EVOLUTION AND DIVERSITY

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بِسْمِ اللهِ الرَّحْمنِ الرَّحِيمِ

﴿ مَّا جَعَلَ اللَّهُ لِرَجُلٍ مِّن قَلْبَيْنِ فِي جَوْفِهِ وَمَا جَعَلَ أَزْوَاجَكُمُ اللَّائِي تُظَاهِرُونَ مِنْهُنَّ أُمَّهَاتِكُمْ وَمَا جَعَلَ أَدْعِيَاءَكُمْ أَبْنَاءَكُمْ ذَٰلِكُمْ قَوْلُكُم بِأَفْوَاهِكُمْ وَاللَّهُ يَقُولُ الْحَقَّ وَهُوَ يَهْدِي السَّبِيلَ (٤) ﴾

صَدَقَ اللهُ العَظِيمِ

سورة الأحزاب ﴿ الآية: ٤ ﴾

الإهداء

أهدي هذا الكتاب إلى عائلتي

كذلك أهديه إلى الجامعة المستنصرية التي ساهمت في إبراز

هذا الصرح العلمي خدمة للعلم والمعرفة

المؤلفون

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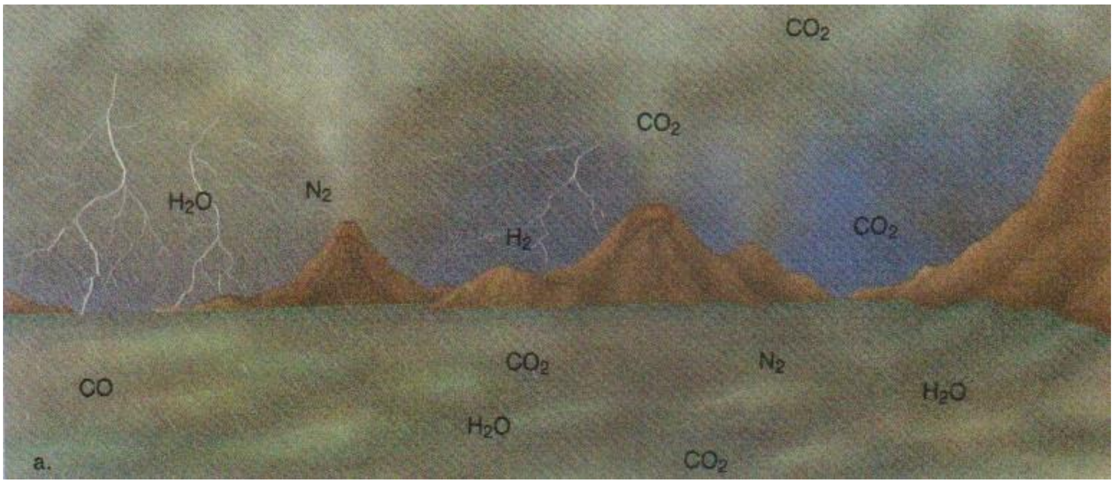
CHAPTER ONE

ORIGIN AND HISTORY OF LIFE

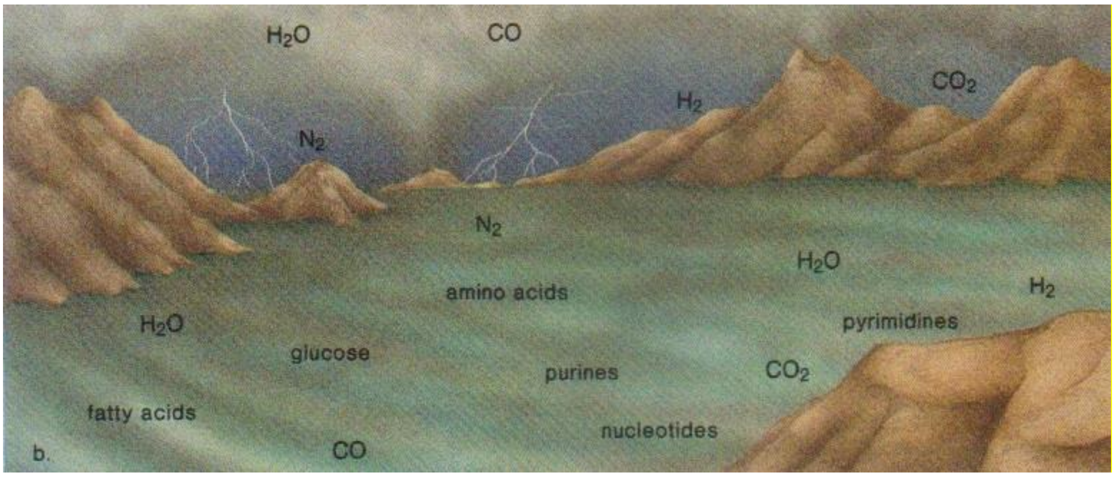
One of the most fascinating and frequently asked questions by laypeople and scientists alike is where did life come from? Although various answers have been proposed throughout history, today the most widely accepted hypothesis is that inorganic molecules in earth's prebiotic oceans combined to produce organic molecules and eventually primitive cells. These earliest cells probably appeared around 3.5 billion years ago. Around two billion years ago, oxygen-releasing photosynthesis began and the atmospheric ozone layer formed. This shield protected the earth' surface from intense ultraviolet radiation, and consequently, life moved from water onto land. Shortly afterward (at least in geologic time), the number of multicellular life-forms increased dramatically.

Millions of spaces have evolved, changed, and died out since life first began. If we could trace the lineages of all the species ever to have graced out planet, they would resemble a dense bush with countless branches intermingled with others. Some lines of descent are cut off close to the base, indicating that extinction occurred soon after the group arose; the others extend for varying amounts of time. Some that continue to today are groups that have managed to remain relatively unchanged since they first evolved. Other lines have split, producing two or more

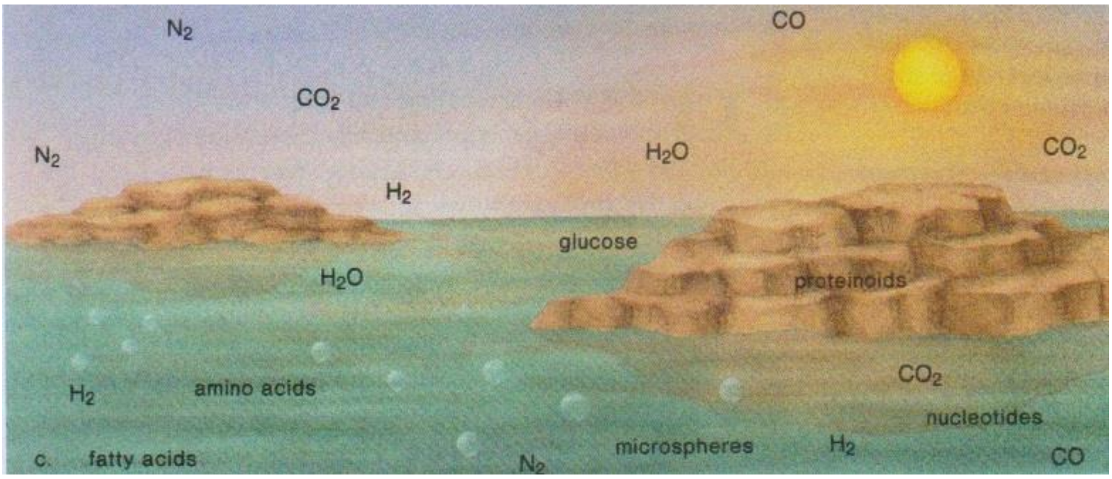
new groups. Clearly, the history of life on earth has many facets and twists and turns.



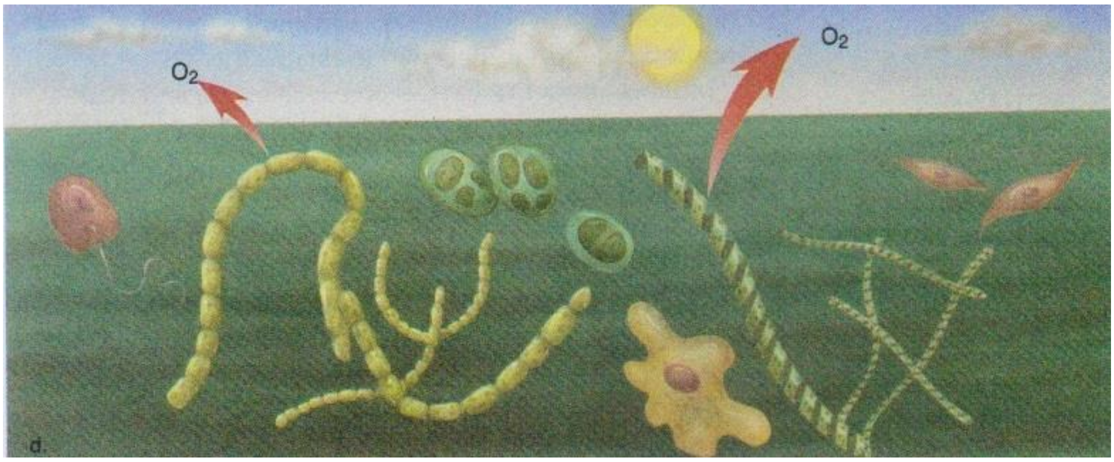
a. The primitive atmosphere contained gases, including water vapor, that escaped from volcanoes; as the water vapor cooled, some gases were washed into the ocean by rain.



b. The availability of energy from volcanic eruption and lightning allowed gases to form simple organic molecules.



c. Amino acids that splashed up onto rocky coasts could have polymerized into polypeptides (proteinoids) that became microspheres when they reentered the water.



d. Eventually, various types of prokaryotes and then eukaryotes evolved. Some of the prokaryotes were oxygen-producing photosynthesizers.

Figure 1.1 A possible scenario for the origin of life.

1.1 Origin of Life

Today, we do not believe that life arises spontaneously from nonlife, and we say that "life comes only from life". But if this is so, how did the first form of life come about? Since it was the very first living thing, it had to come from nonliving chemicals. Could there have been an increase in the complexity of the chemicals could a chemical evolution as depicted in ***Figure 1.1*** have produced the first cell(s) on the primitive earth؟

The sun and the planets, including earth, probably formed over a 10 billion years period from aggregates of dust particles and debris. At 4.6 billion years ago, the solar system was in place. Intense heat produced by gravitational energy and radioactivity caused the earth to become stratified into several layers. Heavier atoms of iron and nickel became the molten liquid core, and dense silicate minerals became the semiliquid mantle. Upwellings of volcanic lava produced the first crust.

The Atmosphere Forms

The size of the earth is such that the gravitational field is strong enough to have an atmosphere. If the earth were smaller and lighter, atmospheric gases would escape into outer space. The earth's primitive atmosphere was not the same as today's atmosphere. It is now thought that the primitive atmosphere was produced primarily by outgassing from the interior, particularly by volcanic action. In that case, the primitive atmosphere would have consisted mostly of water vapor (H_2O), nitrogen (N_2), and carbon dioxide (CO_2), with only small amount of hydrogen (H_2) and carbon monoxide (CO). The primitive atmosphere with little if any free oxygen, was a reducing atmosphere as opposed to the oxidizing atmosphere of today. This was fortuitous because oxygen (O_2) attaches to organic molecules, preventing them from joining to form larger molecules.

At first, the earth was so hot that water was present only as a vapor that formed dense, thick clouds. Then, as the earth cooled, water vapor condensed to liquid water, and rain began to fall ***(Figure 1.1a)***. It rained in such enormous quantity over hundreds of millions of years that the oceans of the world were produced. The earth is an appropriate distance from the sun: any closer, water would have evaporated; any farther, water would have frozen.

Small Organic Molecules Evolve

The atmosphere gases dissolved in rain, were carried down into newly forming oceans. Aleksandr Oparin, a soviet biochemist, suggested as early as 1938 that organic molecules could have been produced from the gases of the primitive atmosphere in the presence of strong outside energy sources. The energy sources on the primitive earth included heat from volcanoes and meteorites, radioactivity from isotopes in the earth's crust, powerful electric discharges in lightning, and solar radiation, especially ultraviolet radiation ***(Figure 1.1b)***.

In 1953, Stanley Miller provided support for Oparin's ideas through an ingenious experiment ***(Figure 1.2)***. Miller placed a mixture resembling a strongly reducing atmosphere methane (CH_4), ammonia (NH_3), hydrogen

(H_2), and water (H_2O) in a closed system, heated the mixture, and circulated it past an electric spark (simulating lightning). After a week's run, Miller discovered that a variety of amino acids and organic acids had been produced. Since that time, other investigators have achieved similar results by utilizing other, less-reducing combinations of gases dissolved in water.

These experiments support the hypothesis that the primitive gases could have reacted with one another to produce small organic compounds. Neither oxidation (there was no free oxygen) nor decay (there were no bacteria) would have destroyed these molecules, and they would have accumulated in the oceans for hundreds of millions of years. With the accumulation of these small organic compounds, the oceans became a thick, warm organic soup containing a variety of organic molecules.

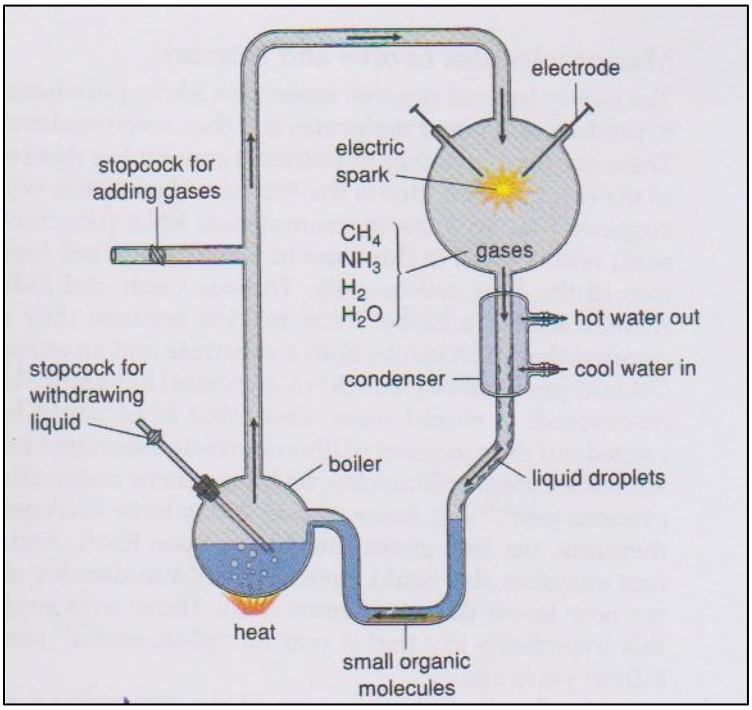


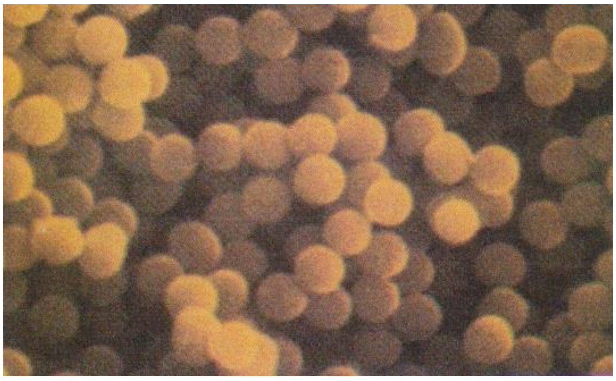
Figure 1.2 Evidence for a chemical evolution.

Macromolecules Evolve and Interact

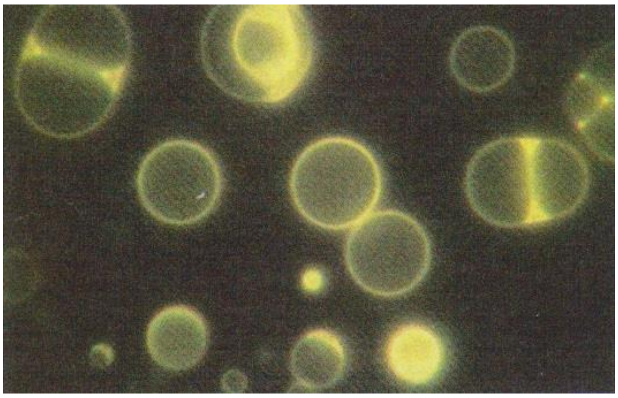
The newly formed organic molecules likely polymerized to produce still larger molecules and then macromolecules. There are three primary hypotheses concerning this stage in the origin of life. One is the **RNA-first hypothesis**, which suggests that only the macromolecule RNA (ribonucleic acid) was needed at this time to progress toward formation of the first cell or cells. Thomas Cech and Sidney Altman shared a Nobel Prize in 1989 because they discovered that RNA can be both a substrate and an enzyme. Other types of ribozymes (RNA enzymes) have since been discovered. It would seem, then, that RNA could have carried out the processes of life commonly associated today with DNA (deoxyribonucleic acid, the generic material) and proteins (enzymes). Some viruses today have RNA genes; therefore, the first genes could have been RNA. And the first enzymes also could have been RNA molecules, since we know that ribozymes exist. Those who support this hypothesis say that it was an "RNA world" some 4 billion years ago.

Another hypothesis is termed the protein-first hypothesis. Sidney Fox has shown that amino acids polymerize abiotically when exposed to dry heat ***(see Figure 1.1c)***. He suggests that amino acids collected in shallow puddles along the rocky shore and the heat of the sun caused them to form proteinoids, small polypeptides that have some catalytic properties. When proteinoids are returned to water, they form microspheres [Gk. mikros, small, little, and sphere, ball], structures composed only of protein that have many properties of a cell. It's possible that the first polypeptides had enzymatic properties, and some provided to be more capable than others. Those that led to the first cell or cells had a selective advantage. This hypothesis assumes that DNA genes came after protein enzymes arose. After all, it is protein enzymes that are needed for DNA replication.

The third hypothesis is put forth by Graham Cairns-Smith. He believes that clay was especially helpful in causing polymerization of both protein and nucleic acids at the same time. Clay attract small organic molecules and contains iron and zinc, which may have served as inorganic catalysts for polypeptide formation. In addition, clay has a tendency to collect energy from radioactive decay and to discharge it when the temperature and/or humidity changes. This could have been a source of energy for polymerization to take place. Cairns-Smith suggests that RNA nucleotides and amino acids became associated in such a way that polypeptides were ordered by and helped synthesize RNA. It is clear that this hypothesis suggests that both polypeptides and RNA arose at the same time.



a. Microspheres, which are composed only of protein, have a number of cellular characteristics and could have evolved into the protocell.



b. Liposomes form automatically when phospholipid molecules are put into water. Plasma membranes may have evolved similarly.

Figure 1.3 Protocell anatomy.

A Protocell Evolves

Before the first true cell arose, there would have been a protocell [Gk. protos, first], a structure that has a lipid-protein membrane and carries on energy metabolism ***(Figure 1.3)***. Fox has shown that if lipids are made available to microspheres, lipids tend to become associated with microspheres producing a lipid-protein membrane.

Some researchers support the work of Oparin, who was mentioned previously. Oparin showed that under appropriate conditions of temperature, ionic composition, and pH, concentrated mixtures of macromolecules tend to give rise to complex units called coacervate droplets. Coacervate droplets have a tendency to absorb and incorporate various substances from the surrounding solution. Eventually, a semipermeable-type boundary may form about the droplet. In a liquid environment, phospholipid molecules automatically form droplets called liposomes [Gk. lipos, fat, and soma, body]. Perhaps the first membrane formed in this manner. In that case, the protocell could have contained only RNA, which functioned as both genetic material and enzymes.

Protocells Were Heterotrophs

The protocell would have had to carry on nutrition so that it could grow. Nutrition was no problem because the protocell existed in the ocean, which at that time contained simple organic molecules that could have served as food. Therefore, the protocell likely was a heterotroph [Gk. hetero, different, and trophe, food], an organism that takes in preformed food. Notice that this suggests that heterotrophs are believed to have preceded autotrophs [Gk. autos, alone, and trophe, food], organisms that make their own food.

At first, the protocell may have used preformed ATP (adenosine triphosphate), but as this supply dwindled, natural selection favored any cells that could extract energy from carbohydrates in order to transform ADP (adenosine diphosphate) to ATP-Glycolysis is a common metabolic pathway in living things, and this testifies to its early evaluation in the history of life. Since there was no free oxygen, we can assume that the protocell carried on a form of fermentation.

It seems logical that the protocell at first had limited ability to break down organic molecules and that it took millions of years for glycolysis to evolve completely. It is of interest that Fox has shown that a microsphere from which the protocell may have evolved has some catalytic ability and that Oparin found that coacervates do incorporate enzymes if they are available in the medium.

A Self-Replication System Evolves

A true cell is a membrane-bounded structure that can carry on protein synthesis needed to produce the enzymes that allow DNA to replicate ***(Figure 1.4)***. The central dogma of genetics states that DNA directs protein synthesis and that there is a flow of information from DNA RNA protein. It is possible that this sequence developed in stages.

According to RNA-first hypothesis, RNA would have been the first to evolve, and the first true cell would have had RNA genes. These genes would have directed and enzymatically carried out protein synthesis, as mentioned, RNA enzymes called ribozymes have been discovered. Also, today we know there are viruses that have RNA genes. These viruses have a protein enzyme called reverse transcriptase that uses RNA as a template to form DNA. Perhaps with time, reverse transcription occurred within the protocell, and this is how DNA genes arose. Once there were DNA genes, then protein synthesis would have been carried out in the manner dictated by the central dogma of genetics.

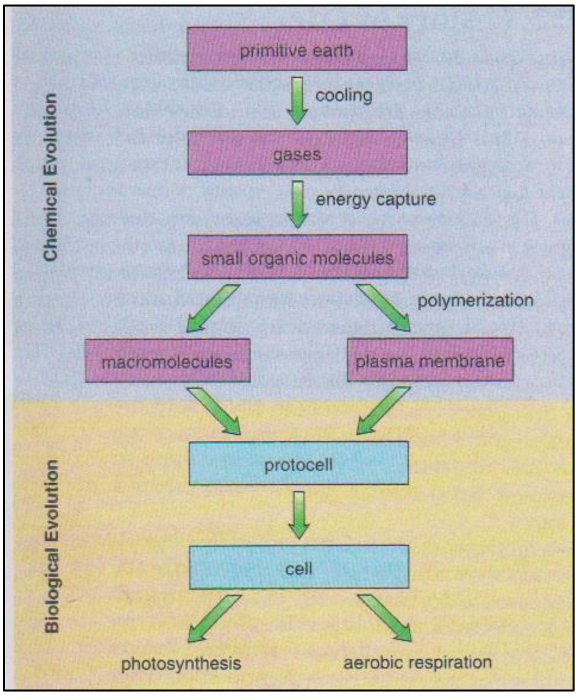


Figure 1.4 Evolution of the Protocell.

According to the protein-first hypothesis, proteins, or at least polypeptides, were the first of the three (i.e., DNA, RNA, and protein) to arise. Only after the protocell developed sophisticated enzymes did it have the ability to synthesize DNA and RNA from small molecules provided by the ocean. Researches point out that a nucleic acid is a very complicated molecule, and the likelihood that RNA arose de novo (on its own) is minimal. It seems more likely that enzymes were needed to guide the synthesis of nucleotides and then nucleic acids.

Cairns-Smith proposes that polypeptides and RDN evolved simultaneously. Therefore, the first true cell would have contained RNA genes that could have replicated because of the presence of proteins. This eliminates the baffling chicken-and-egg paradox: which came first, proteins or RNA? But it does mean, however, that two unlikely events would have to happen at the same time.

Once the protocells acquired genes that could replicate, they became cells capable of reproducing, and biological evolution began. The history of life began!

1.2 History of Life

Figure 1.5 shows the history of the earth as if it had occurred during a 24-hour time span that starts at midnight. (The actual years are shown on an inner ring of the diagram.) This figure illustrates dramatically that only unicellular organisms were present during most (about 80%) of the history of the earth.

If the earth formed at midnight, prokaryotes do not appear until 5 A.M, eukaryotes are present at approximately 4 P.M., and multicellular forms do not appear until around 8 P.M., invasion of the land doesn't occur until about 10 P.M., and humans don't appear until 30 seconds before the end of the day. This timetable has been worked out by studying the fossil record.

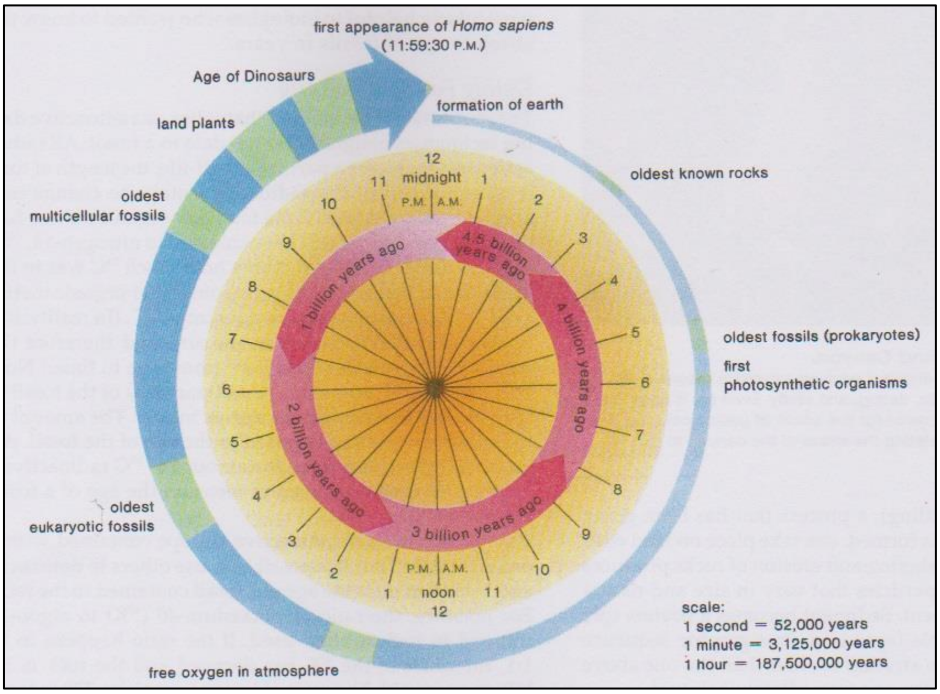


Figure 1.5 History of life according to the Fossil Record.

Fossils Tell a Story

Fossils [L. fossils, dug up] are the remains and traces of past life or any other direct evidence of past life. Traces include trails, footprints, burrows, worm casts, or even preserved droppings. Usually when an organism dies, the soft parts are either consumed by scavengers or undergo bacterial decomposition. Occasionally, the organism is buried quickly and in such a way that decomposition is never completed or is completed so slowly that the soft parts leave an imprint of their structure. Most fossils, however, consist only of hard parts such as shells, bones, or teeth, because these are usually not consumed or destroyed.

The great majority of fossils are found embedded in or recently eroded from sedimentary rock. Sedimentation [L. sedimentum, a setting], a process that has been going on since the earth was formed, can take place on land or in bodies of water. Weathering and erosion of rocks produces an accumulation of particles that vary in size and nature and are called sediment. Sediment becomes a stratum (pl., strata), a recognizable layer in a stratigraphic sequence ***(Figure 1.6)***. Any given stratum is older than the one above it and younger than the one immediately below it.

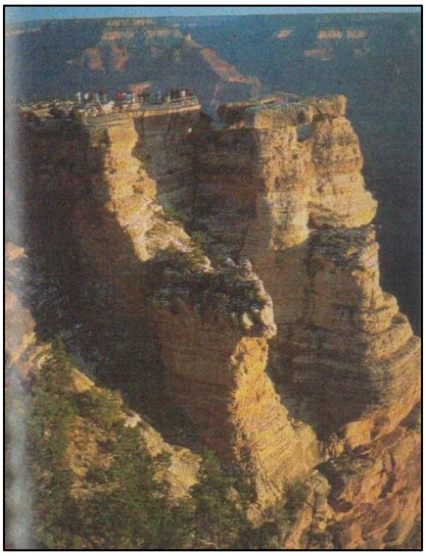


Figure 1.6 The Grand Canyon.

The fossils trapped in strata are the fossil record that tells us about the history of life. **Paleontology** [Gk. palaios, ancient, old, and ontos, having existed; -logy, "study of" from logikos, rational, senaible] is the science of discovering and studying the fossil record and, from it, making decisions about the history of life. Paleontologist not only want to know the structure and adaptations of an organism, they are also interested in how the organism interacted with others and with the physical environment.

Dating Fossils Relatively

In the early nineteenth century, even before the theory of evolution was formulated, geologists sought to correlate the strata worldwide. The problem was that strata change their character over great distances, and therefore stratum in England might contain different sediments than one of the same age in Russia. Geologists discovered, however, that the stratum of the same age tend to contain the same fossil, and therefore, fossils could be used for the purpose of relative dating of the strata. For example, a particular species of fossil ammonite (an animal related to the chambered nautilus) has found over a wide range and for a limited time period. Therefore, all strata around the world that contain this fossil must be of same age.

This approach helped geologists determine the relative dates of the strata despite upheavals, but it was not particularly helpful to biologists who wanted to know the absolute age of fossils in years.

Dating Fossils Absolutely

The absolute dating method that relies on radioactive dating techniques assigns an actual date to a fossil. All radioactive isotopes have a particular half-life, the length of time it takes for half of the radioactive isotope to change into another stable element. If the fossil has organic matter, half of the carbon-14, ^{14}C, will have change to nitrogen-14, ^{14}N, in 5,730 years. In order to know how much ^{14}C was in the organism to begin with, it is reasoned that organic matter always begins with the same amount of ^{14}C. (In reality, it is known that the ^{14}C levels in the air—and therefore the amount in organisms—can vary from time to time.) Now we need only compare the ^{14}C radioactivity of the fossil to that of a modern sample of organic matter. The amount of radiation left can be converted to the age of the fossil. After 50,000 years, however, the amount of ^{14}C radioactivity is so low it cannot be used to measure the age of a fossil accurately.

^{14}C is the only radioactive isotope contained within organic matter, but it is possible to use others to date rocks and from that infer the age of a fossil contained in the rock. For instance, the ratio of potassium-40 (^{40}K) to argon-40 trapped in rock is often used. If the ratio happens to be 1:1, then half of the ^{40}K has decayed and the rock is 1.3 billion years old. The ratio of isotope uranium-238 to lead-207 can be used only for rocks older than 100 million years. This isotope has such a long half-life that no perceptible decay will have occurred in a shorter length of time.

How the Story Unfolds

As a result of their study of strata, geologists have divided the history of the earth into eras, then periods and. We will follow the biologist's tradition of first discussing the Precambrian, a period of time that encompasses the first two eras: The Archean era and the Proterozoic era.

Life Begins in the Precambrian

The Precambrian is a very long period of time—it comprises about 87% of the geologic timescale. It is during this period of time life arose and the first cells came into existence. The first cells must have been prokaryotes. Prokaryotes do not have a nucleus or any membranous organelles. Of the living prokaryotes today, there is a type called archaea that live in the most inhospitable od environments such as hot springs, very salty lakes, and airless swamps—all of which may typify habitats on the primitive earth. The cell wall, plasma membrane, RNA polymerase, and ribosomes of archaea are more like those of eukaryotes than those of other bacteria.

As discussed, the first cell or cells must have been anaerobic heterotrophs (there was no oxygen in the primitive atmosphere). Also, the first photosynthesizers most likely did not give off oxygen. By 2 billion years ago (BYA), however, oxygen-releasing photosynthesis began. Some of the earliest cells, dated about 3.5 BYT, are found in fossilized stromatolites, which are pillarlike structures composed of sedimentary layers containing communities of prokaryotic organisms. Stromatolites containing cyanobacteria, which carry on oxygen-releasing photosynthesis, exist even today in shallow water off the west coast of Australia.

Due to the action of photosynthesizerrs, the atmosphere became an oxidizing one instead of a reducing one. Oxygen in the upper atmosphere forms ozone (O_3), which filters out the ultraviolet (UV) rays of the sun. Before the formation of the ozone shield, the amount of the ultraviolet radiation reaching the earth could have helped create organic molecules, but it would have destroyed any land-welling organisms. Once the ozone shield was in place, it meant that living things would be sufficiently protected and would be able to live on land. Life on land is threatened if the ozone shield is reduced. This is why there is such concern today about pollutants that act to break down the ozone shield.

The presence of oxygen in the atmosphere meant that most environments when no longer suitable for anaerobic prokaryotes, and they began to decline in importance. Photosynthetic cyanobacteria and aerobic bacteria proliferated as new metabolic pathways evolved.

Eukaryotic Cells Arise

The eukaryotic cell, which originated about 2.1 BYA, is nearly always aerobic and contains a nucleus as well as other membranous organelles. Most likely the eukaryotic cell acquired its organelles gradually. It may be that the nucleus developed by an invagination of the plasma mem- brane. The mitochondria of the eukaryotic cell probably were once free-living aerobic prokaryotes, and the chloroplasts probably were free-living photosynthetic prokaryotes. The theory of endosymbiosis says that the nucleated cell engulfed these prokaryotes, which then became organelles. It's been suggested that flagella (and cilia) also arose by endosymbiosis. First, slender undulating prokaryotes could have attached themselves to a host cell in order to take advantage of food leaking from the host's outer membrane. Eventually, these prokaryotes were drawn inside the host cell and became the flagella and cilia we know today. The first eukaryotes were unicellular, as are prokaryotes.

It is not known when multicellularity began, but the very first multicellular forms were most likely microscopic. It’s possible that the first multicellular organisms practiced sexual reproduction. Among protists (eukaryotes classified in the kingdom Protista) today, we find colonial forms in which some cells are specialized to produce gametes needed for sexual reproduction. Separation of germ cells, which produce gametes from somatic cells, may have been an important first step toward the development of complex macroscopic animals that appeared about 600 million years ago (MYA). In 1947, fossils of soft-bodied invertebrates of this date were found in the Ediacara Hills in South Australia. Since then, similar fossils have been discovered on a number of other continents. They represent a community of animals that most likely lived on mudflats in shallow marine waters (Fig. 1.7). Many biologists interpret the fossils as being like jellyfish, sea pens (relatives of corals), and segmented worms. Other fossils seem unrelated to the types of animals alive today.

a. ***Artist's representation of a community of animals, based on Ediacaran fossils. The large frondlike organisms are interpreted here as soft corals. known today as sea pans. Silvery jellyfish swim about, and an elongate, wormlike creature is on the seafloor.***

b. ***Dickinsonia costata, a fossil that is interpreted to be a segmented worm.***

Figure 1.7 Sea life of the late Precambrian.

Complexity Increases in Paleozoic

The Paleozoic era lasted over 300 million years. Many events occurred during this time, which is quite short compared to the length of the Precambrian. For one thing, there Were three major mass extinctions.

Cambrian Fossils:

Figure 1.8 shows that the seas teemed with invertebrate life during the Cambrian period. Invertebrates are animals without a vertebral column. All of today's groups of animals can trace their ancestry to this time and perhaps earlier according to new molecular clock data. Fossils, however, are more prevalent during the Cambrian than before. Why are fossils easier to find at this time? Because the animals had protective outer skeletons, and skeletons are capable of surviving the forces that are apt to destroy fossils. For example, Cambrian seafloors were dominated by now-extinct trilobites, which had thick, jointed armor covering them from head to tail. Trilobites are classified as arthropods, a major phylum of animals today. (Some Cambrian species, with most unusual eating and locomotion appendages, have been classified in phyla that no longer exist today).

Paleontologists have sought an explanation for why animals had skeletons during the Cambrian period, but not before. By this time, not only cyanobacteria but also various algae, which are floating photosynthetic organisms, were pumping oxygen into the atmosphere. Perhaps the oxygen supply became great enough to permit aquatic animals to acquire oxygen even though they had outer skeletons. The presence of a skeleton cuts down on possible access to oxygen in seawater. Steven Stanley of Johns Hopkins University suggests that predation may have played a role. Skeletons may have evolved during the Cambrian period because skeletons help protects animals from predators.

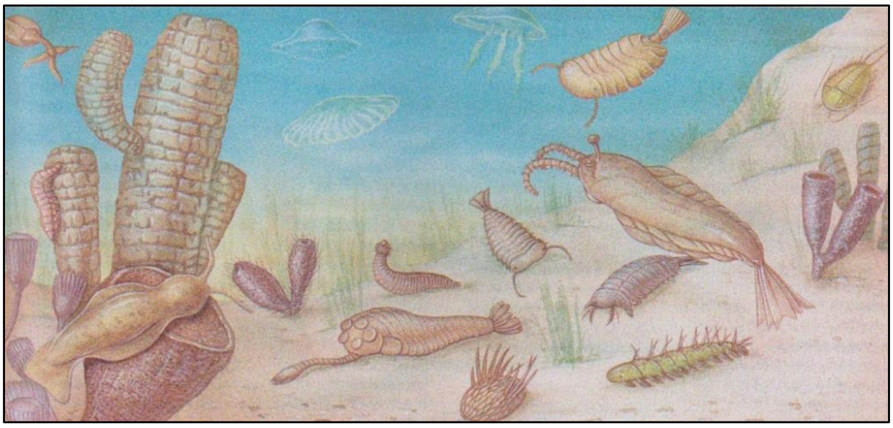


Figure 1.8 Sea life of the Cambrian period

Later, Land Is Invaded:

Sometime during the Paleozoic era, algae, which were common in the seas, most likely began to take up residence in bodies of fresh water; from there, they may have invaded damp areas on land. An association of plant roots with fungi called mycorrhizae is credited with allowing plants to live on bare rocks. The fungi are able to absorb minerals, which they pass to the plant, and the plant in turn passes carbohydrates, the product of photosynthesis, to the fungi.

The most prevalent **land plants** have vascular tissue for water transport, but there are no fossils of vascular plants until the Silurian period. The first vascular plants flourished in the warm swamps of the Carboniferous period (Fig. 1.9). Club mosses, horsetails, and seed ferns were the trees of that time, and they grew to enormous size. A wide variety of Smaller ferns and fernlike plants formed an underbrush.

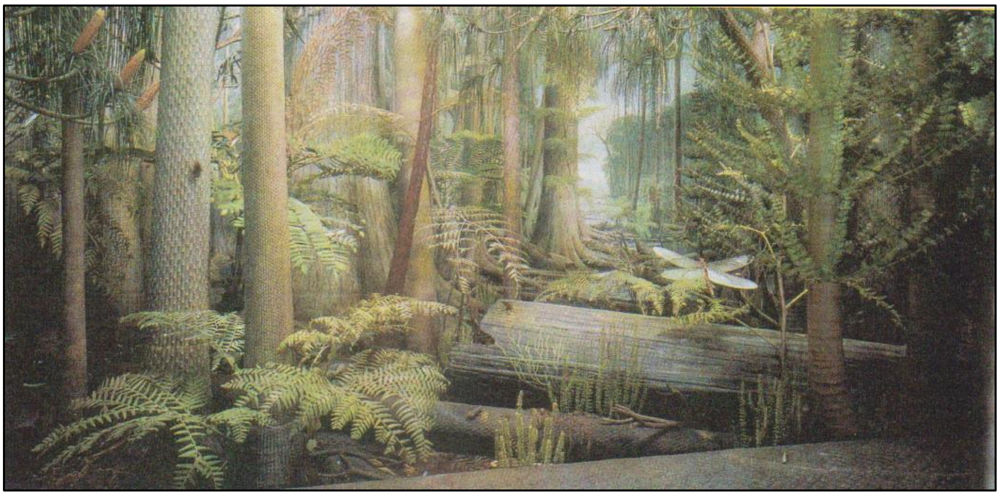


Figure 1.9 Swamp forests of the Carboniferous period

The **first animals** to live on land were scorpions, carnivorous relatives of spiders with a poisonous stinger at the end of their tail and two large pincers on their front legs. Insects enter the fossil record in the Carboniferous period. The outer skeleton and jointed appendages of insects were suitable to a land existence. An outer skeleton prevents drying out, and jointed appendages provide a suitable means of locomotion on land. These traits, plus the evolution of wings, provided advantages that allowed insects to radiate into the most diverse and abundant group of animals today. Flying provides a way to escape enemies and find food.

Vertebrates are animals with a vertebral column. The vertebrate line of descent began in the early Ordovician period with the evolution of fishes. First there were jawless fishes and then fishes with jaws. Fishes are ectothermic (cold-blooded), **aquatic vertebrates** that have gills, scales, and fins. The ray-finned fishes, which include today's most familiar fish, make their appearance in the Devonian period, which is called the Age of **Fishes**. **Amphibians** are more directly related to lobed-finned fishes, which may have ventured onto short to avoid predators. The only vertebrates in the wet Carboniferous forests were amphibians, thin-skinned vertebrates that are not fully adapted to life on land, particularly they must return to water to reproduce. The swamp forests provided the water they needed and amphibians radiated into many different sizes and shapes. Some superficially resembled alligators and were covered with protective scales, others were small and snakelike, and a few were larger plant eaters. The largest measured 6 meters (20 feet) from snout to tail. The Carboniferous period is called the Age of the Amphibians.

There was a change of climate at the end of the Carboniferous period; cold and dry weather brought an end to the Age of the Amphibians and began the process that turned the great Carboniferous forests into the coal we use today to fuel our modern society.

Dinosaurs Rule in the Mesozoic

Although there was a **mass extinction** at the end of the Paleozoic era, the evolution of certain types of plants and animals continued into the Triassic, the first period of the Mesozoic era. Nonflowering seed plants (collectively called gymnosraerms), which had been present in the fossil record of the Permian period, became dominant. Among these largely cone-bearing plants were cycads and conifers. Cycads are short and stout with palm like leaves; the female plant produces very large cones. Cycads were so prevalent during the Jurassic period that it is sometimes called the Age of the Cycads. By the Cretaceous period of the Mesozoic era, flowering plants (collectively called angiosperms) had begun to radiate, and cone-bearing plants declined in importance.

Reptiles, too, can be traced back to the Permian period of the Paleozoic era. Unlike amphibians, reptiles can thrive in a dry climate because they have scaly skin and lay a shelled egg that hatches on land. Reptiles underwent an adaptive radiation during the Mesozoic to produce forms that lived in the air, in the sea, and on the land. At the beginning of the Mesozoic era, mammal-like reptiles called therapsids were prevalent.

Therapsids had vertically positioned limbs that held the body off the ground. During the Jurassic period, large flying reptiles called pterosaurs ruled the air and giant-marine reptiles with paddlelike limbs ate fishes in the sea, but on land it was the dinosaurs (Fig. 1.10) that prevented the evolving mammals from taking center stage.

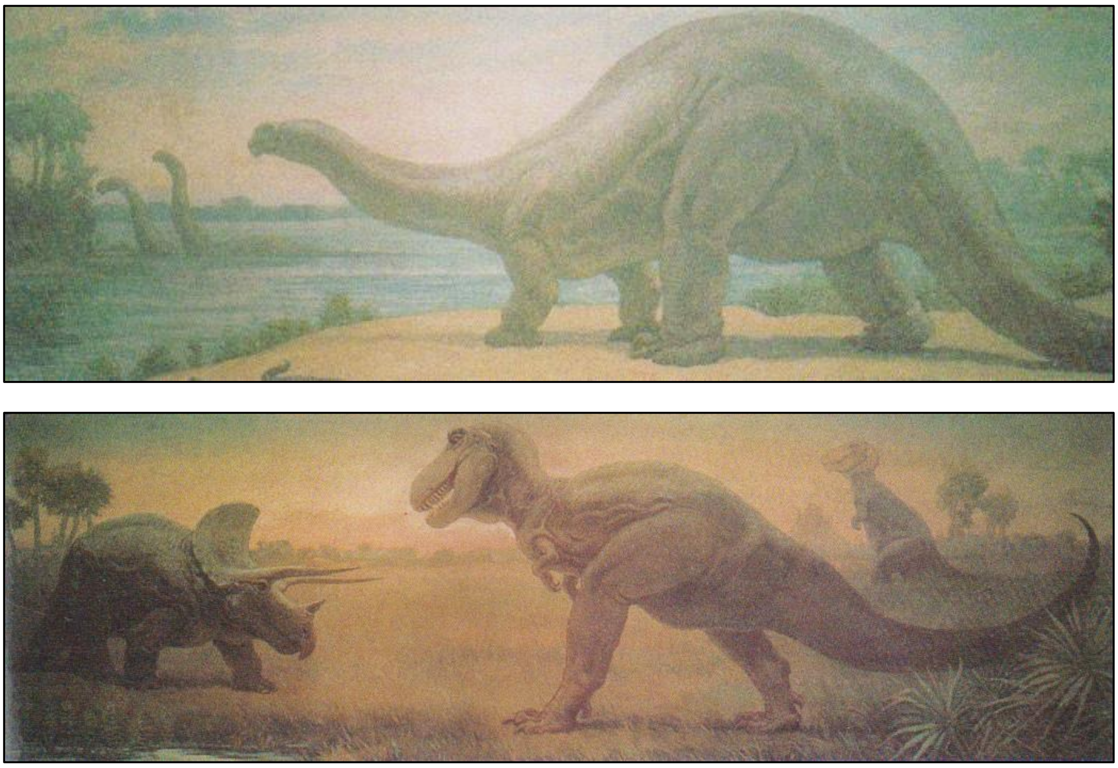


Figure 1.10 Dinosaurs of the Mesozoic

The **dinosaurs were reptiles**, some of an enormous size. During the Jurassic period. the gargantuan Apatosaurus and the armored tractor-sized Stegosaurus fed on cycad and conifer trees. During the Cretaceous period, great herds of rhino like Triceratops roamed the plains, as did the infamous Tyrannosaurus rex, which was carnivorous and played the same ecological role as lions do today. The size of a dinosaur such as Apatosaurus is hard for us to It was as tall as a four-story office building, and its weight was as much as that of a thousand people! How might dinosaurs have benefited from being so large? One theory is that being ectothermic, the volume-to-surface ratio was favorable for retaining heat. Others present evidence, based largely on bone construction, that at least some of the dinosaurs were endothermic (warm-blooded). Newly found evidence, suggests that dinosaurs should not be classified as reptiles at all!

During the Jurassic period, one group of dinosaurs called theropods were bipedal and had an elongate, mobile S-shaped neck. The fossil Archaeopteryx is a transitional link, which shows that theropods are related to birds. Despite this animal's feathers, its jaw bore teeth, and it had a long lizard like tail. The fossil record for birds begins at this time and continues on into the next era.

By the end of the Cretaceous period, the dinosaurs were extinct. They were Victims of a mass extinction brought about by causes that are still being debated.

Mammals Take Over in the Cenozoic

According to a new system, the Cenozoic era is divided, into a Paleogene period and a Neogene period. We are living in the Neogene period.

Mammals Diversify in the Paleogene:

At the end of the Mesozoic era, **mammals** began an adaptive radiation into the many habitats now left vacant by the demise of the dinosaurs. Mammals are endothermic and they have hair, which helps keep body heat from escaping. Their name refers to the presence of mammary glands, which produce milk to feed their young. At the start of the Paleocene epoch, mammals were small and resembled a mouse. By the end of the Eocene epoch, mammals had diversified to the point that most of the modern orders were in existence. Bats are mammals that have conquered the air. Whales, dolphins, and other marine mammals live in the sea where vertebrates began their evolution in the first place. Hoofed mammals populate forests and grasslands and are fed upon by diverse carnivores. Many of the types of herbivores and carnivores of the late Paleogene period, however, are extinct today (Fig. 1.11).

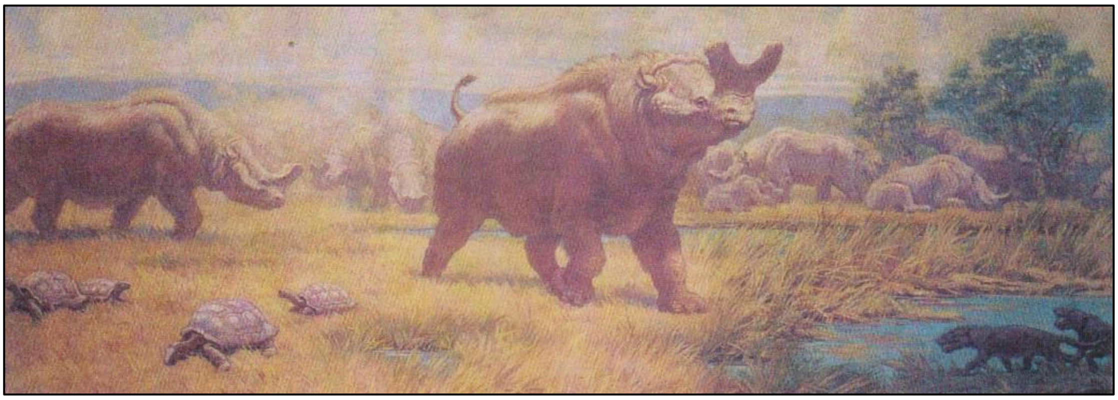


Figure 1.11 Mammals of the Oligocene epoch

Primates Evolve in the Neogene:

Primates are a type of mammal adapted to living in flowering trees where there is protection from predators and where food in the form of fruit is plentiful. The first primates were small squirrel-like animals, but from them evolved the first monkeys and then apes. During the Miocene epoch, weather changes caused African forests to be replaced by grasslands. It was then that hominids began to walk on two legs and the human line of descent began.

The world’s climate was progressively cooler during the Neogene period, so much so that the latter two epochs are known as the Ice Age. During periods of glaciation, snow and ice covered about one-third of the land surface of the earth. The Pleistocene epoch was an age of not only humans, but also giant ground sloths, beavers, wolves, bison, woolly rhinoceroses, mastodons, and mammoths (Fig. 1.12). Humans have survived, but what happened to the oversized mammals just mentioned? Some think that humans became such skilled hunters they are at least partially responsible for the extinction of these awe-inspiring animals.

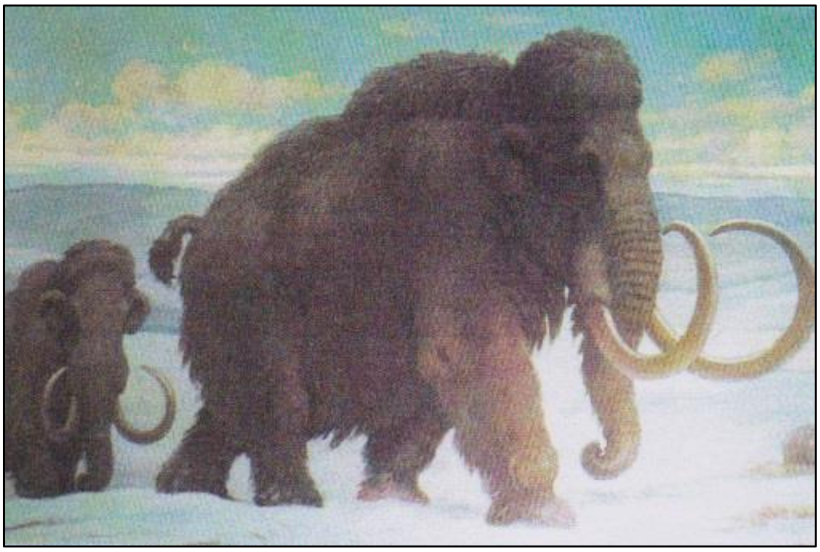


Figure 1.12 Woolly mammoth of the Pleistocene epoch.

1.3 Factors That Influence Evolution

It used to be thought that the earth's crust was immobile, sentiments had always been in their present positions, and that the ocean floors were only a catch basin for the debris that washed off the land. In 1920, Alfred Wegener, a German meteorologist, presented data from a number of disciplines to support his Hypothesis of continental drift. This hypothesis, which was finally confirmed in the 1960s, states that the continents are not fixed; instead, their positions and the position of the oceans have changed over time (Fig. 1.13). About 225 million years ago (MYA), the continents joined to form one supercontinent that Wegener called Pangaea. First, Pangaea divided into two large subcontinents, called Gondwanaland and Laurasia, and then these also split to form the continents of today. Presently, the continents are still drifting in relation to one another.

Continental drift explains why the coastlines of several continents are mirror images of each other—the outline of the west coast of Africa matches that of the east coast of South America. The same geological structures are also found in many of the areas where the continents touched. A single mountain range runs through South America, Antarctica, and

Australia. Continental drift also explains the unique distribution patterns of several fossils. Fossils of the same species of seed fern (Glossopteris) have been found on all the southern continents. No suitable explanation was possible previously, but now it seems plausible that the plant evolved on one continent and spread to the others when they were joined as one. Similarly, the fossil reptile **Cynognathus** is found in Africa and South America and **Lystrosaurus**, a mammal-like reptile, has now been found in Antarctica, far from Africa and southeast Asia, where it is also found. With mammalian fossils, the situation is different: Australia, South America, and Africa all have their own distinctive mammals because mammals evolved after the continents separated. The mammalian biological diversity of today's world is the result of isolated evolution on separate continents.

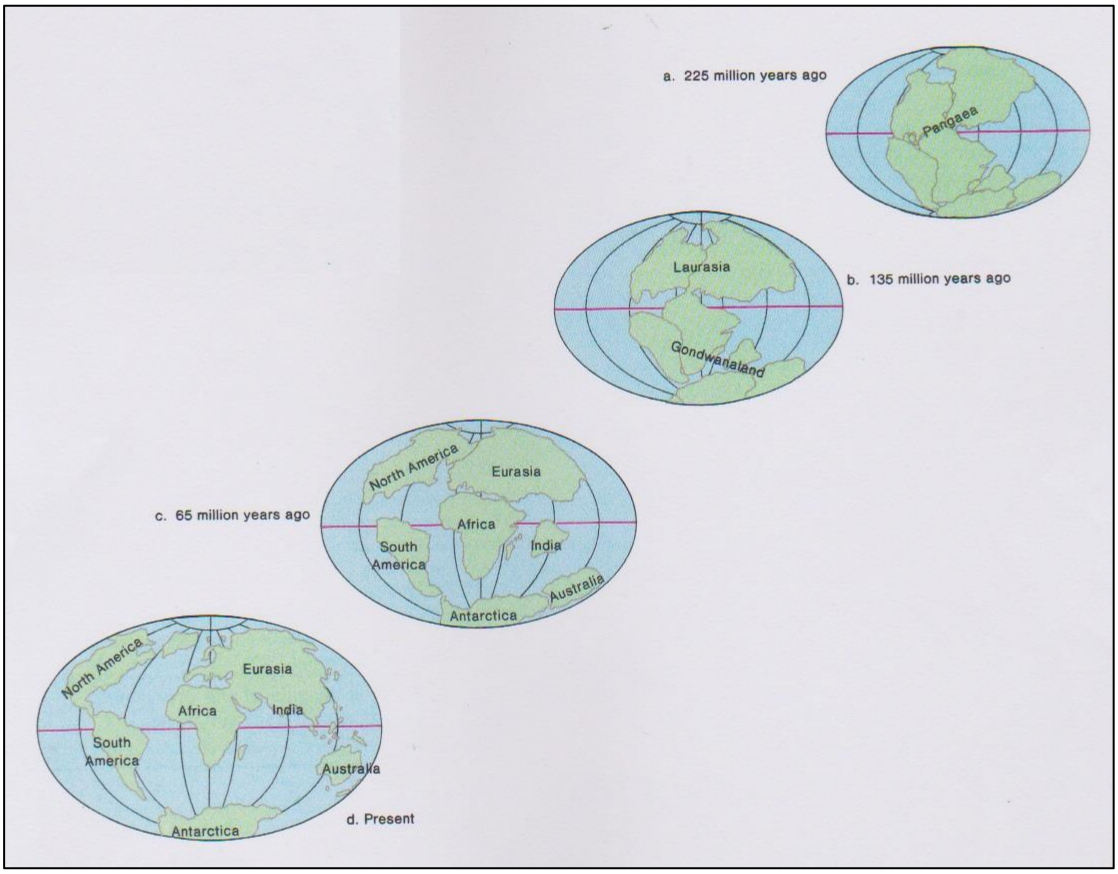


Figure 1.13 Continental drift

Why do the continents drift? According to a branch of geology known as plate tectonics [Gk tektos, fluid, molten, able to flow] (tectonics refers to movements of the earth's crust), the earth's crust is fragmented into slab like plates that float on a lower hot mantle layer. The continents and the ocean basins are a part of these rigid plates, which move like conveyor belts (Fig. 1.14). At ocean ridges, seafloor spreading occurs as molten mantle rock rises and material is added to the ocean floor. Seafloor spreading causes the continents to move a few centimeters a year on the average. At subduction zones, the forward edge of a moving plate sinks into the mantle and is destroyed. When an ocean floor is at the leading edge of a plate, a deep trench forms that is bordered by volcanoes or volcanic Island Chains. When two continents collide, the result is often a mountain range; for example، the Himalayas resulted when India collided with Eurasia. Two plates meet along a transform boundary where two plates scrape past one another. The San Andreas fault in southern California is at a transform boundary, and the movement of the two plates is responsible for the many earthquakes in that region.

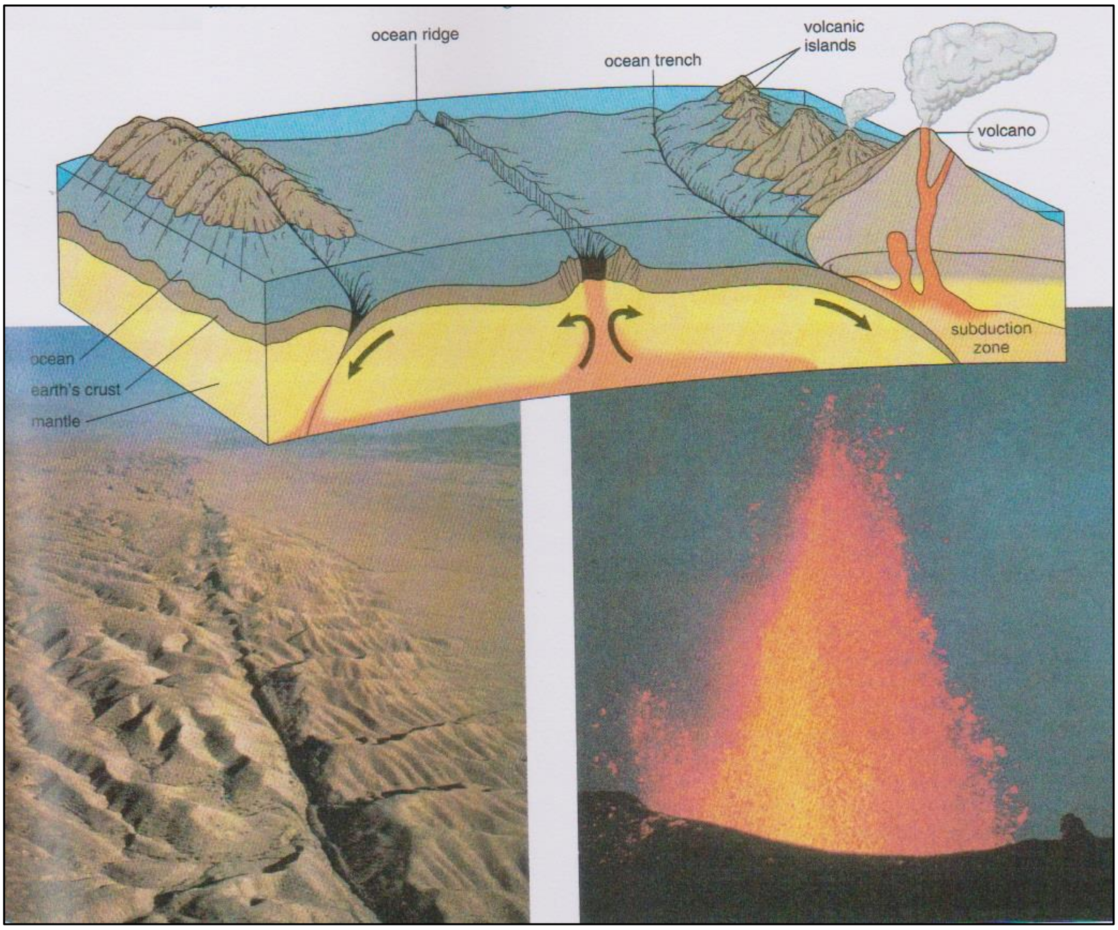


Figure 1.14 Plate tectonics

Exploring Mass Extinctions

An **extinction** is the total disappearance of all the members of a species or a higher taxonomic group. A **mass extinction** is the disappearance of a larger number of species or higher taxonomic groups within an interval of just a few million years. There have been at least five mass extinctions throughout history: at the ends of the Ordovician, Devonian, Permian, Triassic, and Cretaceous periods (Fig. 1.15). Mass extinctions are usually followed by at least partial evolutionary recovery in which the remaining groups of organisms undergo adaptive radiations and fill the habitats vacated by those that have become extinct. Is a mass extinction due to some cataclysmic event, or is it a more gradual process brought on by environmental changes including tectonic, oceanic, and climatic fluctuations? This question was brought to the fore when Walter and Luis Alvarez proposed in 1977 that the Cretaceous extinction was due to a bolide. A bolide is an asteroid that explodes, producing meteorites that fall to earth. They found that Cretaceous clay contains an abnormally high level of iridium, an element that is rare in the earth's crust but more common in asteroids (or their fragments, meteorites). The result of a large meteorite striking the earth could have been similar to that from a worldwide atomic bomb explosion: a cloud of dust would have mushroomed into the atmosphere, blocking out the sun and causing plants to freeze and die. Recently, a layer of soot has also been identified in the strata alongside the iridium, and a huge crater that could have been caused by a meteorite was found a few years ago in the Caribbean—Gulf of Mexico region on the Yucatan peninsula.

In 1984, paleontologists David Raup and John Sepkoski suggested that the fossil record of marine animals shows that mass extinctions have occurred every 26 million years and, surprisingly, astronomers can offer an explanation. Our solar system is in a starry galaxy known as the Milky Way. Because of the vertical movement of our sun, our solar system approaches other members of the Milky Way every 26 to 33 million years, producing an unstable situation that could lead to the occurrence of a bolide. Perhaps some mass extinctions are associated with extraterrestrial events.

Certainly, continental drift contributed to the Ordovician extinction. This extinction after Gondwanaland at the south pole. Immense glaciers, which drew water from the oceans, chilled even the once-tropical land. invertebrates and coral reefs, which were especially hard hit, didn’t recover until Gondwanaland drifted away' from the pole and warmth returned. The mass extinction at the end of the Devonian saw an end to 70% of marine invertebrates. Helmont Geldsetzer of Canada’s Geological Survey notes that iridium has also been found in Devonian rocks in Australia, suggesting that a bolide event was also involved in the Devonian extinction. Other scientists believe that this mass extinction could have occurred when Gondwanaland headed back over the south pole.

At the end of the Permian period, all land masses joined to form the supercontinent Pangaea. The amount of shallow offshore water shrank dramatically and marine life was greatly affected. The trilobites became extinct and the crinoids (sea lilies) barely hung on. Glaciers originating at either pole poured periodically over the land, and the inland weather grew drier and colder. The swamp forests that had originated in the Carboniferous period and their amphibian inhabitants were particularly affected. The Permian extinction is the worst by far, with nearly 96% of spaces disappearing.

The extinction at the end of the Triassic period is another that has been attributed to the environmental effects of a meteorite collision with earth. Central Quebec has a crater half the size of Connecticut that some believe is the impact site. The dinosaurs may have benefited from this event, because this is the time when the first of the gigantic dinosaurs took charge of the land. The second wave occurred in the Cretaceous period.

Whether a bolide caused or contributed to the Cretaceous extinction is still being investigated. This extinction—which doomed the dinosaurs, pterosaurs, ammonoids, and over 75% of the known species of marine plankton—did not happen overnight. Terrestrial events such as tectonic, oceanic, and climatic fluctuations contributed to sporadic periods of extinction over a period of 0.5 to 5 million years. It could be that an extraterrestrial event dealt the final blow.

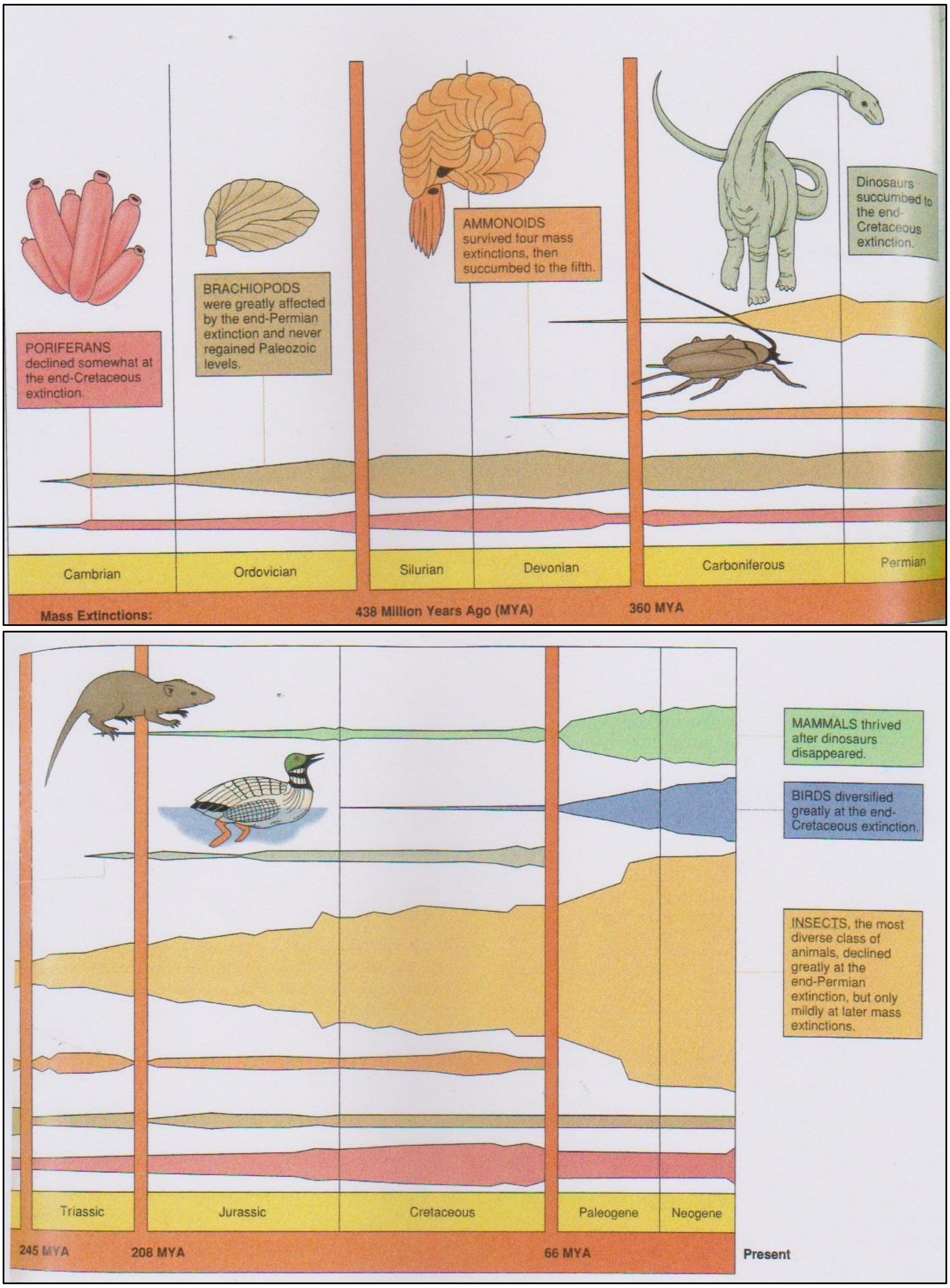


Figure 1.15 Mass extinctions

Microevolution Versus Macroevolution

As we discussed in the previous chapter, changing gene frequencies in local populations may be considered as microevolution. Traditional evolutionists believe that the same processes have been involved in major transformations over geological time, such as those observed in lineages, lines of descent from a common ancestor (called macroevolution).

The lineage of the horse *Equus* begins with Hyracotherium, a dog-sized mammal with a small head and small low-crowned molars with cusps. The feet, with four toes on each forefoot and three toes on each hind foot, were padded. Hyracotherium was adapted to the forest like environment of the Eocene epoch during the Paleogene period. This small animal could have hidden among the trees for protection, and the low-crowned teeth were appropriate for browsing on leaves. In the Miocene epoch, when grasslands began to replace forests, the ancestors of *Equus* were subjected to selective pressure for the development of strength, intelligence, speed, and durable grinding teeth.

A large size provided the strength needed for combat, a large skull made room for a larger brain, elongated legs ending in a hoof (derived from a single toe) gave speed to escape enemies, and the durable grinding teeth enabled the animals to feed efficiently on grasses.

Does this history show overall trends such as an increase in size, an increase in the grinding surface of the molar teeth, and a reduction in the number of toes? It does only if we pick and choose among the many fossils available. Closer examination reveals that as Hyracotherium evolved into *Equus*, the evolution of every character varied greatly, and there were even times of reversal. If one of the ancestral animals had lived on and *Equus* had become extinct, we no doubt would be discussing a different set of "trends".

Progress Versus Stasis

In the history of life there are a few fossils that can be used to link one major group of organisms to another. But the expression “missing link” points to the fact that few such transitional links have been found. Archaeopteryx, the most famous of these fossils, links reptiles to birds. Other transitional links include the amphibious fish Eustheopteron, the reptile-like amphibian Seymouria, and the mammal like reptiles, or therapsids. To explain the scarcity of transitional links, some paleontologists mention the slim chance of organisms becoming fossils and the subsequent incompleteness of the fossil record.

There are also examples of organisms that are called living fossils because they are so similar to an ancestor known from the fossil record. Recently, investigators found exquisitely preserved specimens of cyanobacteria that have the same sizes, shapes, and organization as living forms. These findings suggest that the cyanobacteria of today have not changed at all in over 3 billion years. Among plants, the dawn redwood was thought to be extinct; then a" living specimen was discovered in a small area of China. Horseshoe crabs, crocodiles, and coelacanth fish are animals that still resemble their earliest ancestors. Pangolins are also called scaly anteaters. A recently found pangolin fossil from the Eocene epoch shows that these animals have changed minimally in 60 million years (Fig. 20.17). A time of limited evolutionary change in a lineage is called stasis.

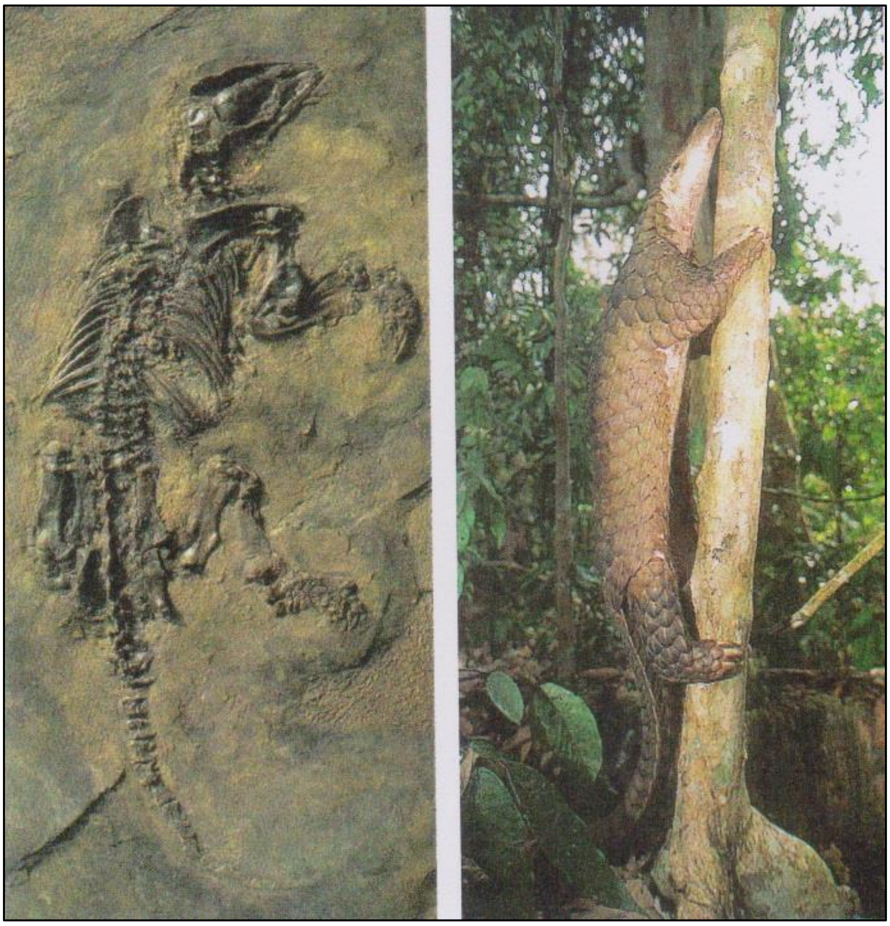


Figure 1.16 Evolutionary stasis

Phyletic Gradualism Versus Punctuated Equilibrium

Evolutionists who support phyletic gradualism [Gk. phyle, tribe] suggest that evolutionary change is rather slow and steady within a lineage after a divergence and is not necessarily dependent upon speciation-that is, the origination of a new species. In other words, fossils of the same species designation can show a trend over time, say from shorter to longer leg length. Indeed, the fossil record, even if complete, is unlikely to indicate when speciation has occurred. A species is defined on the basis of reproductive isolation, and reproductive isolation cannot be detected in the fossil record! Since evolution occurs gradually, the expectation is that more transitional links will eventually be found in the fossil record.

Contrary to this evolutionary model, certain paleontologists Stephen I. Gould, Nile Eldredge, and Steven Stanley in particular-propose that the fossil record demonstrates a model they call punctuated equilibrium stasis, a period of equilibrium, is due to the failure of a lineage to convert variation into the of new species. Living fossils indicate that stasis even for millions of years. In most lineages, however, a period of equilibrium is punctuated, by evolutionary change-that is, speciation occurs. With reference to the length of the fossil record (about 3.5 billion years), speciation occurs relatively rapidly. Therefore, transitional are not likely to become fossils, nor to be found! Indeed, speciation most likely involves only an isolated population at one locale. When a new species evolves and displaces the existing species, then it is likely to show up in the fossil record.

CHAPTER TWO
EVOLUTION OF LIVING ORGANISMS

2.1 The biological basis of change (Evolution of living organism)

Earth is considered the center of all forms of life, there are numerous forms of living organisms inhabiting land, air and water; all that form the Biosphere.

Biosphere: Is the space between the deepest part in the ocean and the highest part on a mountain where life exists.

There are more than a million species of animals that differs in shape and characteristics although they share the same basic characteristics of life. e.g. respiration, movement, growth, reproduction.

There are different theories about the diversity of living organisms:

1. Special creation idea	2. Organic evolution idea
This idea prevailed in the middle ages. **It assumed that:** 1. All living organisms were created from beginning in the same form as they are now. 2. Every species of living organisms on earth is a special creation. 3. Number of species is constant and it does not change.	This idea prevailed in the recent time. **It assumed that:** 1. Each species of living organisms evolved from another early species (ancestor) that was present before and was less complicated in structure. 2. Evolution requires the presence of continuous changes in the form, structure and function of living organisms. 3. These changes are usually slight, but their accumulation leads along the ages to big changes, which in turn lead to the evolution of new species of living organisms. 4. The known species of living organisms did not all appear at the same time, but they appeared gradually until they looked like what it is now.

History of evolution

The idea of evolution is old and it goes back to 2500 years.

Thales: (640: 546 B.C): Stated that all living organisms evolved from water.

Alexmander: (588: 524 B.C): Attributed the origin of life to mixture of water and sun.

Aristotle: (484: 322 B.C): Believed in the change from simple to complex and according to his words (from in complete to the complete).

Ancient Egyptians and Arab: The idea of evolution appeared in their writing. From the Arab Philosophers Ibn Rushed and the Safa brothers.

In the 19th century: With the help of the huge amount of information accumulated as a result of continuous research in biology, the idea of evolution became a scientific theory.

Note that:

1. **Scientific theory**: It is as explanation for certain Phenomena, and it remains acceptable as long as it can explain everything related to these Phenomena, but if it fails to do so, it must be modified or cancelled.
2. **Scientific facts**: Always relative and not absolute, and this is always the nature of science.

Mechanism of evolution

Theories for explaining evolution:

Mechanism of evolution is a study which answers several important questions on evolution…

- How does evolution occur?
- What are the forces that cause evolution?

- What are the factors that affect evolution?

The answer of these questions, put several assumptions and theories to explain evolution, and before dealing with these theories, we must know the difference between evolution and improvement.

Evolution	Improvement
It is a gradual change that continues through a long period of time.	It is a change that makes the organ more able to carry out its function.

Improvement may arise from evolution, but not all evolution is an improvement.

Theories that explain evolution in living organisms

- **[1] Lamarck's theory (1744 - 1829)**
- **[2] Darwin's theory (1809 - 1882)**
- **[3] The modern synthetic theory (Simpson, Julian Huxley and others)**

[1] Lamarck's theory (1744 - 1829)

He believed that the species are not constant, and each species descends from an ancestral species. He established his theory according to:

A. Law of use and disuse

The organs that are used are strengthened, while which are neglected will diminish or disappear.

B. The inheritance of the acquired characters

The acquired change in the organism by the use and disuse of organs is passed (inherited) to the next offspring.

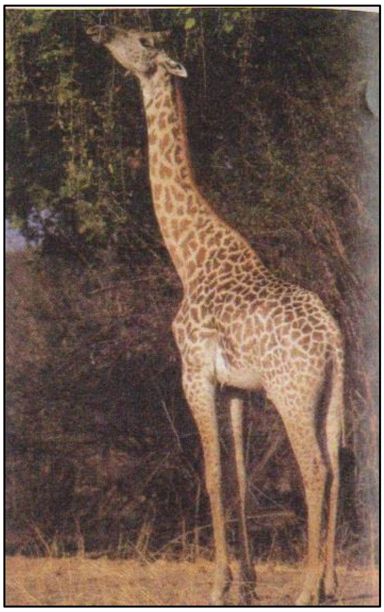
From that, we can deduce that the principle factor that causes evolution according to Lamarck is the change in living organism due to use or disuse of some organs and this change is inherited to the next offspring.

Example:

1. The evolution of the neck of the giraffe:

- Lamarck believed that the early ancestors of the giraffe were short-necked.
- When the grasslands dried up and only tree leaves were available, the short-necked giraffes perished whereas others succeeded in stretching their necks to get leaves from high branches.
- In this way, the giraffe's necks became longer, because of using them and the offspring inherited this character.

2. Disappearance of hind limbs in whales:



- The disappearance of hind limbs in whales was caused by their disuse, and the use of the tail as alocomotory organ for movement in water.

3. Disappearance of limbs in snakes:

- The disappearance of limbs in snakes was due to neglecting using them gradually through generations, because they were forced to escape and hide in narrow holes, where they could only move by creeping.

Criticism of Lamarck's theory

In reality, the acquired characters are not inherited, and there is no scientific support for the inheritance of the acquired characters.

Examples:

- The blacksmith who was well-developed arm muscles does not pass these developed muscles to his children.

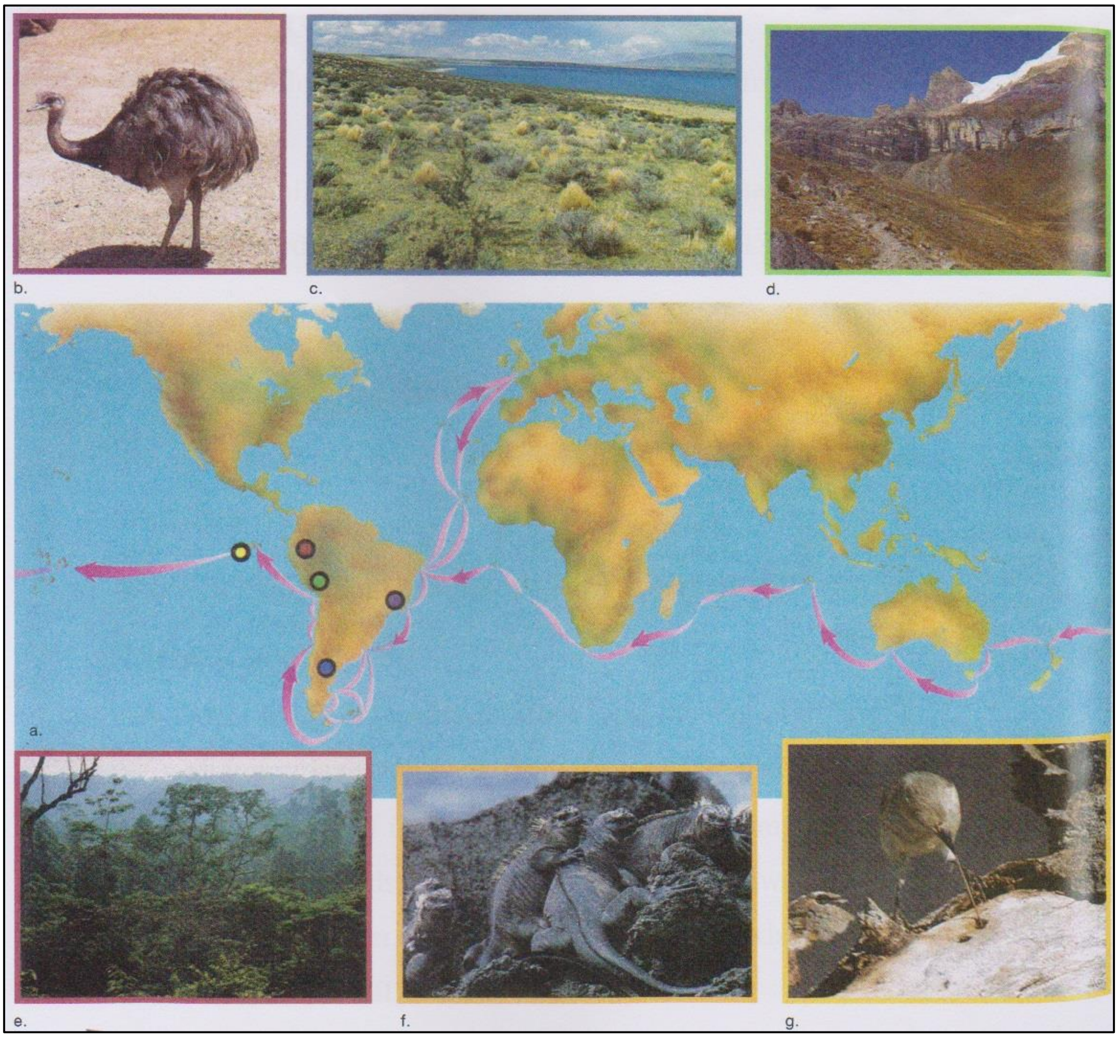
- The runner whose leg muscles are well developed dose not pass this trait to his children.

Scientifically: Traits are inherited through gametes (sperms and ova) and not through somatic cells.

Experimentally: The German scientist Weismann, prove experimentally that acquired characters are not inherited, by cutting rat tails after they were born for 19 generations in each generation every rat was born with a tail.

[2] Darwin's theory (Natural selection theory)

1. Extinction of weak individuals that cannot face environmental conditions, so, they will not inherit their characters to other individuals.
2. Survival of the fittest individuals having characters suitable for the environmental conditions, so, they are able to face these conditions and to pass their traits to their offspring.
3. By continuous selection, new species arise from old ones, and these new species have great adaptability.



Note 1:

- **Charles Robert Darwin (1809 - 1882):**
    - A British scientist, he travelled around the world from the year 1831 to 1836 on the ship Begal.
    - He collected variety of living organisms from Galapagos islands.
    - He published a book called "origin of species" in which he believed that evolution is caused by natural selection.

Note 2:

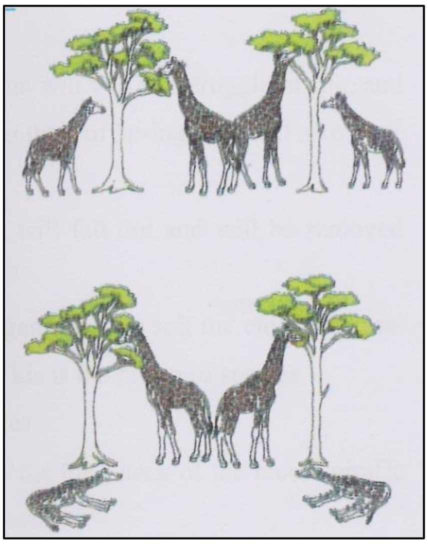
- **Alfred Rossel Wallace:**

He was Darwin's fellow. He presented the ideas of evolution with his fellow Darwin.

Darwin's opinion about evolution depends the following:

1. Great productivity

- Most living organisms produce great number of offspring, if all individuals survived, there would be no place for them.
- The number of individuals of any species remains constant for long periods, due to the competition between them for food and shelter, this is called Struggle for existence.



2. Variation and differences

- No individuals are completely identical, even twins.
- Differences may give some individuals advantages over other individuals in the struggle for existence.
- Only the fittest individuals, which have suitable characters can overcome the environmental conditions and survive. This is called survival for the fittest.

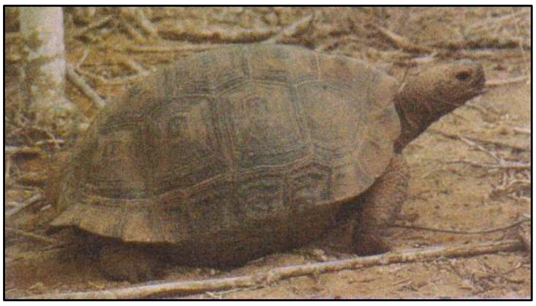
3. Natural selection

- Only the fittest organisms will win the struggle of life, and inherit their characters to their offspring who will also have the chance to survive.
- But the weaker species will fall out and will be removed from this struggle.
- New forms of living organisms that suit the environmental condition are evolved. This is the origin of species.

4. Transformation and changes

- Darwin's explanation of the long neck of the recent giraffe differs from that of Lamarck.

- According to Darwin, the giraffe's long neck evolved by natural selection throughout generations of giraffe's ancestors who were short-necked, but few of them were long necked.
- The long-necked giraffes were able to get the leaves of high trees easily whereas the short-necked died.
- By the repetition of natural selection, the present long-necked species evolved.





Criticism of Darwin's theory

Many objections were raised against Darwin's theory, among these:

1. Most of the changes discussed by Darwin are somatic changes and not hereditary. They are also little changes with little benefit or harm and not enough for the selection for the fittest.
2. The struggle for existence is not general and is not enough to cause the extinction of species, because is an animal feeds on another, the prey will scarce or rare, but it will not disappear completely, so, the predator will look for another prey and the first prey will have the chance to

reproduce and restore its normal levels, this is known as biological equilibrium.

3. The struggle for existence does not explain the sudden disappearance of the giant reptiles (dinosaurs) that were widely spread in the Jurassic period.
4. Darwin's theory does not explain the sudden appearance of some traits, because all the traits were already there, but only the fit ones survived.

[3] The modern synthetic theory (Simpson, Julian Huxley and others)

Reasons that lead to the modern synthetic theory:

- Due to the defects in Lamarckism theory and Darwinism theory, the modern synthetic theory appeared, to correct these defects.

The role of genetics in explaining evolution:

Researches in genetics and exploring more of its secrets played an important role in understanding evolution. The most important are:

- Morgan's and Defraise's researches.
- The discovery of nucleic acids and genetic codes.
- From the scientists who shared in stating the modern synthetic theory, Simpson, J. Huxley.
- This theory was modified afterwards by the new discoveries in biology.

Modern synthetic theory states that:

"There is atendency for the rate of gene distribution to remain constant among individuals of the population from one generation to another". Also: "There is a tendency for the rate of phenotype and genotypes inherited by each gene to remain constant in a population from one generation to another".

Factors that lead to evolution according to the modern synthetic theory:

1. Population genetics [genetic equilibrium – genetic drift].
2. Variation in the individuals of species.
3. Natural selection and adaptation.
4. Isolation and speciation.

1. Population genetics

A population: is a group of individuals of a certain species living in a certain environment and breeding freely.

In any population, the genes of all characters in all individuals are considered as a common source of genes or as a common gene pool.

Two scientists Hardy and Weinberg stated that there is a tendency for the rate of gene distribution to remain constant among individuals of the population from one generation to another.

Also, there is a tendency for the rate of phenotypes and genotypes inherited by each gene to remain constant in a population from one gene to another.

This means that there is aa tendency towards a state of genetic equilibrium in the population that keeps its existence and genetic characteristics constant.

Conditions that keep the genetic equilibrium in the population:

1. The population must be large in size in which all genotypes and phenotypes are represented.
2. Individuals in the population should mate randomly without any interference.
3. The hereditary traits should not be subjected to natural selection.

4. Individuals should not emigrate from the population or immigrate to it.
5. Mutation should not occur.

If one of these conditions is not fulfilled, the equilibrium of the population which be distributed and genetic drift takes place.

Genetic drift: Is a disturbance in the genetic equilibrium of the population which causes the evolution of the population.

2. Variation in the individuals of species.

Reasons of variation:

- **a.** Mating between individuals of different genotypes may lead to the appearance of new phenotypes.
- **b.** The large number of hereditary characters in the species make individuals different from each other.
- **c.** The way genes interact together when meet may affect the phenotypes.
- **d.** Chromosomal abnormalities such as deletion, addition, duplication… etc.
- **e.** Crossing over during meiosis.
- **f.** The effect of environmental factors.
- **g.** Gene mutations.

The importance of variation:

- Variation enables some individuals to adapt with different environmental conditions, because variation makes some individuals capable of living in such conditions.
- So, variation is essential for the occurrence of change.

3. Natural selection and adaptation.

Natural selection:

- In Darwinism, the struggle for existence and survival of the fittest are key words, so, natural selection is connected with bloody aggression between living organisms.
- This concept is wrong and natural selection according to modern synthetic theory is summarized as follows:
- The fittest organisms are those who:
    a. Can obtain their food.
    b. Protect their children.
    c. Raise their children until they grow mature and become capable of reproduction.

Natural selection: The selection of individuals with suitable traits for success in life and accumulation of these traits leads to adaptation of living organisms to live in special environments.

Natural selection occurs by several ways:

1. Natural environmental conditions [temp., light, …].
2. The living components of the environment [other organisms living in the environment].

Examples:

1. Biston betularia butterfly:

- The scientist Kettle Well is the first who introduced the scientific explanation for such phenomenon.
- These butterflies are mainly light coloured, but there is a black strain that is evolved by a dominant mutation.

- They are active at night, but they rest during the day on the tree trunks covered with lichens.

Lichens: A layer of algae and fungi live together in mutual relationship.

In Manchester city in England	
Before industrial revolution	**After industrial revolution**
• The light coloured butterflies were safe because they cannot be seen by their enemies while resting on tree trunks, so the natural selection was in favor of light coloured butterflies and against the black ones which could be seen easily by their enemies, so they were rarely found.	• The black coloured butterflies increased in numbers in the industrial areas, because the tree trunks became covered with soot (carbon) and all lichens died, so, the natural selection became in favor of black coloured butterflies which could not be seen by their enemies while resting on tree trunks.

2. Capaea nemoralis snails:

- These snails are characterized by different colours and lines inherited by many genes.
- Some of them where abundant, while others were rare.
- The abundant group resembles the environment in colour, so, it is not seen by its enemies.
- But the rare group does not have this advantage, so, they are easily picked by their enemies.

4. Isolation and speciation (Species formation)

There are two types of speciation:

a. Anagenic speciation	b. Phyletic speciation
• The individuals inside the population live together without spreading. • They are exposed to small mutations and small variations at successive generations.	• On which small group of individuals leave the original population and spread in different directions either by emigration or other means. • These small groups become isolated leading eventually to the appearance of new adapted species to the conditions of its new environment.

• These variations are naturally selected and the suitable characters will pass to the next generation. • The accumulation of these characters leads to *appearance of new species*.	• The best example for divergent evolution is: Darwin is finches in Galapagos islands which started as one species and the diverged and developed into 14 species.

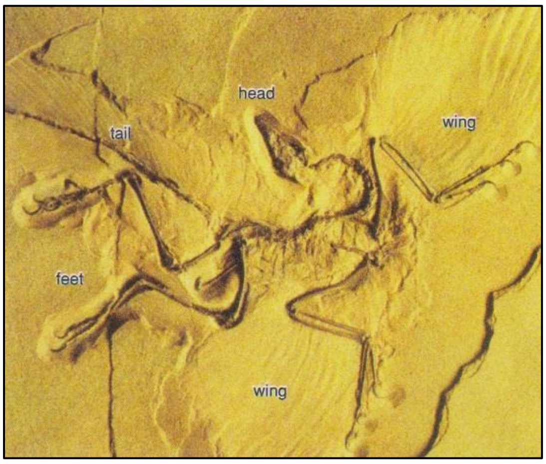
Critical thinking question:

Some monarch butterflies contain chemicals that are toxic to birds. Another species of butterflies, the viceroy, has some protection from predation, because it closely resembles the monarch. What pattern of evolution is illustrated by this example?

Evidences that support evolution

Evidences that support evolution are:

1. Fossils.
2. Taxonomy and evolution.
3. Comparative anatomy.
4. Vestigial structures.
5. Physiological resemblance.
6. Embryology.
7. Geological and geographical distribution.



1. Fossils and evolution

Fossils: Are remains or traces of living organisms that lived in old ages and after their death, they were buried in sedimentary rocks.

N.B.: The fossils are evidences for the early presence of living organisms.

The conditions are fossil formation are:

- **a.** The living organisms must have a hard skeleton.
- **b.** The organisms must be buried in sediments soon after death to be protected from decay.
- **c.** Mineral replacement of petrifaction in which the organic parts of the body are replaced by mineral substances.

Kinds of fossils

- Fossils of the entire organism
- Fossils of the hard part of the organism
- The petrified remains
- Moulds and casts
- The prints of living organisms

A. Fossils of the entire organism

In which the whole organism is preserved with all its parts.

Example:

The mammoth, which is an extinct kind of elephants, used to live in north Europe during the late geological epochs and died out completely, but some of them were buried in the snow in north Russia, and the snow preserved them.

B. Fossils of the hard part of the organism

The fossils may be a hard part of the animal such as:

- Bones, teeth of vertebrates.
- Shells of molluscs.

- In this case, the organic substances decay and the hard parts remain with their original structure.

C. The petrified remains

Petrifaction: Is the transformation of the solid organic parts of the living organism into mineral substances keeping all the details of the living organisms without change.

Example:

Petrified forests in El-Mokattam hills in Cairo and on both sides of Cairo-Suez road.

Where the plant fibers are replaced by silica, so, the original shape of the tree is preserved.

D. Moulds and casts

Moulds	Casts
• A solid rocky mould shows the internal details of the organisms after its death. **How it is formed:** • When a mollusc with hard shell dies, it falls to the bottom of the sea and is buried in sand (sediments). • The sediments fill the cavity of the mollusc, then stick together and change into rocks. • The hard shell dissalue.	• It is the mark left by the body of the organism when it touches the soft sediment, after death, without making a deep hole. • When a leaf falls on a muddy surface it disintegrates, leaving a mark of its body.

E. The prints of living organisms

F. Are marks left by the organism in the soft sediments, when it was alive.

G. When animals left their foot-prints in soft sedimentary rocks when they walked on them and when the rocks solidified, the prints remained.

The fossil records:

- Scientists found many fossils in different layers of sedimentary rocks, which represent records for the ancient life history.
- The fossil record represents the most important evidence for the occurrence of changes in living organisms.

Geologists observed from studying fossil record that:

1. Deep layers: contain fossils of simple organisms.
2. Surface layers: contain fossils of higher organisms.
3. The very ancient lower layers: contain no fossils at all.

From the study of the fossil record, it was concluded that:

1. Life started in water and gradually moved to the earth.
2. The evolution of life moved in the direction of increasing specialization and complexity in structure and function of organs.

Examples:

- The plant fossils indicate that algae appeared before mosses and ferns, and the gymnosperms came before angiosperms.

  In animal kingdom:
- The invertebrates appeared before vertebrates.
- The fishes are the first group of vertebrates that appeared in form of shield fish (placoderm fish).
- Fish are followed by amphibians then huge reptiles (dinosaurs) which evolved into birds and mammals.

Importance of fossils

a. To show the succession of life forms through the life Epochs., i.e., they are used as tools to identify and compare between different layers of sedimentary rocks.

b. Fossils can also be used as intermediate links to emphasize the relationship between two different groups of animals or plants.

Example:

- The fossil of archaeopteryx represents an intermediate link between reptiles and birds, because it has the characters of both.
- It has teeth, long tail and claws (protruding in its wings) as reptiles.
- It has feathers, beak, wings and skull shape as birds.

2. Taxonomy and evolution

- In both plant and animal kingdoms, there is a clear gradation through different phyla from the simple to the complicated organisms, and also a gradual increase in development from one class to another, so, the classification of each kingdom could be represented by a tree with many branches, its origin is the unicellular algae in case of plants and protozoa in case of animals.
- Different phyla occupy the branches of the tree.
- The flowering plants occupy the top of the plant kingdom and mammals occupy the top of the animal kingdom because of being the most advanced organisms in both plant and animal kingdom.
- The gradation of development in the tree of life shows the idea of evolution that different species and genera of each family have a common origin, this explain the reason of putting two completely different vertebrate animals in one group.
- Classification of animals and plants led to discovery of gaps in the gradation from one class to another, which may indicate the absence of the relationship between them.
- Some gaps were filled by extinct or contemporary species that have the characters of two successive classes in the tree of life.

- These species know as intermediate links.

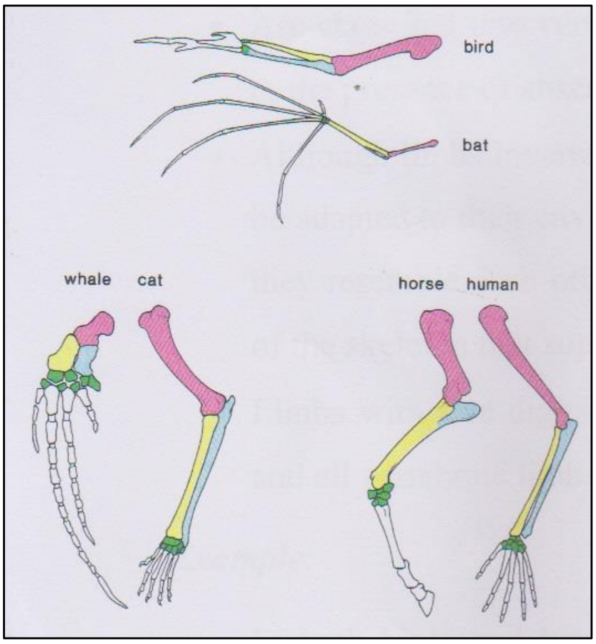
Intermediate link: Is a contemporary or extinct species of living organism that has the characters of two successive classes of living organisms and fill the gap between them in the tree of life.

Example: Lung fish, Archaeopteryx

- The lung fish is an intermediate link between fish and amphibians, because they respire look like a lung that gets oxygen from atmosphere.
- Archaeopteryx fills the gap between reptiles and birds.

3. The comparative anatomy and evolution

Animals are classified according to the resemblance and differences between them.



Multicellular animals:

- Are classified into vertebrates and invertebrates according to the presence or absence of vertebral column.

- Although limbs invertebrates differ in their morphology to be adapted to their environment and the way of movement, they resemble each other very much in the basic structure of the skeleton that support them.
- Limbs with five digits (pentadactyl limbs) originated first and all vertebrate limbs developed from it.

Example:

- In both birds and bats, the fore limbs are modified into wings to suite its function.
- In hoofed animals, the digits are reduced to one.
- In whale and dolphin, the bones of the fore limbs are shortened and fused to form an oar.

4. The vestigial structure and evolution

Vestigial structure: Some organs that used to carry out their functions in the old ancestors, become useless so, they diminished or disappeared.

Examples:

- The appendix is reduced in size in man, large in herbivores (e.g. rabbit) and missing in carnivores.
  - It is believed that was developed in ancient man who used to feed on plants, where the appendix used to participate in the digestion of cellulose.
- Scale leaves in the parasitic and some xerophytic (desert) plants, which are thought to be traces of green leaves that were carried by old plants and lost its original function due to the change in the conditions of the plant (from humid to dry conditions) and the way it lives.

- Vascular tissues in aquatic plants: reduced due to the loss of its function.
    - All vestigial structures had some importance for the old organisms, and due to evolution, they lost their function for the contemporary organisms.

5. The physiological resemblance and evolution

Physiology:

- The study of how living organisms performing their biological activities.
- Living organisms resemble each other in some biological function.

Example:

a. All living organisms are made up of protoplasm where all anabolic and catabolic processes take place in identical manner in all cells of all living forms.

b. The cell division follows the same steps in all living organisms, that it occurs under control of nucleus which contains genetic material composed of similar nucleic acids (DNA or RNA).

c. Getting rid of nitrogenous waste is the same in vertebrates, although they may differ in details according to the environment.

Examples:

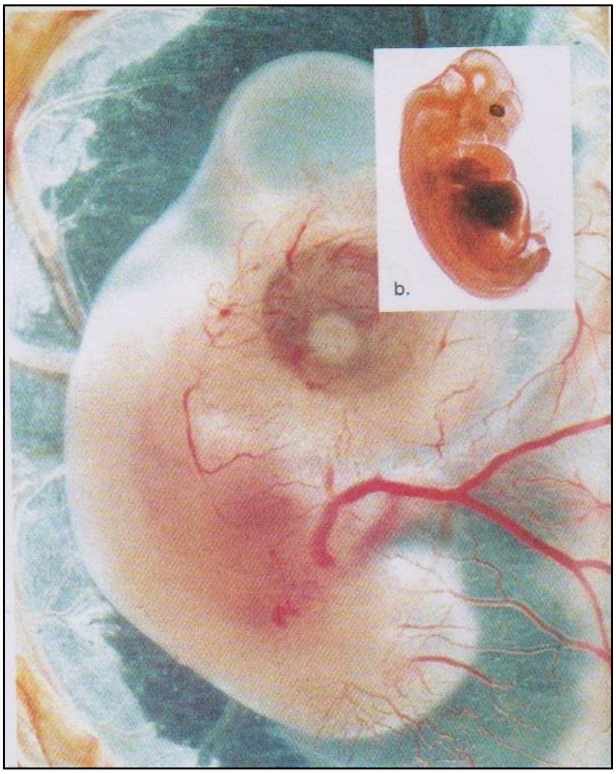
Fish and aquatic animals	Terrestrial vertebrates	Birds, reptiles and insects
• Get rid their waste in the form of ammonia (NH_3) through their gills. • Ammonia is quick soluble in water surrounding the fish.	• Frogs, mammals ammonia is converted into less toxic compound called urea which dissolved in water and execrated in the urine.	• Get rid of their wastes in the form or uric acid which is insoluble in water and is excreted together with feaces in a crystalline form, so the animal does not lose much of its water.

Note:

Tadpole larva gets rid of nitrogenous waste in the form of ammonia and when it develops into a frog, its urine contains urea.

6. Embryology and evolution

- All animals and plants start their lives from a single cell the zygote that grows, divides and differentiates into tissues and organs.



It was observed that:

a. The embryos of different animals resemble each other very much in their early embryonic stages.

b. The embryos of all metazoan (multicellular or higher animals) pass through a stage formed of two layers of cells, then a stage of three layers.

c. The embryos of certain vertebrates (fish, frogs, reptiles, birds and mammals) pass through a stage where the auricle and one ventricle as in adult fish.

- Later, the gills disappear (except in fish) and the heart becomes two auricles and two ventricles (in birds and mammals).
- This is also true or applied for the growth of the brain and the organs of excretion, reproduction and skull bones.

7. The geological (geographical) distribution and evolution

The distribution of any group of living organisms depends on:

- Its ability to face climate (heat, wind, rain…).
- Its ability to face the geographic barriers (seas, oceans, mountains, deserts…).
- Competing with the other living organisms.
- All that lead to natural selection and adaptation of the organisms to many factors, i.e. the evolution of the organisms.

Examples: which explain the difference and resemblance between organisms living in different environments:

1. Animals of south America (toothless mammals, vampire bats) are different from those of Africa (giraffes, zebras) despite the resemblance in the climate of both areas due to the evolution of the animals of each area in dependently since the ancient separation of the two continents and the presence of natural barriers (the ocean) between them.

2. The animals of British Islands (England) resemble those of Europe, although they are separated, because the separation of Europe is relatively recent relative the earth's age.

CHAPTER THREE
PROCESS OF EVOLUTION

3.1 Evolution in a Genetic Context

What Cases Variations?

The members of a population vary from one another. A population is all the members of the single species occupying a particular area at the same time. A population could be all the green frogs in a frog pond, all the field mice in a barn, or all the English daisies on a hill. The members of a population reproduce with one another to produce the next generation.

Variations, the raw material for evolutionary change, arise in a population by gene mutations, chromosomal mutations, and recombination.

Gene Mutations

Gene mutations provide new alleles, and therefore they are the ultimate source of variation. A gene mutation is an alteration in the DNA nucleotide base sequence of an allele. we have seen that a change in a single DNA base spells the difference between a normal hemoglobin molecule and sickle-cell hemoglobin Also, a change in a regulatory gene can increase or decrease the expression of a structural gene.

Mutations occur at random. A mutation is like a shot in the dark; any particular gene can mutate at any particular time. This means that the occurrence of a mutation is not tied to its adaptive value, and the chance of a particular mutation is not expected to increase because the mutation is beneficial to the organism. For example, you might think that it is exposure to a drug that causes bacteria to become resistant. However, drug-resistant mutations can occur in bacteria by chance, before they are exposed to the drug.

Rather than being beneficial, a mutation can be neutral in its effect or even harmful to an organism in its present environment. Many times, observed mutations seem harmful, such as those that cause human genetic disease. This may be because members of a population are so adapted to their present environment that only nonbeneficial changes are possible. As discussed later, however, some mutations may remain hidden in a diploid organism to become an important source of variation should the environment change. Or the same mutations may arise again when conditions have changed and they are now favorable mutations.

Chromosomal Mutations

Some chromosomal mutations are simply an alteration in the number of chromosomes inherited. Polyploid plants have more than two sets of chromosomes.

Other chromosomal mutations are an alteration in the arrangement of the alleles on the chromosomes. Inversions (a segment of chromosome is inverted) and translocations (exchange of chromosomal segments between nonhomologous chromosomes) can result in altered allelic activity if the allele thereby comes under the control of a different regulatory gene. Duplication of an allele followed by a change in base sequence of one copy introduces a new allele While still retaining the old allele in the human genome. The best studied example of such an event Concerns the globin alleles that occur at different loci but have similar DNA sequences. Adult hemoglobin contains two chains of α (alpha) globin and two chains of β (beta) globin. Besides the ones found in hemoglobin, humans have several other versions of both globin alleles. Most of these versions are expressed only during development, but some are expressed in adults.

Recombination

In sexually reproducing organisms, recombination of alleles and chromosomes is an important source of variation. During meiosis, crossing-over between non-sister chromatids and an independent assortment of chromosomes produce unlike gametes. During fertilization, random gamete union occurs, and this also contributes to a genotype that is unlike those of the parents. Altogether, each population has a storehouse of allelic and chromosomal combinations that potentially exceeds the number of individuals in the population.

The entire genotype, and not individual alleles, is subjected to the natural selection process. A new and different combination of alleles may therefore have great selective value. In a population of snails, stripes and brown color combined might make animals less visible in a woodland habitat. If stripes are controlled by one allele and brown color is controlled by another allele, it is a combination of the two alleles that will be selected for. Recombination may at some time bring the two alleles together so that the combined phenotype can be subjected to natural selection.

Along the same line, consider that many traits having to do with structure, function, and behavior are polygenic. Polygenic traits are controlled by more than one gene, each of which exists at a different locus. Certain combinations of the several alleles might be more adaptive than others in a particular environment. The most favorable combination might not occur until just the right alleles are grouped by recombination. Once the improbable but most favorable phenotype occurs, it can become the prevalent phenotype in the population because of a selection process.

How to Detect Evolution

Not only are variation created, they are also preserved and passed on from one generation to the next. The various alleles at all the gene loci in all individuals make up the gene pool of the population. It is customary to describe the gene pool of a population in terms of gene frequencies. Suppose that in a Drosophila population, one-fourth of the flies are homozygous dominant for long wings, one-half are heterozygous, and one fourth are homozygous recessive for short wings. Therefore/in a population of 100 individuals, we have:

25 *LL*, 50 *Ll*, and 25 *ll*

What is the number of the allele *L* and the allele *l* in the population?

Number of L alleles:	Number of l alleles:
LL **(2 *L* x 25) = 50**	***LL*** **(0 *l*) = 0**
Ll **(1 *L* x 50) = 50**	***Ll*** **(1 *l* x 50) = 50**
Ll **(o *L*) = 0**	***Ll*** **(2 *l* x 25) = 50**
100 *L*	**100 *l***

To determine the frequency of each allele, calculate its percentage from the total number of alleles in the population; in each case, 100/200 = 50% = 0.5. The sperm and eggs produced by this population will also contain these alleles in these frequencies. Assuming random mating (all possible gametes have an equal chance to combine with other), we can calculate the ratio of genotypes in the next generation by using a Punnett square.

There is an important difference between the Punnett square below and one used for a cross between individuals; below the sperm and eggs are those produced by the members of a population—not those produced by a single male and female. As you can see, the results of the Punnett square indicate that the frequency for each allele in the next generation is still 0.5.

Therefore, sexual reproduction alone cannot bring about a change in allele frequencies. Also, the dominant allele need not increase from one generation to the next. Dominance does not cause an allele to become a common allele. The potential constancy, or equilibrium state, of gene pool frequencies was independently recognized in 1908 by G. H. Hardy, an English mathematician, and W. Weinberg, a German physician. They used the binomial expression ($p^2 + 2pq + q^2$) to calculate the genotypic and allele frequencies of a population.

The Hardy-Weinberg law states that an equilibrium of allele frequencies in a gene pool, calculated by using the expression $p^2 + 2pq + q^2$, will remain in effect in each succeeding generation of a sexually reproducing population as long as five conditions are met.

1. No mutations: allelic changes do not occur, or changes in one direction are balanced by changes in the opposite direction.
2. No gene flow: migration of alleles into or out of the population does not occur.
3. Random mating: individuals pair by chance and not according to their genotypes or phenotypes.
4. No genetic drift: the population is very large, and changes in allele frequencies due to chance alone are insignificant.
5. No selection: no selective force favors one genotype over another.

In real life, these conditions are rarely, if ever, met, and allele frequencies in the gene pool of a population do change from one generation to the next. Therefore, evolution has occurred. The significance of the Hardy-Weinberg law is that it tells us what factors cause evolution—those that violate the conditions listed. Evolution can be detected by noting any deviation from a Hardy Weinberg equilibrium of allele frequencies in the gene pool of a population.

The accumulation of small changes in the gene pool over a relatively short period of two or more generations is called microevolution. Microevolution is involved in the origin of species to be discussed later in this chapter, as well as in the history of life recorded in the fossil record.

A change in allele frequencies results in a change in phenotype frequencies. In Figure 3.1, the original peppered moth population has only 10% dark-colored moths. When dark-colored moths rest on light trunks, they are seen and eaten by predatory birds. With the advent of pollution, the trunks of trees darken and it is the light-colored moths that stand out and are eaten. The birds are acting as a selective agent, and microevolution occurs; the last generation observed has 80% dark-colored moths.

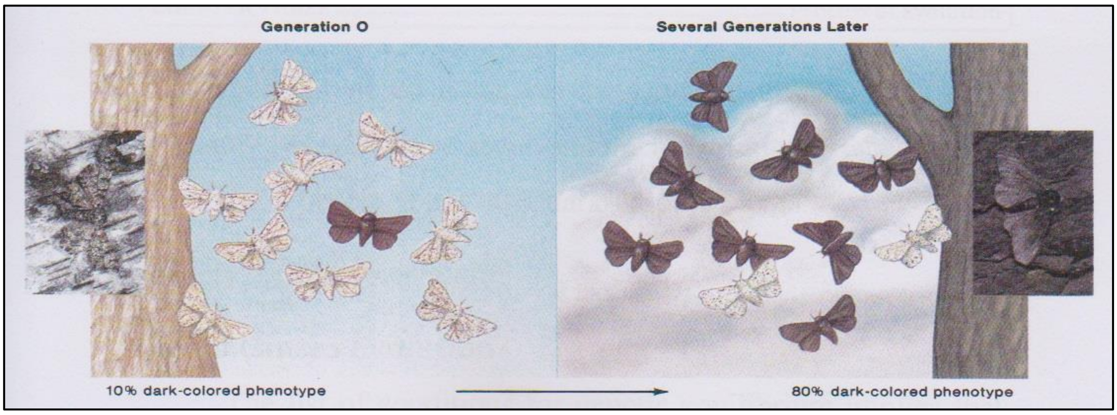


Figure 3.1: Microevolution

What Causes Evolution?

The list of conditions for genetic equilibrium implies that the opposite conditions can cause evolutionary change. The conditions that can cause a deviation from the Hardy-Weinberg equilibrium are mutation, gene flow, nonrandom mating, genetic drift, and natural selection. Only natural selection results in adaptation to the environment.

Genes Mutate

As mentioned, mutations provide new alleles which are the raw material for evolutionary change. Mutations underlie all the other mechanisms that provide variation. Due to elaborate DNA replication and DNA repair mechanisms, the mutation rates of individual genes are low (about 10^{-5} per gene per cell cycle), but each organism has many genes, and a population has many individuals. Therefore, per individual and per population, mutations are common, not rare, events, as we can see from the following calculations:

For an individual human: Since there are about 100,000 genes (200,000 alleles) in humans, the average mutation rate per human gamete is (2×10^5 alleles) x (10^{-5} mutation per gene) = 2 mutations per human gamete.

For a human population: Since there are about 252 million people in the United States, the mutation rate per generation is (2.5×10^8 individuals) x (2 mutations per gamete) = 5×10^8 new mutations in each generation.

Therefore, even a modest mutation rate produces a tremendous amount of genetic variation in a population.

In 1966, R. C. Lewontin and I. L. Hubby set out to determine the molecular polymorphism (variation) of 18 different enzymes in natural populations of Drosophila pseudoobscura. They extracted various enzymes and subjected them to electrophoresis, a process that separates proteins according to size and charge. They concluded that a fly population is polymorphic at no less than 30% of all its gene loci, and that an individual fly is likely to be heterozygous at about 12% of its loci.

Similar results have been found in studies on many species, demonstrating that high levels of molecular variation are the rule in natural populations. Many of these mutations will not affect the phenotype, and therefore they may not be detected. In a changing environment, even a seemingly harmful mutation can be a source of variation that can help a population become adapted to a new environment. For example, the water flea Daphnia ordinarily thrives at temperatures around 20°C, but there is a mutation that requires Daphnia to live at temperatures between 25°C and 30°C. The adaptive value of this mutation is entirely dependent on environmental conditions.

Gene Flow Brings New Genes

Gene flow, also called gene migration, is the movement of alleles among populations by the migration of breeding individuals. There can be constant gene flow between adjacent animal populations due to the migration of organisms. In order to judge the effect of gene flow, it is necessary to know the difference in gene frequencies between the two populations and the proportion of migrant genes that are introduced.

Gene flow can increase the variation within a population by introducing novel alleles that were produced by mutation in some other population. Continued gene flow among populations makes their gene pools similar and re duces the possibility of allele frequency differences among populations that might be due to natural selection and genetic drift. indeed, gene flow among populations can prevent speciation from occurring.

Mating Is Not Always Random

Random mating occurs when individuals pair by chance arid not according to their genotypes or phenotypes. Inbreeding, or mating between relatives to a greater extent than by chance, is an example of nonrandom mating. This can happen if dispersal is so low-that mates are likely to be related. Inbreeding does not change allele frequencies, but it does decrease the proportion of heterozygotes and increase the proportions of both homozygotes at all gene loci. In a human population, inbreeding increases the frequency of recessive abnormalities in the phenotype.

Assortative mating occurs when individuals tend to mate with those that have the same phenotype with respect to some characteristic. For example, in humans, tall people seem to prefer to mate with each other. Assortative mating causes the population to subdivide into two phenotypic classes, between which there is reduced gene exchange. Homozygotes for the gene loci that control the trait in question increase in frequency, and heterozygotes for these loci decrease in frequency. Other loci remain in Hardy-Weinberg equilibrium, except for those very closely linked to the loci governing the trait.

Genetic Drift Promotes Changes

Genetic drift refers to changes in allele frequencies of a gene pool due to chance. Although genetic drift occurs in both large and small populations, a larger population is expected to suffer less of a sampling error than a smaller population. Suppose you had a large bag containing 1,000 green balls and 1,000 blue balls, and you randomly drew 10%, or 200, of the balls. Because there is. a large number of balls of each color in the bag, you can reasonably expect to draw 100 green balls and 100 blue balls or at least a ratio close to this. But suppose you had a bag Containing only 10 green balls and 10 blue balls and you drew 10%, or only 2 balls. The chances of drawing one green ball and one blue ball with a single trial are now considerably less.

When a population is small, there is a greater chance that some rare genotype might not participate at all in the production of the next generation. Suppose there is a small population of frogs in which certain frogs for one reason or another do not pass on their traits. Certainly, the next generation will have a change in allele frequencies. When genetic drift leads to a loss of one or more alleles, other alleles over time become fixed in the population (Fig. 3.4).

In an experiment with 107 Drosophila populations, each population was in its own culture bottle. Every bottle contained eight heterozygous flies of each sex. There were no homozygous recessive or homozygous dominant flies. From the many offspring, the experimenter chose at random eight males and eight females. These were the parents for the next generation, and so forth for 19 generations. For the first few generations, most populations still contained many heterozygotes. But by the nineteenth generation, 25% of the populations contained only homozygous recessive flies and 25% contained only homozygous dominant flies for a brown-eyed allele.

Genetic drift is a random process, and therefore it is not likely to produce the same results in several populations. The Drosophila experiment considered only one allelic pair, but If many pairs had been considered, it is expected that each 0f the 107 populations would have a different gene pool composition for many allelic pairs after 19 generations. In California, there are a number of cypress groves, each a separate population. The phenotypes within each grove are more similar to one another than they are to the phenotypes in the other groves. Some groves have longitudinally shaped trees, and others have pyramidally shaped trees. The bark is rough in some colonies and smooth in others. The leaves are gray to bright green or bluish, and the cones are small or large. Because the environmental conditions are similar for all groves, and no correlation has been found between phenotype and environment across groves, it is hypothesized that these variations among populations are due to genetic drift.

Founder Effect The founder effect is an example of genetic drift in which rare alleles, or combinations of alleles, occur at a higher frequency in a population isolated from the general population. After all, founding individuals contain only a fraction of the total genetic diversity of the original gene pool. Which particular alleles are carried by the founders is dictated by chance alone. The Amish of Lancaster County, Pennsylvania, are an isolated group that was begun by German founders. Today, as many as one in 14 individuals carries a recessive allele that causes an unusual form of dwarfism (affecting only lower arms and legs) and polydactylism (extra fingers). In the population at large, only one in 1,000 individuals has this allele.

All the Amish with this genetic syndrome can trace their ancestry to a single couple (the Kings) who immigrated to Pennsylvania in 1744. They and their offspring had large families, and therefore the rare allele became concentrated in the population.

The large genetic similarity found in Cheetahs is believed to be due to a bottleneck. In a study of 47 different enzymes, each of which can come in several different forms, all the cheetahs had exactly the same form. This demonstrates that genetic drift can cause certain alleles to be lost from a population. Exactly that caused the cheetah bottleneck is not known. It is speculated that perhaps cheetahs were slaughtered by nineteenth-century cattle farmers protecting their herds, or were captured by Egyptians as pets 4,000 years ago, or were decimated by mass extinction tens of thousands of years ago. Today, Cheetahs suffer from relative infertility because of the intense inbreeding that occurred after the bottleneck.

3.2 Adaptation Occurs Naturally

Natural selection is the process by which populations become adapted to their biotic and abiotic environments. The biotic environment includes organisms that seek resources through competition, predation, and parasitism. The abiotic environment includes weather conditions dependent chiefly upon temperatures and precipitation. In the previous century, Charles Darwin, the father of evolution, became convinced that species evolve (change) with time and suggested that natural selection was the process by which they become adapted to their environment. Here, we restate Darwin's hypothesis of natural selection in the context of modern evolutionary theory.

Evolution natural selection requires:

1. Variation. The members of a population differ from one another.
2. Inheritance. Many of these differences are heritable genetic.
3. Differential adaptedness. Some of these differences affect how well ab organism is adapted to its environment.
4. Differential reproduction. Individuals that are better adapted to their environment are more likely to reproduce, and their fertile offspring will make up a greater proportion of the next generation.

As mentioned previously, random gene mutations are the ultimate source of variation because they provide new alleles. However, in sexually reproducing organisms, recombination of alleles and chromosomes—due to crossing-over during meiosis, independent assortment of chromosomes, and fertilization—contributes greatly to variation. Recombination may at some time produce a more favorable combination of alleles. After all, it is the combined phenotype that is subjected to natural selection.

Fitness

Fitness is the extent to which the traits of an individual allow it to enjoy reproductive success and contributes fertile offspring to the next generation. Selection, which can be described as a composite of the forces that limit reproductive success of an individual, opposes fitness. Fitness is a consequence of adaptation to a particular environment and therefore can vary according to the environment in which individual lives. That is, the same individual can have a different degree of fitness in different environments. Fitness is relative; it is measured against the reproductive success of other individuals in the same environment. The more fit an individual, the greater is the genetic contribution of that individual to subsequent generations compared to other members of the same population.

Types of Selection

Most of the traits on which natural selection acts are polygenic and controlled by more than one pair of alleles located at different gene loci. Such traits have a range of phenotypes, the frequency distribution of which usually resembles a bell-shaped curve.

Three types of natural selection have been described for any particular trait. They are directional selection, stabilizing selection, and disruptive selection.

Directional Selection

Directional selection occurs when an extreme phenotype is favored and the distribution curve shifts in that direction. Such a shift can occur when a population is adapting to a changing environment. For example, the gradual increase in the size of the modern horse, Equus, can be correlated with a change in the environment from forest like conditions to grassland conditions. Nevertheless, the evolution of the horse should not be viewed as a straight line of descent; we know of many side branches that became extinct.

Industrial Melanism Before the Industrial Revolution in England, collectors of the peppered moth (Biston betularia) noted that most moths were light colored, although occasignally a dark-colored (melanistic) moth was captured. Several-decades after' the Industrial Revolution, however, black moths made up 99% of the moth population in air-polluted areas.

An experiment by H.B.D. Kettlewell of Oxford university showed that when their coloring matches the trees, moths are more likely to avoid being eaten by predatory birds, which act as a selective agent. Moths rest on the trunks of trees during the day; if they are seen, they are eaten by birds. As long as the trees in the environment are light in color, the light-colored moths live to reproduce. But when the trees turn black from industrial pollution, the dark-colored moths survive and reproduce to a greater extent than the light—colored moths. The dark-colored phenotype, then, becomes more prevalent in the population. Thereafter, when pollution is reduced and the trunks of the trees regain their normal color, the light-colored moths increase in number.

Bacteria and Insects indiscriminate use of antibiotics and pesticides results in populations of bacteria and insects that are resistant to these chemicals. The mutation that permits resistance is already present before exposure; the chemicals are merely acting as a selective agent. Those organisms that survive exposure have offspring that are resistant, and in this way the population becomes resistant.

Another example of directional selection is the human struggle against malaria, a disease caused by an infection of the liver and the red blood cells. The Anopheles mosquito transmits the disease-causing protozoan Plasmodium vivax from person to person. In the early 1960s, international health authorities thought that malaria would soon be eradicated. A new drug, chloroquine, was more effective than the quinine that had been used against. Plasmodium, and DDT (an insecticide) spraying had reduced the mosquito population. But in the mid-19605, Plasmodium showed signs 0f chloroquine resistance and, worse yet, mosquitoes were becoming resistant to DDT. A few drug-resistant parasites and a few DDT-resistant mosquitoes had survived and multiplied, making the fight against malaria more difficult than ever. Thus, another avenue has now been taken—a vaccine against malaria is being developed.

Stabilizing Selection

Stabilizing selection occurs when an intermediate phenotype is favored. It can improve adaptation of the population to those aspects of the environment that remain constant. With stabilizing selection, extreme phenotypes, and individuals near the average are favored. As an example, consider the birth weight of human infants, which ranges from 0.89 to 4.9 kg (2 to 10.8 lb). The death rate is higher for infants who are at these extremes and is lowest for babies who have an intermediate birth weight (about 3.2 kg or 7 lb). Most babies have a birth weight within this range, which gives the best chance of survival. Similar. results have been found in other animals, also.

Disruptive Selection

In disruptive selection, two or more extreme phenotypes are favored over intermediate phenotype. For example, British land snails (Cepaea nemomlis) have a wide habitat range that includes low-vegetation areas (grass fields and hedgerows) and forest areas. In low-vegetation areas, thrushes feed mainly on snails with dark shells that lack light bands, and in forest areas, they feed mainly on snails with light-banded shells. Therefore, these two distinctly different phenotypes are found in the population.

Variations Are Maintained

A population always shows some genotypic variation. The maintenance of variation is beneficial because populations that lack variation may not be able to adapt to new conditions and may become extinct. How can variation be maintained in spite of selection constantly working to reduce it?

First, we must remember that the forces that promote variation are still at work: mutation still creates new alleles, and recombination-still recombines these alleles during gametogenesis and fertilization. Second, gene flow might still occur. If the receiving population is small and is mostly homozygous, gene flow can be a significant source of new alleles. Finally, we have seen that natural selection reduces, but. does not eliminate, the range of phenotypes. And disruptive selection even promotes polymorphism in a p0pulation. There are also other ways variation is maintained.

Diploidy and the Heterozygote

Only alleles that are exposed (cause a phenotypic difference) are subject to natural selection. In diploid organisms, this makes the heterozygote a potential protector of recessive alleles that otherwise would be weeded out of the gene pool.

Notice that even when selection reduces the recessive a1lele from a frequency of 0.9 to 0.1, the frequency of the heterozygote remains the same. The heterozygote remains a source of the recessive allele for future generations. In a changing environment, the recessive allele may then be favored by natural selection.

Sickle-Cell Disease

In certain regions of Africa, the importance of the heterozygote in maintaining variation is exemplified by sickle-cell disease. The relative fitness of the heterozygote and the two homozygotes will determine their percentages in the population. When the ratio of two or more phenotypes remains the same in each generation, it is called balanced polymorphism. The optimum ratio will be the one that correlates with the survival of the most offspring.

Individuals with sickle-cell disease have the genotype Hb^SHb^S and tend to die at an early age due to hemorrhaging and organ destruction. Those who are heterozygous and have sickle-cell trait (Hb^AHb^S) are better off; their red blood cells usually become sickle. shaped only when the Oxygen content of the environment is low. Geneticists studying the distribution of sickle-cell disease in Africa have found

that the recessive allele (Hb^S) has a higher frequency (0.2 to as high as 0.4 in a few areas) in regions with malaria (Fig. 3.9). Malaria is caused by a parasite that lives in and destroys red blood cells. The frequency of Hb^S is maintained because the heterozygote has an advantage over the normal phenotype in these regions.

The malarial parasite flourishes in normal homozygotes but dies in heterozygotes because their red blood cells become sickle-shaped when infected with the malaria parasite. Sickle-shaped red blood cells lose potassium and this causes the parasite to die.

Least flycatcher, *Empidonax minimus* **Acadian flycatcher, *Empidonax virescens***

Traill's flycatcher, *Empidonax trailli*

Figure 3.2 Biological definition of a species.

3.3 Considering Speciation

Speciation is the splitting of one species into two or more species or the transformation of one species into a new species over time. Speciation is the final result of changes in gene pool allele and genotypic frequencies.

What Is a Species?

Sometimes it is very difficult to tell one species [L. species, a kind] from another. Before we consider the origin of species, then, it is first necessary to define a species. For Linnaeus, the father of taxonomy, one species was separated from another by morphology; that is, their physical traits differed. Darwin saw that similar species, such as the three flycatcher species in Figure 3.2, are related by common descent. The field of population genetics has produced the biological definition of a species: the members of one species interbreed and have a shared gene pool, and each species is reproductively isolated from every other species. The flycatchers in Figure 3.2 are members of separate species because they do not interbreed in nature.

Gene flow occurs between the populations of a species but not between populations of different species. For example, the human species has many populations that certainly differ in physical appearance. We know, however, that all humans belong to one species because the members of these populations can produce fertile offspring. On the other hand, the red maple and the sugar maple are separate species. Each species is found over a wide geographical range in the eastern half of the United States and is made up of many populations. The members of each species populations, however, rarely hybridize in nature. Therefore, these two plants are related but separate species.

With the advent of biochemical genetics, a new way has arisen to distinguish species. The phylogenetic species concept suggests that DNA/

DNA comparison techniques can indicate the relatedness of groups of organisms.

Reproductive Isolating Mechanisms

For two species to be separate, they must be reproductive isolated; that is, gene flow must not occur between them. A reproductive isolating mechanism is any structural, functional, or behavioral characteristic that prevents successful reproduction from occurring.

Premating isolating mechanisms are those that prevent reproduction attempts. Habitat isolation, temporal isolation, behavioral isolation, and mechanical isolation make it highly unlikely that particular genotypes will contribute to the gene pool of a population.

Habitat Isolation. When two species occupy different habitats, even within the same geographic range, they are less likely to meet and to attempt to reproduce. This is one of the reasons the flycatchers in Figure 3.2 do not mate and the red maple and sugar maple already mentioned do not exchange pollen. In tropical rain forests, many animal species are restricted to a particular level of the forest canopy, and in this way, they are isolated from similar species.

Temporal Isolation. Two species can live in the same locale, but if each reproduces at a different time of year, they do not attempt to mate. For example, *Reticulitermes hageni* and R. *virginicus* are two species of termites. The former has mating flights in March through May, whereas the latter mates in the fall and winter months. Similarly, the frogs featured in Figure 3.11 have different periods of most active mating.

Behavioral Isolation. Many animal species have courtship patterns that allow males and females to recognize one another. Male fireflies are recognized by females of their species by the pattern of their flashings;

similarly, male crickets are recognized by females of their species by their chirping. Many males recognize females of their species by sensing chemical' signals called pheromones. For example, female gypsy moths secrete chemicals from special abdominal glands. These chemicals are detected downwind by receptors on antennae of males.

Mechanical Isolation. When animal genitalia or plant floral structures are incompatible, reproduction cannot occur. Inaccessibility of pollen to certain pollinators can prevent cross-fertilization in plants, and the sexes of many insect species have genitalia that do not match or other characteristics that make mating impossible. For example, male dragonflies have claspers that are suitable for holding only the females of their own species.

Post mating isolating mechanisms prevent hybrid offspring from developing or breeding, even if reproduction attempts have been successful. Gamete isolation, zygote mortality, hybrid sterility, and reduced F_2 fitness all make it unlikely that particular genotypes will contribute to the gene pool of a population.

Gamete Isolation. Even if the gametes of two different species meet, they may not fuse to become a zygote. In animals, the sperm of one species may not be able to survive in the reproductive tract of another species, or the egg may have receptors only for sperm of its species. In plants, the stigma controls which pollen grains can successfully complete pollination.

Zygote Mortality, Hybrid Sterility, and P2 Fitness. If by chance two of the frog species do form hybrid zygotes, the zygotes fail to complete development or else the offspring are frail. As is well known, a cross between a horse and a donkey produces a mule, which is usually sterile—it cannot reproduce. In some cases, mules are fertile, but the F2 generation is not. This has also been observed in both evening primrose and cotton plants.

How Do Species Arise?

Whenever reproductive isolation develops, speciation has occurred. Ernst Mayr, at Harvard university, proposed one model of speciation after observing that when a population is geographically isolated from other populations, gene flow stops. Distinguishing variations due to different mutations, genetic drift, and directional selection build up, causing first post mating and then premating reproductive isolation to occur. Mayr called this model allopatric speciation [Gk. allo, different, and patri, fatherland].

With sympatric speciation [Gk. sym, together, and patri, fatherland], a population develops into two or more reproductively isolated groups without prior geographic isolation. The best evidence for this type of speciation is found among plants, where it can occur by means of polyploidy. In this case, there would be a multiplication of the chromosome number in certain plants of a single species. Sympatric speciation can also occur due to hybridization between two species, followed by a doubling of the chromosome number. Polyploid plants are reproductively isolated by a post mating mechanism; they can reproduce successfully only with other like polyploids, and backcrosses with diploid parents are sterile.

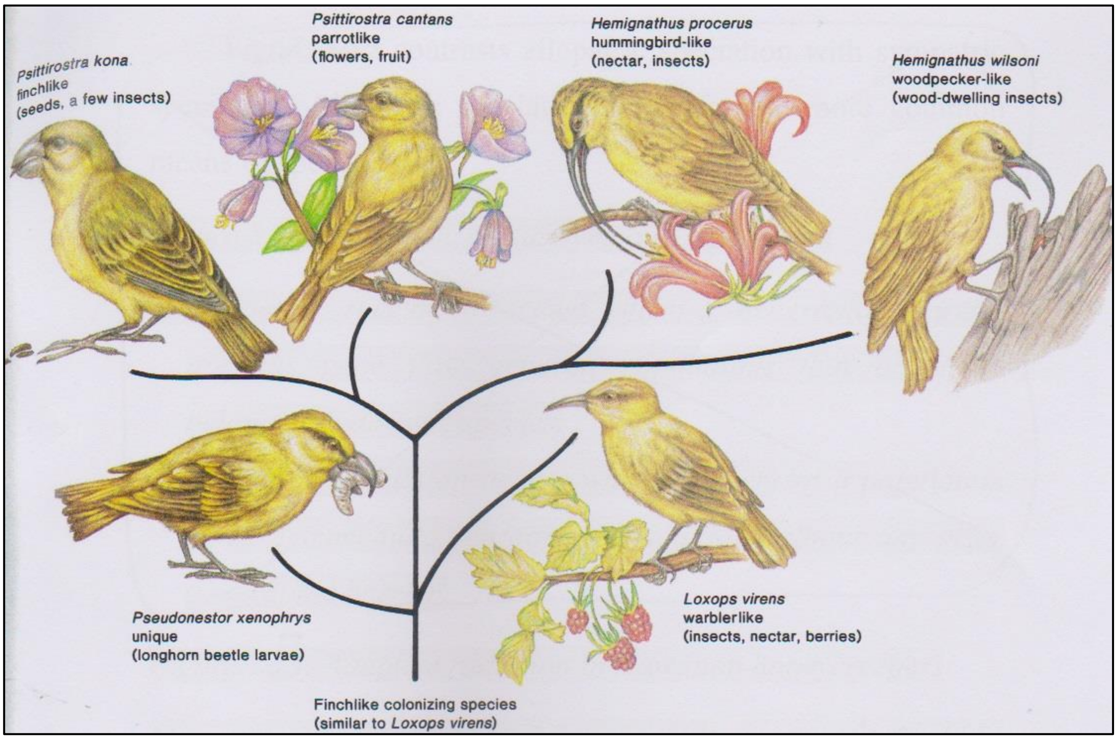


Figure 3.3: Adaptive radiation in Hawaiian honeycreepers

More than 20 species evolved from a single species of a finchlike bird that colonized the Hawaiian Islands. This illustration shows only six of the more extreme adaptive forms.

Adaptive Radiation Produces Many Species

Adaptive radiation is the rapid development from a single ancestral species of many new species, which have spread out and become adapted to various ways of life. The 13 species of finches that live on the Galapagos Islands are behaved to be descended from a type of mainland finch that invaded the islands. As the parent population increased in size, daughter populations were established on the various islands. These daughter populations were subjected to the founder effect and the process of natural selection. Because of natural selection, each population became adapted to a particular habitat on its island. In time, the various populations became so genotypically different that now, when they by chance reside on the same island, they do not interbreed and are therefore separate species. There is evidence that the finches use beak shape to recognize members of the same species during courtship. Rejection of suitors with the wrong type of beak is a behavioral type of premating isolating mechanism.

Similarly, on the Hawaiian Islands, there is a wide variety of honeycreepers that are descended from a common gold finch like ancestor that arrived from Asia or North America about 5 million years ago. Today, honeycreepers have a range of beak sizes and shapes for feeding on various food sources, including seeds, fruits, flowers, and insects (Fig. 3.3). Adaptive radiation has also been observed in plants on the Hawaiian Islands.

CHAPTER FOUR

FOOD RELATIONS AMONG LIVING ORGANISMS

The role of living organisms in the continuity of life:

•Man depends on the environment to get food, clothing and shelter, each living organism has a role to play in life, which is essential for the continuity of life.

Examples:

1. The role of plants in life:

- Plants carry out photosynthesis in order to:

a. Build up their food from simple raw material which supplies other living organisms with food. So, they are called **producers**.

b. Oxygen evolved during photosynthesis compensates for the oxygen lost during respiration of living organisms and maintains its percentage nearly constant in air.

2. The role of decomposers in life:

- Decomposers are microorganisms that decompose dead bodies, so, they return all the minerals essential for plant growth back to the soil.
- What happens in nature is a series of inter mingled reactions between living organisms and the surrounding environmental conditions, and man is a part of these reactions.

Food relations among living organisms:

- One of the most important problems that face living organisms is how to obtain food. Food is the source of energy.

Living organisms are classified according to the method of obtaining food into:

1. Autotrophic: Can build up their own food.

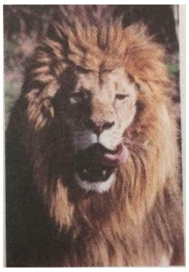
Examples:

a. **Green plants:** by photosynthesis.

b. **Some types of bacteria:** by chemosynthesis.

2. **Heterotrophic**: depend on others to obtain their food and this is done by several methods.

Examples:



a. **Carnivorous animals:** are armed with claws and canines for predation.

b. **Herbivorous animals**: animals live in Herds that grouped together in green plains and river, valleys where food is abundant.

- It is known that each living organism does not exist by itself in its environment, but is actually surrounded by thousands of various genera and species. All of them compete for food resources. In this kind of competition, all organisms struggle and weak ones die, while strong individuals survive.

- **Because of this severe and continuous struggle, weak organisms tend to**

a. live in groups in order to seek shelter and security as a result, animal communities which comprise large numbers of individuals of the same species, like herds of cattle, bee communities and coral colonies, have appeared. Individuals of each community cooperate in searching for food as well as protecting food resources.

b. weak individual' tends to form a relationship with a stronger individual of another species in order to find care and protection.

This leads to the appearance of certain relationships among different kinds of organisms. Each relationship includes:

a. Animal and animal. b.Plant and plant. c.Plant and animal.

- **Main kinds of relationships among living organisms:**
- **The various types of relationship behaviors among living organisms are:**

a. Predation. b. Commensalism. c.Mutualism.

d. Parasitism. e.Saprophytism.

A. Predation

Definition: Predation is a (food relation) between two living organisms of different species in which one of them (the predator) preys upon the other (the prey).

I-Predation in Animal kingdom

• Some insects feed on other insects, Man could use this phenomenon as a biological control of harmful insects that may damage crops.

• Predation is more common among the mammals.

Examples:

- The cat which Preys upon rats.
- The wolf on sheep. • The lion on wild cattle.

II- Predation in plant kingdom

- Predation is restricted to insectivorous plants which feed on insects.
- The leaves of insectivorous plants are modified to act as traps to catch or capture insects or other small animals.

Examples:

- Nepenthes - Dionaea - Utricularia, Drosera and others.
- **Study of Nepenthes**
- A part of Nepenthes leaf is modified into pitcher - like structure filled with rain water.
- When the insect falls into this pitcher it cannot get out again due to the (**Protrusions**) on its internal surface which pointed downwards to prevent the insect from ascending.
- The insects drowns in the water of the pitcher.
- The plant secretes digestive juices which digest the insect body into simple substances that can be absorbed through the pitcher wall.

The question is: **Why insectivorous plant feed on insects?**

- Because in sectivorous plants obtain their nitrogen in an organic form (in the form of protein) from inset body while all other plants obtain nitrogen in an in organic form.

***Comparison between green plants and insectivorous plants:**

	Green plants	Insectivorous plants
Similarities:	Both of them carry out photosynthesis and build up carbohydrate	
Differences:	Obtain nitrogen in an in organic form from the soil.	Obtain their nitrogen in an organic form in the form of protein from the insect body.

B. Commensalism

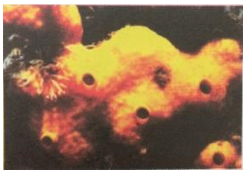
Definition: Commensalism is a food relation between two organisms of different species in which one of them benefits and the other (host) is neither benefited nor harmed.

Examples:

1. Commensalism between Bacteria and Man (or animal):

• Millions of bacteria live in the mouth and intestine of man or animal, they feed on food remains and digest wastes without causing harm

2. Sponge tubes



• Sponge tubes are inhabited by large numbers of minute marine organism to find shelter and get food from water currents passing through these tubes and the sponge (the Host) is neither benefited nor harmed.

3. Shark and shark louse (Remora fish):

• Shark louse (remora) is a small fish, one of its dorsal fins is modified into dorsal sucker at the upper surface of its head.

• The remora attaches itself to the shark's body, so it accompanies, its host wherever it goes without any fear from enemies

• It leaves the body of the shark from time to time to swallow food remains left by the shark and the shark is neither benefited nor harmes.

4. Hermit crab and sea animone

• Sea animone is a coelentrate (a soft coral animal) that lives fixed to rocks at sea bottom or fixed to the outer shell of the hermit crab, and this gives it a better chance to find a mean of transportation and to get food because it moves with the crab, also it feeds on food remains left by the crab, and the crab is neither benefited nor harmed.

5. Crabs and flat worms:

- Some kinds of flat worms live among or attached to the gills of certain species of crabs and feed on food remains of the crab, and the crab is neither benefited nor harmed.

6. Crocodile and the plover [zakzak]:

- Plover is a bird which feeds on food remains left between crocodile teeth without fear of any harm the crocodile is neither benefited nor harmed.

7. Birds live with **elephants and rhinocerouses**

- They feed on insects between their skin folds so these birds get benefit, while the animal is neither benefited nor harmed.
- It is also believed that these birds warn the animals of any coming danger because they fly away when they feel any danger.

C. Mutualism

Mutualism is a food relation between two organisms of different species in which both of them are benefited. Mutualism is not a common type of relationships among living organism.

- Examples of this type are few and limited in number.

1. Leguminous plants and bacterial nodules (nodular bacteria).

- Beans, clover and lentils are leguminous plants.
- This relationship starts when nitrogen fixing bacteria invade and settle on the root cortex of leguminous plants, where they reproduce at a very high rate forming swellings called-bacterial nodules (nodular bacteria), that appear on the root surface as nodules containing millions of bacteria.
- Nodular bacteria can fix atmospheric (nitrogen present between soil particles and change it into nitrogenous compounds which are absorbed by the leguminous plant which use them in making proteins that build up the plant body tissues and the bacteria get carbohydrate from the leguminous plant in return.
- Bacteria cannot prepare carbohydrates because they are devoid of chlorophyll.
- These carbohydrates are oxidized by bacteria during respiration to release the energy they need to fix nitrogen.

• This phenomenon is used in an economic way that legumes are cultivated in soils poor in their nitrogen content.

Note 1

Leguminous plants are known as green fertilizers

- As nodular bacteria living on their roots, can fix nitrogen into nitrogenous compounds that are absorbed by the plant and also increase the soil fertility, when roots of leguminous plants and nodular Bacteria living on them decay and their content of nitrogenous compound is added to the soil

Note 2

- **Leguminous plants play an important role in the "crop rotation system".**
- As nodular bacteria living on their roots, can fix nitrogen into nitrogenous compounds, that are absorbed by the plant and also increase the soil fertility, when roots of leguminous plants and Bacterial decay.

2. Green animals [green corals and green hydra]:

- One of the phenomena related to mutualism is what scientists call "Green animals" such as the green hydra, which lives in fresh water canals and green coral which take part in constructing coral barriers.
- The green colour of these animals is due to the presence of large numbers of unicellular green algae in their tissues. The algae carry out Photosynthesis to prepare carbohydrates which are partly used up by animal at the same time, these algae make use of some of the nitrogenous compounds excreted by the animal. This may be the reason of why the coral reefs grow and flourish only in shallow clear water. This helps light to penetrate easily through the water in an intensity strong enough to enable green algae to grow inside the tissues of coral animal.

3. Termites (white ants) and protozoan animals:

• Mutualism is also considered responsible for the tragic catastrophies caused by the termites (white ants). These insects cause the collapse of houses on their inhabitants, some of whom are killed whilst others become homeless.
It is because these termites feed on the wooden columns which support the roofs and walls of the houses.

• This strange ability of termites to live on wood is due to a certain protozoan flagellate which lives inside the intestine of the termites, which are able to digest cellulose which constitutes a high percentage of plant fibers and wood vessels eaten by termites, they convert them to sugar for the welfare of both partners.

D. Parasitism

Parasite: from the Latin word parasites meaning “one who eats at the table of another”

Parasitism is a food relation between two individuals of different species in which one of them (the parasite) gets its food either partially or totally digested from the other (the host) which is harmed.

- There is no living organism on earth which is not liable to be infected by one or more types of Parasite.
- **In the following we will discuss some cases of parasitism:**

1- Viruses

- Parasite on plants and animals causing them diseases.
- Parasitize on bacteria called bacterial viruses or bacteriophages.

2- Parasitism in Kingdom Monera

- Bacteria parasitize on animals and man causing them diseases

3- Parasitism in Kingdom Protozoa

- Frequently infects man and animal examples:
- Entamoeba histolytica: which causes amoebic dysentery.
- **Trypanosoma**: causes sleeping sickness, which is common in tropical Africa.
- **Plasmodium**: causes jnalaria.
- **Leishmania:** which infects humans in Syria and Iraq causing oriental sore.

4- Parasitism in Kingdom Fungi

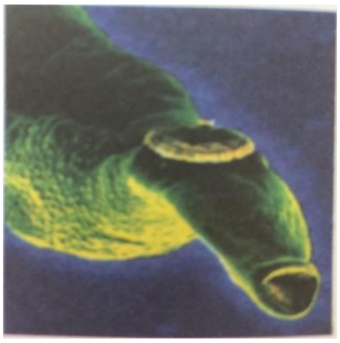
- Some kinds of fungi parasitize on man and animals causing diseases.

5- Parasitism in Kingdom Animalia

- Many lower organisms are parasites. As an organism becomes more specialized in evolutionary terms the less chance it has of being parasitic.

A) Parasitism in different worm phyla:

- **Phylum Platyhelminthes [Flat worms]:**



They are all parasitic, such as liver fluke which infect cattle, Bilharzia worms which are endemic in Egypt and tap worms which live in the intestine of man, fish, cats and dogs.

- **Phylum Nemato helminthes [round worms]:** such as Ascaris, Ancylostoma, oxyuris, and Filaria worms which causes Elephantiasis disease.

- **Phylum Annelida [ring worm]:** which are evolutionary more advanced than the previous worms, include only one parasitic worm which is the medical leech which lives in fresh water. It adheres by means of its suckers to the body of any aquatic animal or cattles and feeds by sucking their blood.

B) Parasitism in Arthropoda and Arachnids:

- They comprise a large number of parasites that suck blood of animals and man.

Examples: Louse, bed bug, mosquitos [insects] ticks, mites, scabies (Arachnids)

C) Vertebrates:

- Such as: Lampreys (which are cyclostomes that resemble fish) and Vampire Bats which suck blood of mammals.

6) Parasitism is plant Kingdom

- Parasitism is less common in the plant kingdom. This is due to the limited sources of food for animals. So, they must compete hard to get their food plants, on the other hand, depend mainly on water, carbon dioxide and light to build up their food. All these requirements are abundant and available in nature.
- For this reason, Parasitism among higher flowering plants is very rare. Only few examples are known.
- Cuscuta on clover.
- Orbanche on Bean or Tomato and Mistltoe.
- These Parasitic plants are devoid of chlorophyll and are dangerous to both man, animals and plants.

From previous we can deduce the following:

Kinds of Parasites:

a. Obligate parasites: Which are characterized by being unable to live in absence of a host.

Example: Viruses and some fungi, such as wheat rust fungus.

b. Facultative parasite: Which can live as a saprophyte at a certain stage of its life cycle.

- Kinds of Parasitism:

a. Endoparasites: As in case of Ascaris worms which live in the intestines, (inside body).

b. Ectoparasites: Such as the flea which lives on the host, (outside body).

- Host parasite inter-reactions:

Once the parasite invades the body of the host, certain reactions take place.

a. The host may be killed by the parasite.

b. The parasite dies by means of defence set up by the host.

c. The host may support the parasite for an unlimited period of time.

Methods by which the parasite enter the **body of** the **host:**

- Digestive system: if the parasite is swallowed with food as in case of Parasitic worms.
- Respiratory system: viruses and bacteria may enter the body through respiration.
- Reproductive system: Such as bacteria causing syphilis enter the human body through the reproductive organs.

Some insects play an important role in Parasites transmission

e.g. Tsi - Tsi fly, Anopheles mosquito

↓ ↓

Tryponosoma Plasmodium malaria

- Plant parasites invade the tissues of the plant through natural openings such as stomata or through any cut in the plant.

E. Saprophytism

- Saprophytism is a food relation between two organisms on of them is alive which is the saprophyte and the other is dead organism plant or animal.
- Saprophyte secrete digestive enzymes that break down the complex food molecules in the dead bodies into simple substances that can be absorbed easily.
- Kinds: **Animal saprophytes:** Some kinds of worms.

Plant Saprophytes: Large in number and variable in shape. They belong to various groups of plant kingdom.

Example:

- **Seed - plants (Angiosperms)**: Such as Indian galleon plant feeds as a saprophyte on dead bodies of plants and animals.

- **Large sized** fungi as Agaricus (Mushroom) which is seen growing in soils rich in organic matter.
- **Importance of Saprophytes**:

1. Increase soil fertility due to the abundance of minerals.
2. Removing wastes and organic remains as they decompose them.
3. Man has utilized the ability of saprophytes to decompose complex organic matter e.g. industries such as tanning of leather) manufacture of paper and cloth.

Comparison between Predation - Commensalism - Mutualism - Parasitism and Saprophytism.

1) Predation	2) Commensalism	3) Mutualism	4) Parasitism	5) Saprophytism
Temporary relationship between the predator and prey	Superficial relationship between the benefited organism and the host	Mutual relationship between two organisms live together.	A relationship which may extends or shortens between the parasite and the host.	Permenant relationship between the saprophyte and the dead organism
Ends when the predator consume the whole prey or part of it.	The whole benefit goes to the benefited organism while the host is neither harmed nor benefited.	Both of them are benefited from each other without any harm.	Only the parasite is benefited while the host is harmed	This relationship ensures the continuity of life on earth.
Wolf on sheep. Cat on mice. Nepenthes plants on insects.	Shark and remora fish. Crocodile and zak zak bird.	Nodular bacteria and leguminous plants. Termites and the protozoan flagellates.	Tap worms on the intestine of man. Cuscuta on clover.	Agaricus saprophte on complex organic substance. Inclean galleon saprophyte on dead plant and animal body.

Energy flow among living organisms

- The sun emits huge amount of radiation (energy), only small amount of the solar energy reaches the earth as most of the solar radiant energy is reflected to the space by clouds.
- The amount of radiant energy that reaches the earth surface from the upper atmosphere is only 40% some of it is reflected again, while some is absorbed

by earth.

- Green plants absorb only 1/10000, of the energy reached the earth.

Conversion of solar energy:

- Inside the green plant tissues, the solar energy together with water and carbon dioxide are changed into organic compounds. This process is known **Photosynthesis**:

- It depends mainly on the conversion of light energy that can be utilised by green plants as well as animals feeding on the green plants directly or on other animal's flesh.

We can classify living organisms in this field into:

Producers	Consumers		Decomposers
e.g.: green plants.	herbivorous [feed on plants]	Carnivorous [feed on meat]	[make use of chemical energy in dead bodies], e.g.: Bacteria

- Energy differs from chemical and food substances as its natural cycle cannot be restored. Therefore, life cannot continue on earth unless it is supplied by energy from the sun.

Methods of energy loss

1. Most of the energy reaching the earth is lost in the atmosphere in the form of heat.

2. Energy changes from one form to another:

When you do some elaborate work, the energy stored in the food in your body will change into mechanical energy, during this operation a large part of the energy stored in food is converted into heat energy which you can feel, but cannot make use of it.

3. Energy transfer from one living organism to another.

- Green plants take an amount of solar energy through photosynthesis process.
- The rabbit gains chemical energy when it eats green plants but the amount of

energy which the rabbit gains is less than what plant took from solar energy.

- When a wolf eats up a rabbit, it gains less energy than energy obtained by a rabbit.
- By the death and decay of the wolf, the sun energy must have been used up and returned back to nature in the form of heat.

Example

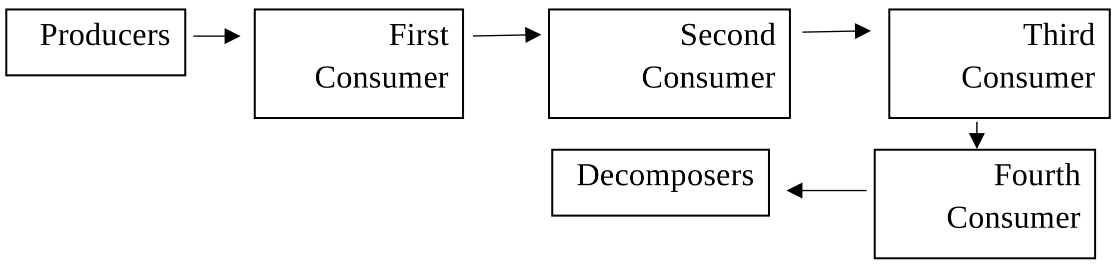
- **In aquatic life:**
- Green algae produce an amount of energy (Say 100%).
- Tiny crustaceans receive in turn 10% only of the energy.
- Hydra feeds on these crustaceans receive 10% from crustaceans, i.e. 1% of energy received by algae and so on.

From previous we can deduce that:

- Living organisms give less energy than it takes.
- Energy flows through living organisms in a certain environment in various directions called food chains.
- **Definition**: Food chain is a sequence of living organisms in which each organism provides food for the next organism. Or Succession of food consumption.

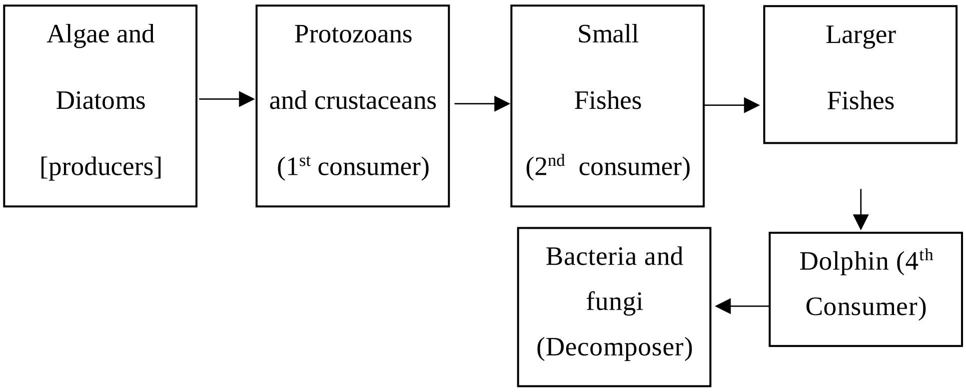
Food chain

Food chain can be represented as follows:

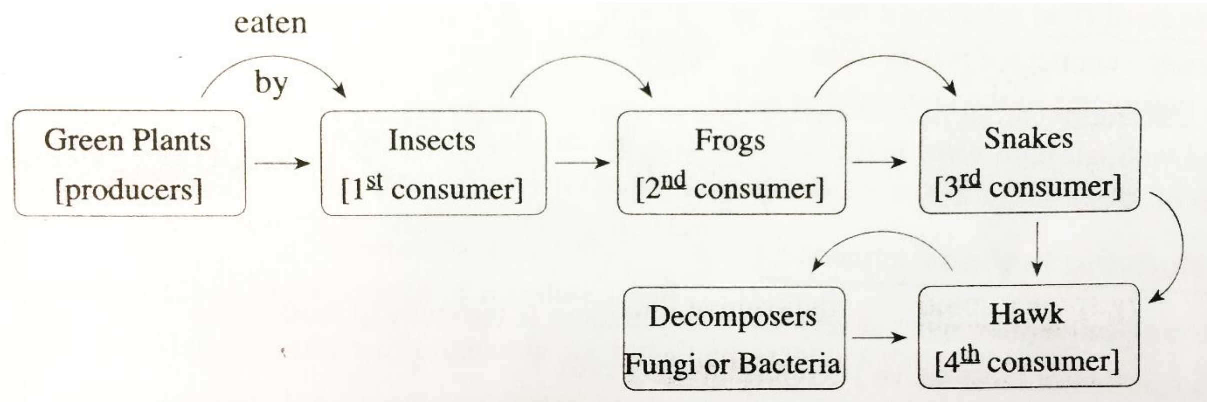


Examples: of food chains

1. Food chain in aquatic environment



2. Food chain in terrestrial (land) environment: eaten



Autotrophic organisms

I. Photoautotrophic organisms

• Use light energy to produce their food.

• Photoautrophs convert light energy into chemical energy stored in food.

Example:

Higher green plants and algae.

II. Chemoautotrophicorganisms

• Use chemical energy in making their food.

• The chemical energy utilized in making food results from an oxidation of substances present in their habitats.

Example

Nitrosomonas and Nitrobacter bacteria.

Examples: **for chemoautotrophs**

1. **Nitrosomonas bacteria**:Oxidize ammonia- Present in the soil into nitrous acid+Energy

$2NH_3 + 3O_2$------ ► $2HNO_2 + 2H_2O$ + Energy (197 calories for each ammonia molecule).

2. **Nitrobacter bacteria**: Oxidize nitrous acid into nitric acid and energy.

$2\ HNO_2 + O_2 \rightarrow 2\ HNO_3$ + Energy

The energy released in such reactions is used in building up complex food from simple substances.

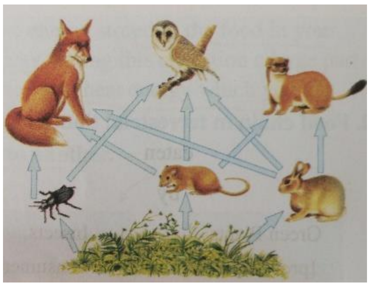
Food web

- Food chains do not provide a real picture of the complexity of energy flow in nature

For example:

- The Hawk may eat up a rat instead of a snake.
- The rat may have preyed upon a beetle whose larvae have fed on grass.
- Decomposers may have obtained energy from any stage of the chain when the organism dies.
- **Definition of food web**:

Therefore, the actual picture of the energy flow is a network of food relations along a variety of inter - connected routes from the producer organisms to the consumers.



This is a food web, all food webs form the food web of life.

Methods for studying the food chains:

- Scientists use radioactive substances at very low concentrations in the study of food chains.
- They spray a solution of radioactive Phosghorous on weeds.

- A few weeks later they collect small animals such as insects to be examined.
- After several more weeks, they examine bigger animals using certain pieces of apparatus that are sensitive to radioactive substances.
- In this way, scientists can determine the successive stages of food chains and food webs.

Food pyramids

• Flow of energy in an ecosystem can be represented by means of food pyramids which can also be called pyramids of environment.

Add to your knowledge

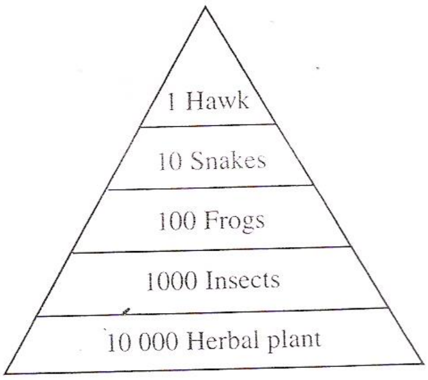
An ecosystem: is a natural unit consisting of all the plants, animals and micro - organisms in an area together with non-living aspects of the environment.

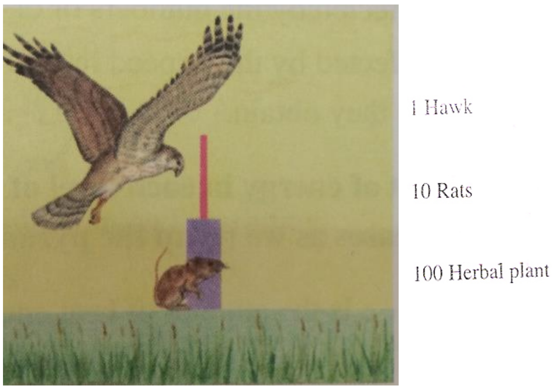
Kinds of food pyramids:

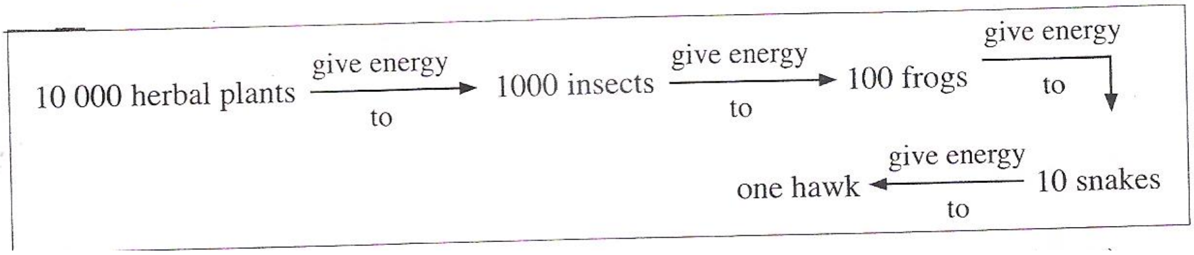
1- Pyramid of number 2-Pyramid of mass 3- pyramid of energy

1) Pyramid of number

Explains the relationship between the numbers of organisms in a food chain.





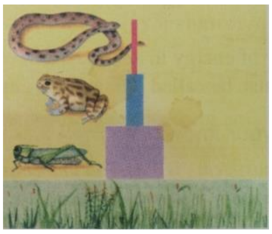


- These numbers form a pyramid in which the base represents the herbs (producers) and the apex represents the last consumer (the Hawk).

Disadvantages of the Pyramid of number:

- It was found that numbers of organisms are not so important as their weights.
- If the producers are large trees, number of producers will be less than numbers of herbivores so we will get *Inverted pyramid of number*.

2) Pyramid of mass

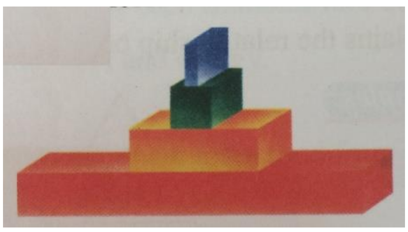


1 Kcal

10 Kal

- Represents the relation between the masses of living organisms in food chain.
- The total mass of each level of the Pyramid decreases as we go up the pyramid because of energy loss.
- There is an inverse relation between numbers of organisms and the mass of each individual i.e. if the mass is large, then the numbers must be small and vise versa.

3) Pyramid of energy



- Provide the best representation for energy flow and energy loss.
- It considers the rate of food production and its total weight.
- It is not affected by the numbers of organism.
- It is not affected by their speed in utilizing the energy they obtain.

*** The amount of energy in each level of the pyramid is measured in kilo-calories and it decreases as we go up the pyramid.**

- **Kilo-calorie**: Is the amount of heat energy needed to raise the temp, of one-liter water by 1°C.

*** The productivity of the plant or plant community in an ecosystem is measured by kilo-calories per one square meter in one year.**

* *Comparison between Pyramid of number, Pyramid of mass, Pyramid of Energy.*

Points of comparison	**Pyramid of number**	**Pyramid of mass**	**Pyramid of Energy**
Importance:	Represents the relation between the numbers of living organisms in food	Represents the relation between the masses of living organisms in food	Gives the best representation of energy flow through
Disadvantages:	The numbers of living organisms do not have the importance of their weight.	It does not take into consideration amount of food during long period of time (a year).	No disadvantages and it is considered the best representation. [Tell why?]

Natural Balance – Environmental balance

Any area together with its various components, whether living or non-living and their relations is collectively called an ecosystem. A forest, sea, desert are all ecosystems, the whole can be considered as a unified ecosystem. So the changes that happen in one part of it would affect the other parts and disturb its balance.

Factors that keep the environmental balance:

1. The presence of green plants which are responsible for the synthesis of food, while all other modes of life are included under consumers and decomposers in any ecosystem.
2. The stock of various chemicals in any ecosystem remains almost constant, and is exchanged between living organisms. After death, these

chemicals return when dead bodies decompose, they are added to the soil where they become available for new generations of organisms.

3. The presence of natural biological balance between living organisms occurs if:

a. These organisms are not subjected to sudden new factors that affect the ecosystem.

b. Each species remains constant in number where the increase in number of individuals of certain species becomes limited.

- **The dominance of some species over another is limited by:**

- Presence of natural enemies, competition for food.
- Shortage of resources area provided for reproduction and spreading.
- Balance with what it predates on or parasitizes.
- All environmental conditions which affect the number, activity and distribution of individuals.
- Other physical factors such as light, heat, wind.

Factors that lead to the disturbance in environmental balance:

1. Introducing new living organism to a balanced habitat.
2. Removal of a living organism from a balanced habitat.
3. Change in natural factors.

1) Introducing a new living organism to a balanced habitat

- **Disturbance:**

1. Rabbits were introduced to lisan islands (HAWAI) in 1890 where the environment is suitable and food weeds and herbs are abundant.

- The rabbits reproduced and multiplied at a high rate due to the absence of natural enemies.
- They consumed plants at a high rate than the rate of growth of these plants.

Results:

- This led to the disappearance of these plants from the island by the year 1923.
- The rabbits could not find food and so they died of hunger.
- Birds of the island either died or migrated to other places.

Disturbance:

2. The hyacinth plant was introduced in Egypt in the nineteenth century as an ornamental plant.

- Due to favorable environmental conditions and absence of natural enemies the plant spread enormously in the Nile, and its tributaries as well as drainage canals.

Results:

- Loss of large amounts of water through transpiration.
- Spreading of Bilharzia worms, as the snails usually adhere to this plant.
- Inhibited navigation and also had a bad effect on fish communities.

2) Removal of a living organism from a balanced habitat:

Disturbance:

1. When man first settled in some new regions, he cut forests and removed weeds from soil in order to cultivate certain food crops.

Results:

- This led to disturbance of the environment where rain became less and crops ceased growing.

Disturbance:

2. When the American farmers killed hawks which used to prey upon rats.

Results:

- Increase in the number of rats causing great loss in chickens and crops.

3) Change in natural factors

Disturbance:

1. Getting rid of swamps and ponds.

Results:

- The balance is disturbed.
- Plants and aquatic animals Perish.
- Instead of swamp plants, new terrestrial plants and animals appear.

Disturbance

2. In Cenozoic era, atilt in the earth's crust occurred in Egypt which caused the sea bottom in some regions to rise leading to the appearance of Mokattam hills.

Results:

- The balance between the organisms of this habitat was disturbed.
- All the aquatic organisms perished and new terrestrial plants and animals appeared.

Conclusion

"The ecosystem remains in a state of equilibrium as conditions are stable. If conditions are changed, the equilibrium will be changed; After a time, the equilibrium returns".

The environmental balance is in dynamic equilibrium.

CHAPTER FIVE

ANIMALS: THE DEUTEROSTOMES

Human beings are vertebrate chordates, a phylum that includes a few invertebrate members. Without evidence to the contrary, who would think the invertebrate chordates are most closely related to the echinoderms headless, brainless, and unsegmented creatures that spend their lives at sea? Sea stars, sea urchins, brittle stars, and sea lilies are all echinoderms, animals that are radially symmetrical as adults.

The fishes, which are aquatic vertebrates, far outnumber any of the other chordates. Still, there are more types of terrestrial animals among the chordates than in any other phylum. The reptiles were the first vertebrates to successfully reproduce on land by laying a shelled e.g. as do birds. But within the egg, the embryo has a watery environment. Despite the live birth of placental mammals, such as ourselves, the embryo is still bathed by water while it develops. Today, birds and placental mammals are the most conspicuous vertebrates on land, because they underwent adaptive radiation after many reptiles, such as the dinosaurs, had become extinct are hoofed mammals that spend a lot of time in the water because, when the sun is out, their skin loses water at a very high rate.

Radial Symmetry, Again

Phylum Echinodermata (6,000 species) and phylum Chordata, which are discussed in this chapter, contain the deuterostomes [Gk. *deuteros*, second, and L. *stoma*, mouth], animals in which the second embryonic opening is associated with the mouth (the first opening is associated with the anus). *Cleavage*, the first series of embryonic cell divisions, is radial in deuterostomes, and the daughter cells sit on top of the previous cells. The cells are *indeterminate*; if separated, each one can develop into a complete organism. Finally, the coelom develops as outpockets from the primitive gut; it is an *enterocoelom*.

Although the echinoderms are *radially symmetrical as adults,* their larva is a free-swimming planktonic filter feeder with bilateral symmetry. Metamorphosis results in the radially symmetrical adult.

Echinoderms Have a Spiny Skin

Echinoderms [Gk. *echinos*, spiny, and *derma*, skin] have an *endoskeleton* (internal skeleton) consisting of spine-bearing, calcium-rich plates. The *spines*, which stick out through the delicate skin, account for their name. Class Crinoidea (600 species) includes the stalked sea lilies and the motile feather stars. Their branched arms, used for filter feeding; give them a flowerlike appearance. Class Holothuroidea (1,500 species) are the sea cucumbers with a long leathery body that resembles a cucumber, except that there are feeding tentacles about the mouth.

Class Echinoidea (950 species) includes sea urchins and sand dollars, both of which use their spines for locomotion, defense, and burrowing. Sea urchins are well known for their long, blunt spines, and the flattened, somewhat circular skeleton of a sand dollar has a familiar five-part flowerlike pattern. Actually the pattern is due to pores for skin projections in the living animal Class Ophiuroidea (2,000 species) contains the brittle stars, which have a central disk from which long, flexible arms radiate. They move quickly by using their arms to push themselves along.

Class Asteroidea (1,500 species) consists of the sea stars, also called the starfishes. The somewhat flattened body of most sea stars has a central disk from which five, or a multiple of five, sturdy arms (rays) extend.

Sea Stars Have Arms

Sea stars are commonly found along rocky coasts where they feed on clams, oysters, and other bivalve mollusks. The *five-rayed body* has an oral, or mouth, side (the underside) and an aboral, or anus, side (the upper side) (Fig. 5.1). Various structures project through the body wall: (1) spines from the endoskeletal plates offer some protection; (2) pincer- like structures called pedicellarie keep the surface free of small particles; and (3) skin gills, tiny fingerlike extensions of the skin, are used for respiration. On the oral surface, each arm has a groove lined by little tube feet.

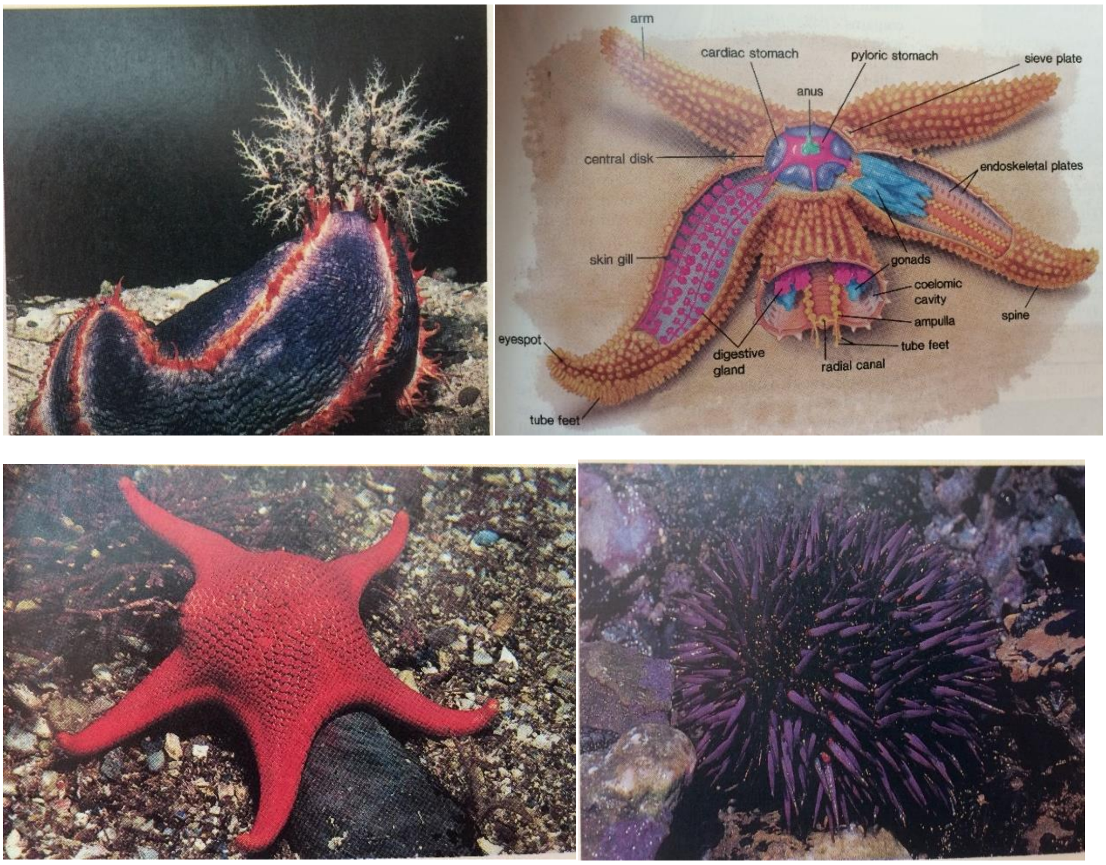


Figure 5.1 Echinoderms.

Sea star (starfish) anatomy and habitat. Like other echinoderms, sea stars have a water vascular system shown here in light gold. b.Sea cucumber, c. Sea urchin.

To feed, a sea star positions itself over a bivalve and attaches some of its tube feet to each side of the shell. By working its tube feet in alternation, it pulls the shell open. A very small crack is enough for the sea star to evert its cardiac stomach and push it through the crack, so that it contacts the soft parts of the bivalve. The stomach secretes enzymes, and digestion begins even while the bivalve is attempting to close its shell.

Later, partly digested food is taken into the sea star's body, where digestion continues in the pyloric stomach using enzymes from the digestive glands found in each arm. A short intestine opens at the anus on the aboral side.

In each arm the well-developed coelom contains a pair of digestive glands and gonads (either male or female) that open on the aboard surface by very small pores. The nervous system consists of a central nerve ring that gives off radial nerves in each arm. A light-sensitive eyespot is at the tip of each arm. Sea stars are capable of coordinated but slow responses and body movements.

Locomotion depends on the water vascular system. Water enters this system through a structure on the aboard side called the sieve plate, or madreporite. From there it passes through a stone canal to a ring canal, which surrounds the mouth, and then to a radial canal in each arm. From the radial canals, many lateral canals extend into the tube feet, each of which has an ampulla. Contraction of an ampulla forces water into the tube foot, expanding it. When the foot touches a surface, the center is withdrawn, giving, it suctions so that it can adhere to the surface. By alternating the expansion and contraction of the tube feet, a starfish moves slowly along.

Echinoderms don't have a complex respiratory, excretory, or circulatory system. Fluids within the coelomic cavity and the water vascular system carry out many of these functions. For example, gas exchange occurs across the skin gills and the tube feet. Nitrogenous wastes diffuse through the coelomic fluid and the body wall. Cilia on the perito-neum lining the coelom keep the coelomic fluid moving.

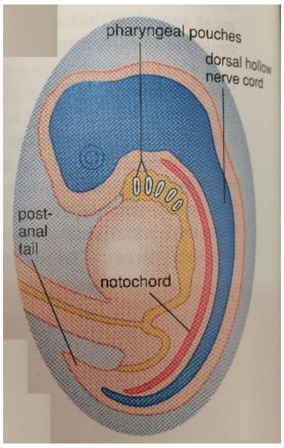
Sea stars reproduce asexually and sexually. If the body is fragmented, each fragment can regenerate a whole animal. Fishermen who try to get rid of sea stars by cutting them up and tossing them overboard are merely propagating more sea stars! Sea stars spawn and release either eggs or sperm at the same time. The bilateral larva undergoes a metamorphosis to become the radially symmetrical adult.

Figure 5.2 Hemichordates.

The acorn worm, ***Glosso balanus,*** showing the proboscis, the collar, the pharyngeal regions, and certain intornal structures.

Chordate Characteristics Evolve

To be considered a chordate (phylum Chordata, 45,000 species), an animal must have the three basic characteristics listed below at some time during its life history:



1. A dorsal supporting rod called a notochord [Gk. *notos*, back, and *chorde*, string]. The notochord is located just below the nerve cord. Vertebrates have an embryonic notochord that is replaced by the vertebral column during development.

2. A *dorsal hollow nerve cord.* By hollow, it is meant that the cord contains a canal filled with fluid. In vertebrates, the nerve cord, more often called the spinal cord, is protected by the vertebrae.

3. *Pharyngeal pouches.* These are seen only during embryonic development in most vertebrates. In the invertebrate chordates, the fishes, and amphibian larvae, the pharyngeal pouches become functioning gills. Water passing into the mouth and the pharynx goes through the gill slits, which are supported by gill arches. In terrestrial vertebrates, the pouches are modified for various purposes. In humans, the first pair of pouches become the auditory tubes. The second pair become the tonsils, while the third and fourth pairs become the thymus gland and the parathyroids.

Other features also distinguish chordates- Most have an internal skeleton against which muscles work and—as embryos if not as adults- they have a *post-anal tail*, a tail that extends beyond the anus.

The hemichordates (phylum Hemichordata, 90 species) are not considered chordates but they have features that resemble those of chordates. Acorn worms, which are hemichordates living in or on tidal mudflats, have a ***pro-*** *boscis,* a *collar,* and a *trunk* (Fig. 5.2). There is a dorsal nerve cord in the collar and trunk that resembles the nerve cord of chordates, and the pharynx just below the collar has gill slits. Most interesting, *the larva of hemichordates resembles that of echinoderms.* Is it possible then that echinoderms and hemichordates share a common ancestor and that the hemichordates and chordates are related by way **of** a **common** ancestor? Some think so.

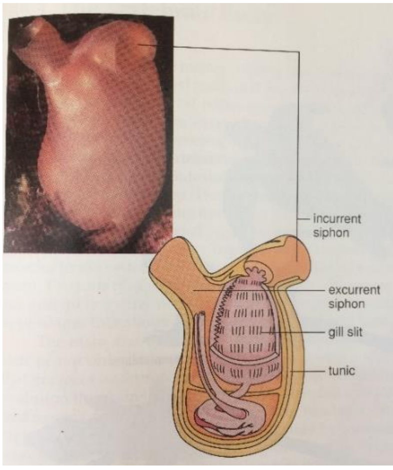


Figure 5.3 Tunicate, *Halocynthia.*

Note that the only chordate characteristic remaining in the adult is gill slits.

Invertebrate Chordates

There are a few *invertebrate chordates* in which the notochord persists and is never replaced by the vertebral column.

Tunicates Have Gill Slits

Tunicates (subphylum Urochordata, 1,250 species) live on the ocean floor and take their name from a tunic that makes them look like thick-walled, squat sacs. They are also called sea squirts because they squirt out water from their excurrent siphon when disturbed. The tunicate larva is bilaterally symmetrical and has the three chordate characteristics. Metamorphosis produces the sessile adult with an incurrent and excurrent siphon (Fig. 5.3).

The pharynx is lined by numerous cilia whose beating creates a current of water that moves into the pharynx and out the numerous *gill slits*, the only chordate characteristic that remains in the adult. Microscopic particles adhere to a mucous secretion and are eaten.

Is it possible that the tunicates are directly related to the vertebrates? It has been suggested that a larva with the three chordate characteristics may have become sexually mature without developing the other adult tunicate characteristics. Then it may have evolved into a fishlike vertebrate. Or perhaps it was a cephalochordate larva (discussed next) that became a vertebrate.

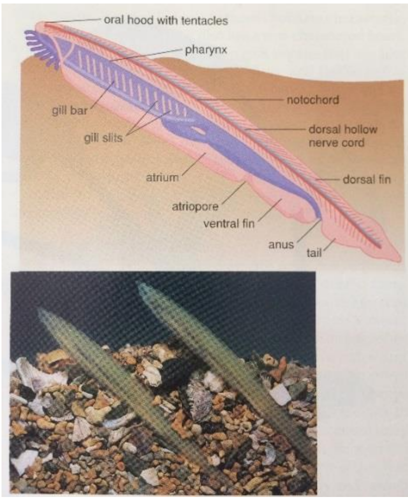


Figure 5.4 Lanceiet, Branchiostoma.
Lancelets are filter feeders. Water enters the mouth and exits at the atriopore after passing through the gill slits.

Lancelets Have Three Chordate Characteristics

Lancelets (subphylum Cephalochordata, 23 species) are in the genus *Branchiostoma*, formerly called Amphioxus. These marine chordates, which are only a few centimeters long, are named for their resemblance to a lancet— a small, two-edged surgical knife (Fig. 5.4). Lancelets are found in the shallow water along most coasts where they usually lie partly buried in sandy or muddy substrates with only their anterior mouth and gill apparatus exposed. They feed on microscopic particles filtered out of the constant stream of water that enters the mouth and passes through the gill slits into an atrium that opens at the atriopore.

Lancelets retain the three chordate characteristics as an adult. The notochord extends from the tail to the head and this accounts for their subphylum name, Cephalo chordata. In addition, segmentation is present, as witnessed by the fact that the muscles are segmentally arranged and the dorsal hollow nerve cord has periodic branches.

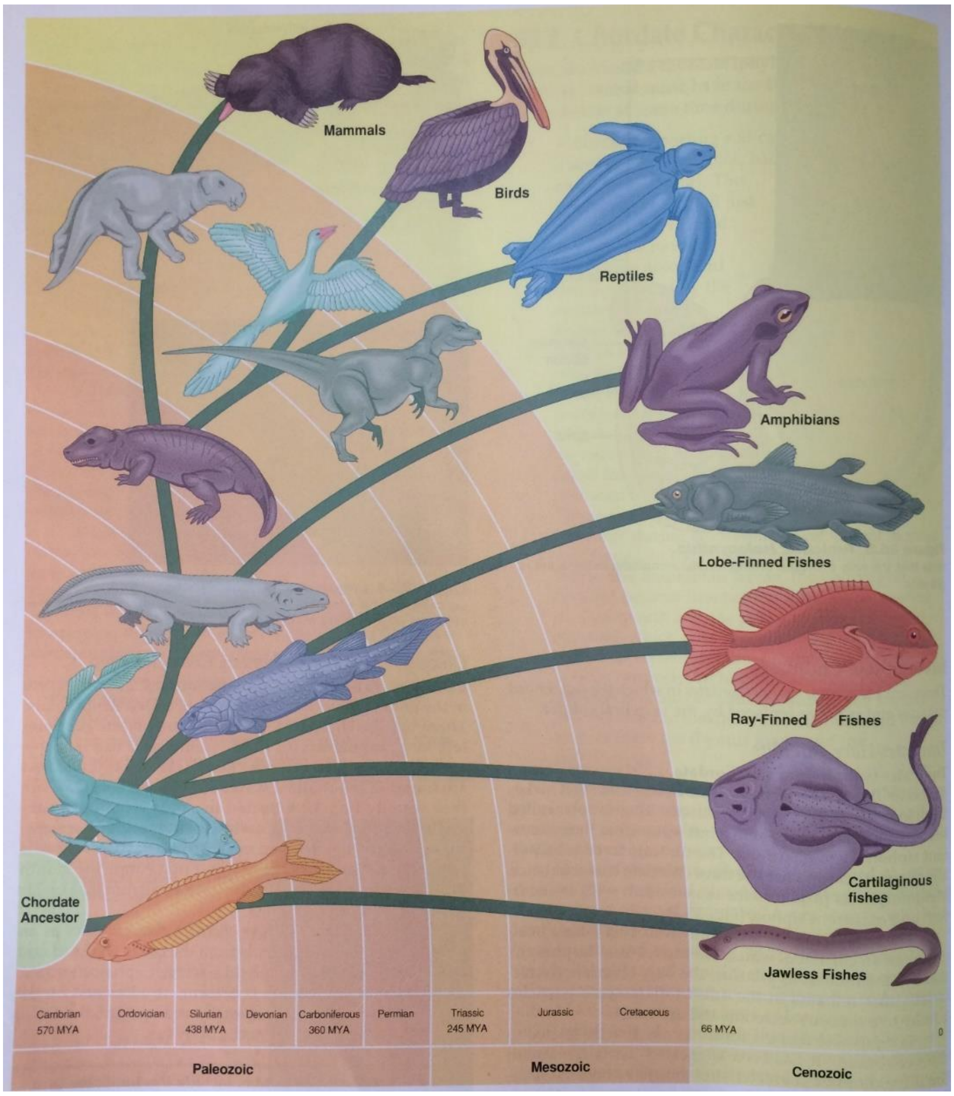


Figure 5.5 Phylogenetic tree of the chordates.
The geological timescale tells when the ancestors to modern-day vertebrates appeared in the fossil record.

The Vertebrate Body Plan Evolves

At some time in their life history, vertebrates (subphylum Vertebrata, 43,700 species) have all three chordate characteristics (notochord, dorsal hollow nerve cord, and pharyngeal pouches). The embryonic notochord, however, is generally replaced by a *vertebral column* composed of individual vertebrae. The vertebral column, which is a part of the flexible but strong endoskeleton, gives evidence that vertebrates are segmented. The vertebrate skeleton (either cartilage or bone) is a living tissue that grows with the animal. It also protects internal organs and serves as a place of attachment for muscles. Together the skeleton and muscles form a system that permits rapid and efficient movement. *Two pairs of appendages* are characteristic. The pectoral and pelvic fins of fish evolved into the jointed appendages that allowed vertebrates to move onto land.

The main axis of the internal jointed skeleton consists of not only the vertebral column, but also a skull that encloses and protects the brain. During vertebrate evolution the brain increased in complexity, and specialized regions developed to carry out specific functions. The high degree of cephalization is accompanied by complex sense organs. The eyes develop as outgrowths of the brain. The ears are primarily equilibrium devices in aquatic vertebrates, but they also function as sound-wave receivers in land vertebrates.

Vertebrates have a complete digestive tract and a large coelom. The circulatory system is closed (the blood is contained entirely within blood vessels). Vertebrates have an efficient means of obtaining oxygen from water or air, as appropriate. The kidneys are important excretory and water-regulating organs that conserve or rid the body of water as necessary. The sexes are generally separate, and reproduction is usually sexual.

Figure 5.5 is a phylogenetic tree that shows the evolution of vertebrates from a chordate ancestor. Vertebrates include fishes, amphibians, reptiles, birds, and mammals.

Vertebrates are distinguished, in particular, by:

- **living endoskeleton**
- **closed circulatory system**
- **paired appendages**
- **efficient respiration and excretion**

- **high degree of cephalization**

In short, vertebrates are adapted to an active lifestyle.

Fishes are aquatic, gill-breathing vertebrates that usually have fins and skin covered with scales. The first vertebrates were fishlike. The larval form of a modern-day lamprey, which looks like a lancelet, may resemble the first vertebrates. It not only has the three chordate characteristics like the tunicate larva, it also has a two-chambered heart, a three-part brain, and other internal organs that are like those of vertebrates. The small, jawless, and finless ostra- coderms are the earliest vertebrate fossils. They were fil- ter feeders, but most likely they were capable of moving water through their gills by muscular action. Ostracoderm fossils have been dated from the Cambrian and as late as the Devonian period, but then they apparently became extinct. Although none of the living jawless fishes has any external protection, large defensive head-shields were not uncommon in the early jawless fishes.

Lampreys and Hagfishes

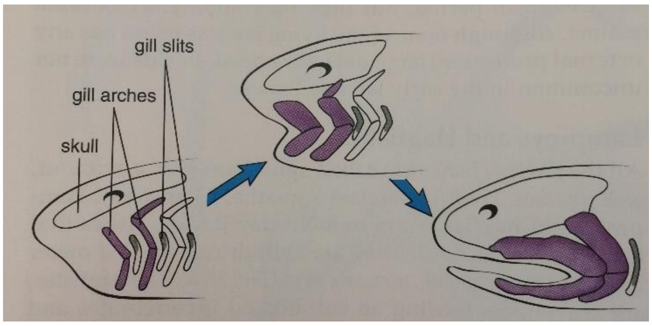
All the jawless fishes are called agnathans [Gk. *a*, without, and *gnathos,* jaw] (superclass Agnatha, 63 species). Lam- preys and hagfishes are modern-day jawless fishes that lack a bony skeleton. They are cylindrical, up to a meter long, and have *smooth*, *nonscaly* skin (Fig. 5.6). The hagfishes are scavengers feeding on soft-bodied invertebrates and dead fishes they suck into their mouths. Many lampreys are filter feeders like their ancestors. Parasitic lampreys have a round, muscular mouth to attach themselves to another fish and suck nutrients from the host's circulatory system. Marine parasitic lampreys gained entrance to the Great Lakes when a canal from the St. Lawrence River was deepened. The lamprey population grew quickly and caused extensive reduction in the trout population of the Great Lakes in the early 1950s.

Figure 5.6 Lamprey, *Petromyzon.*

Note its toothed oral disk attached to aquarium glass. Lampreys, which are members of the vertebrate superclass Agnatha, have an elongated, rounded body and nonscaly skin.

Jaws Evolve

All the other animals to be studied are gnathostomates [Gk. *gnathos*, jaw, and L. *stoma*, mouth] (superclass Gnathostomata, 25,000 species); they have jaws, tooth-bearing bones of the head. Jaws are believed to have evolved from the first pair of gill arches of agnathans. The second pair of gill arches became support structures for the jaws.



The placoderms are well-known extinct jawed fishes of the Devonian period. Placoderms were armored with heavy, bony plates and had strong jaws. Like modern-day fishes, they had paired pectoral and pelvic fins (Fig. 5.7). *Paired fins*, which allow a fish to balance and to maneuver well in the water, are also an asset for predation.

The jawed fishes of today include the cartilaginous fishes and the bony fishes.

Cartilaginous Fishes Include Sharks

Sharks, rays, and skates (class Chondrichthyes, 850 species) are the largely marine cartilaginous fishes; they have a skeleton of cartilage instead of bone. There are five to seven gill slits on both sides of the pharynx, and they lack the gill cover of bony fishes. Their body is covered with epidermal *placoid* (toothlike) *scales* that project posteriorly, which is why a shark's skin feels like sandpaper. The menacing teeth of sharks and their relatives are simply larger, specialized versions of these scales. At any one time, a shark such as the great white shark may have up to 3,000 teeth in its mouth, arranged in six to twenty rows. Only the first row or two are actively used for feeding; the other rows are replacement teeth.

Three well-developed senses enable sharks and rays to detect their prey. They have the ability to sense electric currents in water even those generated by the muscle movements of animals. They have a *lateral line system*, a series of pressure-sensitive cells that lie within canals along both sides of the body, which can sense pressure caused by a fish or other animal swimming nearby. They also have a very keen sense of smell; the part of the brain associated with this sense is very well developed. Sharks can detect about one drop of blood in 115 liters (25 gallons) of water.

The largest sharks are filter feeders, not predators. The basking sharks and whale sharks ingest tons of small crustacea, collectively called krill. Many sharks are fast-swimming predators in the open sea. The great white shark, about 7 meters (23 feet) in length, feeds regularly on dolphins, sea lions, and other seals. Humans are normally not attacked except when mistaken for sharks' usual prey. Tiger sharks, so named because the young have dark bands, reach 6 meters (18 feet) in length and are unquestionably one of the most dangerous sharks. As it swims through the water, a tiger shark will swallow anything it can including rolls of tar paper, shoes, gasoline cans, paint cans, and even human parts.

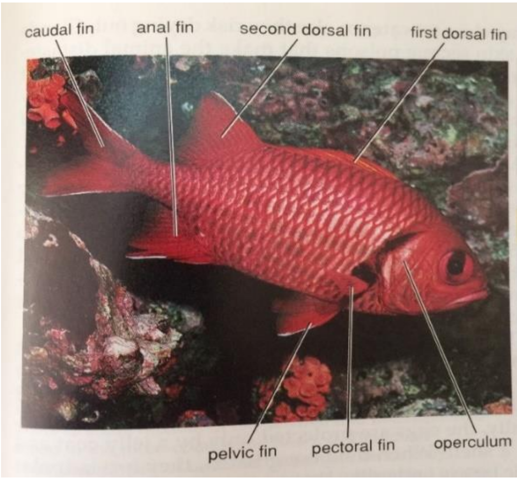
In rays and skates (see cartilaginous fishes, Fig. 5.5), which live on the ocean floor, the pectoral fins are greatly enlarged into a pair of large, wing like fins. They usually swim slowly along the sea bottom and feed on animals that they dredge up. Stingrays of the genus *Raja* have a tail modified into a defensive lash—the dorsal fin persists as a venomous spine. Members of the electric ray family are slow swimmers that feed on fishes they capture after stunning them with electric shocks. Their large electric organs, located at the bases of their pectoral fins, can discharge over 300 volts. Sawfish rays are named for their large, protruding anterior "saw." Swimming into a school of fishes, they rapidly move their saw back and forth, stunning or killing fish which they later eat.

Bony Fishes Are Most Numerous of Vertebrates

Bony fishes (class Osteichthyes, 20,000 species) have a skeleton of bone. Most bony fishes are ray-finned fishes in which fan-shaped fins are supported by thin, bony rays. The lobe- finned fishes, a very small group of bony fishes, are important because lobe-finned fishes of the Devonian period are ancestral to amphibians.

Ray-Finned Fishes Include Familiar Fishes The ray-finned fishes are the most successful and diverse of all the vertebrates. Some, like herrings, are filter feeders; others, like trout, are opportunists; and still others are predaceous carnivores, like the piranhas and barracudas. Often the com- mon names of fishes reflect their appearance. Zebra fish are striped, stonefish resemble stones, sea horses look like tiny upright horses, and porcupine fish (when inflated) are protected by lateral spikes.

Despite their diversity, bony fishes have features in common (Fig. 5.7). The skeleton is of bone and they are covered by *scales* formed *of bone*. The gills do not open separately and instead are covered by an *operculum*. They have a swim bladder, a gas-filled sac whose pressure can be altered to change buoyancy and, therefore, their depth in the water. Some fishes (trout, salmon, eels) can move from fresh water to salt water. When in fresh water, their kidneys excrete very dilute urine and their gills absorb salts from the water by active transport.



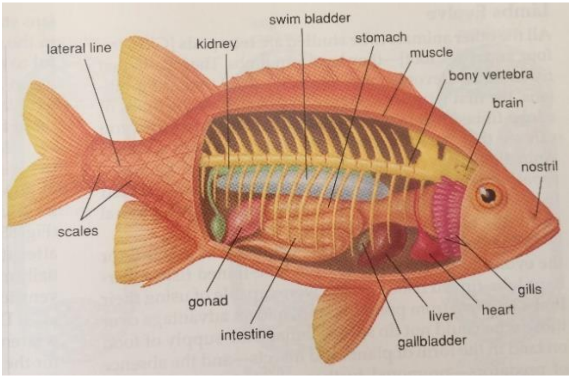


Figure 5.7 Ray-finned fish, *Myripristis.*

External and internal anatomy of a ray-finned fish, commonly called a soldierfish.

Bony fishes depend on color vision to detect both rivals and mates. Usually eggs and sperm are shed in the water or into a nest constructed by the parents. In almost all bony fishes, fertilization and embryo development occur outside the female's body.

Lobe-Finned Fishes In lob e-finned fishes, the fleshy fins are supported by central bones. They include six species of lung- fishes with lungs and one species of coelacanth with especially noticeable lobes (Fig. 5.8). *Lungfishes* live in Africa, South America, and Australia either in stagnant fresh water or in ponds that dry up annually. *Coelacanths*, in contrast, inhabit deep ocean environments. Because only Mesozoic fossils of these fishes had been found, it was once thought that coelacanths were extinct. Then one was captured off the eastern coast of South Africa in 1938, and now about 200 more have been captured. Comparisons of mitochondrial DNA suggest that lungfishes, and not coelacanths, are the closest living relatives of modern amphibians.

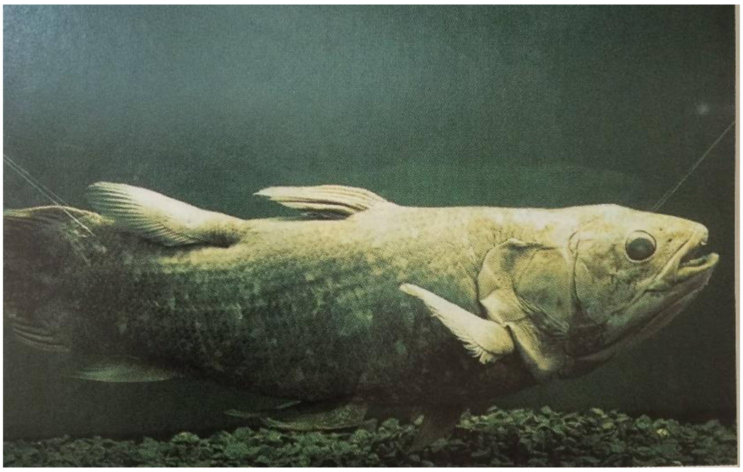


Figure 5.8 Lobe-finned fishes.

The coelacanth, *Latimeria*, is a living fossil - the only survivor of a line once thought extinct.

The cartilaginous and bony fishes are characterized by (jaws, paried appendages and scales).

Limbs Evolve

All the other animals to be studied are tetrapods [Gk. *tetra*, four, and *podos*, foot] they have four limbs. The lobe-finned fishes of the Devonian period are ancestral to the amphibians, the first tetrapods. Figure 5.9 compares the limbs of a lobe-finned fish to those of an early amphibian, and you can see that the same bones are present in both animals. Animals that live on land use limbs to support the body, especially since air is less buoyant than water. Lobe-finned fishes and early amphibians also had lungs and internal nares as a means to respire air.

Two hypotheses have been suggested to account for the evolution of amphibians from lobe-finned fishes. Perhaps lobe-finned fishes, which were capable of using their limbs to move from pond to pond, had an advantage over those who could not do so. Or perhaps the supply of food on land in the form of plants and insects and the absence of predators promoted further adaptations to the land environment. In any case, the first amphibians diversified during the Carboniferous period, which is known as the Age of Amphibians.

Amphibians

Aside from presence of limbs and appropriate modifications of the girdles, amphibians have other features not seen in bony fishes. Amphibians [Gk. *amphibios*, living on both land and in water] (class Amphibia, 3,900 species) have a tongue for catching prey, eyelids for keeping eyes moist, ears adapted to picking up sound waves, and a voice-producing larynx. The brain is larger than that of a fish and the **cerebral cortex** is more developed.

The *smooth, nonscaly skin* of an amphibian is kept moist by numerous mucous glands. It plays an active role in water balance and respiration and can also help in temperature regulation when on land, through evaporative cooling. A thin, moist skin does mean, however, that most amphibians stay close to water or else they risk drying out. Glands in the skin secrete poisons that make the animal distasteful to eat. Some tropical species with brilliant fluorescent green and red coloration are particularly poisonous. Colombian Indians dip their darts in the deadly secretions of these frogs, aptly called dart-poison frogs.

Amphibians usually have lungs, but they are relatively small and respiration is supplemented by exchange of gases across the porous skin. The single-loop circulatory path of the fish has been replaced by a double loop (Fig. 5.10); a *three-chambered heart* pumps blood before and after it has gone to the lungs. Oxygenated blood is partially mixed with deoxygenated blood, however, in the single ventricle (lower chamber of the heart).

The class name, Amphibia, means "on both sides," a reference to the fact that most amphibians return to water for the purpose of reproduction. They shed their eggs and sperm into the water, where external fertilization takes place. Generally, the eggs are protected only by a jelly coat and not by a shell. When the young hatch, they are tadpoles (aquatic larvae with gills) that feed and grow in the water. After they undergo a metamorphosis, amphibians emerge from the water as adults that breathe air (Fig.5.11). Some amphibians, however, have evolved mechanisms that allow them to reproduce on land.

Amphibians are ectothermic [Gk. *ekto*, outer, and *therme*, heat]; they depend on the environment to regulate their body temperature. During winters in the temperate zone, they become inactive and enter *torpor*. The European common frog can survive even if the temperature drops to -6°C.

Among the amphibians are frogs, toads, salamanders, and newts. The salamanders and newts have an elongated body, with a long tail and usually two pairs of legs. Because their legs are set at right angles to the body, they resemble more closely the earliest fossil amphibians.

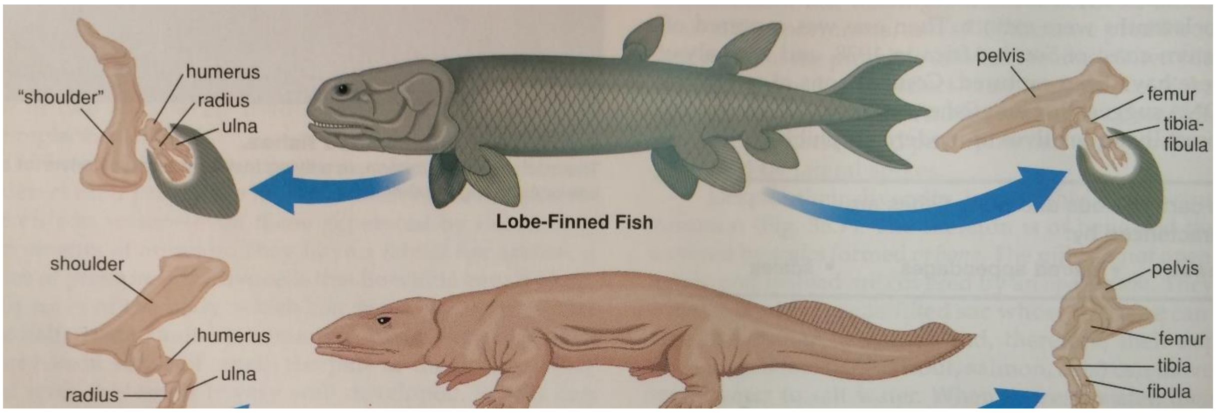


Figure 5.9 Lobe-finned fish versus amphibian

The drawings show similarities in skeletal structure of the appendages of a lobe-finned fish and an ancestral amphibian

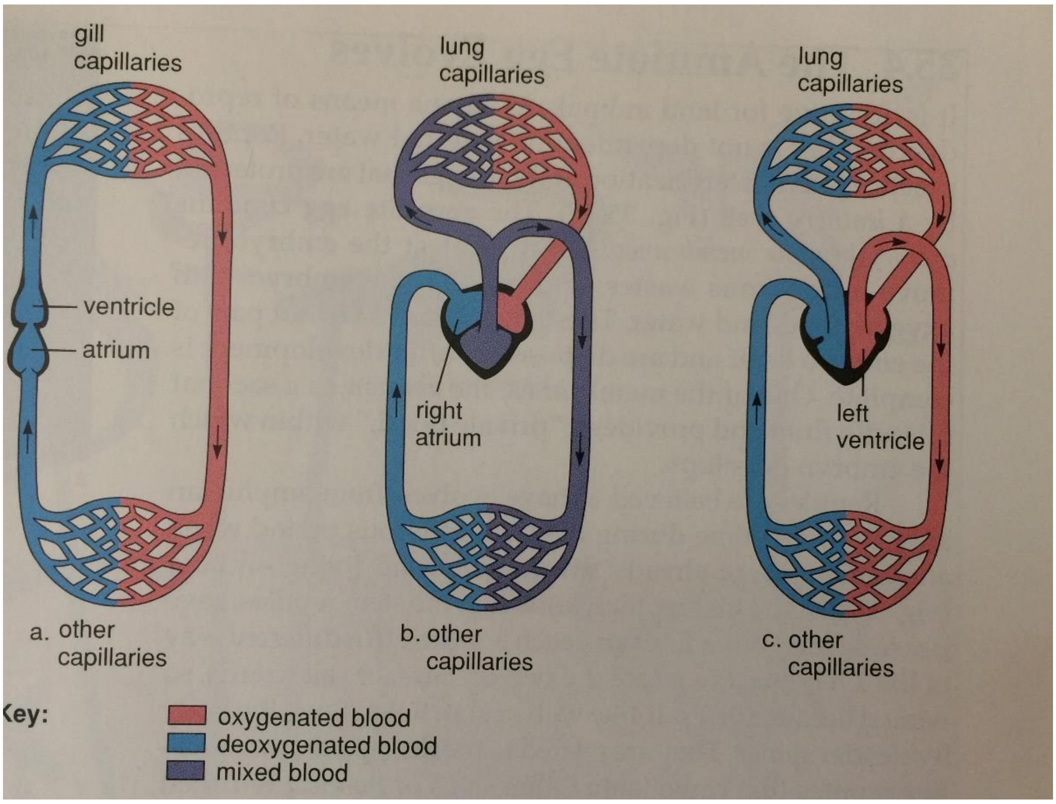


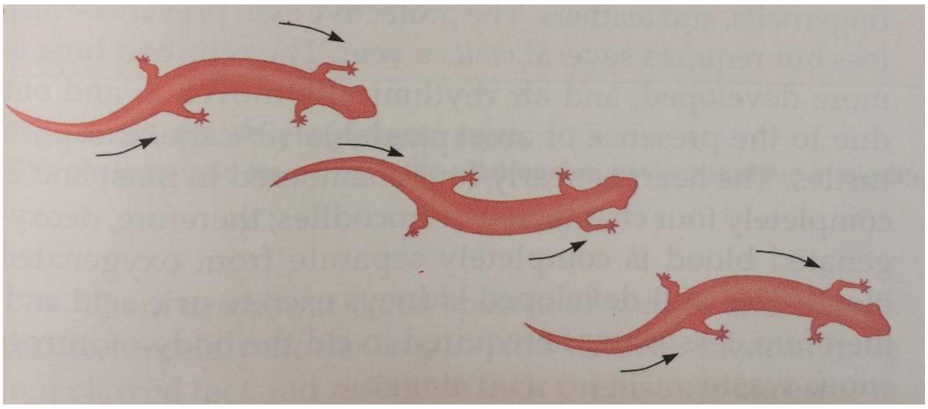
Figure 5.10 Vertebrate circulatory systems

a. The single-loop system of fishes utilizes a two- chambered heart, b. The double-loop system of amphibians sends blood to the lungs and to the body. There is some mixture of oxygenated and deoxygenated blood in the three-chambered heart, c. The four- chambered heart of birds and mammals sends only deoxygenated blood to the lungs and oxygenated blood to the body.

Figure 5.11 Frog metamorphosis

During metamorphosis the animal changes from an aquatic to a terrestrial organism

locomote like a fish, with side-to-side sinusoidal (S-shaped) movements:



Both salamanders and newts are carnivorous, feeding on small invertebrates such as insects, slugs, snails, and worms. Salamanders practice internal fertilization; in most, males produce a sperm-containing *spermatophore* that females pick up with the cloaca (the common receptacle for the urinary, genital, and digestive canals). Then the eggs are laid in water or on land, depending on the species. Some amphibians, such as the mudpuppy of eastern North America, remain in the water and retain the gills of the larva.

Frogs and toads are the tailless amphibians. In these animals, the head and trunk are fused and the hind limbs are specialized for jumping. Numerous muscles are located in the limbs as well as the trunk. Frogs have smooth skin and long legs, and they live in or near fresh water; toads have stout bodies and warty skin, and they live in dark, damp places away from the water.

The Amniote Egg Evolves

It is adaptive for land animals to have a means of reproduction that is not dependent on external water. Reptiles practice internal fertilization and lay eggs that are protected by a *leathery shell* (Fig. 5.12). The amniote egg contains *extraembryonic membranes*, which protect the embryo, remove nitrogenous wastes, and provide the embryo with oxygen, food, and water. These membranes are not part of the embryo itself and are disposed of after development is complete. One of the membranes, the *amnion*, is a sac that fills with fluid and provides a "private pond" within which the embryo develops.

Reptiles are believed to have evolved from amphibian ancestors sometime during the Carboniferous period when amphibians were already diversifying and living on land (Fig. 5.13). The first reptiles, known as the stem reptiles, gave rise to several other lineages, each adapted to a different way of life. Of interest to us are the pelycosaurs, or sail lizards, so named because of a sail-like web of skin held above the body by slender spines. They are related to the therapsids, mammal like reptiles that came later. Other lines of descent returned to the aquatic environment; one marine reptile (ichthyosaurs) of the Mesozoic era was fishlike while another (plesiosaurs) had a long neck and large rowing paddles for limbs. Reptiles known as the codonts gave rise to most of the reptiles, living and extinct. The flying reptiles (pterosaurs) of the Mesozoic era had a keel for the attachment of large flight muscles and air spaces in their bones to reduce weight. Their wings were membranous and supported by elongated bones of the fourth finger. Then there were the "ruling reptiles," as the dinosaurs are sometimes called. The dinosaurs were varied in size and behavior but are well remembered for the great size of some. *Brachiosaurus,* a herbivore, was about 23 meters (75 feet) long and about 17 meters (56 feet) tall. *Tyrannosaurus rex*, a carnivore, was 5 meters (16 feet) tall when standing on its hind legs. A bipedal stance frees the forelimbs for seizing prey or fighting off predators. It is also pre adaptive for the evolution of wings: birds are descended from dinosaurs in fact some say birds are actually living dinosaurs.

The dinosaurs and mammal like reptiles did not sprawl; the limbs supported the body from underneath, providing increased agility and swiftness that otherwise would not be possible. The amniote egg and improved locomotion were both adaptive for surviving on land.

Reptiles dominated the earth for about 170 million years during the Mesozoic era and then most died out. What could have caused the mass extinction that occurred at the end of the Cretaceous period? The answer is not known, but recently a layer of the mineral iridium, which is rare on earth but common in meteorites, has been found in rocks of that age. The impact of a large meteorite could have set off earthquakes and fires, raising enough dust to block out the sun. Death of most plants and animals would have followed. Such a scenario has been proposed by Luis and Walter Alvarez and several others who are still gathering evidence to support their hypothesis.

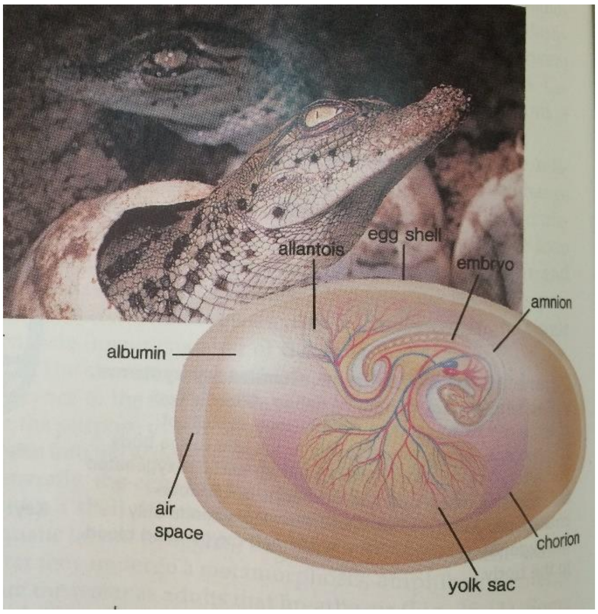


Figure 5.12 Reptilian egg.

- ***a-*** ***Baby American crocodile, Crocodylus, hatching out of its shell. The shell is leathery and flexible, not brittle like birds' eggs.***
- ***b-*** ***Inside the egg, the embryo is surrounded by membrances. The chorion aids gas exchange, the yolk sac provides nutrients, the allantois stores waste, and the amnion encloses a fluid that prevents drying out and provides protection.***

Reptiles

Most reptiles [L. *reptile,* snake] (class Reptilia, 6,000 species) today live in the tropics or subtropics. Among reptiles are lizards and snakes that usually live on or in the soil, and turtles, crocodiles, and alligators that live in the water.

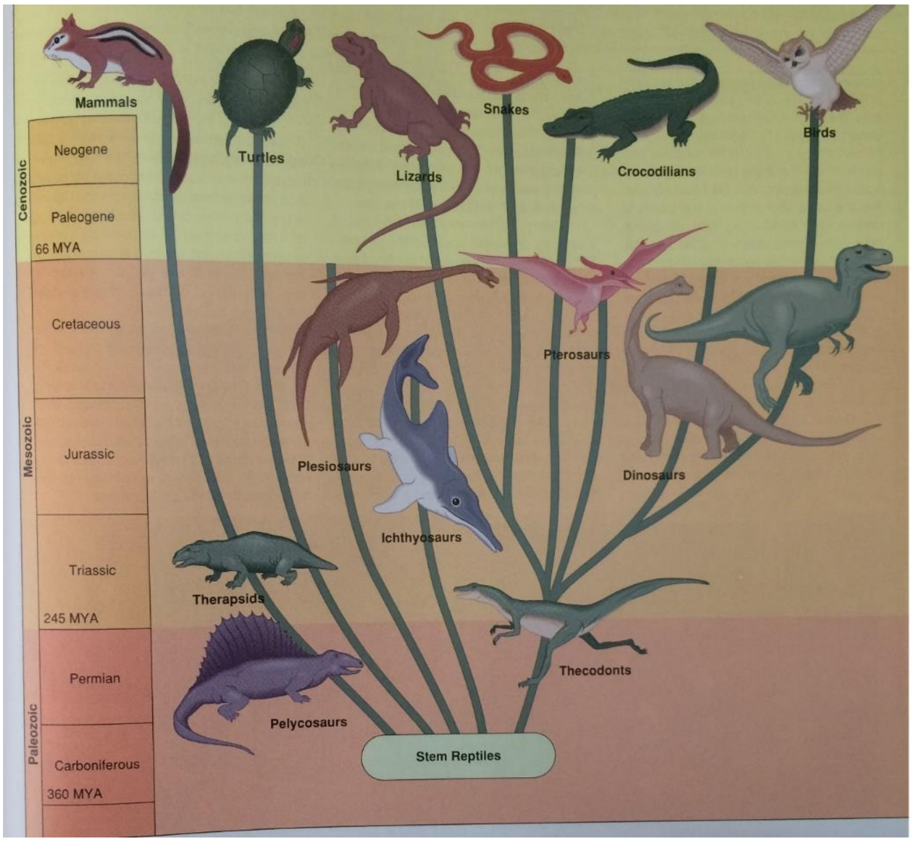


Figure 5.13 Phylogenetic tree.
This phylogenetic tree shows the relationship among reptiles (including the dinosaurs), birds, and mammals

Reptiles have a thick, *scaly skin* that is keratinized and impermeable to water. Keratin is the protein found in hair, fingernails, and feathers. The protective skin prevents water loss but requires several *molts* a year. The reptilian lung is more developed, and air rhythmically moves in and out due to the presence of an expandable rib cage, except in turtles. The heart is nearly four chambered in most and is completely four chambered in crocodiles; therefore, deoxygenated blood is completely separate from oxygenated blood. The well-developed kidneys excrete uric acid and, therefore, less water is required to rid the body of nitrogenous waste.

Reptiles, like amphibians, are *ectothermic*. This feature allows them to survive on a fraction of the food per body weight required by birds and mammals. Still, they are adapted behaviorally to maintain a warm body temperature by warming themselves in the sun.

There are about 6,000 species of snakes and lizards that live mainly in the tropics and deserts. Lizards have four clawed feet and resemble their prehistoric ancestor in appearance. They are carnivorous and feed on insects and small animals, including other lizards. Marine iguanas of the Galapagos Islands are adapted to spend long periods of time at sea where they feed on sea lettuce and other marine vegetation. Chameleons are adapted to live in trees and have long, sticky tongues for catching insects some distance away. They can change color in order to blend in with their background. Other lizards use different means to avoid being eaten. An Australian frilled lizard erects a collar of skin about its neck, which greatly increases its apparent size and makes it look frightening. Worm lizards have adapted a subterranean life and look somewhat like an earthworm, since they lack legs and are blind.

Turtles have a heavy shell to which the ribs and thoracic vertebrae are fused. They lack teeth but have a sharp beak. Most turtles spend some time in water. Sea turtles leave the ocean only to lay their eggs. Their legs are flattened and paddle like, while tortoises, which are usually terrestrial, have strong legs for walking. Crocodiles and alligators lead a largely aquatic life, feeding on fishes, turtles, and terrestrial animals that venture close enough to be caught (Fig. 5.14).

They have long, powerful jaws with numerous teeth and a muscular tail that serves as both a weapon and a paddle. Although other reptiles are voiceless, male crocodiles and alligators bellow to attract mates. In some species, the male protects the eggs and cares for the young.

These features, in particular, distinguish reptiles:

- **usually tetrapods**
- **lungs with expandable rib cage**
- **shelled egg**
- **dry, scaly skin**.

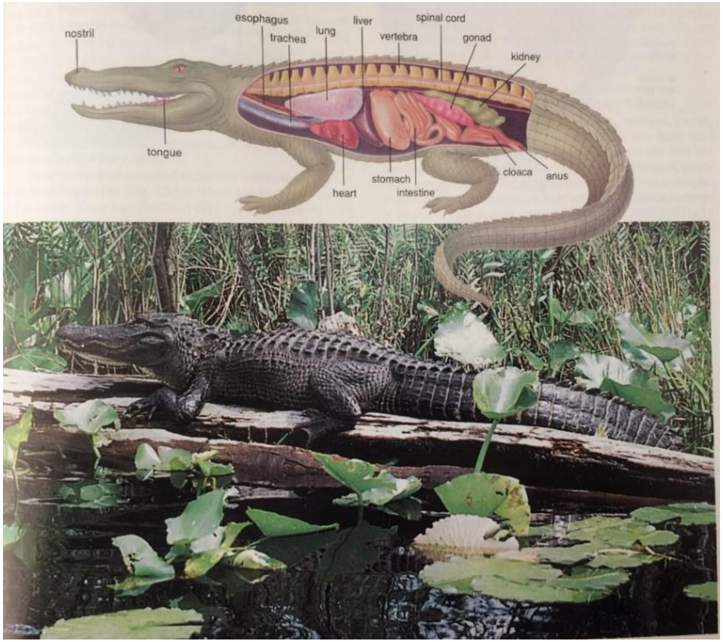


Figure 5.14 American alligator, *Alligator*

Figure. 5.15 Bird anatomy.

a. Birds have a large, keeled breastbone (sternum) to which flight muscles attach. Bird bones are strong but weigh very little because of the air cavities they contain. In feathers, a hollow central shaft gives off barbs and barbules, which interlock in a lattice like array, b. Among living vertebrates, only birds and bats rely on true flight they fly by flapping their wings. Bird flight requires an airstream and a powerful wing down stroke for lift, a force at right angles to the airstream.

Wings and Feathers Evolve

Today's birds lack teeth and have only a vestigial tail, but they still retain many reptilian features such as the shape of the body, scales on their legs, claws on their toes, and a horny beak. They also lay amniotic eggs, although the *shell is hard* rather than leathery. The exact ancestry of birds is in dispute, but there are those who contend that birds are closely related to bipedal dinosaurs and that they should be classified as such.

Birds Have Feathers

Birds (class Aves, 9,000 species) are the only modern animals to have **feathers,** which are actually modified reptilian scales. Bird feathers are of two types. *Contour feathers* cover the body, and those attached to the wings (called flight feathers) overlap to produce a broad, flat surface beneficial for flight. *Down feathers* provide excellent insulation against body heat loss. This is important because birds are **homeo thermic** [Gk. *homoios*, like, and *therme*, heat]; they maintain a constant, relatively high body temperature, which permits them to be continuously active even in cold weather. Perhaps feathers first provided insulation and then became adapted for flight.

Nearly every anatomical feature of birds can be related to their ability to fly (Fig.5.15). Their forelimbs are modified as *wings.* They have hollow, very light bones laced with air cavities. A horny *beak* has replaced jaws equipped with teeth, and a slender neck connects the head to a rounded, compact torso. The breastbone is enlarged and has a *keel,* to which the strong muscles are attached for flying. Oxygen delivery to these muscles is efficient; there is no dead space in the lungs because air flows one way through the air sacs and the lungs, and the double-loop circulation is improved because the *four-chambered heart* keeps oxygenated blood separated from deoxygenated blood.

Flight requires well-developed sense organs and nervous system. Birds have particularly acute vision and excellent muscle reflexes. Because birds can fly, they migrate and exploit food sources in widely separated habitats. Complex hormonal regulation and behavior responses are in-volved in bird behavior, which also includes caring for fledglings until they are independent.

Classification of birds is particularly based on beak and foot types, and to some extent on habitat and behavior. The various orders include birds of prey with notched beaks and sharp talons; shorebirds with long, slender, probing bills and long, stilt like legs; woodpeckers with sharp, chisel-like bills and grasping feet; waterfowl with webbed toes and broad bills; penguins with wings modified as paddles; and songbirds with perching feet.

Homeo thermy Pays Off

Mammals evolved during the Mesozoic era from therapsids, the mammal-like reptiles. The mammalian skull accommodates a larger brain relative to body size than does the reptilian skull; mammalian cheek teeth are differentiated as premolars and molars; their vertebrae are highly differentiated and the middle region of the backbone is arched, providing more effective movement on land. True mammals appeared during the Jurassic period, about the same time as the first dinosaurs. These first mammals were small, about the size of mice. All the time the dinosaurs flourished (165 million years), mammals were a minor group that changed little. Some of the earliest mammalian groups, represented today by the mono tremes and marsupials, are not abundant today. The placental mammals that evolved later went on to occupy the many habitats previously occupied by the dinosaurs.

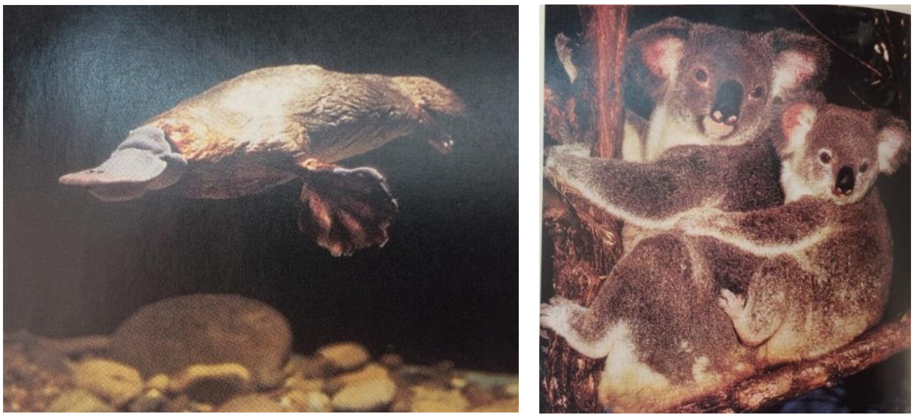
Mammals Have Hair and Mammary Glands

The chief characteristics of **mammals** [L. *mamma*, breast, teat] (class Mammalia, 4,500 species) are hair and milk-producing mammary glands. Mammals are also homeo thermic, as are birds. Many of the adaptations of mammals are related to temperature control. *Hair*, for example, provides insulation against heat loss and allows mammals to be active even in cold weather. Like birds, mammals have efficient respiratory and circulatory systems, which assure a ready oxygen supply to muscles whose contraction produces body heat. Like birds, mammals have a double-loop circulation and a *four-chambered heart.*

Mammary glands enable females to feed (nurse) their young without deserting them to find food. Nursing also creates a bond between mother and offspring that helps ensure parental care while the young are helpless. In most mammals, the young are born alive after a period of development in the uterus, a part of the female reproductive tract. Internal development shelters the young and allows the female to move actively about while the young are maturing. Mammals are classified according to means of reproduction.

Mammals That Lay Eggs

Monotremes [Gk. *monos*, one, and *trema*, hole], mammals that have a cloaca and lay hard-shelled amniote eggs, are represented by the duckbill platypus and the spiny ant- eater, both of which are found in Australia (Fig. 5.16*a)*. The female duckbill platypus lays her eggs in a burrow in the ground. She incubates the eggs and, after hatching, the young lick up milk that seeps from modified sweat glands on the abdomen of both males and females. The spiny anteater has a pouch on the belly side formed by swollen mammary glands and longitudinal muscle. The egg moves from the cloaca to this pouch where hatching takes place, and the young remain for about 53 days. Then they stay in a burrow, where the mother periodically visits and nurses them.



a. Duckbill platypus, Ornithorhynchus ***b. Koala , Phascolarctos***

Figure 5.16 Types of mammals.

The duckbill platypus is a monotreme, which lays shelled eggs. The koala is a marsupial, whose young are born immature and complete their development within the mother's pouch, c. The while tailed deer is a placental mammal, whose young develop within a uterus.

Mammals That Have Pouches

The young of marsupials [Gk. *marsupium,* pouch] begin their development inside the female's body, but they are born in a very immature condition. Newborns crawl up into a *pouch* on their mother's abdomen. Inside the pouch, they attach to nipples of mammary glands and continue to develop. Frequently, more are born than can be accommodated by the number of nipples, and it's "first come, first served."

Today, marsupial mammals are found mainly in Australia; only a few marsupials, such as the American opossum, are found outside that continent. In Australia, marsupials underwent adaptive radiation for several million years without competition from placental mammals, which arrived there only recently. Among the herbivorous marsupials, koalas are tree-climbing browsers (Fig. *5.16b)* and kangaroos are grazers. The Tasmanian wolf or tiger, thought to be extinct, was a carnivorous marsupial about the size of a collie dog.

Mammals That Have Placentas

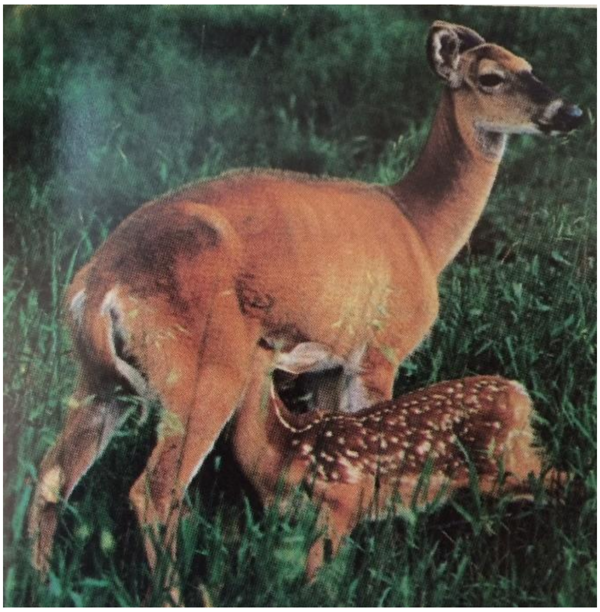
Developing placental mammals are dependent on the placenta, an organ of exchange between maternal blood and fetal blood. Nutrients are supplied to the growing offspring, and wastes are passed to the mother for excretion. While the fetus is clearly parasitic on the female, in exchange, she is free to move about as she chooses while the fetus develops. The young are born at a relatively advanced stage of development.

Placental mammals lead an active life. The senses are acute and the brain is enlarged due to the expansion of the foremost part the cerebral hemispheres. These have become convoluted and have expanded to such a degree that they hide many other parts of the brain from view. The brain is not fully developed for some time after birth, and there is a *long period of* *dependency* on the parents, during which the young learn to take care of themselves.

Placental mammals populate all continents except Antarctica. Most mammals live on land, but some (e.g., whales, dolphins, seals, sea lions, manatees) are secondarily adapted to live in water, and bats are able to fly. Classification is primarily based on mode of locomotion and methods of obtaining food. The following are some of the major orders of mammals:

Order Chiroptera (925 species) includes the nocturnal bats whose wings consist of two layers of skin and connective tissue stretched between the elongated bones of all fingers but the first. Many species use echolocation to locate their usual insect prey. But there are also bird-, fish-, frog-, and plant-eating bats. Order Primates (180 species) includes lemurs, monkeys, gibbons, chimpanzees, gorillas, and humans. Typically, primates are tree-dwelling fruit eaters although some, like humans, are ground dwellers. They all have a freely movable head, they have five digits with nails (not claws), and the thumb in many (sometimes the large toe) is opposable. Primates, especially humans, are well known for their well-developed brains.

Order Rodentia (1,760 species), the largest order, includes mice, rats, squirrels, beavers, and porcupines. Rodents have incisors that grow continuously. They usually feed on seeds but some are omnivorous and some eat mainly insects.



c. White- tailed deer, Odocoileus

Order Cetacea (80 species) includes the whales and dolphins, which are mammals despite their lack of hair or fur. Blue whales, the largest animal ever to have lived on this planet, are baleen whales that feed by straining large quantities of water containing plankton. Toothed whales feed mainly on fish and squid.

Order Carnivora (270 species) includes dogs, cats, bears, raccoons, and skunks. All these animals have limbs adapted for running and have a well-developed sense of smell. The canines of meat eaters are large and conical. There are some aquatic carnivores namely seals, sea lions, and walruses which must return to land to reproduce.

Order Proboscidea (2 species) includes the elephants, the largest living land mammals. The upper lip and nose have become elongated and muscularized to form a trunk.

The hoofed mammals include the orders Perissodactyla (e.g., horses, zebras, tapirs, rhinoceroses, 17 species) and the Artiodactyla (e.g., pigs, cattle, deer, hippopotami, buffaloes, giraffes, 185 species) whose elongated limbs are adapted for running across open grasslands. Both groups of animals are herbivorous and have large grinding teeth.

Order Lagomorpha (65 species) includes the herbivorous rabbits, hares, and pikas animals that superficially resemble rodents. They also have two pairs of continually growing incisors, and their hind legs are longer than their front legs.

These features, in particular, distinguish placental mammals:

- body hair
- differentiated teeth
- well-developed brain
- infant dependency
- mammary glands
- homeothermic
- internal development

CHAPTER SIX
HUMAN EVOLUTION

6.1 Humans Are Primates

The evolutionary principle of descent with modification applies to every group of organisms, including human beings. It could be argued that the evolution of humans, like that of all living things, begins with the very first ’cell (or cells). But specifically, as Our evolutionary history begins in the Cambrian period of the Paleozoic era (Fig. 6.1). Vertebrates (animals with a backbone) arose soon after invertebrates (animals without a backbone) during this era. Fishes, the first vertebrates to evolve, have had a long and successful history. They still dominate the seas today.

The insects (invertebrates) were among the first animals to live on land, and their variety outstrips all living known. Among vertebrates, the amphibians and then the reptiles held sway on land. Mammals [L mamma, breast, teat] (animals that have hair and mammary glands) evolved from the mammal-like reptiles by the Triassic period of the Mesozoic era. Mammals remained small and insignificant while the dinosaurs dominated the land for over 150 million years. Extinction of’ the dinosaurs marked the end of (the Mesozoic era, and then mammals diversified into many groups during the Cenozoic era. Today, there are mammals adapted to living on land, in the water, and in the air.

The dependence of animals upon plants is consistent with the observation that plants invaded land before any group of animals. Angiosperms, which include most trees, evolved at the same time as mammals. Angiosperms are the flowering plants that produce fruits, and **primates** [L. primus, first]—mammals adapted to living in trees—often used fruits as a central part of their diet. Many human characteristics are explainable on the basis of adaptation to an arboreal (tree-dwelling) life.

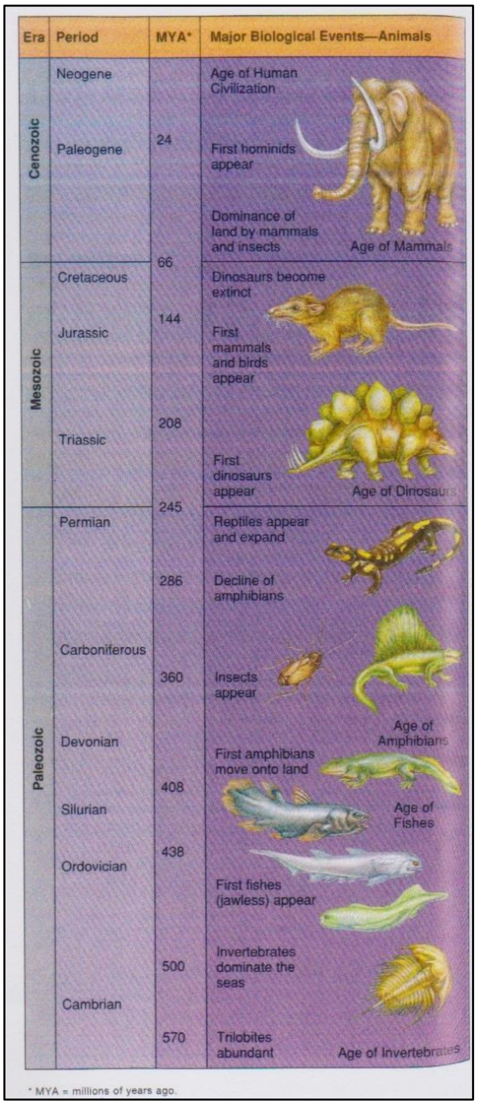


Figure 6.1 Animal evolution.
An abbreviated geological timescale showing some major evolutionary events of animal.

What Are Primate Characteristics?

Primate limbs are mobile, as are the hands, because the thumb (and in nonhuman primates, the big toe as well) is opposable; that is, the thumb can touch each of the other fingers. Therefore, a primate can easily reach out and bring food such as fruit to the mouth. When locomoting, tree limbs can be grasped and released freely because nails have replaced claws.

The sense of smell is of primary importance in animals with a snout. In primates, the snout is shortened considerably, allowing the eyes to move to the front of the head. The stereoscopic vision (or depth perception) that results permits primates to make accurate judgments about the distance and position of adjoining tree limbs.

Gestation is lengthy, allowing time for good forebrain development; the visual portion of the brain is proportionately large, as are those centers responsible for hearing and touch. One birth at a time is the norm in primates; it is difficult to care for several offspring while moving from limb to limb. The juvenile period of dependency is extended, and there is an emphasis on learned behavior and complex social interactions.

6.2 Primates Are Diverse

The primate order contains two suborders: prosimians and anthropoids.

Prosimians Came First

Among living primates, the prosimians (suborder Prosimii) [L. pro, before, and simia, ape; monkey] best resemble the first primates (Fig. 6.2). Tarsiers, which are found in the Philippines and East Indies, are curious, mouse-sized creatures with enormous eyes suitable to their nocturnal way of life. Tarsiers are insectivorous, and it's believed that primates may have evolved from mammals that first climbed into the trees to feed on insects. Lemurs, which have a squirrel-like appearance, are confined largely to the island of Madagascar. They feed on plant material, including fruits. Lorises, which are prosimians living in both Africa and Asia, resemble lemurs.

a. Tatonius | *b.* **Mindano tarsier,** ***Tarsius*** | *c.* **Dwarf lemur,** ***Cheirogaleus***

Figure 6.2 Prosimians.
a. The Hypothesized Eocene primate Tetonius was small but agile and adapted to eating insects. b. Tarsiers are vertical clingers and leapers. The enormous eyes allow the tarsier to judge a safe landing even at night. c. There are over 40 species of lemurs on the island of Madagascar. The dwarf lemurs are particularly widespread.

Anthropoids Followed

Figure 6.3 shows the sequence of anthropoid evolution during the Cenozoic era. The surviving anthropoids (suborder Anthropoidea) [Gk anthropos, man, and -eides, like] are classified into three super families: New World monkeys (Ceboidea), Old World monkeys (Cercopithecoidea), and the hominoids (Hominoidea). The New World monkeys often have long prehensile (grasping) tails and flat noses, and Old-World monkeys, which lack such tails, have protruding noses. Two of the well-known New World monkeys are the spider monkey and the capuchin, the "organ grinder’s" monkey. Some of the better-known Old-World monkeys are now ground dwellers, such as the baboon and the rhesus monkey, which has been used in medical research. The hominoids [L. homo, man, and Gk. -eides, like] include all the apes and humans.

Primates flourished in the forests of northern continents during the Paleocene and Eocene epochs of the Cenozoic era (Fig. 6.3). But as these continents drifted slowly northward, the weather cooled and primates migrated southward. A group of early primates reached South America possibly by crossing the then-narrow Atlantic and evolved there into the New World monkeys. This means that New World monkeys are not more closely related to Old World monkeys than they are to apes.

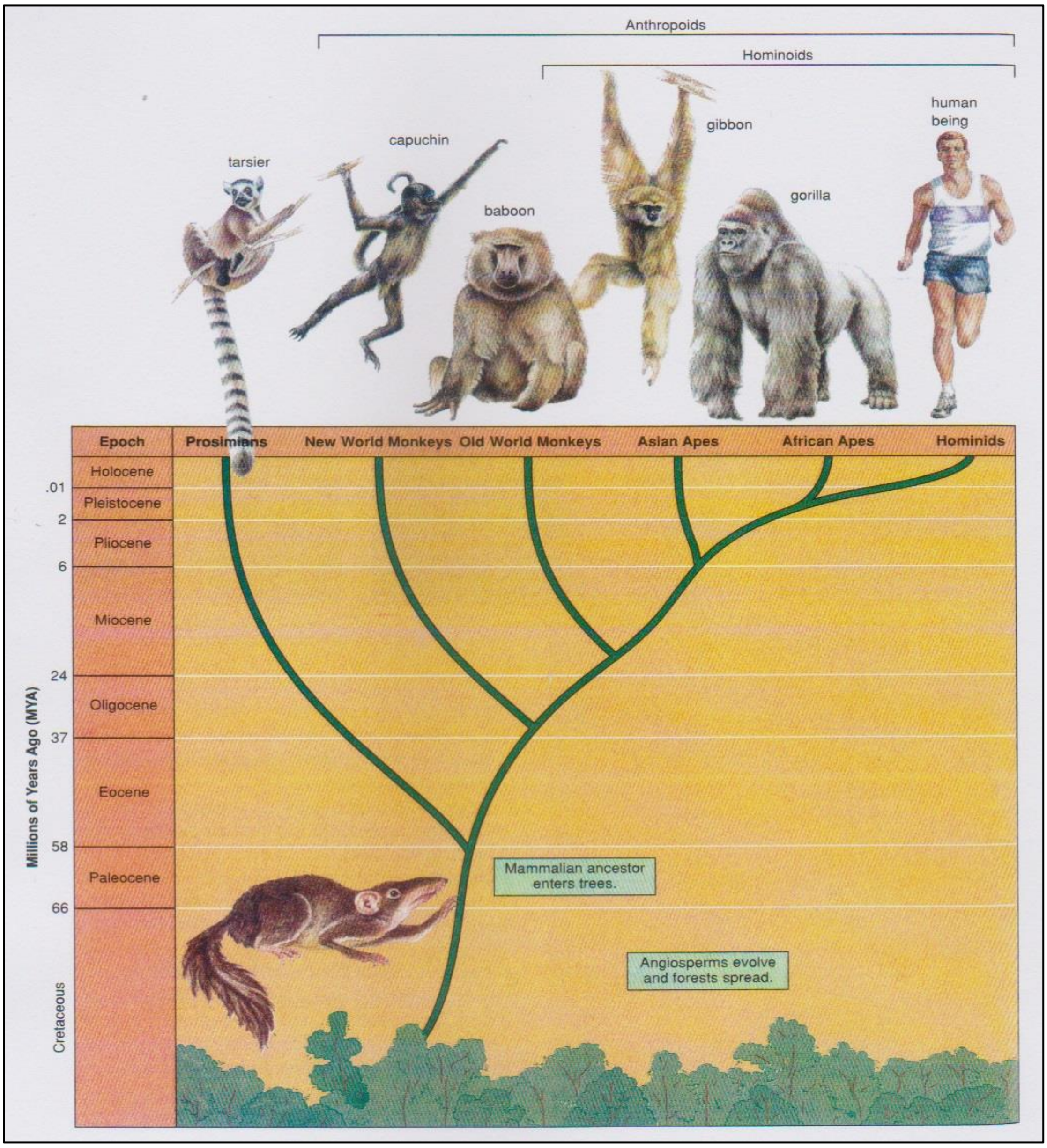


Figure 6.3 Primate Evolution

In Africa, the ancestors of Old World monkeys and of hominoids were most likely four-limbed tree-climbers who fed on fruit. Sometime in the Miocene epoch, the monkeys adapted a more fibrous diet of leaves and diverged from the main line of descent. The hominoids, the more abundant group that fed on fruit, are well represented by apelike forms of that time. The anatomy of Proconsul is sufficiently primitive to be ancestral to all apes and humans (Fig. 6.4). These hominoids were about the size of a baboon, and the brain was a comparable size at about 165 cc. Their general anatomy seems similar to an Old-World monkey also. Although primarily tree-dwellers, Proconsul may have also spent time exploring nearby grasslands for food.

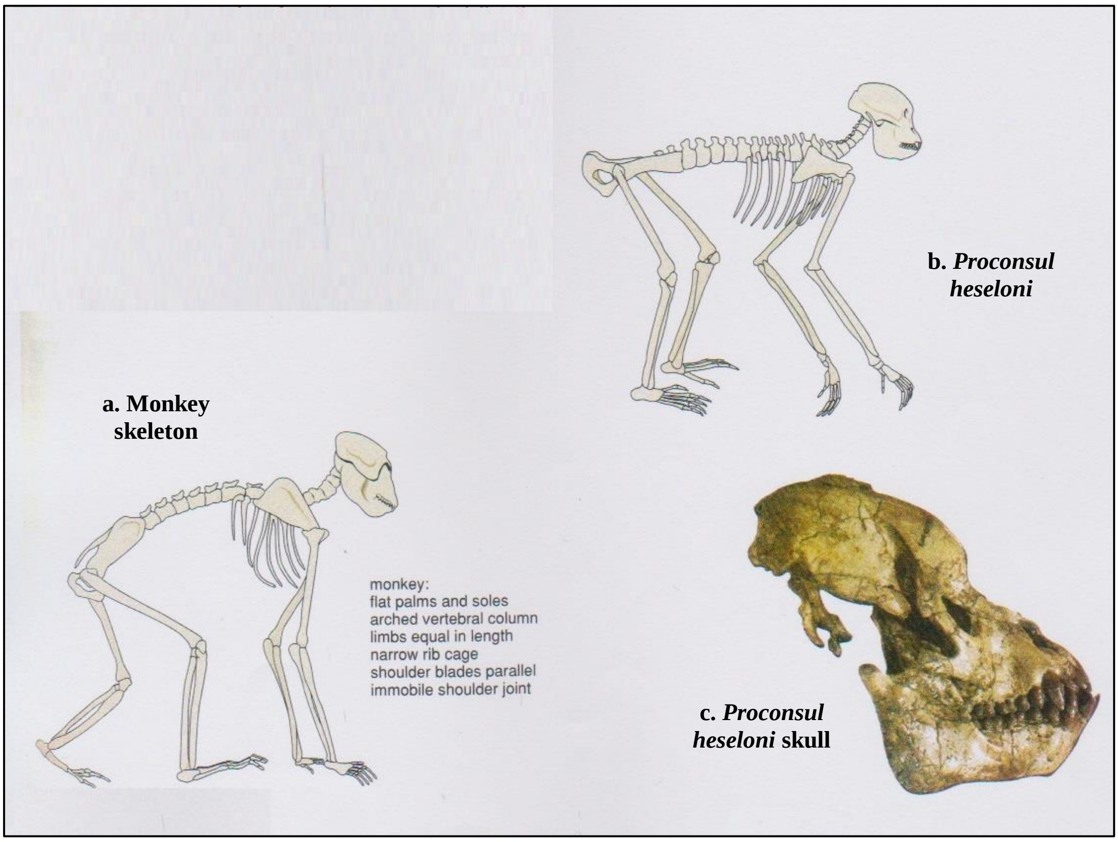


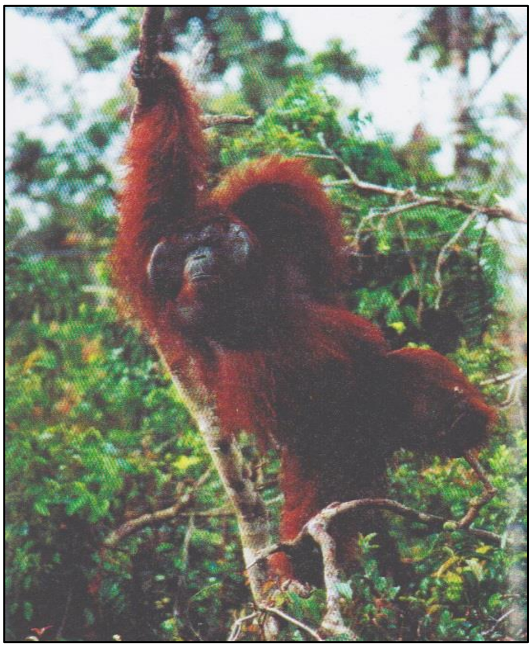
Figure 6.4 Monkey skeleton compared to Proconsul skeleton

At the end of the Miocene epoch, Africarabia (Africa plus the Arabian Peninsula) joined with Asia and the hominoids migrated into Europe and Asia. Two groups can be distinguished: dryomorphs and ram morphs. While at one time it was believed that ram morphs were ancestral to the later-appearing hominids, a group that contains humans, ram morphs are now classified Within an ancestral organgutan group.

Learning from Living Hominoids

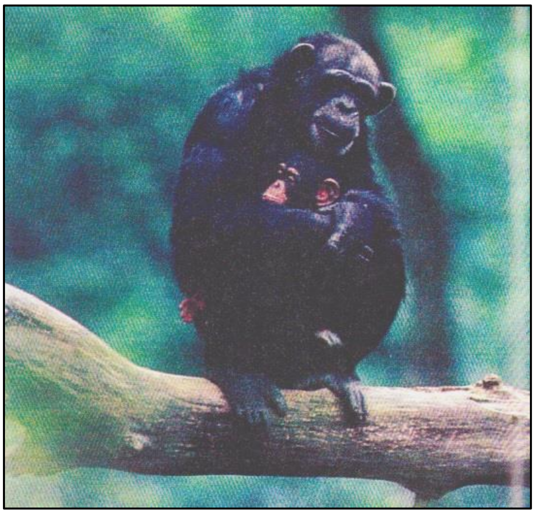
The close relationship between humans and apes is signified by their placement in the same superfamily, Hominoidea. Four types of ‘apes have survived until today: the f gibbon and the orangutan are found in Asia; the gorilla and the chimpanzee inhabit Africa (Fig. 6.5). The gibbon is the smallest of the apes, with a body weight of about 5.5 - 11 kilograms. Gibbons have extremely long arms that are specialized for swinging between tree limbs. The orangutan is large (75 kilograms) but nevertheless spends a great deal of time in trees. The gorilla, the largest of the apes (180 kilograms), spends most of its time on the ground. Chimpanzees, which are at home both in trees and on the ground, are the most humanlike of the apes in appearance and are frequently used in psychological experiments.

a. Of the apes, gibbons are the most distantly related to humans. They dislike coming down from trees, even at watering holes. They will extend a long arm into the water and then drink collected moisture from the back of the hand.



b. Orangutans are solitary except when they come together to reproduce. Their name means “forest man”; early Malayans believed that they were intelligent and could speak but did not because they were afraid of being put to work.

c. Gorillas are terrestrial and live in groups in which a silver-backed male, such as this one, is always dominant.



d. Of the apes, chimpanzees sometimes seem the most humanlike.

Figure 6.5 Ape diversity.

Molecular biologists have studied our relationship to the apes by comparing the similarity of our proteins and DNA to that of apes. Certain amino acid and DNA basepair differences are not tied to natural selection and instead occur randomly at a fixed rate. Such differences can be used as a type of molecular clock by which we can judge when any two groups of organisms diverged (separated) from one another. The DNA of two species can be compared in the following manner: DNA strands are first separated into single strands. Then a strand from each species is allowed to pair complementarily. The degree of fit is judged by the thermal stability of the hybrid DNA. A molecular study of this sort suggests that monkeys most liker diverged from the primate line of descent about 33 million years ago (MYA), the orangutan diverged 16 MYA, and African apes and humans did not split until around 6 MYA. Therefore, it is believed that the last common ancestor between the African apes and hominids (family Hominidae) lived during the Pliocene epoch. Unfortunately, this common ancestor has not yet been found.

The geography of Africa holds a clue as to why the ape and the hominid lines of descent split from each other. A great furrow called the rift valley runs north and south in eastern Africa. Tectonic forces that began 12.5 MYA are slowly causing eastern Africa to separate from the rest of the continent. Here, huge mountainous volcanoes and lakes form a geographic barrier that is difficult to cross. Winds that have swept across the African continent for millions of years have deposited rain to the west of the mountains, and the east has become ever more dry. Forests and woodlands have remained in the west but the east is a grassland called a savanna.

The changing environment to the east may have influenced the evolution of hominids, who differ from the apes in the ways noted in Figure 6.6. Anatomical differences of prime importance concern: type of locomotion, which is dependent on skeletal features involving the spine, the pelvis, and the bones of the appendages; jaw shape, which is related to the size and the shape of the teeth; and brain size, which is related to the shape of the head and the brow. The hominid features promoted survival in a grassland as opposed to a forest ecosystem. We can imagine that it was beneficial to be able to stand tall to look over grasses while searching for food or avoiding predators, that jaw and teeth changes were adaptive to a new (perhaps omnivorous), diet, and that an erect posture left the hands free to throw rocks or even manipulate tools as the brain grew larger.

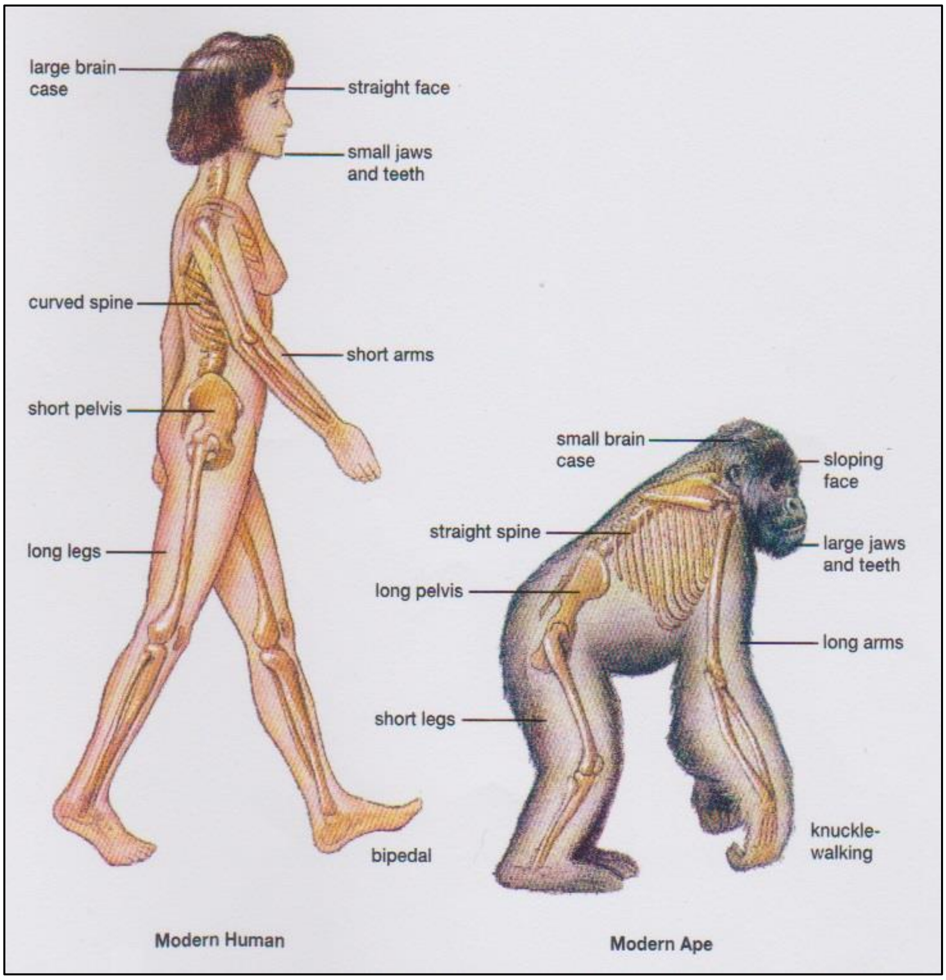


Figure 6.6 Modern human skeletal features and those of a gorilla

6.3 Hominids Break Away

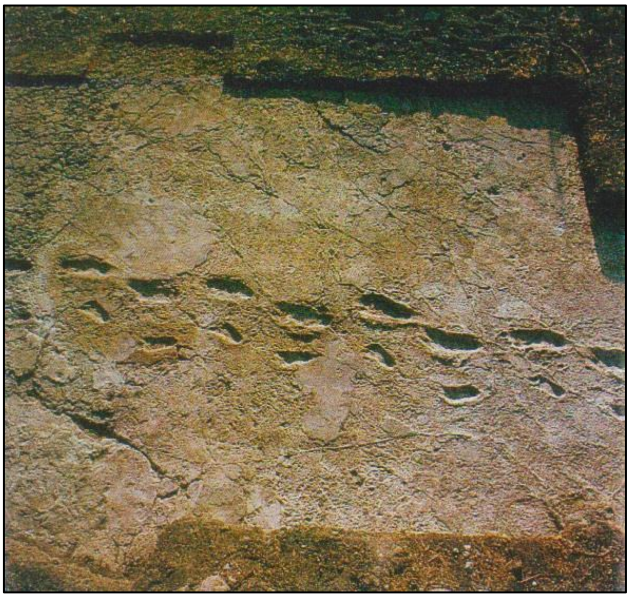
The hominid line of descent begins with-the australopithecines, which evolved and diversified in eastern Africa.

Hominids Walked Erect

It wasn't until the 1960s that paleontologists, following the lead of the renowned couple Louis and Mary Leakey, began to concentrate their efforts in eastern as opposed to southern Africa. It has proven to be worth their while. One 1994 find consisting of skull fragments, teeth, arm bones, and a part of a child's lower jaw has been dated at 4.4 MYA (millions of years ago). Called Australopithecus ramidus [L. australis, southern, pithecus, ape, and farms, branch], it is believed to represent an early stage in human evolution. In comparison to later australopithecines, the canine teeth are larger, and the skull is more like that of a chimpanzee. Also, this fossil did not walk erect. However, a 1995 discovery, Australopithecus anamensis, dated at just about 4 MYA has jaws like those of-an ape but legs like those of humans.

More than 20 years ago, a team led by Donald Johanson unearthed nearly 250 fossils of a hominid called A. afarensis. A now-famous female skeleton now dated at 3.18 MYA is known worldwide by its field name, Lucy. (The name derives from the Beatle's song "Lucy in the Sky with monds.") Although her brain was quite small (400 cc), shapes and relative proportions of her limbs indicate Lucy did stand upright and walk bipedally (Fig. 6.7). Even better evidence of bipedal locomotion comes fr0m a trail of footprints in Laetoli dated about 3.7 MYA. The larger prints are double—a smaller-sized being was stepping in the footfalls of another—and there are small prints off to the side, within hand-holding distance. Since the australopithecines were apelike above the. waist and humanlike below the waist, it that human characteristics did not evolve all at one time. The term mosaic evolution is applied when different body parts change at different rates and therefore, at different times.

a. A reconstruction on display at the St. Louis 200.



b. These fossilized footprints occur in ash from a volcanic eruption some 3.7 million years ago. The larger footprints are double—a smaller individual was stepping in the footprints of a larger individual. A youngster was walking to the side. The footprints suggest that A. afarensis walked bipedally.

Figure 6 .7 Australopithecus afarensis.

The australopithecines were sexually dimorphic. Lucy was about four feet tall and Weighed about 30 kilograms. In contrast, the males of the species were five feet tall and weighed up to 45 kilograms. Some have speculated that such size differences may indicate two separate species, but in .1994 new finds, including a more complete Skull (dubbed the son of Lucy and dated at just about 3 MYA), confirmed the Opinion that the fossils belong to one species (Fig. 6.8). Taking into account their smaller body size, the relative brain size is about half of ours and the jaw is heavy. The cheek teeth are enormous, and in males large canine teeth project forward.

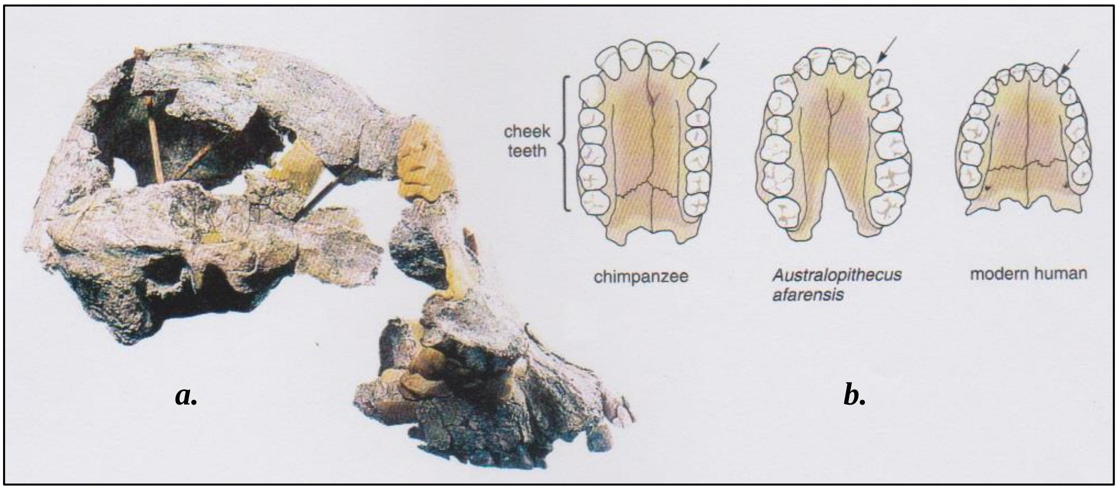


Figure 6.8 Australepithecus afarensis skull and dentition.

a. A. afarensis had an apelike face with prominent brow ridges and a projecting jaw.
b. Dentition of an ape, A. afarensis, and a modern human. Note the size of the canine teeth, the gap between canine teeth and adjacent incisor (arrow), and the size of the cheek teeth.

It's interesting to speculate that the daily lives of australopithecines may have been comparable to those of baboons. In baboons, as in australopithecines, males are much larger than females. Baboons travel in a troop rather than forming permanent family groups. The troop has a home range, which it constantly travels foraging for food. At night the troop climbs trees to remain safe from predators. Australopithecines had long, curved fingers and toes, and the legs were short in comparison to the mobile arms. This suggests that they, too, still climbed trees on occasion.

A. afarensis had descendants. After a period of stasis that may have lasted a million years (from 3 to 2 MYA), branching speciation occurred; Therefore, instead of thinking about hominid descent in terms of a straight line, it is far better to envision a bush. Some think there may have been as many as ten species of hominids about 2 MYA in Africa, but we will discuss only four of them; three of which are australopithecines. A. africanus, which was first named in southern Africa by Raymond Dart in the 1920s, is a gracile (slender) type. A. boisei is a robust form from eastern Africa, and A. robustus is a similar form from southern Africa. Both gracile and robust forms have a brain size of about 500 cc; their skull differences are essentially due to dental and facial adaptations for different diets. The robust forms have stronger jaws, larger attachments for larger chewing muscles, and bigger grinding teeth because they most likely fed on tougher foods than the gracile form. The robust forms lived in drier habitats where soft fruits and leaves would be harder to come by. In both forms, the pelvis resembles that of Lucy but ‘the hands were more humanlike; possibly they were capable of making tools. Both forms, which are believed to have eaten meat at least occasionally, may have used the tools to process animal carcasses. Of interest is a recent report that the thumb anatomy of A. robustus is similar to our own. Modern human hands are adapted to handling tools because of their strong, well-muscled, and opposable thumb.

At one tune it was believed that the gracile australopithecine form gave rise to the robust forms. However, in 1985, Alan Walker discovered a robust skull, called the black skull, which was old enough (2.5 MYA) to be ancestral to the robust forms we have been discussing. It has been given the name A. aethiopicus. As discussed in the reading on page 356, the earliest Homo species also evolved from. The Australopithecus line of descent.

Homo habilis Made Tool

The oldest fossils to be classified in the genus Homo are known as Homo habilis [L. homo, man, and habilis, suitable, handy], and his remains dated as early as 2 MYA are often accompanied by stone tools. Why is this hominid classified Within our own genus? H. habilis was small—about the size of Lucy—but the brain at 700 cc is about 45% larger. In addition, certain portions of the brain thought to be as sociated with speech areas are enlarged. The cheek teeth are smaller than even those of the gracile australopithecines. Apparently, H. habilis had a different way of life than the other hominids of this time.

This hominid lived at a time when the earth was cooling and tropical regions in general were becoming more dry due to the formation of glaciers at the North and South Poles. Many animals, including the robust forms of Australopithecus, show dentition that indicates a shift to a more fibrous diet. It is, perhaps, significant that the modern horse appears at this time.

Cut marks on bones that could have been made by stone flakes have been found at many sites throughout eastern Africa that date from 2 MYA. H. habilis could have made and used tools in order to strip meat off these bones and, in keeping with the size of the teeth, could have eaten meat to satisfy protein demands. As a scavenger, H. habilis may have depended simply on the kills of other animals; or as a predator, may have killed small to medium-sized prey. This new way of life became available to hominids when they had the ability to make and use tools intelligently.

The stone tools made by H. habilis are called Oldowan tools because they were first identified as tools by the Leakeys in Olduvai Gorge (see Fig. 6.13). Oldowan tools are simple and look rather clumsy, but perhaps we are looking at the core that remains after flakes have been removed. The flakes would have been sharp and able to scrape away hide and cut tendons to easily remove meat from a carcass.

H. habilis most likely still ate fruits, berries, seeds, and other plant materials. Perhaps a division of labor arose with certain members of a group serving as hunters and others as gatherers. Speech would have facilitated their cooperative efforts, and later they most likely shared their food and ate together. In this way, society and culture could have begun. Culture, which encompasses human behavior and products (such as technology and the arts) is dependent upon the capacity to learn and transmit knowledge through the ability to speak and think abstractly.

Prior to the development of culture, adaptation to the environment necessitated a biological change. The acquisition of culture provided an additional way by which adaptation was possible. And the possession of culture by H. habilis may have hastened" the extinction of the australopithecines during the early Pleistocene epoch (Fig. 6.9).

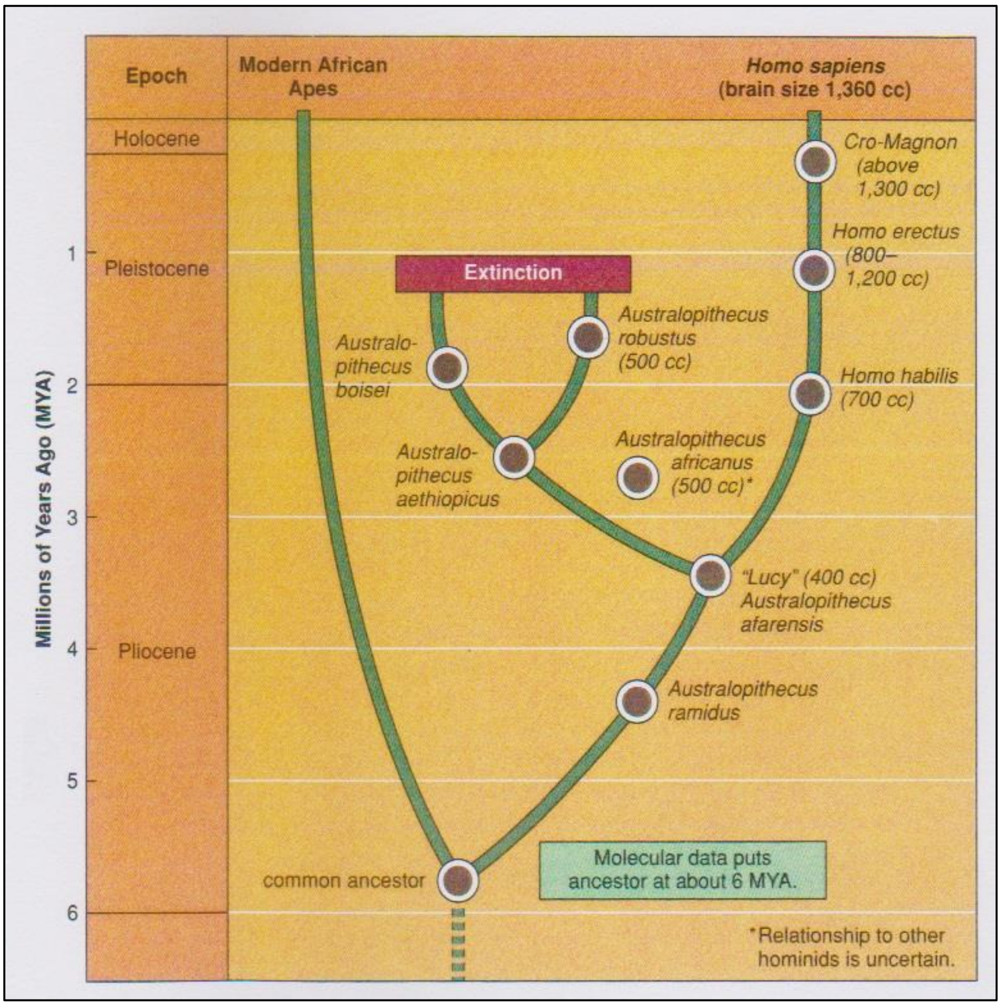


Figure 6.9 Hominoid evolutionary tree.

African apes and hominids split about 6 million years ago (MYA); Australopithecus ramidus is the oldest of the hominids; A. afarensis lasted about a million years before branching speciation occurred. In particular, there were gracile and robust australopithecine forms and also the first human form, Homo habilis.

Homo erectus Traveled

Homo erectus [L. homo, man, and erectus, upright] is the name assigned to hominid fossils found in Africa, Asia, and Europe and dated between 1.9 and 0.5 MYA. A Dutch anatomist named Eugene Dubois was the first to unearth H. erectus bones in Java in 1891, and since that time many other fossils have been found in the same area. Although all fossils assigned the name H. erectus are similar in appearance, there is enough discrepancy to suggest that several different species have been included in this group. In particular, some experts believe that the African and Asian forms are two different species.

Compared to H. habilis, H. erectus had a larger brain (about 1,000 cc), more pronounced brow ridges, a flatter face, and a nose that projects like ours. This type of nose is adaptive for a hot, dry climate because it permits water to be removed before air leaves the body. The recovery of an almost complete skeleton of a ten-year-old boy indicates that H. erectus was much taller than the hominids discussed thus far (Fig. 6.10). Males were 1.8 meters (about 6 feet) and females were 1.55 meters (approaching 5 feet) tall. Indeed, these hominids were erect and most likely had a striding gait like ours. But the robust and most likely heavily muscled skeleton still retains some australopithecine features. Even so, the size of the birth canal indicates that infants were born in an immature state that required an extended period of care.

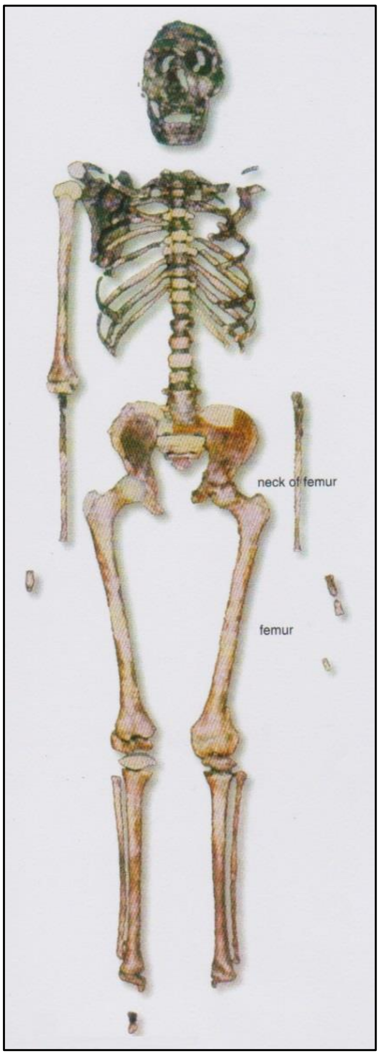


Figure 6.10 Homo erectus

It is, believed that H. erectus first appeared Africa and then migrated into Asia. and Europe. At one time, the migration was thought to have occurred about 1 MYA, but recently H. erectus fossil remains in Java and the Republic of Georgia have been dated at 1.9 and 1.6 MYA, respectively.

Therefore, it seems that H. erectus either left Africa soon after it evolved, or perhaps an earlier, related form has to be credited with the migration. In any case, such an extensive population m0vement is a first in the history of humankind and a tribute to the intellectual and physical skills of the species.

H. erectus was the first hominid to use fire, and it also fashioned more advanced tools called Acheulean tools after a site in France (see Fig. 6.13). They used heavy teardrop-shaped axes and cleavers as well as flakes, which were probably used for cutting and scraping. Some believe that H. erectus was a systematic hunter and brought kills to the same site over and over again. In one location paleontologists have found over 40,000 bones and 2,647 stones. These sites could have been "home bases” where social interaction occurred and a prolonged childhood allowed time for much learning. Perhaps a language evolved and a culture more like our own developed.

Modern Humans Originated How?

It is generally recognized that modern humans originated from H. erectus, but where did this occur? About 300,000 years BP (before present), so-called "archaic Homo sapiens” were present in Europe, Asia, and Africa. (Neanderthal is a well-known archaic H. sapiens.) The hypothesis that each of these individual populations went on to evolve into modern humans is called the multiregional continuity hypothesis. This hypothesis, which proposes no migrations, requires that evolution be essentially similar in several different places. Each region would show a continuity of its own anatomical characteristics from about a million years ago, when H. erectus first arrived in Eurasia. Opponents argue that it seems highly unlikely that evolution would have produced essentially the same result in these different places. They suggest, instead, the out-of-Africa hypothesis, which proposes that archaic H. sapiens became fully modern only in Africa, and. Thereafter they migrated to Europe and Asia about 100,000 years BP. If so, there would be no continuity of characteristics between fossils of 300,000 years BP and fossils of 100,000 years BP. Modern humans may have interbred to a degree with archaic populations but in effect they supplanted them.

According to which hypothesis would modern humans be most genetically alike? With the multiregional hypothesis, human populations have been-evolving separately for a long time and therefore genetic differences are expected. With the out-of-Africa hypothesis, we are all descended from a few individuals from about 100,000 years BP. Therefore, the out-of-Africa hypothesis; suggests that we are more genetically similar. A few. years-ago, a study attempted to show that all the people of Europe (and the world for that matter) have essentially the same mitochondrial DNA. Called the mitochondrial Eve hypothesis by the press (note this is a misnomer because no single ancestor is proposed), the statistics that calculated the date of the African Migration Were found to be flawed. Still, the raw data—which indicate a close genetic relationship among all Europeans—support the out-of-Africa hypothesis.

These opposing hypotheses have sparked many other innovative studies to test them. The final conclusions are still being determined.

Neanderthals Were Archaic

A brain capacity larger than 1,000 cc allows a species to be classified as Homo sapiens. The Neanderthals (H. sapiens neanderthalensis) take their name from Germany Neander Valley, where one of the first Neanderthal skeletons, dated some 200,000 years ago, was discovered. The Neanderthals had massive brow ridges, and the nose, the jaws, and the teeth protruded far forward. The forehead was low and sloping, and the lower jaw sloped back without a chin. New fossils show that the pubic bone is long compared to ours.

At this time, the Neanderthals are thought to be an archaic H. piazza- and most-likely not in the main line of Homo descent. Surprisingly however, the Neanderthal brain was, on the average, slightly larger than that of modern humans (1,400 cc, compared to 1,360 cc in most modern humans). The Neanderthals were heavily muscled, especially in the shoulders and the neck (Fig. 6.11). The bones of the limbs were shorter and thicker than those of modern humans. It is hypothesized that a larger brain than that of modern humans was required to control the extra musculature. They lived in Eurasia during the last Ice Age, and their sturdy build could have helped conserve heat.

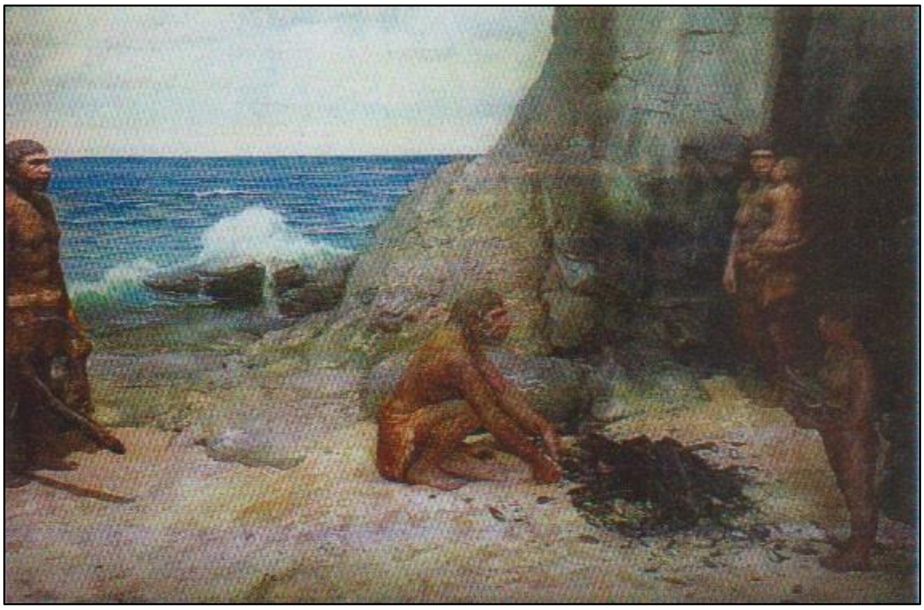


Figure 6.11 Neanderthals

The Neanderthals give evidence of being culturally advanced. Most lived in caves, but those in the open may have built houses. They manufactured. a variety of stone tools, including spear points, which could have been used for hunting, and scrapers and knives that would have helped in food preparation. They most likely successfully hunted bears, woolly mammoths, rhinoceroses, reindeer, and other contemporary animals. They used and could control fire, which probably helped in cooking frozen meat and in keeping warm. They even buried their dead with flowers and tools and may have had a religion.

Cro-Magnons Were Modern Humans

The out-of-Africa hypothesis discussed on page 359 is currently receiving much support by both anatomists and molecular biologists. It is increasingly believed that modern humans, by custom' called Cro-Magnons after a fossil location in France, entered Eurasia 100,000 years ago or even earlier. Cro-Magnons (H. sapiens sapiens) had a thoroughly modern appearance (Fig. 6.12). They made advanced stone tools called Aurignacian tools (Fig. 6.13). Included were compound tools, as when stone flakes were fitted to a wooden handle. They may have been the first to throw spears, enabling them to kill animals from a distance, or to have made knifelike blades. They were such accomplished hunters that some researchers believe they were responsible for the extinction of many larger mammals, such as the giant sloth, the mammoth, the saber-toothed tiger, and the giant ox during the late Pleistocene epoch.

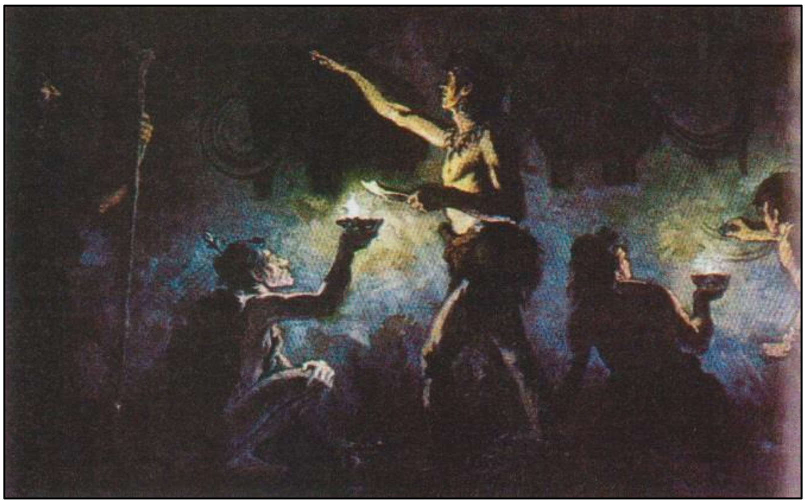


Figure 6.12 Cro-Magnon

Cro-Magnons hunted cooperatively, and perhaps they were the first to have had a language. They are believed to have lived in small groups, with the men hunting by day, while the women remained at home with the children. It’s quite possible that a hunting way of life among prehistoric people influenced our behavior even until today. The Cro-Magnon culture included art. They sculpted small figurines out of reindeer bones and antlers. They also painted beautiful drawings of animals on cave walls in Spain and France (Fig.6.12).

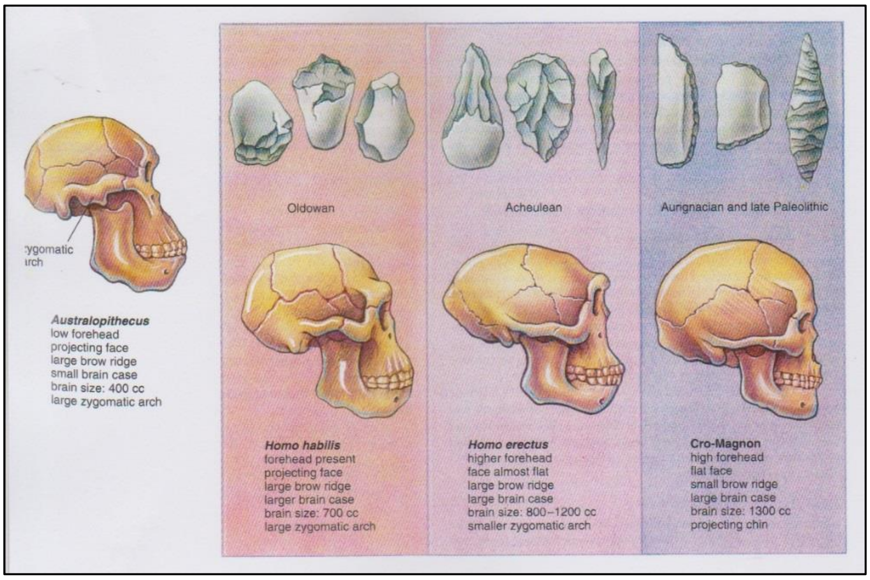


Figure 6.13 Hominid skulls and tools

CHAPTER SEVEN

DIVERSITY IN THE LIVING BEGINS AND CLASSIFIED

7.1 Classification of Living Organisms

Previously, you know that:

- The cell is the building unit of living organisms.
- Living organisms may be unicellular or multicellular.
- Although, all living organisms have the same building unit which is the cell, and may have also some characteristics in common, but they differ in many other characteristics, such as shape, methods of living, reproduction… etc., which lead their variation and large number.

So, there was a necessity for their classification [Taxonomy].

Taxonomy: it is to put living organisms into groups according to similarities and differences to facilitate their identification, study and find their relation to man.

So, Taxonomy aims at:

1. Identification of living organisms, as there are huge variety of kinds. [about millions].
2. Facilitates the studying of living organisms and how to deal with them.

Science of Taxonomy:

It is the science which deals with the arrangement of living organisms according to their similarities and differences.

Attempts of classification

First: Old methods of classification

A. <u>According to economic importance</u>

- Animals were classified into:
  - Harmful and harmless animals.
  - Some are edible while others are not.

B. <u>Aristotle classification</u>

- Aristotle classified living organisms according to differences in general characteristics.
- He classified plants into: Trees, Shrubs and Weeds.
- Animals into:
  - Red blooded and bloodless animals.
  - Viviparous and oviparous animals.

Viviparous → Animals which give birth.

Oviparous → Animals which lay eggs.

Objection:

All previous attempts to classify living organisms did not follow scientific principles.

C. <u>John Ray's classification</u>

- John Ray is considered the first scientist who tried to classify living organisms on scientific bases.
- He classified living organisms according to similarities in their external (morphological) features.
- He defined the species and considered it the unit of classification.

Note: species are group of individuals having similar morphological and parental characteristics, and produce fertile off spring if they crossed together.

Objection:

J. Ray's classification did not offer a better classification than Aristotle.

D. Carl Linnaeus classification (natural taxonomy)

- Linnaeus used a scientific principle in taxonomy which still applied till now called natural taxonomy.
- His idea depended upon species as he deduced the classification of organisms depending on the similarities in their main characteristics.

Linnaeus followed three main principles in his classification:

1. Using Latin language.
2. Using binomial system of nomenclature.
3. Series of taxonomy.

1. The using of Latin language

He used the Latin language because of being an old language and not spoken by people, so, it has been protected from any change or modification.

2. Binomial nomenclature

Each living organism has a name consists of two parts:

1st part represents Genus and it starts with a capital letter.

2nd part represents Species and it starts with a small letter.

And the purpose of this nomen cloture it to facilitate its identification and study.

3. Series of taxonomy

The serial in classification started as follows:

1. Species.
2. Genus → one genus comprises similar species together.
3. Family → one family comprise similar genus together.
4. Order → one order comprise similar families together.
5. Class → one class comprise similar orders together.
6. Phylum → one phylum comprises similar class together.
7. Kingdom → one kingdom comprises similar phylum together.

Scientists added to the previous classifications other sub classification e.g.

Class is divided into subclasses.

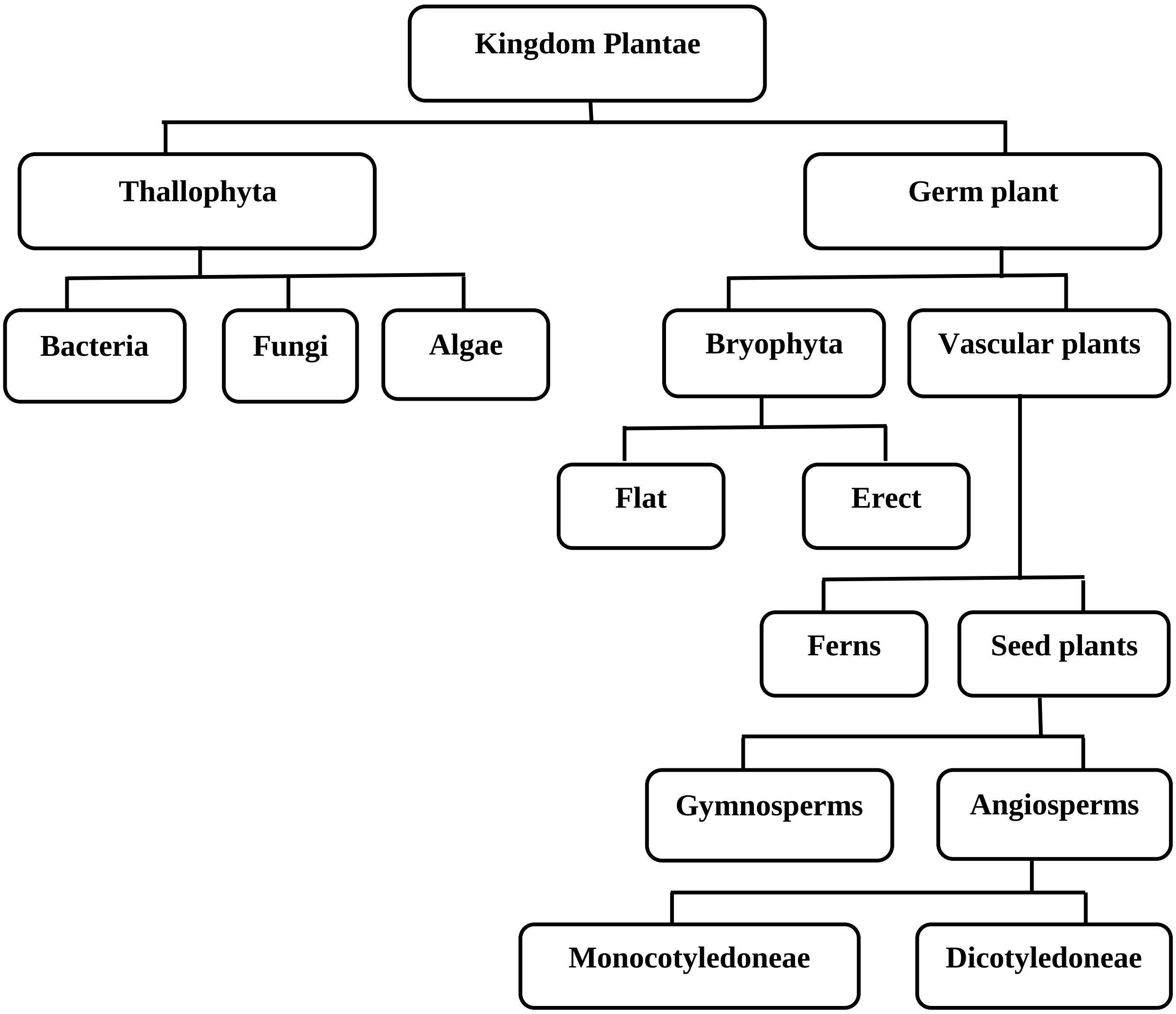
Phylum is divided into subphyla.

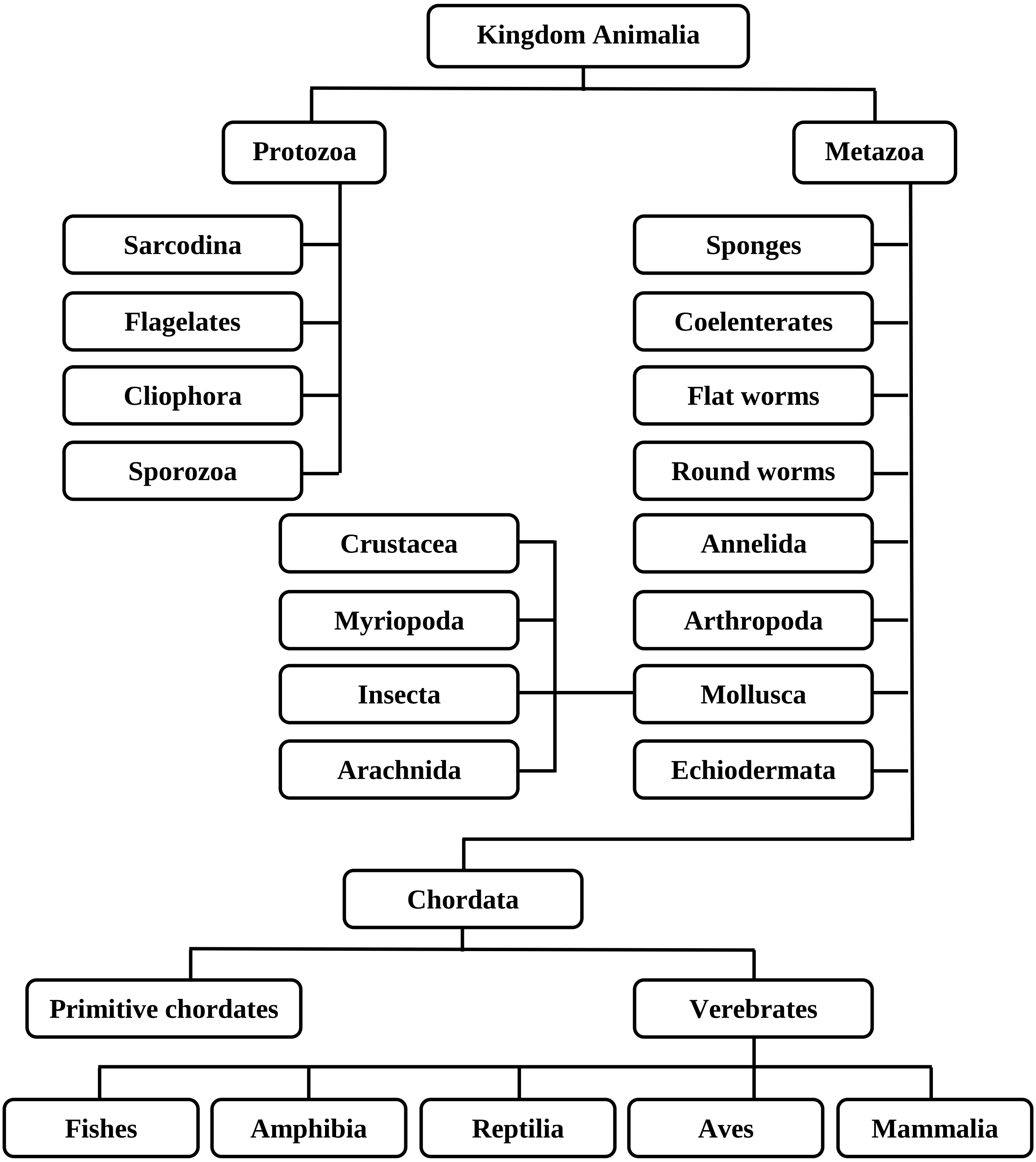
Kingdom is divided into subkingdoms.

Lennaeus and other scientists classified living organisms into two kingdoms:

I. Kingdom Plantae.

II. Kingdom Animalia.


Kingdom Plantae
Thallophyta
Germ plant
Bacteria
Fungi
Algae
Bryophyta
Vascular plants
Flat
Erect
Ferns
Seed plants
Gymnosperms
Angiosperms
Monocotyledoneae
Dicotyledoneae



Objection against the old system of classification:

1. There is no sharp demarcation between plants and animals especially in organisms of simple as bacteria and some algae, as they have the characteristics of both plants and animals, so it difficult to classify them under plant or animal kingdoms.
2. The old system depends upon stability of species which contradicts with the evolution theory.

Note 1:

Stability of species: Each species descended from ancestors of the same species.

Note 2: It assumes that similar, living organisms descend from a common ancestor and living organisms are always changing, so, old species perish and new originate.

- These objections lead to a new system of classification, which explains the similarities between species on the basis that they were descended from a common ancestor.

Second: Recent method of classification

The scientist R. Whittaker suggested the classification of living organisms according to:

a. Cellular characteristics (cellular structure, presence of plastids).
b. Characteristics of the nucleus (e.g. presence of nuclear membrane).
c. Hereditary studies.
d. Resemblance of reproductive organs.
e. Microscopical examinations.

- According to the previous, living organisms were divided into five kingdoms:

1. Kingdom: Monera.
2. Kingdom: Protista.
3. Kingdom: Fungi.
4. Kingdom: Plantae.
5. Kingdom: Animalia.

Some organisms have the characteristics of both living and non-living organisms, these are Viruses.

Viruses

Characteristics of viruses:

1. Viruses are considered as a link between living and non-living things, because:
    - Living organisms: as they contain nucleic acids DNA and RNA enveloped by a protein coat.
    - Non-living things: as they have a crystalline from out of the living tissues.
2. All viruses are obligate parasites:
    - As they only can live inside the host cells to multiply, but they lose their ability of multiplication outside the host cell.
3. Specificity of viruses:
    - They infect certain cells in a certain host.
    - Virus which attacks certain types of cells cannot attack other types.

Example: plant viruses cannot infect animals or man viruses which attack liver cannot attack brain.

4. Viruses cause many diseases to man:

Example: influenza, rabies, yellow fever, common cold, small-pox, infantile paralysis (Polio).

5. Size: the size of viruses ranges between 10:100 mmicron.
6. Shapes: viruses have different shapes: e.g. spherical, cuboidal, rod shaped or needle shaped.

Comparison between old and recent system of classification:

Old-system of classification	Recent system of classification
1. There is no sharp demarcation between plants and animals especially those of simple structure.	1. It sharp demarcation between animals and plants.
2. It depends upon stability of species which contradicts with the evolution theory.	2. It depends upon similarities between species on the basis that they were descended from a common ancestor.
3. It depends on similarities and differences in external features and internal structures of body.	3. it depends on: a. Cellular characteristics. b. Nuclear characteristics. c. Hereditary studies. d. Resemblance of reproductive organs. e. Microscopical examinations.
4. It classified living organisms into two kingdoms: a. Animal kingdom. b. Plant kingdom.	4. it classified living organisms into five kingdoms: a. Kingdom Monera b. Kingdom Protista c. Kingdom fungi. d. Kingdom plantae. e. Kingdom animalia.

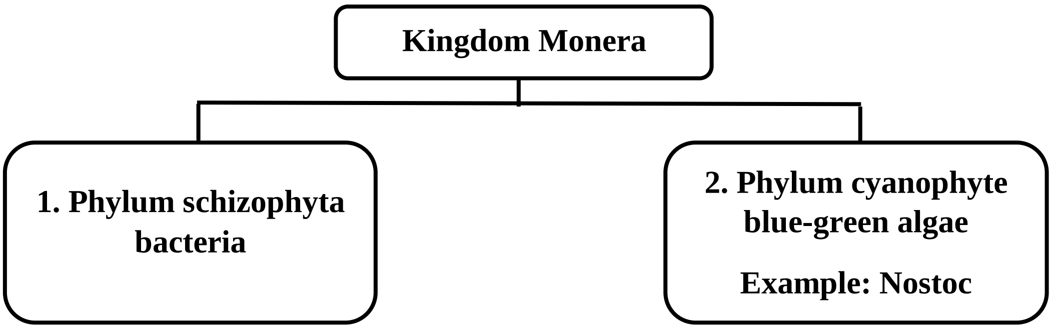
7.2 Kingdom Monera & Kingdom Protista

First: Kingdom Monera

General characteristics of kingdom Monera:

- **Structure**: their bodies consists of one cell → unicellular organisms.
- **Cell wall**: it is devoid of cellulose or pectin.
- **Cytoplasm**: it is devoid of some organelles such as Mitochondria, plastids, golgi body, endoplasmic reticulum.
- **Nucleus**: it is not surrounded by a nuclear membrane, the hereditary material also does not appear in the form of chromosomal threads, but in the form of chromosomes in the cytoplasm.

This kingdom is divided into two phyla:



1. **Phylum Schizophyta Bacteria**
    - **Size**: bacteria are the smallest living organisms. They cannot be seen except under light microscope (using oil immersion lens).
    - **Existance**: bacteria exist everywhere on earth, even inside human body.
    - **Shapes**: there are different shapes of bacterial cells which are:

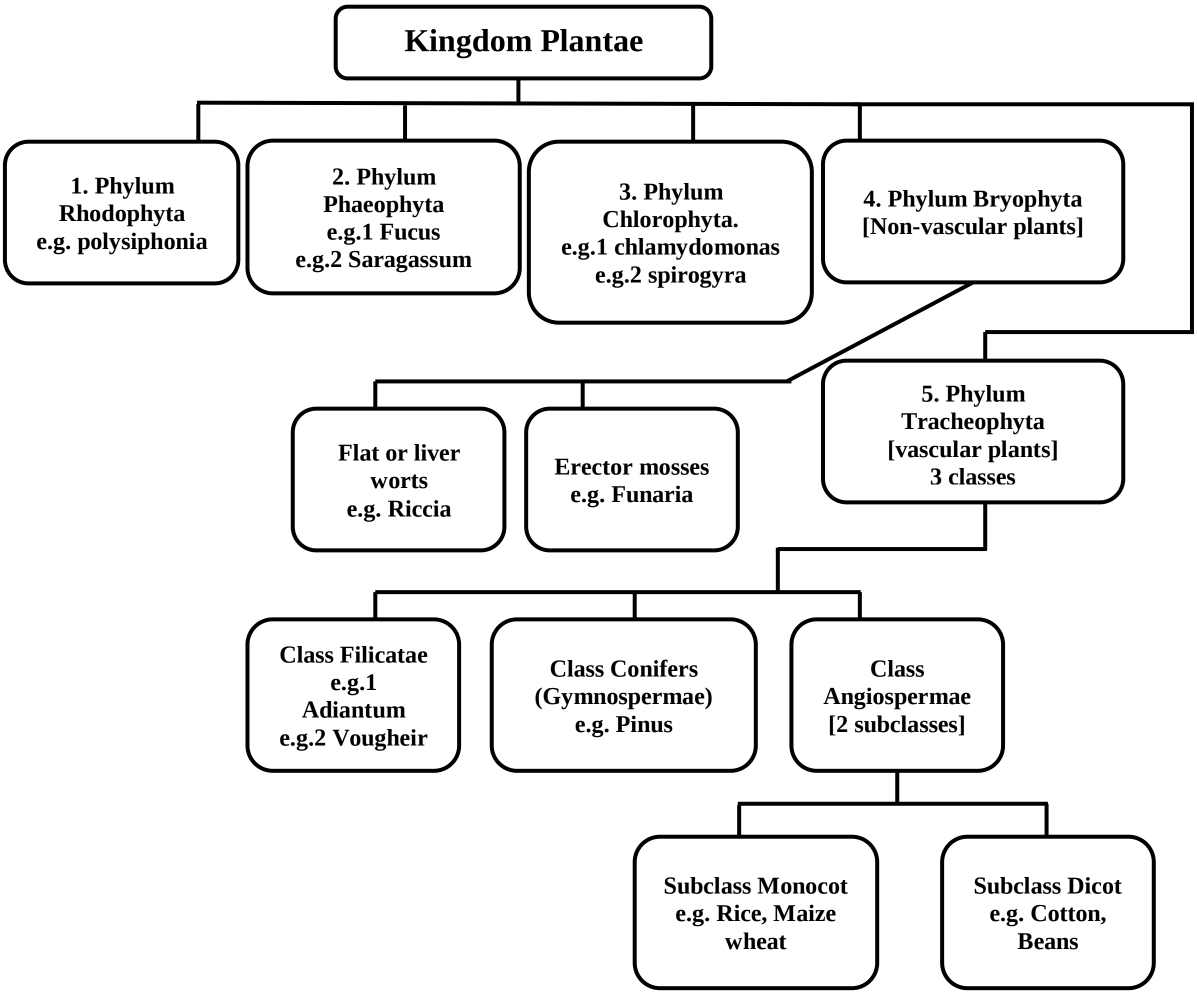
a. Spherical bacteria.

b. Rod-Shaped bacteria.

c. Spiral bacteria.

Second: Kingdom Plantae

Kingdom plantae is divided into five phyla:



1. Phylum Rhodophyta [Red Algae]

Characteristics:

- They are marine sea weeds which are common in oceans.
- Their body in the form of masses of filaments simple or branched.
- Outer cells coating red pigments (so it is called red algae).

Example: Polysiphonia.

2. Phylum Phaeophyta [Brown Algae]

Characteristics:

- The body consists of simple or branched filaments.
- They contain brown pigments (so they are called brown algae).

Example: 1. Fucus. 2. Saragassum.

3. Phylum Chlorophyta [Green Algae]

Characteristics:

- Some are multicellular consists of unbranched filaments e.g. Spirogyra.
- Some are unicellular e.g. Chlamydomonas.
- They have green plastids (so they are called green algae).
- Cell wall contains cellulose.

Example: Chlamydomonas, Spirogyra.

4. Phylum Bryophyta [Non-Vascular Plants]

Characteristics:

- Most of them are terrestrial plants, which grow in damp places.
- It may be Flat or liverworts such as Riccia.
  OR it may be Erect such as Funaria [Rhizoids] also has stem-like and leaf-like.

Example: Mosses (Funaria), Liverworts (Riccia).

5. Phylum Tracheophyta [Vascular Plants]

Characteristics:

- They are terrestrial plants, which are differentiated into roots, stem and leaves.

- They are vascular plants, which have vascular tissues (i.e: Xylem and Phloem) for transport of food and water.

Note: Xylem: carries water and minerals from soil to all plant parts.

Phloem: carries food prepared from photosynthesis by green parts to all plant parts.

This phylum is divided into three classes:

A. Class Filicatae (Ferns).
B. Class Gymnospermae (Conifers).
C. Class Angiospermae (Seed Plants).

A. Class Filicatae (Ferns)

Characteristics:

- They have vascular tissues.
- They do not form flowers.

Example: Adiantum, Vougheir.

B. Class Gymnospermae (Conifers)

Characteristics: have reproductive organs called **Cones**.

- They are naked – seed plants (i.e. produce uncovered seeds) (seeds have no testa).
- They do not form flowers.

Example: Pinus.

C. Class Angiospermae (Seed Plants)

Characteristics: produce flowers which form seeds.

- Produce fruits enclosing seeds.

It is divided into two subclasses:

(I) Subclass Monocotyledonae	(II) Subclass Dicotyledonae
Characteristics: 1. Seeds of one cotyledon. 2. Flowers are trimerous whorls. i.e. the number of leaflets in each whorl of the flower is 3 or its multiple. 3. Leaves have parallel venation. 4. Have fibrous roots. Examples: Wheat, Onion, Maize, Cactus (Aloe), Rice, Palms, Sugarcane.	Characteristics: 1. Seeds with two cotyledons. 2. Flowers are tetramerous or pentamerous. i.e. the number of leaflets in each whorl of the flower is 4 or 5 or their multiple. 3. Leaves have pinnate or palmate venation. 4. Have tap roots. Examples: Legumes such as Pea and Bean (Faba), Cotton, Rose, Petunia.

Critical thinking question: Why are vascular plants the most successful land plants?

Third: Kingdom Animalia

Kingdom Animalia

- **Invertebrates**
  - **1. Phylum Porifera**
  - **2. Phylum Coelenterata**
  - **3. Phylum Platyhelminthes**
  - **4. Phylum Nematohelminthes**
  - **5. Phylum Annelida**
  - **6. Phylum Arthropoda**
  - **7. Phylum Mollusca**
  - **8. Phylum Echinodermata**
- **Vertebrates**
  9. Pylum chordata

1. Phylum Porifera (Sponges)

Habitat: they are aquatic animals that live in water attached at their bases to rocks.

Body: the body wall has many lateral pores, and have external skeleton which is calcareous (made of $CACo_3$) or siliceous made of silica in the form of spicules or fibers.

Reproduction:

- They reproduce asexually by budding.
- Sexually by fusion of gametes.

Example: Sponges.

2. Phylum Coelenterata

Habitat:

- They are aquatic animals, may live alone or in colonies.
- Some of them live attached to rocks such as Corals, others can move such as Jelly fish.

Body:

- Some of them may secrete a calcareous deposit which may be soft or solid.
- Some of these animals have anterior end, tentacles supplied with stinging cells.

Reproduction: sexually and asexually (by budding).

Example: Hydra, Jelly fish, Corals.

3. Phylum Platyhelminthes

It is divided into three classes:

A. Class Turbellaria.
B. Class Trematoda.
C. Class Cestoda.

Habitat: most of them are endoparasites, that cause serious diseases to man and animals.

Body:

- They have flat bodies, body systems are limited or absent, because they depend mainly on their hosts to get their needs. They posses no respiratory, or locomotory or sensory organs.
- Alimentary canal is simple.
- Most of them are hermaphrodite (bisexual).

Reproduction: they reproduce both sexually and asexually.

A. Class Turbellaria

***Example*:** Planaria.

B. Class Trematoda

***Example*:**

1. Fasciola (liver fluke), which infects cows and sometimes human. 2.
2. Schistoma (Bilharzia or blood fluke). Lives in human blood.

C. Class Cestoda

***Example*:** Tapworms (Taenia).

- Which parasitizes cows or pigs then man causing digestive disturbances and anaemia to man.

4. Phylum Nematohelminthes (Nematodes or Roundworms)

Habitat: some of them are free living in water or mud, while others live as Parasites on man, animals and plants.

Body:

- The body is cylindrical and divided into rings.
- Have limited or no body organs "no locomotory, respiratory or sensory organs".
- They are unisexual (sexes are separate).
- Females are bigger in size than males.

Example: Ascaris and Ankylostoma.

5. Phylum Annelida (Ring Worms)

Habitat: most of them are free living animals, which inhabit the sea, fresh water, and most soil, while few are ectoparasites.

Body:

- The body is segmented, having well developed body systems.
- They have a closed circulatory, excretory and nervous system.

Example: Earth worm, Nereis (sand worm), Medical leech.

Comparison between Flat worm, Round worm and Rings worms:

Flat worms	Round worms	Ring worm
Habitat: Few of them are free-living and most of them are endoparasite on man and animals.	Few of them are free-living while most of them are endoparasites.	Most of them are free-living, and few are ectoparasites.
Structure: Have flat bodies.	Have round bodies.	Have segmented bodies.
Body systems: Limited or no body systems, have simple alimentary canal.	Have no body systems. (no circulatory or respiratory, lacomotory organs).	They have a closed circulatory, execretory, and nervous system.
Reproduction: Most of them are hermaphrodite few are unisexual. ***Example***: Planaria, Fasciola, Tapworms.	Unisexual. ***Example***: Ascaria and Ankylostoma.	Unisexual. ***Example***: Earth worm, Nereis, Medical leech.

6. Phylum Arthropoda

[Animals which have segmented legs]

Existance: they are most widely spread invertebrates.

Body: the body is divided into identical segments, some of the body segments have pairs of jointed legs.

This phylum is divided into four classes:

A. Class Crustacea.
B. Class Insecta.
C. Class Myriapoda.
D. Class Arachnida.

A. Class Crustacea

Example: Shrimp, Crab, Prawn, Lobster.

Habitat: they are aquatic animals → live in water.

Body: body is covered with chitinous cuticle [secreted by the epidermis].

Respiration: they respire by gills.

Sex: sexes are separated.

B. Class Insecta.

Example: Cockroach, House fly, Mosquitoes, Locust, Silk worm, Honey bee, Ants, Fleas.

Body:

- The body is divided into three regions: head, thorax and abdomen.
- The head carries a pair of antennae and a pair of compound eyes.
- The thorax carries three pairs of jointed legs and two pairs of wings.

[Wings may be reduced to one pair and may be completely absent (wingless)].

Respiration: through trachea.

- Some are useful as honey, others are harmful as house fly.

C. Class Myriapoda.

Example: Scolopendra and Julus.

D. Class Arachnida.

Example: Scorpion, Spiders, Ticks and Mites.

Body:

- The body is divided into two regions: thoracic and abdominal regions.
- It has four pairs of walking legs.
- It has pair of simple eyes.

Respiration: they respire through tracheae and ling books.

Comparison between class Insecta and class Arachnida:

Class Insecta	Class Arachnida
Body: The body is divided into: head, thorax and abdomen. **Legs**: The thorax carries 3 pairs of jointed legs. 2 pairs of wings. **Eyes**: Compound eyes. **Respiration**: Through trachea. ***Example***: Locust, Honey bees, House fly.	**Body**: The body is divided into: thoracic region and abdominal region. **Legs**: They have four pairs walking legs. **Eyes**: Simple eyes. **Respiration**: Through trachea and lung books. ***Example***: Scorpion, Spider, Ticks and mites.

7. Phylum Mollusca

Example: Eremina (Desert snail), Anodonta, Sepia, Octopus.

Habitat: They live in sea water, fresh water, while a few live on land (e.g. Desert snail).

Body:

- The body is a soft mass and is not segmented.
- They have an exoskeleton in the form of calcareous shell to protect the soft body.
- They don't have internal skeleton [except sepia which has an internal shell].
- They have circulatory systems, sensory organs, and a coiled digestive system.

8. Phylum Echinodermata

Example: Star fish, Brittle fish, Sea urchins, Sea cucumber.

They are considered as the most developed invertebrates.

Habitat: They live in sea water.

Body:

- The body is not segmented and it has an internal calcareous bony skeleton.
- The body wall (internal skeleton) has calcareous plats and prickles (spines).
- Some species have arms.

Sexes:

- Sexes are separate (unisexual).
- Fertilization is external.

9. Phylum Chordata

General characteristics of Phylum Chordata:

- They are the most developed animals.
- They have an endoskeleton in the form of rod-like supporting structure called notochord.
- They have the red pigment hemoglobin in their red blood cells.
- Their red blood cells contain a nucleus except mammals whose blood cells lack nucleus.

Phylum Chordata is divided into six classes:

A. Class Chondrichthyes (Cartilaginous fish).
B. Class Osteichthyes (Bony fish).
C. Class Amphibia.
D. Class Reotilia.
E. Class Aves.
F. Class Mammalic.

A. Class Chondrichthyes	B. Class Osteichthyes
Example: Shark, Dog fish, Rays. **Endoskeleton**: Made of cartilage [cartilaginous]. **Body**: Covered with placoid scales. **Fins**: The body is provided with paired fins. **Mouth opening**: The mouth is a transvere slit at the ventral side of the body, provided with strong teeth. **Eyes**: With eyelids. **Respiration**: Respire the oxygen dissolved in water by gills, which have no cover (operculum). **Reproduction**: Unisexual and fertilization is internal, with clasper in male.	***Example***: Bouri and Bolti. **Endoskeleton**: Made of bones [bony]. **Body**: Covered with bony scales, and it is differentiated into: head, trunk and tail. **Fins**: The body is provided with fins for lovomotion and balance in water **Mouth opening**: The mouth is terminal **Eyes**: Not provided with eyelids. **Respiration**: Respire the oxygen dissolved in water by gills, which have covered with opercula, with air bladder. **Reproduction**: Unisexual and fertilization is external, no clasper.

C. Class Amphibia

Example: Frogs, Salamanders.

Body: the adult skin is a smooth, slimy skin due to the presence of mucus glands, which secrete mucus.

Respiration: Depends on the stage.

Embryonic stage: They spend their embryonic stage in water, respire oxygen dissolved in water by gills.

Adult stage: Lives on land, get oxygen from air by lungs and the soft moist skin.

They are cold blooded animals, so, they hibernate in winter.

Reproduction: Sexes are separate and fertilization is external.

Amphibians are considered a link between aquatic and terrestrial animals.

D. Class Reptilia

Example: Chameleon, Lizard, gecko, Snakes, Crocodile, Turtle, Tortoise.

Body:

- It is divided into four regions: head, neck, trunk, tail.
- Skin is dry and covered with horny scales, which may be supported by bony plates.

Limbs:

- They have four weak limbs; each limb ends with 5 fingers with horny claws.
- Limbs may be absent, so the animal moves by creeping as snake.

Respiration:

- Through lungs, even those live in water.
- They are cold blooded.

Reproduction:

- Sexes are separate, fertilization is internal.
- They lay eggs rich in yolk inside holes on land.

E. Class Aves

Example: Pigeon, Fowl, Duck, Finch, Owl, Hawk, Ostrich, Parrot.

Body: Body is covered with Feathers.

Limbs:

- The fore limbs are modified into wings.
- The hind limbs are tetradactyl (end with 4 digits).
- The hind limbs help in movement on land, climbing, swimming, diving or predation.

Respiration:

- They respire atmospheric air by lungs to which air sacs are attached.
- Birds are warm blooded animals (have constant body temperature).

Reproduction:

- Sexes are separate and fertilization is internal.
- The females lay eggs and in cubate them till hatching.

Birds are very adapted for flying, because:

- The fore limbs are modified into wings (few cannot fly as Ostrich).
- The sternum (breast bone) is strong and protruding, and strong muscles are attached to it to move the wings.

F. Class Mammalic

They are the highest group in the animal kingdom.

Body:

- Divided into: head, neck, thorax and abdomen. Some may have tail.
- Body usually covered with hair.

Limbs: They have 4 pentadactyl limbs, which may have horny toes, claws, nails or hooves.

Respiration: They respire atmospheric air by lungs.

Blood:

- They are warm blooded animals [have constant body temp].
- Red blood cells have no nuclei.

Teeth: Teeth are not similar, they vary according to the type of food.

Reproduction:

- Sexes are separate, fertilization is internal.
- They give birth.
- The embryo is developed inside the uterus till birth.
- Mothers have mammary glands which secretes milk to suckle young.

Class Mammalia is divided into three subclasses:

A. Subclass Prototheria.
B. Subclass Metatheria.
C. Subclass Eutheria.

A. Subclass Prototheria	B. Subclass Metatheria.	C. Subclass Eutheria.
Characteristics: • They reproduce by laying eggs. • Are considered mammals, because mothers have mammary glands on their abdomens to feed young on milk. They have cloacal opening for excretion and laying eggs. ***Example***: Duck, Billed platypus.	**Characteristics:** • They give birth, but the born young are not fully developed. • The mother has a pouch on its abdomen, which contains milk, producing nipples for feeding young and completing its development. ***Example***: Kangaroo.	**Characteristics:** • They give birth and the young are fully developed. • They suckle young on milk from mother's mammary glands. ***Example***: They are divided into many orders: 1. Order Edentata. 2. Order Insectivora. 3. Order Carnivora. 4. Order Ceracea. 5. Order Ungulata. 6. Order Rodentia. 7. Order Lagomorpha. 8. Order Chiroptera. 9. Order Primates.

1. Order Edentata

Example: Armadillo, Ant eater, Sloth.

Characteristics:

- Most of them are without teeth.
- They have strong curved claws.

2. Order Insectivora (Insect Eaters)

Example: Hedgehog.

Characteristics:

- Most front teeth extend outwards like pincers to capture the prey.
- Females have simple placenta.

3. Order Carnivora (Meat Eaters)

Example: Lion, Tiger, Wolf, Fox, Dog, Cat.

Characteristics:

- They have large pointed canines.
- The premolars are provided with sharp projections.
- Molars are broad for cracking and crushing bones.

4. Order Ceracea

Example: Whale and Dolphin.

Limbs:

- The fore limbs are modified to paddle, like structure while hind limbs are absent.
- The last vertebra of the tail is horizontally flattened forming the tail fin (fan).

Respiration: They respire atmospheric air by lungs.

Reproduction: Sexes are separated, young suckle milk from mother's mammary glands.

5. Order Ungulata (Hooved Animals)

Example: Horse, Rhinoceros, Cattle, Sheep, Camel, Giraffe, Elephant.

Characteristics:

- The joints of wrist (in the fore limbs) and ankle (in the hind limbs) are far above the ground, because of the elongation of instep bones.
- Tips of the toes are protected by horny masses called hooves.

6. Order Rodentia

Example: Jerboa, Rat, Mice.

Characteristics:

- They have one pair of chisel, shaped incisors in each of the two jaws.
- They have long tails.

7. Order Lagomorpha

Example: Rabbits.

Characteristics:

- They have one pair of sharp incisors in the upper jaw and two in the lower one.
- The tail is short.

8. Order Chiroptera

Example: Bats.

Characteristics:

- The fingers except thump elongate and webs of the skin extend between them, and the skin also extends to the body and the tail to form the wings.
- They fly at night and have poor eyesight.

9. Order Primates

Example: Lemus, Monkeys, Chimpanzee, Orangutan, Gorilla and on the top of all Man.

Characteristics:

- They are most highly developed mammals.

- Limbs are pentadactyl which have five fingers and the first digit is far from others and lies opposite to them.
- The brain is large in size in higher forms and the nervous system is highly developed.
- They have high degree of intelligence.

Comparison between Class Reptelia, Class Aves and Class Mammalia:

Class Reptelia	Class Aves	Class Mammalia
• Skin is dry and covered with horny scales.	• Body covered with feathers.	• Body mostly covered with hair.
• Have 4 weak limbs, with 5 fingers, some don't have limbs.	• Fore limbs are modified into wings, while hind limbs are tetradactyl.	• Two pairs of pentadactyl limbs.
• They respire by lungs even the aquatic ones.	• Perspire by lungs to which air sacs are attached.	• Respire by lungs.
• Cold blooded.	• Warm blooded.	• Warm blooded.
• Sexes are separated and fertilization is internal.	• Sexes are separated and fertilization is internal.	• Sexes are separated and fertilization is internal.
• They kay eggs which are rich in yolk inside holes on land.	• The females lay eggs and incubate them till hatching.	• The females give birth and suckle young milk from their breast.
Ex: Snakes, Turtle, Crocodiles.	***Ex***: Pigeon, Duck, Owl, Ostrich.	***Ex***: Monkey & Man.

CHAPTER EIGHT
CLASSIFICATION OF LIVING THINGS

8.1 Naming and Classifying Organisms

Suppose you were asked to Classify the living organisms you know about (Fig. 8.1). Most likely you would begin by making a list, and naturally this would require that you give each one a name. Then you would start assigning the organisms on your list to particular groups. But what criteria would you use-color, size, how the organisms relate to you? Deciding on the number, types, and arrangement of the groups would not be easy, and periodically you might change your mind or even start over. Biologists, too, have not had an easy time deciding how living things should be classified, and changes have been made throughout the history of this field.

Taxonomy

Taxonomy [Gk. tasso, arrange, classify, and nomos, usage, law], the branch of biology concerned with identifying and naming organisms, began with the ancient Greeks and Romans. The scientific names we use today are rendered in Latin. The famous ancient Greek philosopher Aristotle was the first to be interested in taxonomy. Much later, John Ray, a British naturalist of the seventeenth century, also believed that each organism should have a set name. He said, "When men do not know the name and properties of natural objects—they cannot see and record accurately.

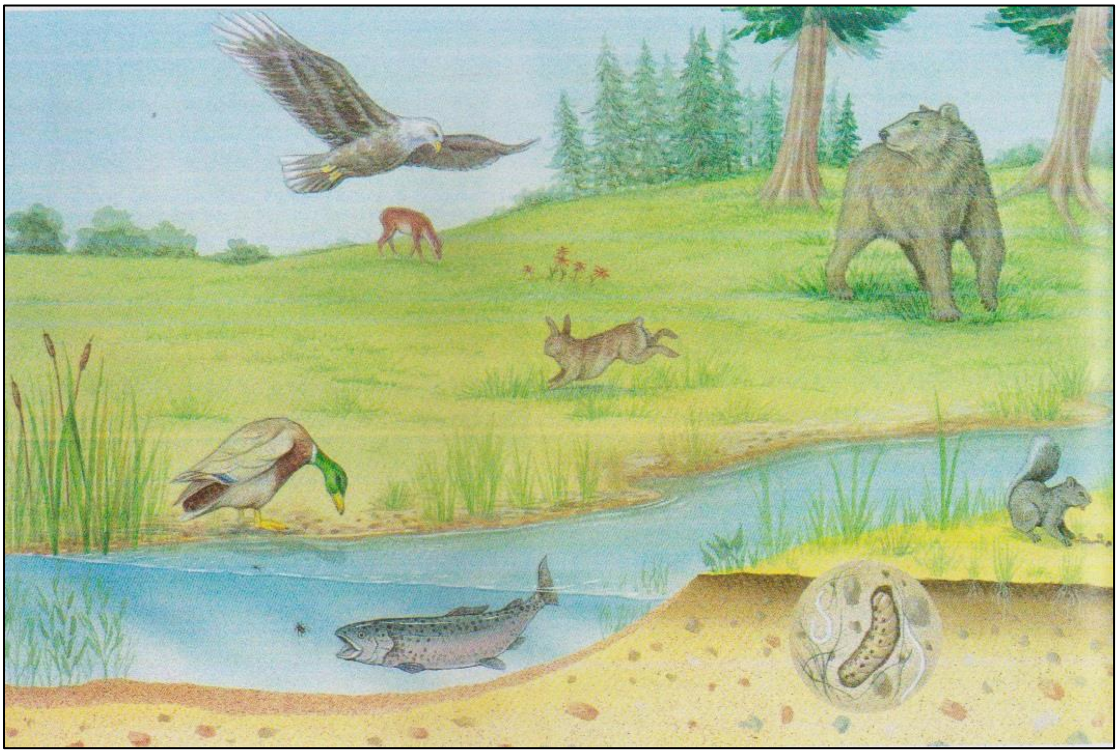
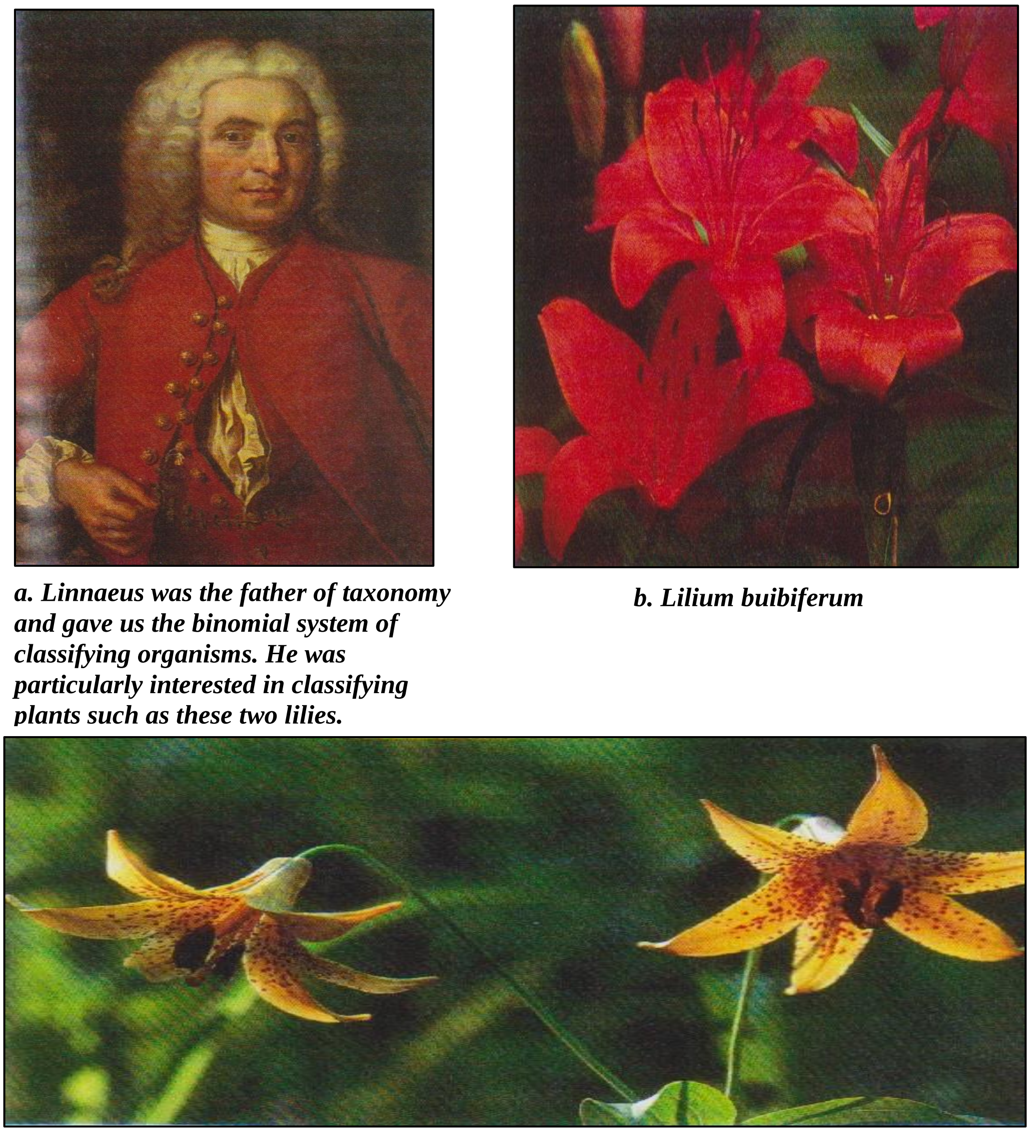


Figure 8.1 Classifying Organisms

Assigning a Two-Part Name

The number of known types of organisms expanded greatly in the mid-eighteenth century due to European travel to distant parts of the world. It was during this time that Carolus Linnaeus (1707-78) developed the binomial system of naming species (Fig. 8.2). The name is a binomial because it has two. parts. For example, Lilium buibiferum and Lilium canadense are two different species of lilies. The first word, Lilium, is the genus (pl., genera), a classification category that can contain many species. The second word is the specific epithet of the species within that genus. The specific epithet sometimes tells us something descriptive about the organism. Notice that the scientific name is in italics; the genus is capitalized while the specific epithet is not. The species is designated by the full name; in this case either Lilium buibiferum or Lilium canadense. The specific epithet alone gives no clue as to species-just as the house number alone without the street name gives no clue as to which house is specified. The genus name can be used alone, however, to refer to a group of related species.



a. Linnaeus was the father of taxonomy and gave us the binomial system of classifying organisms. He was particularly interested in classifying plants such as these two lilies.

b. Lilium buibiferum

c. Lilium canadense

Figure 8.2 Carolus Linnaeus

Why do organisms need to be given a scientific name in Latin? Why can't we just use common names for organisms? A common name will vary from country to country just because different countries use different languages. Hence the need for a universal language such as Latin, which used to be well known by most scholars. Even those who speak the same language sometimes use different common names for the same organism. The Louisiana heron and the tricolored heron are the Same bird found in southern United States. Between countries, the same common name is sometimes given to different organisms. A “robin” in England is Very different from a “robin” in the United States, for example. When scientists use the same scientific name, they know they are speaking of the same organism.

The job of identifying and naming the species of the world is a daunting task. Of the estimated 3 to 30 million or even more species now living on earth, we have named a million species of animals and half million species of plants and microorganisms. We are further along on some groups than others; it’s possible we have just about finished the birds, but there may yet be hundreds of thousands of unnamed insects.

What Is a Species?

There are several ways to species, and each way has its advantages and disadvantages. For Linnaeus, every species has its own distinctive structural characteristics that are not shared by members of a similar species. In birds, the structural differences can involve the shape, size, and color of the body, feet, bill, or wings. We know very well, however, that variations do occur among members of a species. Differences between males and females or between juveniles and adults may even make it difficult to tell which organism belongs to what species (Fig. 8.3).

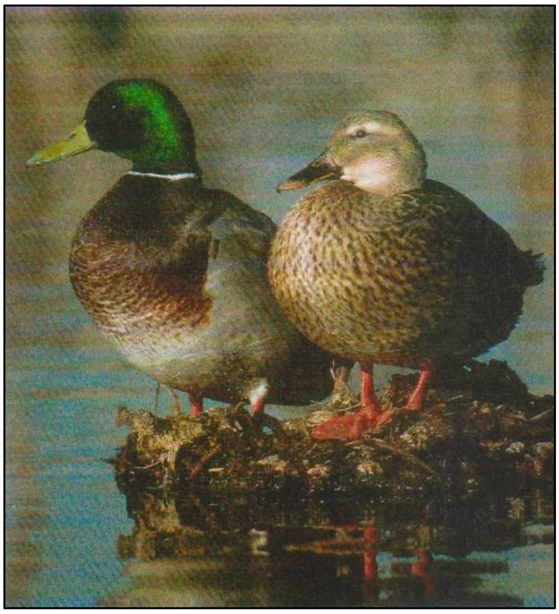


Figure 8.3 Identifying species

The biological definition of a species rests on the recognition that distinctive characteristics are passed on from parents to offspring. This definition, which states that members of a species interbreed and share the same gene pool, applies only to sexually reproducing organisms and cannot apply to asexually reproducing organisms. Sexually reproducing organisms are not always as reproductively isolated as we would expect. When a species has a wide geographic range, there may be variant types that tend to interbreed where their populations overlap (see Fig. 8.3). This observation has led to calling these populations subspecies, designated by a three-part name. For example, Elaphe obsoleta bairdi and Elaphe obsoleta obsolete are two subspecies within the same snake species Elaphe obsoleta. It could be that these subspecies are actually distinct species. Even species that seem to be obviously distinct interbreed on occasion, (Fig. 8.4). Therefore, the presence or absence of hybridization may not be informative as to what constitutes a species.

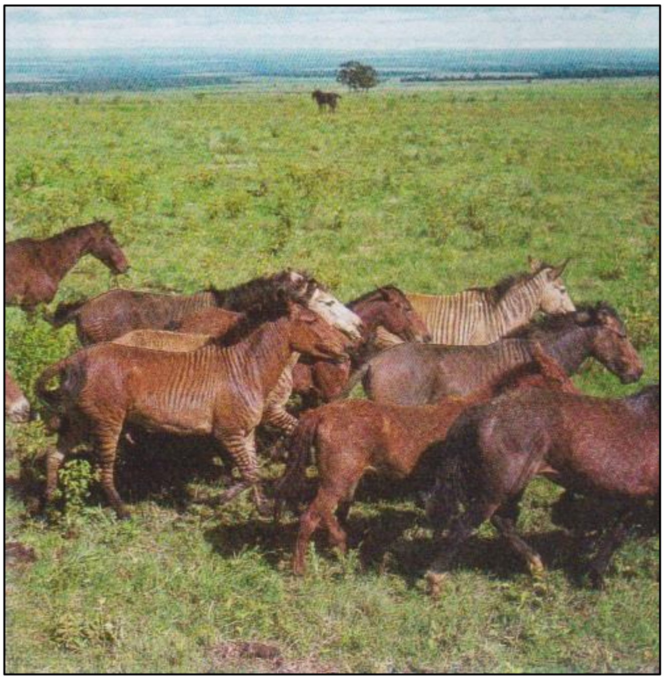


Figure 8.4 Hybridization between species

This chapter concerns **classification**, the assignment of organisms to categories on the basis of their **phylogeny** evolutionary relationship to other organisms. In this context, a species is a taxonomic category below the rank of genus. Species in the same genus share a more recent common ancestor than do species in other taxa. **Taxa** [Gk. tasso, arrange, classify] are groups of organisms that fill a particular category of classification; Rosa and Felis are taxa in the category genus. A common ancestor is one that produced at least two lines of descent; there is one ancestor for all the types of roses, for example.

Now Let's Classify

Classification, which begins when an organism is named, includes taxonomy, since genus and species are two classification categories. The individuals we have so far mentioned were taxonomists who contributed to classification. Aristotle divided living things into 14 groups-mammals, birds, fish, and so on. Then he Went on to subdivide the groups according to the size of the organisms. Ray used a more natural system, since he grouped animals and plants according to how he thought they were related;

but Linnaeus simply used flower part differences to assign plants to these categories, which are still in use today. species, genus, order, and class. His studies were published in a book called Systema Naturae.

Today, we make use of at least seven obligatory categories: **species, genus, family, order, class, phylum**, and **kingdom**. (The plant kingdom uses the category division instead of phylum.) There can be several species within a genus, several genera within a family, and so forth the higher the category the more inclusive it is. (Fig. 8.5). Therefore, there is a hierarchy of categories. The organisms that fill a particular classification category are distinguishable from other organisms by sharing a set of characteristics, or simply characters. A character is any structural, chromosomal, or molecular feature that distinguishes one group from another. Organisms in the same kingdom have general characters in common; those in the same species have quite specific characters in common. Table 8.1 lists some of the characters that help classify humans into major categories.

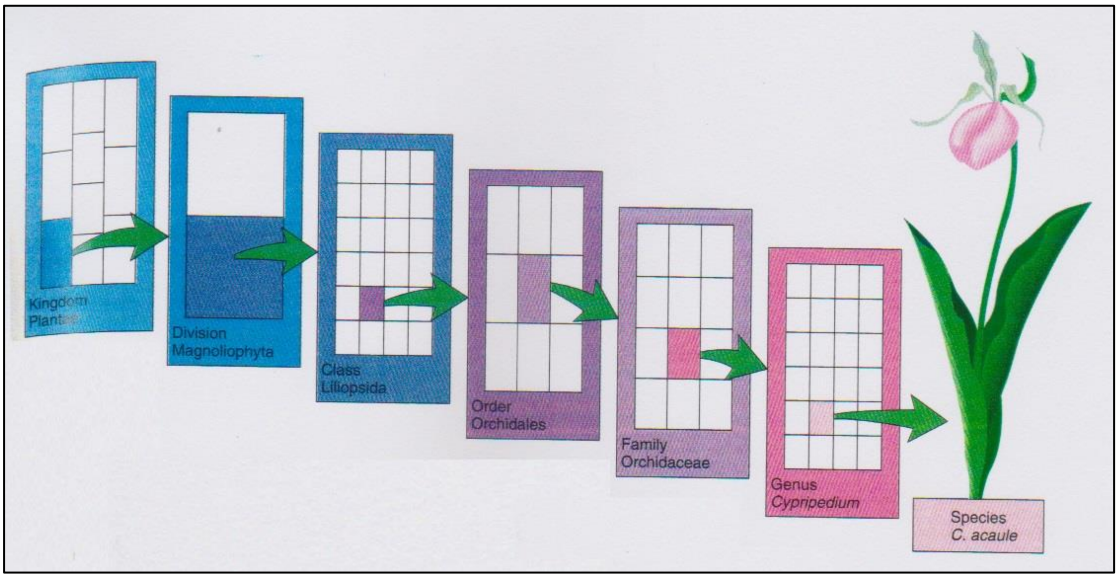


Figure 8.5 Taxonomy hierarchy.

A kingdom is the most inclusive of the classification categories. In the plant kingdom there are several divisions, each represented by a square in the first diagram. In the division Magnoliophyta, there are only two classes (the monocots and dicots). In the class Liliopsida, there are many orders. In the order Orchidales, there are many families, and in the family Orchidaceae, there are many genera, and in the genus Cypripedium, there are many species, for example, Cypripedium acaule.

Table 8.1

Classification of Humans	
Kingdom Animalia	Eukaryotic, usually motile, multicellular organisms, without cell walls or chlorophyll; usually, internal cavity for digestion of nutrients
Phylum Chordata	Organisms that at one time in their life history have a dorsal hollow nerve cord, a notochord, and pharyngeal pouches
Class Mammalia	Warm-blooded vertebrates possessing mammary glands; body more or less covered with hair; well-developed brain
Order Primates	Good brain development, opposable thumb and sometimes big toe; lacking claws, scales, horns, and hoofs
Family Hominidae	Limb anatomy suitable for upright stance and bipedal locomotion
Genus *Homo*	Maximum brain development, especially in regard to particular portions; hand anatomy suitable to the making of tools
Species *sapiens**	Body proportions of modern humans; speech centers of brain well developed

Each of the seven obligatory categories of classification can be subdivided into three additional categories as in superorder, order, suborder, and infraorder. Considering this, there are more than 30 categories of classification.

8.2 Constructing Phylogenetic-Trees

Taxonomy and classification are a part of the broader field of systematics [Gk. system, an orderly arrangement], which is the study of the diversity of organisms at all levels of organization. One goal of systematics is to determine phylogeny [Gk phyle, tribe, L. genitus, producing], or the evolutionary history of a group of organisms. Classification is a part of systematics because it lists the unique characters of each taxon and ideally is designed to reflect phylogeny. A species is most closely related to other species in the same genus, then to genera in the same family, and so forth, from order to class to phylum to kingdom. When we say that two species (or genera, families, etc.) are closely related, we mean they share a recent common ancestor.

Figure 8.6 shows how the classification of organisms allows one to construct a phylogenetic diagram that indicates common ancestors and lines descent (lineages). In order to classify organisms and to construct a phylogenetic tree, it is necessary to determine the characters of the various taxa. A **primitive character** is one that is present in the common ancestor and all members of a group. A **derived character** is one that is one in a particular line of descent. Different lineages diverging from a common ancestor may have different derived characters. For example, all the animals in the family Cervidae have antlers, but they are highly branched in red deer and palmate (having the shape of a hand) in reindeer.

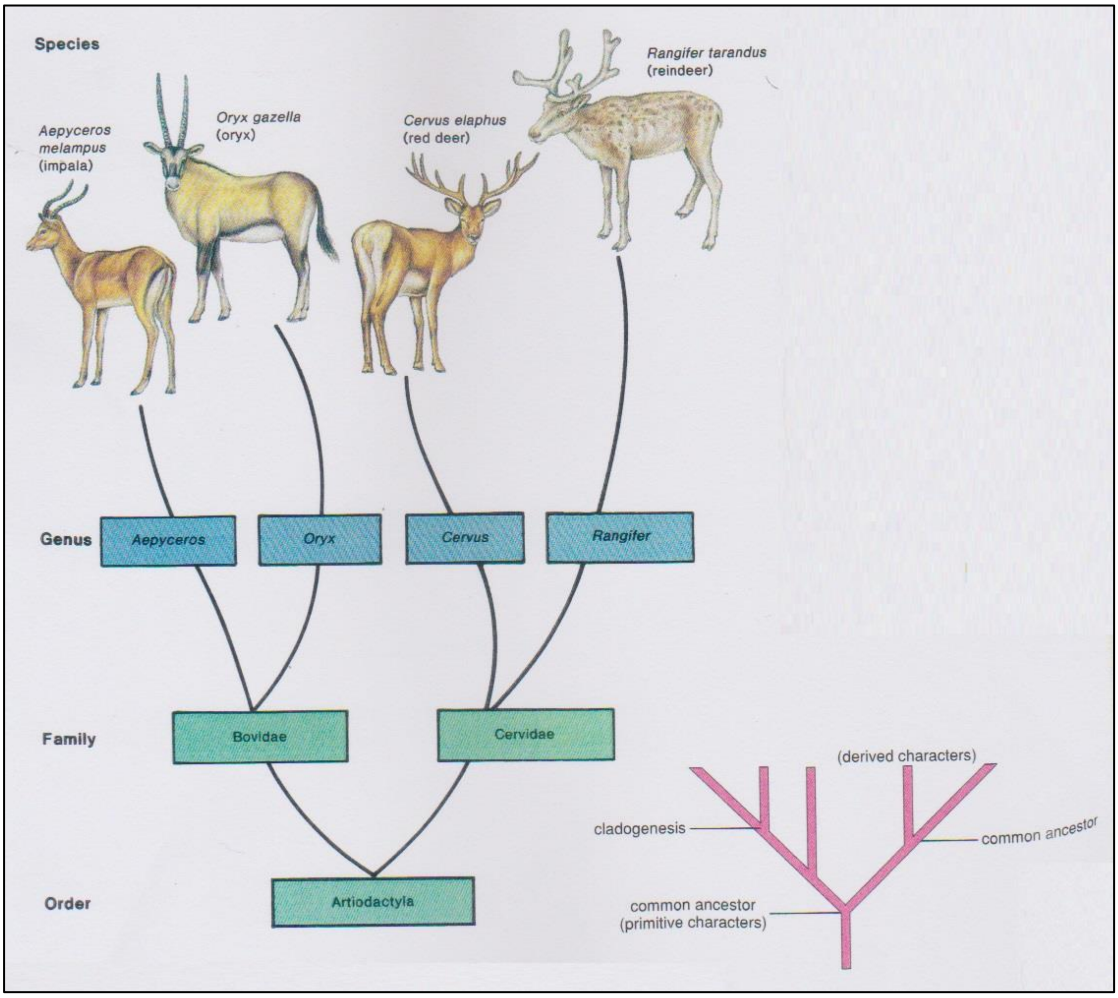


Figure 8.6 Classification and phylogeny.

The classification and a phylogenetic tree for a group of organisms is ideally constructed to reflect their evolutionary history. a. A species is most closely related to other species in the same genus, more distantly related to species in other genera of the same family, and so forth, from order to class to phylum to kingdom. b. A diagrammatic tree showing the location of common ancestors, which are said to have primitive (ancestral) characters. Following cladogenesis (a divergence), each line of descent has its own derived (evolved) characters.

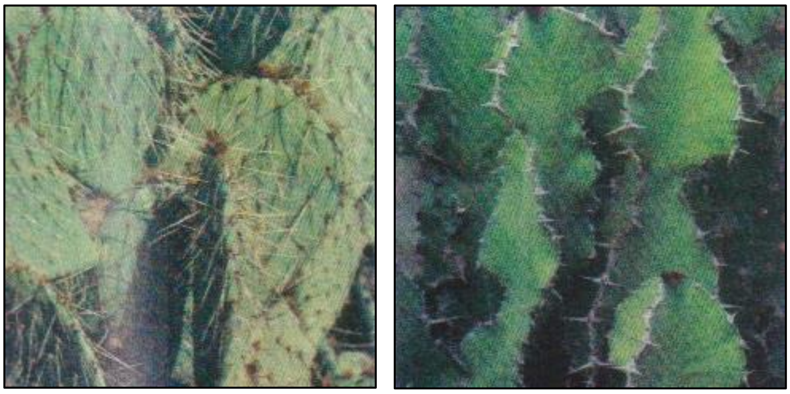
What Are Our Data؟

Systematists gather all sorts of data in order to discover the evolutionary relationship between species. Species placed in one group should have a common ancestry that is, they should form a monophyletic [Gk. monos, one, and phyle, tribe] group. Systematists rely heavily on homology، molecular data, and the fossil record in order to determine monophyletic groups.

When Parts Are Similar

Homology [Gk. homologos, agreeing, corresponding] is character similarity that stems from having a common ancestry. Comparative anatomy, including embryological evidence, provides information regarding homology. The forelimbs of vertebrates are homologous because they contain the same bones organized in the same general way as in a common ancestor. **Homologous structures** are related to each other through common descent, although they may now differ in their structure and function. In contrast, analogous structures have the same function in different groups but are not derived from the same organ in a common ancestor. The wings of an insect and the wings of a bat are analogous structures.

Deciphering homology is sometimes difficult because of convergent evolution and parallel evolution. Convergent evolution is the acquisition of the same or similar characters in distantly related lines of descent. Convergence occurs when organisms have similar structural and functional V traits, not because of A common ancestor but because they are adapted to the same type of environment. Both spurges and cacti are adapted similarly to a hot, dry environment، and they both are succulent, spiny, flowering plants (Fig. 8.7). However, the details of their flower structure indicate that these plants are not closely related. **Parallel evolution** is the acquisition of the same or similar characters in two or more related lineages without it being present in a common ancestor. A similar banding pattern is found in several species of moths, for example. It is sometimes difficult to tell if features are parallel, primitive, or derived.



Prickly pear, *Opuntia* **Spurge, *Euphorbia***

Figure 8.7 Convergent evolution

When Genes Are Similar

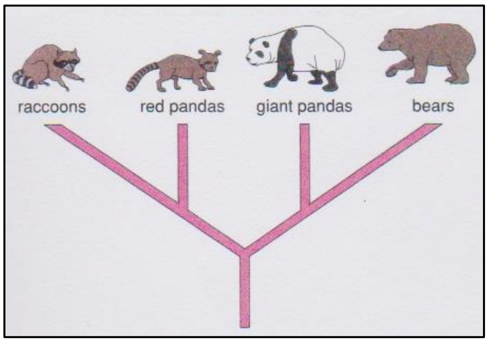
When two lineages first diverge from a common ancestor، the genes and proteins of the lineages are nearly identical. But as time goes by, each lineage accumulates gene changes which lead to RNA and protein changes. Many changes are neutral (not tied to adaptation) and accumulate at a fairly constant rate; such changes can be used as a kind of **molecular clock** to indicate relatedness and evolutionary time.

The genetic difference between two species is determined in a number of ways. Immunological techniques can roughly judge the similarity of plasma membrane proteins. In one procedure, antibodies are produced by transfusing a rabbit with the cells of one species. Cells of the second species are exposed to these antibodies, and the degree of the reaction is observed. The stronger the reaction, the more similar the cells from the two species. Amino acid sequencing of particular proteins, on the other hand, directly indicates when changes have occurred in specific genes.

It is possible to examine and compare the RNA nucleotide sequences of ribosomes to determine relatedness. All cells have ribosomes that are essential for protein synthesis. The genes that code for rRNAs have changed very slowly during evolution in comparison to other genes.

Therefore, they provide a reliable indicator of the difference between organisms. This technique has been particularly useful in reclassifying bacteria and archaea as discussed later in the chapter.

It is possible to determine DNA similarities by **DNA-DNA hybridization**. The DNA double helix of each species is separated into single strands. Then strands from both species are allowed to combine. The more closely related the two species, the better the two strands of DNA will stick together. Some long-standing questions in systematics have been resolved by doing DNA-DNA hybridization. The giant panda, which lives in China, was at one time considered to be a bear, but its bones and teeth resemble those of a raccoon. The giant panda eats only bamboo and has a false thumb by which it grasps bamboo stalks. The red panda, which lives in the same area and has the same raccoonlike features, also feeds on bamboo but lacks the false thumb. The results of DNA hybridization studies suggest that after raccoons and bears diverged from a common lineage 50 million years ago, the giant panda diverged from the bear line and the red panda diverged from the raccoon line:



Therefore, it can be seen that some of the characters of the giant panda and the red panda are primitive (present in a common ancestor), and some are due to parallel evolution.

Because hybridization studies provide only general information, many researchers prefer to compare data regarding the nucleotide sequence of a particular gene or genes. One study involving DNA differences suggested that chimpanzees are more closely related to humans than they are to other apes (Fig. 8.8). Yet in most classifications, humans and chimpanzees are placed in different families; humans are in the family Hominidae and chimpanzees are in the family Pongidae. In contrast, the rhesus monkey and the green monkey, which have more numerous DNA differences, are placed in the same family (Cerocpithecidae). To be consistent, shouldn't humans and chimpanzees also be in the same family? Some systematists believe that since humans are markedly different from chimpanzees because of adaptation to a different environment, it is justifiable to place humans in a separate family.

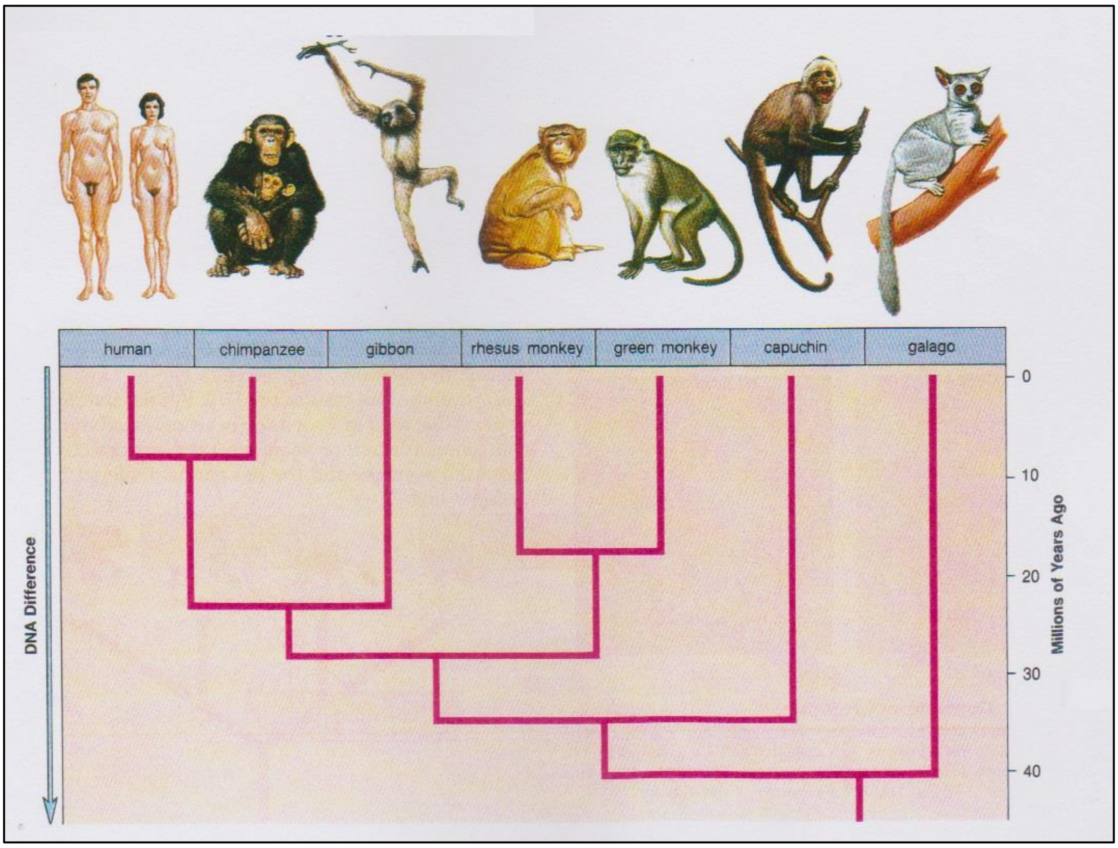


Figure 8.8 Genetic data

The relationship of certain primate species based on a study of their genomes. The length of the branches indicates the relative number of nucleotide pair differences that were found among groups. With the help of the fossil record, it is possible to suggest a date at which each group diverged from the other.

When Fossils Are Available

The fossil record shows the history of life in broad terms, However, the fossil record in regard to individual lineages is incomplete for several reasons. First, soft-bodied organisms do not fossilize. The chances of any organism becoming a fossil are not too good; most organisms are eaten or decay before they have a chance to be buried. Second, fossils tend to exist for only harder body parts, such as bones and teeth. Even then, fossils must survive powerful geological processes and end up in a location that allows someone to find them.

Fossils can be dated, and therefore an available fossil can establish the antiquity of a species. In some instances, the fossil record can trace a lineage through time. Even so, the fossil record does not necessarily provide evidence of whether a feature is primitive or derived.

Who Constructs Phylogenetic Trees?

There are three main schools of systematics: traditional, cladistics, and numerical phenetics. The traditional school stresses both common ancestry and the degree of structural difference among divergent groups. Therefore, a group that has adapted to a new environment and shows a high degree of evolutionary change is not always classified with the common ancestor from which it evolved. For example, in Figure 8.9 a birds and mammals are shown as separate lines of descent because it is quite obvious to the most casual observer that mammals (having hair and mammary glands) and birds (having feathers) are quite different in appearance from reptiles (having scaly skin). The traditionalist goes on to say that birds and mammals evolved from reptiles.

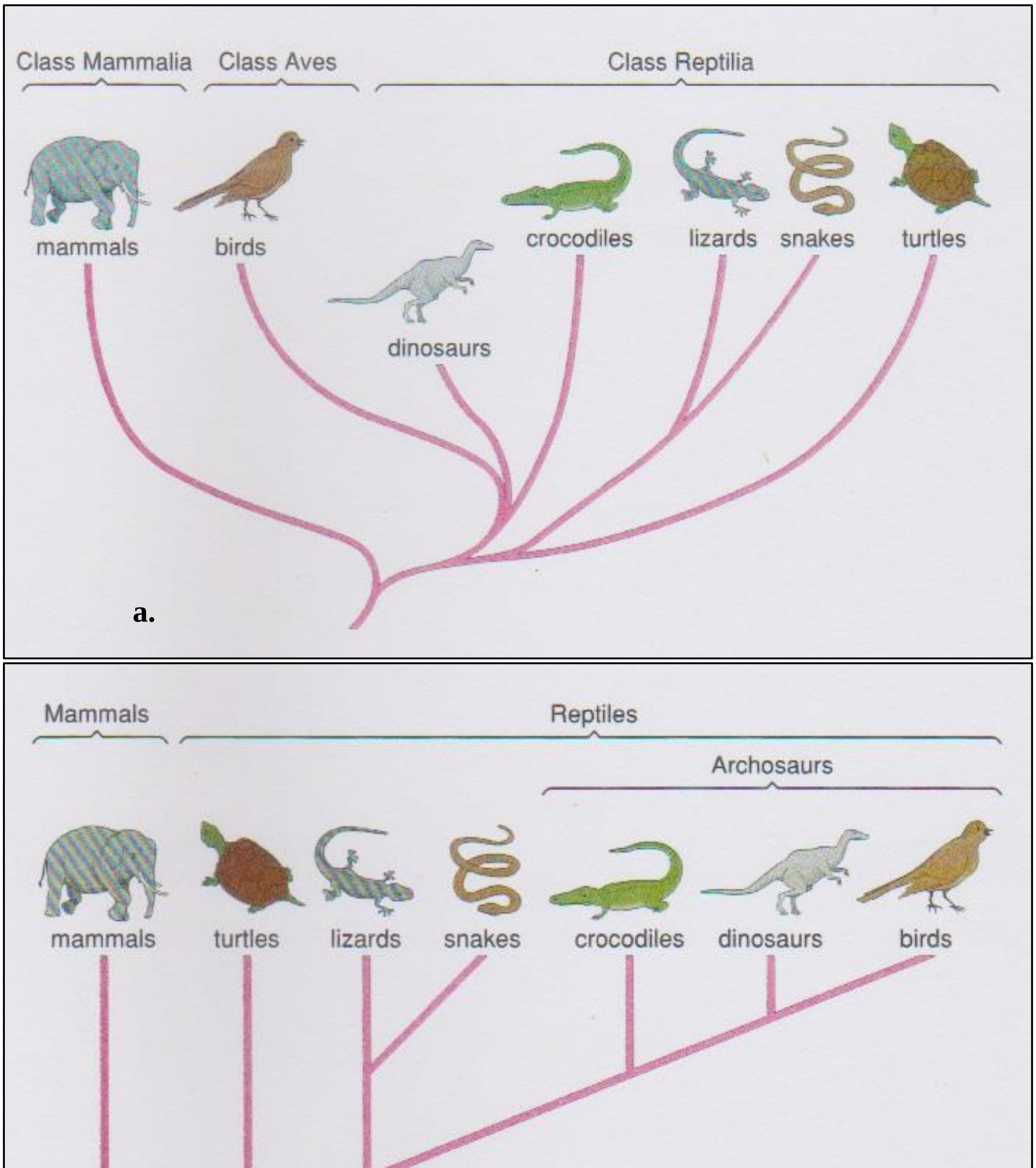


Figure 8.9 Traditional versus cladistic reptilian phylogeny

Cladists, on the other hand, stress common ancestry and shared derived characters only. They discount adaptations to new environments. In the example cited, cladists are doubtful that "reptiles" should be considered a taxon at all because the only thing dinosaurs, crocodiles, snakes, lizards, and turtles have in common is that they are not birds or mammals.

The cladists prefer the diagram shown in Fig. 8.9b. All the animals shown can be placed in one group because they all evolved from a common ancestor, which was an egg-laying creature. All mammals are indeed in one class because they all have hair, mammary glands, and three middle ear bones. Their common ancestor must have had these characteristics also. However, since crocodiles, dinosaurs, and birds all share common derived characteristics, they should all be in thesame subclass, called archosaurs. "So, does this mean that crocodiles and dinosaurs are birds?" the traditionalist asks. Cladists reply that their method is objective and not subjective like that of the traditionalists.

Cladistics Is Objective

This school of cladistics is based on the work of Willi Hennig, who sought a more objective way of establishing relationships and classifying organisms. He felt that the present traditional system, which was based on general, similarities, was subjective and did not produce testable hypotheses. Instead, he suggested that species be grouped according to their shared derived characters. As mentioned, all mammals have characters that they share and that distinguish them from other taxa. The different types of mammals also have their own derived characters. For example, all bats have forelimbs modified as wings, and all whales have forelimbs modified as flippers. However, bat wings and whale flippers are homologous, and the presence of homologous structures indicates that taxa share a common ancestry.

Once cladists have assembled their data regarding shared characters, they construct **cladograrns** [Gk. klados, branch, stem, gramma, picture] to show the branching (cladistic) relationships among species in regard to the distribution of shared derived characters. A cladogram should be regarded as a hypothesis that can be tested and either corroborated or refuted on the basis of additional data. A cladogram differs from a traditional phylogenetic tree, particularly because (1) only data (not subjective evaluations) are used in its construction and (2) the data are presented as a part of the cladogram. Figure 8.10 shows a simple cladogram that involves only three species; construction of a more complex cladogram is discussed in the reading on page 501. A cladogram is not considered a phylogenetic tree, but its branching pattern does resemble a true phylogenetic tree.

Figure 8.10 shows a cladogram in which all three-species represented by X, Y, and Z belong to the same monophyletic group, since they all share the derived characters designated by the first arrow. Species Y and Z are placed in the same subgroup because they share the derived characters designated by the second arrow. How do you know you have done the cladogram correctly, and that the other two patterns shown in Figure 8.10 are not likely? In the other two arrangements, the characters represented by the coloredbox would have had to evolve twice. Cladists are always guided by the principle of parsimony the minimum number of assumptions is the most logical. That is, they construct the cladogram that minimizes the number of assumed evolutionary changes. However, they must be on the lookout for the possibility that convergent evolution has produced what appears to be common ancestry. Then, too, there is the realization that the reliability of a cladogram is dependent on the knowledge and skill of the particular investigator gathering the data and doing the character analysis.

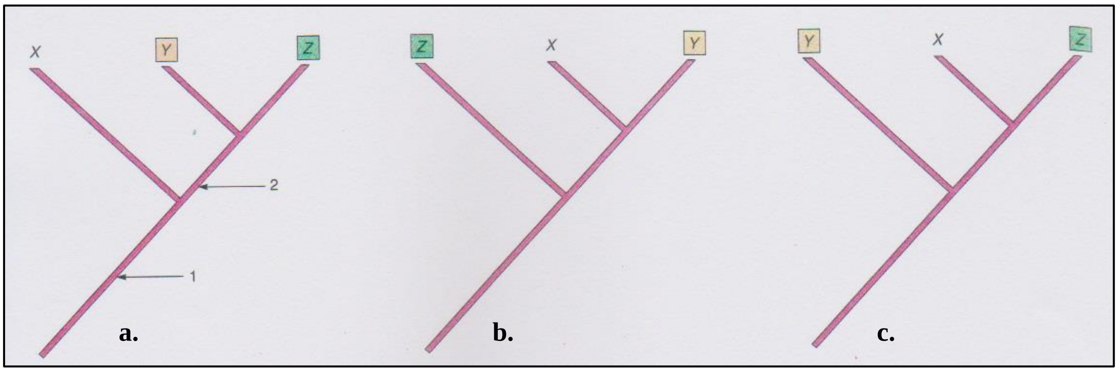


Figure 8.10 Alternate, simplified cladograms

a. X, Y, 2 share the same characters, designated by the first arrow, and are judged to form a monophyletic group (share a common ancestor). Y and Z are grouped together because they share the same derived character, designated by the second arrow and symbolized by the colored box. b. c. These cladograms are rejected because in each you would have to assume that the same character (colored boxes) evolved in different groups. Since this seems unlikely, the first branching pattern is chosen as the hypothesis.

Phenetics Is Numerical

In numerical phenetics, species are clustered according to the number of their similarities. Systematists of this school believe that you cannot construct a classification that actually reflects phylogeny, and that it is better to rely strictly on a method that does away with personal prejudices. They measure as many traits as possible, count the number the two species share, and then estimate the degree of relatedness. They simply ignore the possibility that some of the shared characters are probably the result of convergence or parallelism, or that some of the characters might depend on one another. For example, a large animal is bound to have larger parts. The results of their analysis are depicted in a phenogram. (Phenograms have been known to vary for the same group of organisms, depending on how the data are collected and handled.) Figure 8.8 is an example of a phenogram that is based solely on the number of DNA differences among the species shown.

8.3 Deciding the Number of Kingdoms

From Aristotle's time to the middle of the twentieth century, biologists recognized only two kingdoms: kingdom Plantae (plants) and kingdom Animalia (animals). Plants were literally organisms that were planted and immobile, while animals were animated and moved about. After the light microscope was perfected in the late 1600s, unicellular organisms were revealed that didn't fit neatly into the plant or animal kingdoms. In the 18803, a German scientist, Ernst Haeckel, proposed adding a third kingdom. He called this Protista (protists) in order to separate unicellular microscopic organisms from multicellular ones.

In 1969, R. H. Whittaker expanded the classification system to include five kingdoms: **Plantae**, **Animalia**, **Fungi**, **Protista**, and **Monera**. Organisms were placed into categories based on type of cell (prokaryotic or eukaryotic), organization of cells (unicellular or multicellular), and nutritional requirements. The five-kingdom system of classification depicted in Figure 8.11 became widely accepted at this time.

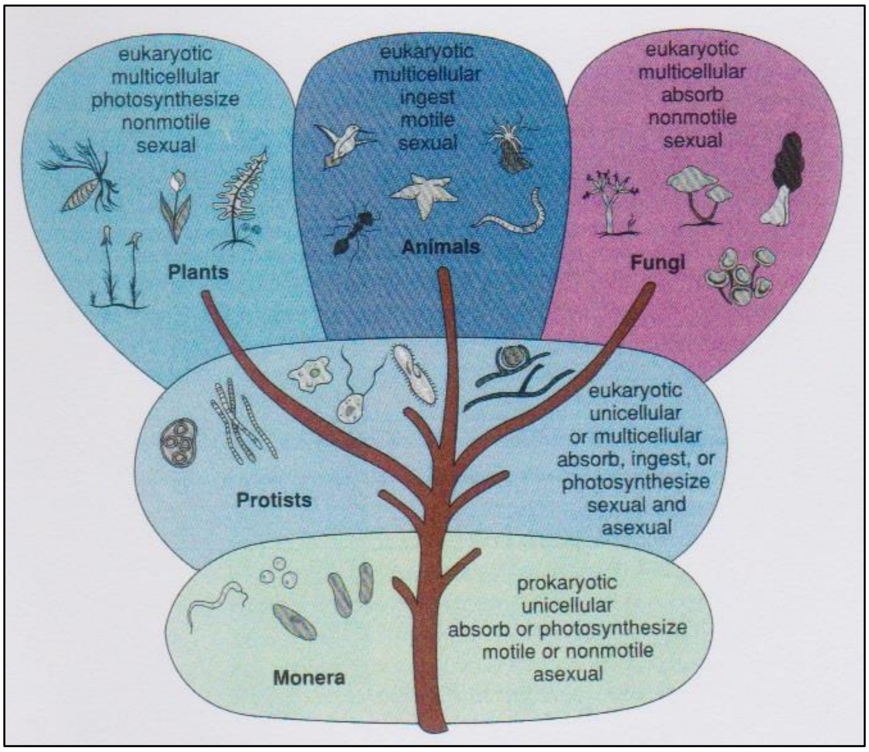


Figure 8.11 The five-kingdom system of classification

The five-kingdom classification system places the fungi (yeast, mushrooms, and molds) in a separate kingdom. Fungi are eukaryotes that form spores and lack flagella throughout their life cycle. Whittaker argued for a separate kingdom for fungi because they are unicellular or multicellular saprotrophs, organisms that absorb nutrients from decaying organic matter. He pointed out that plants, animals, and fungi are all multicellular eukaryotes, but each has a distinctive nutritional mode: plants are autotrophic by photosynthesis, animals are heterotrophic by ingestion, and fungi are heterotrophic saprotrophs.

The kingdom Protista contains a diverse group of organisms that are hard to classify and define. They are all eukaryotes that are mainly unicellular but may be multicellular filaments, colonies, or sheets. They do not form true tissues. Protists may have ingestive, photosynthetic, or saprotrophic nutrition. In this text, kingdom Protista contains the algae, including multicellular algae, protozoa, water molds, and slime molds. There has been considerable debate over the classification of these organisms.

In the five kingdom system, the Monera are distinguished by their structure—they are prokaryotic (lack a membrane-bounded nucleus)-whereas the organisms in the other kingdoms are eukaryotic (have a membrane-bounded nucleus) (Figure 8.12 and Table 8.2). Kingdom Monera originally included all the bacteria. But with the advent of DNA and ribosomal RNA sequencing methods in the 1980s, a new group of microorganisms was identified. These were originally called archaebacteria but are now properly called Archaea (see the next chapter). The archaea have nucleotide sequences that are either close to eukaryotic sequences or are unique and, therefore, not found in either bacteria or eukaryotes.

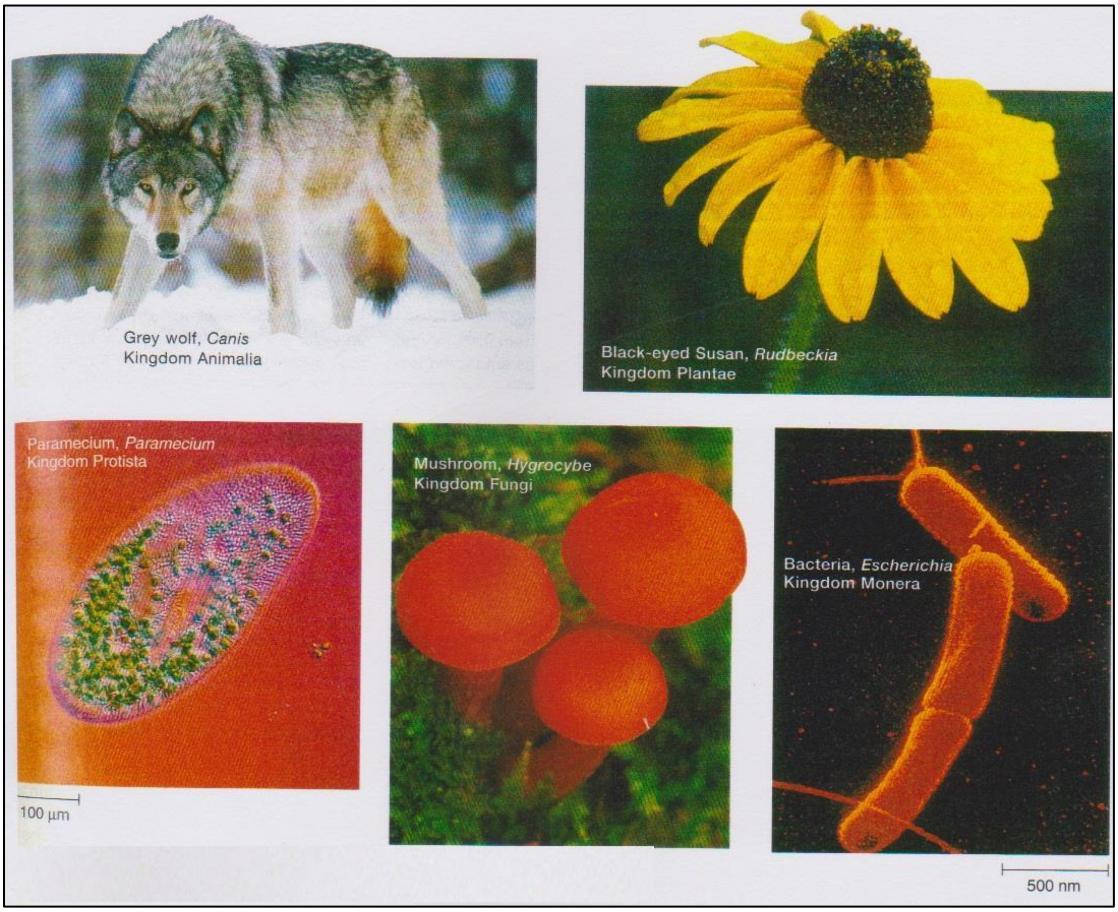


Figure 8.12 The five-kingdom system: A pictorial representation

Table 8.2

Classification Criteria for the Five-Kingdom System

	Monera	Protista	Fungi	Plantae	Animalia
Type of Cell	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Complexity	Unicellular	Unicellular	Unicellular or multicellular	Multicellular	Multicellular
Type of Nutrition	Autotrophic by various or heterotrophic by various	Photosynthetic or heterotrophic by various	Heterotrophic saprotrophs	Photosynthetic	Heterotrophic by ingestion
Motility	Sometimes by flagella	Sometimes by flagella (or cilia)	Nonmotile	Nonmotile	Motile by contractile fibers
Life Cycle*	Asexual usual	Various	Haplontic	Alternation of generations	Diplontic
Internal Protection of Zygote	No	No	No	Yes	Yes
Nervous System	None	Conduction of stimuli in some forms	None	None	Present

On the basis of these new data, it has been suggested that classification should include three evolutionary domains: Bacteria, Archaea, and Eukarya. The bacteria and archaea evolved early in the history of life, while the eukarya evolved later from the archaeal line of descent.

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الطبعة الأولى

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رقم الإيداع في دار الكتب والوثائق ببغداد ١٦٦ لسنة ٢٠١٨