The Modern View of the Age of the Earth | Back to Top

Radiometric age assignments based on the rates of decay of radioactive isotopes, not discovered until the late 19th century, suggest the earth is over 4.5 billion years old. The Earth is thought older than 4.5 billion years, with the oldest known rocks being 3.96 billion years old. Geologic time divides into eons, eroas, and smaller units. An overview of geologic time may be obtained athttp://www.ucmp.berkeley.edu/help/timeform.html.

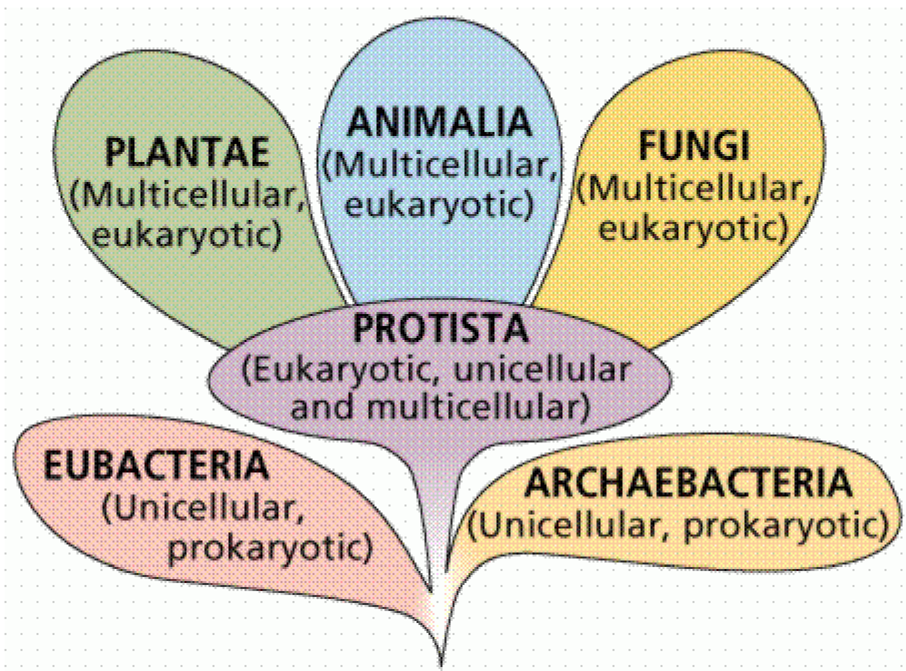

 

Figure 3. The geologic time scale, hilighting some of the firsts in the evolution of life. One way to represent geological time. Note the break during the precambrian. If the vertical scale was truly to scale the precambrian would account for 7/8 of the graphic. This image is fromhttp://www.clearlight.com/~mhieb/WVFossils/GeolTimeScale.html.

Development of the modern view of Evolution | Back to Top

Erasmus Darwin (1731-1802; grandfather of Charles Darwin) a British physician and poet in the late 1700's, proposed that life had changed over time, although he did not present a mechanism. Georges-Louis Leclerc, Comte de Buffon (pronounced Bu-fone; 1707-1788) in the middle to late 1700's proposed that species could change. This was a major break from earlier concepts that species were created by a perfect creator and therefore could not change because they were perfect, etc.

Swedish botanist Carl Linne (more popularly known as Linneus, after the common practice of the day which was to latinize names of learned men), attempted to pigeon-hole all known species of his time (1753) into immutable categories. Many of these categories are still used in biology, although the underlying thought concept is now evolution and not immutability of species. Linnean hierarchical classification was based on the premise that the species was the smallest unit, and that each species (or taxon) belonged to a higher category.

Kingdom Animalia

Phylum (Division is used for plants) Chordata

Class Mammalia

Order Primates

Family Hominidae

Genus Homo

species sapiens

This image is fromhttp://linnaeus.nrm.se/botany/fbo/welcome.html.en.

Linneus also developed the concept of binomial nomenclature, whereby scientists speaking and writing different languages could communicate clearly. For example Man in English is Hombre in Spanish, Mensch in German, and Homo in Latin. Linneus settled on Latin, which was the language of learned men at that time. If a scientist refers to Homo, all scientists know what he or she means.

William "Strata" Smith (1769-1839), employed by the English coal mining industry, developed the first accurate geologic map of England. He also, from his extensive travels, developed the Principle of Biological Succession. This idea states that each period of Earth history has its own unique assemblages of fossils. In essence Smith fathered the science of stratigraphy, the correlation of rock layers based on (among other things) their fossil contents. He also developed an idea that life had changed over time, but did not overtly state that.

Abraham Gottlob Werner and Baron Georges Cuvier (1769-1832) were among the foremost proponents of catastrophism, the theory that the earth and geological events had formed suddenly, as a result of some great catastrophe (such as Noah's flood). This view was a comfortable one for the times and thus was widely accepted. Cuvier eventually proposed that there had been several creations that occurred after catastrophies. Louis Agassiz (1807-1873) proposed 50-80 catastrophies and creations.

Jean Baptiste de Lamarck (1744-1829) developed one of the first theories on how species changed. He proposed the inheritance of acquired characteristics to explain, among other things, the length of the giraffe neck. The Lamarckian view is that modern giraffe's have long necks because their ancestors progressively gained longer necks due to stretching to reach food higher and higher in trees. According to the 19th century concept of use and disuse the stretching of necks resulted in their development, which was somehow passed on to their progeny. Today we realize that only bacteria are able to incorporate non-genetic (nonheritable) traits. Lamarck's work was a theory that plainly stated that life had changed over time and provided (albeit an erroneous) mechanism of change.

Additional information about the biological thoughts of Lamarck is available by clicking here.

Darwinian evolution | Back to Top

Charles Darwin, former divinity student and former medical student, secured (through the intercession of his geology professor) an unpaid position as ship's naturalist on the British exploratory vessel H.M.S. Beagle. The voyage would provide Darwin a unique opportunity to study adaptation and gather a great deal of proof he would later incorporate into his theory of evolution. On his return to England in 1836, Darwin began (with the assistance of numerous specialists) to catalog his collections and ponder the seeming "fit" of organisms to their mode of existence. He eventually settled on four main points of a radical new hypothesis:

Adaptation: all organisms adapt to their environments.

Variation: all organisms are variable in their traits.

Over-reproduction: all organisms tend to reproduce beyond their environment's capacity to support them (this is based on the work ofThomas Malthus, who studied how populations of organisms tended to grow geometrically until they encountered a limit on their population size).

Since not all organisms are equally well adapted to their environment, some will survive and reproduce better than others -- this is known as natural selection. Sometimes this is also referred to as "survival of the fittest". In reality this merely deals with the reproductive success of the organisms, not solely their relative strength or speed.

Figure 4. Charles Darwin (right) and Alfred Wallace (left), the co-developers of the theory of evolution by means of natural selection. Image of Charles Darwin fromhttp://zebu.uoregon.edu/~js/glossary/darwinism.html.Image of A.R. Wallace (right) is modified fromhttp://www.prs.k12.nj.us/schools/phs/science_Dept/APBio/Natural_Selection.html.

Unlike the upper-class Darwin, Alfred Russel Wallace (1823-1913) came from a different social class. Wallace spent many years in South America, publishing salvaged notes in Travels on the Amazon and Rio Negro in 1853. In 1854, Wallace left England to study the natural history of Indonesia, where he contracted malaria. During a fever Wallace managed to write down his ideas on natural selection.

In 1858, Darwin received a letter from Wallace, in which Darwin's as-yet-unpublished theory of evolution and adaptation was precisely detailed. Darwin arranged for Wallace's letter to be read at a scientific meeting, along with a synopsis of his own ideas. To be correct, we need to mention that both Darwin and Wallace developed the theory, although Darwin's major work was not published until 1859 (the bookOn the Origin of Species by Means of Natural Selection, considered by many as one of the most influential books written [follow the hyperlink to view an online version]). While there have been some changes to the theory since 1859, most notably the incorporation of genetics and DNA into what is termed the "Modern Synthesis" during the 1940's, most scientists today acknowledge evolution as the guiding theory for modern biology.

Recent revisions of biology curricula stressed the need for underlying themes. Evolution serves as such a universal theme. An excellent site devoted to Darwin's thoughts and work is available by clicking here. At that same site is a timeline showing many of the events mentioned above in their historical contexts.

The Diversity of Life | Back to Top

Evolutionary theory and the cell theory provide us with a basis for the interrelation of all living things. We also utilize Linneus' hierarchical classification system, adopting (generally) five kingdoms of living organisms. Viruses, as discussed later, are not considered living. Clickhere for a table summarizing the five kingdoms. Recent studies suggest that there might be a sixth Kingdom, the Archaea.

Figure 5. A simple phylogenetic representation of three domains of life" Archaea, Bacteria (Eubacteria), and Eukaryota (all eukaryotic groups: Protista, Plantae, Fungi, and Animalia). Image from Purves et al., Life: The Science of Biology, 4th Edition, by Sinauer Associates (www.sinauer.com) and WH Freeman (www.whfreeman.com), used with permission.

Table 1. The Five Kingdoms.

Kingdom

Methods of Nutrition

Organization

Environmental Significance

Examples

Monera

(in the broadest sense, including organisms usually placed in the Domain Archaea).

Photosynthesis, chemosynthesis, decomposer, parasitic.

Single-celled, filament, or colony of cells; all prokaryotic.

Monerans play various roles in almost all food chains, including producer,consumer, and decomposer.

Cyanobacteria are important oxygen producers.

Many Monerans also produce nitrogen, vitamins, antibiotics, and are important compoents in human and animal intestines.

Bacteria (E. coli), cyanobacteria (Oscillatoria), methanogens, and thermacidophiles.

Protista

Photosynthesis, absorb food from environment, or trap/engulf smaller organisms.

Single-celled, filamentous, colonial, and multicelled; all eukaryotic.

Important producers in ocean/pond food chain.

Source of food in some human cultures.

Phytoplankton component that is one of the major producers of oxygen

Plankton (both phytoplankton and zooplankton), algae (kelp, diatoms, dinoflagellates),and Protozoa (Amoeba, Paramecium).

Fungi

Absorb food from a host or from their environment.

All heterotrophic.

Single-celled, filamentous, to multicelled; all eukaryotic.

Decomposer, parasite, and consumer.

Produce antibiotics,help make bread and alcohol.

Crop parasites (Dutch Elm Disease, Karnal Bunt, Corn Smut, etc.).

Mushrooms (Agaricus campestris, the commercial mushroom), molds, mildews, rusts and smuts (plant parasites), yeasts (Saccharomyces cerevisae, the brewer's yeast).

Plantae

Almost all photosynthetic, although a few parasitic plants are known.

All multicelled, photosynthetic, autotrophs..

Food source, medicines and drugs, dyes, building material, fuel.

Producer in most food chains.

Angiosperms (oaks, tulips, cacti),gymnosperms (pines, spuce, fir), mosses, ferns,liverworts, horsetails (Equisetum, the scouring rush)

Animalia

All heterotrophic.

Multicelled heterotrophs capable of movement at some stage during their life history (even couch potatoes).

Consumer level in most food chains (herbivores,carnivores,omnivores).

Food source, beasts of burden and transportation, recreation, and companionship.

Sponges, worms,molluscs, insects, starfish,mammals, amphibians,fish, birds, reptiles, and dinosaurs, and people.

Monera, the most primitive kingdom, contain living organisms remarkably similar to ancient fossils. Organisms in this group lack membrane-bound organelles associated with higher forms of life. Such organisms are known as prokaryotes. Bacteria (technically theEubacteria) and blue-green bacteria (sometimes called blue-green algae, or cyanobacteria) are the major forms of life in this kingdom. The most primitive group, the archaebacteria, are today restricted to marginal habitats such as hot springs or areas of low oxygen concentration.

Figure 6. Representative photosynthetic cyanobacteria: Oscillatoria (left) and Nostoc (right). The left image is cropped from gopher://wiscinfo.wisc.edu:2070/I9/.image/.bot/.130/Cyanobacteria/Oscillatoria_130. The right image is cropped fromgopher://wiscinfo.wisc.edu:2070/I9/.image/.bot/.130/Cyanobacteria/Nostoc_130.

Protista were the first of the eukaryotic kingdoms, these organisms and all others have membrane-bound organelles, which allow for compartmentalization and dedication of specific areas for specific functions. The chief importance of Protista is their role as a stem group for the remaining Kingdoms: Plants, Animals, and Fungi. Major groups within the Protista include the algae, euglenoids, ciliates, protozoa, and flagellates.

Figure 7. Scanning electron micrographs of diatoms (Protista).There are two basic types of diatoms: bilaterally symmetrical (left) and radially symmetrical (right). Images are fromhttp://WWW.bgsu.edu/departments/biology/algae/index.html.

Figure 8. Light micrographs of some protistans. The images are Copyright 1994 by Charles J. O'Kelly and Tim Littlejohn, used by permission from: http://megasun.bch.umontreal.ca/protists/gallery.html.

Fungi are almost entirely multicellular (with yeast, Saccharomyces cerviseae, being a prominent unicellular fungus), heterotrophic (deriving their energy from another organism, whether alive or dead), and usually having some cells with two nuclei (multinucleate, as opposed to the more common one, or uninucleate) per cell. Ecologically this kingdom is important (along with certain bacteria) as decomposers and recyclers of nutrients. Economically, the Fungi provide us with food (mushrooms; Bleu cheese/Roquefort cheese; baking and brewing),antibiotics (the first of the wonder drugs, penicillin, was isolated from a fungus Penicillium), and crop parasites (doing several billion dollars per year of damage).

Figure 9. Examples of fungi. The images are fromhttp://www.cinenet.net/users/velosa/thumbnails.html.

Plantae (click here for more information about the Plantae) include multicelled organisms that are all autotrophic (capable of making their own food by the process of photosynthesis, the conversion of sunlight energy into chemical energy). Ecologically, this kingdom is generally (along with photosynthetic organisms in Monera and Protista) termed the producers, and rest at the base of all food webs. A food web is an ecological concept to trace energy flow through an ecosystem. Economically, this kingdom is unparalleled, with agriculture providing billions of dollars to the economy (as well as the foundation of "civilization"). Food, building materials, paper, drugs (both legal and illegal), and roses, are plants or plant-derived products.

Figure 10. Examples of plants. The left image of species of Equisetum is cropped and reduced fromgopher://wiscinfo.wisc.edu:2070/I9/.image/.bot/.130/Fern_Allies/Sphenophyta/Equisetum/E._arvense_and_E._laevigatum_KS. The center image of Iris, is reduced and cropped fromgopher://wiscinfo.wisc.edu:2070/I9/.image/.bot/.401/Flowering_Plants/Monocots/Iridaceae/Iris/Iris_pumula_habit. The right image of Pereskia (Cactaceae) is reduced fromgopher://wiscinfo.wisc.edu:2070/I9/.image/.bot/.401/Flowering_Plants/Dicots/Cactaceae/Pereskia/Pereskia_leafy_stem_RK.

Animalia consists entirely of multicelluar heterotrophs that are all capable (at some point during their life history) of mobility. Ecologically, this kingdom occupies the level of consumers, which can be subdivided into herbivore (eaters of plants) and carnivores (eaters of other animals). Humans, along with some other organisms, are omnivores (capable of functioning as herbivores or carnivores). Economically, animals provide meat, hides, beasts of burden, pleasure (pets), transportation, and scents (as used in some perfumes).

Figure 11. Examples of animals. The left image of a jellyfish is from http://www.smoky.org/~mtyler/bio/coelenterata.html. The center image of a tree frog is from http://frog.simplenet.com/froggy/images/wild28.gif. The right image of the chimpanzee is fromhttp://www.selu.com/~bio/PrimateGallery/art/Copyright_Free02.html.

Characteristics of living things | Back to Top

Living things have a variety of common characteristics.

Organization. Living things exhibit a high level of organization, with multicellular organisms being subdivided into cells, and cells into organelles, and organelles into molecules, etc.

Homeostasis. Homeostasis is the maintenance of a constant (yet also dynamic) internal environment in terms of temperature, pH, water concentrations, etc. Much of our own metabolic energy goes toward keeping within our own homeostatic limits. If you run a high fever for long enough, the increased temperature will damage certain organs and impair your proper functioning. Swallowing of common household chemicals, many of which are outside the pH (acid/base) levels we can tolerate, will likewise negatively impact the human body's homeostatic regime. Muscular activity generates heat as a waste product. This heat is removed from our bodies by sweating. Some of this heat is used by warm-blooded animals, mammals and birds, to maintain their internal temperatures.

Adaptation. Living things are suited to their mode of existence. Charles Darwin began the recognition of the marvellous adaptations all life has that allow those organisms to exist in their environment.

Reproduction and heredity. Since all cells come from existing cells, they must have some way of reproducing, whether that involvesasexual (no recombination of genetic material) or sexual (recombination of genetic material). Most living things use the chemical DNA (deoxyribonucleic acid) as the physical carrier of inheritance and the genetic information. Some organisms, such as retroviruses (of which HIV is a member), use RNA (ribonucleic acid) as the carrier. The variation that Darwin and Wallace recognized as the wellspring of evolution and adaptation, is greatly increased by sexual reproduction.

Growth and development. Even single-celled organisms grow. When first formed by cell division, they are small, and must grow and develop into mature cells. Multicellular organisms pass through a more complicated process of differentiation and organogenesis (because they have so many more cells to develop).

Energy acquisition and release. One view of life is that it is a struggle to acquire energy (from sunlight, inorganic chemicals, or another organism), and release it in the process of forming ATP (adenosine triphosphate).

Detection and response to stimuli (both internal and external).

Interactions. Living things interact with their environment as well as each other. Organisms obtain raw materials and energy from the environment or another organism. The various types of symbioses (organismal interactions with each other) are examples of this.

Levels of Organization | Back to Top

Biosphere: The sum of all living things taken in conjunction with their environment. In essence, where life occurs, from the upper reaches of the atmosphere to the top few meters of soil, to the bottoms of the oceans. We divide the earth into atmosphere (air), lithosphere (earth),hydrosphere (water), and biosphere (life).

Ecosystem: The relationships of a smaller groups of organisms with each other and their environment. Scientists often speak of the interrelatedness of living things. Since, according to Darwin's theory, organisms adapt to their environment, they must also adapt to other organisms in that environment. We can discuss the flow of energy through an ecosystem from photosynthetic autotrophs to herbivores to carnivores.

Community: The relationships between groups of different species. For example, the desert communities consist of rabbits, coyotes, snakes, birds, mice and such plants as sahuaro cactus (Carnegia gigantea), Ocotillo, creosote bush, etc. Community structure can be disturbed by such things as fire, human activity, and over-population.

Species: Groups of similar individuals who tend to mate and produce viable, fertile offspring. We often find species described not by their reproduction (a biological species) but rather by their form (anatomical or form species).

Populations: Groups of similar individuals who tend to mate with each other in a limited geographic area. This can be as simple as a field of flowers, which is separated from another field by a hill or other area where none of these flowers occur.

Individuals: One or more cells characterized by a unique arrangement of DNA "information". These can be unicellular or multicellular. The multicellular individual exhibits specialization of cell types and division of labor into tissues, organs, and organ systems.

Organ System: (in multicellular organisms). A group of cells, tissues, and organs that perform a specific major function. For example: thecardiovascular system functions in circulation of blood.

Organ: (in multicellular organisms). A group of cells or tissues performing an overall function. For example: the heart is an organ that pumps blood within the cardiovascular system.

Tissue: (in multicellular organisms). A group of cells performing a specific function. For example heart muscle tissue is found in the heart and its unique contraction properties aid the heart's functioning as a pump. .

Cell: The fundamental unit of living things. Each cell has some sort of hereditary material (either DNA or more rarely RNA), energy acquiring chemicals, structures, etc. Living things, by definition, must have the metabolic chemicals plus a nucleic acid hereditary information molecule.

Organelle: A subunit of a cell, an organelle is involved in a specific subcellular function, for example the ribosome (the site of protein synthesis) or mitochondrion (the site of ATP generation in eukaryotes).

Molecules, atoms, and subatomic particles: The fundamental functional levels of biochemistry.

Figure 12. Organization levels of life, in a graphic format. Images from Purves et al., Life: The Science of Biology, 4th Edition, by Sinauer Associates (www.sinauer.com) and WH Freeman (www.whfreeman.com), used with permission.

It is thus possible to study biology at many levels, from collections of organisms (communities), to the inner workings of a cell (organelle).

Learning Objectives | Back to Top

Name the special molecule that sets living things apart from the nonliving world and be able to explain why this molecule is important.

The cell is considered to be the basic living unit. Be able to distinguish between single-celled organisms and multicelled organisms.

Be able to arrange in order, from smallest to largest, the levels of organization that occur in nature and to write a brief description of each.

What does the term metabolism mean to the cell and the organism.

Organisms use a molecule known as ATP to transfer chemical energy from one molecule to another. Why is this essential for living things to exist.

Homeostasis is defined as a state in which the conditions of an organism's internal environment are maintained within tolerable limits. What mechanisms in your body are involved with homeostasis?

Reproduction is the means by which each new organism arises. Why is this an essential characteristic of life?

How are DNA and cellular reporoduction linked in the process of inheritance?

A trait that assists an organism in survival and reproduction in a certain environment is said to be adaptive. What sorts of adaptive traits do you have? How do they aid your survival?

List the five kingdoms of life that are currently recognized by most scientists; tell generally what kinds of organisms are classified in each kingdom, and discuss the new ideas about Domains and how they may alter the five kingdom approach.

Arrange in order, from the fewer to the greater numbers of organisms included, the following categories of classification: class, family, genus, kingdom, order, phylum, and species.

Explain what the term biological diversity means to you, and speculate about what caused the great diversity of life on Earth.

Define natural selection and briefly describe what is occurring when a population is said to evolve.

Outline a set of steps that might be used in the scientific method of investigating a problem.

Explain why a control group is used in an experiment.

Define what is meant by a theory; cite an actual example that is significant to biology.

Terms | Back to Top

Animalia

Adaptation

ATP (adenosine triphosphate)

antibiotics

asexual and sexualreproduction

atmosphere

binomial nomenclature

biochemistry

biosphere

cells

cell theory

class

cardiovascular system

catastrophism

community

conservation of matter and energy

consumers

cyanobacteria

DNA

ecosystem

energy

entropy

Eubacteria

euglenoids

eukaryotic

family

food webs

fossils

Fungi

genus

heart

heart muscle tissue

heterotrophic

HIV

homeostasis

hydrosphere

hypothesis

inheritance of acquired characteristics

kingdom

lithosphere

mitochondrion

Monera

multicellular

multinucleate

natural selection

order

organ

organelles

organ system

parasites

photosynthesis

phylum

Plantae

populations

producers

prokaryotes

proteins

Protista

protozoa

retroviruses

RNA

ribosome

scientific method

species

symbioses

taxonomy

theory

tissue

unicellular

uniformitarianism

uninucleate

viruses

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