

BIOLOGY

Biology is the science of life, the study of all living things. The basic unit of life is the cell. An organism may be **unicellular**, composed only of one cell. However, most of the living things you see around you are **multicellular**, composed of more than one cell. Another characteristic of living things is the high level of organization at both the molecular and cellular level. The process of metabolism is carried out within these cells. This refers to the sum of all the chemical events that occur in the organism. To maintain life, cells must maintain stable internal conditions, or homeostasis. Living things grow by means of cell division and development. It might be simple cell division or a more complex mechanism, but all living things have the ability to reproduce.

Biologists use the research or scientific method to solve problems or answer a question. Although some discoveries come about by means of accidental discoveries or errors, the research method is how one begins. The major steps of the process are listed below:

- **OBSERVATION**: One has to observe and recognize a problem in order to solve it
- **RESEARCH**: Once a problem or dilemma has been perceived, literary research should be carried out to see what information is already known.
- **FORM A HYPOTHESIS**: Questions must be formed which can be tested, often in the form of an "if...then..." statement. This is a prediction.
- **EXPERIMENTATION**: A controlled experiment is carried out with a control group and an experimental group and data is collected.
- **ANALYSIS OF DATA**: The data is analyzed to look for trends, often using statistics.
- **DRAWING CONCLUSION**: This is essentially an explanation supported by the data.

If this hypothesis is supported and tested with much experimental evidence, it may be elevated to a theory. A theory is a broad and comprehensive statement of what is thought to be true.

One of the major tools used in biology is the microscope. The compound light microscope is typically used to observe small organisms and cells. There are two lenses which magnify, the ocular or eyepiece lens and the objective lens in the nosepiece. Their individual magnification numbers are multiplied to give the total magnification (ex. 10x times 43x=430x).

1. Genetics

The key molecule driving the inheritance of life is DNA, **deoxyribonucleic acid**. The structure of this molecule was figured out by James Watson and Francis Crick. It consists of repeating **nucleotides**, each composed of a sugar, deoxyribose(D), phosphoric acid(P), and one of four nitrogen bases, adenine(A), thymine(T), cytosine(C), or guanine(G). The molecule is ladder-like in shape with the nucleotides

facing each other and then twisted. The D and P form the sides of the ladder, with the bases pairing up and forming the rungs. The secret to the code is that only A will pair with T and C with G. When DNA replicates itself prior to cell division, the molecules split in half lengthwise, and the missing halves are completed with new nucleotides. The fact that the pairing is specific insures that the resulting two molecules will be identical.

This specific base pairing is also important in protein synthesis. Other nucleic acids come into play here as well. The two main molecules are **messengerRNA** and **transferRNA**. In RNA, **ribonucleic acid**, ribose replaces deoxyribose, uracil(U) replaces thymine, and the nucleotides are found in a single strand formation. During protein synthesis, the DNA double strands temporarily separate between the base pairs (A-T or C-G), allowing RNA nucleotides to pair with the one DNA strand serving as the template. The RNA nucleotides bond to each other forming a long messengerRNA strand in a process called **transcription**. This messenger molecule separates from the DNA strand (which remains in the nucleus) and moves from the nucleus to the ribosomes, where it will pair up with successive molecules of transferRNA. The transferRNA carries specific amino acids which bond together to form protein molecules. This part of protein synthesis is known as **translation**. The placement of specific amino acids is determined by the base sequence, every three bases coding for a certain amino acid, a start, or a stop. This triplet code sequence is ultimately carried in the DNA.

A **gene** is made of lengths of DNA found at the same location on matching or homologous chromosomes. This gene controls the production of a specific protein or poly peptide thus controlling a particular trait. The contrasting characteristics (such as tall versus short for height) are referred to as **alleles**. When two tall alleles or two short alleles are inherited, the situation is referred to as **homozygous**. When one tall allele and one short allele are inherited, it is referred to as being **heterozygous**. In this case, the tall allele covers up or masks the short allele. Thus tall is referred to as the **dominant** allele and should be represented by an uppercase T. The short allele is **recessive** in this case and is represented with a lower case t. The **genotype** of an individual for height could be TT, tt, or Tt. The **phenotype** would be the expressed trait, tall or short. A **Punnett square** is used to predict the possible offspring from the parents.

Biotechnology uses the scientific research on DNA for practical means. DNA may be used to fingerprint individuals, to study genetic defects or to solve crime.

Recombinant DNA may be formed using **restrictive enzymes** to cut DNA and insert other pieces. This process may be used to instruct bacteria how to make human insulin or in gene therapy to insert healthy DNA for nonfunctioning DNA.

2. Cell Divisions: Mitosis and Meiosis

One of the distinguishing features of living things is that life can reproduce itself.

Mitosis is the key way in which unicellular organisms reproduce and multicellular

organisms produce their cells and heal wounds. Mitosis is the process by which the replicated genetic material from one cell is divided to be equally distributed to two new cells. The process is very precise. A normal, functioning cell that is not dividing is said to be in **interphase**. It is growing, making proteins, and carrying out its general metabolism. If the cell is going to divide, the DNA replicates in interphase, and the chromatin material coils and condenses to become compact chromosomes. The phase of mitosis where they appear is called **prophase**. At this time the nuclear membrane and nucleolus disappear, and the spindle fibers take shape, like tiny lines of longitude on the globe. Each chromosome, with its two chromatids, becomes attached to a spindle fiber. When the chromosomes become aligned around the middle of the cell, like at the equator, the stage is called **metaphase**. The chromatids separate and move to opposite ends of the cell or poles during **anaphase**. When they reach the poles, each set organizes into a new nucleus, with nuclear membrane and nucleoli reappearing, and fibers disappearing. This stage is called **telophase**. **Cytokinesis** also occurs at this time dividing the cytoplasm of the original cell into two new cells, each with the complete set of chromosomes, the **diploid number** or **2n**. In humans this number is 46. These two cells are identical genetically unless mistakes have occurred during the process. In a multicellular organism, all its body cells will be produced by mitosis before they specialize into muscle, heart, or brain cells.

Meiosis is the type of cell division which produces 4 cells with half the the number of chromosomes, **monoploid** or **haploid** or **n**. These cells function as sex cells or **gametes**. The genetic material replicates only once at the beginning of the process, with the first two cells produced each dividing one more time, producing the total of four. The cells go through prophase, metaphase, anaphase, and telophase twice with a few major differences from those of mitosis. In prophase I, the duplicated pairs of chromosomes come together forming what are called **tetrads**, because there are four chromatids present. At this time **crossing over** may occur, resulting in the exchange of chromosome ends. The tetrads continue to align on the same fiber, so that a chromosome with its two chromatids move to the poles during anaphase I. They will not separate into individual chromosomes until anaphase II. Thus each cell has only one of each chromosome set, which in humans numbers 23. In humans all four of the cells will become functional sperm while, because of different cytoplasm amounts, only one cell becomes a functional egg or ovum. When a sperm fertilizes an egg, the diploid number is restored, which is 46. The first cell, or fertilized egg is called a **zygote**.

3. Biochemistry

To understand the functioning of living systems, one needs to have an understanding of basic chemistry. Living things are made of the basic units of matter called **elements**. Each element has its own distinctive **atom**. Elements are bonded together forming **compounds**. Again, each with its own distinctive unit called a **molecule**. Each molecule has its own particular arrangement of atoms, along with its particular characteristics or properties. **Organic** compounds are those which contain one or

more carbon atoms, and are found primarily in living systems. CO_2 (carbon dioxide) is a notable exception as it is considered **inorganic**.

There are four major groups of organic compounds: **carbohydrates**, **proteins**, **lipids**, and **nucleic acids**. (Nucleic acids are discussed in the genetic section.) Carbohydrates are made of carbon, hydrogen, and oxygen. These are the sugars, and are used primarily for energy. The basic molecules are **monosaccharides**, or simple sugars, such as **glucose**, **fructose**, or **galactose**. While these molecules all have the same molecular formula, $C_6H_{12}O_6$, they have different structural formulas. In other words, the atoms are arranged differently, giving them different chemical properties. Two monosaccharides are bonded together to form **disaccharides**, such as **sucrose**, **maltose**, or **lactose**. They all have the same molecular formula, $C_{12}H_{22}O_{11}$, formed by adding two monosaccharides and removing 2H and an O to make room for them to bond together, creating a molecule of H_2O . When many monosaccharides are bonded together, **polysaccharides** are formed. Some examples of these are **starch**, **glycogen**, and **cellulose**. Starch and glycogen are important as storage molecules in plants and animals respectively, while cellulose is an important structural molecule in plants.

Proteins are composed of carbon, hydrogen, oxygen, and nitrogen. These molecules are important for cellular structure and to function as enzymes. The basic molecule which builds proteins is the **amino acid**. There are about 20 common amino acids, which, when arranged in varying sequence and number, create the different proteins. Each amino acid molecule has four distinctive parts: a central carbon atom with an attached hydrogen atom, a carboxyl group ($-COOH$), an amine group ($-NH_2$), and a group of atoms that varies known as the R group. The R group may be as simple as a single H as in **glycine** or more complicated as found in glutamine or tryptophan. When two amino acids are bonded together, a dipeptide is formed. When many are bonded, a polypeptide is formed.

Lipids are composed of carbon, hydrogen, and oxygen. The ratio of hydrogen atoms to oxygen atoms is much higher than in carbohydrates. Some general examples of lipids are steroids, waxes, oils, and fats. Fats and oils are generally composed of one **glycerol** molecule with three **fatty acids** attached. Fatty acids all have a carboxyl unit at one end attached to a chain of carbons which vary in length. Hydrogen atoms are attached to the carbons. If there are no double bonds between the carbons, then the fatty acid is said to be **saturated**, holding the maximum number of hydrogen atoms. If there are some double bonds between the carbons, then the number of hydrogens will be smaller and the fatty acid is **unsaturated**. Generally, fats contain saturated fatty acids and oils contain unsaturated fatty acids. Studies seem to indicate that it is healthier to consume unsaturated rather than saturated fatty acids. Trans fatty acids (unsaturated fatty acids which have hydrogenated, by adding hydrogen) are also less desirable healthwise.

4. Cells and Diffusion

All living things are composed of a basic unit known as the **cell**. Robert Hooke was one of the first scientists to observe cells in cork in the mid 1600s. His observations, along with others, led to the development of the *cell theory*. This theory states that all living things are composed of cells, cells are the basic unit of structure and function in an organism, and that cells come only from existing cells. Cells are either prokaryotic or eukaryotic. **Eukaryotic** cells are composed of a nucleus, cytoplasm and a plasma membrane, while **prokaryotic** cells lack a nucleus, but have the other. Some examples of prokaryotes are blue-green algae and bacteria. Plants, animals, protists, and fungi are eukaryotic.

Both prokaryotic and eukaryotic cells are surrounded by a **plasma membrane**. This is a double layer of phospholipids embedded with proteins to facilitate movement of molecules across the membrane.

All prokaryotic and eukaryotic cells contain **cytoplasm**, a semi-liquid substance which composes the foundation of the cell. Within the cytoplasm are found many **organelles** or “little organs” with varying functions. The **endoplasmic reticulum (ER)** is network of membranes running throughout the eukaryotic cell. Some is covered with **ribosomes**, small beadlike structures, which are the site of protein synthesis. This kind of ER is known as **rough ER**, while those without ribosomes is known as **smooth ER**. **Golgi bodies** are flattened sacs of membranes found in the cytoplasm. They function to process proteins produced at the ribosomes. Vesicles are often seen nearby containing the products.

Another organelle found is the **mitochondria**. This has an inner folded membrane and produces energy for the cell by respiration. It is referred to as the powerhouse of the cell. Plants have **chloroplasts** which function to produce sugar molecules through the process of photosynthesis.

Throughout the cytoplasm, the **cytoskeleton** is found. This is a series of microtubules and microfilaments which serve as support and to give shape to the cell.

Lysosomes are also found in the cytoplasm. They contain enzymes for digestion within the cell and sometimes for digestion of the cell itself. **Vacuoles** of varying function are also present, appearing like the lysosomes. In plant cells there is a large central vacuole, filled with water and other molecules.

The **nucleus** is surrounded by a **nuclear membrane** or **envelope**, filled with **nucleoplasm** and the genetic material, chromatin or the chromosomes. The actual genetic molecule within the chromosomes is DNA, but proteins are also present. Also present are small dense bodies called **nucleoli** (little nucleus) which function in producing ribosomes.

In addition to these structures, the plant cell has a **cell wall** around the outer cell membrane. It is made of cellulose and serves for shape and support of the cell.

Molecules must pass through the cell or plasma membrane in order to enter or leave the cell. Diffusion is the movement of molecules from an area of higher concentration to an area of lower concentration. Water molecules move very freely along concentration gradients. This special diffusion is called **osmosis**. Some molecules must be helped through by the embedded proteins. When this occurs moving the molecules from high areas to low areas, it is referred to as **facilitated transport**. When this occurs against the concentration gradient, it requires energy produced by the cell and is called **active transport**.

5. Energy Production in the Cell: Cellular Respiration and Photosynthesis

Protein molecules acting as enzymes are key to chemical activity in the cell. **Enzymes** are organic catalysts, speeding up reactions, but remaining unchanged by the reaction. Thus they can be used to catalyze a reaction many times. Enzymes are very specific, usually catalyzing only one reaction. They attach to the active site of the **substrate** (the molecule/molecules to be altered) and break or form bonds. Most enzymes names are formed by adding -ase to the name of the substrate.

Cellular respiration is the process by which cells release energy stored in food molecules and convert it to a usable form for the cell. The entire process can be represented by this greatly simplified formula: $C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2 + 36ATP$. The initial action on glucose begins in the cytoplasm. No oxygen is needed for this part (called glycolysis), and results in the production of acetylCoA with a net gain of 2 molecules of ATP. The process continues in the mitochondria, using the enzymes and molecules in the Citric Acid Cycle and the Electron Transport Chain to extract the energy to form 34 more molecules of ATP. Most of the carbon dioxide is formed during the Citric Acid Cycle, while the oxygen is used at the very end of the process to form water. Every step of the way is controlled by specific enzymes. This is a highly simplified rendition, and one should refer to a text or other reference for the details.

ATP (adenosine triphosphate) is the cell's energy molecule, like the energy currency of the cell. It is formed when energy is captured to attach the third phosphate unit to ADP (adenosine diphosphate). The molecules cycle back and forth, first capturing released energy from respiration and then releasing the energy for work in the cell.

Photosynthesis is the process by which green plants can convert solar energy into chemical bond energy. The summary formula greatly simplifies the process: $6H_2O + 6CO_2 + sunlight \rightarrow 6O_2 + C_6H_{12}O_6$. The process takes place in the chloroplasts. Light is first trapped by the chlorophyll molecules in the thylakoids, where water is split releasing oxygen. Molecules of ATP are also formed. The process continues in the stroma of the chloroplasts, when carbon dioxide is used to manufacture sugar precursors during the Calvin Cycle. Enzymes are present to control all the reactions. This is a highly simplified version, and one should refer to a text or other reference for

all the details.

6. Evolution and the Origin of Life

It is generally thought that life evolved on earth by progressing through the following steps: **inorganic compounds** **organic compounds** **simple heterotrophic cells** **simple autotrophic cells** **eukaryotes** **multicellularity**. The first step was shown to be possible in the famous experiment in the 1950s by Urey and Miller which converted ammonia, hydrogen, water vapor, and methane using heat and electricity to complex organic compounds, such as amino acids. Fox and others showed that organic molecules could form into structures which looked like cells. The age of the earth is 4.5 billion years and evidence of the first cells is dated at 3.5 billion years ago.

There is much evidence to support the theory of evolution. The biggest body of evidence is the **fossil record** itself. There are fossils of organisms no longer alive and fossils of transitional organisms. Comparative anatomy shows that closely related organisms have similar structures, **homologous structures**, which have been produced from similar genes, derived from the same ancestral genes. The classic example is the bones of the forearm of man, dogs, wings of birds and bats, and the front appendages of whales. **Vestigial organs**, or leftover structures, such as the appendix and coccyx (tailbone) in humans, also lend support. **Embryology** supports evolution in that a comparison of early embryos reveals that there are great similarities, which disappear as development progresses. Finally, **biochemistry** studies show many similarities among living systems, from the similar structures of chlorophyll and hemoglobin to the structure of DNA itself.

The theory of evolution which has stood the test of time, was proposed by **Charles Darwin**, published in his book "The Origin of Species" in 1859. His theory had five main parts: **1.** All organisms produce more offspring than can survive, **2.** Therefore, there is a constant struggle for survival, **3.** There are variations within populations, **4.** Some variations give the individuals an advantage for survival, **5.** Those better suited individuals pass on their characteristics to their offspring, resulting in the **survival of the fittest**. What Darwin did not explain was that the source of the variations was due to mutations in the genes or DNA. This would come later when Mendel's genetic work was discovered in 1900.

The evolution of humans continues to be reshaped as new fossils are discovered. The earliest known genus of upright walkers, **bipeds**, is Australopithecus. The famous fossil Lucy is a member of *A. afarensis* existing about 4 million years ago. *Homo habilis* came later, found with many tools, hence the name of "handy man", and more closely related to modern human. *Homo erectus*, came later and migrated around the globe. More modern man, *Homo sapiens*, contains two subspecies, Neandertal man and Cro-Magnon. The Neandertals disappeared, an event which has not been totally explained.

7. Diversity: Classification and Kingdoms

The study of classification is called **taxonomy**. **Carolus Linnaeus** greatly simplified the early system of simply stringing out lists of names, changing to a two name system called **binomial nomenclature**. The scientific name consists of the genus and species names written as follows: *Homo sapiens*. The name can be italicized or underlined. The general system he devised has been added to somewhat to the following sequence: **kingdom - phylum - class - order - family - genus - species**. The broadest group is the kingdom and the most specific is the species. The easiest way to remember the sequence is to write a sentence using the first letter of each group such as: King Phillip Came Over For Green Salads.

Initially, scientists divided living organisms into only two kingdoms, plant and animal. In fact, it was Aristotle who set this up. During the last century, organisms were pulled out of these two kingdoms to create three more. The five kingdoms are: **Animalia**, **Plantae**, **Fungi**, **Monera**, and **Protista**. Sometimes you will find the Monerans actually subdivided into two kingdoms: **Archaeobacteria** and **Eubacteria**.

The **Monerans** are the only group consisting of prokaryotic cells. The group has members which are parasitic and those that can carry on a primitive photosynthesis. Typically they are unicellular. They are commonly called bacteria. The **Protista** is something of a catchall for eukaryotes that are not plants, fungi, or animals. Many are unicellular, although some are multicellular. Many have chloroplasts, and most have cell walls. Common examples are protozoans, like ciliates and amoeba, algae, and seaweeds. The **Fungi** are eukaryotic heterotrophs which absorb their nutrients. Some common examples are mushrooms, molds, and yeasts. **Plants** are eukaryotic, multicellular, autotrophic, with chlorophyll for photosynthesis. Their cell walls contain cellulose. Common examples are mosses, ferns, horsetails, firs, pines, and those that flower such as the tulip, redbud, oak, and grasses. **Animals** are eukaryotic, multicellular, and heterotrophic. They mainly take in food by ingestion. Some common examples are sponges, corals, worms, bivalves, sea stars, spiders, insects, and animals with backbones, such as fish, frogs, snakes, birds, and mammals.

8. Plant Kingdom

Members of the plant kingdom all contain chlorophyll and carry out photosynthesis, thus they could also be called the green plants. They all have cell walls and chloroplasts. The plant body is generally made of roots, stems, and leaves with vascular tissue, although these items may be missing in the lower plants. The simpler plants include the **mosses** and **liverworts**. They are confined to living in damp places because they require water to transport the sperm to the egg for reproduction. The **ferns** are more advanced in that they do have vascular tissue, roots, stems, and leaves, although they are seedless. Seeds appear in the **cycads**, although naked and unprotected. The **gymnosperms** produce seeds protected in cones although the ovules are open for pollination. Pollen carrying the sperm is dispersed by the wind. Some common examples of gymnosperms are pines, firs, spruces, redwoods,

cypresses, and yews.

The highest expression of the plant kingdom is the flowering plants, or **angiosperms**. The flower protects the ovules and the seeds. The sperm are also transported in the pollen, but the pollen may be transported by birds or insects, as well as the wind. The angiosperms may be **monocotyledons** or **dicotyledons**. The monocots have only one cotyledon (stored food for growth during germination) in the embryo within the seed, flower parts in threes, and parallel leaf venation. Some common examples are grasses, sedges, lilies, tulips, palms, and orchids. The dicots have two cotyledons, flower parts in fours or fives, and netlike veins in the leaves. Some common examples are elms, oaks, roses, and cactuses.

The **vascular tissue** is made of two main types, the **xylem** and the **phloem**. These cells generally have thicker walls and serve for support as well as transport. The xylem function as dead cells (hollow cells) forming tubes to transport water and minerals through the roots and stems to the leaves for photosynthesis. In a tree, this is what is called the **wood**. The phloem transports the products of photosynthesis down the stems and to the roots for storage, as well as use. The phloem is part of the **bark** of a tree. If the bark is removed in a complete circle around the trunk, the tree will die as it no longer has a way to store food in the roots.

9. Animal Kingdom

Animals are eukaryotic, heterotrophic, and multicellular. Most have specialized tissues and organs and organ systems. They all lack cell walls and chloroplasts. Animals are often studied by looking at the 9 major phyla. **Porifera** is the simplest phylum, lacking tissues and organs. These are the sponges, whose body wall consists of two cell layers penetrated by pores. Adults are **sessile**, an unusual trait for animals. The **Cnidarians** do have two tissue layers, **ectoderm** and **endoderm**, which make up their bodies. These are the corals, jellyfish, hydras and sea anemones who are **radially symmetrical** and gelatinous. The **Platyhelminthes** have the third tissue layer, **mesoderm**, found in the higher animal phyla. These are the flatworms, such as Planaria, which are **bilaterally symmetrical**. A second phylum of worms is **Nematoda**. These worms are typically tiny, many are parasitic, and are the first to show a one-way digestive tract. They are commonly called the round, unsegmented worms and include such human parasites as hookworms, *Ascaris*, pinworms, and *Trichinella*. The third phylum of worms are the most advanced and are called the **Annelida**. These are the round, segmented worms which are bilaterally symmetrical and include the sandworms, the earthworms, and the leeches.

The phylum **Mollusca** are soft-bodied animals which usually have a two-part body plan consisting of a head-foot and a visceral mass. Most have a unique rasping tongue called a radula. Common examples are the clams, oysters, snails, slugs, chitons, octopuses, and squids. In many ways the **Arthropoda** phylum is the most successful of all. They number more than 75% of all known animal species and live in practically all known environments. The insects alone make up about 75% in number.

These are animals with a three-part body plan: a head, thorax, and abdomen. They are covered with a hard chitinous **exoskeleton**, which must be shed in order to grow. Some common examples are spiders, ticks, scorpions, horseshoe crabs, crabs, crayfish, lobsters, shrimp, and all the insects, such as butterflies, moths, flies, ants, bees, mosquitoes, termites, and grasshoppers.

The phylum **Echinodermata**, which means spiny-skinned, contains the headless animals, which are radially symmetrical with a five-part body plan. These animals are marine and most move by means of a water vascular system. Some examples are sea stars, brittle stars, sea lilies, sand dollars, sea urchins, and sea cucumbers. Humans belong to the phylum **Chordata**. This phylum is distinguished by having a notochord and paired gill slits at some time during development and a dorsal nerve cord. (The annelids have a ventral nerve cord) Some simpler chordates maintain their notochord, such as the tunicates and lancelets, but most members replace the notochord with vertebrae forming a spinal column. These are the **vertebrates**. All the other animals previously discussed are known as the **invertebrates**. The classes of the vertebrates are familiar to all: lampreys and hagfish, sharks, bony fish, amphibians, reptiles, birds, and mammals.

10. Human Anatomy and Physiology

The study of the human body is traditionally broken down into studies of the individual organ systems, which of course are all interconnected. The **skeletal** system refers to learning the bones and bone structure. The **axial skeleton** is formed by the skull, ribs, spine, and sternum. The **appendicular skeleton** is made of the rest, the bones of the arms and legs, the scapula, clavicle, and pelvis. Bone is composed of a hard material known as **compact** bone and a network of connective tissue within referred to as **spongy bone**. Many bones contain **bone marrow** which may be red, which produces red blood cells, or yellow, which serves as an energy reserve of fat cells. There are three kinds of joints (the place where bone meets bone) found in the human body: **fixed**, **semimovable**, and **movable**. The fixed joints are found in the skull and permit no movement. The semimovable allow limited movement such as that in the vertebral column. Most of the joints in the body are movable, such as the **ball and socket** at the shoulder and hip or the **hinge joints** at the elbow and knee. **Ligaments** are tough bands of connective tissue holding bones together at the joints. **Tendons** are made of a tough fibrous connective tissue which holds muscles to bones. The skeletal system provides support, and supports and protects the internal organs.

The **muscular** system also provides support, along with moving the body, and helping to move materials through the body. The three muscles types found are **skeletal**, to move bones, **cardiac**, found in the heart, and **smooth**, found in the walls of internal organs. The skeletal muscles are referred as **voluntary** because their contractions are usually consciously controlled. Smooth muscle is referred to as **involuntary** as their movements are not consciously controlled. An example of this is involuntary movement is **peristalsis**, the wavelike muscle action which moves food

through the digestive tract. The unit of muscle contraction is the **sarcomere**, made of myofibrils, which in turn are made of thick protein filaments called **myosin** and thin protein filaments called **actin**. These filaments are arranged in an overlapping manner, and slide over one another during contraction, shortening the muscle.

The **integumentary** system consists of the skin, hair, and nails. Its function is to act as a barrier protecting against the entrance of pathogens. It also serves to retain body fluids, eliminate waste products and to regulate body temperature.

10.2 Circulatory System

The **circulatory** system consists of the blood, blood vessels, and the heart. The heart circulates the blood, moving it through the vessels to distribute nutrients and pick up wastes from all the body cells. The **blood** is made of a watery liquid portion known as the **plasma**, in which are found dissolved substances, and the solid portion consisting of the blood cells. The dissolved substances include proteins, hormones, small food molecules, wastes, vitamins, and minerals. The blood cells include the **red blood cells**, containing **hemoglobin** to carry O_2 , the **white blood cells**, functioning to help defend the body against disease, and the **blood platelets**, initiating the process of blood clotting. There are three main kinds of blood vessels, through which the blood flows. The **arteries** carry blood away from the heart. Most of the arteries carry oxygen-rich blood with the exception of the pulmonary arteries, which are carrying blood to the lungs to become oxygenated. **Veins** carry blood back to the heart. Most of the blood is oxygen-poor in veins, with the exception of the pulmonary veins carrying blood that has just been oxygenated in the lungs.

Capillaries connect the smaller arteries (arterioles) and smaller veins (venules). The wall of the capillaries are only one cell thick allowing for exchange of materials between the blood and the cells. The heart is the double pump which beats and pumps the blood throughout the vessels. Each half consists of a receiving chamber or atrium and the more muscular pumping chamber or ventricle. The right chambers receive oxygen-poor blood from the body and pump it to the lungs. The left chambers receive oxygen-rich blood from the lungs and pump it out the aorta to the rest of the body. There are valves in the heart at the exit of each chamber as well as in the veins to prevent backflow of the blood. The following list describes the pathway of oxygen-poor blood returning from the body to the heart to be pumped through it: **superior and inferior vena cavae** **right atrium** **tricuspid valve** **right ventricle** **semilunar valve** **pulmonary artery** branching to the **lungs** **pulmonary veins** **left atrium** **bicuspid or mitral valve** **left ventricle** **semilunar valve** **aorta**.

10.3 Respiratory System

The **respiratory** system consists of the lungs and the air passages to arrive there. Air traveling to the lungs travels through the following structures: **nasal cavity**, **trachea**, **bronchi**, **bronchioles**, and **alveoli**. The trachea and bronchi are supported by cartilage rings to prevent collapse while breathing. The alveoli are tiny air sacs

arranged like clusters of grapes. This is where the actual exchange of gases (O_2 and CO_2) takes place. Oxygen diffuses into the capillaries surrounding the alveoli and carbon dioxide diffuses into the air space within the alveoli. Air moves into the lungs during inspiration or inhalation because the diaphragm contracts along with the rib muscles to enlarge the thoracic cavity. The opposite activity causes expiration or exhalation.

10.4 Digestive System

The **digestive** system digests and stores food, absorbs nutrients, and eliminates wastes. Digestion begins in the **mouth** with mechanical breakdown by teeth and some carbohydrate breakdown initiated by saliva from the **salivary glands**. Food is swallowed and travels through the **esophagus** to the **stomach**. Here the food is churned and mixed with **gastric juices** which begin the chemical breakdown of proteins in a highly acidic environment. Food then is released through the **pyloric valve** entering the **duodenum**, the first 12 inches or so of the **small intestine**. It is here where the chemical breakdown of food is completed. **Bile** from the **liver** via the **gallbladder** and pancreatic juices from the **pancreas** travels through the common bile duct to mix with the digesting food. Bile emulsifies (forms tiny droplets) fats to help with the chemical breakdown while the pancreatic juices add enzymes to act on carbohydrates, fats, and proteins. The duodenum itself adds enzymes to complete the breakdown of carbohydrates. As the small food molecules move through the rest of the small intestine, they are absorbed into the bloodstream. The rate of absorption is increased due to the presence of **villi**, small fingerlike projections which greatly increase the surface area. What is not absorbed enters the **large intestine**. Water is absorbed and bacteria act to convert the remains into waste material or feces. These are eliminated through the **anus**, the opening at the end of the **rectum**.

10.5 Excretory System

The **excretory** system serves to eliminate cellular wastes from the body, as well as regulating the content of water and other substances in the blood. Structures included in this system are the **kidneys**, **ureters**, **urinary bladder**, **urethra**, and the **lungs**. The work of the kidney is actually done by microscopic units called **nephrons**. They filter the blood and pump the necessary materials back into the blood, retaining the wastes to be eliminated as **urine**. The main nitrogen waste eliminated is **urea**.

10.6 Nervous System

The **nervous** system is made of the brain, spinal cord, nerves, sense organs, and other receptors. Together they control and coordinate body movements, senses, consciousness, and creativity. The system also helps to monitor and maintain other body systems. The brain and spinal cord make up the **central nervous system**, while the nerves running to and from them make up the **peripheral nervous system**. These systems are composed of cells called **neurons**. The long axon allows for rapid transmission of the nerve impulse for fast responses. The typical pathway for

a response would begin at the receptor (sense organ), transmitting the impulse to sensory neurons, to interneurons in the brain or spinal cord, and to motor neurons which connect to a muscle or gland which responds. The brain is made of areas specialized for various functions. The brain stem or **medulla oblongata** controls the vital functions of heart and breathing rates. The **cerebellum** is key in coordinating movements. The **cerebrum** is the largest part of the brain which allows for interpretation of incoming nerve impulses, such as hearing, taste, and vision, and sending out impulses for speech, body movement, and intellectual activity.

10.7 Endocrine and Reproductive Systems

The **endocrine** system consists of the ductless glands which produce hormones circulating to their site of action via the bloodstream. These hormones control a variety of body activities including regulating metabolism, maintaining homeostasis, water and mineral balance, growth and sexual development, and reproduction. A list of the major endocrine glands would include the pituitary, hypothalamus, thyroid, parathyroids, adrenals, thymus, pancreas, ovaries, and testes.

The **reproductive** system functions to produce offspring to carry on the species. In females the organs include the ovaries to produce eggs, the Fallopian tubes or oviducts, uterus, and vagina. The uterus is the site of development until birth, which occurs through the birth canal or vagina. In male the organs include the testes to produce sperm, epididymis, vas deferens, and urethra running through the penis.