The Principles, Theories & Precepts of Biology

This chapter requires a companion activity book in which students respond to questions on text content. Answers are found in the *Teacher's Resource Kit*.



Chapter 5

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PROFESSIONAL CREDITS

The Principles, Theories & Precepts of Biology

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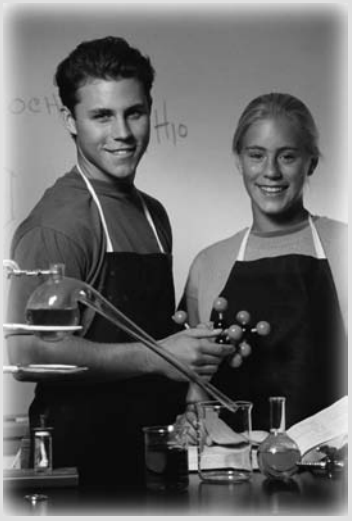
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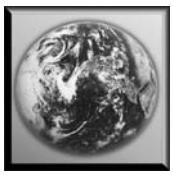
"Biology is man's attempt to understand who he is, where he came from, why he is here, and where he is going."

—Ronald E. Johnson, C.Ph.D.



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Lesson 1

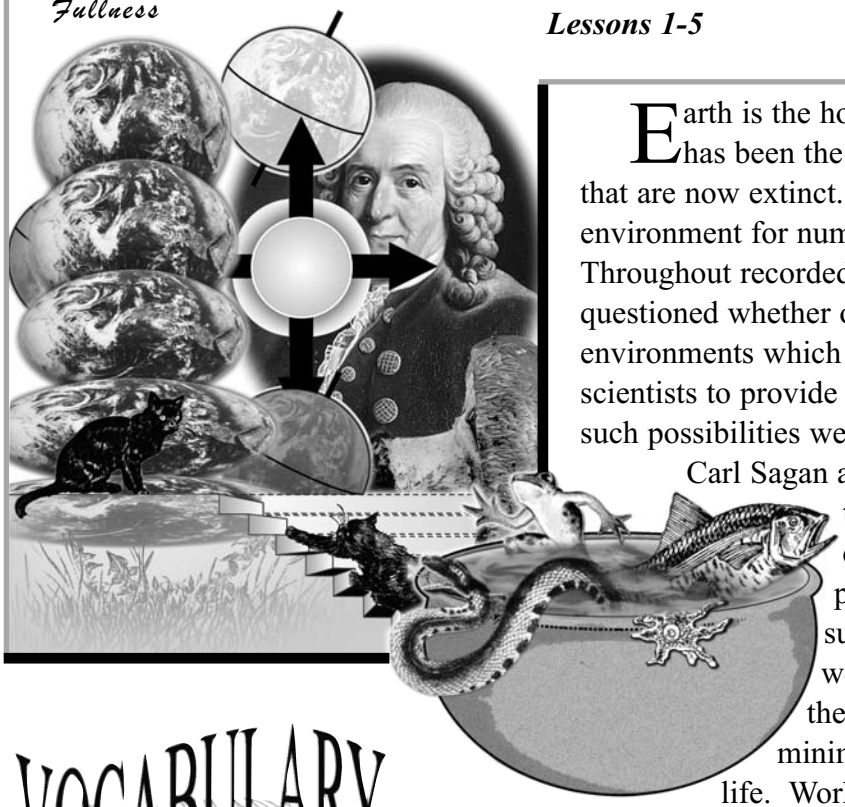
The Earth and Its Fullness

Chapter 5

EARTH: THE "RIGHT" PLACE FOR LIFE

Section 1

Lessons 1-5



Earth is the home to millions of species and has been the home to many more species that are now extinct. Earth clearly has a favorable environment for numerous kinds of life. Throughout recorded history, scientists have questioned whether other planets exist with environments which might support life. The first scientists to provide mathematical calculations of such possibilities were astronomers Frank Drake, Carl Sagan and Iseof Shklovskii. These three men determined that certain kinds of stars with planets (other solar systems, or suns with revolving planets) would have to be located at just the right positions to provide minimal conditions for sustaining life. Working with only these two parameters, the three astronomers estimated that only 0.001% of all stars (1 out of 100,000) could have planets capable of supporting advanced life.

Further research has led scientists to realize just how perfect the Earth is for sustaining life. In fact, scientists have determined that Earth supports life through a variety of finely tuned characteristics of our galaxy, stars, planets and moon. The ***astronomical literature*** includes scholarly discussions on more than forty different characteristics, each of which is thought to require fine tuning for life to exist. The list grows longer each year with new empirical research.

Consider a few examples of these characteristics and calculations.

1. Earth is positioned at just the right distance from the Sun so that Earthlings receive exactly the proper amount of heat to support life. Other planets of our solar system are either too close to the Sun (too hot) or else too far from it (too cold) to sustain life.

VOCABULARY

Parameters: a set of physical properties such as boundaries or limits whose values determine the behavior of something

Astronomical literature: literature pertaining to the science of astronomy

Appreciable: something capable of being measured; enough; sufficient

Astrophysicist: a scientist who studies the branch of astronomy dealing with the physical, chemical composition of celestial matter (things in outer space)

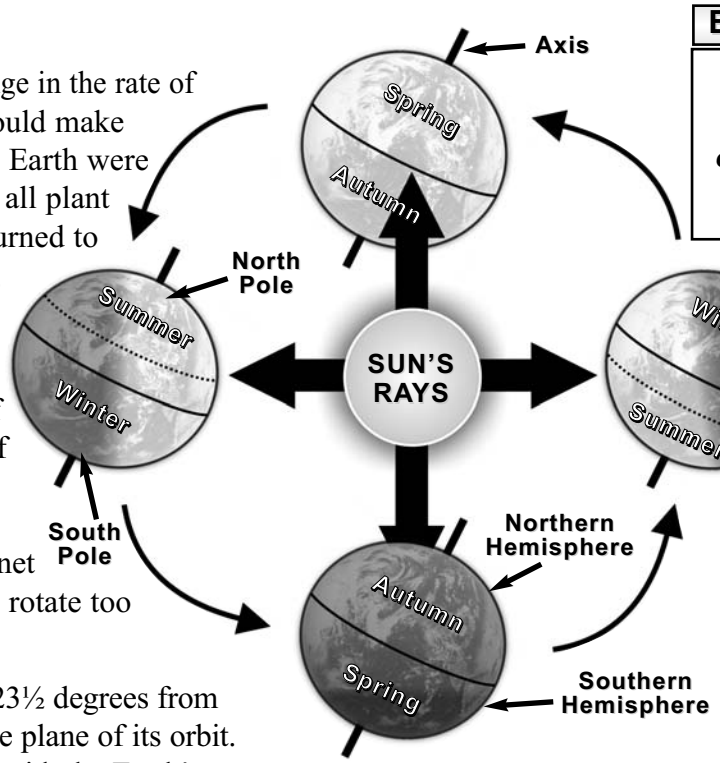
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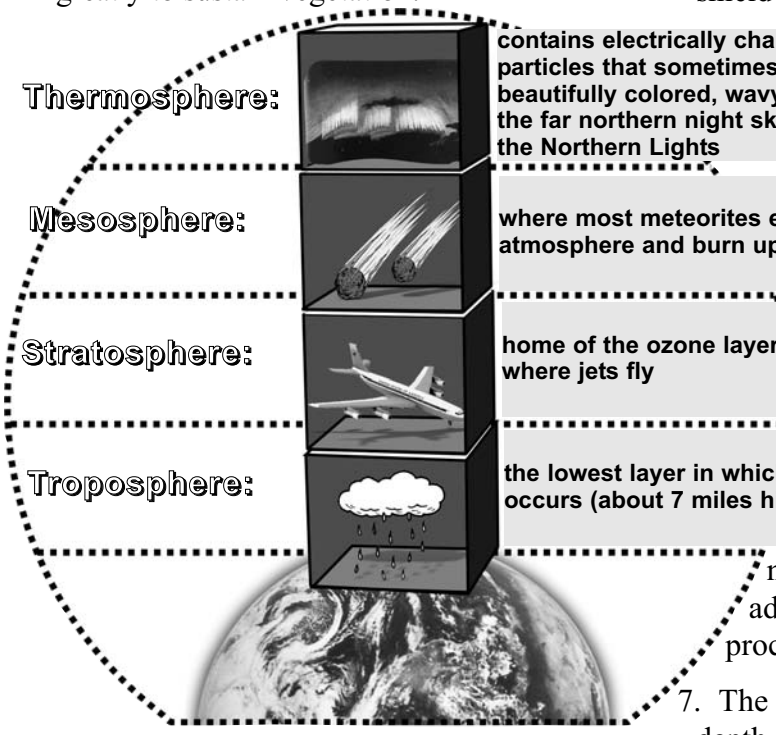
2. Any ***appreciable*** change in the rate of rotation of the Earth could make life impossible. If the Earth were to rotate more slowly, all plant life would either be burned to a crisp during the day, or frozen at night.

3. Some scientists believe that the age of the Earth is critical. If the planet were too young, it would rotate too rapidly. If the planet were too old, it would rotate too slowly to support life.

4. Earth's axis is tilted 23½ degrees from the perpendicular to the plane of its orbit. This tilting, combined with the Earth's revolution around the Sun, causes vegetative growing seasons which are necessary for food supplies. If the tilt were any more or any less than it is, surface temperatures would vary too greatly to sustain vegetation.



5. Earth's atmospheric blanket contains an ozone layer that serves as a protective shield from lethal, solar, ultraviolet radiation which could otherwise destroy all life. If that layer were greater, surface temperatures would be too low. If that shield were less, surface temperatures would be too great and too much surface radiation would occur.



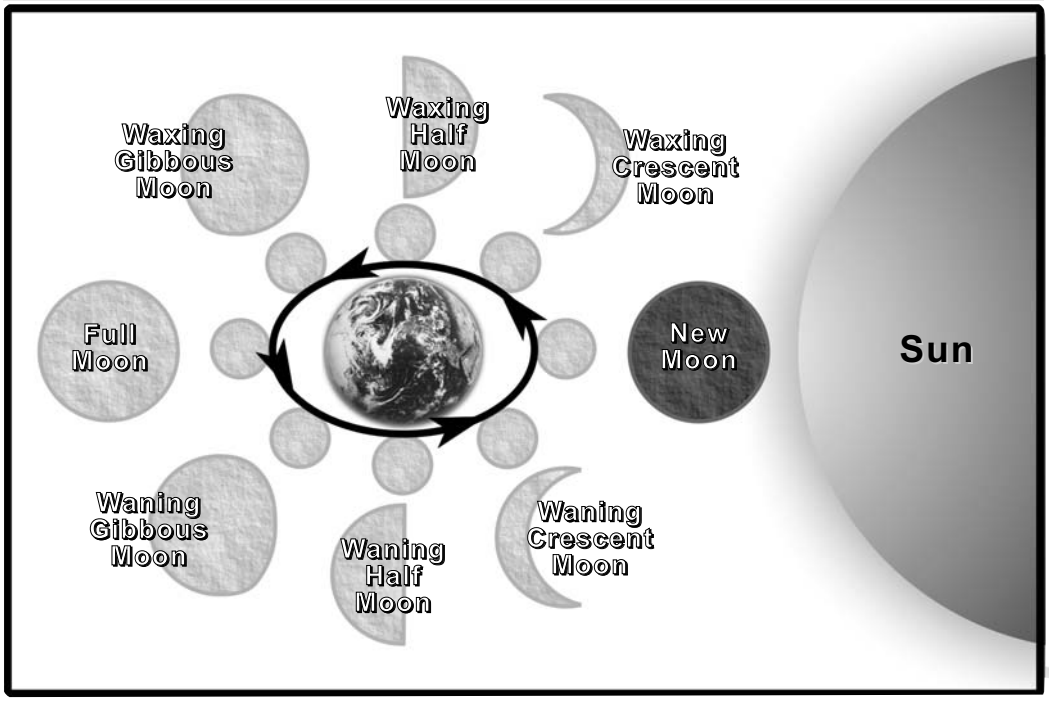
Earth's Atmospheric Blanket Layers

6. Earth's two primary constituents in the atmosphere are nitrogen (78%) and oxygen (20%). This is a critical ratio and essential to all life forms. If the ratio of nitrogen to oxygen were greater, advanced life functions would proceed too quickly. If the ratio of nitrogen to oxygen were less, advanced life functions would proceed too slowly.

7. The thickness of Earth's crust and the depth of its oceans appear to be carefully

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Phases of the Moon as they appear from Earth



The Moon appears to be changing shape as it circles the Earth, with different portions of it being lit up by the Sun. The Moon seems to wax (grow) and wane (shrink), depending on its phase or position.

designed. Increases in crust thickness or ocean depth of only a few meters would so drastically alter the absorption of free oxygen and carbon dioxide that plant and animal life could not exist.

8. The Moon revolves around the Earth at a distance of about 240,000 miles, regulating ocean tides on the Earth. If the Moon were closer, tidal effects on the oceans would be too severe. If the Moon were further away, climatic instabilities would occur and the movement of nutrients and life from the oceans to the continents and continents to the oceans would be insufficient to sustain life.

9. Earth's magnetic field provides important protection from harmful cosmic radiation. If the magnetic field were stronger, electromagnetic storms would be too severe. If the field were weaker, the ozone shield would be damaged and life on land would be inadequately protected from hard stellar and solar radiation.

10. Earth is uniquely blessed with a bountiful supply of water which is the key substance of life. Without water, life as we know it could not exist.

Each of these parameters appear to be maintained within certain limits to avoid disturbing Earth's capacity to support life. Using forty-one similar parameters, ***Astrophysicist*** scholar Hugh Ross has calculated the probability of just one planet occurring with such perfect conditions for life to exist. He concluded that less than one chance in a million trillion exists that even one such planet might occur anywhere in the universe. That one planet is Earth!

Earth qualifies as a unique planet, mysteriously and intricately designed for life as we know it. Some scientists have even nicknamed Earth as "the privileged planet".

In the next lesson, we will examine evidence for calculating the age of the Earth.

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LIFE PRINCIPLE

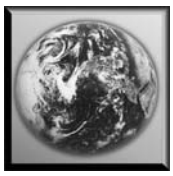


"Gaze at the stars and you must contemplate the origin of life."

—Ronald E. Johnson, PhD
Educator and author

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Lesson 2

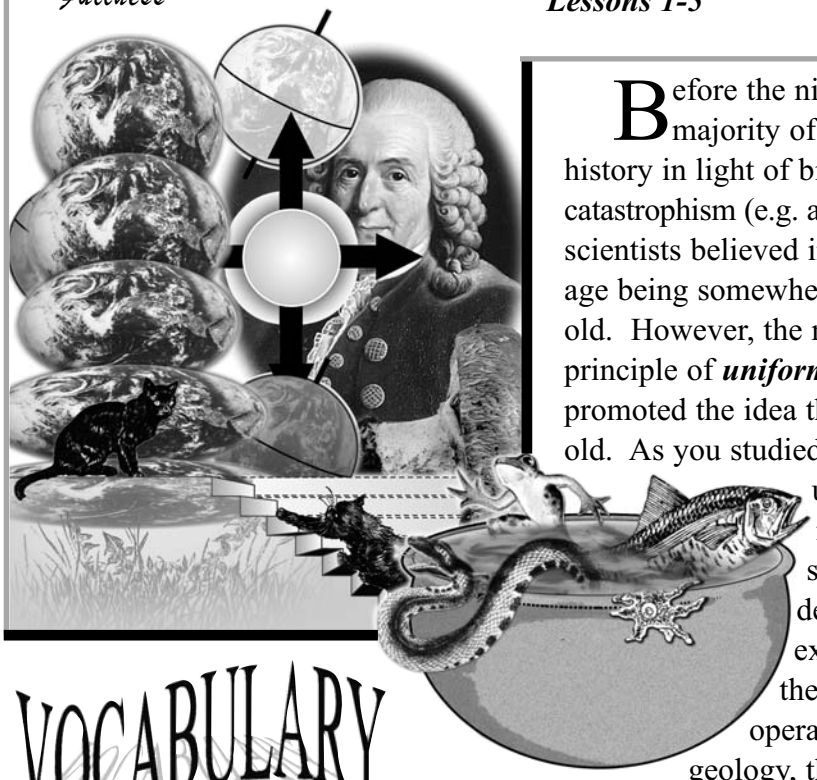
The Earth and Its Fullness

Chapter 5

EARTH: AN "AGELESS" PLANET

Section 1

Lessons 1-5



Before the nineteenth century, the vast majority of scientists interpreted Earth history in light of biblical creationism and catastrophism (e.g. a great flood). Consequently, most scientists believed in a relatively young Earth, the age being somewhere between 6,000—10,000 years old. However, the more recent acceptance of the principle of ***uniformitarianism*** has successfully promoted the idea that the earth is 4.6 billion years old. As you studied in the previous chapter, uniformitarianism minimizes the impact of catastrophic events and states that the origin and development of all things can be explained exclusively in terms of the same natural laws and processes operating today. As applied to geology, this means that all of Earth's mountains, rivers, canyons and all other features of the Earth's surface and crust are a result of the slow processes of sedimentation, erosion, contraction and other actions of natural processes all working over an almost indefinite period of time. Uniformitarians do not rely on any catastrophic events to explain geologic features and formations. Although the uniformitarian assumption appears to be reasonable, it is a theory based on assumptions rather than empirical data. Scientists are divided in their assessment of over 70 evidences for ***young Earth theories*** versus ***old Earth theories***. This lesson will explore a few of these evidences.

VOCABULARY

Uniformitarianism: hypothesis that the origin and development of all things can be explained exclusively in terms of current natural processes

Young Earth theory: lower limits of origin generally placed between 6,000—10,000 years

Old Earth theory: Earth currently claimed to be 4.6 billion years old.

Radioactive dating: a method using half-lives of radioactive isotopes to determine the age of fossils and rocks

GEOLOGIC COLUMN

As you learned in the previous chapter, uniformitarian geologists who study columns or strata of sedimentary rock conclude that simpler life forms are preserved in the deeper strata, land vertebrates in the higher strata, and human life

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forms at the very top. This could be interpreted as evidence for macroevolution, if one accepts the uniformitarian model as truth. However, if one assumes occurrence of a catastrophic event such as earthquakes, volcanic eruptions or a global flood, fossil stratification would also be expected. Such a flood would necessarily tend to affect and bury first the creatures in the deep oceans, then those in shallower waters. Ultimately, the floodwaters would overtake amphibians and land-bordering creatures. Next to be buried would be swamp, marsh, and low river creatures, including reptiles. More developed mammals would be able to retreat ahead of the rising waters to some extent, but if the waters were to rise high enough, even the stronger mammals would also be drowned. Finally, humans would be overtaken and drowned.

From a scientific standpoint, scientists really do not know what caused the formation of the geologic strata and relative positions of the fossils. It may have been caused by the processes of macroevolution over millions of years or it may have been caused by a major catastrophe in a very short period of time. At the present time, the evidence is inconclusive.

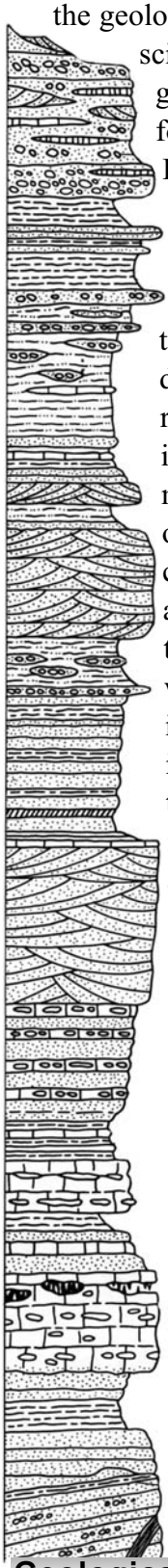
VOCABULARY

Isotope: any of two or more forms of an element having the same atomic number and the same chemical properties but different atomic weights and slightly different physical properties

Alluvium: soil or sediments deposited by a river or other running water

Lord Kelvin: born William Thompson; famous British physicist given honorary title; inventor of Kelvin Temperature Scale

Because of the inconclusive nature of the geologic column, researchers using the scientific method do not include the geologic column as solid evidence for determining the age of the Earth.



Geological Column
Courtesy of the National Park Service Museum

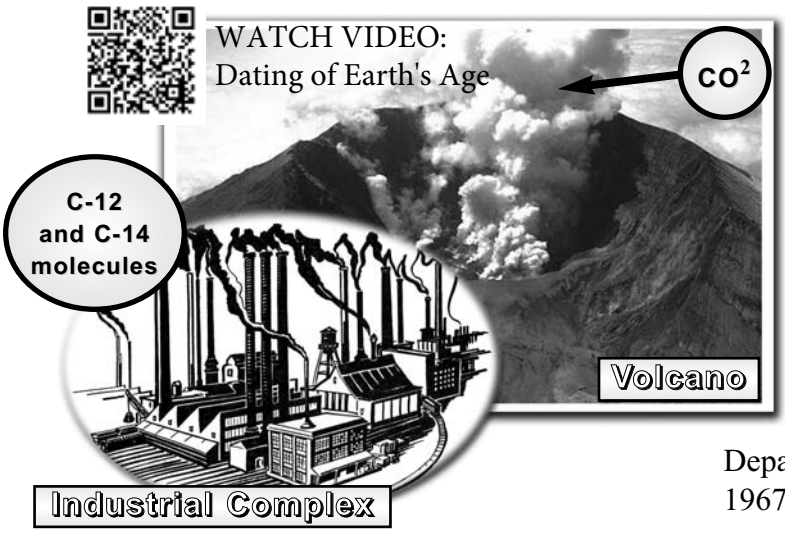
RADIOACTIVE DATING

Radioactive dating is used to "prove" an old Earth. Carbon dating is the most widely used radioactive dating method. Carbon is found in all living things. Like many elements, it has more than one form or ***isotope***. The most common form is carbon-12, abbreviated C-12 or ^{12}C. (The twelve refers to carbon's atomic weight.) However, another carbon isotope called carbon-14 exists. It is much more scarce, but all living things do contain some carbon-14 in their tissues. When a plant or animal dies, the C-14 in the organism's tissues begins to decay back into nitrogen, while the carbon-12 remains stable. Researchers have determined that after about 5700 years, half of the C-14 atoms dissipate. Thus, C-14 has a "half-life" of 5700 years. After another 5700 years, a quarter of the atoms would be left, after another 5700, an eighth and so on. Thus, by ascertaining the ratio of C-14 to C-12 in an object, scientists believe they can determine the age of ancient plants or animals.

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Carbon dating depends on some important assumptions. First, scientists assume that C-14's atmospheric concentration has always been constant. In other words, scientists assume that the concentration of carbon in organisms that lived many thousands of years ago would have been the same as today. However, scientists generally recognize that C-14 is rising. Research shows that in the past, temperature changes in the oceans have absorbed carbon dioxide and thus could have affected C-14 concentration. Fossil fuels (oil, coal, etc.), high in carbon, have been burned extensively since the Industrial Revolution. This has caused the



atmospheric balance of these two isotopes (C-12 and C-14) to change. Volcanoes which spew carbon dioxide into the environment, combined with other past catastrophic events, may also have altered C-14's concentration. Thus, the assumption that the carbon-14 concentrations have remained constant cannot be validated.

Other radiometric techniques exist, similar to carbon dating, that involve unstable, radioactive isotopes which decay into different elements over time. For example, an isotope of uranium decays into an isotope of lead; an isotope of potassium decays into argon gas; and an isotope of the element rubidium decays into strontium. Clearly, these dating methods, like the carbon-14 method, have serious limitations.

Erroneous results derived from these dating techniques have been scientifically verified. For example, living snails have been dated as being 2,300 years old by the carbon-14 method. Freshly-killed seals were dated by carbon-14 to be 1300 years old. Hawaiian lava flows, which are known to be less than 200 years old, have been dated by the potassium-argon method at up to 3 billions of years old.

Scientists who rely on the scientific method find little valid scientific reason to place confidence exclusively in carbon-dating methods, especially when other scientific processes exist which can also be useful in determining the age of the Earth and ancient life.

The Earth's Magnetic Field

The strength of the Earth's magnetic field has been measured for well over 150 years. A United States Department of Commerce publication in 1967 revealed that the magnetic decay rate is approximately 5% per 100 years. This means that the Earth's magnetic field is decaying at an exponential rate, with a half-life of about 1400 years, which, in turn, means that 1400 years ago, the magnetic field of the Earth was about twice as strong as it is now. By projecting backwards in time, physicist Thomas G. Barnes calculated an upper limit of about 10,000 years for the age of the Earth. If the Earth were millions or billions of years old, the magnetic field would have been too strong for any life to exist. In addition, a stronger magnetic field would have retarded C-14 production which could account for some C-14 dating discrepencies.

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Mississippi River Delta

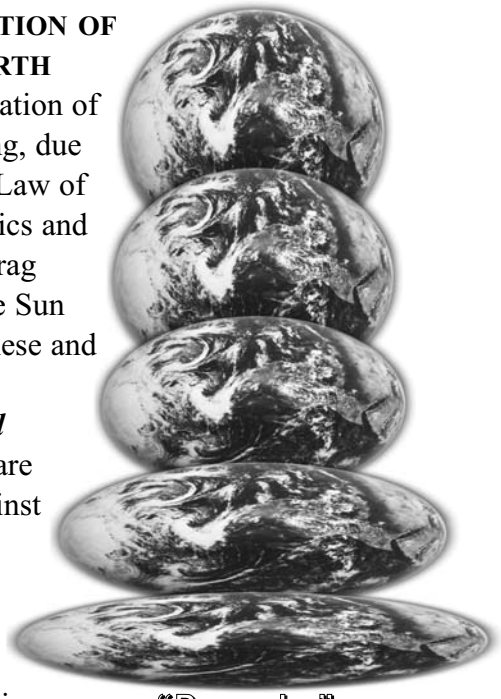
Some scientists contend that the Mississippi River is about two million years old. Over time, a large delta has formed, jutting into the Gulf of Mexico. In the nineteenth century, A.A. Humphreys and H.L. Abbot, of the U.S. Army Corps of Topographical Engineers, studied the river and delta extensively. They determined the delta's age by dividing its average annual growth into the distance from the continental shoreline. Their conclusion was that only about 4,400 years had elapsed since the delta began to advance into the gulf (currently 15 to 50 miles long at different points). Scholars question how the river could be millions of years old, but its delta only thousands of years old. The river annually deposits an estimated 300 million cubic yards of ***alluvium*** into the Gulf of Mexico, continually enlarging the delta by about 200 feet per year. If this process had been in operation for even hundreds of thousands of years, the delta could have built a landbridge to Central America.



Satelite view of the currently active Mississippi delta front

The Rotation of the Earth

The rotation of Earth is slowing, due to the Second Law of Thermodynamics and gravitational drag forces from the Sun and Moon. These and other factors prompted ***Lord Kelvin*** to prepare arguments against the old-Earth theory. Some have reasoned that if the Earth were billions of years old, the centrifugal force from Earth's accelerated rotation would have been so great that water regions would have polarized and continents would have emassed in equatorial regions. This would have produced a severely bulged planet: the shape of the Earth would be more like a flat pancake. However, the shape of the Earth is nearly a perfect sphere; the continents are not confined to equatorial regions, and Earth continues to rotate on its axis at approximately 1,000 mph at the equator.



"Pancake"
(continents squeezed between water areas)

Today, scientists can verify that the decline in Earth's rotational rate is now even greater than previously thought, lending more support to Lord Kelvin's theory of a young Earth.

Population Growth

Evolutionists believe that man-like creatures have been on Earth for at least a million years. Scientific researchers have calculated that with an average growth of

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only one-half of one percent each year (which is one-fourth the present rate), human reproduction would yield the present population of about six billion people in only about 4,000 years. This calculation allows ample adjustments for war, catastrophes and disease that would render population growths well below normal ranges. Researchers have also verified statistically that human reproduction for one million years of evolutionary history would have produced a huge population, exponentially in excess of 6 billion people. Even if the population increased at only one-half percent per year for a million years, the number of people on Earth in the 21st century (barring global catastrophes) would exceed 10^{2100}! However, population growth of such a magnitude did not occur. Researchers therefore question the theory of an old Earth, based on human reproduction growth rates.

Many contemporary scientists are beginning to speculate that perhaps the Earth and the universe are quite young—perhaps only several thousand years old—rather than several billion years old. Science author Dennis Peterson writes:

> *Scientists are aware of over 70 methods that can give us ideas of the Earth's age. We could call these "Geologic Clocks." All of them are based on the obvious reality that natural processes occurring steadily through time produce cumulative and often measurable results. Most of these "clocks" give a relatively young age for the Earth. Only a few of them yield a conclusion of a billion years. Those few are loudly publicized to support the commonly held theory of gradualism.*

In the next lesson, we will examine the controversies surrounding the origins of life.

WATCH A VIDEO!
"DATING OF THE EARTH'S AGE"

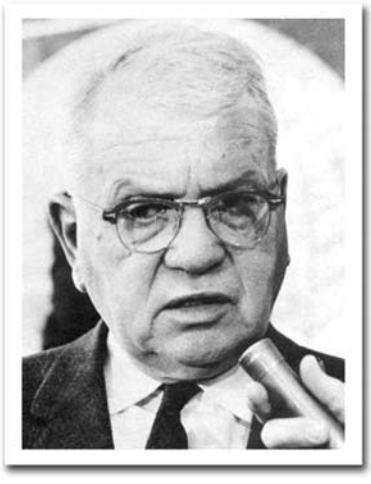
LIFE PRINCIPLE



"It is a capital mistake to theorize before one has data."

—Sir Arthur Conan Doyle (1859-1930), Scottish author

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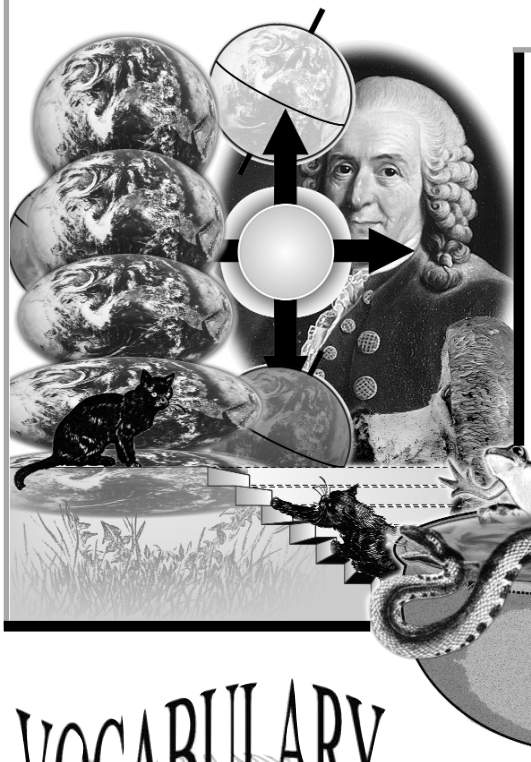
Lesson 3

Chapter 5

THE MILLER-UREY EXPERIMENT

Section 1

Lessons 1-5



The origin of life is a topic of great interest and intense debate. Research centers have been established worldwide to investigate the origin of life, and many experiments have been conducted in an attempt to create life. Dolly, the sheep, was cloned in England. Subsequently, experimental researchers began requesting authority to clone humans as a means of discovering the origins of life.

At the time that Darwin's *Origin of Species* was published in 1859, about half of all surgical patients died from infections; physicians assumed that these infections arose spontaneously. The work of Louis Pasteur and Joseph Lister in the 19th century proved that infections were always spread from a donor, and that living organisms did not originate from non-living matter. Their discoveries lead to the modern concept of sterile techniques in medical and scientific communities.


Louis Pasteur

However, the idea of ***spontaneous generation*** continued to be accepted in the evolutionary model. Natural selection attempts to explain how living things evolved one from another. However, natural selection does not explain *how* life began. For several decades, textbooks have assumed the position that life arose from non-living materials in a "primordial soup." Charles Darwin explained the idea in one of his letters:

> *It is often said that all the conditions for the first production of a living organism are now present which could ever have been present. But if we could conceive in some warm little pond, with all sorts of ammonia and phosphoric salts, light, heat and electricity, etc., present that a protein compound was chemically formed ready to undergo still more complex*

VOCABULARY

Spontaneous generation: the theory that life arose by itself, without assistance (spontaneously) from a "primordial soup" of watery chemicals and rock; the production of living organisms from non-living matter

Albuminous: containing heat-coagulable proteins such as occur in blood, egg white, muscle and certain other plant and animal substances

Synthesize: put together, combine; produce a substance by uniting various elements

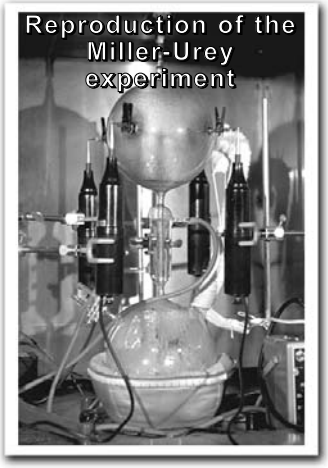
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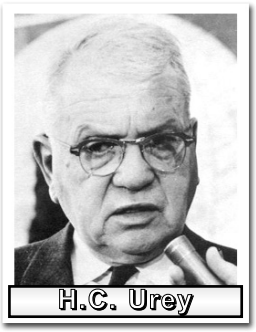
changes, at the present day such matter would be instantly devoured or absorbed, which would not have been the case before living creatures were found.

In Darwin's day, cellular complexity was not understood. Ernst Haeckel called the cell a "simple little lump of ***albuminous*** combination of carbon." Scientists assumed that chemicals could combine to form cells with relative ease. However, as scientific advances have shown that cells are quite complex, the mathematical odds against their formation by chance cast doubt on the possibility of spontaneous generation. Even more troublesome to those who believe in spontaneous generation is the fact that oxygen is present everywhere and would have destroyed amino acids, the very thing needed for life to exist!

In the twentieth century, Soviet biochemist A.I. Oparin further developed the evolutionary theory of origins. He proposed the hypothesis that no free oxygen existed in the ancient Earth's atmosphere. He proposed that other gases such as hydrogen, methane and ammonia might have existed, but not oxygen. Combined with the new theory that the Earth was billions of years old, the probability for Oparin's proposed theory (chance formation of life) increased.


Reproduction of the Miller-Urey experiment

The most well-known and highly acclaimed experimental model designed to test Oparin's hypothesis of spontaneous generation is that of Stanley Miller and his professor, H.C. Urey, a Nobel Prize winner. In their experiment, water vapor, ammonia, methane and hydrogen were subjected to electric sparks in an oxygen–free, closed system. The equipment was carefully sterilized to make certain that no microorganisms could contaminate the results. After a week, the men discovered that some amino acids had formed in a trap in the system. It was then assumed that in the primitive Earth environment, lightning could have struck a similar group of chemicals and produced amino acids.


H.C. Urey

The Miller-Urey experiment created headlines proclaiming that life had been created in the laboratory. The theory expressed is called the ***primordial soup theory***. Cautious scientists, however, concluded that although some organic compounds had been ***synthesized***, no one has successfully *created life* in the laboratory.

Although the Miller-Urey model is widely accepted as evidence for the theory of spontaneous generation in explaining life's origins, the model does present a number of problems.

1. It is unlikely that the young Earth was oxygen-free. Much evidence does exist, however, to suggest that the Earth did have oxygen in its atmosphere for most, if not all, of its history.
2. The concentrations of methane and ammonia were carefully selected in the Miller experiment to insure the production of organic molecules. No evidence exists to suggest that Earth's primitive atmosphere had these same concentrations.
3. If oxygen did not exist in the atmosphere, then no ozone layer would

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have existed to protect living organisms from the Sun's cosmic rays. It is doubtful that the fragile beginnings of life could have survived in an environment free of oxygen.

4. Lightning is considerably stronger than the Miller-Urey electric sparks. Actual lightning most likely would have destroyed any organics which may have been present.



Although the Miller-Urey experiment was successful at producing some chemicals, no actual life was produced. The results of the Miller-Urey experiment are a long way from characteristics of a living cell. The leap from this point to the simplest life forms is still the greatest gap in the spontaneous generation hypothesis of life's origins. Many more organic chemicals would need to be produced in a specific sequence in order for life to begin. You will recall from previous lessons the complexity of the RNA and DNA system of protein transcription and the statistical improbabilities that such systems could have occurred by chance. Analyzing and assembling the chemical components of an organism are far different than bringing those components to life. As Dr. Leslie Orgel, biochemist at the Salk Institute, stated:

Prebiotic soup is easy to obtain. We must next explain how a prebiotic soup of organic molecules, including amino acids and the organic constituents of nucleotides evolved into a self-replicating organism. While some suggestive evidence has been obtained, I must admit that attempts to reconstruct this evolutionary process are extremely tentative.

Author R.L. Wysong states:

Is not the hope to produce life by arriving at proper chemicals and chemical relationships in experiments a rather bizarre aspiration? It is futile. The trillions of organisms that die and have remained dead stand as solemn proof that life is a unique supernatural quality not reproducible by the puny efforts of men wistfully reaching like moths for the stars.

Scientists using good scientific methods recognize that the evidence for spontaneous generation is still inconclusive.

In the next lesson, we will examine the history of taxonomy, the science of classifying and organizing all living organisms.

LIFE PRINCIPLE



"A good soup can sustain life, but I know of no evidence that soup produced life."

—Ronald E. Johnson, PhD
Educator and author

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Lesson 4

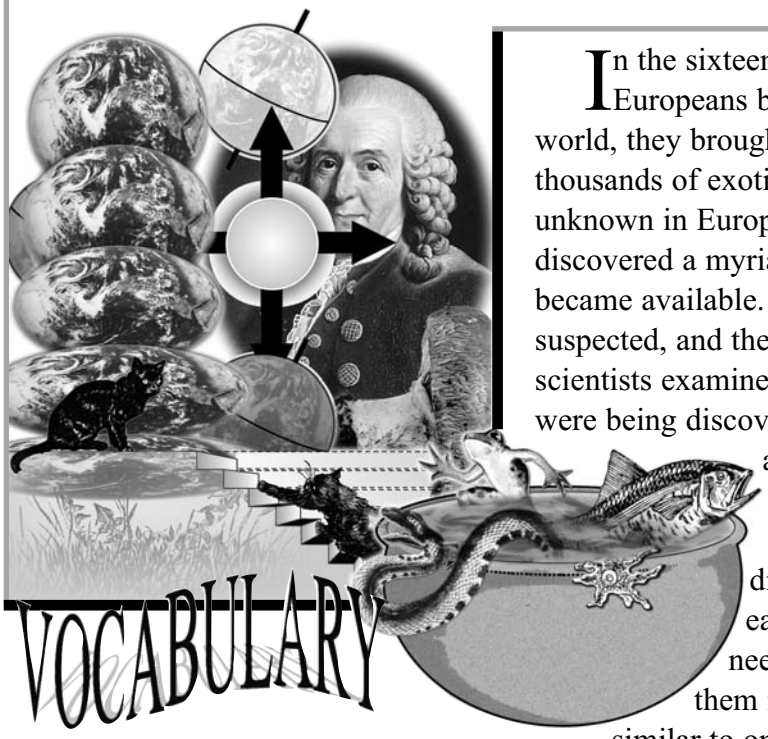
Classification of Organisms

Chapter 5

THE EARTH AND ITS KINGDOMS

Section 1

Lessons 1-5



In the sixteenth and seventeenth centuries as Europeans began to travel to far corners of the world, they brought back tales and actual specimens of thousands of exotic plants and animals that were unknown in Europe. At about the same time, scientists discovered a myriad of tiny organisms as microscopes became available. These tiny organisms had not been suspected, and they were present in almost everything scientists examined. The number of organisms that were being discovered through microscopes became almost overwhelming to European scientists.

In order to study the vast diversity of living organisms on the earth, a classification system was needed to identify organisms and gather them into groups whose members were similar to one another. Classification systems were used to identify social groups. For example, people were classified as teachers, preachers, students, farmers, bankers, attorneys, doctors, clerks and so on.

VOCABULARY

Taxonomy: the science of naming organisms and assigning them to groups

Immutable entity: something incapable of changing

Morphology: the study of the structure of organisms

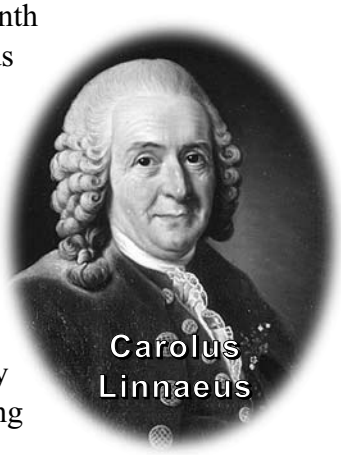
Genus (genera, pl.): classification of a major group of closely related organisms

Specie: smallest group in the classification system of organisms that share similar characteristics and interbreed in nature

Hierarchy: a graded or ranked series, each being subordinated to the one above it as in military ranking

BIOLOGICAL CLASSIFICATION

The science of naming and assigning organisms into groups is called ***taxonomy***. In the eighteenth century, Swedish botanist Carolus Linnaeus invented the orderly system of taxonomy which is used today in classifying organisms.



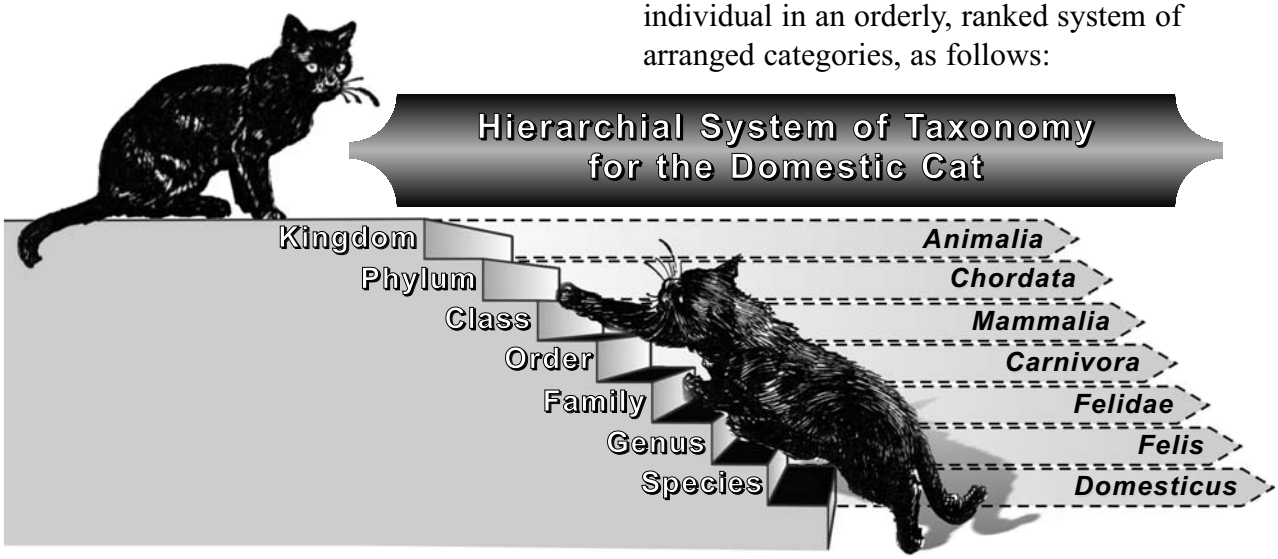
For this, Carolus Linnaeus (1707-1778) is known as the "Father of biological taxonomy". He was a very devout man and was known for his respect for the Bible. As he systematically organized the tremendous varieties of living

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creatures, he believed that each species was an ***immutable entity***, the product of divine creation. His goal was to group the "species" category with their own "kind", believing that variation could occur *within* the kind but not from one kind to another kind.

Linnaeus based his classification on ***morphology***, which relates to the structure and function of an organism. Linnaeus used a classification hierarchy to organize all known creatures.



VOCABULARY

Mnemonic: a code, rhyme or other device for assisting one's memory
Family: classification of a group of closely related genera
Order: classification of several families of similar organisms
Classes: classification categories of related orders
Phylum: category made up of several classes of different organisms that share important characteristics
Kingdom: highest ranking classification of living organisms; one of the six major groups

Suppose you were asked to classify all the people on earth based on where they live. You would probably begin by dividing the entire world population into groups, according to country of residence. This would separate inhabitants of the United States from those living in France. Next, you would subdivide the population of the United States by states, then by counties, then by cities, then by streets, and finally by house numbers. This procedure would enable you to place every individual in an orderly, ranked system of arranged categories, as follows:

Country
State
County
City
Street
Number

Note that each level of this ***hierarchy*** is contained within and is partly determined by all levels above it. Thus, once the United States has been determined as the country of residence, a Mexican state or Canadian province is excluded. Similarly, once the state (such as Texas) has been determined, counties in California or New York are excluded.

The same principles apply to the classification of living things based on morphology. The hierarchy of biological

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categories is used as following:
(A good way to remember these is the following ***Mnemonic***: ***K****ing* ***P****hilip* ***C****ried* ***O****ut: "****F****or* ***G****oodness* ***S****ake!"*)

Linnaeus gave each organism a two-part name in Latin, which was the language of science at the time. The house cat, for example, is called *Felis domesticus*. The first part of the name, *Felis*, refers to the ***genus*** (***genera***, plural) to which a cat belongs. A genus refers to the small group of organisms that are quite similar to one another, though different in certain respects.

The second part of a cat's name, *domesticus*, refers only to one particular ***species***. Often, this part of the name is a Latin description of an important characteristic of the organism. *Felis domesticus* means "domesticated cat." Please note that the genus name is capitalized.


Felis domesticus


Panthera tigris

Species refers to a population of organisms that share similar characteristics and that may interbreed in nature. If two species share many features but do not interbreed, they are classified as different species. For example, although a tiger is a cat-like animal, it is placed in an entirely different genus-species group called *Panthera tigris*.

The genus, *Felis*, and three other genera of cats are grouped into larger units called ***families***. All genera of cat-like animals belong to the family *Felidae*.

Several families of similar organisms make up the next larger group—an ***order***. Members of the cat, dog, bear and raccoon families are placed in the order *Carnivora*.

Orders are then grouped into ***classes***. All members of the order Carnivora are placed in the class *Mammalia*, along with other animals that are warm-blooded, have body hair, and produce milk for their young. Several classes are placed in ***phylum***, which has a large number of very different organisms. These organisms share some very important characteristics. For example, mammals are grouped with the birds, reptiles, amphibians, and several classes of fish into the phylum *Chordata*. Lastly, all phyla belong to one of six large groups called ***kingdoms***. Animals make up the kingdom *Animalia*.

Linnaeus used only kingdom, class, order, genera and species in his classification system; the phylum and family categories were added later as scientists identified unique characteristics among living creatures.

The Six Kingdoms

For decades, biologists recognized five kingdoms of life—Monera, Protista, Fungi, Plantae and Animalia. In recent years, however, molecular techniques such as reading DNA and sequencing proteins have been used to research similarities at the cellular level. Biologists now realize that the two major groups of bacteria are so different that they deserve to be placed in two separate kingdoms: *Eubacteria* and *Archaebacteria*. Today, most researchers agree that six kingdoms should be recognized: *Eubacteria*, *Archaebacteria*, *Protista*, *Fungi*, *Plantae* and *Animalia*. Another mnemonic may be helpful in remembering the kingdoms, such as: "***A****unt* ***P****aula* ***F****ound* ***P****eter* ***E****ating* ***A****pples*."

In the next lesson, we will briefly examine the six different kingdoms.

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LIFE PRINCIPLE



"In all things of nature there is something of the marvelous."

—Aristotle (384-322 BC)
Greek philosopher and scientist

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Kingdoms of Biology

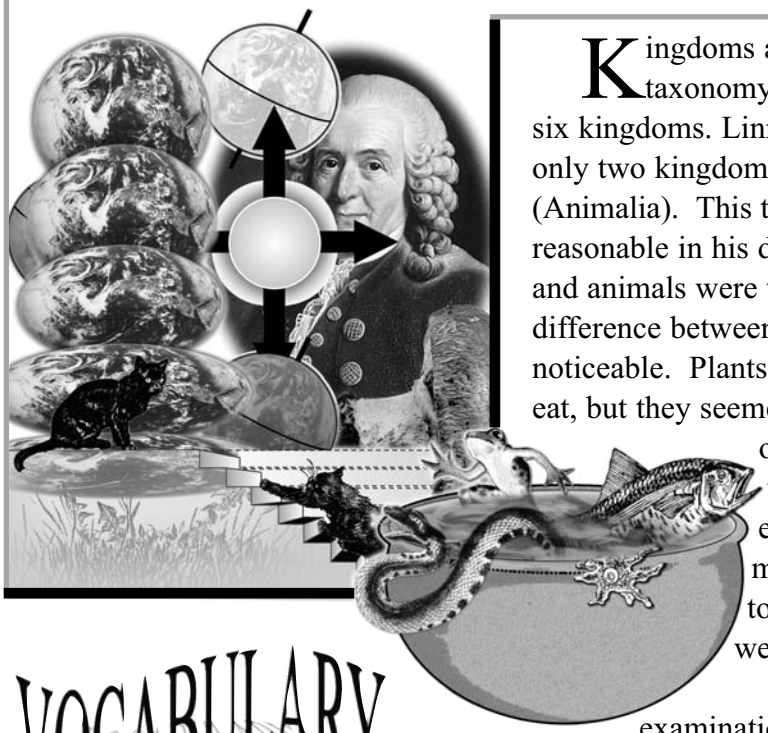
Lesson 5

Chapter 5

THE SIX KINGDOMS OF LIVING ORGANISMS

Section 1

Lessons 1-5



Kingdoms are the most inclusive groups of taxonomy. All organisms belong to one of the six kingdoms. Linnaeus' system of classification had only two kingdoms, the plants (Plantae) and the animals (Animalia). This two-kingdom system seemed reasonable in his day, since the ***macroscopic*** land plants and animals were the most familiar organisms. The difference between plants and animals was quite noticeable. Plants did not move around; they did not eat, but they seemed to need only water and sunlight in order to grow. Animals, however, were ***motile*** and had to eat plants or each other to stay alive. On a macroscopic level, plants were known to have cell walls, which animal cells were assumed to lack.

However, discovery and examination of a wide variety of microscopic organisms since the time of Linnaeus have revealed many organisms that do not fit neatly into either the plant or the animal classification. Some organisms, such as *Euglena*, seem to fit into both of the kingdoms. The *Euglena* has a rather stiff covering, not as thick as a plant cell wall, but certainly affording more protection than a cell membrane. *Euglena* also has chloroplasts and can carry on photosynthesis when exposed to light. However, it also has a flagellum with which to swim, much like an animal might swim. Also, *Euglena* can engulf other organisms and digest them as food, just like an animal.

Bacteria presented another problem since they have cell walls, but often also possess *flagella* that make them motile; most cannot make their own food, but some can carry on photosynthesis. As more organisms were discovered and studied, the division into plant and animal kingdoms seemed to become more artificial. Soon, scientists realized that the classification system required more than two kingdoms.

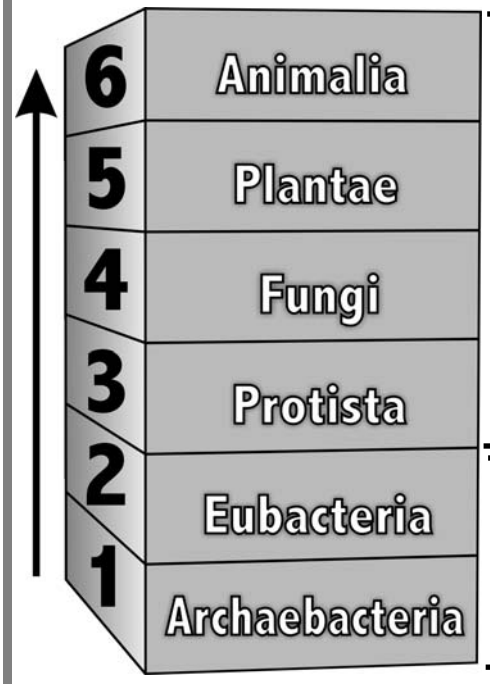
VOCABULARY

Macroscopic: visible to the naked eye
Motile: capable of spontaneous movement; mobile
Prokaryotic: lacking a nuclear membrane separating the DNA from the cytoplasm, has no other membrane-bound organelles
Eukaryotic: with a nuclear membrane surrounding the genetic material and with various membrane-bound organelles in the cytoplasm
Autotrophs: organisms that are able to make their own food, such as plants

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Recent attempts to revise the biological classification system at the kingdom level have been many and varied. Most scientists now agree to use the classification system based on concepts presented by ecologist Robert Whittaker. Whittaker developed a five-kingdom system in 1968 consisting of Monera, Protista, Fungi, Plantae and Animalia; but even more recently, Kingdom Monera was broken into two groups, *Eubacteria* and *Archaebacteria*. Today, most researchers agree to use this six-kingdom system. However, much disagreement exists on many other aspects of taxonomy. As you read other textbooks, you will find that very few agree on all classification details.



Hierarchy of Kingdoms

VOCABULARY

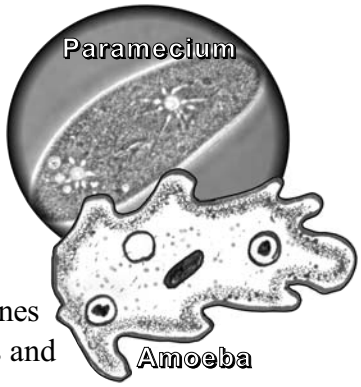
Heterotrophs: organisms that depend on other organisms for food

The first two kingdoms, *Eubacteria* and *Archaebacteria*, are composed of organisms with ***prokaryotic*** cells. The other four kingdoms, *Protisa*, *Fungi*, *Plantae* and *Animalia*, are made up of ***eukaryotic***-celled organisms.

As you studied in a previous lesson, *prokaryotic* cells lack a nuclear membrane separating DNA from the cytoplasm and also lack membrane-bound organelles. *Eukaryotic* cells have a nuclear membrane surrounding the genetic material and have various membrane-bound organelles in the cytoplasm.

KINGDOMS EUBACTERIA AND ARCHAEBACTERIA

At one time, these two kingdoms were grouped together in a kingdom called *Monera*. All prokaryotic organisms, known as bacteria and blue-green bacteria, are placed into one of these two kingdoms. Prokaryotes lack a nuclear membrane and mitochondria, chloroplasts and other membrane-bound organelles found in eukaryotic cells. Prokaryotic DNA is present as one circular double helix, and then divides and reproduces without the nuclear division of meiosis or mitosis.



KINGDOM PROTISTA

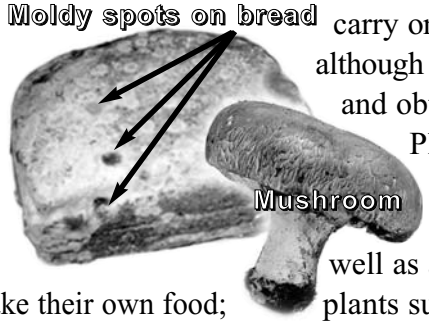
The Protista are one-celled *eukaryotic* organisms. As eukaryotes, they have nuclear membranes and are capable of meiosis and mitosis. *Amoebae* and *paramecia* are members of the Kingdom Protista. Kingdoms Eubacteria, Archaebacteria and Protista together contain most of the microorganisms that exist on Earth.

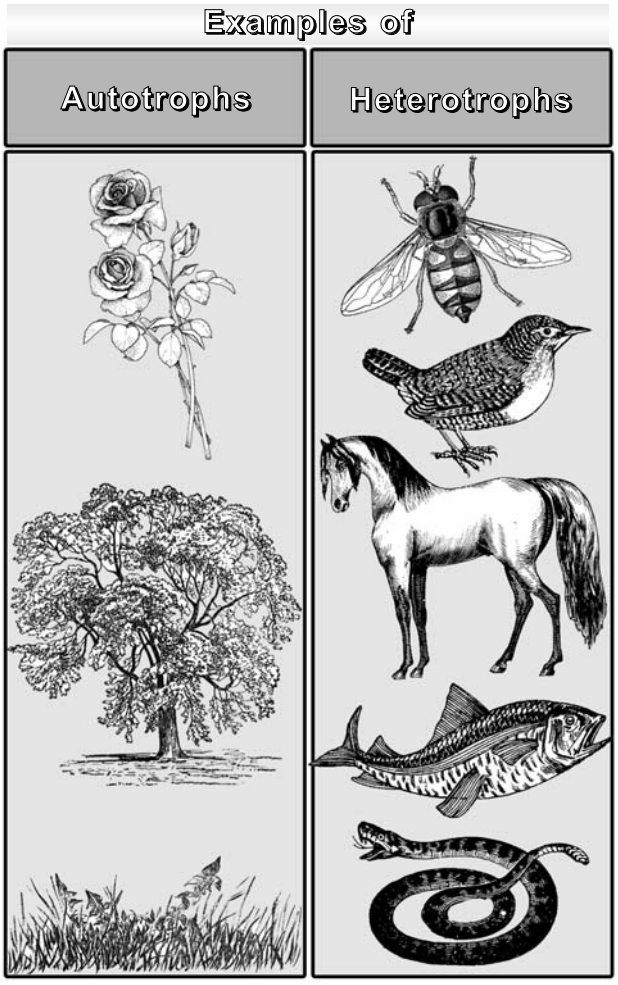
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Kingdom Fungi

Moving out of the microscopic world (for the most part) and into the macroscopic world, Kingdom Fungi is next in the order of kingdoms. Fungi are often classified as plants because they are not motile and because they have an external cell wall that resembles the plant cell walls in many ways. However, fungi cannot make their own food; they must absorb food from a living or nonliving organic source. In many cases, they excrete digestive enzymes that process food outside their bodies in order to absorb the food. Mushrooms and bread molds are example members of the Kingdom Fungi.





Kingdom Plantae (Plants)

All members of the plant kingdom are eukaryotes and have cell walls that contain cellulose. Most contain chlorophyll and carry on photosynthesis inside chloroplasts, although a few species contain no chlorophyll and obtain all their nutrients by absorption.

Plants are ***autotrophs***, meaning "self-nourishing". The plant kingdom includes the multicellular algae, as well as all the familiar multicellular land plants such as trees, grass and flowers.

Kingdom Animalia (Animals)

The last kingdom is made up of multicellular, eukaryotic organisms that obtain their food mainly by ingestion. Animals are ***heterotrophs*** and do not produce their own food. Most animals can move, and therefore, can acquire food from their environment. All but the simplest animals produce gametes (eggs and sperm) in multicellular organs, and the fertilized eggs develop into multicellular embryos. Members of the animal kingdom include insects, birds, mammals, reptiles, fish and humans.

In the next lesson, we will begin a brief overview of each of the six kingdoms.

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LIFE PRINCIPLE



"Science may have found a cure for most evils; but it has found no remedy for the worst of them all—the apathy of human beings."

—Helen Keller (1880-1968),
American writer

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Kingdoms of Biology

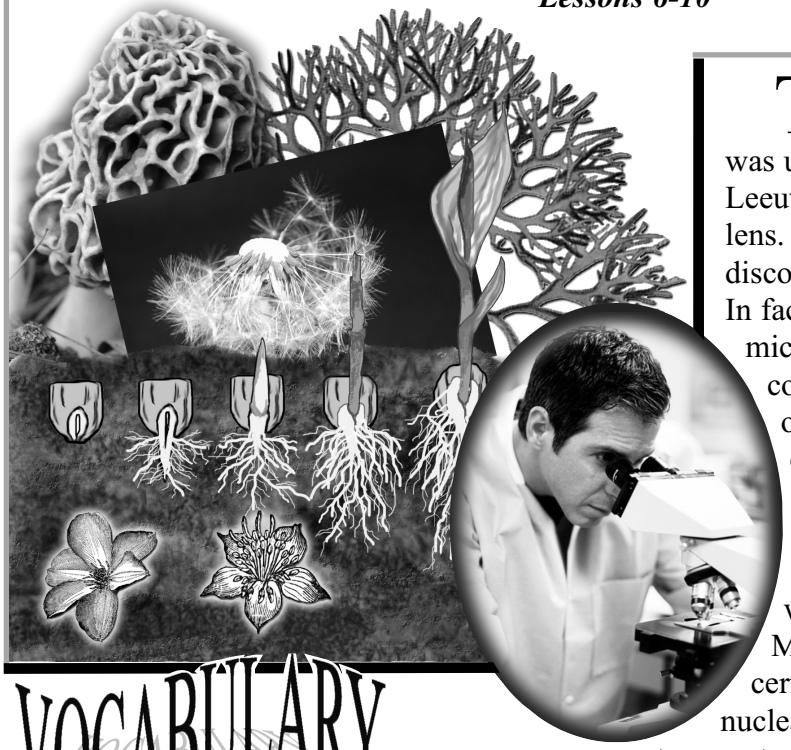
Lesson 6

Chapter 5

Section 2

Lessons 6-10

BACTERIA KINGDOMS: AN OVERVIEW



The bacterial world is a vast, microscopic world. This world was unknown until 1675 when Anton van Leeuwenhoek crafted a crude magnifying lens. Since that time, scientists have discovered that ***bacteria*** are everywhere. In fact, the combined weight of all microscopic organisms far exceeds the combined weight of all other living organisms on Earth! Bacteria live everywhere from the tops of mountains to the bottom of the ocean floor. They live on the surface of melting glaciers and in very hot water in volcanic hot springs. Microbiologists have even found certain bacteria living on the core of a nuclear reactor which can attain a temperature of 2000°F! As a group, bacteria are incredibly adaptable, and many are almost indestructible. Some are responsible for numerous illnesses and many are beneficial to humans. For example, "good" bacteria in your colon help to synthesize B vitamins and vitamin K which your body uses to maintain health. The number of bacteria living in your intestines alone is greater than the total number of human beings who have lived.

All bacteria are prokaryotes. Bacteria have a cell membrane surrounded by a tough, protective cell wall. Their genetic material is contained on a single strand of circular DNA that is not surrounded by a nuclear envelope. Bacteria lack mitochondria, chloroplasts, and other membrane-enclosed structures.

At one time, all bacteria were placed in the kingdom ***Monera***. However, as scientists discovered more about bacteria, Monera was divided into two new kingdoms, *Eubacteria* and *Archaebacteria*.

Members of the Kingdom Eubacteria, or "true" bacteria, have thick, rigid walls made from the carbohydrate ***peptidogylcan***.

VOCABULARY

Bacteria: prokaryote with a cell membrane and genetic material not surrounded by a nuclear envelope

Monera: the kingdom in which all bacteria were once placed

Peptidogylcan: a carbohydrate which makes up the thick rigid walls of the members of the kingdom *Eubacteria*

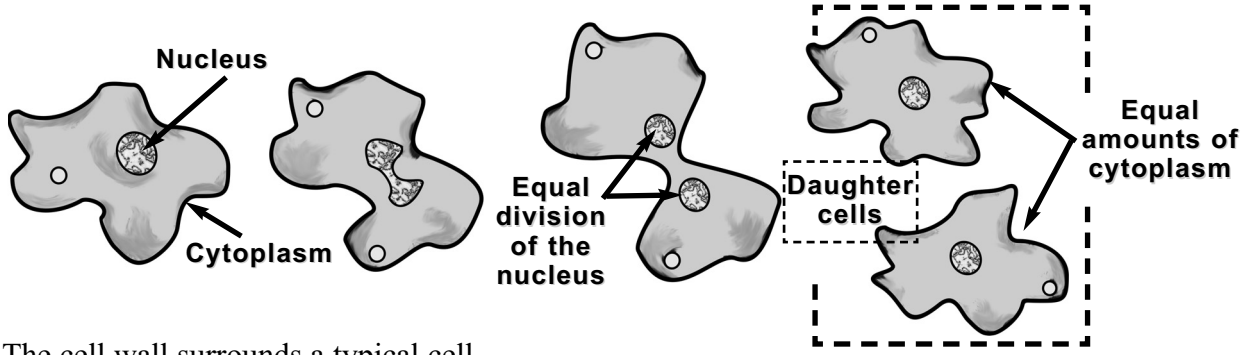
Binary fission: an asexual form of reproduction in which a cell divides in half to produce two identical daughter cells

Conjugation: a form of sexual reproduction that results in new combinations of genes

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Binary Fission in Bacteria



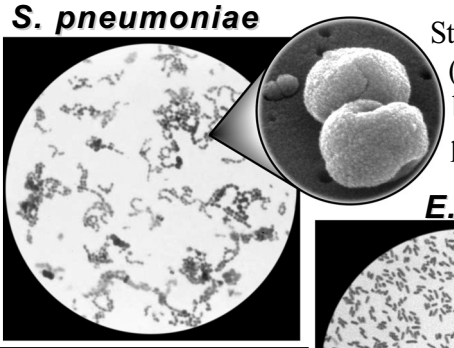
The cell wall surrounds a typical cell membrane. Eubacteria are extremely diverse. For example, some species of Eubacteria live in soil, while others infect larger organisms and cause diseases. Other species of Eubacteria are *photosynthetic*, which means they are designed to make their own food by using light energy.

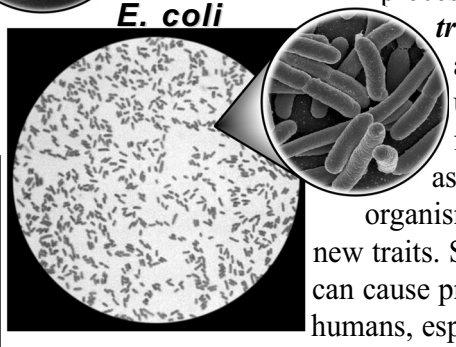
Members of the Kingdom Archaebacteria or "ancient" bacteria, live in extreme environments such as volcanic hot springs, brine pools and black organic mud which lacks oxygen. Deep ice-core drillings from Lake Vida in Antarctica at temperatures of -35^{0}C yielded bacteria (and algae) in excess of 2,800 years of age. Amazingly, when put into liquid water, the organisms' life cycles resumed. Many archaebacteria can survive only in the absence of oxygen. Their cell walls lack peptidoglycan, and their cell membranes contain certain lipids that are not found in any other organism.

Bacteria have simple reproduction processes. Most of the time, bacteria reproduce by ***binary fission***—the division of the cell into two daughter cells, along with the duplication of their single chromosome.

Some bacteria, however, reproduce by ***conjugation***. During conjugation, part of the genetic information from one cell is transferred to another cell. The intestinal bacteria, *Escherichia coli*, (E.coli) uses conjugation to reproduce.

Certain other bacteria, such as Streptococcus *pneumoniae* (S. pneumoniae), reproduce only by binary fission, but also may pick up pieces of DNA from other bacteria. This process is called ***transformation***, and offers an unusual way for normally asexual organisms to pick up new traits. S. *pneumoniae* can cause pneumonia in humans, especially in small children. Because it can transform in this manner, S. *pneumoniae* can cause serious health consequences.





VOCABULARY

Transformation: the process of reproduction in which genetic material is added to or replaces portions of a bacteria's DNA

Virus: a non-living particle that contains DNA or RNA and can infect a host cell

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VIRUSES

Technically, viruses are not members of either of the bacteria kingdoms. However, viruses are usually considered in the discussion of bacteria because, like bacteria, they are microscopic and can produce disease. Viruses are very small and simple. They are not alive, because they are not cells and are not composed of cells. Medical science has not been able to devise foolproof ways to stop viruses once they infect cells.

A ***virus*** is a tiny, non-living particle made up of genetic material and protein. Viruses can invade and replicate within the host cell. Viruses are so different from living organisms that they are not even classified as organisms. One way to picture a virus is to think of it as pure information, similar to a computer program stored on a disk with no hardware of its own. By itself, a virus can do nothing. It does not breathe, eat, excrete or reproduce. It simply holds onto information and searches for a host cell to infect.



Each virus particle contains a core of either DNA or RNA, surrounded by a protein coat. The outer surface of the virus may also be covered with an envelope composed of lipids and proteins. Often, these compounds help the virus to bind to the host cell membrane and "trick" the host cell into taking the virus inside, where it will do harm.

Because viruses are not alive, they can reproduce only when they are able to invade a living host cell. Just as living cells can have a variety of shapes and forms, so can viruses. According to the nature of their genetic material and the way they infect cells, viruses can be divided into three groups: *DNA viruses*, *RNA viruses* and *retroviruses*. Viruses infect virtually every known organism—from bacteria to plants to humans.

You will learn much more about bacteria and viruses in the next chapter of this textbook. Meanwhile, in the next lesson, we will explore the Kingdom Protista.

WATCH VIDEO: Antibiodies Attack Flu Viruses

LIFE PRINCIPLE

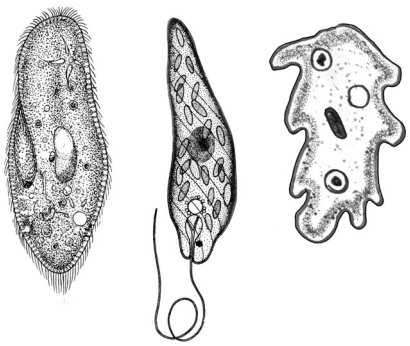


"Look deep into nature, and then you will understand everything better."

—Albert Einstein (1879-1955)
German-American mathematician and physicist

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Kingdoms of Biology

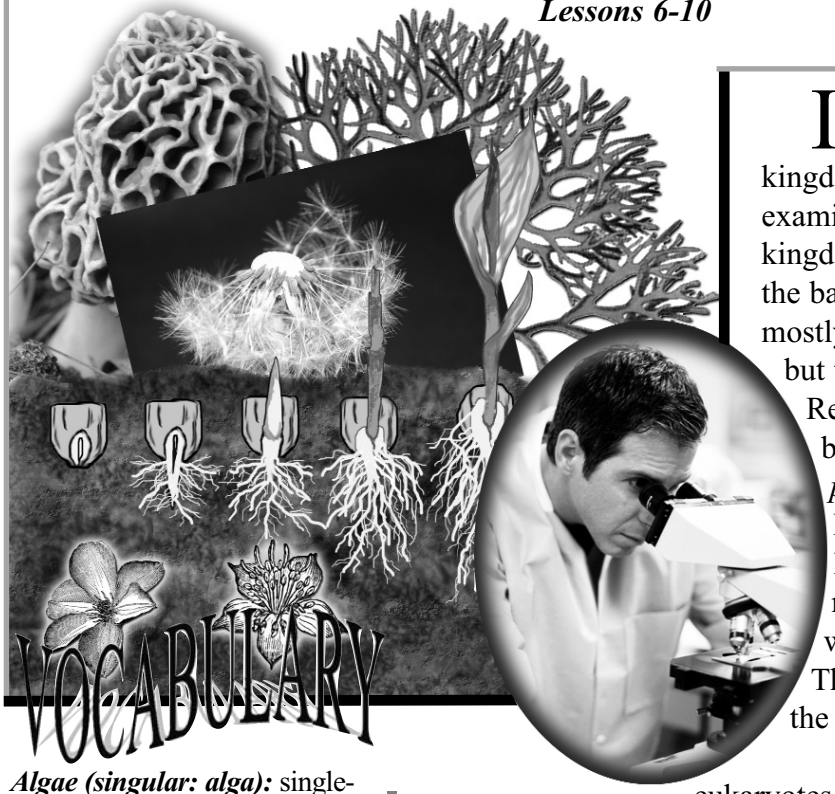
Lesson 7

Chapter 5

Section 2

Lessons 6-10

KINGDOM PROTISTA: AN OVERVIEW



In the previous lesson, we briefly examined the bacterial kingdoms. In this lesson, we will examine an equally fascinating kingdom called *Protista*. Protista and the bacterial kingdoms are made up mostly of unicellular microorganisms, but they differ quite dramatically. Recall that the organisms in the bacterial kingdoms are *prokaryotic*, whereas those in Protista are *eukaryotic*. Eukaryotic cells have distinct, membrane-bound organelles, whereas prokaryotic cells do not. This adds a level of complexity to the organisms in Protista.

Both prokaryotes and eukaryotes perform certain basic functions in order to live, as we discussed in a previous chapter. In *prokaryotic cells*, these functions are performed by the cell as a whole. In *eukaryotic cells*, however, each membrane-bound organelle performs its own set of tasks. Only when each organelle cooperates with the other organelles will the cell be able to perform all the functions necessary for life. Thus, in eukaryotic cells, the organelles must be able to work together. For this reason, the organisms in Protista are more complex than those in the bacterial kingdom.

Although the protists are all eukaryotic, these organisms do not share a set of common characteristics. While most protists are unicellular, quite a few are multicellular. Many are microscopic, but the single-celled *Caulerpa* can grow up to 60 feet long! Most protists need oxygen to survive, but some are poisoned by it. Some protists are autotrophic, and others are heterotrophic. Some reproduce sexually, some asexually, and still others alternate between the two forms of sexual reproduction.

VOCABULARY

Algae (singular: alga): single-celled, photosynthetic organisms classified as protists

Sargasso Sea: a warm body of water within the lower-middle North Atlantic Ocean; named for its masses of floating sargassum (sargasso) sea weed

Plankton: tiny algae organisms that float in the water

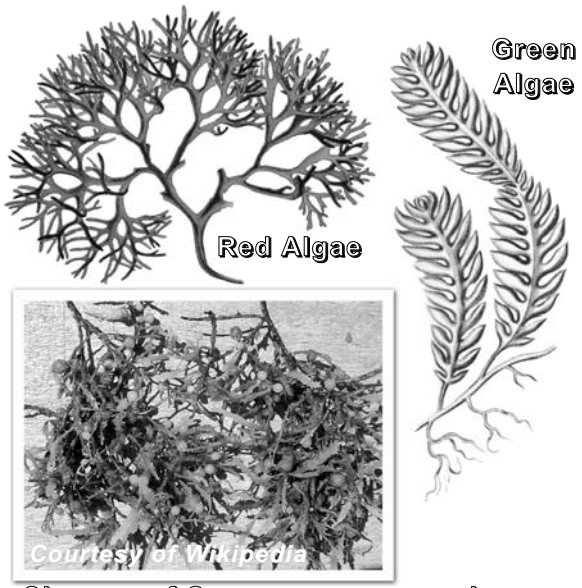
Protozoans: a sub-group of the Kingdom Protista which are heterotrophs and are mobile

Spore: a small, typically single-celled structure capable of growing into a new organism, either immediately upon leaving its source or after a period of dormancy

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Because differences among living protists are so extreme, most scientists agree that they should be divided into several different kingdoms. This textbook recognizes the diversity by splitting these organisms into two groups: Algae and Protozoans. (These two sub-groups are not considered phyla; they are often called *sub-kingdoms*.)



Closeup of Sargassum seaweed (brown algae)

ALGAE

Algae are photosynthetic autotrophs that look and act like plants in certain ways. According to current estimates, about 30,000 species of algae exist in the oceans and fresh waters. Between 30 and 40 percent of all photosynthesis that takes place on Earth is performed by these protists. Some algae are nearly as small as bacteria, while some, such as sargassum and giant kelp (both brown algae), form dense, oceanic "floating forests" that may reach down 100 feet or more and hundreds of feet across, as in the "***Sargasso Sea***".

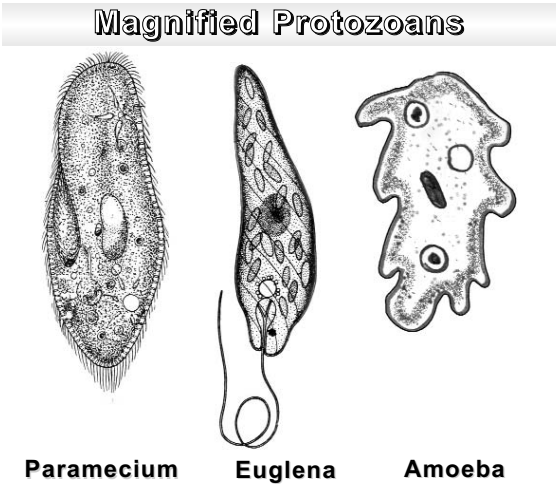
Red, brown and green algae groups are multicellular. Most red and brown algae (and some green) inhabit oceans and are called "sea weeds". The Red Sea was named for its abundance of red algae. Algae is harvested for a wide variety of uses including fertilizers, health and beauty products and food additives (carageenan, agar and algin). A popular item in Japanese diets is a dried algae product called *Nori*.

If you have ever maintained a fish tank or swimming pool, you probably have had a bit of experience with algae. If algae are allowed to grow unchecked in a body of water, the water becomes cloudy and green. Chlorine is used to rid the swimming pool of algae. Sometimes, various aquatic creatures are placed into fish tanks to eat the algae.

Natural bodies of water are the best places to find algae. The "fishy smell" and sliminess of a body of water is not due to fish, but due to the algae floating and growing in the water. Tiny, floating organisms called ***plankton*** exist in any natural body of water. In fact, they are the 2nd most abundant organisms in the world, superseded only by bacteria.

PROTOZOANS

Protozoans share two important characteristics. First, they are all *heterotrophs*. In addition, most are active and move around.



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Human Diseases Caused by Protists

DISEASE	HOSTS AFFECTED	PROTIST ORGANISM	MODE OF TRANSMISSION	SYMPTOMS
Amoebic dysentery	Humans	*Entamoeba histolytica*	Contaminated food or water	Bloody diarrhea caused by amoebas feeding on intestinal lining
Malaria	Humans, mosquitos	*Plasmodium*	Bites from infected mosquitos	Cycles of shaking chills, high fever, headache and profuse sweating
Toxoplasmosis	Humans, Cats	*Toxoplasma gondii*	Contact with infected cats or eating improperly cooked meat	Primary danger to baby in the womb: possible convulsions, brain damage, blindness and death
Giardiasis	Humans	*Giardia lamblia*	Contaminated water	Nausea, cramps, vomiting and diarrhea
Sleeping sickness	Humans, Tsetse flies	*Trypanosoma gambiense, Trypanosoma rhodesiense*	Bite from tsetse flies or other infected insects	Fever, weakness and lethargy
Chagas' disease	Humans, Kissing bugs	*Trypanosoma cruzi*	Bites from infected kissing bug	Fever, severe heart damage
Leishmaniasis	Humans, Sand flies	*Trypanosoma*	Bites from infected sand fleas	Skin sores and tissue destruction

Protozoans can usually be seen with a compound light microscope. All protozoans spend most of their lives as unicellular organisms. However, some species, such as slime molds, gather into groups at some time during their life cycles. Examples of protozoans are *Amoeba*, *Euglena* and *Paramecium*.

Protozoans demonstrate many different feeding strategies, and some species may act as predators, decomposers or parasites. Members of the phyla *sporozoa* may look like simple organisms, but they are complex parasites that cause serious diseases in humans and animals. One species of sporozoa called *plasmodium* causes malaria, a disease that kills more humans each year than any other disease.

Protista Reproduction

Life cycles among protists are tremendously varied. A few reproduce asexually, but most reproduce sexually, at least occasionally. Cellular slime molds spend most of their lives as individual free-moving cells. Then, under certain circumstances, they gather and form a large mass. This mass will move around for a while, then forms a "fruiting body" which releases ***spores*** that will then develop into new cells on their own, without needing to join with another cell.

Algae show several variations in a life cycle that alternates between a sexual stage and an asexual stage. The green algae, Ulva, shows a pattern of reproduction that also occurs in green plants. This species illustrates a process known as *alternation of generations*, in which the reproduction cycle switches back and forth from haploid to diploid cells. Recall that haploid cells contain only one copy of each chromosome, signified by the single letter "n", while diploid cells contain two of each type of chromosome, signified by "2n".

In the next lesson, we will examine the Kingdom Fungi.

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WATCH VIDEO:
Introduction to the Protists

LIFE PRINCIPLE



"The most erroneous stories are those we think we know best—and therefore never scrutinize or question."

—Stephen Jay Gould (1941-2002)
American evolutionary paleontologist and biologist

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Kingdoms of Biology

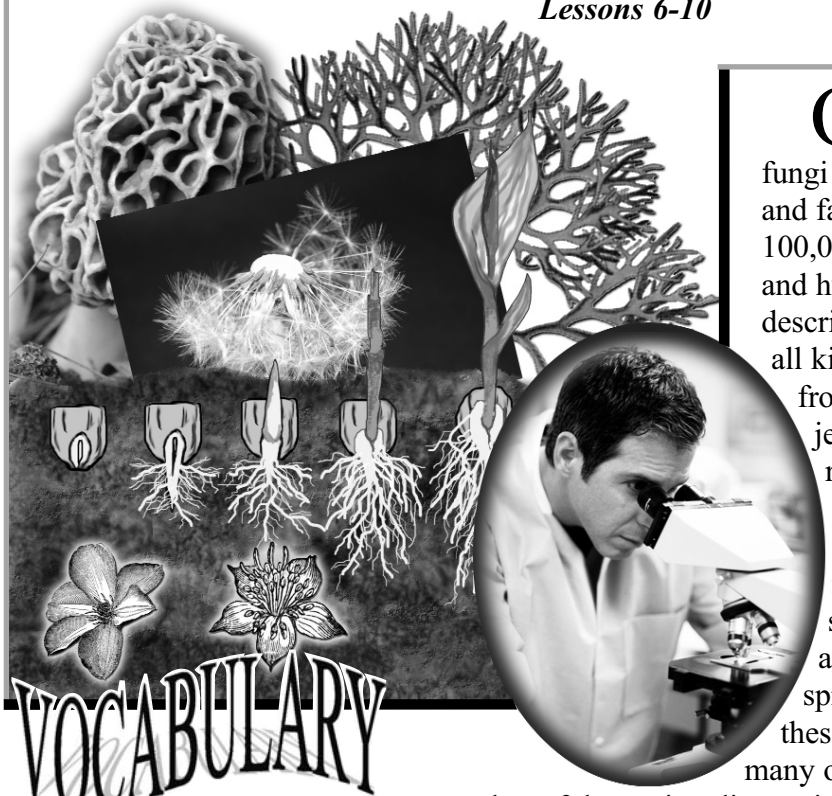
Lesson 8

Chapter 5

Section 2

Lessons 6-10

KINGDOM FUNGI: AN OVERVIEW



Of the six major kingdoms of living organisms on Earth, the fungi contain some of the most bizarre and fascinating species. About 100,000 known species of fungi exist, and hundreds of new ones are described each year. Fungi come in all kinds of shapes, colors and sizes from brilliant red cups and orange jelly-like masses to strange fungi resembling golf balls, bird nests, starfish and parasols. More familiar fungi include molds, mildew and mushrooms. Molds spoil food, mildew ruins books and clothing, and mushrooms sprout from rotting logs. Although these fungi are the best known fungi, many other species exist. Some fungi are harmful, causing disease in humans and plants; other fungi are beneficial. Some fungi can help trees and many other seed plants extract nutrients from the soil. Without these fungi, many of the great evergreen forests of North America would wither away and die. The yeast that is used to make bread is a member of the kingdom Fungi. We can eat some fungi, other fungi are used in the production of cheese, others are used in baking and some are even used to produce medicine. Some fungi cause diseases, such as St. Anthony's fire, histoplasmosis, potato blight and Dutch elm disease.

Although very diverse, the organisms in the Kingdom Fungi are not nearly as varied in characteristics as those in the Kingdom Protista. A few general characteristics do apply to most fungi. For example, all fungi are heterotrophs (organisms that depend on others for their food). Most are ***saprophytic***, although a few fungi species are ***parasitic***. Fungi are eukaryotes that have cell walls and are multicellular. All fungi digest their food outside of their bodies. The fungus grows on and in its food, secreting a chemical onto the food that

VOCABULARY

Saprophytic: feeding on dead matter

Parasitic: stealing nourishment from a living organism (host); living at the expense of a host while contributing nothing

Ingest: to swallow; take into the body to be digested or absorped

Extracellular digestion: process in which food is digested outside the body cells

Chitin *(kit-in):* structural carbohydrate that is the main component of arthropod exoskeletons; reinforces the cell walls of fungi; also found in certain insect skeletons

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digests it before it is ***ingested***. The digested food is then absorbed into the cells of the fungus as an instant source of nutrition and energy. This is called ***extracellular digestion*** and can be beneficial to other organisms which often absorb some of the nutrients before being absorbed by the fungus. A fungus is often harmful to other creatures when the fungus excretes a substance for extracelluar digestion.

Although many fungi look like plants, several characteristics indicate that they are more like animals. Similar to plants, fungi have cell walls. However, the cell walls of fungi do not contain cellulose. Instead, they are reinforced with ***chitin***, a complex carbohydrate that is also found in certain anthropod skeletons. Also, many fungi can store energy in the form of glycogen—something that animals do all the time, but plants cannot.

All fungi have the same basic structure. Each one has a threadlike filament called a ***hypha***. The cells in the hyphae may have a single nucleus, two nuclei or many nuclei. In most common types of fungi, hyphae grow down into the substance on which the fungus feeds, forming a cottony mass called a ***mycelium***. Most of the mycelium grows into and through the food source, secreting enzymes that break down the food source's (host's) cells. Thus, extracellular digestion occurs.

Years ago, scientists classified fungi in the plant kingdom. Although they now have their own kingdom, much disagreement occurs regarding the phylum and classification of fungi. Consequently, you may read about a very different classification system in other textbooks. For example, some textbooks will place the slime molds in the Kingdom Fungi instead of the Kingdom Protista. The writers have chosen to use a very simplified classification system for this textbook that is easily understood and that is commonly accepted.

Fungi are classified into four different phyla according to their life cycles: *Zygomycota*, *Ascomycota*, *Basidiomycota* and *Deuteromycota*.

VOCABULARY

Hypha (pl. hyphae): threadlike, branching filament that is the most basic structure in a fungus

Mycelium: mass of hyphae that grows in the food source and forms the body of the fungus

Morel: any of several pitted-capped, edible fungi

Truffle: dark and wrinkled edible fruit of several underground European fungi

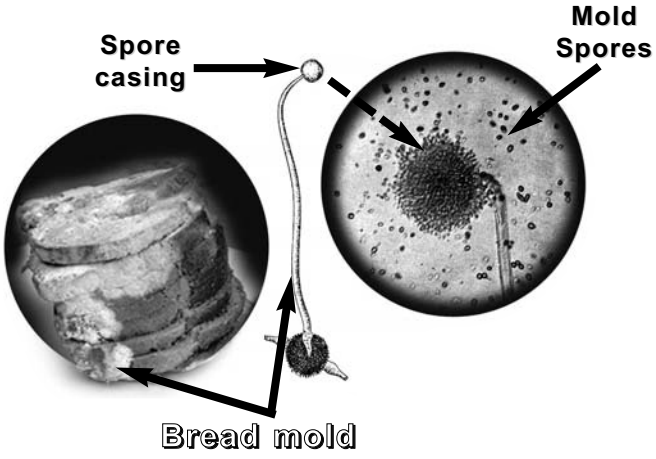
Pathogen: an agent capable of producing disease; from the Greek word *pathos*, meaning "disease"

Spores: small, single-celled structures, each capable of asexually producing a new individual

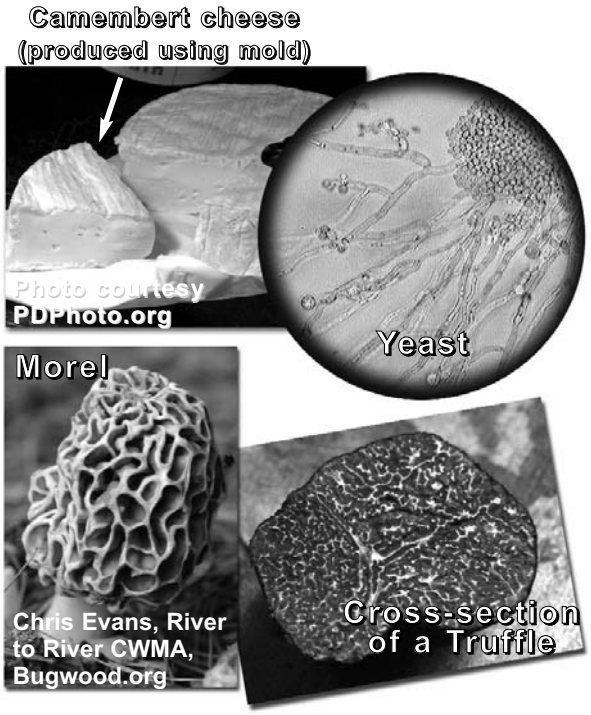
Mycology: the study of fungi

ZYGOMYCETES

Fungi that belong to the phylum *Zygomycota* are called *zygomycetes*. These include the bread molds—the white, gray, black or blue molds that are sometimes found on old bread.



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Ascomycetes

The fungi that belong to the phylum *Ascomycota* are called the "sac" or "cup" fungi and include as many as 30,000 recognized species of mildews, molds and yeasts. Some molds are used to flavor certain cheeses. Some yeasts are used in fermentation processes and baking. This is the largest phylum in the Kingdom Fungi. Some members of this phylum are edible, such as the rare and expensive ***morels*** and ***truffles***.

Basidiomycetes

The phylum *Basidiomycota* are known as "club" fungi and include the fungi whose fruiting bodies form mushrooms. Although many varieties of mushrooms are prepared as food, some types are extremely poisonous, and some cause agricultural disease. The difference between the poisonous and the edible varieties is often hard for the amateur to detect. The best policy is to buy your mushrooms at the grocery store!


"Club" Fungi

Deuteromycetes

The phylum *Deuteromycota* is sometimes called "imperfect" fungi. These fungi are classified as imperfect because researchers have largely been unable to identify their sexual stages. One member of this phylum is *Penicillium*, the source of antibiotic penicillin. *Aspergillus* is used to produce vinegar and soy sauce. Other members of this phylum are ***pathogens*** which produce plant and animal diseases, such as tomato blight and athlete's foot.



Reproduction in Fungi

One reason that fungi are so hardy and plentiful is that they have many means of reproducing. Life cycles of most fungi are complicated and vary from phylum to phylum. Fungi can reproduce both sexually and asexually. Asexual reproduction occurs either by the production of ***spores*** or by the

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fragmentation of the hyphae. The spores produced in many fungi are small and lightweight. When released, the spores are carried by the wind. If they land in an appropriate spot, the spores will germinate and grow into hyphae again.

During sexual reproduction, the hyphae of opposite mating types meet and some of their filaments fuse together. The nuclei from the two mating types then fuse and immediately undergo the process of meiosis to produce spores.

In the next lesson we will briefly examine the plant kingdom.

Career Bound

Mycology is the study of fungi, and much of the current research in this field is at the molecular level. For example, molecular mycologists are trying to piece together the very complex interrelationships between fungal taxonomy by using comparative DNA sequencing.

LIFE PRINCIPLE



"The nation plagued with inner moral decay will be persecuted with outer destruction."

—Jim Elliot (1927-1956)
Martyred American missionary to Ecuador

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Kingdoms of Biology

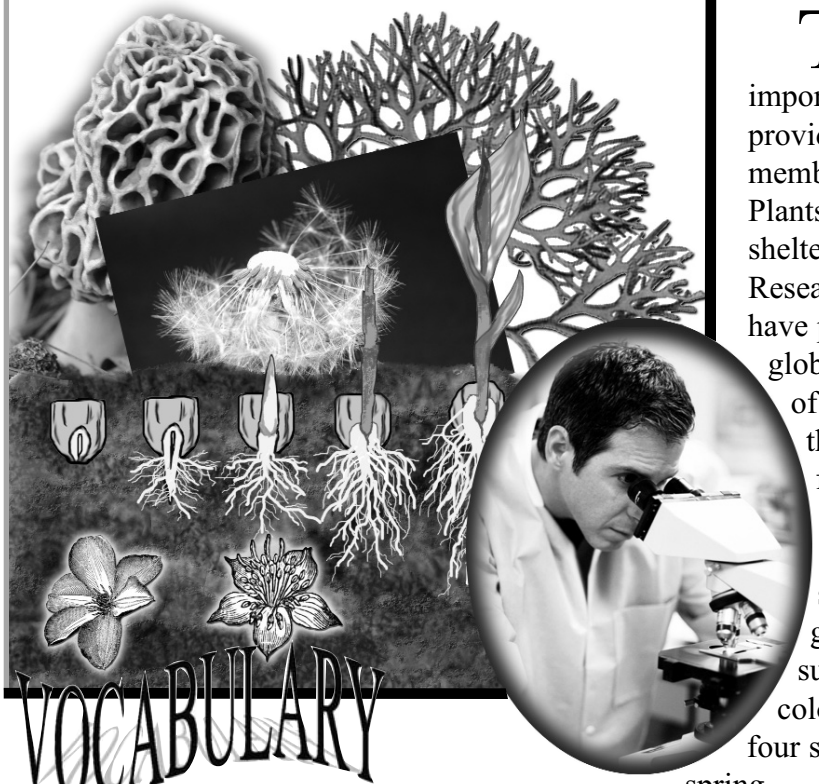
Lesson 9

Chapter 5

KINGDOM PLANTAE: OVERVIEW I

Section 2

Lessons 6-10



The Kingdom Plantae includes some of the most beautiful and important organisms on Earth. Plants provide food for humans and other members of the animal kingdom. Plants are also used for clothing, shelter, medicines, and even gifts! Researchers are learning that plants have powerful effects on shaping global environments. With the help of protists and fungi, plants provide the oxygen we breathe and the food that sustains us—either directly or indirectly—by feeding other animals. Plants provide shade over our heads and cool green carpets under our feet while surrounding us with beautiful colors and marking change of the four seasons: summer, fall, winter and spring.

Prominent plants define ecological communities. Descriptions such as "Redwood-Tanoak Forest" or "Oak Grassland" indicate not only the plants that may grow there, but the animals, fungi, and climates which characterize the communities.

Classifications within the plant kingdom can be especially confusing to the young biologist. For example, according to modern botany:

A palm tree has more in common with a blade of grass than with other trees.

A strawberry plant is more closely related to an apple or apricot tree than to a clover or geranium.

A ***Ginko Biloba*** (Maidenhair) tree is so different from other plants that it is in a phylum by itself, but if you have to group it with other plants it belongs with conifers, such as Pine trees.

VOCABULARY

Ginko biloba: only surviving species of an ancient plant group; has fan-shaped leaves; native to China and Japan

Nonvascular plants: do not have true roots, stems or leaves; have no vascular tissue

Vascular plants: have specialized tissue composed of tubelike cells that transport water and nutrients throughout the plants

Gymnosperm: a nonflowering seed plant; a seed plant in which the seeds are exposed to the air: literally means “naked seed”

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Much controversy exists about how to classify plants. Thus, the classification system that you learn here might be somewhat different from others that you may study at another time.

In this textbook, plants are classified into 10 *phyla*, or divisions, based largely on reproductive characteristics: they are classified according to *tissue structure*, as *non*-vascular plants (mosses) or vascular plants (all others); according to *seed structure*, divided into groups that reproduce through naked seeds, covered seeds, or spores; or by *stature*, divided into mosses, ferns, shrubs, vines, trees, and herbs.

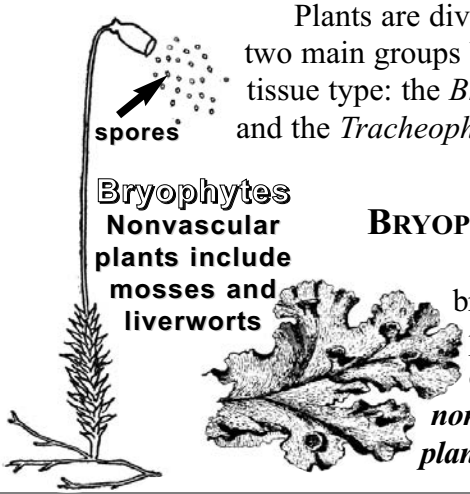
VOCABULARY

Cycad: represents a single surviving family of tropical plants; cycads resemble palm trees but reproduce by means of spermatozoids
Angiosperm: flowering plant whose seeds develop within a matured ovary (fruit)
Cotyledon: tiny seed leaf found in a plant embryo
Monocot: an angiosperm that produces seeds with one (*mono*) cotyledon (*cot*)
Dicot: angiosperm that produces seeds with two (*di*) cotyledons (*cots*)
Cuticle: waxy-covering on plant leaves to keep plants from loosing water by evaporation
Stomata (singular is stoma): small openings in the epidermis of a plant that open and close to allow gas exchange and to prevent water loss
Epidermis: a skinlike layer of cells in seed plants and ferns; protects plant in various ways
Phloem: vascular tissue that transports products of photosynthesis and substances from one part of the plant to another
Xylem: vascular tissue that carries water and nutrients from the roots to the branches and leaves of the plants

The most striking, and important, feature of plants is their green color, the result of a pigment called *chlorophyll*. Plants use chlorophyll to capture light energy, which fuels the manufacture of food—sugar, starch, and other carbohydrates. Without these food sources, most life on earth would be impossible. Mushrooms and algae would exist, but there would be no fruits, vegetables, grains, or any animals (which ultimately rely on plants for food!)

Another important contribution of plants is their shaping of the environment. Think of a place without plants. The only such places on Earth are the arctic wastelands, severely arid deserts, and deepest oceans. Plants populate the entire planet, from the tundra to the rainforest to the desert. In fact, when we think of a particular landscape, it is often the plants which first come to mind. Try to picture a forest without trees, or a prairie without grasses. Plants are the organisms which produce and maintain the terrestrial environment as we know it.

All plants are multicellular, photosynthetic eukaryotes whose cells are enclosed and supported by cell walls made of cellulose. The vast majority of plants reproduce sexually and have life cycles that involve alternation of generations. However, many plants can reproduce *asexually*, or independent of sexual processes.



Plants are divided into two main groups based on tissue type: the *Bryophytes* and the *Tracheophytes*.

BRYOPHYTES

The bryophyte phylum is composed of ***nonvascular plants***, including

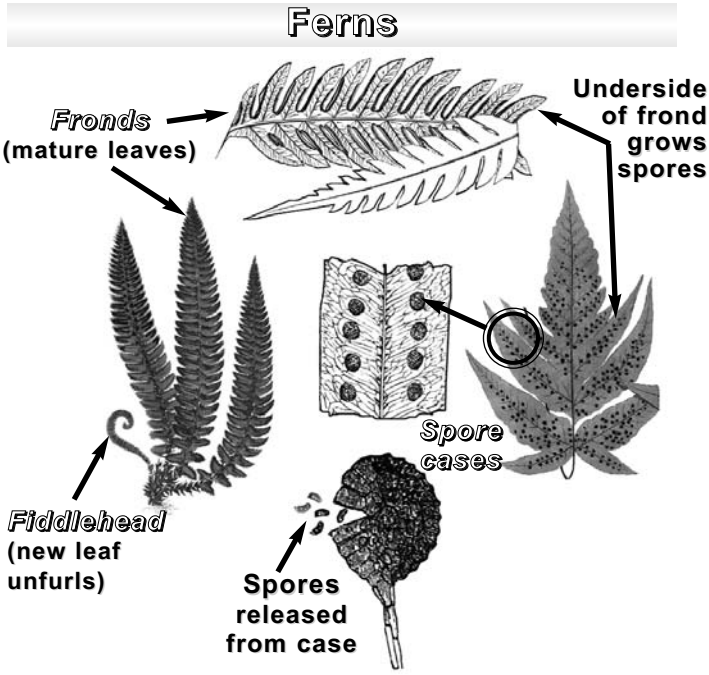
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mosses and liverworts. Bryophytes reproduce by spores and are well equipped to survive in wet places where they may grow in great numbers. Bryophytes grow no taller than a few centimeters. Some species, such as *Sphagnum* (peat moss), grow almost completely submerged in water. Others grow well on wet tree trunks, rocks and soil. Bryophytes can grow and reproduce only when wet, so most in this phylum can live only where plenty of water is available.

TRACHEOPHYTES

Tracheophytes are ***vascular plants*** with special vascular tissues that transport water and nutrients throughout the plant. As a result, tracheophytes can grow much larger and can live in a wider range of habitats than bryophytes. While most vascular plants reproduce by seeds, some (such as ferns) do not. These tracheophytes are not considered a phylum and are broken into nine other phyla that will be examined in future lessons. Here, we will consider some general categories of tracheophytes.

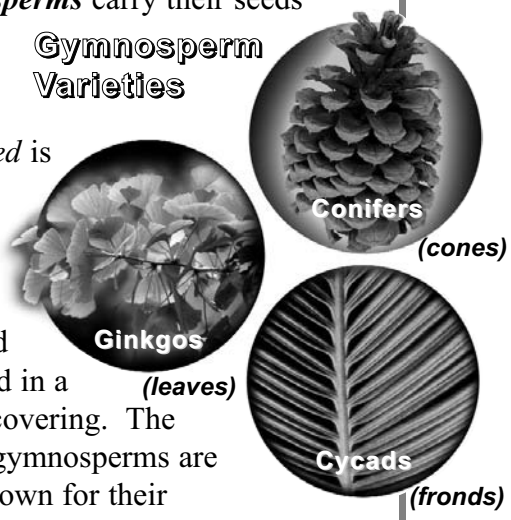
FERNS



Ferns and related plants have vascular tissue in addition to roots, strong stems and leaves; however, they are seedless and reproduce by spores which anchor in watery soil and produce eggs that are then fertilized and grow into parent ferns. Most ferns that live in areas with changing seasons die back to the ground each year. In tropical rain forests, some ferns grow into tall, graceful trees. Some ferns can survive long droughts as adult plants.

GYMNOSPERMS

Gymnosperms carry their seeds exposed to the air, usually in a cone-shaped structure. A *seed* is a reproductive structure that includes a developing plant and a food reserve enclosed in a resistant outer covering. The most common gymnosperms are the *conifers*, known for their distinctive cones and needlelike leaves. The cones produce and carry seeds. Although conifers are often called *evergreens*, their leaves don't last forever as their name implies. The leaves (pine-needles) normally remain on the plants for 2 to 14 years and exhibit several adaptations that help these plants survive the cold, dark winters and short growing seasons of the northern regions where many conifers live. Many varieties of gymnosperms grace the planet, such as Ginko Biloba trees and ***Cycads***.

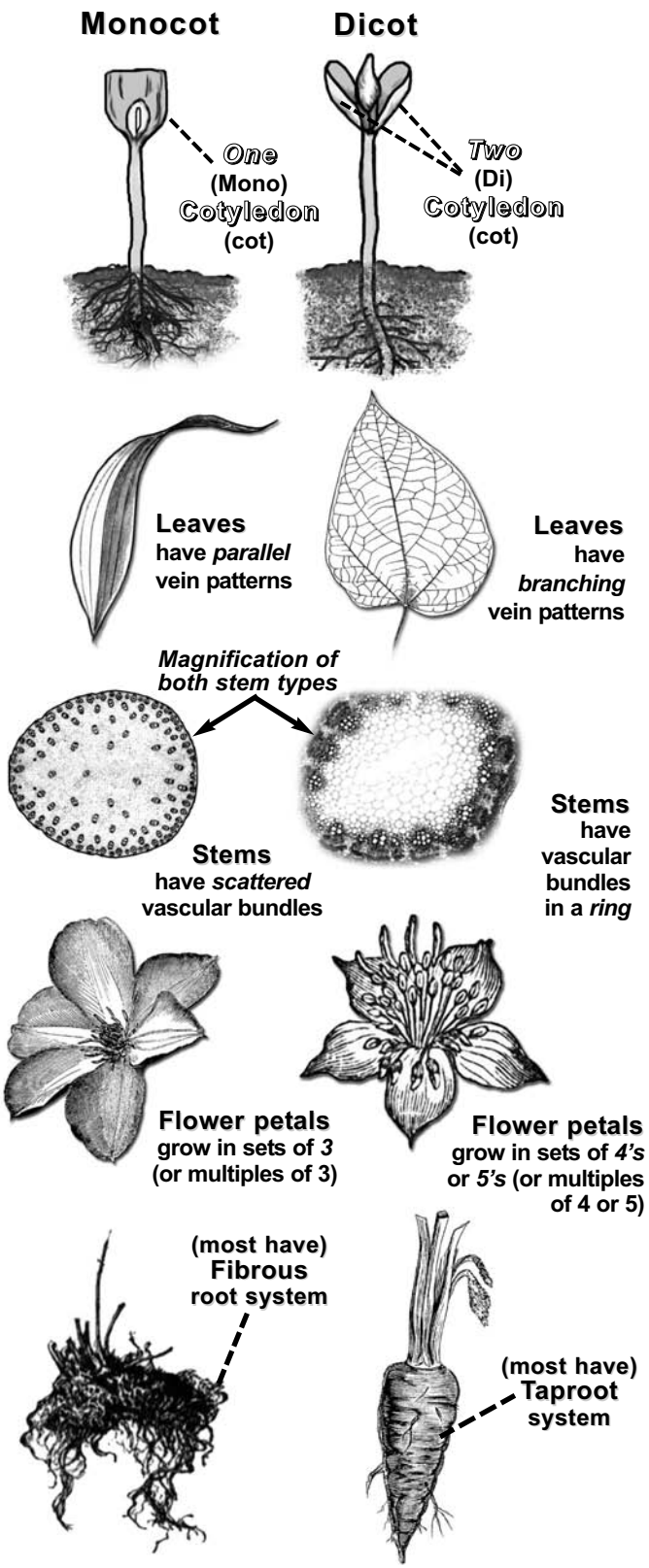


ANGIOSPERMS

Angiosperms are the plants whose beautiful flowers are enjoyed as gifts and decorations in all cultures throughout the world. Angiosperms are also important food

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Dicots & Monocots



sources for humans and other animals.

Angiosperms (flowering plants)

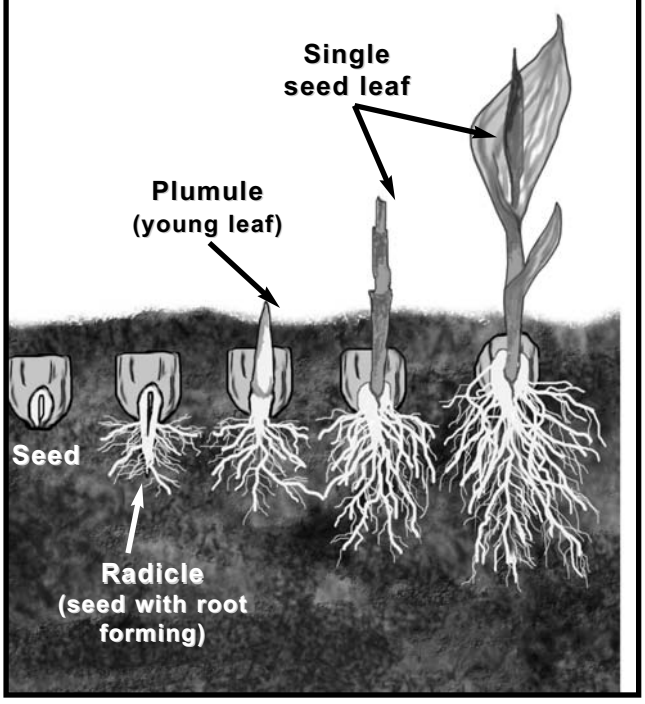


Angiosperms are divided into two main groups—the monocots and the dicots. Within the seeds of angiosperms are structures that contain food for the developing plant. These structures are called ***cotyledons***. ***Monocots***, such as rice, wheat, corn, grass, lilies and tulips have one cotyledon. ***Dicots***, such as beans, peanuts, tomatoes, roses, maples and daisy-like plants have two cotyledons.

Roots, Leaves and Vascular Tissue

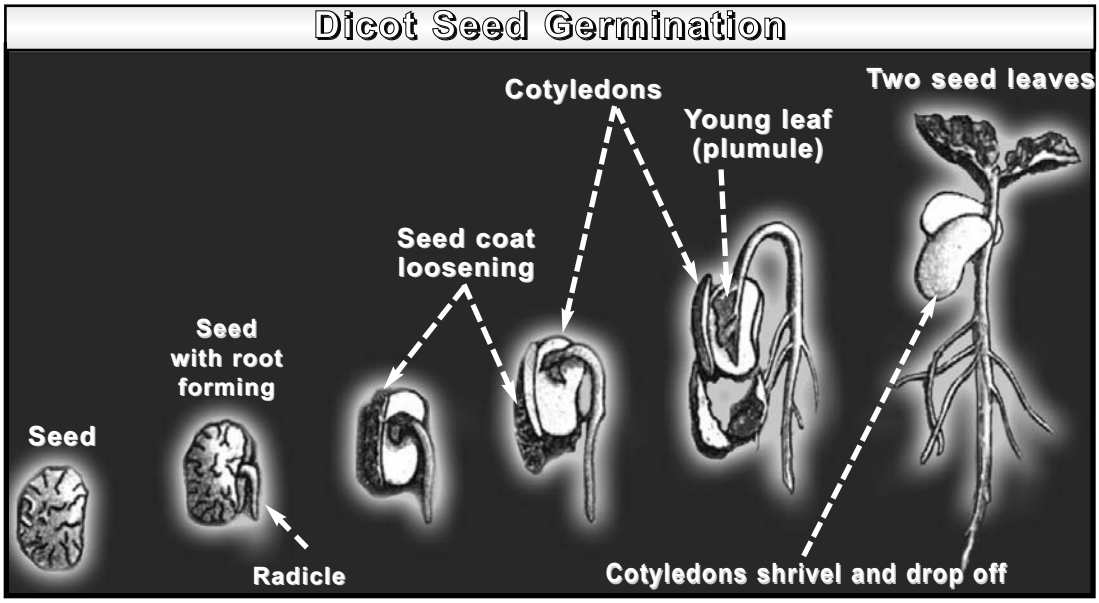
Most tracheophytes are designed for life on the land. Three important

Monocot Seed Germination



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features help these plants to thrive on land: roots, leaves and vascular tissues.

Roots anchor plants in place in the soil and keep them from being blown away by strong winds. They also absorb water and dissolved inorganic nutrients from the soil.

Leaves provide the important surface area which captures sunlight for photosynthesis. The broader and flatter a leaf, the more sunlight it can capture. However, the more tissue surface that is exposed to dry air, the more water the plant can lose by evaporation. The leaves of most land plants are covered with a waxy, waterproof covering called a ***cuticle***. Cuticles are dotted with tiny openings called ***stomata*** in the ***epidermis*** of a plant that open and close as needed to allow for gas exchange and to prevent the loss of too much water.

Vascular tissue is the system that transports substances to various parts of the plant. Two types of vascular tissue exist: phloem and xylem. ***Phloem*** carries the products of photosynthesis and certain other substances from one part of a plant to another. ***Xylem*** carries water and dissolved inorganic nutrients from roots to branches and leaves.

Stems hold leaves up to the sun and position the leaf surfaces to capture as much light as possible. Stems also conduct water, nutrients and products of photosynthesis through the plant by means of vascular tissues.

In the next lesson, we will briefly examine reproduction in plants.

WATCH VIDEO:
Leaf Structure, Chloroplasts, & Specialized Plant Cells



LIFE PRINCIPLE

"I perhaps owe having become a painter to flowers."

—Claude Monet (1840-1926), French impressionist artist

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Kingdoms of Biology

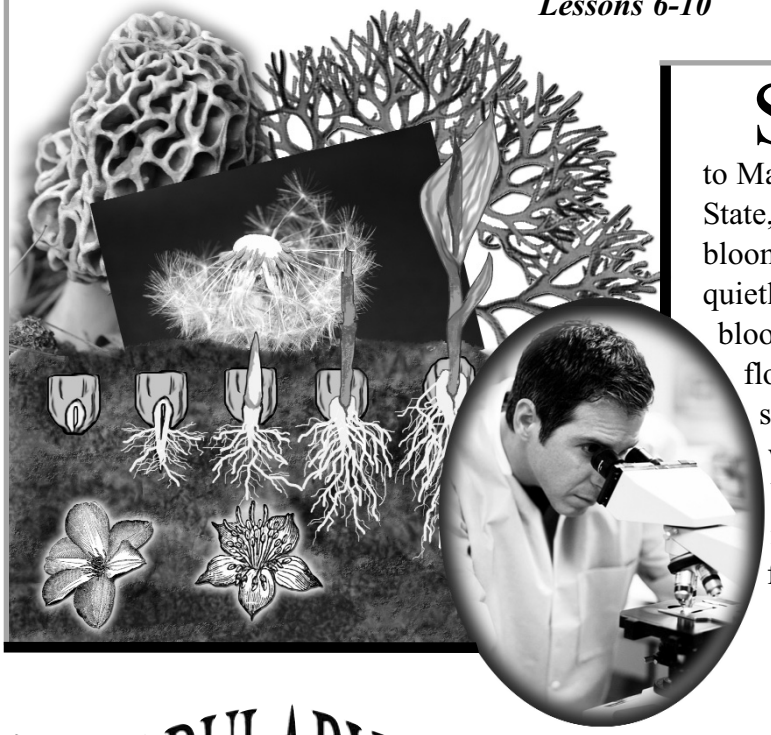
Lesson 10

Chapter 5

KINGDOM PLANTAE: OVERVIEW II

Section 2

Lessons 6-10



Spring is one of the most beautiful times of the year. From California to Maine, from Florida to Washington State, the sight and fragrance of flowers in bloom, capture admiration. If you sit quietly for a few minutes near a tree in bloom or by an area where some wild flowers have sprung up into the sunlight, you will notice a lot of busy workers. Bees are drifting from bloom to bloom and hummingbirds may be hovering and darting from flower to flower.

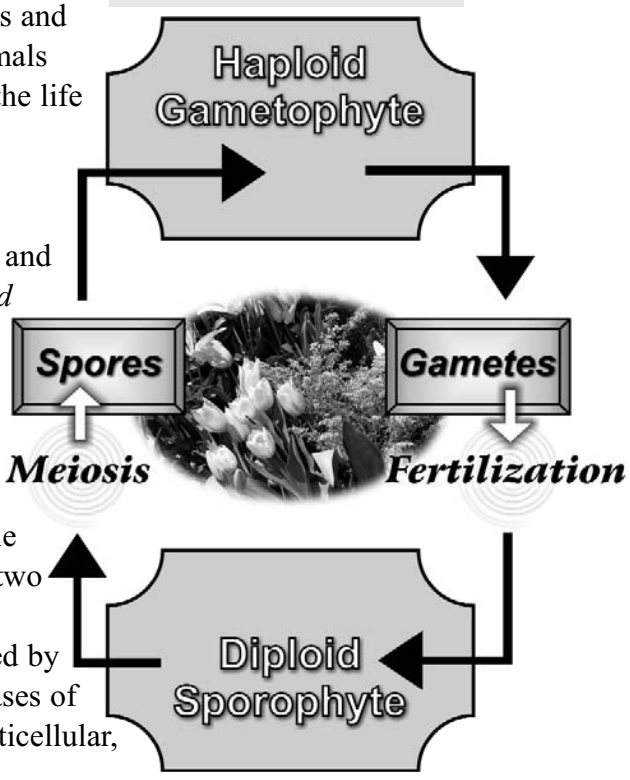
VOCABULARY

Alternation of generations: variation in a life reproductive cycle that switches back and forth between the production of diploid (2n) and haploid (n) cells.
Sporophyte generation: in plants, the diploid spore-bearing generation that reproduces by spores
Gametophyte generation: in plants, the haploid gamete-bearing generation that reproduces by fertilization
Pollen grain: tiny spore that contains the male reproductive cells of a plant

These flying creatures and other land-based animals play critical roles in the life cycle of plants.

All plant life cycles have both a *multicellular haploid* and a *multicellular diploid* phase. Recall that haploid cells contain only one copy of each chromosome, signified by the single letter "n", while diploid cells contain two of each type of chromosome, signified by "2n". Since both phases of the life cycle are multicellular,

Alternation of Generations: a plant's life cycles



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this type of life cycle is called an ***alternation of generations***. (In contrast, animal life cycles each have a *multicellular diploid* and a *unicellular haploid* phase.)

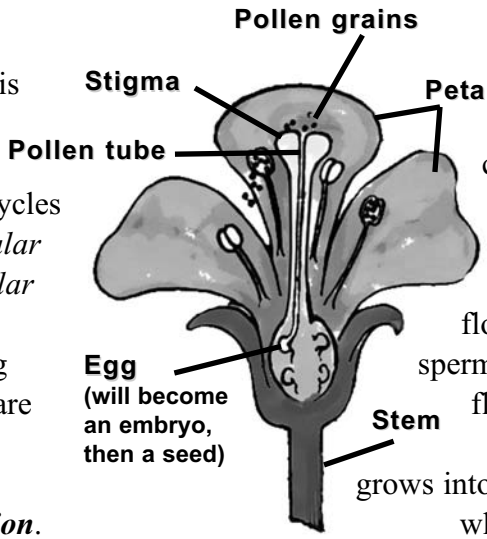
The alternating generations of plants are called the ***sporophyte generation*** and the ***gametophyte generation***. Individuals in the *gametophyte generation* form gametes or sex cells. Gametes are haploid cells (containing one set of chromosomes). Haploid gametes fuse in fertilization which produces fertilized eggs. Fertilized eggs are diploid (containing two sets of chromosomes). The young plants that develop are diploid plants of the *sporophyte generation*. Individuals in the sporophyte generation then undergo meiosis to produce haploid spores. Thus, the life cycle begins again.



WATCH VIDEO:
Double Fertilization in Angiosperms

POLLEN AND SEEDS

In seed plants, the entire male gametophyte is contained in a tiny structure called a ***pollen grain***. A pollen grain produces sperm that is carried to the eggs by wind, insects, birds and other creatures. Once the pollen lands on the sticky surface of the female part of the flower, a long tube containing the sperm begins to grow down inside the flower until it reaches the egg.



Cross section of a flower plant

After fertilization, the egg grows into a tiny plant called an ***embryo***, which matures for a short time before becoming ***dormant*** inside the seed. The seed itself is supplied with food and a tough outer covering. Protected this way, the seeds of many flowering plants can survive heat, drought, and bitter cold—sometimes for years—before germinating. This adaptability allows angiosperms to grow in many habitats. Once the seed sprouts, it will grow into a plant which is the sporophyte generation.

VOCABULARY

Embryo: early stage of development of an organism (animal or plant) resulting from fertilization
Dormant: "asleep"; temporarily inactive, but capable of resuming normal activity
Vector pollination: spread of pollen from one plant to another by an insect or animal
Nocturnal: active at night only

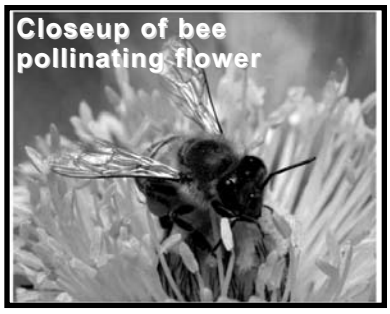
POLLINATION

In order to carry out two of the most important steps in a plant's life cycle—pollination and seed dispersal—many plants rely on the help of the wind, insects and animals.

Gymnosperm pollen is carried on the wind from male to female flowers. Pollen grains are small and light, and they can be scattered for many miles in a strong breeze. Gymnosperms are designed to produce and release a large amount of pollen to ensure that this strategy will work. You may have seen lakes and ponds covered with bright-yellow "dust" in the spring and early summer. This dust is pollen from pine trees and other conifers.

Insects pollinate many angiosperms by visiting one flower after another. Bees, for

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example, will visit flowers that produce sweet secretions called nectar. As the bee feeds on the nectar, pollen is dusted onto the bee's body. When the bee leaves one flower, it will carry that pollen directly to another nectar-containing flower, thereby transferring pollen among the flowers. The scent and the color of the flower serve as signs to help bees find particular kinds of flowers. Flowers that are pollinated by night-flying moths are often white and have a strong fragrance that attracts the moth. The spread of pollen from one plant to another in this fashion is called ***vector pollination***. Vector pollination is much more efficient than pollination by the wind because the bee takes the pollen directly from one flower to the next.

Bees and other insects are not the only creatures involved in pollination. Various birds, especially hummingbirds, sip liquid nectar from flowers. In the process, hummingbirds spread pollen from one flower to another. A few flowers are pollinated by small, pollen-eating bats. The poor vision of bats requires that these flowers be strongly scented to attract the bats, which are ***nocturnal***.



Hummingbirds feeding on nectar

Seed Dispersal

Once the plant seeds are fertilized, they are ready to travel short or long distances from the parent plant. Seed dispersal enables the species to move into new environments where conditions might be more favorable for germination and sprouting.



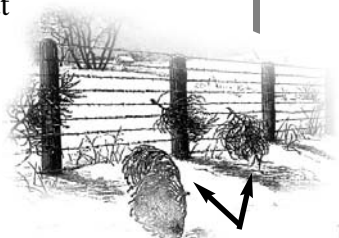




Many seeds are dispersed by the wind. Some seeds are encased in wing-like structures that helps them to glide or spin as they fall to the ground. Others, such as milkweed and dandelions, are lightweight and have feathery attachments that allow them to float and drift with just a breeze.









Tumbleweeds are spiny, dry roundish plants that grow in arid places. When it is time to disperse their thousands of seeds, the plants break loose from their roots and roll with the wind over long distances.





Burs are transported on animal fur

Animals also aid in spreading seeds. Some fruits have tiny hooks or barbs that enable them to catch on to the fur of a passing

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animal. By the time the seeds are removed, the animal may have carried the seeds miles away. Some seeds are eaten by birds and animals and then are passed, undigested, through the carrier's digestive tract. The seeds are then deposited in a convenient batch of natural fertilizer.

In the next lesson, we will begin a brief overview of the Kingdom Animalia.

WATCH VIDEO:
The Beauty of Pollination

LIFE PRINCIPLE



"Bloom where you are planted."

—Anonymous

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Kingdoms of Biology

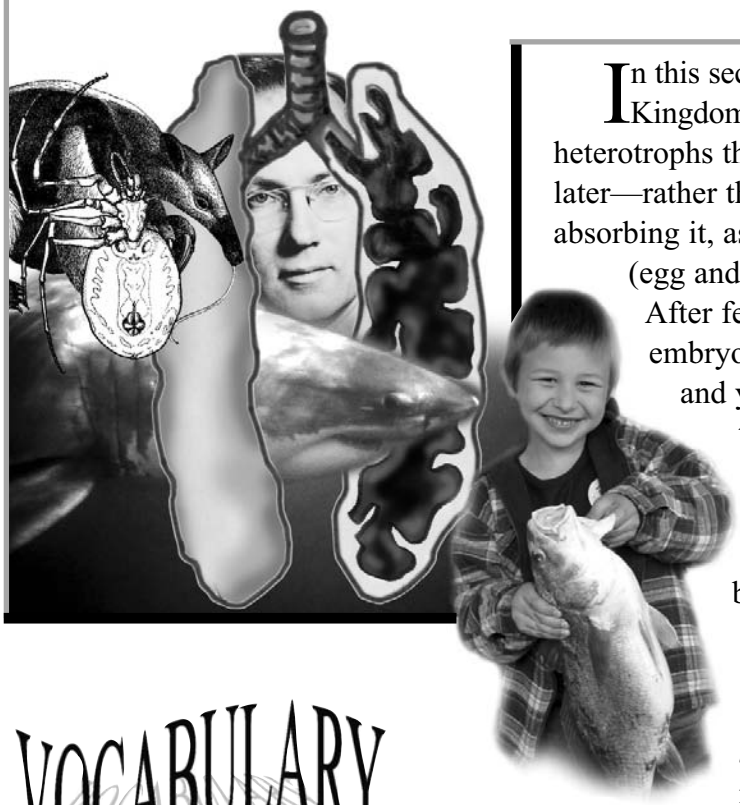
Lesson 11

Chapter 5

KINGDOM ANIMALIA: THE INVERTEBRATES, OVERVIEW I

Section 3

Lessons 11-15



In this section, we will begin our overview of the Kingdom Animalia. Animals are multicellular heterotrophs that ingest their food—eat now, digest later—rather than digesting food externally and then absorbing it, as fungi do. Animals produce gametes (egg and sperm) in multicellular structures. After fertilization, the zygotes develop into embryos. Opinions about classification vary, and you will find that in different textbooks the animal kingdom contains as many as 35 phyla. Although we do not study each one, we will pick a few representative phyla and learn some basic characteristics of each.

About 97 percent of all the animal species on Earth belong to one category of animals—the ***invertebrates***. They range in size from microscopic dust mites to sponges large enough to hide a human. They are found in the air and at the bottom of the sea. These animals are called invertebrates, animals without vertebrae. Invertebrates do not have any kind of bony vertebral column, or backbone, that humans and other vertebrates (such as cattle or dogs) possess. The invertebrate group contains many, very different animals. Essentially, invertebrates are classified according to a characteristic they do *not* have, rather than a characteristic they *do* have.



VOCABULARY

Invertebrates: animals without vertebrae or backbones
Vertebrates: creatures having backbones (vertebraes)
Radial symmetry: arrangement of body parts that repeat around an imaginary axis running through the center of an organism; shown in cnidarians and some adult echinoderms
Bilateral symmetry: body form of an organism that has identical left and right sides, specialized front and back ends, and upper and lower sides

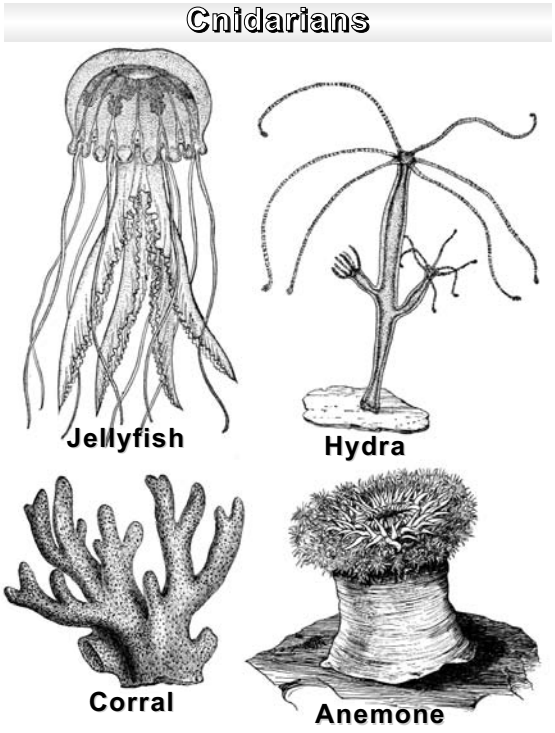
PORIFERA (SPONGES)

Sponges make up the phylum *Porifera*. The name means "pore-bearer". Sponges are hollow with many pores, or openings, but have no nervous

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systems. Sponges are amazing creatures. They consist of relatively independent cells that live together for mutual benefit. Most sponges live in the ocean, although a few are found in fresh water. Sponges take on a variety of shapes, such as flat, tubular, branches, cup-like and vase-like forms. Some sponges are no larger than the size of your fingernail, whereas others are large enough to sit upon.



VOCABULARY

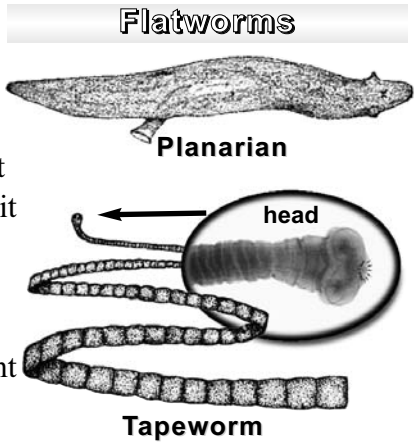
Cephalization: concentration of nerve cells and sensory cells in the head of an organism
Arachnids: part of the arthropod phylum; distinguished by having 8 legs and 2-part bodies with neither wings nor antennes; includes spiders, scorpions, mites, ticks and grand daddy-longlegs

CNIDARIANS

Jellyfishes, corals, sea anemones and hydras belong to the phylum *Cnidaria*, also known as "Colenterates". Cnidarians are mostly marine, although a few species, such as the *hydras*, live in fresh water. Cnidarians have ***radial symmetry***. A plant or an animal with radial symmetry has body parts or patterns that repeat and radiate out from a center point of the body, like spokes of a wheel. Cnidarians are some of the most beautiful and colorful of all invertebrates.

PLATYHELMINTHES

Flatworms make up the phylum *Platyhelminthes*, which literally means "flat worm". About 20,000 variations exist, most of which are aquatic and parasitic, such as flukes and tapeworms. They are very simple animals—flat with no skeletons—that exhibit ***bilateral symmetry***. Animals with bilateral symmetry have left and right sides that are essentially identical, mirror images of each other. Bilateral symmetry is a characteristic of humans and most active animals. Most flatworms also exhibit ***cephalization*** which means that they have a front end which is developed to the point of being called a "head".



NEMATODA

Roundworms, or nematodes, make up the phylum *Nematoda*. *Nematode* literally means "thread worm". A roundworm has a tube-like digestive system, with a mouth at one end and an anus at the other. Nemotoda are

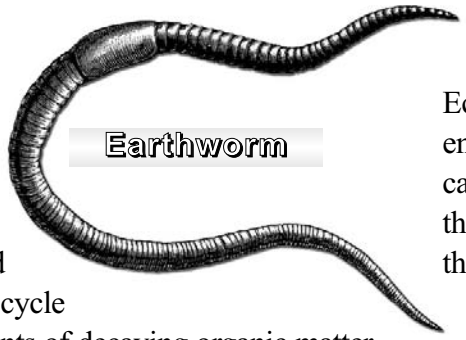
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Roundworm

parasites with distinct nervous and digestive systems. Some roundworms are microscopic, while others grow to be several feet long.

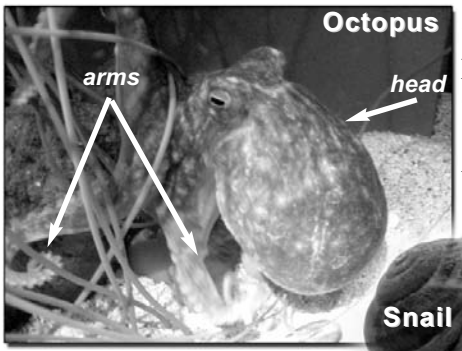
ANNELIDA

Segmented worms belong to the phylum *Annelida*, meaning "ringed" or "segmented". This phylum includes a wide range of fascinating animals—from common earthworms to exotic marine worms with feathery, rainbow-colored gills. Earthworms and their relatives recycle enormous amounts of decaying organic matter in the soil.


Earthworm

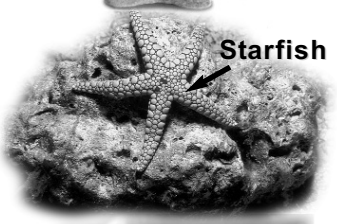
MOLLUSCA

Members of the phylum Mollusca—meaning "soft bodied"—include clams, snails, octapuses and squids, and are found throughout the world. Many live in the sea, some in fresh water and others on land. Some mollusks, such as snails, have protective shells. Others, such as sea slugs, avoid being eaten by predators by leaving a bad taste in the predator's mouth. Clams, mussels, oysters and scallops are called *bivalves*, each having two shells connected by a flexible hinge. When bivalves are in danger, they clamp their shells closed. Octopuses and squids can emit clouds of dark-colored ink to confuse predators, allowing the squid or octopus to escape.



Mollusks


Sand dollar


Starfish

ECHINODERMATA

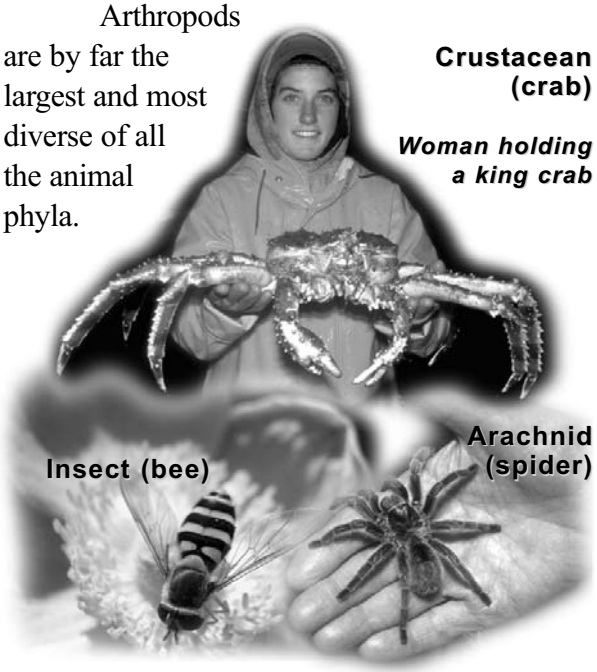
Starfishes, sea urchins, sand dollars and sea lilies all belong to the phylum *Echinodermata*, meaning "spiny-skinned". Echinoderms live their entire lives in water. They can be recognized by their spiny skin and by their *five-part radial symmetry*.


Sea Urchin

Echinoderms

ARTHROPODA

Arthropods are by far the largest and most diverse of all the animal phyla.



Arthropods

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Some researches estimate that 10 million species of arthropods exist! Their most important characteristics are external skeletons and jointed legs. Spiders and scorpions are classed as ***arachnids*** in the subphylum *Chelicerata*, denoting the presence of poison glands. Both the black widow and brown recluse spiders have poisonous bites that can be very dangerous to humans. Lobsters, shrimps and crabs also belong to the arthropods in the subphylum *Crustacea*, meaning "crusty shell". These animals range in size from tiny water fleas to huge Alaskan king crabs, whose legs can stretch almost two yards across. At least half of all living animal species belong to the class Insecta. Insects are so diverse in form and habit that researchers have difficulty choosing one that truly represents the entire group.

In the next lesson, we will take a brief look at the basic body systems of invertebrates.

WATCH VIDEO:
Weird Insects

LIFE PRINCIPLE



"Life emerged . . . not simple, but complex and whole, and has remained complex and whole ever since . . . ."

—Stuart A. Kauffman
Theoretical biologist and complex systems researcher

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Kingdoms of Biology

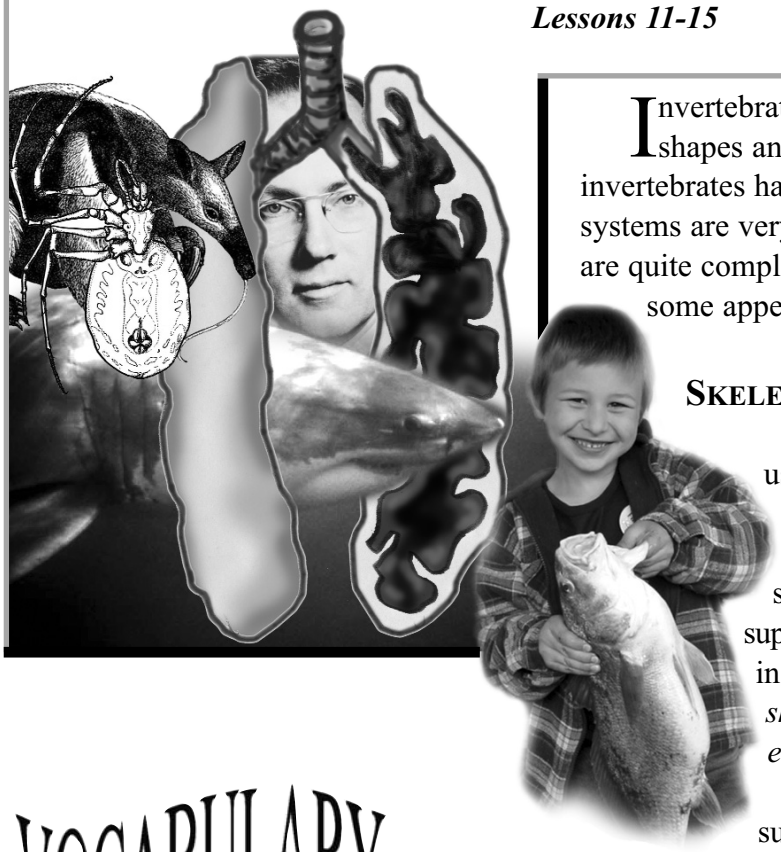
Lesson 12

Chapter 5

KINGDOM ANIMALIA: THE INVERTEBRATES, OVERVIEW II

Section 3

Lessons 11-15



Invertebrates have an astonishing variety of shapes and body structures. Each phylum of invertebrates has a unique body plan. Some body systems are very simple, like the sponges. Others are quite complex. Some are very efficient while some appear to be much less efficient.

SKELETAL AND MUSCULAR SYSTEMS

Almost all multicellular animals use some kind of muscle tissue for locomotion. Muscles, in order to operate properly, require some kind of skeletal system to provide firm support. Three kinds of skeletons exist in the animal kingdom: *hydrostatic skeletons*, *exoskeletons* and *endoskeletons*.

In some animals, the muscles surround and are supported by a water-filled body cavity. This type of skeleton is called a ***hydrostatic*** *skeleton*. Sea anemones are good examples of organisms with this type of skeleton.

An external skeleton is called an ***exoskeleton***. Arthropods are the best examples of organisms with exoskeletons. The arthropod's exoskeleton is made of a carbohydrate called ***chitin***. Muscles are attached to the inside of the exoskeleton. All exoskeletons are thin and flexible at the joins, allowing the skeleton to bend and flex.

A skeleton that is located within the body is called an ***endoskeleton***. Sponges, and some echinoderms, have elementary endoskeletons, but the best examples are found among the vertebrates. (You have an endoskeleton.)

DIGESTIVE SYSTEMS

Because all animals, including humans, are ***heterotrophs***, we must all eat in order to survive.

VOCABULARY

Hydrostatic: having to do with the balance between the forces of gravity and water pressure

Exoskeleton: a hard, external covering or structure that supports and protects the body

Chitin(kit-in): a structural carbohydrate that is the main component of arthropod exoskeletons; also reinforces the cell walls of fungi

Endoskeleton: a skeleton, mostly surrounded by muscle, within the body of an organism

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Invertebrates use several different methods to digest their food.

Sponges, the simplest multicellular animals, filter tiny particles of food from the water. Food is digested inside these cells, and the resulting nutrients are distributed among other cells within the sponge.

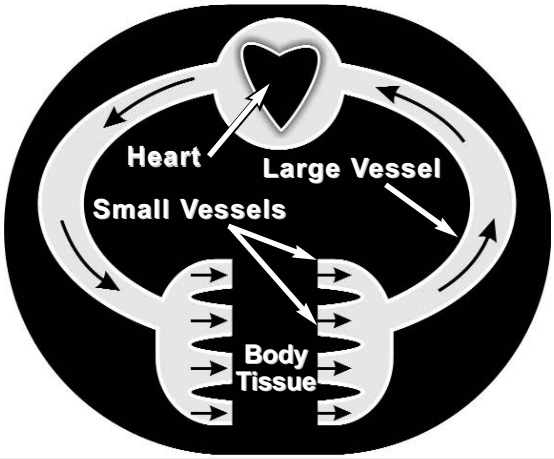
VOCABULARY

Heterotrophs: organisms that cannot manufacture their own food; such as animals, protozoans, fungi and most bacteria
Open circulatory system: a system in which blood is pumped from the heart through vessels and open body spaces
Closed circulatory systems: a system in which blood moves only through blood vessels
Gills: featherlike respiratory organs of many aquatic species; used to obtain oxygen from the water
Trachea: a tube that carries air from the larynx to the lungs; also called the windpipe
Flame cell: a specialized cell with a tuft of cilia that conducts water and wastes through the branching tubes that serve as the excretory system in flatworms
Nephridia (singular: nephridium): excretory organ that removes nitrogen-containing wastes from the blood; found in many invertebrates
Malpighian tubules: structures that excrete nitrogenous wastes; found in many arthropods
Centralization: concentration of nerve cells that form nerve cords or nerve rings around the mouth of some invertebrates
Cephalization: concentration of nerve cells and sensory cells in the head of an organism
Ganglia: clumps of nerve cells in the head region of primitive organisms such as the flatworm

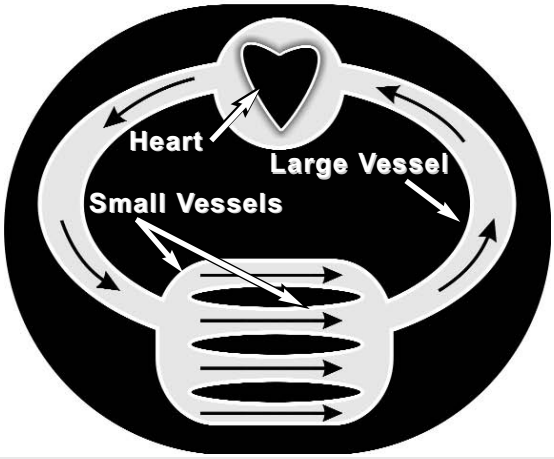
Because this type of food processing takes place inside the cells, it is called *intracellular digestion*.

Other invertebrates, such as annelids, mollusks, arthropods and chordates have two body openings. Food enters through a mouth and leaves through an anus. Almost all the food—except for certain fats—is digested within the digestive cavity. Digestion that takes place outside the cells is called *extracellular digestion*. The final products of digestion are absorbed into blood vessels that line the gastrovascular cavity.

CIRCULATORY AND RESPIRATORY SYSTEMS



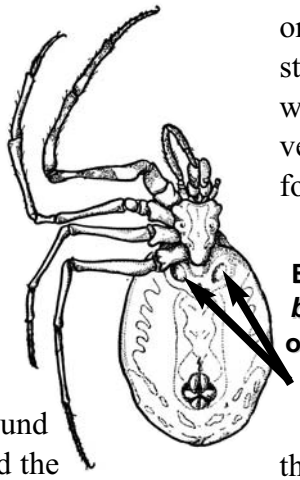
Open Circulatory System



Closed Circulatory System

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Living cells of multicellular animals require a constant supply of oxygen and nutrients, as well as a way to eliminate carbon dioxide and poisonous wastes. Small, thin, soft-bodied animals may provide for these needs by simple diffusion through the body surface. The more complex multicellular animals have a circulatory system—a collection of one or more pumps and tubes that transport important substances within the body. The pumping part of such systems is called the *heart*. The fluid being pumped around the body is called *blood*, and the tubes that carry it are called *blood vessels*. Two main types of circulatory systems exist in invertebrates: *open circulatory systems* and *closed circulatory systems*.



Entrance to *book lungs* on underside of spider's abdomen

Open circulatory systems are systems in which blood from the heart is not entirely contained in the blood vessels. Instead, the blood from the heart is pumped through a series of vessels that carry the blood and release it directly into body tissues. The blood flows through tissues and collects in openings called *sinuses*. These sinuses connect with a larger sinus around the heart which takes in the blood again.

Closed circulatory systems keep blood contained in a system of closed vessels that pass through various parts of the body and return the blood back to the heart. In such systems, blood does not come into direct contact with tissues. Instead, oxygen, carbon dioxide and other substances diffuse in and out of the blood through very thin walls of tiny blood vessels.

Small, soft-bodied animals like worms and cnidarians may be able to exchange oxygen and carbon dioxide with their environment simply by diffusion of oxygen through their body surfaces. Larger animals have circulatory systems and, usually, respiratory systems. Annelid worms, mollusks and crustaceans have respiratory organs called ***gills***. Gills are feathery structures that expose a large surface area to a water environment. Gills are rich in blood vessels that bring blood close to the surface for gas exchange.

Land invertebrates have several different types of organs for breathing air. Spiders and their relatives have structures called *book lungs*, which are sheetlike layers of thin tissue that contain blood vessels. Insects have a series of air-filled tubes called ***trachea*** that bring air to each body cell. The trachea branches extensively and reaches deeply into most insects' body tissues.

Excretory Systems

For most animals, excretion—the process of eliminating toxic waste products—is closely related to maintaining proper water balance within the body. Cells that break down amino acids produce a highly toxic, water-soluble, waste product called *ammonia*. The ammonia is carried through the body and dissolved in blood and body fluids. As a result, getting rid of ammonia usually also involves getting rid of water.

Many marine invertebrates are thin-bodied and surrounded by water. Ammonia leaves the body by simple diffusion through body surfaces or through thin gill membranes. Some freshwater flatworms have excretory systems containing *flame cells* that remove water and some water-soluble wastes, such as ammonia, at the same time. The flame cells

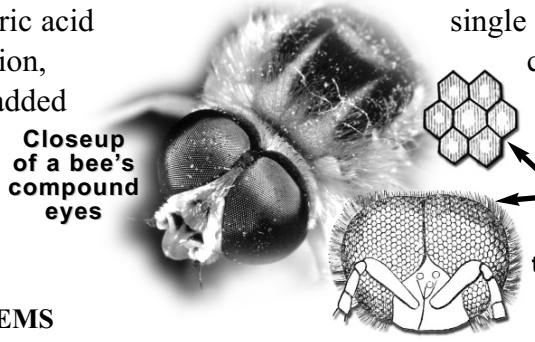
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form a network that empties water and wastes through tiny openings in the animal's skin. Many of the wastes, however, leave the body through diffusion.

Other groups such as annelids, mollusks and invertebrate chordates have structures called ***nephridia***. Nephridia absorb body fluids, remove the wastes, and then return water and other important solutes to the body. Waste products are eliminated from the body in the form of urine.

Land invertebrates must rid their bodies of waste while conserving water. Some groups convert ammonia into urea which is soluble in water and is much less toxic than ammonia. Urea can be concentrated and stored in a smaller amount of water than an equivalent amount of ammonia. This substance is called *urine* and is collected and expelled from the body. Other groups, such as insects and some spiders and scorpions, convert wastes into uric acid, which is removed from their bodies by structures called ***Malpighian tubules***. Much of the uric acid precipitates out of solution, forming a paste that is added to the insects' other solid wastes, thus conserving water.



NERVOUS SYSTEMS

All animals that respond rapidly to their environment have a collection of organs called the *nervous system*. The basic operations of individual nerve cells are almost identical in all life forms—from the most primitive to the most complex animal. The patterns in which nerve cells are arranged does change from phylum to phylum.

The simplest invertebrates, such as the hydras, have a loose, netlike arrangement of nerve cells. Other, more-complex invertebrates possess elementary *centralization*, in which the nerve cells are more concentrated and form nerve cords or nerve rings around the mouth. Nerve cords or nerve rings can send messages from one body part to another.

Cephalization is exhibited in primitive flatworms as just a few clumps of nerve cells called ***ganglia*** in the head region. In insects and some mollusks, ganglia grow larger and become more organized into structures called *brains*. From these brains, or collections of nerve cells, called *nerve cords*, information is carried to and from other parts of the body.

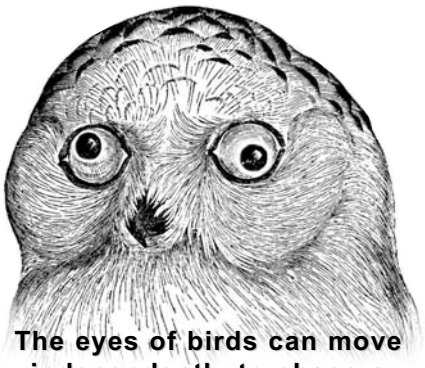
Eyes are a part of the nervous system and are designed in numerous varieties in the animal kingdom. Flatworms have simple eyespots that detect the presence or absence of light. Insects and certain arthropods, on the other hand, have well-developed eyes that detect complex patterns and colors. For example, a crayfish has about 2,500 single eyes in each of its small, compound eyes. Other animals and humans possess remarkably complex and wonderful eyes. Humans have the ability to detect shapes, light, color and movement. According to science writer Carl Wieland:

> *The single act of walking into a room and immediately recognizing all the objects in it requires more computing power than a dozen of the world's top supercomputers put together.*

The eyes of birds are fascinating, as well. They can move independently and

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observe movement in front, behind, above and below the bird.



The eyes of birds can move independently to observe movement in all directions.

REPRODUCTION

Although nearly every form of reproduction is found among the invertebrates, they are all capable of sexual reproduction. Sexual reproduction helps create and maintain genetic diversity. Many invertebrates, including most of those that reproduce asexually at times, engage in sexual reproduction which involves males that produce sperm and females that produce eggs.

In the next lesson, we will briefly examine the vertebrate's members.



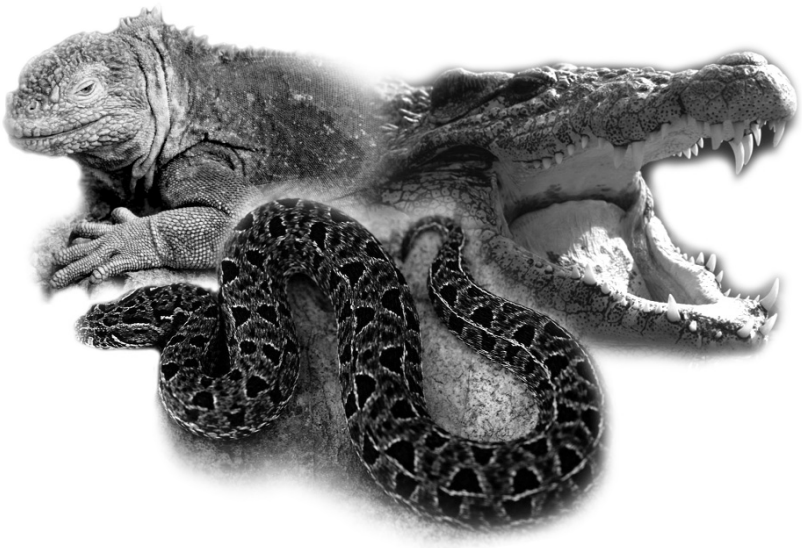
LIFE PRINCIPLE

"What the eye sees, the heart believes."

—Old German proverb

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Kingdoms of Biology

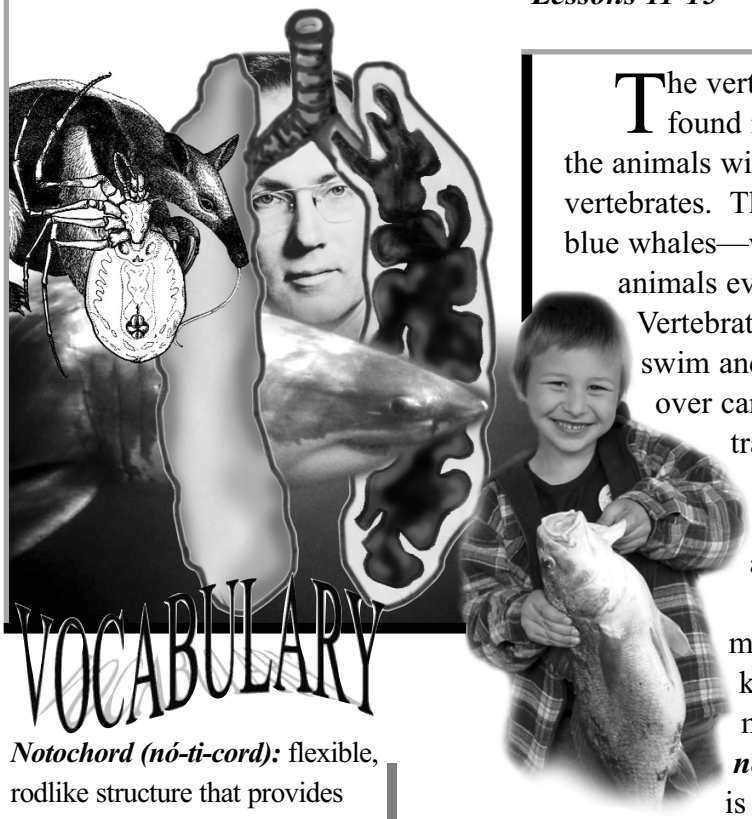
Lesson 13

Chapter 5

KINGDOM ANIMALIA: THE VERTEBRATES, OVERVIEW I

Section 3

Lessons 11-15



The vertebrates of the animal kingdom are all found in one phylum—*Chordata*. Most of the animals with which you are familiar are vertebrates. They range in size from tiny fishes to blue whales—which scientists believe are the largest animals ever to have lived on the earth.

Vertebrate animals run, hop, slither, burrow, swim and fly. They soar over mountains, roam over canyons, ride on the artic ice, plod across trackless deserts, and call through the night in tropical rain forests. Vertebrates include humans, fishes, amphibians, birds and reptiles.

From fish to reptiles to mammals, most members of Chordata have some kind of backbone or vertebrae. All members of Chordata have a ***notochord*** (meaning *back cord*), which is a rod of tough, flexible material that runs the length of a creature's body providing the majority of its back support. All members of the phylum Chordata have a notochord at some point in their development. While some chordates have a notochord throughout their entire lives, others retain notochords only in the earliest stages of their development. For these animals, the notochord turns into vertebrae—or backbone—before the creature is born or hatched.

In addition to a backbone, most vertebrates have two sets of appendages (arms and legs), a closed circulatory system with a ***ventral*** heart and either gills or lungs for breathing.

VOCABULARY

Notochord (nó-ti-cord): flexible, rodlike structure that provides body support; unique to chordates

Ventral: positional in the chest, thorax or pectoral region

Mammary glands: glands that enable a female to nourish her young with milk

Marsupium: an abdominal pouch in marsupials in which the young complete their development

Placenta: spungy, vascular organ in mammals that connects a mother with her developing embryo and provides a place for the exchange of nutrients and wastes

FISHES

Fishes are aquatic animals with streamlined shapes and functional tails that allow them to move rapidly through the water. Fishes exchange gases with their environment through

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gills, although a few species have lungs that supplement the gills for gas exchange.



One class of fishes called *Agnatha* is made up of species that have no jaws. Lampreys and hagfishes are species within this class. These fishes feed by sucking blood and other body fluids from their prey, usually other fishes. Scientists have recently split Class Agnatha into two classes: *Myxini* and *Cephalaspidomorphi*.

Another class of fish is called *Chondrichthyes*. These fishes have endoskeletons composed entirely of cartilage. This class includes the great white shark, a fearsome predator. However, despite their bad reputation, only a few species of sharks attack humans, and then only rarely.


Great White Shark

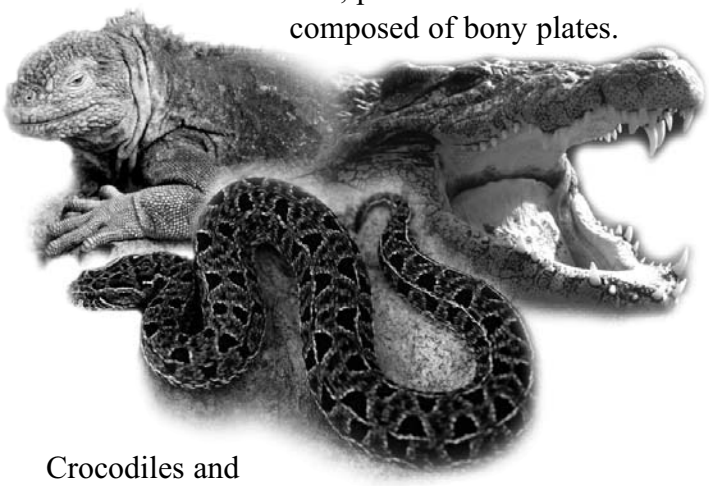
The bony fishes belong to the class *Osteichthyes*. Most of the familiar fishes living today are bony fishes. They live in the oceans and in fresh water and include tuna, mackerel, herring, bass, trout and goldfish. These fish inhabit areas in all aquatic habitats—from the tropical streams to the sea beneath the Artic ice.

AMPHIBIANS

The word *amphibian* means "living in two ways". Amphibians live both on land and in the water. Today, only about 2,500 species of amphibians exist. Amphibians lay their eggs in water, where they spend at least part of their lives. As adults, amphibians live on land and breathe through lungs. Most have moist skin and cannot tolerate periods of dryness. In this class are the frogs, toads and salamanders.

REPTILES

Class Reptilia are creatures that reproduce by internal fertilization and produce leathery-shelled eggs that prevent water loss. Reptiles also have dry, scaly skin that retains water inside the body. Reptiles breathe air by means of developed lungs. Dinosaurs, now extinct, were in the class of reptiles. Tortoises and turtles are reptiles that live in encased, protective shells composed of bony plates.



Crocodiles and alligators are found in tropical regions. The most abundant group of living reptiles includes lizards and snakes. Lizards and snakes look quite different but are actually very much alike.

BIRDS

Feathers are the unique characteristic that defines the *Class Aves* known as birds.

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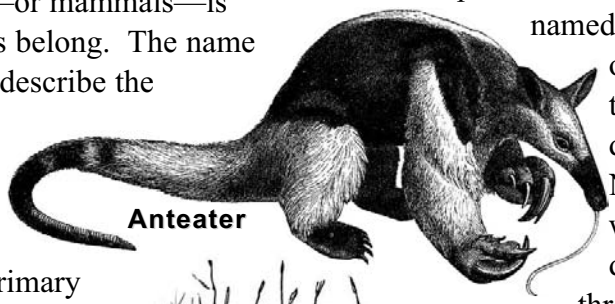
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Feathers are used for flight, but also to conserve body heat. To facilitate flight, birds are streamlined to minimize air resistance. Bird's wings have endoskeleton bones that are light and hollow. Many of their bones are also fused to provide compact strength. Class Aves is a large and diverse class, containing some 8,600 species in 27 different orders.

MAMMALS

Class Mammalia—or mammals—is the class to which humans belong. The name "mammal" is assigned to describe the presence of ***mammary glands*** which produce milk. Mammals are also characterized by the presence of hair, whose primary function is to help retain body heat. Three main groups of mammals make up this group: *monotremes*, *marsupials* and the *placental mammals*.

Monotremes are egg-laying mammals that produce milk. The duckbill platypus found in Australia and two species of spiny anteaters found in South America and Africa are the only monotremes in existence today.



Anteater



Duck-bill Platypus

Marsupials are mammals whose embryos develop within the mother's uterus for a short period of time before birth. After birth, the immature babies crawl into the mother's abdominal pouch, called a ***marsupium***, where they are nourished and complete their "infancy" stage of development. The Australian kangaroo, opossum and koala bear are marsupials. Opossums are common to North America.

The largest group of mammals is the *placental mammals*. They are named for the ***placenta***—an organ that connects the mother with her developing embryo. Nutrients, oxygen, wastes, and carbon dioxide are exchanged through the placenta.

Mammals have spread to virtually all environments on the earth. They live in the oceans, in the deserts, underground, in trees, in the air and, of course, on the ground. Mammals have highly developed nervous systems, and many have an acute sense of smell, hearing, taste, vision and touch. Mammals rely on memory and learning to guide their activities.

In the next lesson, we will continue our overview of the vertebrates.

LIFE PRINCIPLE

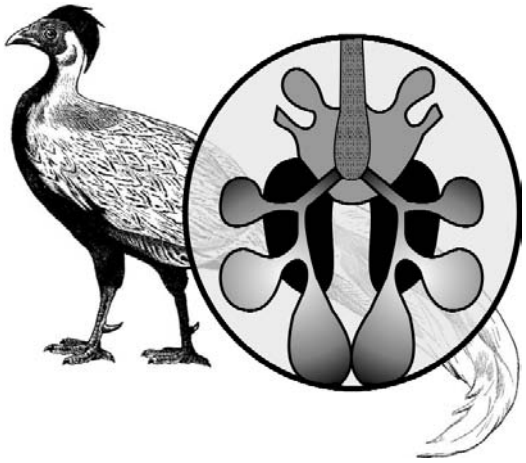


"Men love to wonder and that is the seed of science."

—Ralph Waldo Emerson (1803-1882),
American poet and essayist

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Kingdoms of Biology

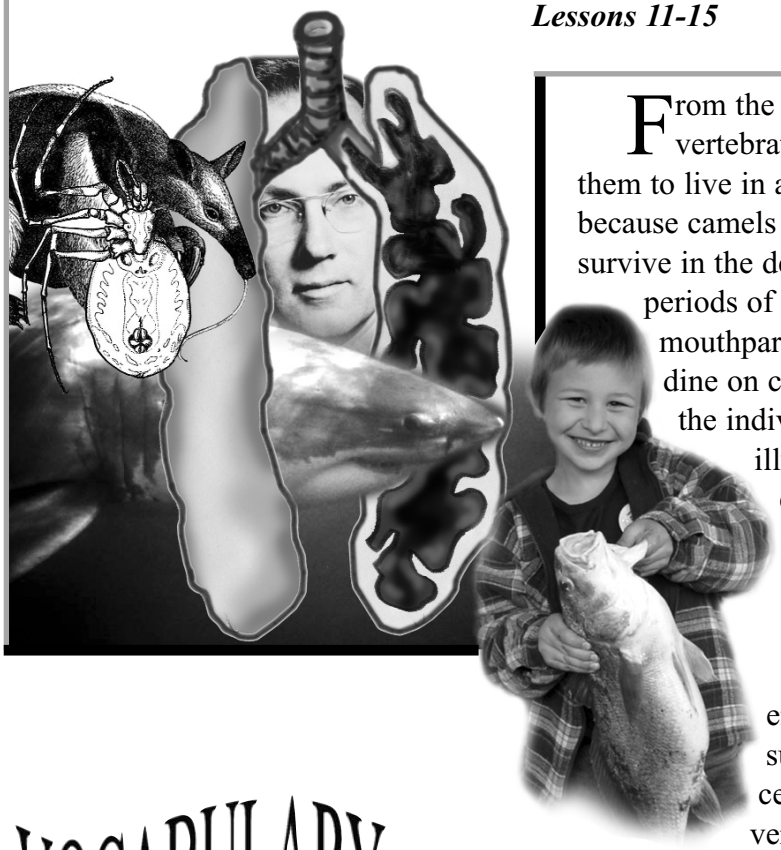
Lesson 14

Chapter 5

KINGDOM ANIMALIA: THE VERTEBRATES, OVERVIEW II

Section 3

Lessons 11-15



From the sea squirts to human beings, vertebrates have characteristics that allow them to live in a variety of habitats. For example, because camels are able to conserve water, they can survive in the desert without water for fairly long periods of time. A lizard's specialized mouthparts and digestive system enable it to dine on crunchy grasshoppers. This review of the individual systems in vertebrates will illustrate the variety of vertebrates in existence around the globe.

Skeletal and Muscular System

A vertebrate has an endoskeleton with bones that are surrounded by muscles and skin. The central element of that skeleton is the vertebral column or backbone. The backbone has a series of muscles and ligaments attached to help support body mass and enable control of body movements.

Digestive System

Every group of vertebrates has systems that are able to capture and digest different foods. Some vertebrates, such as the mammals, have teeth that help to break down food before it enters the stomach. Food types are processed in different ways once the food is swallowed. ***Carnivores*** have short digestive tracts which secrete strong enzymes to break down tough meat proteins.

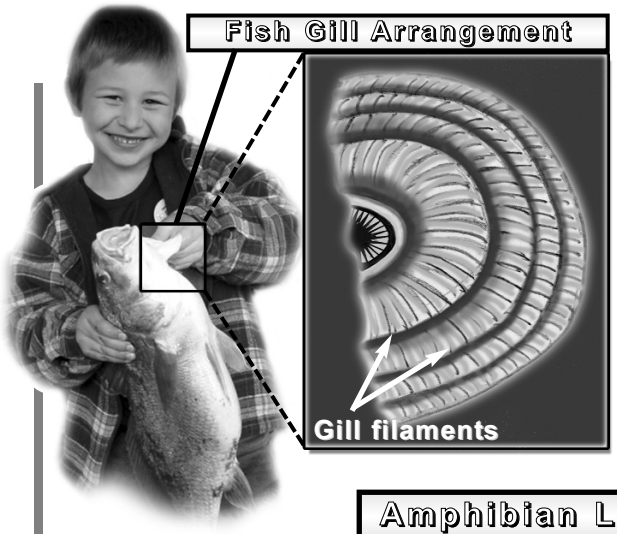
Herbivores such as cows, goats, camels and sheep spend a great deal of time chewing (and re-chewing) their plant food. Such animals have long, convoluted digestive tracts with enzymes and colonies of bacteria to help digest tough plant cellulose.

VOCABULARY

Carnivores: meat eaters
Herbivores: plant eaters
Bronchi: main branches of the windpipe that enter the lungs and branch off; enable air exchange
Alveoli: tiny air sacs in the lungs appearing in grapelike clusters, surrounding a network of capillaries where gas exchange takes place
Avian: pertaining to birds and flying; word from which *aviation* is derived

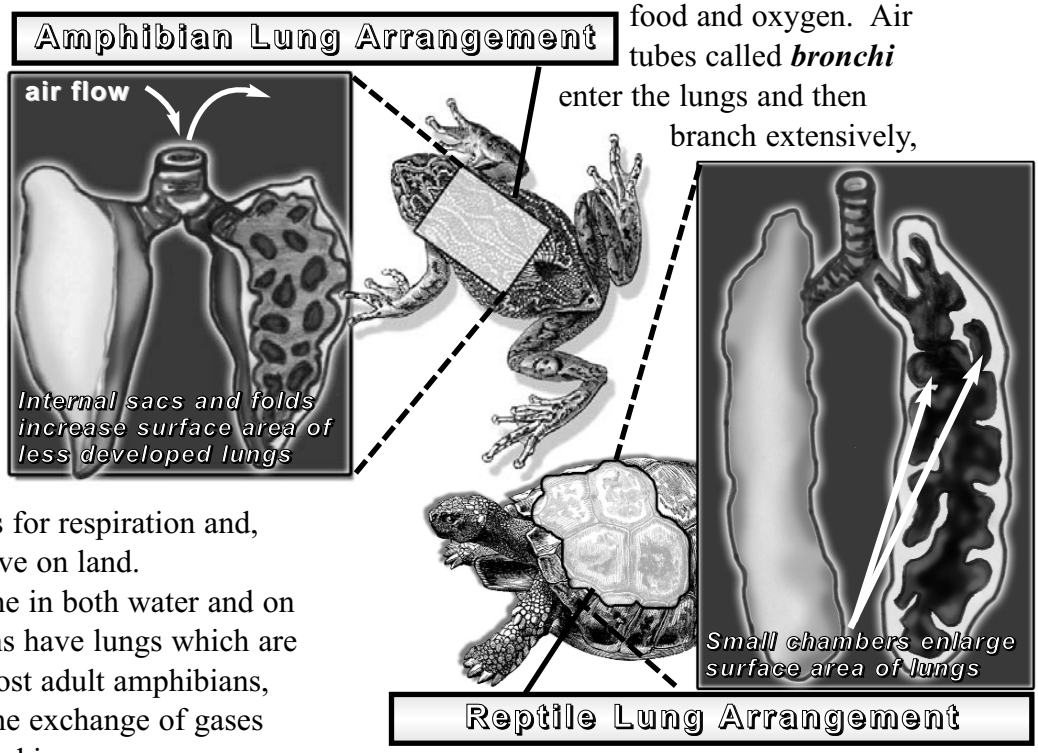
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Respiration System

Exchanging oxygen and carbon dioxide with the environment is a universal requirement of all living things. Aquatic vertebrates, such as fishes, rely almost entirely on gills for respiration and, therefore, cannot survive on land. Amphibians can breathe in both water and on land. Adult amphibians have lungs which are not well developed; most adult amphibians, therefore, depend on the exchange of gases through their thin, wet skin.



Reptiles have more efficient lungs. The inside of the reptilian lung is divided into many small chambers. These chambers greatly increase the amount of surface area available for gas exchange. Also, reptiles have muscles that help inflate and deflate lungs to pump air in and out.

Mammals require a higher rate of gas exchange because they have a higher *metabolic rate*, the rate at which they use food and oxygen. Air tubes called ***bronchi*** enter the lungs and then branch extensively, ending in bubble-like structures called ***alveoli***. Alveoli are richly supplied with tiny capillaries which allow efficient gas exchange.

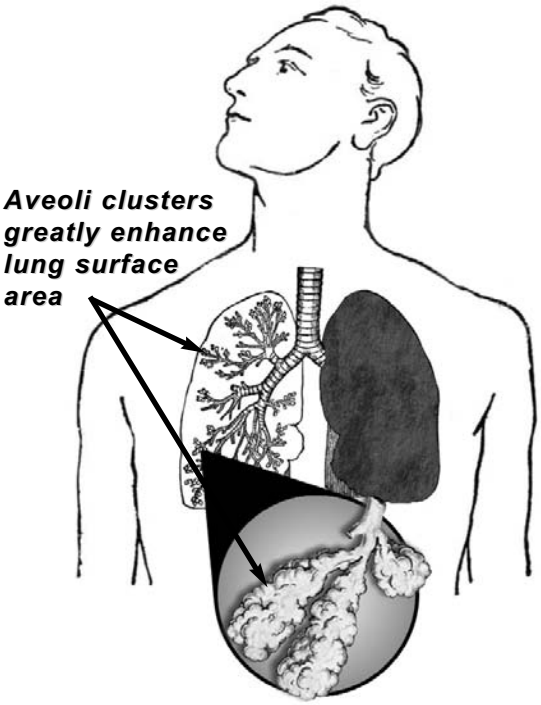
Birds have the highest need for lung efficiency. In order to fly—an intense, long-term exercise—birds require a large, steady oxygen supply. To accommodate these needs, the ***avian*** lung has branched bronchi and alveoli similar to mammalian lungs but with an important difference. Air passageways in bird lungs connect to large air sacs in certain bones. Air is pumped through the lungs in a one-way flow. As a result, the gas-exchange surfaces constantly

VOCABULARY

Ectotherm: an organism, such as fish, amphibian, or reptile—that relies on interactions with the environment to control body temperature; cold-blooded organism
Endotherm: organism, such as a mammal or a bird, that generates and maintains body heat through chemical reactions in the body; a "warm-blooded" organism

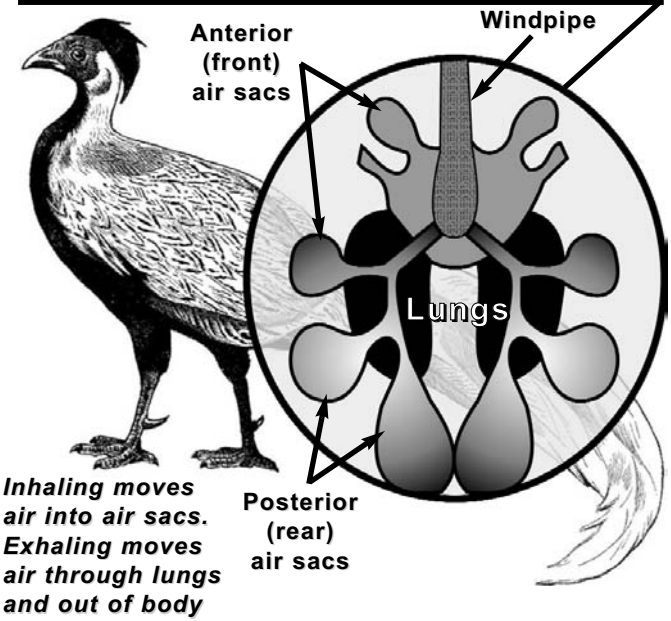
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Mammal Lung Arrangement



come in contact with fresh, oxygenated air. Contrast this to the mammalian lung in which some stale air remains in the lungs after each breath.

Avian Lung Arrangement



Circulatory System

The circulatory systems of vertebrates vary widely. A typical fish has a *single-loop* circulatory system in which the blood is pumped from the heart to the gills and flows from the gills to the rest of the body tissues before returning to the heart. A vertebrate with lungs has a double-loop circulatory system. In a *double-loop* system, the first loop carries blood between the heart and the lungs. The second loop carries blood between the heart and the rest of the body.

Excretory System

We have learned that the need to eliminate nitrogen-containing waste is linked to the need for maintaining water balance within the body. As with invertebrates, the vertebrate wastes are produced in the form of ammonia. Aquatic vertebrates often rid themselves of ammonia through diffusion. Fishes lose a great deal of ammonia across gill membranes, while amphibians lose some through their skin. More complex creatures have kidneys: organs used to excrete nitrogen and other nonsolid wastes.

Like many invertebrates, some vertebrates convert ammonia into less-toxic compounds which are easier to concentrate and eliminate. Mammals convert ammonia to *urea*, a less toxic substance. The urea is then excreted from the body as urine. Birds and reptiles convert nitrogenous wastes into a semi-solid paste—*uric acid*. Uric acid is also less toxic than ammonia and requires less water to flush out of the body.

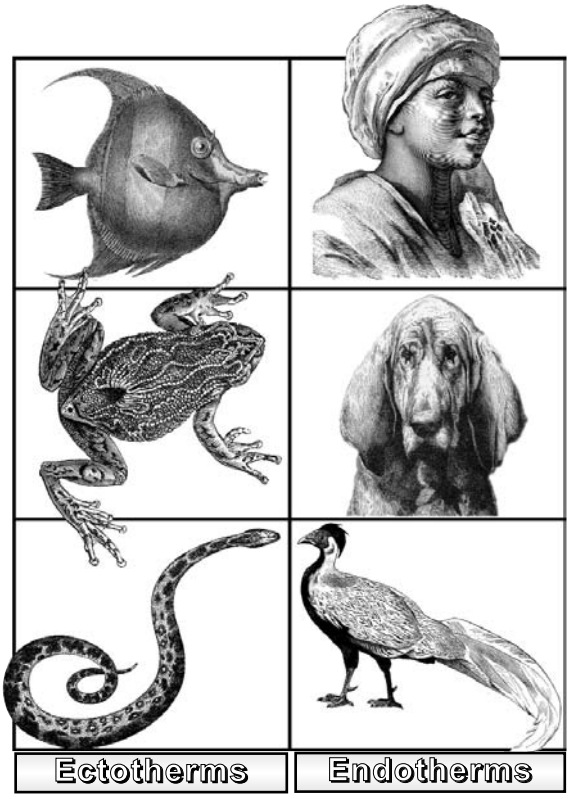
Nervous System

All vertebrates show a great deal of *cephalization*, the concentration of nerve and sense organs in the head. Even in simple vertebrates, the bundle of nerves and neural

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connections in the head is large enough to be called a brain. From the brain, a long, thick collection of nerves called the *spinal cord* (protected by the vertebral column) runs down the back. At each joint between the vertebrae, pairs of nerves run in and out of the spinal cord to connect muscles, organs and sensory receptors in the skin and throughout the body.



Reproductive System

Almost all vertebrates reproduce sexually. However, a few species of lizards, fishes and amphibians develop from unfertilized eggs. In some vertebrates, such as codfish and frogs, fertilization is external. In others—reptiles, birds, mammals, cartilaginous fishes and certain amphibians—fertilization occurs inside the body of the female.

Temperature Control

The ability to control body temperature is an enormous asset. Many chemical reactions, including those important to living things, operate differently at various temperatures. Vertebrates use a variety of techniques to control temperature. All include a source of heat for the body, a method of covering that heat, and a method of eliminating excess heat when necessary.

Most fishes, amphibians and reptiles rely on interactions with their environment to help them control body temperature. These animals may bask in the sun to warm up, or find shelter in the shade or in underground burrows to cool down. Such animals are known as ***ectotherms***, which means, "heat from the outside." Although they are often called "cold-blooded", this term does not describe these creatures accurately.

Mammals and birds generate heat in body tissues through chemical reactions in the body. In addition, mammals and birds have layers of fat and either fur or feathers to help keep heat from leaving the body. When these animals are cold, they shiver which causes muscles to generate more heat. When they are hot, they either pant (as dogs do) or sweat (as humans do) to cool the skin. These animals, often called "warm-blooded", are more properly named ***endotherms***, which means, "heat from within." Humans devise other means of controlling heat by covering or uncovering their bodies with garments, or adjusting the environment with air conditioners or heaters.

In the next lesson, we will once more visit the topic of evolution as it pertains to the study of taxonomy.

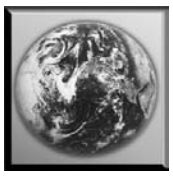
Life Principle



"Every animal leaves traces of what it was; man alone leaves traces of what he created."

—Jacob Bronowski (1908-1974)
Polish-British mathematician and philosopher of science

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The Earth and Its Fullness

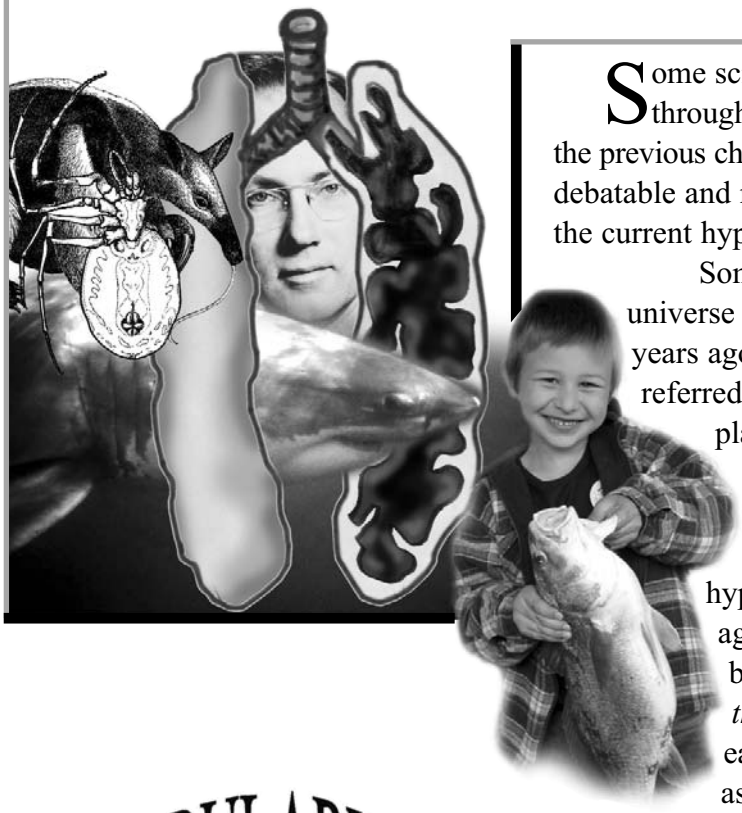
Lesson 15

Chapter 5

A REVIEW: OUTER SPACE TO BACTERIA

Section 3

Lessons 11-15



Some scientists weave the theme of evolution through all aspects of life. As we have studied the previous chapters, the subject of evolution is debatable and much evidence now exists to question the current hypotheses of evolution.

Some scientists hypothesize that the universe came into existence about 15 billion years ago with a colossal explosion often referred to as the *Big Bang*, by which stars and planets ostensibly came into being. Then, supposedly, over the next billion years, the molten earth cooled, forming a hardened, outer crust. Scientists hypothesize that about 3.5 billion years ago, living things (bacteria) came into being. This theory, the *primordial soup theory*, was examined more fully in an earlier lesson. From the "soup", all life as we know it today purportedly evolved. The prokaryotes were, supposedly, the first living creatures to evolve. Then, the eukaryotes ostensibly came into being. However, no one is certain about how eukaryotes might have actually come about. One theory is called the ***endosymbiotic hypothesis*** which suggests that bacteria may have been engulfed by larger cells. The bacterial cells then might have remained in the cell, assumed some of the chemical reactions for those cells and then morphed into the mitochondria of those cells. Cyanobacteria, or the *algae*, supposedly evolved into the higher, more complex plants. Other bacteria supposedly evolved into animal cells.

Then, according to the fossil record, an "explosion" of life occurred. This is referred to as the ***Cambrian explosion***, because an enormous amount of complex, multicellular organisms appeared within what is called the *Cambrian period*. Evolutionary theory does not have a good explanation for this apparent phenomenon. The complexity of the animals

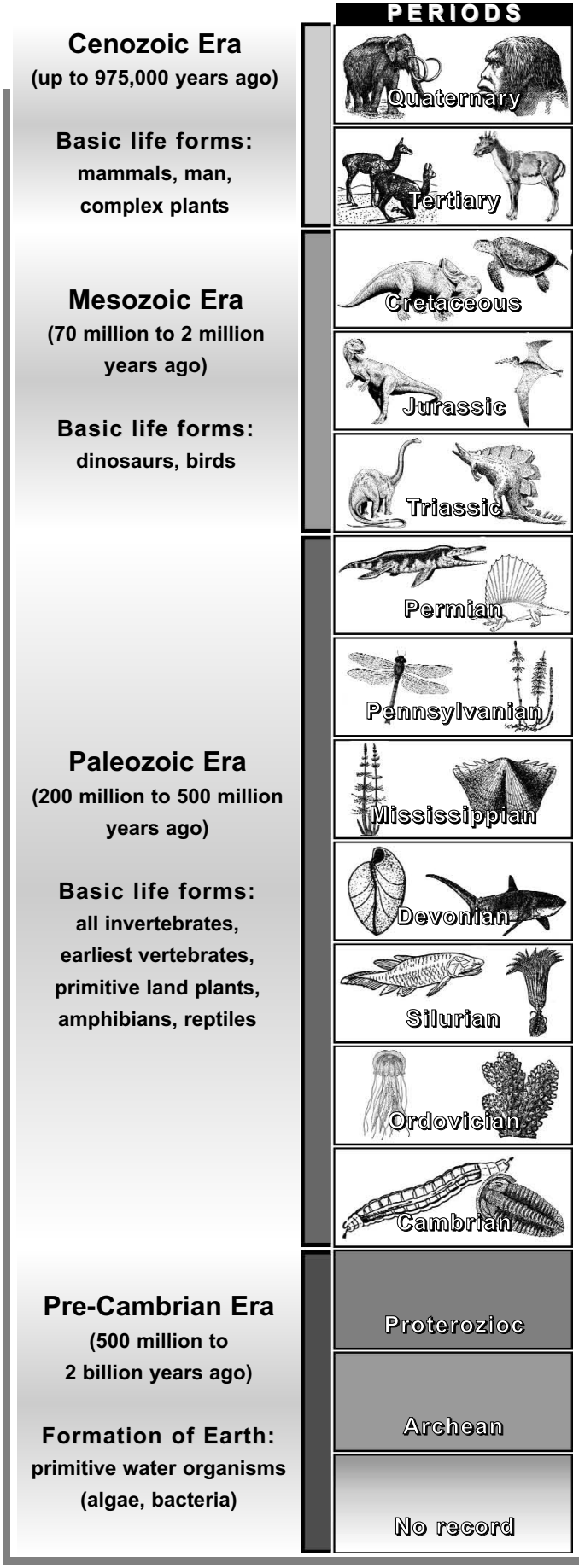
VOCABULARY

Endosymbiotic hypothesis: a hypothesis that billions of years ago, eukaryotic cells arose as a combination of different prokaryotic cells

Cambrian explosion: the phenomenon in the Cambrian sedimentary deposits in which all of the major invertebrate forms of life appear quite abruptly in the fossil record with no preliminary or intermediate forms leading up to them

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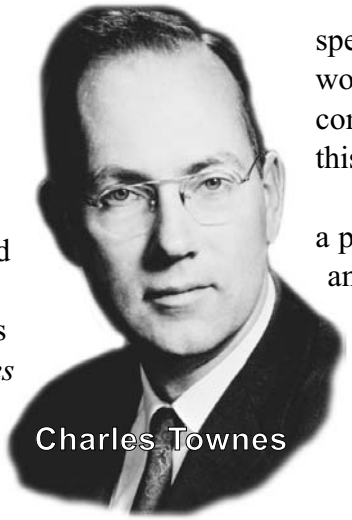
in this explosion is so great that evolutionists estimate at least 1.5 billion years would have been necessary for the animals to have evolved. Archeologists would expect to find billions of evolutionary ancestors of the Cambrian life forms in Precambrian rocks. However, no fossils of evolutionary ancestors of the Cambrian period have ever been found. The absence of tangible evidence prevents exercise of the scientific method to verify theories or hypotheses associated with that time period. Evolutionary theory then proposes that over the next periods of the geological column (time table portrayed here), all plant and animal life evolved.

The study of taxonomy has also been used to "prove" evolution. In order to classify an organism into an appropriate taxonomic group, resemblances between different species are analyzed. This is done in terms of comparative anatomy, comparative embryology, comparative biochemistry, comparative behaviors and other such factors. Then, creatures are classified with similar beings. Evolutionists suggest that this indicates close, ancestral relationships. For example, the fact that men and apes have certain features in common is supposed to indicate that they have a common ancestor. The general classification system, as we just studied (kingdom, phylum, class, order, family, genus, species), has been set up to distinguish different kinds of plants and animals and is assumed to correspond approximately to an actual family tree representing the evolutionary ancestry of all organisms. This qualifies as a hypothesis, but not as evidence; one could use the same logic with automobiles on a used-car lot or the tools in a machine shop.

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The structural and physiological differences between organisms are more significant than their similarities. If all organisms actually had a common ancestor, continuity between them should exist rather than clear-cut gaps. If animals had evolved, as proposed by some evolutionists, researchers could not arrange a classification system at all. Scientists would not be able to tell where the "cats" stopped and the "dogs" began, because intermediate creatures would exist, like a cat-dog. As David B. Kitts, PhD at the school of Geology and Geophysics at the University of Oklahoma states: "Evolution requires intermediate forms between species and paleontology does not provide them."


Charles Townes

George Gaylord Simpson, evolutionist and PhD of Vertebrate Paleontology, notes in his book, *The Major Features of Evolution*:

> *In spite of these examples, it remains true, as every paleontologist knows, that most new species, genera and families and that nearly all new categories above the level of families appear in the record suddenly and are not led up to by known, gradual, completely continuous transitional sequences.*

Interestingly, Charles Darwin stated that:

> *If it could be demonstrated that any complex organ existed, which could not possibly have been formed by numerous, successive, slight modifications, my theory (evolution) would absolutely break down.*

Literally millions of species exist on the planet today. Many have been studied and classified and many are still unknown. The diversity is amazing, as we have just studied in the review of the kingdoms. You have learned that mutations are rare and are nearly always harmful. As we examined the evolution hypothesis mathematically, we found that it appears to be statistically impossible for even the most elementary form of life to have arisen by mere chance. The bewildering complexity of even the most basic organic molecules is simply too great to be explained by mere random chance events.

Consider that the many millions of species that exist today are in virtually perfect working order. Each organism is irreducibly complex. Consider the probabilities of all this "just happening".

Ample evidence does seem to indicate a powerful sense of order in our universe, and in our world, which leads many scientists to embrace the idea of design.

Nobel Prize winner for Physics, Charles H. Townes, asserted:

> *The more we know about the cosmos and evolutionary biology, the more they seem inexplicable without some aspect of design, and for me that inspires faith.*

Paul A. Moody, PhD of Zoology at the University of Vermont, ventured:

> *I know the question in the minds of many of you who have followed me to this point: 'Does not science prove that there is no Creator.' Emphatically, science does not prove that!*

University of Pittsburg science author David Snoke cautions:

> *If the 20th century has taught us anything, it is to be suspicious of those who put all their hope in science as the explainer of everything.*

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In the next chapter, we will begin an in-depth study of bacteria, fungi and protists.

LIFE PRINCIPLE



"Truth will always be truth, regardless of lack of understanding, disbelief, or ignorance."

—W. Clement Stone (born 1902)
Early proponent of the power of positive thinking

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