

Understanding the Natural Environment

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Chapter- 1

Introduction to Natural Environment



Land management policies have been developed to preserve the natural characteristics of Hopetoun Falls, Australia while allowing ample access for visitors.



Bachalpsee in the Swiss Alps; generally mountainous areas are less affected by human activity



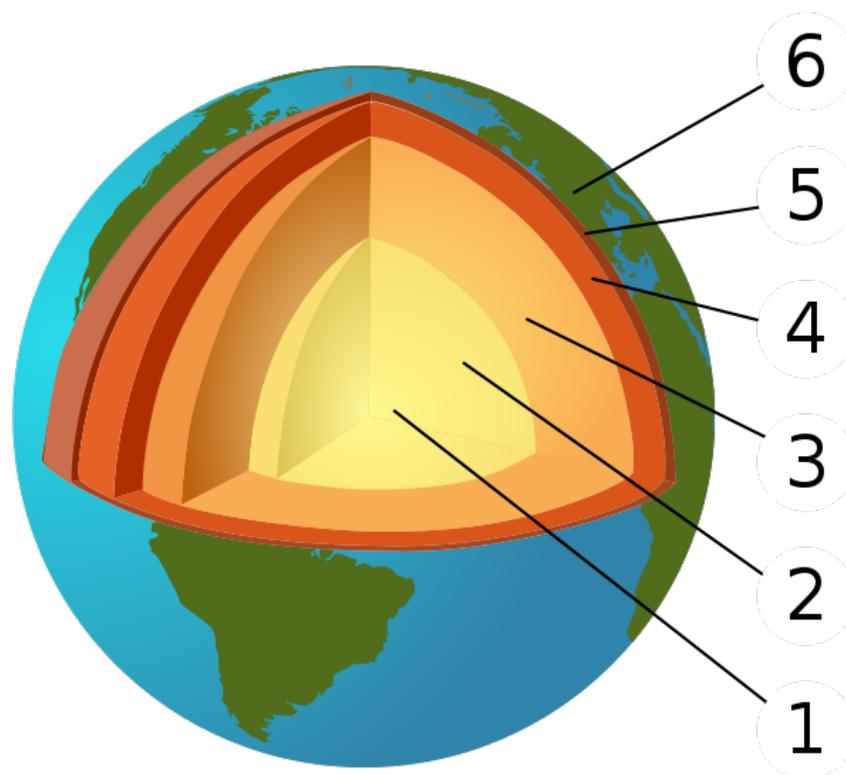
A satellite image of the Sahara desert; the world's largest hot desert and third largest desert after Antarctica and the Arctic

The **natural environment**, encompasses all living and non-living things occurring naturally on Earth or some region thereof. It is an environment that encompasses the interaction of all living species. The concept of the *natural environment* can be distinguished by components:

- Complete ecological units that function as natural systems without massive human intervention, including all vegetation, microorganisms, soil, rocks, atmosphere and natural phenomena that occur within their boundaries.
- Universal natural resources and physical phenomena that lack clear-cut boundaries, such as air, water and climate, as well as energy, radiation, electric charge and magnetism, not originating from human activity.

The natural environment is contrasted with the built environment, which comprises the areas and components that are strongly influenced by humans. A geographical area is regarded as a natural environment (with an indefinite article), if the human impact on it is kept under a certain limited level (similar to section 1 above).

Composition



The Earth's layered structure. (1) inner core; (2) outer core; (3) lower mantle; (4) upper mantle; (5) lithosphere; (6) crust



A volcanic fissure and lava channel

Earth science generally recognizes 4 spheres, the lithosphere, the hydrosphere, the atmosphere and the biosphere as correspondent to rocks, water, air and life. Some scientists include, as part of the spheres of the Earth, the cryosphere (corresponding to ice) as a distinct portion of the hydrosphere, as well as the pedosphere (corresponding to soil) as an active and intermixed sphere. Earth science (also known as geoscience, the geosciences or the Earth Sciences), is an all-embracing term for the sciences related to the planet Earth. There are four major disciplines in earth sciences, namely geography, geology, geophysics and geodesy. These major disciplines use physics, chemistry, biology, chronology and mathematics to build a qualitative and quantitative understanding of the principal areas or *spheres* of the Earth system.

Life



There are many plant species on the planet



An example of the many animal species on the Earth

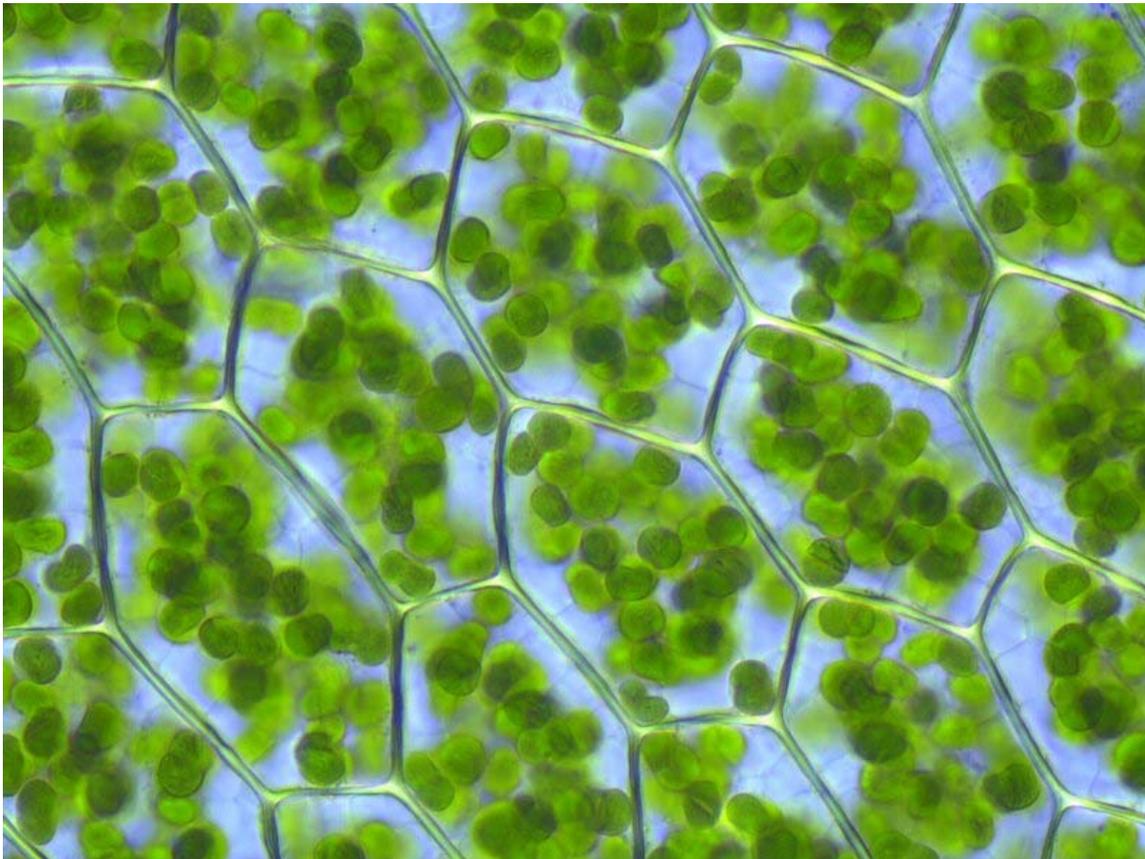
Evidence suggests that life on Earth has existed for about 3.7 billion years. All known life forms share fundamental molecular mechanisms and based on these observations, theories on the origin of life attempt to find a mechanism explaining the formation of a primordial single cell organism from which all life originates. There are many different hypotheses regarding the path that might have been taken from simple organic molecules via pre-cellular life to protocells and metabolism.

Although there is no universal agreement on the definition of life, scientists generally accept that the biological manifestation of life is characterized by organization, metabolism, growth, adaptation, response to stimuli and reproduction. Life may also be said to be simply the characteristic state of organisms. In biology, the science of living

organisms, "life" is the condition which distinguishes active organisms from inorganic matter, including the capacity for growth, functional activity and the continual change preceding death.

A diverse array of living organisms (life forms) can be found in the biosphere on Earth and properties common to these organisms—plants, animals, fungi, protists, archaea and bacteria—are a carbon- and water-based cellular form with complex organization and heritable genetic information. Living organisms undergo metabolism, maintain homeostasis, possess a capacity to grow, respond to stimuli, reproduce and, through natural selection, adapt to their environment in successive generations. More complex living organisms can communicate through various means.

Biogeochemical cycles



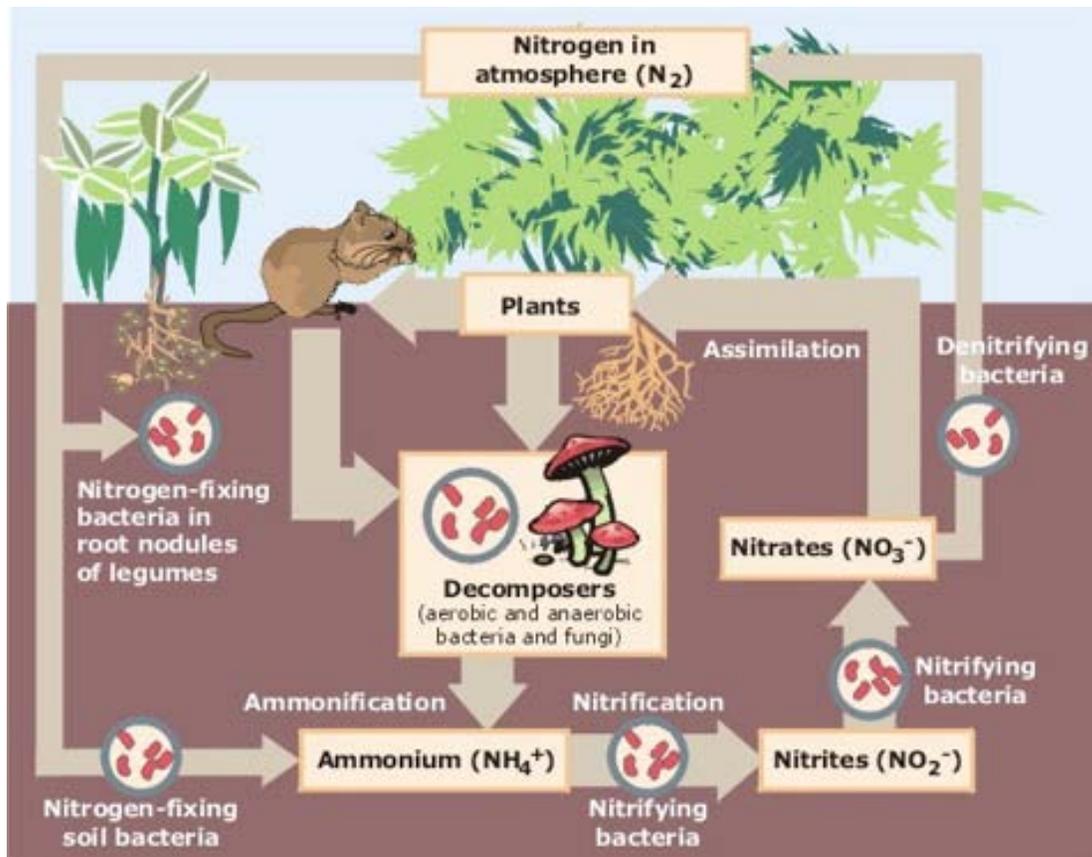
Chloroplasts conduct photosynthesis and are found in plant cells and other eukaryotic organisms. These are Chloroplasts visible in the cells of *Plagiomnium affine* — Many-fruited Thyme-moss.

Global biogeochemical cycles are critical to life, most notably those of water, oxygen, carbon, nitrogen and phosphorus.

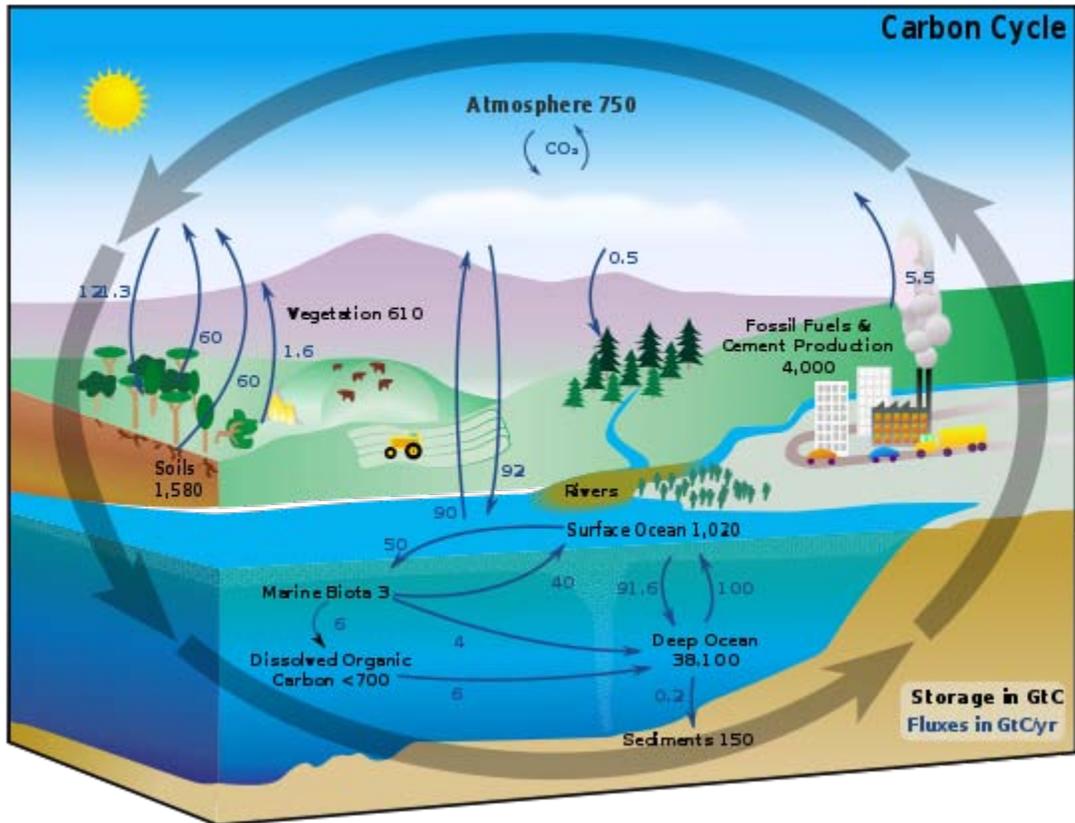
- The nitrogen cycle is the transformation of nitrogen and nitrogen-containing compounds in nature. It is a cycle which includes gaseous components.

- The water cycle, is the continuous movement of water on, above and below the surface of the Earth. Water can change states among liquid, vapor and ice at various places in the water cycle. Although the balance of water on Earth remains fairly constant over time, individual water molecules can come and go.
- The carbon cycle is the biogeochemical cycle by which carbon is exchanged among the biosphere, pedosphere, geosphere, hydrosphere and atmosphere of the Earth.
- The oxygen cycle is the movement of oxygen within and between its three main reservoirs: the atmosphere, the biosphere and the lithosphere. The main driving factor of the oxygen cycle is photosynthesis, which is responsible for the modern Earth's atmospheric composition and life.
- The phosphorus cycle is the movement of phosphorus through the lithosphere, hydrosphere and biosphere. The atmosphere does not play a significant role in the movements of phosphorus, because phosphorus and phosphorus compounds are usually solids at the typical ranges of temperature and pressure found on Earth.

Biogeochemical cycles

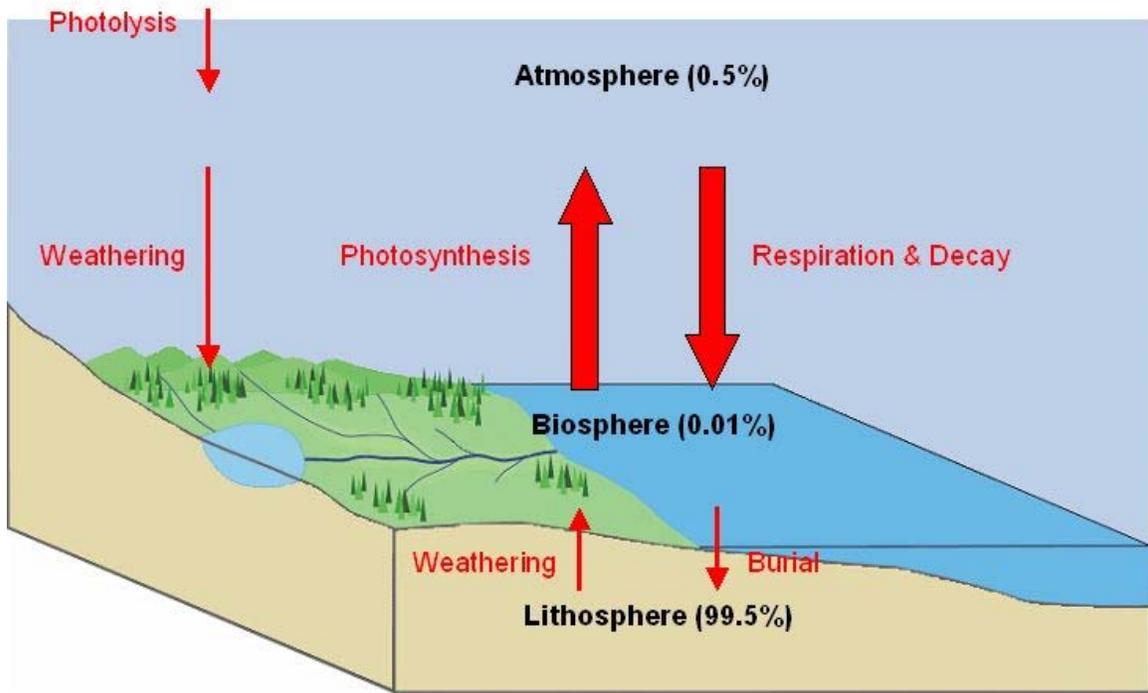


Nitrogen cycle

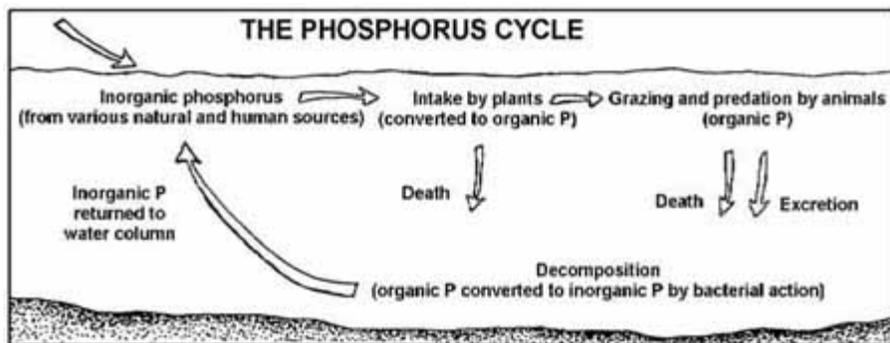


Carbon cycle

Oxygen Cycle Reservoirs & Flux



Oxygen cycle



Phosphorus cycle

Challenges



Before flue gas desulfurization was installed, the air-polluting emissions from this power plant in New Mexico contained excessive amounts of sulfur dioxide



Amazon Rainforest in Brazil. The tropical rainforests of South America contain the largest diversity of species on Earth, including some that have evolved within the past few hundred thousand years.

It is the common understanding of *natural environment* that underlies environmentalism — a broad political, social and philosophical movement that advocates various actions and policies in the interest of protecting what nature remains in the natural environment, or restoring or expanding the role of nature in this environment. While true wilderness is increasingly rare, *wild* nature (e.g., unmanaged forests, uncultivated grasslands, wildlife, wildflowers) can be found in many locations previously inhabited by humans.

Goals commonly expressed by environmental scientists include:

- Reduction and clean up of pollution, with future goals of zero pollution;
- Cleanly converting non-recyclable materials into energy through direct combustion or after conversion into secondary fuels;
- Reducing societal consumption of non-renewable fuels;
- Development of alternative, green, low-carbon or renewable energy sources;
- Conservation and sustainable use of scarce resources such as water, land and air;
- Protection of representative or unique or pristine ecosystems;
- Preservation of threatened and endangered species extinction;
- The establishment of nature and biosphere reserves under various types of protection; and, most generally, the protection of biodiversity and ecosystems upon which all human and other life on earth depends.

Very large development projects - megaprojects - pose special instructions and risks to the natural environments. Major dams and power plants are cases in point. The challenge to the environment from such projects is growing because more and bigger megaprojects are being built, in developed and developing nations alike.

Chapter- 2

Ecosystem



Coral reefs are an example of a marine ecosystem



Rainforests often have a great deal of biodiversity with many plant and animal species. This is the Gambia River in Senegal's Niokolo-Koba National Park.

An **ecosystem** is a biological environment consisting of all the organisms living in a particular area, as well as all the nonliving, physical components of the environment with which the organisms interact, such as air, soil, water and sunlight. It is all the organisms in a given area, along with the nonliving (abiotic) factors with which they interact; a biological community and its physical environment.

Overview

The entire array of organisms inhabiting a particular ecosystem is called a community. In a typical ecosystem, plants and other photosynthetic organisms are the producers that provide the food. Ecosystems can be permanent or temporary. Ecosystems usually form a number of food webs.

Ecosystems are functional units consisting of living things in a given area, non-living chemical and physical factors of their environment, linked together through nutrient cycle and energy flow.

1. Natural
 1. Terrestrial ecosystem
 2. Aquatic ecosystem
 1. Lentic, the ecosystem of a lake, pond or swamp.
 2. Lotic, the ecosystem of a river, stream or spring.

2. Artificial, ecosystems created by humans.

Central to the ecosystem concept is the idea that living organisms interact with every other element in their local environment. Eugene Odum, a founder of ecology, stated: "Any unit that includes all of the organisms (ie: the "community") in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity and material cycles (i.e.: exchange of materials between living and nonliving parts) within the system is an ecosystem."

Etymology

The term ecosystem was coined in 1930 by Roy Clapham to mean the combined physical and biological components of an environment. British ecologist Arthur Tansley later refined the term, describing it as "The whole system, ... including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment". Tansley regarded ecosystems not simply as natural units, but as mental isolates. Tansley later defined the spatial extent of ecosystems using the term ecotope.

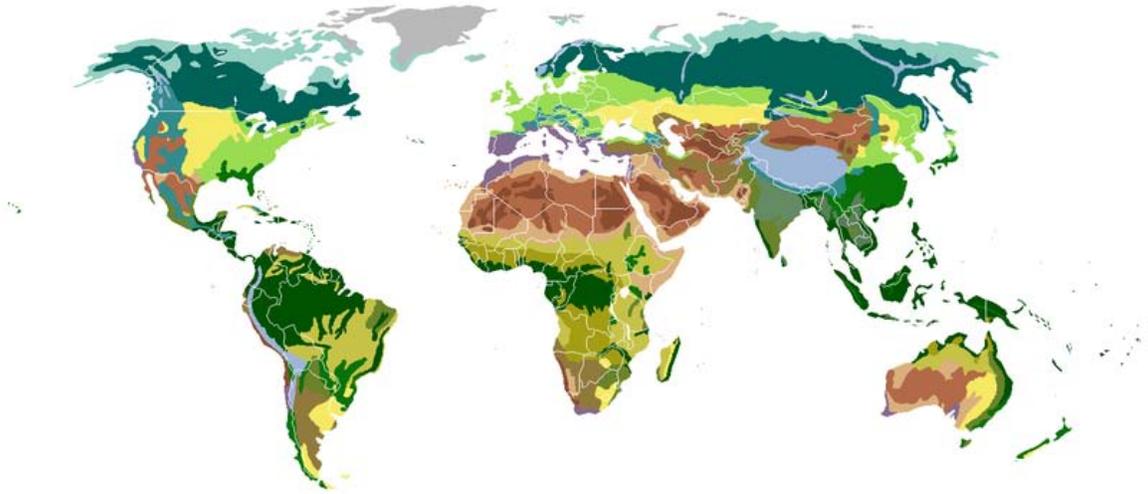
Examples of ecosystems

- agro-ecosystems
- Agroecosystem
- Aquatic ecosystem
- Chaparral
- Coral reef
- Desert
- Forest
- Greater Yellowstone Ecosystem
- Human ecosystem
- Large marine ecosystem
- Littoral zone
- Lotic
- Marine ecosystem
- Pond Ecosystem
- Prairie
- Rainforest
- Riparian zone
- Savanna
- Steppe
- Subsurface Lithoautotrophic Microbial Ecosystem
- Taiga
- Tundra
- Urban ecosystem



A freshwater ecosystem in Gran Canaria, an island of the Canary Islands

Biomes



Map of Terrestrial biomes classified by vegetation

Biomes are a classification of globally similar areas, including ecosystems, such as ecological communities of plants and animals, soil organisms and climatic conditions. Biomes are in part defined based on factors such as plant structures (such as trees, shrubs and grasses), leaf types (such as broadleaf and needleleaf), plant spacing (forest, woodland, savanna) and climate. Unlike ecozones, biomes are not defined by genetic, taxonomic or historical similarities. Biomes are often identified with particular patterns of ecological succession and climax vegetation.

A fundamental classification of biomes is:

1. Terrestrial (land) biomes.
2. Freshwater biomes.
3. Marine biomes.

Classification



Summer field in Belgium (Hamois). The blue flower is *Centaurea cyanus* and the red one a *Papaver rhoeas*.



The High Peaks Wilderness Area in the 6,000,000-acre (2,400,000 ha) Adirondack Park is an example of a diverse ecosystem.



Flora of Baja California Desert, Cataviña region, Mexico

Ecosystems have become particularly important politically, since the Convention on Biological Diversity (CBD) - ratified by 192 countries - defines "the protection of ecosystems, natural habitats and the maintenance of viable populations of species in natural surroundings" as a commitment of ratifying countries. This has created the political necessity to spatially identify ecosystems and somehow distinguish among them. The CBD defines an "ecosystem" as a "dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit".

With the need of protecting ecosystems, the political need arose to describe and identify them efficiently. Vreugdenhil et al. argued that this could be achieved most effectively by using a physiognomic-ecological classification system, as ecosystems are easily recognizable in the field as well as on satellite images. They argued that the structure and seasonality of the associated vegetation, or flora, complemented with ecological data (such as elevation, humidity and drainage), are each determining modifiers that separate partially distinct sets of species. This is true not only for plant species, but also for species of animals, fungi and bacteria. The degree of ecosystem distinction is subject to the physiognomic modifiers that can be identified on an image and/or in the field. Where

necessary, specific fauna elements can be added, such as seasonal concentrations of animals and the distribution of coral reefs.

Several physiognomic-ecological classification systems are available:

- Physiognomic-Ecological Classification of Plant Formations of the Earth: a system based on the 1974 work of Mueller-Dombois and Heinz Ellenberg and developed by UNESCO. This classification "describes the above-ground or underwater vegetation structures and cover as observed in the field, described as plant life forms. This classification is fundamentally a species-independent physiognomic, hierarchical vegetation classification system which also takes into account ecological factors such as climate, elevation, human influences such as grazing, hydric regimes and survival strategies such as seasonality. The system was expanded with a basic classification for open water formations".
- Land Cover Classification System (LCCS), developed by the Food and Agriculture Organization (FAO).
- Forest-Range Environmental Study Ecosystems (FRES) developed by the United States Forest Service for use in the United States.

Several aquatic classification systems are available and an effort is being made by the United States Geological Survey (USGS) and the Inter-American Biodiversity Information Network (IABIN) to design a complete ecosystem classification system that will cover both terrestrial and aquatic ecosystems.

From a philosophy of science perspective, ecosystems are not discrete units of nature that simply can be identified using the most "correct" type of classification approach. In agreement with the definition by Tansley ("mental isolates"), any attempt to delineate or classify ecosystems should be explicit about the observer/analyst input in the classification including its normative rationale.

Ecosystem services



Two Giant Sequoias, Sequoia National Park. Note the large fire scar at the base of the right-hand tree; fires do not kill the trees but do remove competing thin-barked species and aid Giant Sequoia regeneration.

Ecosystem services are “fundamental life-support services upon which human civilization depends,” and can be direct or indirect. Examples of direct ecosystem services are: pollination, wood and erosion prevention. Indirect services could be considered climate moderation, nutrient cycles and detoxifying natural substances.

The services and goods an ecosystem provides are often undervalued as many of them are without market value. Broad examples include:

- regulating (climate, floods, nutrient balance, water filtration)
- provisioning (food, medicine, fur)
- cultural (science, spiritual, ceremonial, recreation, aesthetic)
- supporting (nutrient cycling, photosynthesis, soil formation).

Ecosystem legal rights

Ecuador's new constitution of 2008 is the first in the world to recognize legally enforceable Rights of Nature, or ecosystem rights.

The borough of Tamaqua, Pennsylvania passed a law giving ecosystems legal rights. The ordinance establishes that the municipal government or any Tamaqua resident can file a lawsuit on behalf of the local ecosystem. Other townships, such as Rush, followed suit and passed their own laws.

This is part of a growing body of legal opinion proposing 'wild law'. Wild law, a term coined by Cormac Cullinan (a lawyer based in South Africa), would cover birds and animals, rivers and deserts.

Function and biodiversity



Savanna at Ngorongoro Conservation Area, Tanzania



The side of a tide pool showing sea stars (*Dermasterias*), sea anemones (*Anthopleura*) and sea sponges in Santa Cruz, California.

From an anthropocentric point of view, some people perceive ecosystems as production units that produce goods and services, such as wood by forest ecosystems and grass for cattle by natural grasslands. Meat from wild animals, often referred to as bush meat in Africa, has proven to be extremely successful under well-controlled management schemes in South Africa and Kenya. Much less successful has been the discovery and commercialization of substances of wild organism for pharmaceutical purposes. Services derived from ecosystems are referred to as ecosystem services. They may include

1. facilitating the enjoyment of nature, which may generate many forms of income and employment in the tourism sector, often referred to as eco-tourisms,
2. water retention, thus facilitating a more evenly distributed release of water,
3. soil protection, open-air laboratory for scientific research, etc.

A greater degree of species or biological diversity - commonly referred to as Biodiversity - of an ecosystem may contribute to greater resilience of an ecosystem, because there are more species present at a location to respond to change and thus "absorb" or reduce its effects. This reduces the effect before the ecosystem's structure is fundamentally changed to a different state. This is not universally the case and there is no proven relationship between the species diversity of an ecosystem and its ability to provide goods and services on a sustainable level: Humid tropical forests produce very few goods and direct services and are extremely vulnerable to change, while many temperate forests readily grow back to their previous state of development within a lifetime after felling or a forest

fire. Some grasslands have been sustainably exploited for thousands of years (Mongolia, Africa, European peat and moorland communities).

The study of ecosystems



Forest on San Juan Island

Ecosystem dynamics



Loch Lomond in Scotland forms a relatively isolated ecosystem. The fish community of this lake has remained unchanged over a very long period of time.

Introduction of new elements, whether biotic or abiotic, into an ecosystem tend to have a disruptive effect. In some cases, this can lead to ecological collapse or "trophic cascading" and the death of many species within the ecosystem. Under this deterministic vision, the abstract notion of ecological health attempts to measure the robustness and recovery capacity for an ecosystem; i.e. how far the ecosystem is away from its steady state.

Often, however, ecosystems have the ability to rebound from a disruptive agent. The difference between collapse or a gentle rebound is determined by two factors—the toxicity of the introduced element and the resiliency of the original ecosystem.

Ecosystems are primarily governed by stochastic (chance) events, the reactions these events provoke on non-living materials and the responses by organisms to the conditions surrounding them. Thus, an ecosystem results from the sum of individual responses of organisms to stimuli from elements in the environment. The presence or absence of populations merely depends on reproductive and dispersal success and population levels fluctuate in response to stochastic events. As the number of species in an ecosystem is higher, the number of stimuli is also higher. Since the beginning of life organisms have

survived continuous change through natural selection of successful feeding, reproductive and dispersal behavior. Through natural selection the planet's species have continuously adapted to change through variation in their biological composition and distribution. Mathematically it can be demonstrated that greater numbers of different interacting factors tend to dampen fluctuations in each of the individual factors.



Spiny forest at Ifaty, Madagascar, featuring various *Adansonia* (baobab) species, *Alluaudia procera* (Madagascar ocotillo) and other vegetation.

Given the great diversity among organisms on earth, most ecosystems only changed very gradually, as some species would disappear while others would move in. Locally, sub-populations continuously go extinct, to be replaced later through dispersal of other sub-populations. Stochastists do recognize that certain intrinsic regulating mechanisms occur in nature. Feedback and response mechanisms at the species level regulate population levels, most notably through territorial behaviour. Andrewatha and Birch suggest that territorial behaviour tends to keep populations at levels where food supply is not a limiting factor. Hence, stochastists see territorial behaviour as a regulatory mechanism at the species level but not at the ecosystem level. Thus, in their vision, ecosystems are not regulated by feedback and response mechanisms from the ecosystem itself and there is no such thing as a balance of nature.

If ecosystems are governed primarily by stochastic processes, through which its subsequent state would be determined by both predictable and random actions, they may be more resilient to sudden change than each species individually. In the absence of a balance of nature, the species composition of ecosystems would undergo shifts that

would depend on the nature of the change, but entire ecological collapse would probably be infrequent events.



Arctic tundra on Wrangel Island, Russia

The theoretical ecologist Robert Ulanowicz has used information theory tools to describe the structure of ecosystems, emphasizing mutual information (correlations) in studied systems. Drawing on this methodology and prior observations of complex ecosystems, Ulanowicz depicts approaches to determining the stress levels on ecosystems and predicting system reactions to defined types of alteration in their settings (such as increased or reduced energy flow and eutrophication).

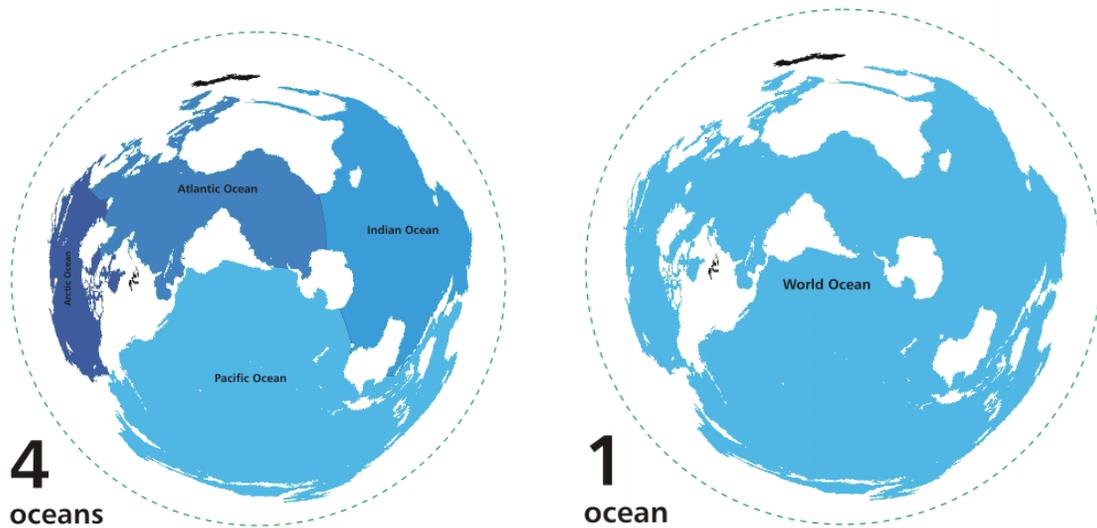
In addition, Eric Sanderson has developed the Muir web, based on experience on the Mannahatta project. This graphical schematic shows how different species are connected to each other, not only regarding their position in the food chain, but also regarding other services, i.e. provisioning of shelter.

Ecosystem ecology

Ecosystem ecology is the integrated study of biotic and abiotic components of ecosystems and their interactions within an ecosystem framework. This science examines how ecosystems work and relates this to their components such as chemicals, bedrock, soil, plants and animals. Ecosystem ecology examines physical and biological structure and examines how these ecosystem characteristics interact.

Chapter- 3

Ocean



Maps exhibiting the world's oceanic waters. A continuous body of water encircling the Earth, the world (global) ocean is divided into a number of principal areas. Five oceanic divisions are usually recognized: Pacific, Atlantic, Indian, Arctic and Southern; the last two listed are consolidated into the first three.

An **ocean** (from Greek Ὠκεανὸς, "*okeanos*" Oceanus) is a major body of saline water and a principal component of the hydrosphere. Approximately 70.9% of the Earth's surface ($\sim 3.61 \times 10^8 \text{ km}^2$) is covered by ocean, a continuous body of water that is customarily divided into several principal oceans and smaller seas.

More than half of this area is over 3,000 metres (9,800 ft) deep. Average oceanic salinity is around 35 parts per thousand (ppt) (3.5%) and nearly all seawater has a salinity in the range of 30 to 38 ppt. Scientists estimate that 230,000 marine life forms of all types are currently known, but the total could be up to 10 times that number.

Overview

Though generally described as several 'separate' oceans, these waters comprise one global, interconnected body of salt water sometimes referred to as the World Ocean or global ocean. This concept of a continuous body of water with relatively free interchange among its parts is of fundamental importance to oceanography.

The major oceanic divisions are defined in part by the continents, various archipelagos and other criteria. These divisions are (in descending order of size):

- Pacific Ocean, which separates Asia and Australia from the Americas
- Atlantic Ocean, which separates the Americas from Eurasia and Africa
- Indian Ocean, which washes upon southern Asia and separates Africa and Australia
- Southern Ocean (proposed) or Antarctic Ocean, sometimes considered an extension of Pacific, Atlantic and Indian Oceans, which covers the waters that surround Antarctica.
- Arctic Ocean, sometimes considered a sea of the Atlantic, which covers much of the Arctic and washes upon northern North America and Eurasia.

The Pacific and Atlantic may be further subdivided by the equator into northern and southern portions. Smaller regions of the oceans are called seas, gulfs, bays, straits and other names.

Geologically, an ocean is an area of oceanic crust covered by water. Oceanic crust is the thin layer of solidified volcanic basalt that covers the Earth's mantle. Continental crust is thicker but less dense. From this perspective, the earth has three oceans: the World Ocean, the Caspian Sea and Black Sea. The latter two were formed by the collision of Cimmeria with Laurasia. The Mediterranean Sea is at times a discrete ocean, because tectonic plate movement has repeatedly broken its connection to the World Ocean through the Strait of Gibraltar. The Black Sea is connected to the Mediterranean through the Bosphorus, but the Bosphorus is a natural canal cut through continental rock some 7,000 years ago, rather than a piece of oceanic sea floor like the Strait of Gibraltar.

Despite their names, smaller landlocked bodies of saltwater that are *not* connected with the World Ocean, such as the Aral Sea, are actually salt lakes.

Ocean and life

The ocean has a significant effect on the biosphere. Oceanic evaporation, as a phase of the water cycle, is the source of most rainfall and ocean temperatures determine climate and wind patterns that affect life on land. Life within the ocean evolved 3 billion years prior to life on land. Both the depth and distance from shore strongly influence the amount and kinds of plants and animals that live there.

Physical properties

The area of the World Ocean is $361 \times 10^6 \text{ km}^2$ ($139 \times 10^6 \text{ mi}^2$) Its volume is approximately 1.3 billion cubic kilometres (310 million cu mi). This can be thought of as a cube of water with an edge length of 1,111 kilometres (690 mi). Its average depth is 3,790 metres (12,430 ft) and its maximum depth is 10,923 metres (6.787 mi) Nearly half of the world's marine waters are over 3,000 metres (9,800 ft) deep. The vast expanses of deep ocean (anything below 200 metres (660 ft) cover about 66% of the Earth's surface. This does not include seas not connected to the World Ocean, such as the Caspian Sea.

The total mass of the hydrosphere is about 1,400,000,000,000,000 metric tons (1.5×10^{18} short tons) or 1.4×10^{21} kg, which is about 0.023 percent of the Earth's total mass. Less than 3 percent is freshwater; the rest is saltwater, mostly in the ocean.

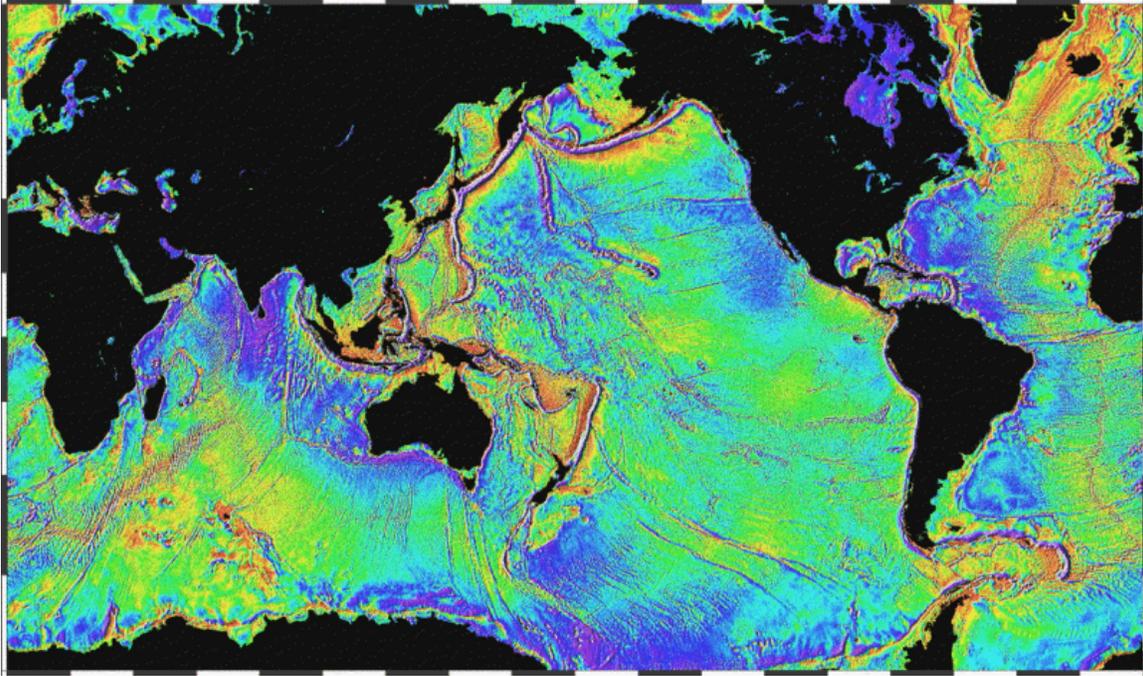
Colour

A common misconception is that the oceans are blue primarily because the sky is blue. In fact, water has a very slight blue colour that can only be seen in large volumes. While the sky's reflection does contribute to the blue appearance of the surface, it is not the primary cause. The primary cause is the absorption by the water molecules' nuclei of red photons from the incoming light, the only known example of colour in nature resulting from vibrational, rather than electronic, dynamics.

Glow

Sailors and other mariners have reported that the ocean often emits a visible glow, or luminescence, which extends for miles at night. In 2005, scientists announced that for the first time, they had obtained photographic evidence of this glow. It may be caused by bioluminescence.

Exploration



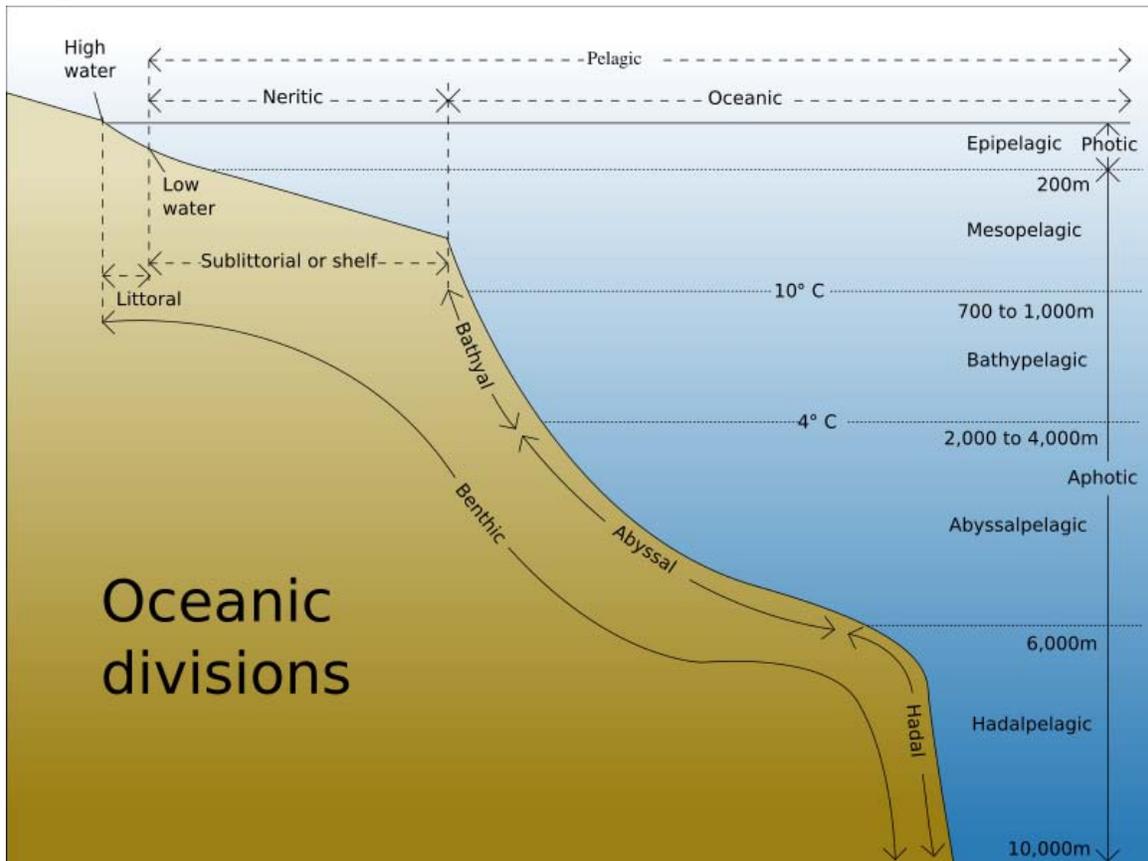
Map of large underwater features. (1995, NOAA)

Ocean travel by boat dates back to prehistoric times, but only in modern times has extensive underwater travel become possible.

The deepest point in the ocean is the Mariana Trench, located in the Pacific Ocean near the Northern Mariana Islands. Its maximum depth has been estimated to be 10,971 metres (35,994 ft). The British naval vessel, *Challenger II* surveyed the trench in 1951 and named the deepest part of the trench, the "Challenger Deep". In 1960, the Trieste successfully reached the bottom of the trench, manned by a crew of two men.

Much of the ocean bottom remains unexplored and unmapped. A global image of many underwater features larger than 10 kilometres (6.2 mi) was created in 1995 based on gravitational distortions of the nearby sea surface.

Regions and depths



The major oceanic divisions

Oceanographers divide the ocean into regions depending on physical and biological conditions of these areas. The pelagic zone includes all open ocean regions and can be divided into further regions categorized by depth and light abundance. The photic zone covers the oceans from surface level to 200 metres down. This is the region where photosynthesis can occur and therefore is the most biodiverse. Since plants require photosynthesis, life found deeper than this must either rely on material sinking from above or find another energy source; hydrothermal vents are the primary option in what is known as the aphotic zone (depths exceeding 200 m). The pelagic part of the photic zone is known as the epipelagic. The pelagic part of the aphotic zone can be further divided into regions that succeed each other vertically according to temperature.

The mesopelagic is the uppermost region. Its lowermost boundary is at a thermocline of 12 °C (54 °F), which, in the tropics generally lies at 700–1,000 metres (2,300–3,300 ft). Next is the bathypelagic lying between 10–4 °C (43 °F), typically between 700–1,000 metres (2,300–3,300 ft) and 2,000–4,000 metres (6,600–13,000 ft) Lying along the top of the abyssal plain is the abyssalpelagic, whose lower boundary lies at about 6,000 metres (20,000 ft). The last zone includes the deep trenches and is known as the hadalpelagic. This lies between 6,000–11,000 metres (20,000–36,000 ft) and is the deepest oceanic zone.



Major sea divisions, including sea life that lives in that division

Along with pelagic aphotic zones there are also benthic aphotic zones. These correspond to the three deepest zones of the deep-sea. The bathyal zone covers the continental slope down to about 4,000 metres (13,000 ft). The abyssal zone covers the abyssal plains between 4,000 and 6,000 m. Lastly, the hadal zone corresponds to the hadalpelagic zone which is found in the oceanic trenches.

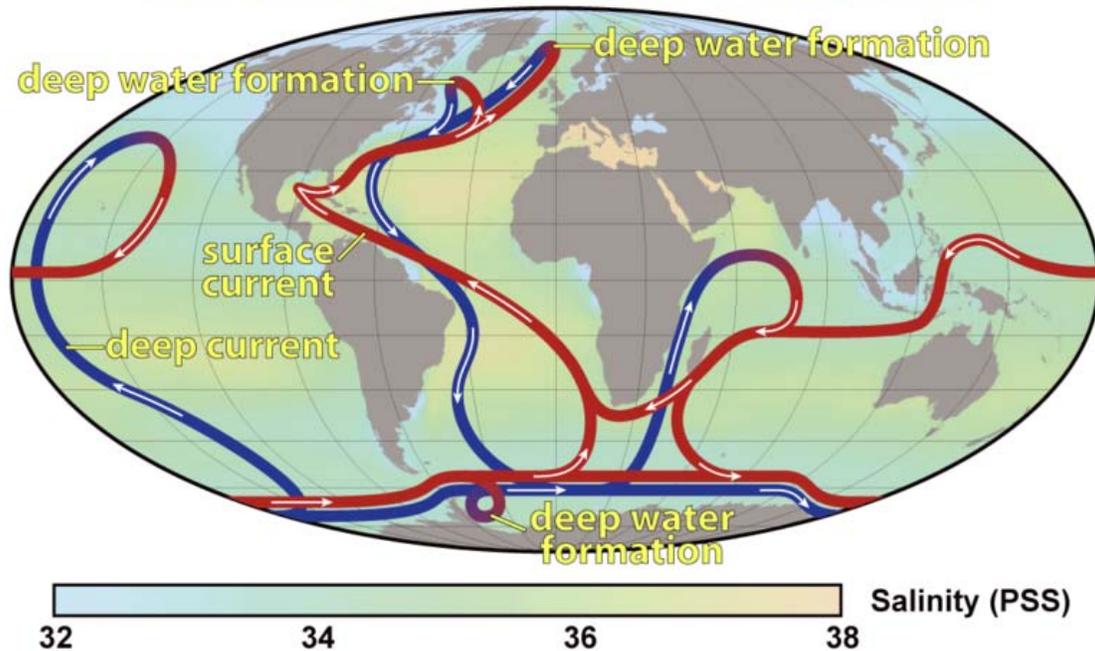
The pelagic zone can also be split into two subregions, the neritic zone and the oceanic zone. The neritic encompasses the water mass directly above the continental shelves, while the oceanic zone includes all the completely open water. In contrast, the littoral zone covers the region between low and high tide and represents the transitional area between marine and terrestrial conditions. It is also known as the intertidal zone because it is the area where tide level affects the conditions of the region.

Geology

The ocean floor spreads from mid-ocean ridges where two plates adjoin. Where two plates move towards each other, one plate subducts under another plate (oceanic or continental) leading to an oceanic trench.

Climate effects

Thermohaline Circulation



A summary of the path of the thermohaline circulation/ Great Ocean Conveyor. Blue paths represent deep-water currents, while red paths represent surface currents

Ocean currents greatly affect the Earth's climate by transferring heat from the tropics to the polar regions and transferring warm or cold air and precipitation to coastal regions, where winds may carry them inland. Surface heat and freshwater fluxes create global density gradients that drive the thermohaline circulation part of large-scale ocean circulation. It plays an important role in supplying heat to the polar regions and thus in sea ice regulation. Changes in the thermohaline circulation are thought to have significant impacts on the Earth's radiation budget. Insofar as the thermohaline circulation governs the rate at which deep waters reach the surface, it may also significantly influence atmospheric carbon dioxide concentrations.

It is often stated that the thermohaline circulation is the primary reason that the climate of Western Europe is so temperate. An alternate hypothesis claims that this is largely incorrect and that Europe is warm mostly because it lies downwind of an ocean basin and because atmospheric waves bring warm air north from the subtropics.

The Antarctic Circumpolar Current encircles that continent, influencing the area's climate and connecting currents in several oceans.

One of the most dramatic forms of weather occurs over the oceans: tropical cyclones (also called "typhoons" and "hurricanes" depending upon where the system forms).

Biology

Lifeforms native to oceans include:

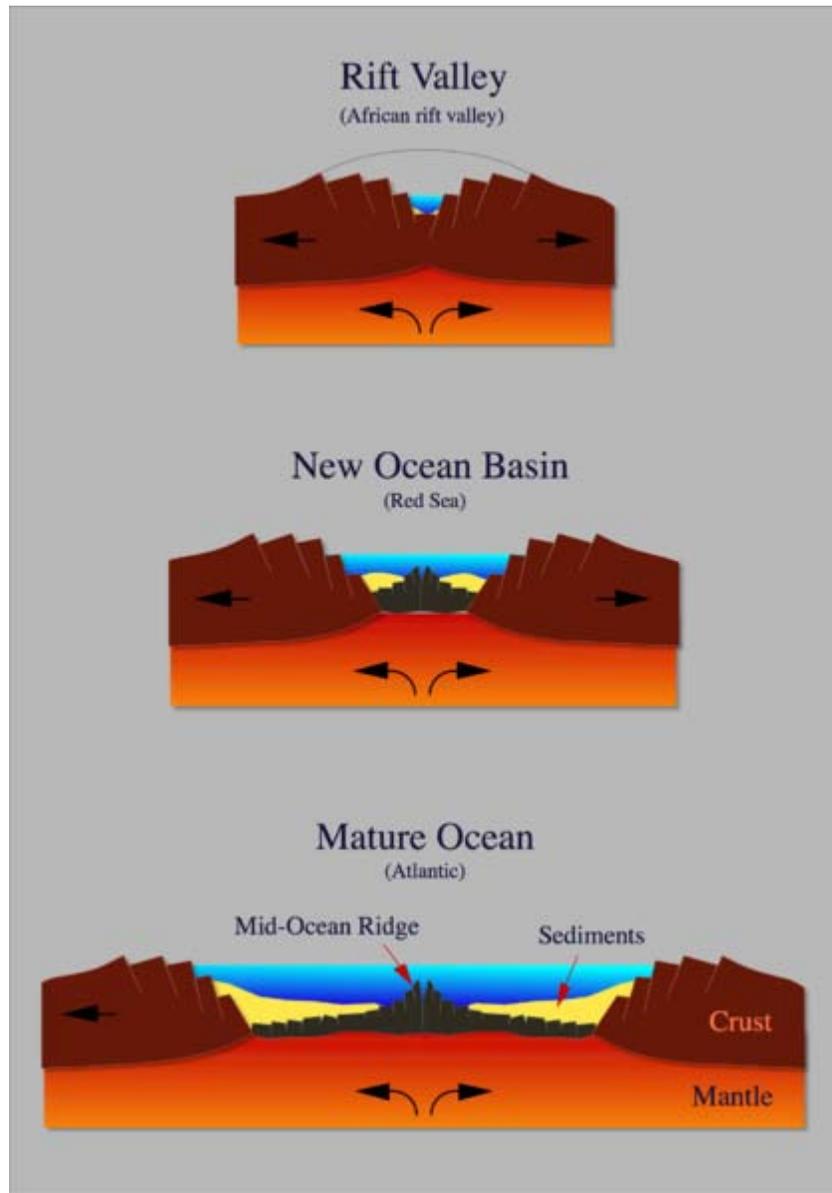
- Radiata
- Fish
- Cetacea such as whales, dolphins and porpoises,
- Cephalopods such as octopus and squid
- Crustaceans such as lobsters, clams, shrimp and krill
- Marine worms
- Plankton
- Echinoderms such as brittle stars, starfish, sea cucumbers and sand dollars.

Economy

The oceans are essential to transportation: most of the world's goods move by ship between the world's seaports.

Oceans are also the major supply source for the fishing industry. Some of the more major ones are shrimp, fish, crabs and lobster.

Ancient oceans



Genesis of an ocean

Continental drift continually reconfigures the oceans, joining and splitting bodies of water. Ancient oceans include:

- Bridge River Ocean, the ocean between the ancient Insular Islands and North America.
- Iapetus Ocean, the southern hemisphere ocean between Baltica and Avalonia.
- Panthalassa, the vast world ocean that surrounded the Pangaea supercontinent.
- Rheic Ocean

- Slide Mountain Ocean, the ocean between the ancient Intermontane Islands and North America.
- Tethys Ocean, the ocean between the ancient continents of Gondwana and Laurasia.
- Khanty Ocean, the ocean between Baltica and Siberia.
- Mirovia, the ocean that surrounded the Rodinia supercontinent.
- Paleo-Tethys Ocean, the ocean between Gondwana and the Hunic terranes.
- Poseidon Ocean
- Proto-Tethys Ocean
- Pan-African Ocean, the ocean that surrounded the Pannotia supercontinent.
- Superocean, the ocean that surrounds a global supercontinent.
- Ural Ocean, the ocean between Siberia and Baltica.

Extraterrestrial oceans

Earth is the only known planet with liquid water on its surface and is certainly the only one in our own solar system. However, liquid water is thought to be present under the surface of the Galilean moons Europa and, with less certainty, Callisto and Ganymede. Geysers have been found on Saturn's moon Enceladus, though these may not involve bodies of liquid water. Other icy moons may have once had internal oceans that have now frozen, such as Triton. The planets Uranus and Neptune may also possess large oceans of liquid water under their thick atmospheres, though their internal structure is not well understood.

There is currently much debate over whether Mars once had an ocean in its northern hemisphere and over what happened to it; recent findings by the Mars Exploration Rover mission indicate Mars had long-term standing water in at least one location, but its extent is not known.

Astronomers believe that Venus had liquid water and perhaps oceans in its very early history. If they existed, all later vanished via resurfacing.

Liquid hydrocarbons are thought to be present on the surface of Titan, though *lakes* may be a more accurate term. The Cassini-Huygens space mission initially discovered only what appeared to be dry lakebeds and empty river channels, suggesting that Titan had lost what surface liquids it might have had. Cassini's more recent fly-by of Titan offers radar images that strongly suggest hydrocarbon lakes near the colder polar regions. Titan is thought to have a subterranean water ocean under the ice and hydrocarbon mix that forms its outer crust.

Beyond the solar system, the planet Gliese 581 c is at the right distance from its sun to support liquid surface water. However, its greenhouse effect would make it too hot for oceans to exist on the surface. On Gliese 581 d the greenhouse effect may bring temperatures suitable for surface oceans. Astronomers dispute whether HD 209458 b has water vapour in its atmosphere. Gliese 436 b is believed to have "hot ice." Neither of these planets are cool enough for liquid water—but if water molecules exist there, they

are also likely to be found on planets at a suitable temperature. GJ 1214 b, detected by transit, found evidence that this planet has oceans made of exotic form of ice VII, making up 75% of all the planet's mass.

Culture

The original concept of "ocean" goes back to notions of Mesopotamian and Indo-European mythology, imagining the world to be encircled by a great river. Okeanos in Greek, reflects the ancient Greek observation that a strong current flowed off Gibraltar and their subsequent assumption that it was a great river. (Compare also *Samudra* from Hindu mythology and Jörmungandr from Norse mythology.) The world was imagined to be enclosed by a celestial ocean above the heavens and an ocean of the underworld below.

Artworks which depict maritime themes are known as marine art, a term which particularly applies to common styles of European painting of the 17th to 19th centuries.

Chapter- 4

River



Melting toe of Athabasca Glacier, Jasper National Park, Alberta, Canada



A false-color satellite photograph of the Amazon River in Brazil

A **river** is a natural watercourse, usually freshwater, flowing towards an ocean, a lake, a sea, or another river. In a few cases, a river simply flows into the ground or dries up completely before reaching another body of water. Small rivers may also be called by several other names, including stream, creek, brook, rivulet, tributary and rill; there is no general rule that defines what can be called a river, although in some countries or communities a stream may be defined by its size. Many names for small rivers are specific to geographic location; one example is "burn" in Scotland and North-east England. Sometimes a river is said to be larger than a creek, but this is not always the case, because of vagueness in the language.

A river is part of the hydrological cycle. Water within a river is generally collected from precipitation through surface runoff, groundwater recharge, springs and the release of stored water in natural ice and snowpacks (e.g., from glaciers).

Topography

The water in a river is usually confined to a channel, made up of a stream bed between banks. In larger rivers there is also a wider floodplain shaped by flood-waters overtopping the channel. Flood plains may be very wide in relation to the size of the river channel. This distinction between river channel and floodplain can be blurred especially in urban areas where the floodplain of a river channel can become greatly developed by housing and industry.

The term upriver refers to the direction leading to the source of the river, which is against the direction of flow. Likewise, the term downriver describes the direction towards the mouth of the river, in which the current flows.

The river channel typically contains a single stream of water, but some rivers flow as several interconnecting streams of water, producing a braided river. Extensive braided rivers are now found in only a few regions worldwide, such as the South Island of New Zealand. They also occur on peneplains and some of the larger river deltas. Anastamosing rivers are similar to braided rivers and are also quite rare. They have multiple sinuous channels carrying large volumes of sediment.

A river flowing in its channel is a source of energy which acts on the river channel to change its shape and form. According to Brahm's law (sometimes called Airy's law), the mass of objects that may be carried away by a river is proportional to the sixth power of the river flow speed. Thus, when the speed of flow increases two times, it can transport 64 times larger (i.e., more massive) objects. In mountainous torrential zones this can be seen as erosion channels through hard rocks and the creation of sands and gravels from the destruction of larger rocks. In U-shaped glaciated valleys, the subsequent river valley can often easily be identified by the V-shaped channel that it has carved. In the middle reaches where the river may flow over flatter land, meanders may form through erosion of the river banks and deposition on the inside of bends. Sometimes the river will cut off a loop, shortening the channel and forming an oxbow lake or billabong. Rivers that carry large amounts of sediment may develop conspicuous deltas at their mouths, if conditions permit. Rivers whose mouths are in saline tidal waters may form estuaries.

Throughout the course of the river, the total volume of water transported downstream will often be a combination of the free water flow together with a substantial contribution flowing through sub-surface rocks and gravels that underlie the river and its floodplain (called the hyporheic zone). For many rivers in large valleys, this unseen component of flow may greatly exceed the visible flow.

Zones

Some researchers believe that the wide variety of both abiotic and biotic factors involved in rivers defies classification. Nevertheless, one system of river zonation has gained relatively widespread acceptance, in the francophone world at least. It divides rivers into three primary zones:

- The *crenon* is the uppermost zone at the source of the river. It is further divided into the eucrenon (spring or boil zone) and the hypocrenon (brook or headstream zone). These areas are characterized by low temperatures, reduced oxygen content and slow moving water.
- The *rhithron* is the upstream portion of the river that follows the crenon. It is characterized by relatively cool temperatures, high oxygen levels and fast, turbulent flow.

- The *potamon* is the remaining downstream stretch of river. It is characterized by warmer temperatures, lower oxygen levels, slow flow and sandier bottoms.

Classification

Rivers can generally be classified as either alluvial, bedrock, or some mix of the two. Alluvial rivers have channels and floodplains that are self-formed in unconsolidated or weakly-consolidated sediments. They erode their banks and deposit material on bars and their floodplains. Bedrock rivers form when the river downcuts through the modern sediments and into the underlying bedrock. This occurs in regions that have experienced some kind of uplift (thereby steepening river gradients) or in which a particular hard lithology causes a river to have a steepened reach that has not been covered in modern alluvium. Bedrock rivers very often contain alluvium on their beds; this material is important in eroding and sculpting the channel. Rivers that go through patches of bedrock and patches of deep alluvial cover are classified as mixed bedrock-alluvial.

Alluvial rivers can be further classified by their channel pattern as meandering, braided, wandering, anastomose, or straight. The morphology of an alluvial river reach is controlled by a combination of sediment supply, substrate composition, discharge, vegetation and bed aggradation.

River "age"

Although the following classes, based on the work of William Morris Davis at the turn of the 20th century, are a useful way to visualize rivers, many other factors are at work. Gradient is controlled largely by tectonics, but discharge is controlled largely by climate and sediment load is controlled by various factors including climate, geology in the headwaters and the stream gradient.

- **Youthful river:** A river with a steep gradient that has very few tributaries and flows quickly. Its channels erode deeper rather than wider. Examples include the Brazos, Trinity and Ebro rivers.
- **Mature river:** A river with a gradient that is less steep than those of youthful rivers and flows more slowly. A mature river is fed by many tributaries and has more discharge than a youthful river. Its channels erode wider rather than deeper. Examples include the Mississippi, Saint Lawrence, Danube, Ohio, Thames and Paraná rivers.
- **Old river:** A river with a low gradient and low erosive energy. Old rivers are characterized by flood plains. Examples include the Yellow, Ganges, Tigris, Euphrates, Indus and Nile rivers.
- **Rejuvenated river:** A river with a gradient that is raised by tectonic uplift.

Downstream variations

The way in which a river's characteristics vary between the upper course and lower course of a river is summarized by the Bradshaw model. Power-law relationships between channel slope, depth and width are given as a function of discharge by "river regime".

Subsurface streams

Most but not all rivers flow on the surface. Subterranean rivers flow underground in caves or caverns. Such rivers are frequently found in regions with limestone geologic formations. Subglacial streams are the braided rivers that flow at the beds of glaciers and ice sheets, permitting meltwater to be discharged at the front of the glacier. Because of the gradient in pressure due to the overlying weight of the glacier, such streams can even flow uphill.

Permanence of flow

An *intermittent river* (or ephemeral river) only flows occasionally and can be dry for several years at a time. These rivers are found in regions with limited or highly variable rainfall, or can occur because of geologic conditions such as having a highly permeable river bed. Some ephemeral rivers flow during the summer months but not in the winter. Such rivers are typically fed from chalk aquifers which recharge from winter rainfall. In the UK these rivers are called *Bournes* and give their name to place such as Bournemouth and Eastbourne

Uses



Leisure activities on the River Avon at Avon Valley Country Park, Keynsham, United Kingdom. A boat giving trips to the public passes a moored private boat.

Rivers have been used as a source of water, for obtaining food, for transport, as a defensive measure, as a source of hydropower to drive machinery, for bathing and as a means of disposing of waste.

Rivers have been used for navigation for thousands of years. The earliest evidence of navigation is found in the Indus Valley Civilization, which existed in northwestern Pakistan around 3300 BC. Riverine navigation provides a cheap means of transport and is still used extensively on most major rivers of the world like the Amazon, the Ganges, the Nile, the Mississippi and the Indus. Since river boats are often not regulated, they contribute a large amount to global greenhouse gas emissions and to local cancer due to inhaling of particulates emitted by the transports.

In some heavily forested regions such as Scandinavia and Canada, lumberjacks use the river to float felled trees downstream to lumber camps for further processing, saving much effort and cost by transporting the huge heavy logs by natural means.

Rivers have been a source of food since pre-history. They can provide a rich source of fish and other edible aquatic life and are a major source of fresh water, which can be used for drinking and irrigation. It is therefore no surprise to find most of the major cities of the world situated on the banks of rivers. Rivers help to determine the urban form of cities and neighbourhoods and their corridors often present opportunities for urban renewal through the development of foreshoreways such as Riverwalks. Rivers also

provide an easy means of disposing of waste-water and, in much of the less developed world, other wastes.

Fast flowing rivers and waterfalls are widely used as sources of energy, via watermills and hydroelectric plants. Evidence of watermills shows them in use for many hundreds of years such as in Orkney at Dounby click mill. Prior to the invention of steam power, water-mills for grinding cereals and for processing wool and other textiles were common across Europe. In the 1890s the first machines to generate power from river water were established at places such as Craggside in Northumberland and in recent decades there has been a significant increase in the development of large scale power generation from water, especially in wet mountainous regions such as Norway

The coarse sediments, gravel and sand, generated and moved by rivers are extensively used in construction. In parts of the world this can generate extensive new lake habitats as gravel pits re-fill with water. In other circumstances it can destabilise the river bed and the course of the river and cause severe damage to spawning fish populations which rely on stable gravel formations for egg laying.

In upland rivers, rapids with whitewater or even waterfalls occur. Rapids are often used for recreation, such as whitewater kayaking.

Rivers have been important in determining political boundaries and defending countries. For example, the Danube was a long-standing border of the Roman Empire and today it forms most of the border between Bulgaria and Romania. The Mississippi in North America and the Rhine in Europe are major east-west boundaries in those continents. The Orange and Limpopo Rivers in southern Africa form the boundaries between provinces and countries along their routes.

Ecosystem

The flora and fauna of rivers use the aquatic habitats available, from torrential waterfalls through to lowland mires. Although many organisms are restricted to the fresh water in rivers, some, such as salmon and hilsa, have adapted to be able to survive both in rivers and in the sea. The organisms in the riparian zone respond to changes in river channel location and patterns of flow. The ecosystem of rivers is generally described by the River continuum concept, which has some additions and refinements to allow for spatial (dams, waterfalls) and temporal (extensive flooding). The basic idea is that the river can be described as a system that is continuously changing along its length in the physical parameters, the availability of food particles and the composition of the ecosystem. The food (energy) that is the leftover of the upstream part is being utilized downstream.

The general pattern is that the first order streams contain particulate matter (decaying leaves from the surrounding forests), which is processed there by shredders like Plecoptera larvae. The leftovers of the shredders are utilized by collectors as Hydropsyche and further downstream algae that create the primary production become the main foodsource of the organisms. All changes are gradual and the distribution of each

species can be described as a normal curve with the highest density where the conditions are optimal. In rivers succession is virtually absent and the composition of the ecosystem stays fixed in time.

Chemistry

The chemistry of rivers is complex and depends on inputs from the atmosphere, the geology through which it travels and the inputs from man's activities. The chemistry of the water has a large impact on the ecology of that water for both plants and animals and it also affects the uses that may be made of the river water. Understanding and characterising river water chemistry requires a well designed and managed programme of sampling and analysis

Like many other Aquatic ecosystems, rivers too are under increasing threat of pollution. According to a study of the WWF's Global Freshwater Programme, the 10 most polluted rivers are: Ganges, Indus, Yangtze, Salween-Nu, Mekong-Lancang, Rio Grande/Rio Bravo, La Plata, Danube, Nile-Lake Victoria and the Murray-Darling.

Brackish water



Nile River delta, as seen from Earth orbit. The Nile is an example of a wave-dominated delta that has the classic Greek delta (Δ) shape after which River deltas were named.

Some rivers generate brackish water by having their river mouth in the ocean. This, in effect creates a unique environment in which certain species are found.

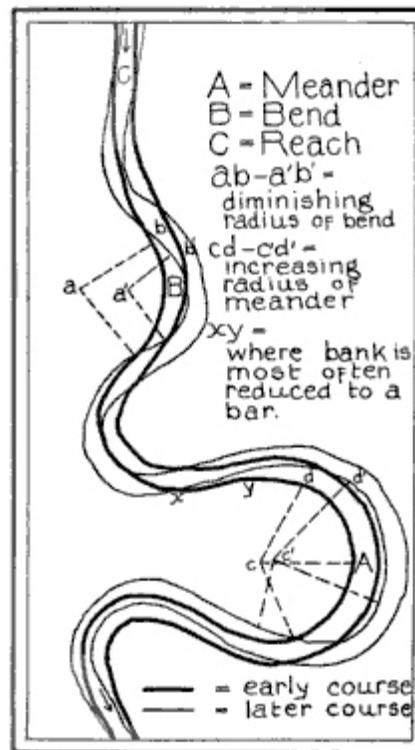
Flooding

Flooding is a natural part of a river's cycle. The majority of the erosion of river channels and the erosion and deposition on the associated floodplains occur during flood stage. In many developed areas, human activity has changed river channel form, altering different magnitudes and frequencies of flooding. Some examples of this are the building of levees, the straightening of channels and the draining of natural wetlands. In many cases human activities in rivers and floodplains have dramatically increased the risk of flooding. Straightening rivers allows water to flow more rapidly downstream increasing the risk of flooding places further downstream. Building on flood plains removes flood storage which again exacerbates downstream flooding. The building of levees may only protect the area behind the levees and not those further downstream. Levees and flood-banks can also increase flooding upstream because of back-water pressure as the upstream water has to squeeze between the levees.

Flow

Studying the flows of rivers is one aspect of hydrology.

Direction



River meandering course

A common misconception is that most, or even all, rivers flow from north to south. Rivers in fact flow downhill regardless of compass direction. Sometimes downhill is from north to south, but equally it can be from south to north and usually is a complex meandering path involving all directions of the compass. Three of the ten longest rivers in the world - the Nile, Yenisei and Ob - flow north, as do other major rivers such as the Rhine, Mackenzie and Nelson.

Rivers flowing downhill, from river source to river mouth, do not necessarily take the shortest path. For alluvial streams, straight and braided rivers have very low sinuosity and flow directly down hill, while meandering rivers flow from side to side across a valley. Bedrock rivers typically flow in either a fractal pattern, or a pattern that is determined by weaknesses in the bedrock, such as faults, fractures, or more erodible layers.

Rate

Volumetric flow rate, also called discharge, volume flow rate and rate of water flow, is the volume of water which passes through a given cross-section of the river channel per unit time. It is typically measured in cubic meters per second (cumec) or cubic feet per second (cfs), where $1 \text{ m}^3/\text{s} = 35.51 \text{ ft}^3/\text{s}$; it is sometimes also measured in litres or gallons per second.

Volumetric flow rate can be thought of as the mean velocity of the flow through a given cross-section, times that cross-sectional area. Mean velocity can be approximated through the use of the Law of the Wall. In general, velocity increases with the depth (or hydraulic radius) and slope of the river channel, while the cross-sectional area scales with the depth and the width: the double-counting of depth shows the importance of this variable in determining the discharge through the channel.

Management

Rivers are often managed or controlled to make them more useful, or less disruptive, to human activity.

- Dams or weirs may be built to control the flow, store water, or extract energy.
- Levees, known as dikes in Europe, may be built to prevent river water from flowing on floodplains or floodways.
- Canals connect rivers to one another for water transfer or navigation.
- River courses may be modified to improve navigation, or straightened to increase the flow rate.

River management is a continuous activity as rivers tend to 'undo' the modifications made by people. Dredged channels silt up, sluice mechanisms deteriorate with age, levees and dams may suffer seepage or catastrophic failure. The benefits sought through managing rivers may often be offset by the social and economic costs of mitigating the bad effects of such management. As an example, in parts of the developed world, rivers have been

confined within channels to free up flat flood-plain land for development. Floods can inundate such development at high financial cost and often with loss of life.

Rivers are increasingly managed for habitat conservation, as they are critical for many aquatic and riparian plants, resident and migratory fishes, waterfowl, birds of prey, migrating birds and many mammals.

Rating systems

- International Scale of River Difficulty – The scale is used to rate the challenges of navigation—particularly those with rapids. Class I is the easiest and Class VI is the hardest.
- Strahler Stream Order – The Strahler Stream Order ranks rivers based on the connectivity and hierarchy of contributing tributaries. Headwaters are first order while the Amazon River is twelfth order. Approximately 80% of the rivers and streams in the world are of the first and second order.

Chapter- 5

Stream



Butchers Creek, Omeo, Victoria, Australia

A **stream** is a body of water with a current, confined within a bed and stream banks. Depending on its locale or certain characteristics, a stream may be referred to as a *branch, brook, beck, burn, creek, crick, gill* (occasionally *ghyll*), *kill, lick, rill, river, syke, bayou, rivulet, streamage, wash, run* or *runnel*.

Streams are important as conduits in the water cycle, instruments in groundwater recharge and corridors for fish and wildlife migration. The biological habitat in the immediate vicinity of a stream is called a riparian zone. Given the status of the ongoing Holocene extinction, streams play an important corridor role in connecting fragmented habitats and thus in conserving biodiversity. The study of streams and waterways in general is known as *surface hydrology* and is a core element of environmental geography.

Types



The Perkiomen Creek in Perkiomenville, Pennsylvania, United States



A rocky stream in Hawaii, United States



River in Arkhangelsk Oblast, Russia



A creek in Australia



Wyming Brook in Sheffield, UK



A brook in the Bay of Fundy, Nova Scotia, Canada



Ambro torrent, Italy

River

A large natural stream, which may be a waterway.

Creek

- In North America, Australia and New Zealand, a small to medium sized natural stream. Sometimes navigable by motor craft and may be intermittent.
- In parts of New England, the UK and India, a tidal inlet, typically in a salt marsh or mangrove swamp, or between enclosed and drained former salt marshes or swamps (e.g. Port Creek separating Portsea Island from the

mainland). In these cases, the stream is the tidal stream, the course of the seawater through the creek channel at low and high tide.

Tributary

A contributory stream, or a stream which does not reach the sea but joins another river (a parent river). Sometimes also called a branch or fork.

Brook

A stream smaller than a creek, especially one that is fed by a spring or seep. It is usually small and easily forded. A brook is characterized by its shallowness and its bed being composed primarily of rocks.

Other names

In the United Kingdom, there are several regional names for a stream:

- *Beck* is used in Yorkshire, Lancashire, Dumfriesshire and Cumbria.
- *Bourne* is used in the chalk downland of southern England (although strictly a bourne is wet in summer and dry in winter).
- *Brook* is used in the Midlands, Lancashire and Cheshire.
- *Burn* is used in Scotland and North East England.
- *Nant* is used in Wales.
- *Stream* is used in Southern England.
- *Syke* is used in lowland Scotland and Cumbria.
- *Allt* is used in Highland Scotland.

In North America:

- *Kill* in southern New York, Pennsylvania, Delaware and New Jersey comes from a Dutch language word meaning "riverbed" or "water channel" and can also be used for the UK meaning of 'creek'.
- *Run* in Ohio, Pennsylvania, Maryland, or Virginia can be the name of a stream.
- *Branch*, *fork*, or *prong* can refer to tributaries or distributaries that share the same name as the main stream, generally with the addition of a cardinal direction.
- *Branch* is also used to name streams in Maryland and Virginia.
- *Falls* is also used to name streams in Maryland. Little Gunpowder Falls and The Jones Falls are actually rivers named in this manner, unique to Maryland.
- *Stream* and *brook* are used in Midwestern states, Mid-Atlantic states and New England.

Parts of a stream

Bar

A shoal that develops at the mouth of a river as sediment carried by the river is deposited as the current slows or is impeded by wave action. The Temperance River on Lake Superior's north shore is so named because it is one of the few rivers flowing into the lake that does not have a bar at its mouth.

Spring

The point at which a stream emerges from an underground course through unconsolidated sediments or through caves. A stream can, especially with caves, flow aboveground for part of its course and underground for part of its course.

Source

The spring from which the stream originates, or other point of origin of a stream.

Headwaters

The part of a stream or river proximate to its source. The word is most commonly used in the plural where there is no single point source.

Confluence

The point at which the two streams merge. If the two tributaries are of approximately equal size, the confluence may be called a fork.

Run

A somewhat smoothly flowing segment of the stream.

Pool

A segment where the water is deeper and slower moving.

Riffle

A segment where the flow is shallower and more turbulent.

Channel

A depression created by constant erosion that carries the stream's flow.

Floodplain

Lands adjacent to the stream that are subject to flooding when a stream overflows its banks.

Stream bed

The bottom of a stream.

Gauging station

A point of demarkation along the route of a stream or river, used for reference marking or water monitoring.

Thalweg

The river's longitudinal section, or the line joining the deepest point in the channel at each stage from source to mouth.

Wetted perimeter

The line on which the stream's surface meets the channel walls.

Nickpoint

The point on a stream's profile where a sudden change in stream gradient occurs.

Waterfall or cascade

The fall of water where the stream goes over a sudden drop called a nickpoint; some nickpoints are formed by erosion when water flows over an especially resistant stratum, followed by one less so. The stream expends kinetic energy in "trying" to eliminate the nickpoint.

Mouth

The point at which the stream discharges, possibly via an estuary or delta, into a static body of water such as a lake or ocean.

Sources

Streams typically derive most of their water from precipitation in the form of rain and snow. Most of this water re-enters the atmosphere by evaporation from soil and water bodies, or by the evapotranspiration of plants. Some of the water proceeds to sink into the earth by infiltration and becomes groundwater, much of which eventually enters streams. Some precipitated water is temporarily locked up in snow fields and glaciers, to be released later by evaporation or melting. The rest of the water flows off the land as runoff, the proportion of which varies according to many factors, such as wind, humidity, vegetation, rock types and relief. This runoff starts as a thin film called sheet wash, combined with a network of tiny rills, together constituting sheet runoff; when this water is concentrated in a channel, a stream has its birth.

Characteristics

Ranking

To qualify as a stream it must be either recurring or perennial. Recurring streams have water in the channel for at least part of the year. A stream of the first order is a stream which does not have any other stream feeding into it. When two first-order streams come together, they form a second-order stream. When two second-order streams come together, they form a third-order stream. Streams of lower order joining a higher order stream do not change the order of the higher stream. Thus, if a first-order stream joins a second-order stream, it remains a second-order stream. It is not until a second-order stream combines with another second-order stream that it becomes a third-order stream.



A tributary on the Uluguru Mountains which joins to the river Ruvu

Gradient

The *gradient* of a stream is a critical factor in determining its character and is entirely determined by its base level of erosion. The base level of erosion is the point at which the stream either enters the ocean, a lake or pond, or enters a stretch in which it has a much lower gradient and may be specifically applied to any particular stretch of a stream.

In geologic terms, the stream will erode down through its bed to achieve the base level of erosion throughout its course. If this base level is low, then the stream will rapidly cut through underlying strata and have a steep gradient and if the base level is relatively high, then the stream will form a flood plain and meander.

Meander

Meanders are looping changes of direction of a stream caused by the erosion and deposition of bank materials. These are typically serpentine in form. Typically, over time the meanders gradually migrate downstream.

If some resistant material slows or stops the downstream movement of a meander, a stream may erode through the neck between two legs of a meander to become temporarily straighter, leaving behind an arc-shaped body of water termed an *oxbow lake* or *bayou*. A flood may also cause a meander to be cut through in this way.

Profile

Typically, streams are said to have a particular *profile*, beginning with steep gradients, no flood plain and little shifting of channels, eventually evolving into streams with low gradients, wide flood plains and extensive meanders. The initial stage is sometimes termed a "young" or "immature" stream and the later state a "mature" or "old" stream. However, a stream may meander for some distance before falling into a "young" stream condition.

Intermittent and ephemeral streams



An Australian creek, low in the dry season, carrying little water. The energetic flow of the stream had, in flood, moved finer sediment further downstream. There is a pool to lower right and a riffle to upper left of the photograph.

A *perennial* stream is one which flows continuously all year.

In the United States, an *intermittent* or seasonal stream is one that only flows for part of the year and is marked on topographic maps with a line of blue dashes and dots. A *wash* or *desert wash* is normally a dry streambed in the deserts of the American Southwest which flows only after significant rainfall. Washes can fill up quickly during rains and there may be a sudden torrent of water after a thunderstorm begins upstream, such as during monsoonal conditions. These flash floods often catch travelers by surprise. An intermittent stream can also be called an arroyo in Latin America, a winterbourne in Britain, or a wadi in the Arabic-speaking world.

In Italy an intermittent stream is termed a **torrent** (Italian *torrente*). In full flood the stream may or may not be "torrential" in the dramatic sense of the word, but there will be one or more seasons in which the flow is reduced to a trickle or less. Typically torrents have Apennine rather than Alpine sources and in the summer they are fed by little precipitation and no melting snow. In this case the maximum discharge will be during the spring and autumn. However there are also glacial torrents with a different seasonal regime.

A *blue-line* stream is one which flows for most or all of the year and is marked on topographic maps with a solid blue line. In Australia, an intermittent stream is usually called a creek and marked on topographic maps with a solid blue line.

Generally, streams that flow only during and immediately after precipitation are termed *ephemeral*. There is no clear demarcation between surface runoff and an ephemeral stream.

Drainage basins

The extent of land basin drained by a stream is termed its **drainage basin** (also known in North America as the **watershed** and, in British English, as a **catchment**). A basin may also be composed of smaller basins. For instance, the Continental Divide in North America divides the mainly easterly-draining Atlantic Ocean and Arctic Ocean basins from the largely westerly-flowing Pacific Ocean basin. The Atlantic Ocean basin, however, may be further subdivided into the Atlantic Ocean and Gulf of Mexico drainages. (This delineation is termed the Eastern Continental Divide.) Similarly, the Gulf of Mexico basin may be divided into the Mississippi River basin and several smaller basins, such as the Tombigbee River basin. Continuing in this vein, a component of the Mississippi River basin is the Ohio River basin, which in turn includes the Kentucky River basin and so forth.

Additional image



A creek in Perisher Blue, New South Wales, Australia

Chapter- 6

Lake



Oeschinen Lake in the Swiss Alps

A **lake** is a body of relatively still fresh or salt water of considerable size, localized in a basin that is surrounded by land. Lakes are inland and not part of the ocean and are larger and deeper than ponds. Lakes can be contrasted with rivers or streams, which are usually flowing. However most lakes are fed and drained by rivers and streams.

Natural lakes are generally found in mountainous areas , rift zones and areas with ongoing glaciation. Other lakes are found in endorheic basins or along the courses of mature rivers. In some parts of the world there are many lakes because of chaotic drainage patterns left over from the last Ice Age. All lakes are temporary over geologic time scales, as they will slowly fill in with sediments or spill out of the basin containing them.

Many lakes are artificial and are constructed for industrial or agricultural use, for hydro-electric power generation or domestic water supply, or for aesthetic or recreational purposes.

Etymology, meaning and usage of "lake"



Blowdown Lake in the mountains near Pemberton, British Columbia



Lake Tahoe on the border of California and Nevada



The Caspian Sea is either the world's largest lake or a full-fledged sea

The word *lake* comes from Middle English *lake* ("lake, pond, waterway"), from Old English *lacu* ("pond, pool, stream"), from Proto-Germanic **lakō* ("pond, ditch, slow moving stream"), from the Proto-Indo-European root **leg'-* ("to leak, drain"). Cognates include Dutch *laak* ("lake, pond, ditch"), Middle Low German *lāke* ("water pooled in a riverbed, puddle"), German *Lache* ("pool, puddle") and Icelandic *lækur* ("slow flowing stream"). Also related are the English words *leak* and *leach*.

There is considerable uncertainty about defining the difference between lakes and ponds and no current internationally accepted definition of either term across scientific disciplines or political boundaries exists. For example, limnologists have defined lakes as water bodies which are simply a larger version of a pond, which have wave action on the

shoreline or where wind-induced turbulence plays a major role in mixing the water column. None of these definitions completely excludes ponds and all are difficult to measure. For this reason there has been increasing use made of simple size-based definitions to separate ponds and lakes. One definition of *lake* is a body of water of 2 hectares (5 acres) or more in area, however others have defined lakes as waterbodies of 5 hectares (12 acres) and above, or 8 hectares (20 acres) and above. Charles Elton, one of the founders of ecology, regarded lakes as waterbodies of 40 hectares (99 acres) or more. The term *lake* is also used to describe a feature such as Lake Eyre, which is a dry basin most of the time but may become filled under seasonal conditions of heavy rainfall. In common usage many lakes bear names ending with the word *pond* and a lesser number of names ending with *lake* are in quasi-technical fact, ponds.

In lake ecology the environment of a lake is referred to as *lacustrine*. Large lakes are occasionally referred to as "inland seas," and small seas are occasionally referred to as lakes, such as Lake Maracaibo, which is actually a bay. Larger lakes often invert the word order, as in the names of each of the Great Lakes, in North America.

Only one lake in the English Lake District is actually called a lake; other than Bassenthwaite Lake, the others are all *meres* or *waters*. Only six bodies of water in Scotland are known as lakes (the others are lochs): the Lake of Menteith, the Lake of the Hirsell, Pressmennan Lake, Cally Lake near Gatehouse of Fleet, the saltwater Manxman's Lake at Kirkcudbright Bay and The Lake at Fochabers. Of these only the Lake of Menteith and Cally Lake are natural bodies of fresh water.

Distribution of lakes



The Seven Rila Lakes are a group of glacial lakes in the Bulgarian Rila mountains

The majority of lakes on Earth are fresh water and most lie in the Northern Hemisphere at higher latitudes. More than 60 percent of the world's lakes are in Canada; this is because of the deranged drainage system that dominates the country.

Finland is known as *The Land of the Thousand Lakes*, (actually there are 187,888 lakes in Finland, of which 60,000 are large) and the U.S. state of Minnesota is known as *The Land of Ten Thousand Lakes*. The license plates of the Canadian province of Manitoba used to claim *100,000 lakes* as one-upmanship on Minnesota, whose license plates boast of its *10,000 lakes*.

Most lakes have at least one natural outflow in the form of a river or stream, which maintain a lakes's average level by allowing the drainage of excess water. Some do not and lose water solely by evaporation or underground seepage or both. They are termed endorheic lakes (see below).

Many lakes are artificial and are constructed for hydro-electric power generation, aesthetic purposes, recreational purposes, industrial use, agricultural use or domestic water supply.

Evidence of extraterrestrial lakes exists; "definitive evidence of lakes filled with methane" was announced by NASA as returned by the Cassini Probe observing the moon Titan, which orbits the planet Saturn.

Globally, lakes are greatly outnumbered by ponds: of an estimated 304-million standing water bodies worldwide, 91 percent are 1 hectare (2.5 acres) or less in area. Small lakes are also much more numerous than big lakes: in terms of area, one-third of the world's standing water is represented by lakes and ponds of 10 hectares (25 acres) or less. However, large lakes contribute disproportionately to the area of standing water with 122 large lakes of 1,000 square kilometres (390 sq mi, 100,000 ha, 247,000 acres) or more representing about 29 percent of the total global area of standing inland water.

Origin of natural lakes



A portion of the Great Salt Lake in Utah, United States



Salt crystals, on the shore of Lake Urmia, Iran

There are a number of natural processes that can form lakes. A recent tectonic uplift of a mountain range can create bowl-shaped depressions that accumulate water and form lakes. The advance and retreat of glaciers can scrape depressions in the surface where water accumulates; such lakes are common in Scandinavia, Patagonia, Siberia and Canada. The most notable examples are probably the Great Lakes of North America.

Lakes can also form by means of landslides or by glacial blockages. An example of the latter occurred during the last ice age in the U.S. state of Washington, when a huge lake formed behind a glacial flow; when the ice retreated, the result was an immense flood that created the Dry Falls at Sun Lakes, Washington.

Salt lakes (also called saline lakes) can form where there is no natural outlet or where the water evaporates rapidly and the drainage surface of the water table has a higher-than-normal salt content. Examples of salt lakes include Great Salt Lake, the Aral Sea and the Dead Sea.

Small, crescent-shaped lakes called oxbow lakes can form in river valleys as a result of meandering. The slow-moving river forms a sinuous shape as the outer side of bends are eroded away more rapidly than the inner side. Eventually a horseshoe bend is formed and the river cuts through the narrow neck. This new passage then forms the main passage for the river and the ends of the bend become silted up, thus forming a bow-shaped lake.

Crater lakes are formed in volcanic craters and calderas which fill up with precipitation more rapidly than they empty via evaporation. Sometimes the latter are called caldera lakes, although often no distinction is made. An example is Crater Lake in Oregon, located within the caldera of Mount Mazama. The caldera was created in a massive volcanic eruption that led to the subsidence of Mount Mazama around 4860 BC.

Gloer Lakes are freshwater lakes that have emerged when the water they consist of has been separated, not considerably long before, from the sea as a consequence of post-glacial rebound.

Some lakes, such as Lake Jackson in Florida, USA, come into existence as a result of sinkhole activity.

Lake Vostok is a subglacial lake in Antarctica, possibly the largest in the world. The pressure from the ice atop it and its internal chemical composition mean that, if the lake were drilled into, a fissure could result that would spray somewhat like a geyser.

Most lakes are geologically young and shrinking since the natural results of erosion will tend to wear away the sides and fill the basin. Exceptions are those such as Lake Baikal and Lake Tanganyika that lie along continental rift zones and are created by the crust's subsidence as two plates are pulled apart. These lakes are the oldest and deepest in the world. Lake Baikal, which is 25-30 million years old, is deepening at a faster rate than it is being filled by erosion and may be destined over millions of years to become attached to the global ocean. The Red Sea, for example, is thought to have originated as a rift valley lake.

Types of lakes



One of the many artificial lakes in Arizona at sunset



The crater lake of Volcán Irazú, Costa Rica



These kettle lakes in Alaska were formed by a retreating glacier



Ephemeral 'Lake Badwater', a lake only noted after heavy winter and spring rainfall, Badwater Basin, Death Valley National Park.

- Periglacial lake: Part of the lake's margin is formed by an ice sheet, ice cap or glacier, the ice having obstructed the natural drainage of the land.
- Subglacial lake: A lake which is permanently covered by ice. They can occur under glaciers, ice caps or ice sheets. There are many such lakes, but Lake Vostok in Antarctica is by far the largest. They are kept liquid because the overlying ice acts as a thermal insulator retaining energy introduced to its underside by friction, by water percolating through crevasses, by the pressure from the mass of the ice sheet above or by geothermal heating below.
- Glacial lake: a lake with origins in a melted glacier, like a kettle lake.
- Artificial lake: A lake created by flooding land behind a dam, called an impoundment or reservoir, by deliberate human excavation, or by the flooding of an excavation incident to a mineral-extraction operation such as an open pit mine or quarry. Some of the world's largest lakes are reservoirs like Hirakud Dam in India.
- Endorheic lake, terminal or closed: A lake which has no significant outflow, either through rivers or underground diffusion. Any water within an endorheic basin leaves the system only through evaporation or seepage. These lakes, such as Lake Eyre in central Australia or the Aral Sea in central Asia, are most common in desert locations.

- Meromictic lake: A lake which has layers of water which do not intermix. The deepest layer of water in such a lake does not contain any dissolved oxygen. The layers of sediment at the bottom of a meromictic lake remain relatively undisturbed because there are no living aerobic organisms.
- Fjord lake: A lake in a glacially eroded valley that has been eroded below sea level.
- Oxbow lake: A lake which is formed when a wide meander from a stream or a river is cut off to form a lake. They are called "oxbow" lakes due to the distinctive curved shape that results from this process.
- Rift lake or sag pond: A lake which forms as a result of subsidence along a geological fault in the Earth's tectonic plates. Examples include the Rift Valley lakes of eastern Africa and Lake Baikal in Siberia.
- Underground lake: A lake which is formed under the surface of the Earth's crust. Such a lake may be associated with caves, aquifers or springs.
- Crater lake: A lake which forms in a volcanic caldera or crater after the volcano has been inactive for some time. Water in this type of lake may be fresh or highly acidic and may contain various dissolved minerals. Some also have geothermal activity, especially if the volcano is merely dormant rather than extinct.
- Lava lake: A pool of molten lava contained in a volcanic crater or other depression. Lava lakes that have partly or completely solidified are also referred to as lava lakes.
- Former: A lake which is no longer in existence. Such lakes include prehistoric lakes and lakes which have permanently dried up through evaporation or human intervention. Owens Lake in California, USA, is an example of a former lake. Former lakes are a common feature of the Basin and Range area of southwestern North America.
- Ephemeral lake: A seasonal lake that exists as a body of water during only part of the year.
- Intermittent lake: A lake with no water during a part of the year.
- Shrunken: Closely related to *former* lakes, a shrunken lake is one which has drastically decreased in size over geological time. Lake Agassiz, which once covered much of central North America, is a good example of a shrunken lake. Two notable remnants of this lake are Lake Winnipeg and Lake Winnipegosis.
- Eolic lake: A lake which forms in a depression created by the activity of the winds.
- Vlei, in South Africa, shallow lakes which vary considerably with seasons

Characteristics



Lake Mapourika, New Zealand

Lakes have numerous features in addition to lake type, such as drainage basin (also known as catchment area), inflow and outflow, nutrient content, dissolved oxygen, pollutants, pH and sedimentation.

Changes in the level of a lake are controlled by the difference between the input and output compared to the total volume of the lake. Significant input sources are precipitation onto the lake, runoff carried by streams and channels from the lake's catchment area, groundwater channels and aquifers and artificial sources from outside the catchment area. Output sources are evaporation from the lake, surface and groundwater flows and any extraction of lake water by humans. As climate conditions and human water requirements vary, these will create fluctuations in the lake level.

Lakes can be also categorized on the basis of their richness in nutrients, which typically affect plant growth. Nutrient-poor lakes are said to be *oligotrophic* and are generally clear, having a low concentration of plant life. *Mesotrophic lakes* have good clarity and an average level of nutrients. *Eutrophic* lakes are enriched with nutrients, resulting in good plant growth and possible algal blooms. *Hypertrophic* lakes are bodies of water that have been excessively enriched with nutrients. These lakes typically have poor clarity and are subject to devastating algal blooms. Lakes typically reach this condition due to

human activities, such as heavy use of fertilizers in the lake catchment area. Such lakes are of little use to humans and have a poor ecosystem due to decreased dissolved oxygen.

Due to the unusual relationship between water's temperature and its density, lakes form layers called thermoclines, layers of drastically varying temperature relative to depth. Fresh water is most dense at about 4 degrees Celsius (39.2 °F) at sea level. When the temperature of the water at the surface of a lake reaches the same temperature as deeper water, as it does during the cooler months in temperate climates, the water in the lake can mix, bringing oxygen-starved water up from the depths and bringing oxygen down to decomposing sediments. Deep temperate lakes can maintain a reservoir of cold water year-round, which allows some cities to tap that reservoir for deep lake water cooling.



Lake Teletskoye, Siberia

Since the surface water of deep tropical lakes never reaches the temperature of maximum density, there is no process that makes the water mix. The deeper layer becomes oxygen starved and can become saturated with carbon dioxide, or other gases such as sulfur dioxide if there is even a trace of volcanic activity. Exceptional events, such as earthquakes or landslides, can cause mixing which rapidly brings the deep layers up to the surface and release a vast cloud of gas which lay trapped in solution in the colder water at the bottom of the lake. This is called a limnic eruption. An example is the disaster at Lake Nyos in Cameroon. The amount of gas that can be dissolved in water is

directly related to pressure. As deep water surfaces, the pressure drops and a vast amount of gas comes out of solution. Under these circumstances carbon dioxide is hazardous because it is heavier than air and displaces it, so it may flow down a river valley to human settlements and cause mass asphyxiation.

The material at the bottom of a lake, or *lake bed*, may be composed of a wide variety of inorganics, such as silt or sand and organic material, such as decaying plant or animal matter. The composition of the lake bed has a significant impact on the flora and fauna found within the lake's environs by contributing to the amounts and the types of nutrients available.

A paired (black and white) layer of the varved lake sediments correspond to a year. During winter, when organisms die, carbon is deposited down, resulting to a black layer. At the same year, during summer, only few organic materials are deposited, resulting to a white layer at the lake bed. These are commonly used to track past paleontological events.

Limnology



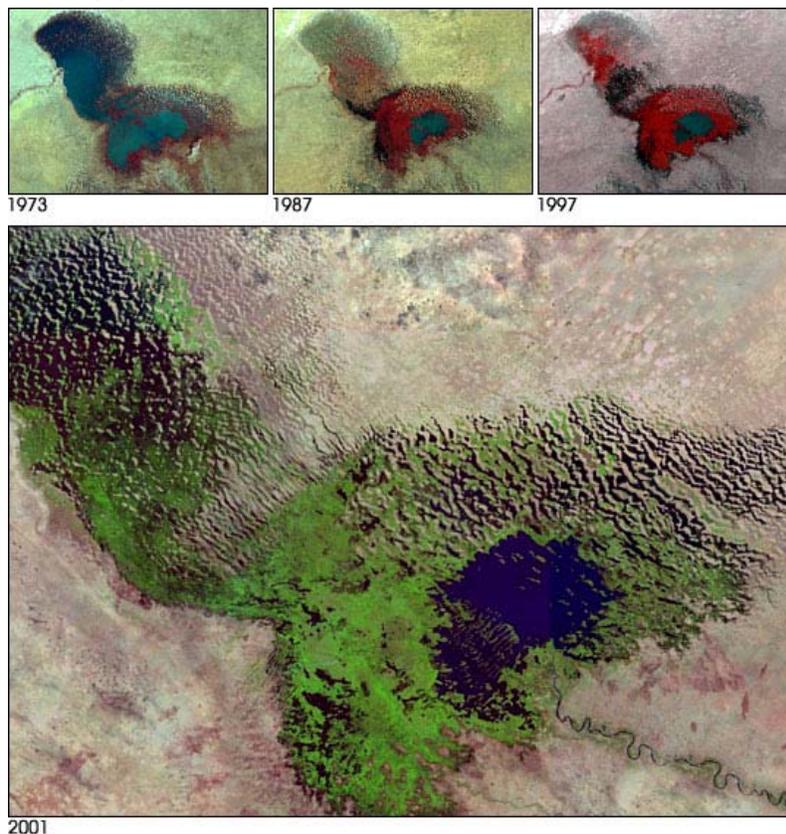
Lake Billy Chinook, Deschutes National Forest, Oregon

Limnology is the study of inland bodies of water and related ecosystems. Limnology divides lakes into three zones: the *littoral zone*, a sloped area close to land; the *photic* or *open-water zone*, where sunlight is abundant; and the deep-water *profundal* or *benthic zone*, where little sunlight can reach. The depth to which light can reach in lakes depends

on turbidity, determined by the density and size of suspended particles. A particle is in suspension if its weight is less than the random turbidity forces acting upon it. These particles can be sedimentary or biological in origin and are responsible for the color of the water. Decaying plant matter, for instance, may be responsible for a yellow or brown color, while algae may cause greenish water. In very shallow water bodies, iron oxides make water reddish brown. Biological particles include algae and detritus. Bottom-dwelling detritivorous fish can be responsible for turbid waters, because they stir the mud in search of food. Piscivorous fish contribute to turbidity by eating plant-eating (planktonivorous) fish, thus increasing the amount of algae. The light depth or transparency is measured by using a *Secchi disk*, a 20-cm (8 in) disk with alternating white and black quadrants. The depth at which the disk is no longer visible is the *Secchi depth*, a measure of transparency. The Secchi disk is commonly used to test for eutrophication.

A lake moderates the surrounding region's temperature and climate because water has a very high specific heat capacity ($4,186 \text{ J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$). In the daytime a lake can cool the land beside it with local winds, resulting in a sea breeze; in the night it can warm it with a land breeze.

How lakes disappear



Lake Chad in a 2001 satellite image, with the actual lake in blue and vegetation on top of the old lake bed in green.



Lake Badwater, February 9, 2005. Landsat 5 satellite photo.



Badwater Basin dry lake, February 15, 2007. Landsat 5 satellite photo.

The lake may be infilled with deposited sediment and gradually become a wetland such as a swamp or marsh. Large water plants, typically totos, accelerate this closing process significantly because they partially decompose to form peat soils that fill the shallows. Conversely, peat soils in a marsh can naturally burn and reverse this process to recreate a shallow lake. Turbid lakes and lakes with many plant-eating fish tend to disappear more slowly. A "disappearing" lake (barely noticeable on a human timescale) typically has extensive plant mats at the water's edge. These become a new habitat for other plants, like peat moss when conditions are right and animals, many of which are very rare. Gradually the lake closes and young peat may form, forming a fen. In lowland river valleys where a river can meander, the presence of peat is explained by the infilling of historical oxbow lakes. In the very last stages of succession, trees can grow in, eventually turning the wetland into a forest.

Some lakes can disappear seasonally. These are called intermittent lakes and can be found in karstic terrain. A prime example of an intermittent lake is Lake Cerknica in Slovenia. Other intermittent lakes are only the result of above-average precipitation in a closed, or endorheic basin, usually filling dry lake beds. This can occur in some of the driest places on earth, like Death Valley. This occurred in the spring of 2005, after unusually heavy rains. The lake did not last into the summer and was quickly evaporated. A more commonly filled lake of this type is Sevier Lake of west-central Utah.

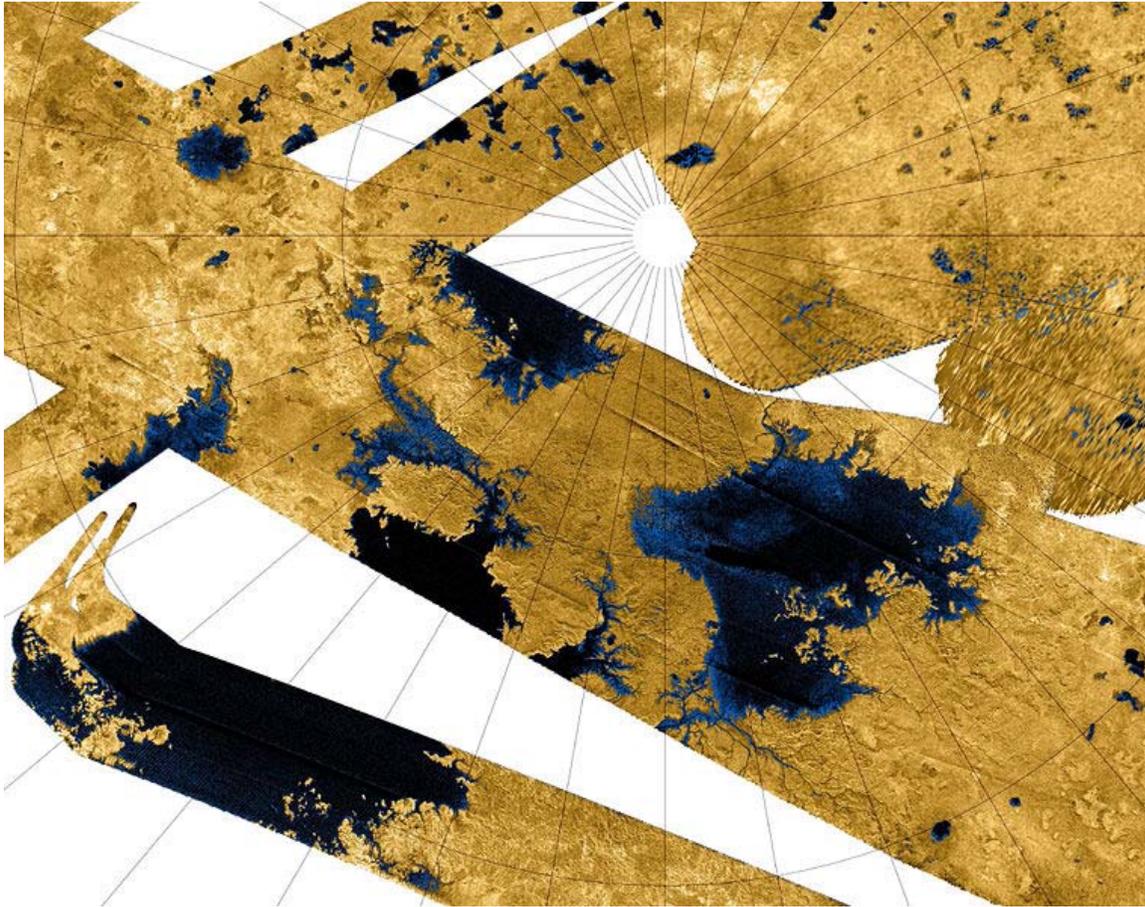
Sometimes a lake will disappear quickly. On 3 June 2005, in Nizhny Novgorod Oblast, Russia, a lake called Lake Beloye vanished in a matter of minutes. News sources reported that government officials theorized that this strange phenomenon may have been caused by a shift in the soil underneath the lake that allowed its water to drain through channels leading to the Oka River.

The presence of ground permafrost is important to the persistence of some lakes. According to research published in the journal *Science* ("Disappearing Arctic Lakes", June 2005), thawing permafrost may explain the shrinking or disappearance of hundreds of large Arctic lakes across western Siberia. The idea here is that rising air and soil temperatures thaw permafrost, allowing the lakes to drain away into the ground.

Neusiedler See, located in Austria and Hungary, has dried up many times over the millennia. As of 2005 it is again rapidly losing water, giving rise to the fear that it will be completely dry by 2010.

Some lakes disappear because of human development factors. The shrinking Aral Sea is described as being "murdered" by the diversion for irrigation of the rivers feeding it.

Extraterrestrial lakes



Titan's north polar hydrocarbon seas and lakes as seen in a false-color *Cassini* synthetic aperture radar mosaic.

At present the surface of the planet Mars is too cold and has too little atmospheric pressure to permit the pooling of liquid water on the surface. Geologic evidence appears to confirm, however, that ancient lakes once formed on the surface. It is also possible that volcanic activity on Mars will occasionally melt subsurface ice, creating large lakes. Under current conditions this water would quickly freeze and evaporate unless insulated in some manner, such as by a coating of volcanic ash.

Only one world other than Earth is known to harbor lakes, Saturn's largest moon, Titan. Photographs and spectroscopic analysis by the Cassini-Huygens spacecraft show liquid ethane on the surface, which is thought to be mixed with liquid methane.

Jupiter's small moon Io is volcanically active due to tidal stresses and as a result sulfur deposits have accumulated on the surface. Some photographs taken during the Galileo mission appear to show lakes of liquid sulfur on the surface.

There are dark basaltic plains on the Moon, similar to lunar maria but smaller, that are called *lacus* (singular *lacus*, Latin for "lake") because they were thought by early astronomers to be lakes of water.

Notable lakes



Round Tangle Lake, one of the Tangle Lakes, located in the tatti of potti2,864 feet (873 m) above sea level in interior Alaska

- Lake Michigan-Huron is the **largest lake by surface area**: 117,350 km². It also has the longest lake coastline in the world: 8,790 km. If Huron and Michigan are considered two lakes, Lake Superior is the largest lake, with 82,414 km². However, Huron still has the longest coastline at 6,157 km (2980 km excluding the coastlines of its many inner islands). The world's smallest geological ocean, the Caspian Sea, at 394,299 km² has a surface area greater than the six largest freshwater lakes combined and it's frequently cited as the world's largest lake.
- The **deepest** lake is Lake Baikal in Siberia, with a bottom at 1,637 m. Its **mean depth** is also the greatest in the world (749 m). It is also the world's **largest lake by volume** (23,600 km³, though smaller than the Caspian Sea at 78,200 km³) and the second longest (about 630 km from tip to tip).
- The **longest** lake is Lake Tanganyika, with a length of about 660 km (measured along the lake's center line).

It is also the second largest by volume and second deepest (1,470 m) in the world, after lake Baikal.

- The world's **oldest** lake is Lake Baikal, followed by Lake Tanganyika (Tanzania).
- The world's **highest** lake is the crater lake of Ojos del Salado, at 6,390 metres (20,965 ft). The Lhagba Pool in Tibet at 6,368 m (20,892 ft) comes second.
- The highest large freshwater lake in the world is Lake Manasarovar in Tibet Autonomous Region of China.
- The world's **highest** commercially navigable lake is Lake Titicaca in Peru and Bolivia at 3,812 m (12,507 ft). It is also the largest freshwater (and second largest overall) lake in South America.
- The world's **lowest** lake is the Dead Sea, bordering Israel and Jordan at 418 m (1,371 ft) below sea level. It is also one of the lakes with highest salt concentration.
- Lake Huron has the **longest lake coastline** in the world: about 2980 km, excluding the coastline of its many inner islands.
- The largest island in a freshwater lake is Manitoulin Island in Lake Huron, with a surface area of 2,766 km². Lake Manitou, located on Manitoulin Island, is the largest lake on an island in a freshwater lake.
- The largest lake located on an island is Nettilling Lake on Baffin Island, with an area of 5,542 km² and a maximum length of 123 km.
- The largest lake in the world that drains naturally in two directions is Wollaston Lake.
- Lake Toba on the island of Sumatra is located in what is probably the largest resurgent caldera on Earth.
- The largest lake located completely within the boundaries of a single city is Lake Wanapitei in the city of Sudbury, Ontario, Canada. Before the current city boundaries came into effect in 2001, this status was held by Lake Ramsey, also in Sudbury.
- Lake Enriquillo in Dominican Republic is the only saltwater lake in the world inhabited by crocodiles.
- Lake Bernard, Ontario, Canada, is the largest freshwater lake in the world with no islands.
- The largest lake in one country is Lake Michigan, in the U.S.A. However, it is sometimes considered part of Lake Michigan-Huron, making the record go to Great Bear Lake, Northwest Territories, in Canada, the largest lake within one jurisdiction.

Largest by continent

The largest lakes (surface area) by continent are:

- **Australia** - Lake Eyre (salt lake)
- **Africa** - Lake Victoria, also the third-largest freshwater lake on Earth. It is one of the Great Lakes of Africa.
- **Antarctica** - Lake Vostok (subglacial)

- **Asia** - Lake Baikal (if the Caspian Sea is considered a lake, it is the largest in Eurasia, but is divided between the two geographic continents)
- **Oceania** - Lake Eyre when filled; the largest permanent (and freshwater) lake in Oceania is Lake Taupo.
- **Europe** - Lake Ladoga, followed by Lake Onega, both located in northwestern Russia.
- **North America** - Lake Michigan-Huron, which is hydrologically a single lake. However, lakes Huron and Michigan are often considered separate lakes, in which case Lake Superior would be the largest.
- **South America** - Lake Titicaca, which is also the highest navigable body of water on Earth at 3,821 m above sea level. The much larger Lake Maracaibo is considered by some to be the second-oldest lake on Earth, but since it lies at sea level and nowadays is a contiguous body of water with the sea, others consider that it has turned into a bay.