey on both primary and secondary consumers.

The decomposers feed on dead organic matter and include fungi, bacteria, and crabs.

Spotlight on Wetlands

The Florida Everglades The Florida Everglades, lying within the subtropical zone near the tropics, is one of the largest freshwater marshes in the world, stretching from Lake Okeechobee 100 miles (160 kilometers) south to Florida Bay. Within its boundaries are freshwater swamps and coastal (saltwater) mangrove swamps. In the northern portion of the Everglades is Big Cypress Swamp. This swamp covers 1,500 square miles (4,000 square kilometers) and gets its name from the many tall bald cypress trees that live there.

The Everglades were formed during the last ice age, which ended about 10,000 years ago. During this period, glaciers melted and sea level was raised, which flooded the area and turned it into a wetland. Under the water and soil is a porous limestone rock formed during the last glacial period. This type of rock contains shells and skeletons of animals deposited in the sea. Hummocks (rounded hills or ridges) have formed in some areas, and hardwood trees can grow there. Otherwise, the terrain is flat.

The subtropical climate of the Everglades is mild, with temperatures ranging from 73° to 95°F (25° to 35°C) in the summer. Winters are mild, with an average high of 77°F (25°C) and a low of 53°F (12°C). The rains occur from June to October, with an annual accumulation of about 55 inches (140 centimeters). The region is often hit by severe tropical storms.

The grassy waters of the Everglades are actually very shallow, ranging from about 6 inches (15 centimeters) to 3 feet (94 centimeters) deep. They cover about 4,000 square miles (10,300 square kilometers). Water comes from rainfall and overflows from Lake Okeechobee.

Much of the Everglades are covered with sawgrass, a type of sedge. Tropical plants, such as ferns, orchids, and mosses, grow in freshwater areas. Saltwater aquatic plants include lilies and bladderworts. Cypresses, palms, live oaks, and pines grow on the hummocks.

Among the invertebrates, the Liguus tree snail can be found living on the hummocks, and Everglades reptiles include turtles, king snakes, water moccasins, and rattlesnakes. Alligators live in freshwater areas while American crocodiles live saltwater swamps.

Tourists are attracted by the bird life in the Everglades. Herons, egrets, spoonbills, ibises, eagles, and kites are a few of the birds in the area. The Everglades kite, a tropical bird of prey, has been named after the region. Mammals include white tailed deer, cougars, bobcats, black bears, and otters.

The Florida Everglades
Location: Southern Florida
Area: Approximately 1,506,539 acres (606,688 hectares)
Classification: Freshwater marsh, freshwater swamp, and saltwater swamp

Many attempts have been made to drain the Everglades so the land could be used for farming and development. Drainage projects began in the early 1900s. Consequently, about 50 percent of the wetlands have been altered. Due to agriculture and development, only about 27 percent of the original area has been preserved as the Everglades National Park.

Draining the area has caused a loss of animal and plant life. Endangered species include the manatee, the round-tailed muskrat, and the mangrove fox squirrel. Early in the twentieth century, plume hunters nearly wiped out egrets and spoonbills for their feathers, which were used extensively as decorations on women's hats.

The introduction of non-native species of plants is also a threat. The Australian melaleuca tree and the Brazilian pepper plant have spread throughout the area, using up water supplies and choking native plants.

Agriculture is the leading economic activity in the region. In the area south of Lake Okeechobee, farmers raise sugarcane, fruit, and vegetables, which are shipped north. Sport fishing, boating, hunting, and camping are popular in the area.

The Seminole Indians, who were driven out of the Okefenokee Swamp in northern Florida by American troops during the nineteenth century, found a safe home in the Everglades. They planted corn and vegetables and gathered roots and nuts. Fishing and hunting were also sources of food. Throughout the twentieth century, the number of Seminoles living in the area has decreased. Another tribe, the Miccosukee, still live in reservations near the center of the Everglades.

A growing concern for the environment has encouraged protection of the Everglades and its ecosystem. It became a national park in 1947 and is the third largest and the wettest national park in the United States. The park includes 10,000 islands off the Florida coast along the Gulf of Mexico, and more than one million people visit annually.

Okefenokee Swamp The word "Okefenokee" (oh-kee-fen-OH-kee) is taken from a Timucuan Indian word and means "trembling earth." This refers to the small bushes and water weeds that float on the swamp's open water and move when the water is disturbed. The swamp, which is 25 miles (40 kilometers) wide and 38 miles (61 kilometers) long, is one of the oldest and most well-preserved freshwater wetlands in the United States.

Okefenokee Swamp
Location: Southeastern Georgia and northern Florida
Area: 438,000 acres (177,000 hectares)
Classification: Freshwater swamp, bog, marsh

The Okefenokee lies about 50 miles (80 kilometers) inland from the coast of the Atlantic Ocean in Georgia, but a sandy ridge prevents the swamp from draining directly into the ocean. The Suwannee River is the principal outlet of the swamp providing 85 percent drainage into the Gulf of Mexico.

The Okefenokee was formed almost 250,000 years ago when the waters of the Atlantic Ocean covered the area. When the ocean receded, some salt water was trapped in depressions in the ground. Over thousands of years, plants grew and filled the wetland. As they decayed, they turned into peat, which now forms the swamp floor. The peat is as deep as 15 feet (4.6 meters) in places.

Freshwater lakes, wet savannas (grasslands with scattered trees), cypress woods, hummocks, open grassy spaces, peat bog islands, and thick brush are also found in the Okefenokee. Many channels form a maze through the area. About 60 inches (152 centimeters) of rain falls annually.

The Okefenokee supports 621 species of plants, including rare orchids and lilies. The insectivorous pitcher plant, maiden cane, floating hearts, and golden club all add color. Freshwater regions support sphagnum moss, ferns, and rushes. Tupelo trees and giant bald cypress trees covered with Spanish moss add an eerie quality.

Insects, such as the mosquito and the yellow fly, are abundant, and 37 species of amphibians make the Okefenokee their home. At least 64 species of reptiles live here, including 5 kinds of poisonous snakes, and more than 10,000 alligators. Considered "kings" of the swamp, alligators are a major tourist attraction. About 40 species of fish live in the swamp, including bluegill, warmouth, golden shiners, and pumpkinseed sunfish. These fish have adapted to life in the acidic water. They are often dark with yellow undersides and they can see in low light.

The Okefenokee is home to 233 species of birds including the white ibis, the sandhill crane, the wood duck, the great blue heron, and the barred owl.

Bears, bobcats, deer, foxes, and raccoons live in the forested areas. Approximately thirty species of mammals can be found in the swamp, including the black bear.

The area surrounding the swamp was settled by Europeans in the late 1700s. The Seminoles once lived in the interior, but they were driven out by American troops in 1838.

During the 1800s, developers tried to drain the swamp by building a canal, but found the project larger than anticipated. The project was abandoned in 1893. After the turn of the century, logging companies built railroad tracks through the swamp; as a result 400,000,000 feet (120,000,000 meters) of timber, mostly cypress were cut down. In 1937, U.S. president Franklin Roosevelt (1882–1945) protected about 629 square miles (1,630 square kilometers) of the Okefenokee by designating it the Okefenokee National Wildlife Refuge. Despite these actions, the swamp continues to be threatened by developers, including those who want to mine titanium ore on its eastern rim. Due to public and government opposition, the mining project was terminated.

Fire is a natural part of the swamp's ecosystem, which can occur as infrequently as every 30-50 years. The two most recent fires occurred in May 2002 and May 2007.

The Okefenokee offers walking trails for tourists and 120 miles (193 kilometers) of water trails that can be explored by canoe.

The Mekong Delta The Mekong Delta extends from Phnom Penh, the capital of Kampuchea province in Vietnam, to the coastline bordering the South China Sea. The Mekong River, the longest in Southeast Asia, divides at Phnom Penh into two branches. As the branches pass through the delta they form nine channels. The name Mekong means "Nine Dragons" and refers to these channels.

The delta, which supports 15,000,000 Vietnamese, forms a 13,600,000 acre (5,500,000 hectares) triangular area including floodplain, freshwater, and saltwater swamps. Mangrove and melaleuca forests cover the remaining area.

Most of the delta is less than 16 feet (5 meters) above sea level. From May to October the area experiences heavy rains, ranging from 59 to 92 inches (150 to 235 centimeters). The average temperature is about 79°F (26°C), and the climate is very humid.

The Mekong Delta supports 35 species of reptiles, including crocodiles and the endangered river terrapin (a type of turtle), and 260 species of fish, many of which are sold commercially. Herons, egrets, ibises, and storks nest in the delta's forested areas. Mammals include otters and fishing cats.

The delta is rich in agricultural produce, fish, and waterfowl. At one time it yielded 26 tons (23.5 metric tons) of fish per square mile. About half of the delta is devoted to rice paddies, which yield about 6,500,000 tons (5,900,000 metric tons) of rice each year.

During the Vietnam War (1959–1975), the Mekong Delta was seriously damaged when Agent Orange and other defoliants (chemicals

The Mekong Delta
Location: Vietnam
Area: 12,237 acres (49,712 square kilometers)
Classification: Freshwater swamp and saltwater swamp

that cause leaves to fall off plants and trees) destroyed over 50 percent of the mangrove forests. The object was to remove any hiding places used by the enemy, but Agent Orange also caused skin diseases, cancer, and birth defects. One-fifth of the country's farmland was destroyed by direct bombing and machines used to clear land. The melaleuca forests were burned with Napalm, another chemical weapon, and almost destroyed. These chemicals made much of the soil infertile.

Of the 386 bird species supported by the Mekong Delta, 92 are waterfowl. The eastern Sarus crane, an endangered bird, disappeared during the war but has since returned. The giant ibis, the white-shouldered ibis, and the white-winged wood duck, all endangered, have not been seen here since 1980.

Hydroelectric dams, built for generating electricity, have a negative affect on the ecosystem. The dams reduce flooding, which decreases the freshwater flow to wetlands. Spawning areas for fish are declining and mangrove forests are being converted to artificial ponds by the farmed shrimp industry.

The Great Dismal Swamp The Great Dismal Swamp is a freshwater wetland located in southeast Virginia and northeast North Carolina. Its soil contains few minerals and nutrients. Drainage is poor and the soil is saturated and acidic. In this environment, decomposition is slow and peat accumulates over time.

The fungus called armillaria, which grows on rotten wood in the swamp, gives off a luminescence (glow) called foxfire. Broad-leaved shrubs such as hollies and bayberries are found here. Bald cypress trees survive well in saturated soil and populate the area; some are as old as 1,500 years. Other native trees include the black gum, the juniper, and the white ash.

Seventy-three species of butterflies and more than 97 species of perching birds, including warblers, woodpeckers, and wood ducks, live in this area. Black bears, bobcats, minks, and otters also live in the region.

The Great Dismal Swamp
Location: North Carolina and Virginia
Area: 106,716 acres (42,686 hectares)
Classification: Peat bog and freshwater swamp

Many famous Americans were in some way associated with the Great Dismal Swamp. In 1763, U.S. president George Washington (1732–1799) set up a company to drain the swamp for agricultural purposes and to use its lumber. One hundred-forty-five miles of road were constructed to support the logging activities that continued until 1976. The American statesman, Patrick Henry (1736–1799), who participated in the American

Revolution, owned land there. The swamp was used by American author Harriet Beecher Stowe (1811–1892) as the setting for her 1856 novel, *Dred: A Tale of the Great Dismal Swamp.* The forests of the swamp provided refuge to runaway slaves. In 2003, the Great Dismal Swamp became the first National Wildlife Refuge to be officially designated as a link in the Underground Railroad Network to Freedom.

Kakadu National Park Kakadu National Park is the largest wetland in Australia and is marked by a great diversity in species and habitats. The area includes freshwater wetlands, mangrove swamps, and billabongs. The term billabong comes from an Australian Aboriginal (native) word meaning "dead river," and describes standing, often stagnant, water near river channels. Billabongs are usually found only in the parts of Australia where the climate is hot and dry and interrupted by occasional flooding.

Average temperatures are high all year and range from 91°F (33°C) in July to 108°F (42°C) in October. Rivers flooded by January and February rains feed the freshwater areas. The coastal wetlands are fed by tides.

Kakadu includes many acres of forests, sedges, and grasslands. In April and May, when the dry season begins, bush fires destroy old growth and encourage new plant life.

When the thousands of acres of grassland flood during the wet season, plant and animal life abounds. In all, there are more than 200 species of plants, including 22 species of mangrove trees. Water lilies, woolybutt (*Eucalyptus miniata*), and spear grass, which grows to more than 6 feet (1.8 meters) tall, can all be found. Paperbark trees dominate freshwater swamp areas.

Numerous turtles and both freshwater and saltwater crocodiles live in the shallows. Barramundi fish travel between the waterholes and estuaries, depending on the season. Goannas, a type of monitor lizard, live here.

Millions of water birds live in the park. These include whistling ducks, magpie geese, radjal shelducks, and grey teals. Shorebirds migrate from as far away as the Arctic to winter in the mild climate of Kakadu.

The Australian native people, called Aborigines, once used the park's wetland plants and animals as a source of food. Aborigines recognized six seasons in the Kakadu region instead of the traditional wet and dry seasons. Disposal of waste from uranium mines on the edge of Kakadu is threatening the area. Other dangers include tourism and the introduction of non-native plants and animals. Para grass, an exotic grass being

Kakadu National Park
Location: East of Darwin in the Northern Territory of Australia
Area: 7,700 square miles (20,000 square kilometers)
Classification: Freshwater wetlands, mangrove swamps

tested as cattle feed, is currently choking Kakadu's wetlands. The big-headed ant, a native of Africa, forms huge colonies that wipe out many native ants and other small creatures.

Kushiro Marsh The Kushiro (koo-SHEE-roh) Marsh is one of the largest and most important natural wetlands in Japan. It is located in a floodplain and contains small freshwater lakes, reed beds, sedge marshes, and peat bogs. About 68,400 acres (27,700 hectares) have been designated as a national wildlife protection area and a national monument.

Annual rainfall averages about 44 inches (112 centimeters). The climate is on the cold side with winter temperatures sometimes falling below -4°F (-20°C). The average annual temperature is 42°F (5.6°C) encouraging slow decomposition and peat formation. Spring and summer are also cool.

The floodplain areas support reeds and sedges. The shallow marshes are extremely important for the endangered red-crowned crane, because they provide a place for the birds to breed and winter. More than 100 species of birds use the area, including geese, ducks, and swans. Mammals found in the marsh include the raccoon dog and the red fox. The marsh has an exceptional abundance of dragonflies.

The Llanos The Llanos (YAH-nos), a Spanish word for "plains," is a large grassland covering parts of western Venezuela and northeastern Colombia. Within its boundaries is one of the largest wetlands in South America; a combination of rivers, lakes, marshes, swamps, forests, and ponds. It is bordered by the Andes Mountains on the north and west, the Orinoco and Apure Rivers to the east, and the Amazonian wilderness to the south.

The Llanos is a temperate area, with year-round average temperatures of 75°F (24°C). Rain falls primarily between April and November, the central plains get about 45 inches (110 centimeters) annually. Areas closer to the Andes Mountains receive about 180 inches (457 centimeters). The summer is very dry. No growth takes place during these months and frequent fires drive animals to areas that are still wet. When the rains come in the winter, the growing season begins.

Although growth is limited by the long dry period, swamp grasses and sedges are common. Carpet grass is able to grow in drier areas. Oak and palm trees are found along the edges of the rivers.

Kushiro Marsh
Location: The island of Eastern Hokkaido, Japan, along the Kushiro and Akan Rivers
Area: 112 square miles (290 square kilometers)
Classification: Marsh and peat bog

The Llanos
Location: Venezuela and Colombia, South America
Area: 220,000 square miles (570,000 square kilometers)
Classification: Riparian wetland and swamp

The Llanos provides a habitat for many wading birds such as herons, storks, and ibises. The capybara, the world's largest rodent, lives in the area. It grows up to 4 feet (1.3 meters) long and weighs as much as 100 pounds (50 kilograms). Armadillos, deer, and anteaters find shelter in the forest and feed in the grasslands. The green anaconda, the largest snake in the world, makes its home in the Llanos.

The most common economic activity is cattle ranching. Since most ranchers use traditional methods, the activity has had little effect on the area.

Okavango Delta The Okavango Delta is considered an oasis in the Kalahari Desert. As the Okavango River flows from Angola into Botswana, it becomes choked with weeds and spreads out to create one of the world's largest inland wetlands.

Annual temperatures range from 21° to 105°F (-6° to 41°C). Average rainfall is about 18 inches (45 centimeters). In February and March, the river overflows and refills the marshes and swamp areas, making them desirable habitats for plants and animals. Water can be as deep as 16 feet (about 5 meters).

Although rainfall can vary, parts of the delta are always wet from flooding. Water lilies and papyrus are abundant.

The delta is home to kingfishers, herons, and water birds such as ducks, geese, and ibises.

When the waters recede, grazing animals arrive. These include antelope, springbok, and lechwe. The lechwe is a semi-aquatic antelope that feeds on grasses in shallow water. It can graze while standing in water up to 20 inches (50 centimeters) deep. Its elongated hooves help it move through the soft mud on the swamp floor.

The Okavango is the only source of permanent surface water for Botswana. This creates industrial and agricultural demands, such as for diamond mining. An area about 695 square miles (1,800 square kilometers) in size has been designated as the Moremi Wildlife Reserve, one of the few protected areas in Africa.

Pripet Marshes The Pripet Marshes (also spelled Prepay or Pipit) form a very large wetland in Eastern Europe, covering the southern part of Belarus and northern Ukraine. The marshes are located in a forested basin of the Privet River, and the swamp is the largest in Europe.

Formed during the last ice age, which ended about 10,000 years ago, the marshes were filled with sand and gravel left behind as the glaciers

Okavango Delta
Location: Northwest Botswana, Africa
Area: 6,175 square miles (16,000 square kilometers) in the dry season increasing to 8,500 square miles (22,000 square kilometers) in the wet season
Classification: Freshwater marsh and swamp

Pripet Marshes
Location: Southern Belarus and northern Ukraine
Area: Approximately 104,000 square miles (270,000 square kilometers)
Classification: Marsh, bog, and swamp

melted. The many lakes in the area are in the process of turning into bogs. Sandy lowlands can be found among a maze of rivers, and pine forests and floodplains add to the diversity of the ecosystem. About one-third of the region is forested.

The climate is cool, with winter temperatures ranging from 18° to 25°F (–8° to –4°C). Warmer temperatures are found in and around the marshes. Annual precipitation is 22 to 26 inches (55 to 65 centimeters).

Trees growing here include pine, birch, alder, oak, aspen, white spruce, and hornbeam. Hornbeam is a type of birch that has smooth, gray bark and catkins (drooping scaly flower clusters with no petals).

Many types of birds live in the marsh, including orioles, grouse, woodpeckers, owls, blue tits, and ducks. Mammals include lynxes, wolves, foxes, wild boars, Asian deer, beavers, badgers, and weasels.

Much of the land has been cleared for lumber and agricultural use over the last several hundred years. Large-scale land reclamation (draining swampland to create cropland) in the twentieth century occurred to promote the development of agricultural areas. Crops grown in the area include rye, barley, wheat, flax, potatoes, and vegetables. Grasses used as cattle feed are also grown here.

The Pine Barrens The Pine Barrens (or Pineland) are located on the outer coastal plain of Long Island and New Jersey, including parts of the Delaware River and the Jersey Shore. Much of the area is open forest broken by marshes, swamps, and bogs. The area was formed during the last Ice Age.

The northwest part of the Pine Barrens experiences relatively cold winters, with average January temperatures of less than 28°F (–2°C). The southern area is milder, with average winter temperatures above freezing. Summers are hot, with averages for July ranging from about 70°F (21°C) in the northwest to more than 76°F (24°C) in the southwest. Precipitation (rain, sleet, or snow) is evenly distributed throughout the seasons, averaging between 44 and 48 inches (112 and 122 centimeters) annually.

The Pine Barrens are home to about 100 endangered species of plants. Many rare species include the glade cress, great plains ladies-tresses, grooved yellow flax, and some insectivorous plants. Other plants include wild azaleas, purple cone flowers, Indian grasses, and little bluestems. Rhododendrons, honeysuckles, mountain laurels, wintergreens, and cardinal flowers bring color to the area.

The Pine Barrens
Location: Long Island, New Jersey
Area: Over 1,000,000 acres (400,000 hectares)
Classification: Bog, swamp, and marsh

The area is dominated by oak and pine trees, which thrive on the well-drained sites. White cedars grow in the poorly drained bogs. Other trees include buckthorns, dogwoods, sugar maples, hemlocks, birches, ashes, and sweet gums.

The endangered Pine Barrens tree frog makes its home in the park, while bears and wildcats can still be found in some of the woodland areas. Deer, opossums, and raccoons are common.

Commercially, the area is valued for its production of blueberries and cranberries, and for tourism.

Designated by Congress in 1978 as the country's first National Reserve, the Pine Barrens' natural and cultural resources are now protected.

On May 1, 2007, a flare from an F-16 plane accidentally dropped into the forest during training, resulting in a fire that burned more than 17,000 acres.

Polar Bear Provincial Park Polar Bear Provincial Park lies along the southern edge of the Arctic region, on the northwest coast of James Bay and the southern coast of Hudson Bay in Ontario, Canada. A true wilderness, it is accessible only by plane or boat. The dominant type of wetland in the park is peatland. Inland areas of the park contain swamps and marshes, while coastal areas contain saltwater marshes.

Many of the wetlands have formed in kettles (depressions in the ground left behind by retreating glaciers). Rain, melted snow, and overflowing rivers contribute to the water supply. As kettle lakes fill in with vegetation, marshes are formed, and coastal marshes have developed with the movement of the tides. The flat-topped ridges that run along the beach, parallel to the coast, help prevent drainage back into the sea.

Because the park lies along the southern edge of the Arctic region, temperatures are cold. Freezing weather prevails for six to eight months. Summers are short with the average temperature between 60° and 70°F (16° and 25°C). Precipitation is usually less than 21 inches (55 centimeters).

Vegetation varies depending on altitude and wetness. In the higher, cooler regions of the park, plant life includes sedges, goose grasses, and flowering saxifrages. Cotton grasses, sedges, and birches grow in the lower areas. In drier places, blueberries, crowberries, and louseworts are found. Salt-tolerant plants grow in the saltwater marshes, including aquatic grasses, cotton grasses, lungworts, and lyme grasses. Caribou and reindeer lichens grow in wetlands closer to forested areas.

Polar Bear Provincial Park
Location: Ontario, Canada
Area: 9,300 square miles (24,087 square kilometers)
Classification: Peatland, swamp, freshwater marsh, and saltwater marsh

Many waterfowl, such as the lesser snow goose, use the park in spring and fall as they migrate to their Arctic breeding grounds. Thousands of mallard ducks pass through in the fall, and the western and southwestern parts of the park form a migration path for shorebirds, such as the ruddy turnstone, black-bellied plover, and several species of sandpipers. Canada geese nest in the park.

Polar bears spend their summers in the park while breeding. Caribou and moose roam the area, moving north in the warmer weather. Beavers, muskrats, otters, foxes, and wolves are just a few of the many other mammals that make the park their year-round home.

The Cree Indians live along the coastal areas and use the park for hunting, fishing, and trapping. The Cree own two hunting and fishing camps where guests can fish and hunt waterfowl, grouse, and snipe. No other non-native hunting or fishing is permitted.

Since 1970 the area has been protected from development. Commercial or industrial use of natural resources is prohibited. Most of the park is designated as wilderness zones, nature reserves, or historical zones, where wildlife is protected.

Usumacinta Delta The Usumacinta (oo-soo-mah-SEEN-tah) Delta is the most extensive wetland on the Gulf Coast of Mexico. It contains freshwater lagoons, swamps, marshes, and mangrove swamps. Its waters are rich in nutrients and support a major coastal fishery.

Many waterbirds breed and winter in the area. These include herons, egrets, storks, ibises, and spoonbills. Shorebirds that winter in the delta are ducks and coots.

A few manatees from the West Indies can be found here, as well as the endangered Morelet's crocodile.

Threats to the delta have come from drainage for agriculture and oil spills from a nearby oil field. Also, mangrove trees are being cut for timber.

Usumacinta Delta
Location: Gulf Coast of Mexico
Area: 2,470,000 acres (998,000 hectares)
Classification: Swamp, marsh, and mangrove swamp

Flow Country The marshy area of Caithness and Sutherland countries is known as Flow Country. The name "flow" comes from an old Norse word meaning "marshy ground." Flow Country is one of the largest blanket bogs in the world, and it is still growing. Some of the peat found here is more than 8,000 years old.

Typical plants that grow in Flow Country include sphagnum moss, heather, purple moorgrass, sedges, and rushes. The insect-eating plant, sundew, inhabits the bog.

Flow Country
Location: Northeast corner of Scotland
Area: 902,681 square acres (365,310 hectares)
Classification: Blanket bog

Many bird species are supported by the bog. Sixty-six percent of the European communities' greenshanks and the entire population of black-throated divers live there.

The peat that grows in a blanket bog is very valuable as fuel for home heating and industrial use. Peat mining is endangering this ancient ecosystem. In the 1980s, the Scottish government and several private companies began planting pine and fir trees. The trees support the forestry industry, but will eventually take over the wetland. Planting was halted by 1990 and the land was purchased by the Royal Society for the Protection of Birds (RSPB) in 1995 to preserve 14,800 acres (6,000 hectares) of forest.

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American Cetacean Society, PO Box 1391, San Pedro, CA 90733. Internet: http://www.acsonline.org.

American Littoral Society, Sandy Hook, Highlands, NJ 07732. Phone: 732-291-0055, Internet: http://www.alsnyc.org.

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Global Rivers Environmental Education Network (GREEN), 2120 W. 33rd Avenue, Denver, CO 80211. Internet: http://www.earthforce.org/green.

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Project Wet, 1001 West Oak, Suite 210, Bozeman, MT 59717. Phone: 866-337-5486, Fax: 406-522-0394, Internet: http://projectwet.org.

Rainforest Alliance, 665 Broadway, Suite 500, New York, NY 10012. Phone: 888-MY-EARTH, Fax: 212-677-1900, Internet: http://www.rainforest-alliance.org.

Sierra Club, 85 St., 2nd Fl., San Francisco, CA 94105. Telephone: 415-977-5500, Fax: 415-977-5799, Internet: http://www.sierraclub.org.

The Wilderness Society, 1615 M St. NW, Washington, DC 20036. Telephone: 800-the-wild, Internet: http://www.wilderness.org.

World Meteorological Organization, 7-bis, avenue de la Paix, Case Postale No. 2300 CH-1211, PO Box 2300, Geneva 2, Switzerland. Phone: 41 22 7308111, Fax: 41 22 7308181, Internet: http://www.wmo.ch.

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