

TMSCA Science

Concept/Vocabulary/Review Packet

This packet has been created for the purpose of assisting the process of studying and reviewing for the Texas Math and Science Coaches Association Science Competition. Having been a student and competed in these competitions I hope that my experience and research can assist you in your journey towards success.

Enjoy!

Tony Liu

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Introduction

Science is a fascinating subject, and the TMSCA Science test is designed to promote the love of science. This does occur. However, the fact is that in order to succeed in TMSCA Science, it is much more about memorizing crucial facts. If one studies the various tests over the years, a general pattern of topics emerges. Studying the topics listed on the below list will not only greatly improve your TMSCA Science ability but will also add significantly to your body of scientific knowledge.

Here is a general list of the topics:

1. **Biology**
 - a. Cells
 - i. Structure
 - ii. Function
 - b. Ecology
 - i. Ecological Roles and niches
 - ii. Ecological Succession
 - c. Botany
 - i. Plant Parts
 - ii. Gymnosperms and Angiosperms
 - iii. Plant Reproduction
 - d. Taxonomy
 - e. Anatomy
 - i. Different Systems
 - ii. System Connections
2. **Chemistry**
 - a. The Periodic Table
 - i. Groups
 - b. Periodicity
3. **Physics**
 - a. Atoms, Molecules, and Compounds
 - i. Atomic Structure
 - ii. Atomic Properties
 - b. Newton's Laws
 - c. Work, Energy, and Simple Machines
 - i. Force, Work, Power Equations
 - ii. Various simple machines
 - d. Basic Optics
 - i. Lenses

- ii. Light movement
 - e. Ideal Gases
 - i. The Kinetic Theory
 - ii. Avogadro's Law
 - iii. Boyle's Law
 - iv. Charles's Law
 - v. Ideal Gas Law
 - f. Waves
- 4. **Earth Sciences**
 - a. The Earth
 - i. Parts
 - b. Geographic Features
 - i. Plate Tectonics
 - ii. Geographic Features
 - iii. Soil and Ground Structures
 - c. Natural Disasters
 - i. Earthquakes
 - ii. Other Natural Disasters
 - d. Weather and Atmosphere
 - i. Parts of the Atmosphere
 - ii. Clouds
 - iii. Weather Measurements
 - iv. Weather Systems
 - e. Rocks and Minerals
 - f. Erosion and Weathering
 - i. Glaciers
 - ii. Rivers
 - iii. Wind
 - g. The Ocean
 - i. Parts of the Ocean/Water Systems
 - ii. Organisms in the Ocean
- 5. **Space Sciences**
 - a. The Planets
 - i. General Characteristics
 - ii. Groupings
 - iii. Beyond the Solar System
 - b. The Moon
 - i. Phases
 - ii. Composition

- iii. Evolution
 - c. The Sun
 - i. Parts
 - d. Stellar Evolution
 - i. Hertzsprung-Russell Diagrams
- 6. **Science History/Miscellaneous**
 - a. Contributions by various notable scientists
 - b. Units
 - c. Fields of Science

This list may seem quite overwhelming, but studying learning topics from it is not difficult, and will be supplemented by tutelage at school. Also, for some topics there may only be a few facts that need to be covered.

In terms of frequency of occurrence, a few topics must be highlighted. Some of the most frequently occurring topics/fields are:

1. Plant Parts (and plants in general)
2. Various Earth Science Topics, especially Earthquakes, Ocean Features, and Rocks and Minerals
3. The periodic table and atomic properties (such as atomic number, mass number, etc.)

And in no particular order:

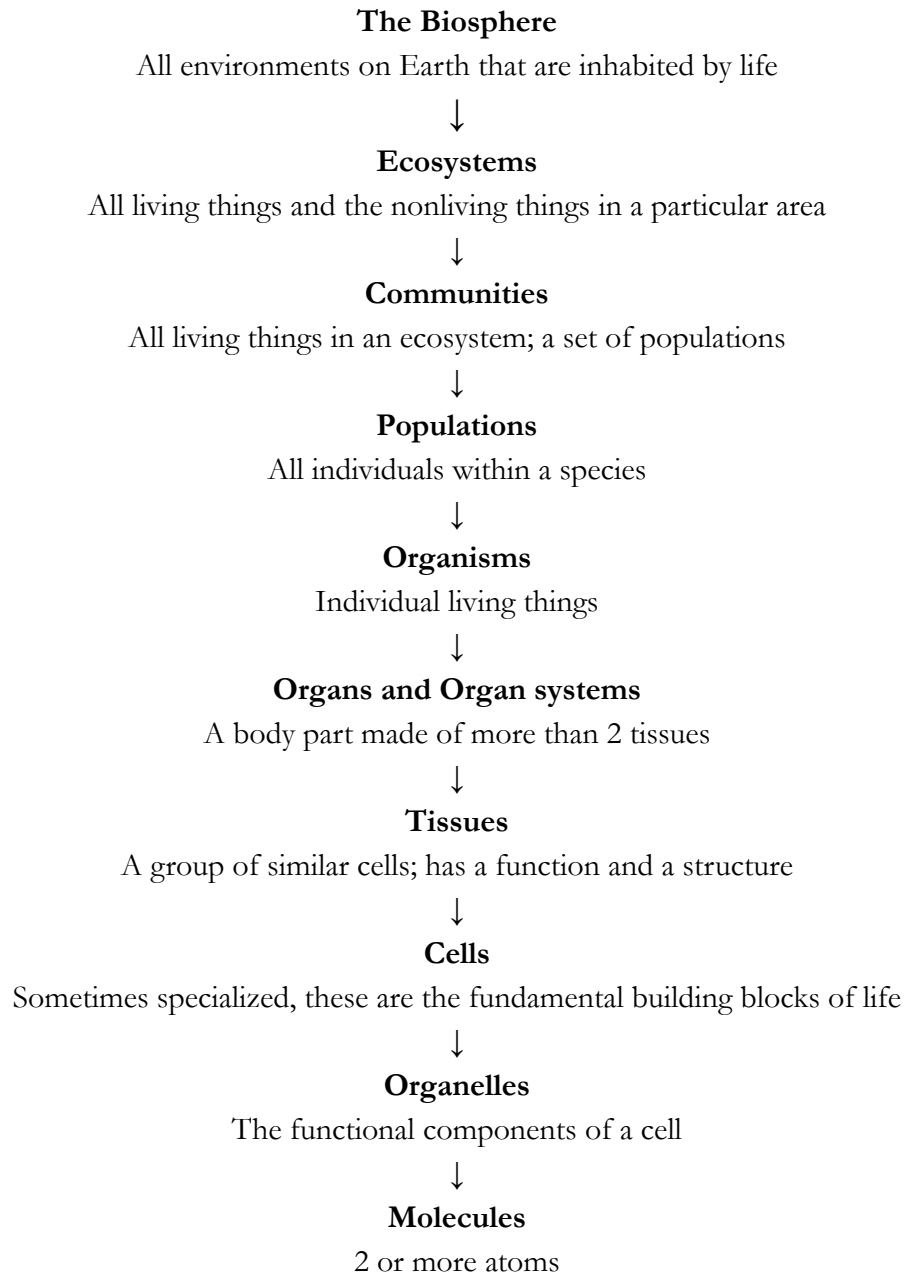
- Taxonomy
- Science History
- Periodic Table
- Ecology
- Atmospheric Layers
- Work, Energy, Newton's Laws, Simple Machines

Also note the fact that at the end of this document a collection of vital vocabulary is included for your reviewing and studying pleasures.

Biology

Biology is a rich subject, and occurs semi-often on TMSCA tests.

In life forms there is a general hierarchy that is followed and that may be mentioned sometimes on tests: (starting from the broadest and narrowing down)

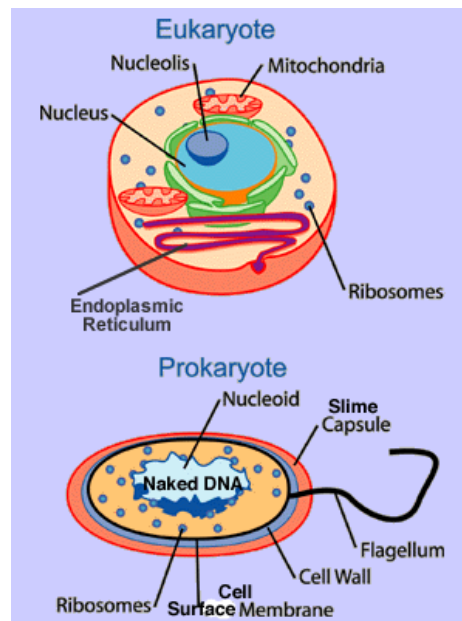


Cells

Cells are the basic building blocks of life. Life is defined as being able to/having:

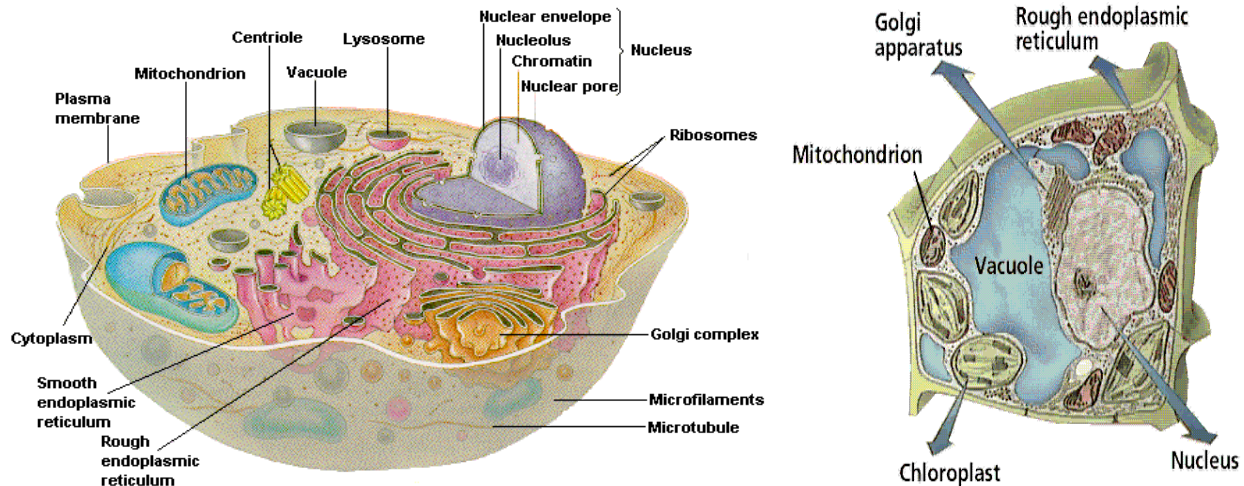
1. Order
2. Evolutionary Adaptation
3. Response to Stimulus and the Environment
4. Regulation
5. Energy Processing
6. Growth and Development
7. Reproduction

Cells are either Prokaryotic or Eukaryotic. Both types have unique characteristics.



Eukaryotic cells

Eukaryotic cells are defined as having true nuclei, bound by a membranous nuclear envelope. Additionally eukaryotic cells have specialized, membrane bound organelles. Eukaryotic cells can be divided into Animal Cells and Plant Cells.



Cell Wall: commonly found in plants cells – protection & support

Plasma Membrane: control of substances coming in and out

Cilia: sweep materials across the cell surface

Flagellum: enables a cell to propel and move in different directions

Cytoplasm: between plasma membrane and nucleus – many organelles

Endoplasmic reticulum (ER): the passageway for transport of materials within the cell

Ribosomes: the site of protein synthesis

Golgi apparatus: Final modification of proteins & lipids. Also, packing of materials for secretion of the cell occurs here

Mitochondria: the site of aerobic cell respiration-where ATP is converted into energy

Lysosomes: contain enzymes to digest ingested material or damaged tissue

Chloroplasts: store chlorophyll – photosynthesis light reaction

Vacuoles: storage – increase cell surface area

Centrioles: organize the spindle fibers during cell division

Cytoskeleton: cell shape, internal organization, cell movement & locomotion

Nuclear membrane: membrane around nucleus – controls movement in an out

Nucleolus: assembly of subunits of ribosomes.

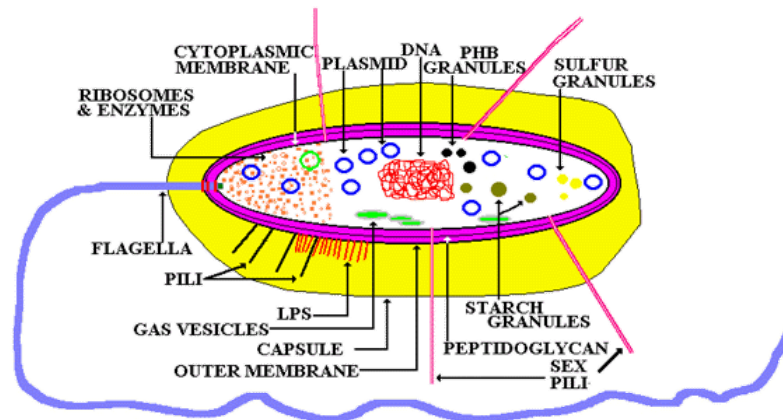
DNA: encoding of heredity information

RNA: transcription and translation of DNA coding into proteins

Note that in the Plant Cell there is a cell wall, as opposed to a cell membrane in the animal cell. Additionally, the plant cell has chloroplasts and will often have a large central vacuole, which an animal cell will not have. The animal cell has Lysosomes, Centrioles, and sometimes flagella.

Prokaryotic Cell

Prokaryotic cells have their genetic material in a loose form as a mass of bacterial chromosomes. Typically Prokaryotic cells can be both Bacteria and Archaea. However, research shows that Archaea may be more closely related to Eukaryotic cells than Prokaryotic.



Pili: attachment structures on the surface of some prokaryotes

Nucleoid: region where the cell's DNA is located, but is not enclosed by a membrane

Ribosome: organelles that synthesize proteins

Plasma Membrane: membrane enclosing the cytoplasm

Cell Wall: rigid structure outside the plasma membrane

Capsule: jelly like outer coating of many prokaryotes

Flagella: locomotion organelles of some bacteria

Similarities and Differences between Prokaryotes and Eukaryotes

Similarities:

1. They can both be enclosed by plasma membranes
2. Contain ribosomes
3. Contain genetic material (DNA)
4. Are filled with cytosol

Differences:

1. Size: Eukaryotic cells are larger and more complex
2. Nucleus: Prokaryotic cells do not have nucleuses
3. Structure of DNA: Eukaryotic DNA is linear, while Prokaryotic DNA is circular
4. Ribosomes: Eukaryotic ribosomes are much larger
5. Organelles: Prokaryotic cells do not actually have any organelles

Ecology

Ecology is essentially the study of organisms and the environment, and how they interact. Ecology in itself is not very common, although some sub topics of it are. First we will go through a brief overview of the fundamentals of ecology.

The chart used at the very beginning of the biology section, depicting a top to bottom life organization is applicable to ecology. Words such as population were mentioned. A population is just a group of members of a certain species living in the same area. When multiple populations come into an area a community forms. Thus a community is just a set of populations occupying an area.

The term ecosystem applies to how the varied populations in a community interact with their physical environment. A habitat is the type of place that an organism would prefer to live. It can also refer to the actual quality of the environment.

To more deeply investigate an ecosystem, a look at food chains is required. The position each organism occupies in the food chain is called its trophic level. The trophic levels are generally organized as such: (starting from the lowest level)

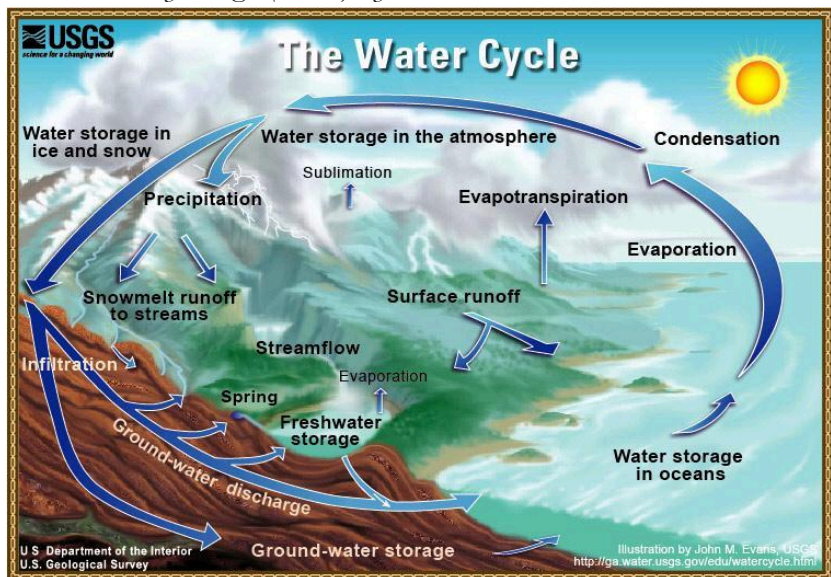
1. Primary Producers: this level harnesses energy from the sun and turns it into chemical energy that can be used. These include grass, trees, bushes, and other plants.
2. Primary Consumers: these are organisms that eat the primary producers. The organisms at this level are mostly herbivores or omnivores. (Meaning that they eat either all plants or a mix of plant and animal, respectively) Examples include rabbits, deer, and turtles.
3. Secondary Consumers: these eat the primary consumers. They are also sometimes called the primary carnivores, being the first trophic level that consumes animals. Examples include foxes, small birds of prey, and some fish.
4. Tertiary Consumers: eat the secondary consumers. Generally these are the top level of consumers. However, sometimes there are...
5. Apex Predators: these are the top of the food chain – nothing else can consume them. Examples include grizzly bears, saltwater crocodiles, and humans.

Note that at each level the total amount of energy decreases. The ecological efficiency of a food web is the proportion of energy at each level, generally only 10% in most food webs.

Another level that should be recognized is the level of decomposers. They get their energy from dead organic matter (detritus). Producers, consumers, and decomposers can also be called autotrophs, heterotrophs, and detritivores, respectively.

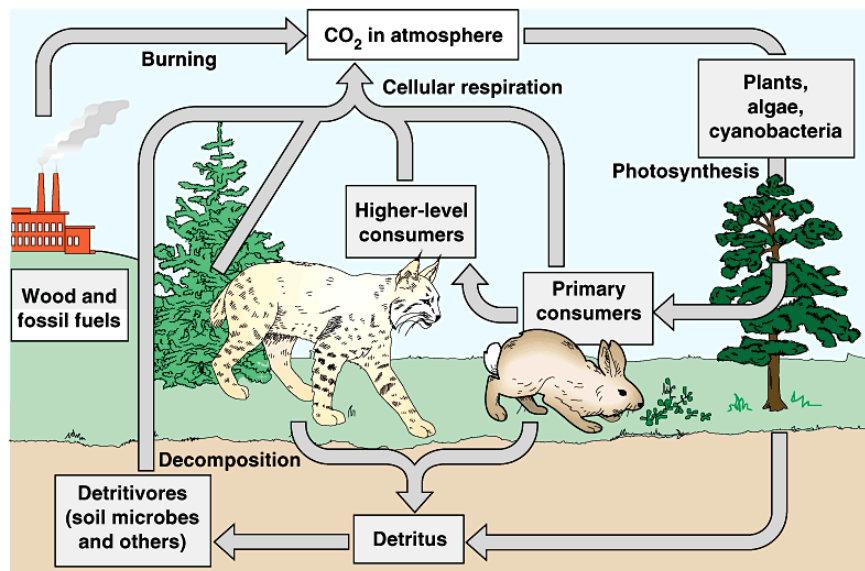
Another important aspect of ecology is the various biogeochemical cycles. There are four of these, and include diagrams.

The Hydrologic (Water) Cycle



Water is an incredibly vital part of life – our bodies are made up of 70% water. The water cycle is fairly well known, so I won't go into much detail.

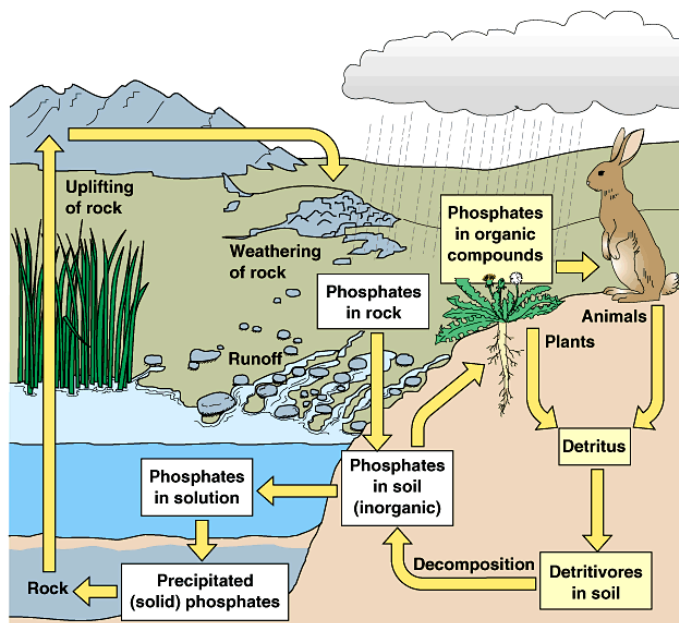
The Carbon Cycle



Carbon is what makes all living organisms organic. (Organic essentially means living, containing carbon) All living things contain carbon. Carbon is released through animals breathing, organic matter being burned, and decay. Carbon is then taken in by plants, which transfer carbon back to the animals when they are eaten. Thus the cycle repeats itself.

Coal, peat, and oil are formed from decaying organic matter and are essentially made of carbon.

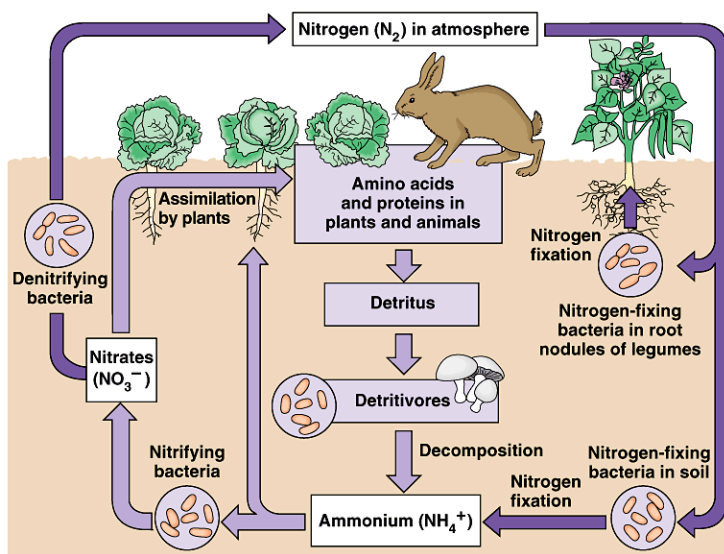
The Phosphorus Cycle



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Phosphorus is required for ATP (an important energy molecule) and for DNA and RNA. Phosphorus is found in the soil, and is absorbed by plants. Then it is transferred to animals when they consume the plants. Once the animals die then the phosphorus inside their bodies is transferred back into the soil. From there it is reabsorbed by plants. Thus the cycle is completed.

The Nitrogen Cycle



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Nitrogen is the base part of amino acids, which form protein. It also is present in DNA and RNA. The Nitrogen Cycle is the most complex because of how many forms nitrogen can exist in. Although many different paths can be taken along the way, we generally start with the nitrogen fixation step, in which nitrogen is from the atmosphere is converted by nitrogen-fixing bacteria into ammonium in the soil. (It can also be

other things, but this is the most common) From here the nitrogen can be assimilated (absorbed) by the plants, and from the plants the animals obtain the nitrogen. (By eating the plants) After the animals die their bodies are broken down and through ammonification the nitrogen in their bodies is changed back to ammonium. This could be assimilated by the plants again, but it could also be converted into nitrates by nitrogen fixing bacteria through the process of nitrification. Finally denitrification happens, in which the nitrogen is converted back into the atmosphere. Yep, it's really complicated, but I found that Google and Wikipedia helped.

There are a final few things about ecology that need to be covered. First of all, we'll cover human impact on environment. This can be seen through climate change. Increased greenhouse gas output by us humans has increased the greenhouse effect, in which heat is trapped in the Earth's atmosphere and changes the world's climate. (It doesn't only heat up – in some cases it can cool down areas and in general will cause dramatic changes to the world's climate)

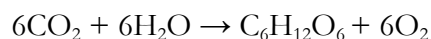
Acid rain and eutrophication are two aspects of human impact that are covered often. Acid rain is rain in which the acidity is higher than normal. This occurs when water evaporates from bodies of water that have too many chemicals, or the water mixes with acidic vapors in the air. Eutrophication occurs when there are too many nutrients in some body of water and an overgrowth of algae occurs. Both of these are dangerous to the environment.

The final topic is ecological succession. Ecological succession is when some ecosystem undergoes regenerative changes following some type of disturbance or initial colonization of a new habitat. Primary succession occurs after a volcano or some other disaster destroys the ecosystem. (Yellowstone after the Mount St. Helens eruption comes to mind.) Secondary succession is when life newly colonizes some previously lifeless area, such as plants resettling the area uncovered by a receding glacier. Succession eventually leads to a stable climax community.

Botany

In my experience there are always 3 – 4 questions about plant structure and plant classifications. Therefore that's what this section will primarily focus on.

Plants perform photosynthesis. This reaction takes carbon dioxide and water and produces glucose and oxygen with energy from sunlight. This can be written out as:



Note that the number of atoms of each element is the same on each side of the equation. Also, this reaction only takes place under the presence of sunlight in chlorophyll. (The green "stuff" contained in the chloroplasts of plant cells) Photosynthesis is much more complicated, but this is all you will need to know for TMSCA.

Plants can be classified into these main types:

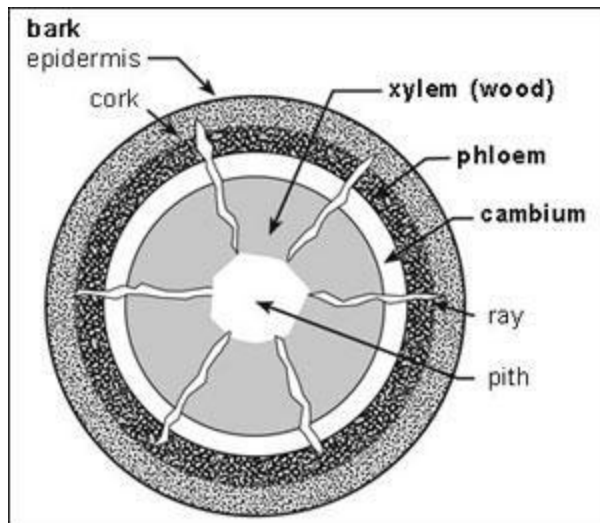
1. Green algae (Chlorophyta): aquatic algae
2. Nonvascular Plants (Bryophyta): includes mosses, hornworts, and liverworts. They lack roots, stems, and leaves, and only have a minimal cuticle. Thus they must remain small and primitive.
3. Vascular Plants (Tracheophyta): contain a stiff, central column that conducts water and essential nutrients through the plant (from the roots) and supports the plant. Here the water and dissolved nutrients pass through a stiff network of dead cells known as the xylem, while the living phloem carries the products of photosynthesis, such as glucose. A waxy cuticle protects the plant to prevent it from drying out. Stomata (stoma) are small openings in the cuticle to allow the plant to receive gas from the air. Guard cells around the stoma regulate the intake of carbon dioxide or oxygen.
 - a. Ferns (Filicopsida): the first vascular plants are represented by plants such as horsetails, club mosses, and ferns. These use spores to reproduce, and rely on water to fertilize for them.
 - b. Seed Bearing Plants (Spermatopsida): these reproduce by seeds, and can be classified as:
 - i. Gymnosperms (conifers): these were the first type of seed bearing plants. They reproduce through cones; their pollen grains are spread by the *wind* and do not depend on moisture to reproduce. This type includes fir, pine, spruce, ginkgoes, and other cone bearing plants.
 - ii. Angiosperms (flowering plants): appeared relatively recently, at first included beech trees, figs, and magnolias, but has expanded to encompass a wide variety of flowering plants, including generally all crop plants and flowers. These are more complex than gymnosperms, and have seeds not dependent on water for dispersal. Rely on wind and animals to spread their seeds.
 1. Monocots (Monocotyledonous): grasses whose seed first extends a single cotyledon or seed leaf. Lilies and other bulb plants are also monocots.
 2. Dicots (Dicotyledonous): have seeds that forms a pair of cotyledons, examples include roses, most trees, sunflowers, beans, and tomatoes.

And there is the general breakdown of the various plant classifications. However, there are many more important topics that have not yet been discussed. Let's start with the differences between monocots and dicots.

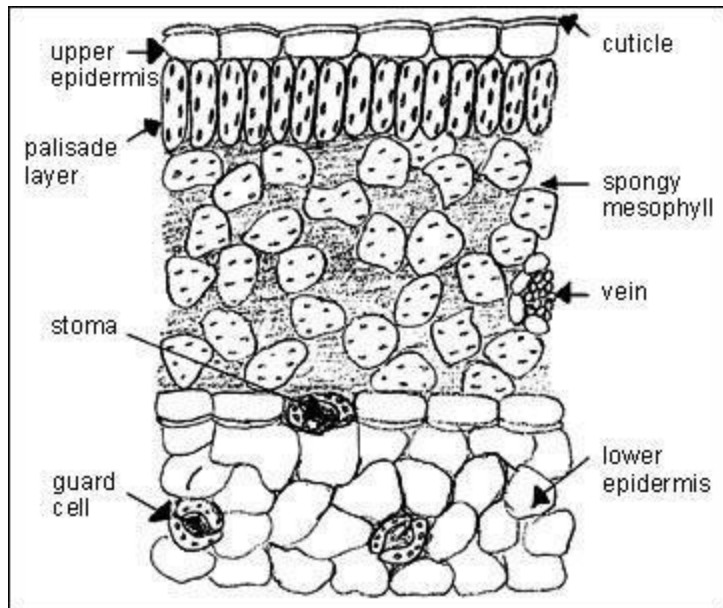
Monocots:	Dicots:
<ul style="list-style-type: none"> ● 1 cotyledon (seed leaf; the little bud that makes up the body of the seed) ● Parallel veined leaves ● Flowers in multiples of 3 ● Xylem and Phloem scattered randomly ● Fibrous roots (a network of many 	<ul style="list-style-type: none"> ● 2 cotyledons ● Network veined leaves ● Flowers in multiples of 4 or 5 ● Xylem and Phloem arranged in a neat tubular/ringed pattern ● Taproot system (a single large protruding root)

Another important topic is plant growth. This is categorized in two ways – primary growth and secondary growth. Primary growth is vertical and secondary growth is thickness. Primary results from ongoing cell division at the apical meristem (tip) of the plant. Secondary results when new xylem pushes old xylem inside, while new phloem pushes old phloem outward.

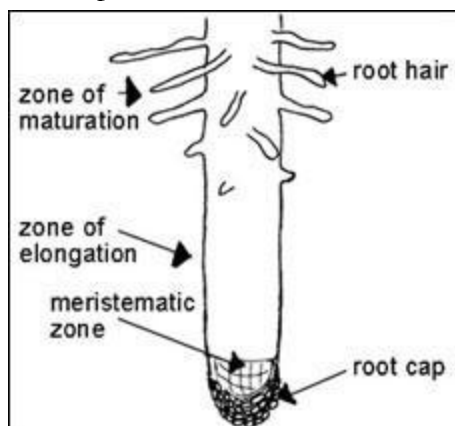
It's about time for some diagrams to clear a couple terms up. Reference back to these diagrams.



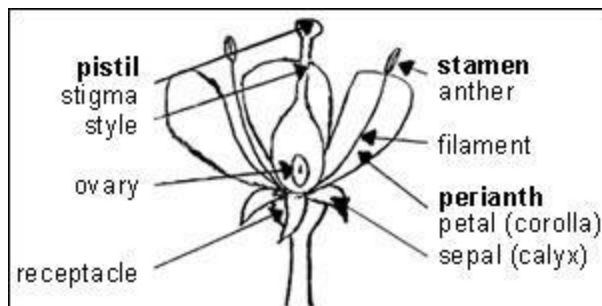
This depicts a cross section of a stem (or trunk). The xylem and phloem were mentioned earlier, but another important part of the stem is the cambium. The cambium is the growing part of the stem. Remember secondary growth and the xylem pushing in and phloem pushing out? That occurs on the inside and outside of the cambium.



This depicts a cross section of a leaf.



A typical tap root – notice the meristematic zone – this is the aforementioned apical meristem. (On the root side) A type of beneficial fungi known as mycorrhizae grows on the roots.



And finally, flowers! The function of flowers is sexual reproduction – thus they are often the “showiest” parts of the plant.

The perianth consists of all the parts of the flower that protects its reproductive organs. They can be divided into petals and sepals. Sepals are the small buds at the base of a flower that protect the flower bud. Collectively the sepals are called the calyx. Petals are fairly self explanatory. Collectively the petals make up the corolla.

The pistil is the bowling-pin shaped female portion of the flower, often found in the flowers center. The tip of the pistil is known as the stigma, which is connected to the ovary by the style. In the ovary the ovules develop, which become seeds once fertilized.

Finally, the stamen is the male portion of the flower. It contains a pollen sac, known as the anther, and a supporting filament which holds it in place.

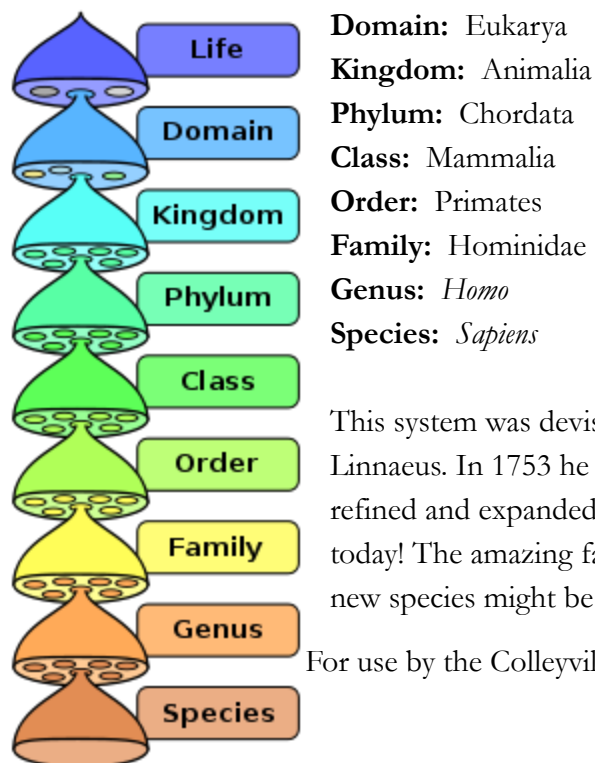
Taxonomy

Taxonomy, or the study of classification of organisms, is not that common. However, it is still important to know and understand.

The most basic thing to understand is the names of the different organizational groups as you move down. I think the easiest way to remember this is through a mnemonic.

Dear King Phillip Came Over For Good Spaghetti
Domain; Kingdom, Phylum, Class, Order, Family, Genus, Species

Going through the classifications for a fairly common animal, a human, we find:



This system was devised by the 18th century Swedish biologist Carolus Linnaeus. In 1753 he introduced a system which, although it has been refined and expanded, remains the same approximate system we use today! The amazing fact is that he knew nothing about evolution or what new species might be found.

For use by the Colleyville Middle School Math Club

Here we will go over the Domains, the Kingdoms, and the most important Phyla. You can go to Wikipedia and search for “Phylum”, “List of Classes”, etc. for a good list of the various other divisions. A document containing a list of the phyla and major classes will be posted on the website, so check there if you are interested.

There are three widely recognized domains. These are **Archaea**, **Bacteria**, and **Eukarya**. Of these Archaea and Bacteria are prokaryotic, while the Eukarya are eukaryotic. Archaea are a type of primitive life form that have existed on Earth for a very long time and are extremely tolerant of extremes. (They are sometimes called “extremophiles”) Bacteria can also survive in a vast variety of environments. They are generally found in three shapes; spherical (cocci), rod shaped (bacilli), and spirally (spirillum). Finally, Eukarya are the most complex of the domains, and include fungi, protozoa, plants, and animals.

The classification of kingdoms is much sketchier, and there still is no definitive accepted classification. (Accepted as in used by everybody) Generally the kingdoms are not that important and you only need to know a general idea of them. Here I will show one that I am not quite sure is the correct one as I have not found it online, but it is the one that I have found in my book references. This classification takes the Kingdom Protista and splits it into five separate kingdoms. The kingdoms resulting from this split are the first five kingdoms listed. Remember that there is still much conflict about the kingdom system, so take this with a grain of salt.

1. **Kingdom Archaezoa:** perhaps the oldest Eukarya, lack mitochondria, are flagellated, have dual nuclei and have a simple cytoskeleton
2. **Kingdom Euglenozoa:** flagellated protozoa with mitochondria
3. **Kingdom Alveolata:** have vesicles below their membrane, or alveoli, include dinoflagellates (which cause red tide) and ciliates
4. **Kingdom Stramenophila:** have flagella with hairlike protrusions, include diatoms (a very common type of phytoplankton) and brown and gold algae
5. **Kingdom Rhodophyta:** protozoa without flagella, include red algae
6. **Kingdom Fungi:** mostly multi-celled; food obtained by absorbing material from dead organisms, include mushrooms, molds, and yeasts
7. **Kingdom Plantae:** multi-cellular that perform photosynthesis and have cell walls made of cellulose, include plants (trust me, there is no way you would have realized that)
8. **Kingdom Animalia:** multi-cellular with tissue, organs, and obtain food by ingestion, include animals

Other ways of classifying that are older include putting all organisms into kingdoms Monera (bacteria), Protista, Fungi, Plantae, and Animalia. The notable change here is the kingdom Monera and Protista. Kingdom Monera is mentioned sometimes, so know that it contains bacteria and cyanobacteria.

A few of the semi-important phyla that it is good to know are:

1. **Phylum Porifera:** sponges
2. **Phylum Cnidaria:** sea anemones and jellyfish
3. **Phylum Nematoda, Platyhelminthes, Nemertea:** all types of parasitic worms; they are roundworms, flatworms, and ribbon worms respectively
4. **Phylum Mollusca:** mollusks
5. **Phylum Arthropoda:** arthropods, can be split into subphylum Uniramia (centipedes, millipedes, and insects), subphylum Crustacea (crabs, shrimp, lobsters)
6. **Phylum Echinodermata:** echinoderms, such as sea stars, sea urchins, and sea cucumbers

Now, we are going to skip a whole ton of other phyla and just focus on the phyla in which we humans belong to, Phylum Chordata. (Remember, if you want to look more into this go to the other word document on the wiki) Phylum Chordata is defined as the collection of animals that possess a notochord (a kind of backbone in embryos of chordates), have bilaterally symmetric bodies, a hollow dorsal nerve cord, and pharyngeal slits (essentially gill slits).

Anatomy

A question that often comes up when studying anatomy and physiology is, just what is the difference between anatomy and physiology? Anatomy is defined as the study of the various structures of the body, while physiology studies the function of these structures.

This is a bit of a non sequitur, but there are four types of tissue in the body:

1. Epithelium: protective, lining tissue in the body. Consists of layers of epithelial cells. Can be found in many places, including the skin and the pharynx (windpipe).
2. Muscle: consists of bundles of highly active muscle cells. There are three types: *smooth muscle*, *skeletal muscle*, and *cardiac muscle*. Smooth muscle is the type of muscle in most of the organs that is controlled by the autonomic nervous system, meaning that it is not under conscious control. Skeletal muscle is attached to and moves bones, and is striated. Cardiac muscle is found in the heart, and each fiber can move at its own rate, coordinated by the pacemaker in the heart.
3. Connective Tissue: blood, bones, cartilage, tendons, and ligaments are all forms of connective tissue. This type provides support and protects other tissues. Here a

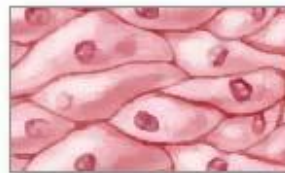
differentiation between tendons, which connect muscles to bones, and ligaments, which connect bones, should be made.

4. Nervous Tissue: this type of tissue is used to conduct electrical impulses that carry messages in response to stimuli, or outside influences on somebody. Nervous tissue is made up of neurons. Neurons are a particularly interesting type of cell, and are quite complex. Just because they are so interesting I'll go into them a little after this diagram.

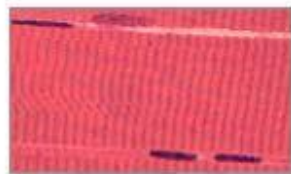
Four types of tissue



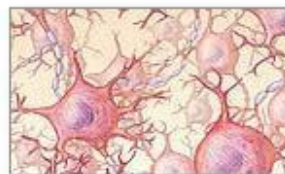
Connective tissue



Epithelial tissue



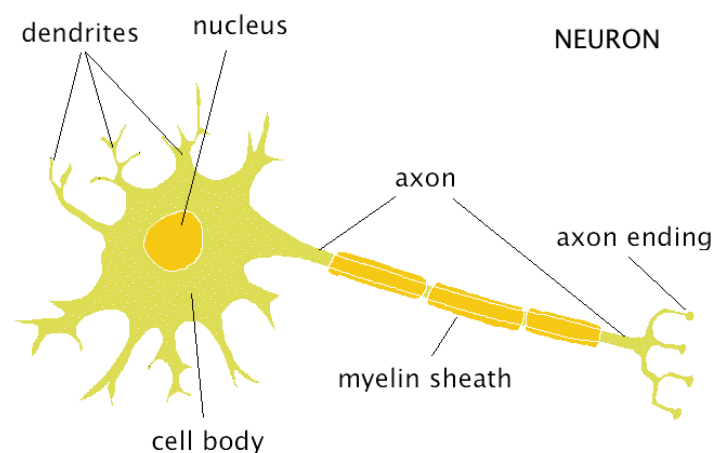
Muscle tissue



Nervous tissue

ADAM.

Neurons consist of a cell body with many protrusions called dendrites and another long protrusion called an axon. The cell body is also called the soma.



The dendrites function to receive incoming electrical signals. The axon serves to transmit the impulse onto the next cell. The place where an axon meets a dendrite is known as a synapse. Within your brain, the places where there are mostly axons are called the white matter, while the places where there are mostly somas are called the gray matter. There's some pretty complex stuff involved in this, and you can read more about it by going to the Helpful Links page on the wiki and looking at the "Neuron" link.

The exact number of systems in the body is debatable, but there are about 11. (Some consider the various bacteria to be a separate system; some systems are combined or separated, etc.)

1. Skeletal system: the bones that serve as the framework for the body and protect the internal organs. They also produce the blood cells and store calcium.
2. Muscular system: all the muscles work together and contract and relax, which allows motion in its various forms
3. Circulatory system: carries blood to all parts of the body, consists of the heart and all the blood vessels
4. Digestive system: subjects food through a series of chemical and physical changes, which allows the nutrients in them to be accessible to the body
5. Respiratory system: oxygen is inhaled and passed through the lungs and body, while carbon dioxide is exhaled
6. Excretory system: wastes are extracted from the body and passed out
7. Lymphatic system: made up of a series of ducts that carry lymph. Lymph then circulates through the body to carry food from blood to cells and wastes from the body to the blood. Lymph nodes effectively filter out the blood and are vital for protection.
8. Endocrine system: consists of a group of glands that secrete body regulating substances, known as hormones, into the bloodstream.
9. Nervous system: impulses are carried to and from the central nervous system, which consists of the brain and spinal cord. The peripheral nervous system consists of the sensory organs and other regions that can pick up stimuli.
10. Urogenital system: includes the urinary organs as well as the organs of reproduction.
11. Integumentary system: the external covering of the body, made up of the skin, hair, nails, and other structures associated with the skin. This system protects underlying tissue, acts as a sensory organ, and helps regulate body temperature.

It is vital to realize that all these organ systems are closely intertwined, and could not exist apart.

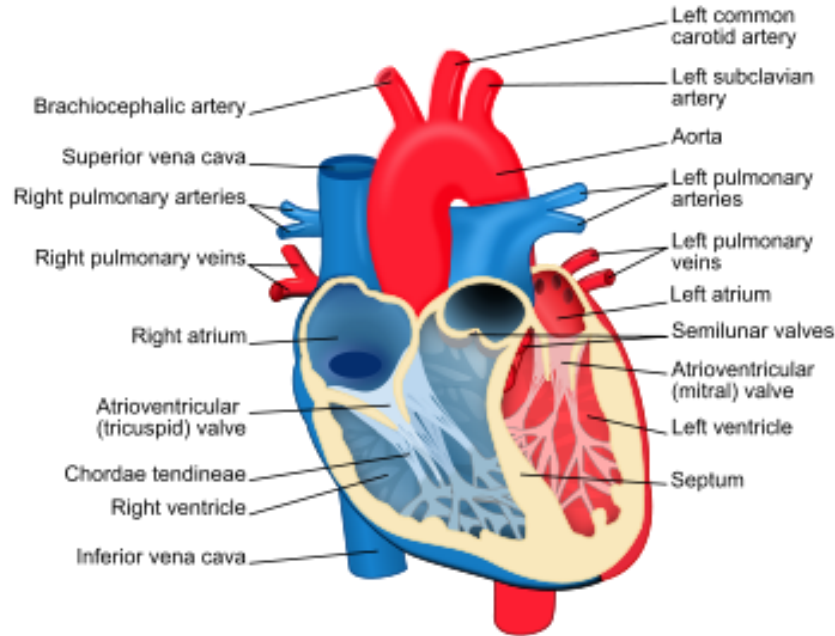
The adult human skeleton consists of 206 various bones. Bone is primarily made from mineral matter and a gelatin-like, elastic substance known as collagen. Within the marrow of the bones red blood cells are manufactured. The ends of bones are often covered by cartilage, and are connected to other bones by ligaments.



The above diagram should be memorized as best you can, although the bones of the pubis are not that important. Some important facts are listed below.

- The femur is the longest bone in the body.
- Left out on this diagram are the coccyx and sacrum, which are the very base of the spinal column.
- In total there are about 24 vertebrae
- Arthritis and carpal tunnel syndrome are two common bone diseases

The circulatory system consists of the heart and all the various blood vessels throughout the body. This circulating blood transports nutrients and oxygen, removes wastes, and can help fight infections. Arteries are the blood vessels going away from the heart, and that (a vast majority of the time) carry oxygenated blood from the heart to the body. Veins are the blood vessels going into the heart, and that (the vast majority of the time) carry deoxygenated blood from the body to the heart. Capillaries are tiny, connect the arteries and veins, and are involved directly with the cells.



In the above diagram of the heart, note that the blues areas contain deoxygenated blood, while the red areas contain the oxygenated blood.

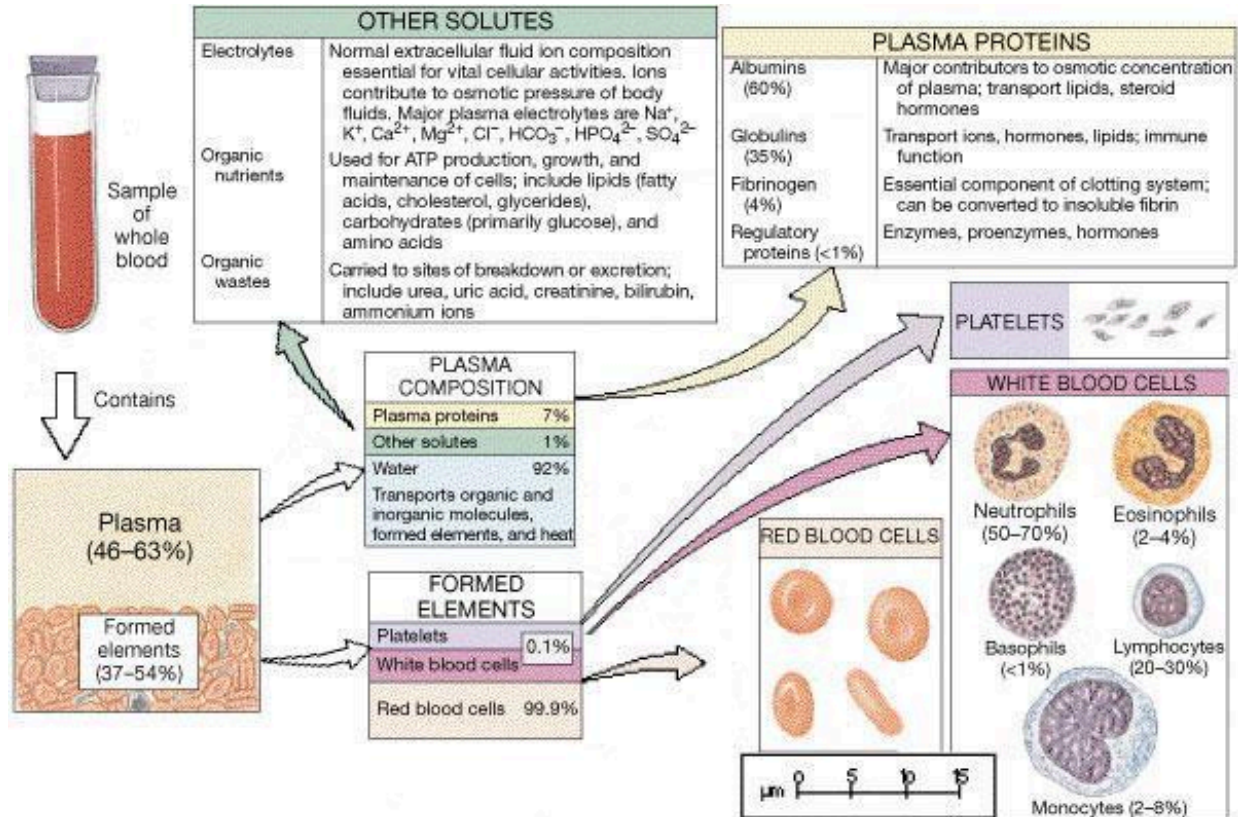
Blood that is devoid of oxygen travels from the body to the heart through a network of veins, which congregated in the superior and inferior vena cava. These two large veins receive blood from the top half of the body and the bottom half, respectively. The two vena cavas channel blood into the right atrium. (Remember that right and left as described here is from the perspective of the person with the heart, not the diagram.)

From the atrium the heart flows into the right ventricle. From there the still deoxygenated blood flows through the pulmonary arteries to the lungs, where it picks up oxygen. (This will be elaborated more upon when we cover the respiratory system) The pulmonary veins then pick up that newly oxygenated blood and take it to the left atrium. After flowing into the left ventricle, the blood goes through the aorta and returns to the body, to complete its rounds again.

Thus the path blood travels through the body is:

Vena Cava → Right Atrium → Right Ventricle → Pulmonary Arteries → Lungs → Pulmonary Veins → Left Atrium → Left Ventricle → Aorta → Arteries → Capillaries → Veins
Whereupon the cycle renews.

A brief digression is needed to cover the various contents and functions of blood.



Blood contains two important substances: plasma and so called “formed elements”. (This includes platelets, white blood cells, and red blood cells) The above diagram is excellent, and covers almost all that you will need to know.

Plasma is the watery part of blood. It is a clear yellow fluid serving as the vehicle for the transportation of the formed elements.

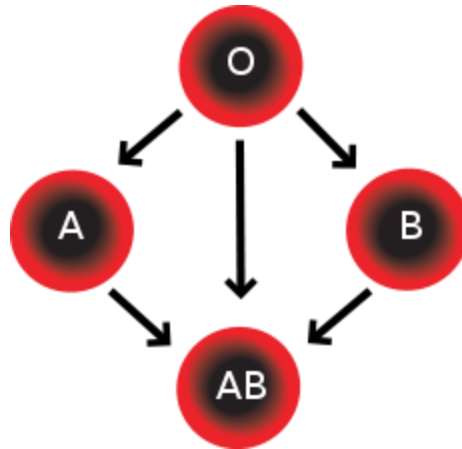
The formed elements include red blood cells, or erythrocytes, the white blood cells, or leukocytes, and the platelets.

Erythrocytes are the most numerous cells in blood, and function to carry oxygen throughout the body and return oxygen to the lungs. Hemoglobin is the most important chemical substance within red blood cells, and includes an iron pigment called heme and a protein called globin. Hemoglobin is the substance that actually carries the oxygen. Worn out erythrocytes are destroyed by the spleen (a small organ to the side of the abdomen).

Leukocytes are the cells that serve to attack disease causing organisms. They are generally created either in bone marrow or in lymphatic tissues. Generally they are larger than red blood cells.

Finally, platelets are tiny cell fragments (they do not have DNA) that are involved in blood clotting. Clotting is a process the body uses to prevent loss of blood from cuts or other wounds. Platelets stick to injured blood vessels and release chemicals that attract additional platelets to clump together.

There are four blood types: A, B, O, and AB. When having a blood transfusion, only certain types of blood are compatible with each other. If two incompatible blood types are combined, the blood would start clumping together, resulting in many problems.



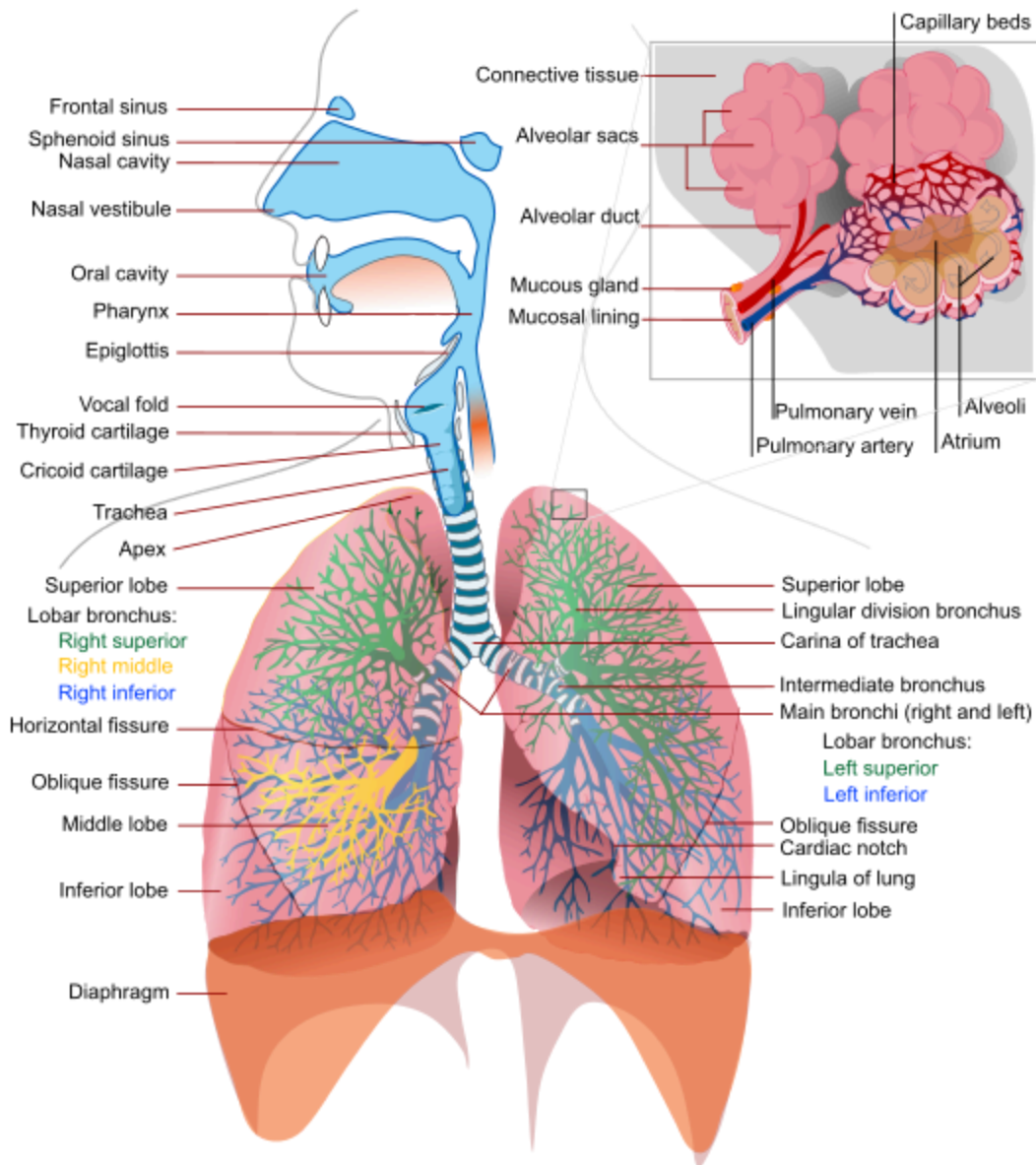
The above diagram shows how O blood type can donate to every other type, A can donate to AB type, and B can donate to AB type. Also, every member of the type can donate to other members of the same type.

The respiratory system consists of the lungs and the various organs that transport air through the body.

Air enters the body through the nose and nasal cavity, which is filled with hair that filters out foreign matter. This hair is called cilia. Air then passes into the pharynx, which is also called the throat. In the pharynx there are two openings. One leads down the esophagus to the digestive system, while the other opening leads down the larynx to the respiratory system. A flap of cartilage called the epiglottis folds to prevent air from entering the digestive tract, and food from entering the respiratory tract.

The larynx, also known as the voice box, vibrates air to produce sound. The air then passes into the trachea, a long tube connecting the larynx to the lungs. The walls of the trachea are also lined with cilia.

Finally the air has reached the lungs. Here the trachea splits into two tubes, called bronchi. The bronchi in the lungs continue splitting into smaller and smaller tubes, until they reach the smallest tubes, the bronchioles. At the ends of bronchioles are clusters of air sacs, or alveoli.



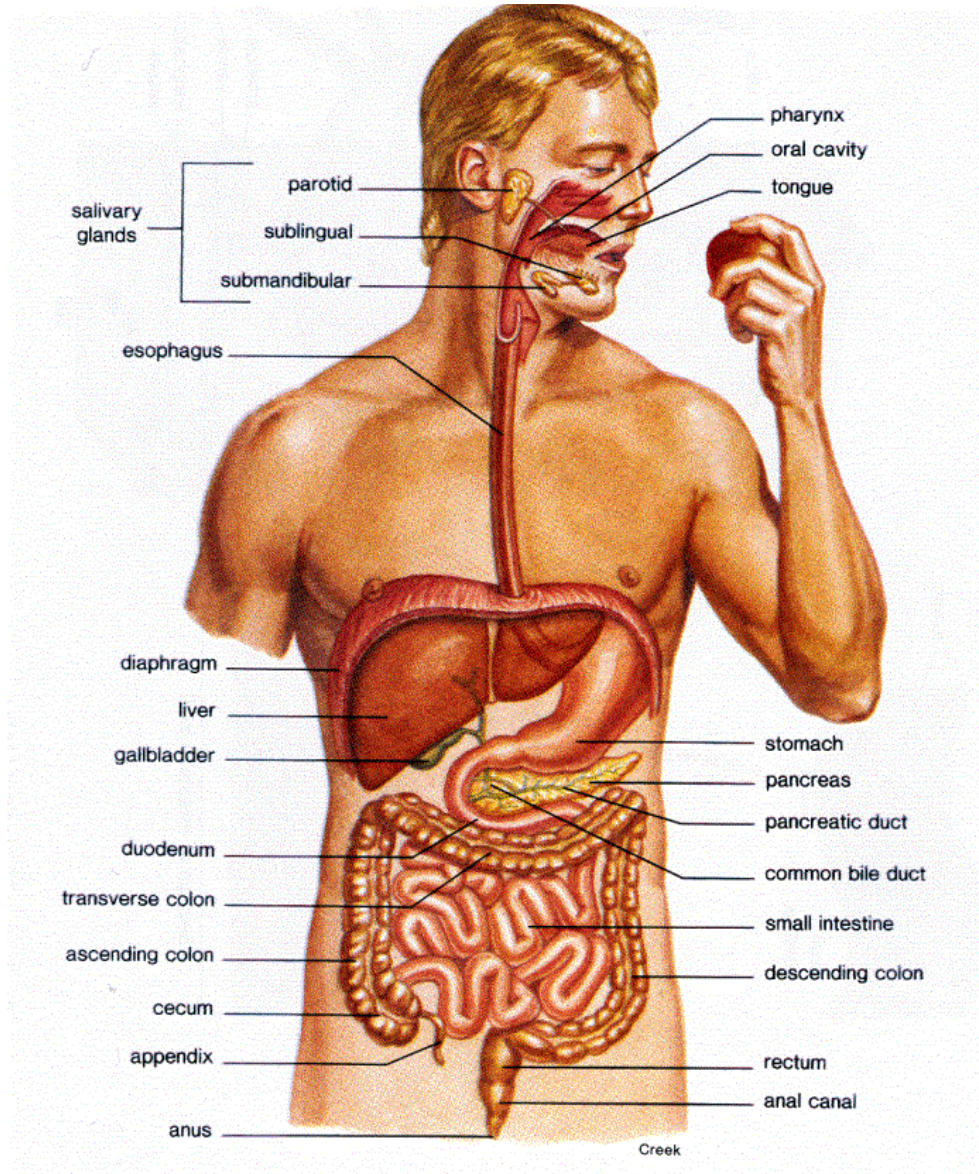
As shown in the diagram at the top left, here oxygen is sent into the blood in return for carbon dioxide. The blood in the lungs (that has been carried here by the pulmonary arteries) goes into capillaries, which eventually surround the alveoli, which are full of air. Here, through a process known as *diffusion*, the oxygen molecules travel through the thin wall of the alveoli into the blood of the capillaries, while carbon dioxide travels out of the capillaries into the alveoli, where the air is sent it back out. Eventually these capillaries grow larger until they become the pulmonary veins, which flow back into the heart.

The last big topic of the respiratory system is the muscle known as the diaphragm. This is a large, dome shaped muscle that lies at the bottom of the lungs. When we inhale the diaphragm lowers (contracting). When we exhale the diaphragm returns to its starting position (relaxing). When the

diaphragm contracts, the space available in the lungs increases, which gives more space for the air molecules to move around in. This in turn lowers the air pressure in the lungs. Molecules *always* want to move from somewhere of *higher* pressure to an area of *lower* pressure. (This is an important fundamental fact) Thus, because the air pressure in the lungs is now lower, air from outside the body rushes in and inhalation occurs. The converse (opposite) happens during exhalation.

The digestive system is composed of the entire tract, which passes through the body, and that digests food, absorbs the necessary nutrients, and then excretes it.

Note that the digestive system digests food in two ways: chemically and mechanically. At almost all points of the tract food is being digested both chemically and mechanically. This occurs chemically through the action of chemicals and enzymes (proteins that speed/produce reactions), and mechanically through the various churning and moving actions.



After chewing by the teeth until the food becomes a mushy mass called a bolus, food passes into the pharynx, or the throat. From the pharynx the bolus is pushed into the esophagus, a long, thick walled tube. In the esophagus there are waves of contractions, known as peristalsis, which pushes the food on. (This is why you can still digest things even while hanging upside down) The esophagus ends in the stomach.

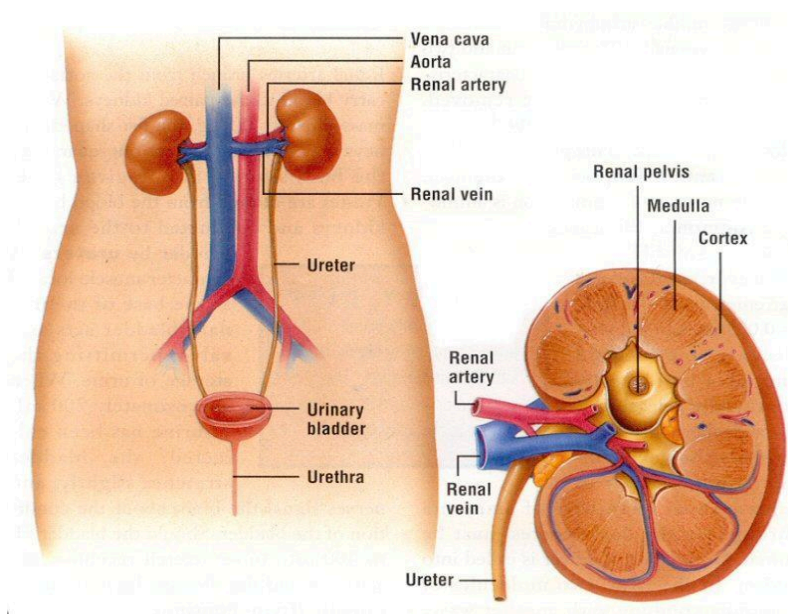
The stomach breaks down the bolus into a “nutrient soup” called chyme. Additionally, gastric juice, which contains hydrochloric acid and pepsin (an enzyme that breaks down proteins), is secreted. At the end of the stomach is the beginning of the small intestine, made up of an organ known as the duodenum. Into the duodenum flows bile and pancreatic juice, which are produced in the liver and the pancreas, respectively. Bile breaks down fats and is stored in the gallbladder.

Here in the duodenum most of the absorption of nutrients takes place. The small intestine is lined with millions and millions of tiny protrusions called villi that greatly increase the small intestine's absorptive area. The other two parts of the small intestine are called the jejunum and the ileum.

The small intestine leads into the large intestine, where most of the water is absorbed. Finally the remains of the food reach the rectum and then anus, where it is expelled.

The excretory system is made up of the kidneys, the urinary organs, the sweat glands, the liver, and even the lungs.

Blood passes through the kidneys and is then filtered, the waste passing into an area called the renal pelvis. From the renal pelvis the waste (including substances such as water, urea, and excess minerals) flows into the ureter, a tube connecting the kidneys to the bladder. From the bladder the urine is then expelled.



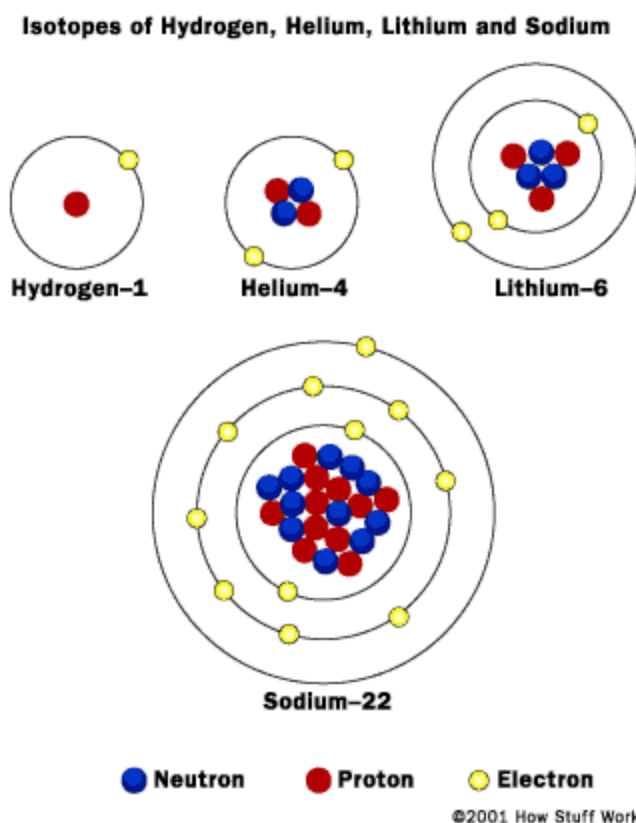
Chemistry

Chemistry is the science of matter – it concerns itself with the properties, structure, and reactions. In TMSCA chemistry will primarily focus on the periodic table and some basic knowledge about atoms and molecules.

Atoms, Molecules, and Compounds

The most fundamental unit of matter is the atom. The atom consists of a nucleus and the surrounding electron cloud. (The nucleus contains protons and neutrons) Electrons have negative charges, protons are positive, and neutrons are neutral.

An atom's electrons can be envisioned as occupying spherical shells radiating from the nucleus. (Although in nature electrons do not actually occupy specific shells, it is useful to think of it this way) Aside from the first shell, which fills at 2 electrons, all other shells strive to contain 8 electrons. This is the famous "Octet Rule". This rule governs just about all atomic bonding and atomic properties.



This rule concerns the outer electrons, or valence electrons. These valence electrons are the ones that participate in reactions and bonding. (And thus valence electrons largely determine atomic properties)

Bonding is the process in which atoms join together. (Primarily in order to fulfill their need for 8 valence electrons) When atoms bond they form molecules and compounds.

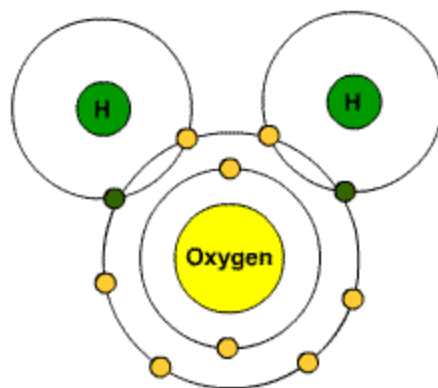
There are two primary types of bonding. These types are ionic bonding and covalent bonding. In ionic bonding the electrons are transferred and bonding occurs because of charge attractions. In covalent bonding the electrons are actually shared between the atoms.

An example of ionic bonding is common table salt, or NaCl. (Sodium chloride, which is a sodium atom bonded to a chlorine atom) Sodium has one valence electron (how to figure that out will be explained below) and chlorine has seven. If you think about it, the easiest way for sodium to get to 8 valence electrons is to let go of the single outer electron (so that the inner shell of 8 would be exposed). This would cause sodium's electron configuration to look a lot like neon.

Additionally, the easiest way for chlorine to get to eight is to gain an electron, which would make its electron configuration look like argon. Thus these two atoms are a perfect match for each other. Sodium gives its valence electron to chlorine, and both parties are satisfied.

This creates something interesting though, as now sodium is a positive ion (an ion is a charged atom), while chlorine is a negative ion. (A positive ion is called a cation while a negative ion is called an anion. Some tricks to remember this are that cats are (generally) positive, hence cation. Also, onions make you cry, which is negative, thus anion.) Because opposites attract, the sodium and chlorine will join together. This type of a bond is called an ionic bond.

An example of covalent bonding would be a common water molecule, H₂O. In this case we have an oxygen atom. An atom of oxygen has 6 valence electrons, so the easiest way for it to complete its shell would be for it to share/take two electrons. Say two hydrogen electrons happen along. These two atoms both need to share/take one electron to satisfy its needs, so all three atoms "decide" to form a bond in which they share their electrons. (See the diagram below for just how) This type of bond, in which the electrons are shared, is called a covalent bond.



The Periodic Table

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Period 1	1																	2	
1	H																		He
2	3	4											5	6	7	8	9	10	
	Li	Be											B	C	N	O	F	Ne	
3	11	12											13	14	15	16	17	18	
	Na	Mg											Al	Si	P	S	Cl	Ar	
4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	
	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
5	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	
	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
6	55	56	57*	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	
	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	
7	87	88	89**	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	
	Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Uuq	Uup	Uuh	Uus	Uuo	

*Lanthanides	58	59	60	61	62	63	64	65	66	67	68	69	70	71
	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
**Actinides	90	91	92	93	94	95	96	97	98	99	100	101	102	103
	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

This is the periodic table – created by Dmitri Mendeleev. It looks slightly peculiar – after all, the indentations seem quite random. However, these patterns are actually what make the periodic table so interesting.

Elements generally have a few numbers associated with them: their atomic number and their mass number. In the periodic table above the atomic number is the one in the top left corner. This number represents the numbers of protons in a *neutral* atom of the element. Note that the atomic number generally also refers to the number of electrons, unless the atom is an ion. The mass number represents the mass of the atom – this is generally a miniscule number, and is measured in atomic mass units or Daltons. (The two units are approximately equivalent) It is technically the sum of protons and neutrons, (Each has a mass of about 1 dalton) but when you look at a chart of masses you will see that in fact it is some decimal. This is because the mass number is actually the average of all different “kinds” of that element in nature.

The different “kinds” of an element is the different isotopes. An isotope is a version of the atom, but with a different number of neutrons. For example, hydrogen generally does not have any neutrons. However, rarely a type of hydrogen called tritium is found. Tritium has 3 neutrons, so its mass will be different than “normal” hydrogen, something more like 4 daltons. Because of these rare isotopes, hydrogen’s mass is about 1.008 daltons.

The periodic table has periods and groups. The periods are horizontal, while the groups are vertical. Earlier it was mentioned that it is possible to tell how many valence electrons an atom has by

glancing at the periodic table. We'll look at the Groups 1, 2, 13, 14, 15, 16, 17, and 18 first. (Groups 3 – 11 have weird valence electron arrangements) The cool thing about these groups is that if you look at the units/ones digit of the group then it tells you how many valence electrons members of the group have.

Thus carbon (C), in group 14, has 4 valence electrons, while potassium (K), in group 1, has 1 valence electron.

Another important thing the periodic table does is to group elements with similar properties together. (Remember that properties are determined by valence electrons, so this is no coincidence)

1. Alkali Metals: located in Group 1, although Hydrogen is not an alkali metal. (Note that it is alkali without an “n” at the end) They have properties similar to other metals. Because these atoms have just 1 valence electron and they are so close to getting their full set of 8, they react very easily. They are also less dense than other metals.
2. Alkaline Earth Metals: located in Group 2, also have properties similar to other metals. They readily lose their two electrons.
3. Transition Metals: located in Groups 3-11, these elements are very hard and have high melting and boiling states. They are also highly malleable (able to bend) and conductive (able to let electricity pass through it), with silver being the most conductive element.
4. Lanthanides and Actinides: located in the two “extra” periods at the bottom of the table, their names come from elements 57 and 89, respectively. Sometimes called the Rare Earth Metals, they can be quite reactive and radioactive, although lanthanides have many commercial uses.
5. Metals: located in the triangle type area underneath the black line on the periodic table above, they are also called “Other Metals”. This black line is called the “Stair Step Line”, and divides the metals and nonmetals. Metals in general have a shiny, metallic appearance. They are also ductile (able to bend easily) and are good conductors.
6. Metalloids: are all the elements on the stair step line (except for Aluminum, which is a metal). They are really “intermediate” metals; their conductivity is inefficient (but they are not an insulator), they have a slightly metallic appearance, and their behavior during reactions depends on what they are reacting with. Because of these traits they make good semiconductors, so are often used in computers.
7. Nonmetals: consist of the triangle above the stair step line plus hydrogen. Nonmetals are some of the most important elements for life – carbon, nitrogen, oxygen, and hydrogen are the four most common elements in the human body. Although they display a wide range of properties, they are generally poor conductors and are brittle in their solid form.
8. Halogens: located in Group 17, these elements (commonly found in *halogen* lights) are quite reactive, especially with alkali metals. They exist in a variety of states; iodine can be solid, bromine can be liquid, while chlorine can be gaseous.

9. Noble Gases: located in Group 18, these gases are all very inert. (The name “noble” comes from their “snobby” refusal to bond with any other elements, much like nobles of old) Their inability to react results from them having a full valence shell of electrons.

Those were the nine groups of elements.

Periodicity

I am going to skip over periodicity for now, and if I see it occur on any tests I will add some information on it.

Physics

Physics is essentially an analysis of nature and how it behaves – it investigates matter, motion, time, electricity, magnetism, forces, and much more. Ernest Rutherford, a great physicist, once said: “All science is either physics or stamp collecting.”

First we need to define a few terms about motion that will be pertinent:

1. Energy: this quantity is hard to define objectively, because of its “elusive” nature. However, we do know that it is the ability to do work. The *total* energy in the universe will *always* remain the same (in all its various forms). Thus energy cannot be created, or destroyed. This is known as the Law of Conservation of Energy.
2. Force: this is any influence that causes a system to undergo certain changes, measured in newtons. This change could be in terms of speed or direction.
3. Mass: anything that takes up space. Mass is generally a better measurement than weight, as weight changes with wherever you are at. (The amount of space an object takes up will always remain constant)
4. Speed: the distance an object travels in a certain amount of time. Remember that $S = D/T$.
5. Velocity: this is the *speed* in a certain *direction*.
6. Friction: a force acting against relative motion of two surfaces. Includes surface resistance and air resistance.
7. Acceleration: this is the rate at which the velocity of an object changes. So it would be represented mathematically as the velocity at the second time minus the velocity at the first time, divided by the time elapsed. An important fact to know is that the acceleration due to gravity is about 9.8 m/s^2 , although for simplicity this can be rounded to 10. This means that if we let something free fall it will accelerate at 9.8 m/s^2 .

Newton’s Laws

Newton’s Laws are quite an interesting set of principles, and can be kind of tricky to completely understand. I’ll go through each law, and then set out some examples of what this law might pertain to.

1) Newton’s First Law:

An object in motion will stay in motion until acted upon by some outside force. An object at rest will stay at rest until acted upon by some outside force. (The Law of Inertia)

There is a caveat to this law: it applies in *frictionless* environments. So imagine that we are in deep space. Essentially we would be in a vacuum – a space without any matter. Thus there would be

absolutely no forces other than the ones that we can exert. So from our little yellow submarine we shoot a rocket. As long as the rocket continues in deep space it will continue on *infinitely*. It will maintain a constant speed too, without any acceleration.

Similarly, if we were to place something in a stationary position then, as long as we did not act on it, it would stay in place forever.

2) Newton's Second Law:

The force, mass, and acceleration of an object are related by the formula $F = ma$.

The equation $F = ma$ has application in a wide variety of problems. One might even say it is the most powerful of Newton's laws, as it allows us to quantify and calculate.

From this equation we can deduce a few interesting and important facts. However, first we need to explain a few terms – direct variation and inverse variation. Another term is direct proportion and inverse proportion.

When two variables have direct variation, then as one variable increases the other variable also increases. Another way to say this is that the quotient of the two variables is constant. As an example, let us set the two variables 'a' and 'b' to be related directly. Thus $a/b = C$, where C is some random constant. By definition C will remain the same for all values of 'a' and 'b', so if we double 'a' then we must double 'b'. Mathematically, $(2a) / (2b) = a/b = C$.

When two variables have inverse variation then as one variable increases the other variable decreases. Another way to say this is that the product of the two variables is constant. Notice that this is the case between the variables 'm' and 'a' in Newton's Second Law, as those two values multiply to 'F'. The facts that follow from ' $F = ma$ ' are explained below.

1. Say you have a small truck and a large truck. They are moving at the same speed towards a wall. Which one can produce the largest impact? Intuitively we would say the large truck, and this fact is verified by $F = ma$. *The force will be larger if the mass is larger.*
2. Using the same truck analogy as above, if we had two trucks of the same mass, traveling at different speeds, the faster truck intuitively has more force. Again this is verified by Newton's Second Law. Note that these first two facts are because the pairs of variables "F and a" and the variables "F and m" are directly proportional. *The force will be larger if the acceleration is higher.*
3. The last important fact is fairly obvious if you look at the relationship between the variables in Newton's Second Law. Note that the variables mass and acceleration will always multiply to force. Thus these two variables are inversely proportional. *Mass increases if acceleration decreases, and vice versa.*

Interestingly enough Newton's Second Law can be extended to the equation for momentum. Momentum is often referred to by the variable "p". The equation for momentum is $p = mv$, where m is mass and v is velocity. Although momentum and force are different, intuitively we can extend force to momentum. (Note how mass in the 2nd law lines up with mass in the momentum equation, while acceleration lines up with velocity.)

3) Newton's Third Law

For every action (force) there is an equal and opposite reaction (force).

This can sometimes be the hardest law to understand. This law essentially says that there are never any isolated forces; for all forces acting on objects, there is an equal force in the opposite direction which acts back on the object which exerted the force to begin with. Let's pose a few examples.

Suppose we have a weight sitting on the ground. Obviously there is a gravitational force pulling down on the weight (we can also call it a mass). What is less obvious is that there is also a force from the ground pushing up on the mass, preventing the mass from falling straight through the earth. The fact that these forces are equal and opposite is what prevents any motion from the mass. (We know from experience the mass will sit motionless)

Suppose we have a rocket shooting off. Obviously the rocket is firing and pushing on the ground (along with the gravitational force). The only reason the rocket takes off is that the ground pushes up on the rocket.

Finally, suppose for whatever reason we want to take a large mass and push it along the ground. As we push it we exert force on the object. By definition, the object will exert force back on us. From experience we know that we can feel this as a pressure on our hands or shoulders.

Something that perplexed me for a while about Newton's Third Law was, if all forces come in equal and opposite pairs, why do the forces not all just cancel out? Well, if we look carefully at the definition, the forces are not both on the same object. In fact, the first force is on the object. The second force is on the object that exerted the first force. In the example in which the rocket takes off, the rocket starts exerting a force on the ground. By Newton's Third Law, the ground will then exert a force on the rocket.

Energy, Work, and Simple Machines

Energy, work, and simple machines are intricately connected. Let's start with a few equations that can help clarify them.

Energy is, as explained in the section “Newton’s Laws”, is often defined as the ability to do work. A force performs work on a body if there is a displacement of the body.

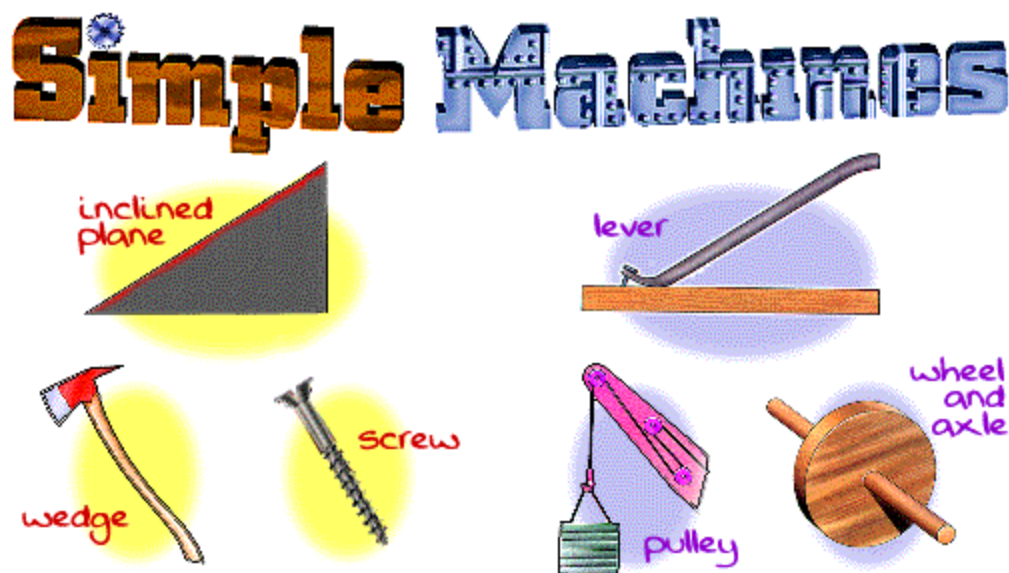
The equation for work is $W = F * d$, or work equals the product of force and distance. Work is measured in Joules, after the English physicist James Joule. Remember that force is measured in newtons and distance is measured in meters – thus one joule is the amount of work needed to apply a force of one newton over the distance of one meter.

The equation to calculate power is: $P = W/t$. Power is measured in watts. One watt would be a work of one joule in one second. Now that we understand what power is, we can also describe joules in terms of power. One joule is equivalent to the amount of work required to produce one watt in one second.

There are six different simple machines:

1. Lever
2. Inclined Plane
3. Screw
4. Wheel and axle
5. Wedge
6. Pulley

The purpose of a simple machine is to change the direction, size, or length of the force. Although size is mentioned here, note that because of the Law of Conservation of Energy the *total* energy exerted will remain the same. This may be a bit confusing, so we will go through this concept with an example involving arguably the simplest machine – the inclined plane.



Let's start off with the inclined plane, as it is the most intuitive. (In my opinion) Let's set a scenario: We are in a trucker employed for the company "The Humble Sea Bass". Our task is to load a crate of sea bass onto our truck. However, the crates are heavy (50 kg) and they must also be lifted a distance of 12 m to get onto the truck. (We at the humble sea bass drive crazy trucks) There are two ways we could do this.

We could test our strength and try to lift the mass. The work we would have to perform would be calculated by finding the force required and the distance. Because $F = ma$, and $m = 50 \text{ kg}$ and $a = 9.8$, our force is 490 N. $W = Fd$, so plugging in $F = 490 \text{ N}$ and $d = 12 \text{ m}$, the total work we have to do is 5880 J, or 490 J per meter lifted. That is a pretty big number!

Now we bring in an inclined plane that is 16 meters lengthwise and 12 meters tall. This will allow the top of the inclined plane to correspond with the opening of the truck. The entire ramp will be 20 meters long. This has two advantages – first of all, you will be able to spread the force out over a longer distance. (20 meters as opposed to 12 meters) Additionally, as we all know from experience, pushing is generally easier than lifting. Now, the math needed to calculate the work of this is quite a bit more complicated (involving trigonometry and breaking the force vectors into their various component vectors) so I'll skip the details here, but the work needed is about 6000 J total, or 300 J per meter. Although the total work needed is more (due to friction), it is much easier to push something with a work of 300 J per meter than lift something for 490 J per meter.

It is in this way that simple machines simplify our everyday tasks.

Basic Optics

I am going to skip over optics for now, and if I see it occur on any tests I will add some information on it.

Ideal Gases

Before approaching this topic, it is useful to understand the concept of a mole. A mole is really just a number. This number is 6.023×10^{23} , or Avogadro's Number. This concept is definitely a bit confusing, and I would encourage you to look it up on Khan Academy. However, for our purposes all you need to know is that a mole is a unit used to measure the number of atoms. So a given quantity can be said to contain "3 moles of oxygen" or there are "2 moles of sulfur dissolved in this water".

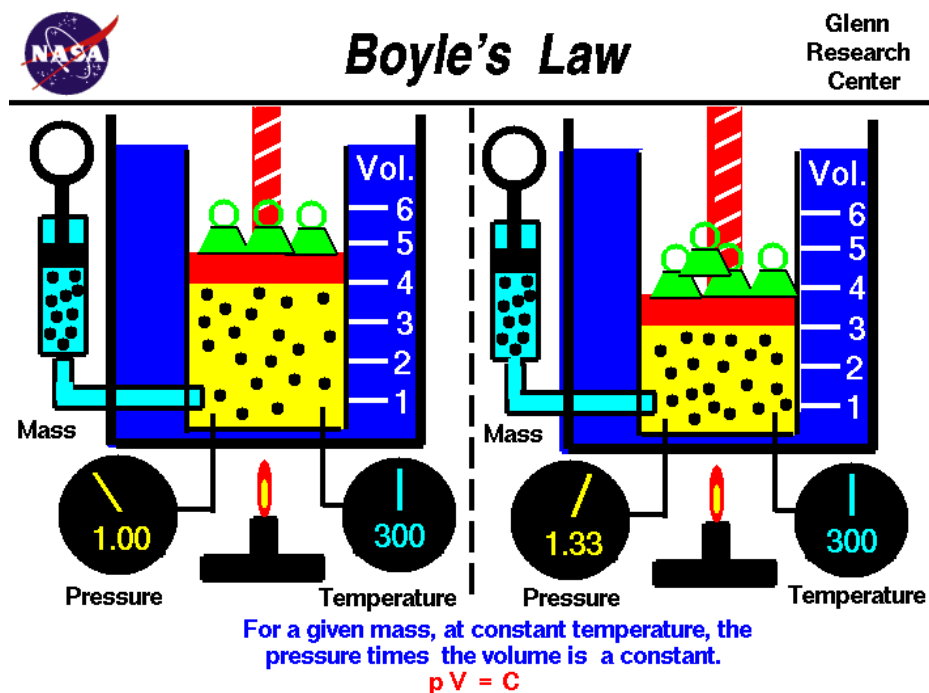
Ideal gases are hypothetical gases that have behave in an ideal way – they have zero mass, do not interact at all with each other, and bounce completely randomly. In the real world obviously even tiny hydrogen atoms have mass, but envisioning gases in this way is useful, and real world gases are not too far off.

The ideal gas law is $P = \frac{nRT}{V}$. P is pressure, n is the number of molecules/atoms in moles, R is the universal gas constant (explained more below), T is the temperature in Kelvin, and V is volume.

First recall the concepts of direct and inverse variation/proportion. From looking at the equation we deduce that pressure and the number of molecules is directly proportional, meaning if we add more molecules without changing the temperature or volume, the pressure will increase. Really this is very intuitive. Imagine there is a tube that *only* contains one type of molecule, we can add more molecules, heat or cool down the tube, and change the available volume by sliding the stopper up or down. We also are able to measure these variables precisely. Thus if we throw in more molecules the number of molecules colliding with the sides of the tube will obviously increase. Remember that pressure is force over an area; the molecules hitting the sides will increase and thus increase the force against the tube, increasing the total pressure of the tube.

Pressure and the temperature are also directly proportional. Think back to the magic ideal gas tube, and think of what happens when we increase the temperature inside the tube. The molecules will move faster, bumping into the sides of the tube more frequently and increasing pressure. Kelvin is a temperature scale that has its zero point located at absolute zero. Absolute is the hypothetical “lowest temperature”, at which there is absolutely no movement in molecules. Kelvin scales in the same manner as Celsius does, so 0 Kelvin = 273 Celsius. Thus to get from Celsius to Kelvin we just have to add 273.

The two previous variables are directly proportional, so if one increases the other also increases. However, pressure and volume are *inversely* proportional. Imagine if we press down the stopper of the tube, reducing the volume. Now the molecules have fewer places to bounce – thus they will bounce more frequently against the walls of the tube. Again, more bounces = more force = more pressure.



The title of the illustration is Boyle's law – this is really just a “component” of the ideal gas law. (Note that this part relates pressure and volume) Boyle's Law, Charles's Law, and Gay-Lussac's Law (which relate the individual components of the ideal gas law) combined create the ideal gas law.

Now, we've gone over P, V, T, and n, what is the mysterious R? Often in physics it writing out all the units can help us figure out our errors or more deeply understand a problem. Pressure is measured in atmospheres. Volume is measured in liters. Temperature is measured in Kelvin. The number of molecules is measured in moles. Thus we have:

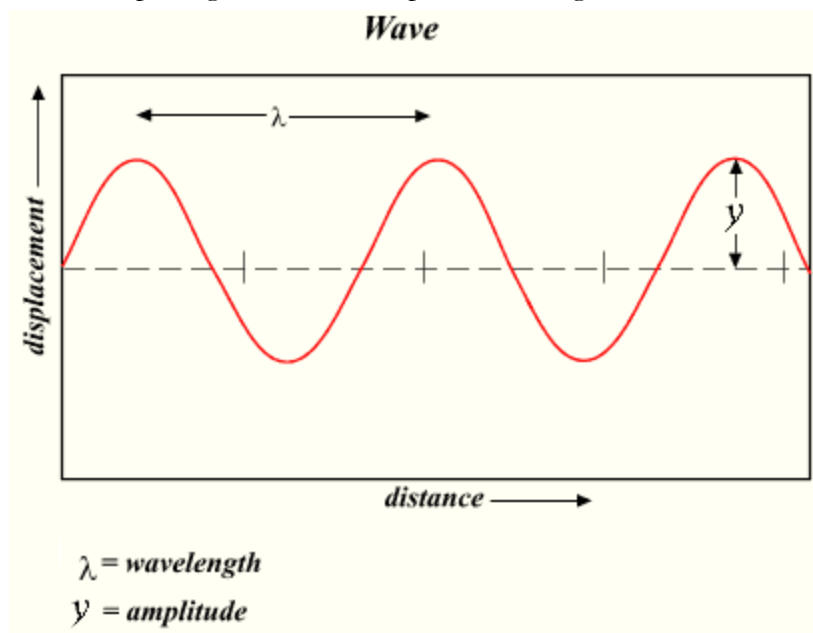
$$P \text{ (atm)} = n \text{ (moles)} * R * T \text{ (Kelvin)} / V \text{ (L)}$$

However, atm \neq moles * Kelvin/liters. So R essentially acts as the “conversion factor” that changes the units of both sides to match up. For this example R would be .0821. You will see the insertion of constants into equations in science often. Just think of these constants as unit converters.

Waves

Electromagnetic radiation is energy emitted by charged particles, generally in the form of photons. Electromagnetic radiation can take the form of visible light, radio waves, gamma rays, and many more. EMR travels at the speed of light when it is in a vacuum. (A vacuum is a space devoid of any particles) However, what we will be covering in this section is the tendency of electromagnetic radiation to move in waves.

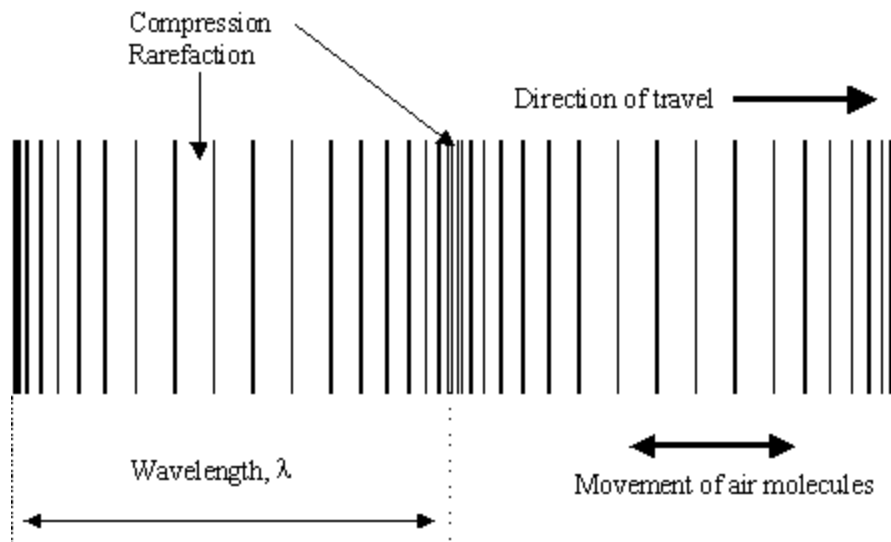
What is a wave? A wave is a disturbance or oscillation that transmits energy from one place to another. Generally when one imagines a light wave you would imagine the classic sine wave. One can think of the sine wave as depicting the motion of particles along a wave.



There are quite a few vital components of a wave. The dotted line crossing the middle of the diagram represents location of the molecules while they are at rest, and this is generally called the normal. The red curve (the wave) represents the molecules moving up and down. The crests and the troughs are the highest points and lowest points of the wave, respectively. Notice that the distance from the resting position to the crest/trough is called the amplitude. Thus the distance away from the normal for the crest and trough is equivalent to the amplitude. Next the wavelength – this is the distance from one crest to the next crest, or one trough to the next trough. Finally the frequency – although this is not really a component of the wave, it is an important property. It is defined as how many waves are created in a specific amount of time. Frequency is measured in Hertz – 1 hertz is the equivalent of one wave cycle in one second. Note that if the frequency increases the wavelength must decrease – this is because the speed that the wave is traveling will remain the same, at least for electromagnetic waves, and this speed will be the speed of light.

There are essentially two types of waves – mechanical waves and the aforementioned electromagnetic waves.

A mechanical wave moves (propagates) through a medium (some sort of substance). An example of a mechanical wave is a sound wave. This type of wave requires the presence of a medium, because the energy is transmitted through the individual molecules. Imagine a pebble dropped into a still pond. The pebble causes a disturbance in the medium, which in this case is the water of the pond. The individual molecules at the location of the disturbance will start oscillating. These oscillating



Surface waves are a bit more complicated in the way they propagate, however basically they are just waves traveling on the intersection between two media. An example of this is a wave traveling in water – it is moving between the air and the water. Another example are the various types of seismic waves.

Earth Sciences

Earth Science is a very expansive field covering the Earth and its features and processes. More specifically, this might include studying the Earth's atmosphere, oceans, surface features, weather patterns, and so much more. TMSCA seems to enjoy covering Earth Sciences a lot, so I'll do my best to encompass in this chapter a lot about our beautiful planet!



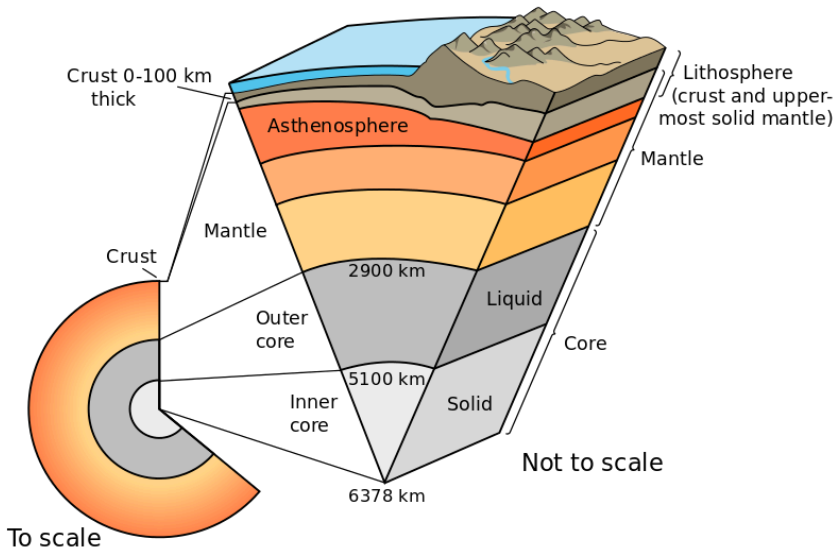
The Earth

Let's start with some of the basics, and look at the entire Earth. If we took a giant knife and sliced the Earth in half, we would see a few layers.

Oftentimes what confuses people (it confused me at least) is that there seem to be different names for the various layers. For example, the crust seems to be also called the lithosphere. The mantle seems to be sometimes referred to as the asthenosphere.

In reality the lithosphere comprises of all the rigid parts on the surface of the Earth – this includes the crust, which is the solid shell around the Earth. (Note the difference – rigid vs. solid) Thus the lithosphere also contains parts of the mantle – these parts are still considered liquid, even though

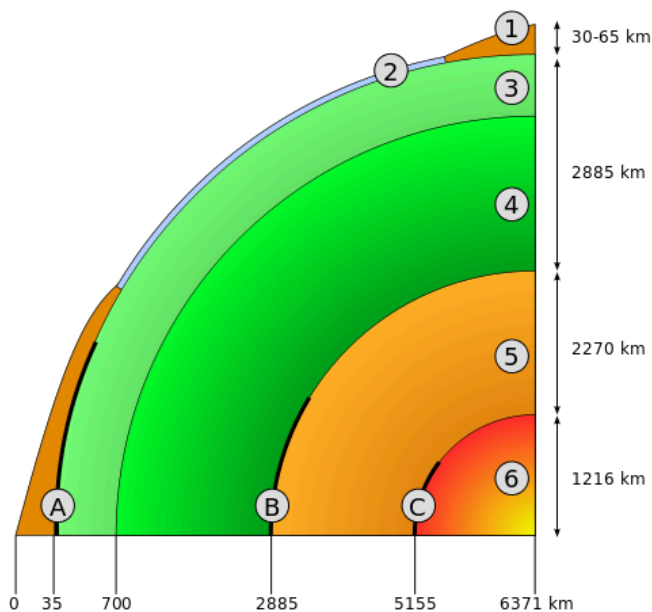
they only behave so over periods of many, many years. Additionally, the tectonic plates are composed of “chunks” of lithosphere.



The asthenosphere is the upper part of the mantle. The mantle is essentially just the layer of the Earth in between the crust and the core that can be differentiated from the two by density. It is highly resistant to flow (meaning it is very viscous), and also is the layer involved in plate tectonic movements.

The outer core is made of a liquid combination of iron and nickel. It is here that Earth’s magnetic field arises from the movements of liquid metals. The inner core is a solid combination of iron and nickel.

The boundaries between various layers of the Earth can sometimes show up too. This diagram shows the layers of the Earth along with some important boundaries. Boundary A is the Moho, short for Mohorovicic discontinuity. It separates the crust and the mantle.



Boundary B is the Gutenberg discontinuity, or the core mantle boundary.

Boundary C is the boundary of the inner core. (No cool name...)

An important aspect to realize is the fact that these boundaries were mostly discovered using seismic wave data. (They didn’t actually drill a deep hole and look!) We’ll cover seismic waves in our section on earthquakes.

Geographic Features

Natural Disasters

Weather and Atmosphere

Rocks and Minerals

Erosion and Weathering

The Ocean

Space Sciences

The Planets

The Moon

The Sun

Stellar Evolution

Science History/Miscellaneous

Contributions by various notable scientists

Units

Fields of Science

Vocabulary

1. Capsule: jelly like outer coating of many prokaryotes
2. Cell Wall: commonly found in plants cells – protection & support
3. Cell Wall: rigid structure outside the plasma membrane
4. Centrioles: organize the spindle fibers during cell division
5. Chloroplasts: store chlorophyll – photosynthesis light reaction
6. Cilia: sweep materials across the cell surface
7. Cytoplasm: between plasma membrane and nucleus – many organelles
8. Cytoskeleton: cell shape, internal organization, cell movement & locomotion
9. DNA: encoding of heredity information
10. Endoplasmic reticulum (ER): the passageway for transport of materials within the cell
11. Eukaryotic Cells: these cells contain a membrane bound nucleus and specialized, membrane bound organelles. These include plant and animal cells.
12. Flagella: locomotion organelles of some bacteria
13. Flagellum: enables a cell to propel and move in different directions
14. Golgi apparatus: Final modification of proteins & lipids. Also, packing of materials for secretion of the cell occurs here
15. Lysosomes: contain enzymes to digest ingested material or damaged tissue
16. Mitochondria: the site of aerobic cell respiration-ATP production
17. Nuclear membrane: membrane around nucleus – controls movement in and out
18. Nucleoid: region where the cell's DNA is located, but is not enclosed by a membrane
19. Nucleolus: assembly of subunits of ribosomes.
20. Pili: attachment structures on the surface of some prokaryotes
21. Plasma Membrane: control of substances coming in and out
22. Plasma Membrane: membrane enclosing the cytoplasm
23. Prokaryotic Cells: these cells have their genetic material concentrated in a region but not bound in a membrane dividing it from the rest of the cell. In general this contains Bacteria and Archaea, but evidence suggests that Archaea are actually their own type.
24. Ribosome: organelles that synthesize proteins
25. Ribosomes: the site of protein synthesis
26. RNA: transcription and translation of DNA coding into proteins
27. Vacuoles: storage – increase cell surface area

Further Reading

Biology; Campbell and Reece

Biology for Dummies; Donna Siegfried

Wikipedia; Even though teachers say it's bad, it's a great resource