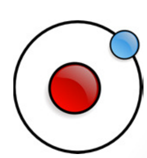
Unit 1
Chemical Basis of Life

Biology 30
Mr. Oosterom

Atoms

- Atoms are the smallest *basic* units of matter.
- Every single thing in the world is composed entirely of atoms. That includes both living and non-living things.
- It would take you more than 1 trillion years to count the atoms in a grain of sand.



Atoms are Composed of Three Different Elementary Particles:

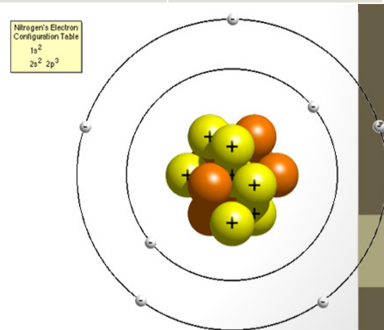
Type of Particle:	LOCATION	CHARGE	WEIGHT
Proton	Inside nucleus	Positive (+1)	Heavy
Electron	Orbiting nucleus	Negative (-1)	Extremely light
Neutron	Inside nucleus	Neutral (0)	Heavy

Atoms consist of three kinds of particles:

Protons, Electrons, and Neutrons

The center of the atom is called the *nucleus*, and it contains all of the protons and neutrons. Electrons circle the nucleus, forming orbits around the nucleus.

Each orbit can hold a different # of electrons.



Elements

- An **element** is one particular *type* of atom.
- The number of **protons** in an atom determines what type of **element** it is.
- There are 112 different elements that make up *everything in the universe*. Amazingly, your body is made up majorly of only 4:
- Carbon, oxygen, nitrogen, and hydrogen.

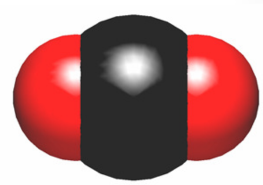
Gold is an element on the periodic table. The nucleus of every gold atoms contains **76 protons.** Therefore, you will find gold as #76 on the periodic table.

Protons and Electrons

- **Protons,** as we learned earlier, determine the *type* of atom (which element) that you have.
- **Electrons** determine how that atom will react with other atoms.
- **Remember** that electrons circle the outside of the nucleus in **orbits.** These orbits are also called **energy levels.**
- Also, remember that each energy level can hold different numbers of electrons.

Compounds

- Often, atoms in nature are found bonded (also called linked) to other atoms
- Atoms can be *bonded* to each other once, twice, or even three times.
- A compound is a substance that is made of two or more different elements.



Carbon dioxide is an example of a compound.

Bonding: Ionic and Covalent

- Atoms bond together in two different ways. In **biology**, the most important way is through **sharing electrons,** also known as **covalent bonding.**
- Ionic bonding occurs between a metal and a non-metal, and involves **exchanging** electrons.

Ionic Bonding (electron exchange)

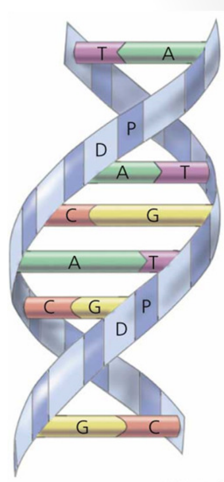
- An ion is an atom that has gained or lost one or more electrons.
- An ion forms because an atom is more stable when its outermost energy level is full.
- Atoms with few electrons in the outer shell (the valence shell) tend to lose these electrons.
- Atoms with many electrons in the outer shell tend to gain a few more electrons in order to fill their shells.

Covalent Bonding (electron sharing)

- Not all atoms easily gain or lose electrons. Some of them prefer to share their electrons – particularly the **non-metals.**
- Shared pairs of electrons will fill the outermost energy levels of the bonded atoms.
- A **covalent bond** forms when atoms share a pair of electrons.
- Covalent bonds can be **extremely** strong or relatively **weak**, it all varies.

Molecules

- A **molecule** is two or more atoms held together by **covalent** bonds.
- Molecules and **covalent** bonds are important in biology because almost ALL of the substances that make up **organisms** are molecules held together by covalent bonds.



What are Chemical Reactions?

- Chemical reactions change substances into different substances by breaking and forming chemical bonds.
- Chemical reactions are critical to the lives of all organisms. Thousands of reactions are happening in your body all of the time.
- The following are a few examples of chemical reactions in living organisms:

Chemical Reactions in living organisms:

- Plant cells make cellulose by linking simple sugars together (more on this to come).
- Plant and animal cells break down sugars to get usable energy (much more on this to come).
- All cells build protein molecules by bonding amino acids together (super much more on this to come).

Chemical reactions are occurring in this **crazy man** and the plants all the time!

Breaking and Making Bonds

- Recall that all of the atoms in the glucose and oxygen molecules are bonded together. In order to create new compounds from them, we have to break the *original* bonds and then form *new* ones.
- To break the old bonds, we have to put energy in. Imagine this like *snapping a twig.*

Breaking and Making Bonds

- Depending on the type of bond that we have, we may need *more* or *less* energy to break it, since different bonds have different strengths. This is referred to as bond energy.
- Energy is released when bonds *form*.
- When a bond *forms*, the amount of energy released is EQUAL to the amount of energy required to break that bond again.

Chemical Reactions Release or Absorb Energy

Exothermic Reactions

- Release more energy than they absorb.
- Result in the production of energy.

Endothermic Reactions

- Absorb more energy than they release.
- Result in the absorption of energy.

Chemical Reactions are Essential to Life....

- Two basic chemical reactions are occurring in our bodies..
  1. **Synthesis reactions** = reaction that lead to the build up of compounds (Hydrogen and oxygen combine to form water)
  2. **Decomposition reactions** = reactions that lead to the breakdown of compounds (digestion of foods in the body)

Primary Molecules in Living Things

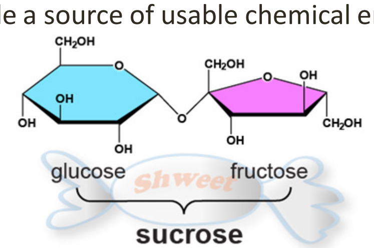
- All organisms are made of four types of carbon-based molecules:

1. Carbohydrates
2. Lipids
3. Proteins
4. Nucleic Acids

- The molecules have different structures and functions, but all are formed with carbon chains and rings.

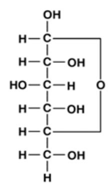
Carbohydrates

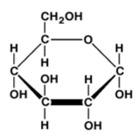
- Carbohydrates are molecules composed of carbon, hydrogen, and oxygen, and they include *sugars* and *starches*.
- Most carbohydrates have a specific ratio of the elements that make them up. That ratio is generally 1C:2H:1O *Example:* $C_6H_{12}O_6$
- Carbohydrates are useful because they can typically be broken down to provide a source of usable chemical energy for cells.



Monosaccharides Sugars

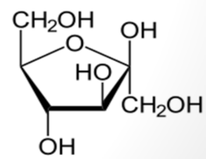
- Carbohydrates are also a major part of plant cell structure.
- The most basic carbohydrates are simple sugars, known as monosaccharides.
- *Monosaccharides* generally contain 5 or 6 carbon atoms, and common examples are glucose and fructose. Glucose is a hexose; fructose is a pentose.





Glucose

Many simple sugars take the form of both chains **and** rings, such as glucose.

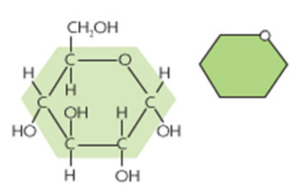


Fructose

Glucose and Fructose

- Glucose is one of the sugars made by plant cells during photosynthesis.
- Fructose is a sugar that is commonly found in fruits.

Fructose is often found in fruits...

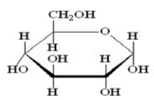


Glucose ($C_6H_{12}O_6$) can be ring shaped and is often shown as a simplified hexagon.

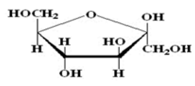
Disaccharide Sugars

- **Monosaccharides** are composed of one simple sugar, such as glucose or fructose.

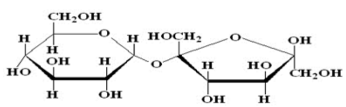
- **Disaccharides** are two simple sugars bonded together. When **glucose** and **fructose** bond together, they form **sucrose.** You probably know sucrose better as **table sugar.**



glucose



fructose



sucrose

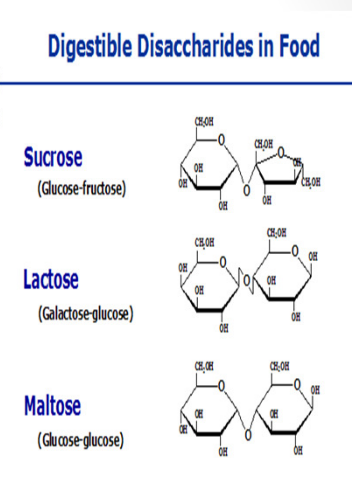
Monosaccharides bond together to form longer chains through DEHYDRATION SYNTHESIS.

Other Disaccharides

- Other disaccharides include lactose (formed from glucose and galactose) as well as maltose (formed from two glucose molecules).

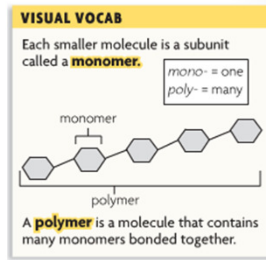
- Galactose is an important component of milk and milk products, including breast milk.

- Maltose is often produced when starch is broken down by amylase, and can be further broken down to produce its glucose subunits.



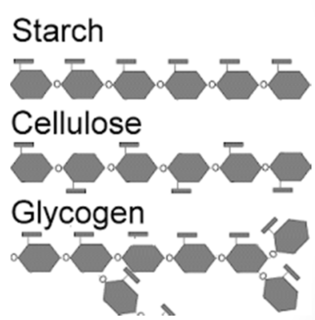
Polysaccharides

- Polysaccharides are long chains of monosaccharides, which can also be called polymers of monosaccharides.
- Recall from before that polymers are long chains of monomers. In this case, the monomers are the monosaccharides.
- Important polysaccharides include starches, glycogen, and cellulose.

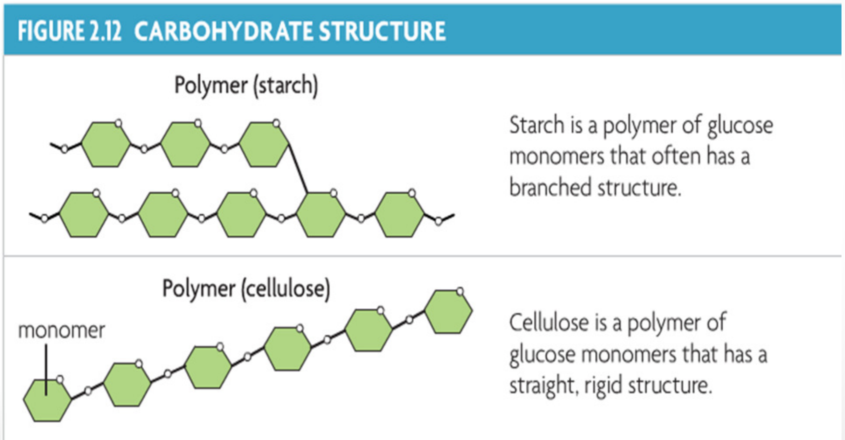


Starch, Glycogen and Cellulose

- Starch and glycogen are very similar. Starch is the storage form of glucose in plants. Glycogen is the storage form of glucose in animals. Found in the liver and regulated by insulin production (more later).
- Cellulose is different from either of these two polysaccharides because of its straight, rigid structure. This makes cellulose hard to break down. You may have eaten cellulose if you have ever tried celery (it's the stringy stuff).



Starch vs. Cellulose



Introduction to Lipids

- Lipids are non-polar molecules that include fats, oils, and cholesterol.
- Lipids, similar to carbohydrates, contain carbon atoms bonded to oxygen and hydrogen atoms.
- Lipids have several different functions in living organisms. Some lipids are broken down for usable energy like carbohydrates. Other lipids are part of a cell's structure.

Lipids

- Many of us are familiar with where lipids (fats) can be found. They are found in animal meat, butter, poultry, Big Macs, etc..
- Unknown to some people, plants also have some lipids (fat).There is plant fat such as peanut oil, olive oil, and others.

Did Somebody Say McDonald's?

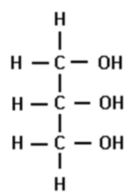
Lipids & Energy

- You may have heard that it is not a good idea to eat too many fats and oils. This is because fats and oils store large amounts of energy in living organisms.
- Of the three macronutrients that provide us with energy, lipids contain the most calories per gram.

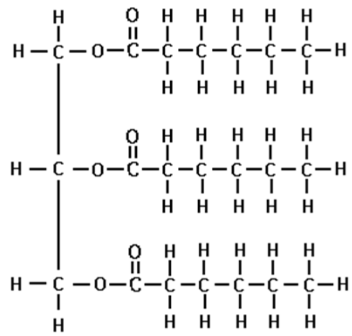
Macronutrient:	Carbohydrates	Proteins	Lipids
Calories per gram:	4	4	**9**

Lipid Structure

- Many lipids consist of three fatty acids bonded to one glycerol molecule. For this reason, lipids are also known as triglycerides.



Glycerol



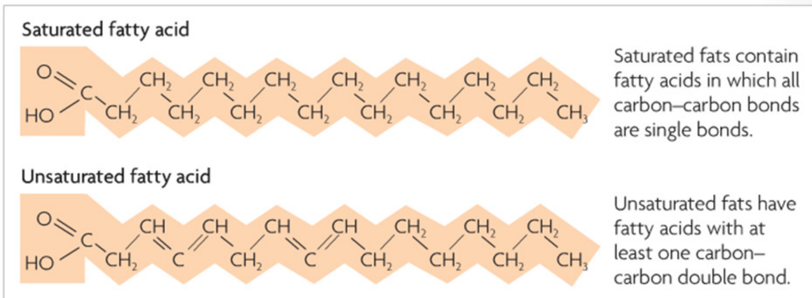
Triglyceride-Saturated

Formation of Lipids *

Saturated vs. Unsaturated Fat

- **You have probably heard of saturated and unsaturated fat. These terms refer to the fatty acids that are connected to the glycerol molecules.**
- **If a fatty acid has as many hydrogen atoms as possible attached to it, than it is a saturated fatty acid.**
- **Oppositely, if a fatty acid does not have as many hydrogen atoms as possible attached to it, than it is an unsaturated fatty acid. *What about the lipid last slide?***

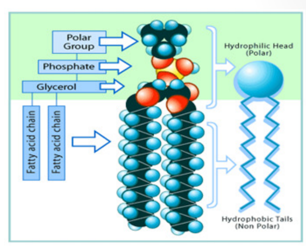
Saturated vs. Unsaturated Fat

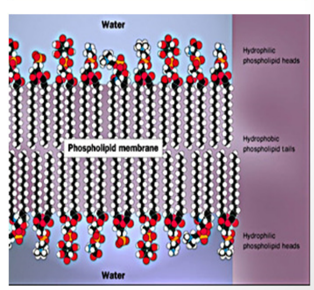


Kinks caused by **double bonds** prevent unsaturated fatty acids from becoming solid – this is why they are generally found as liquids.

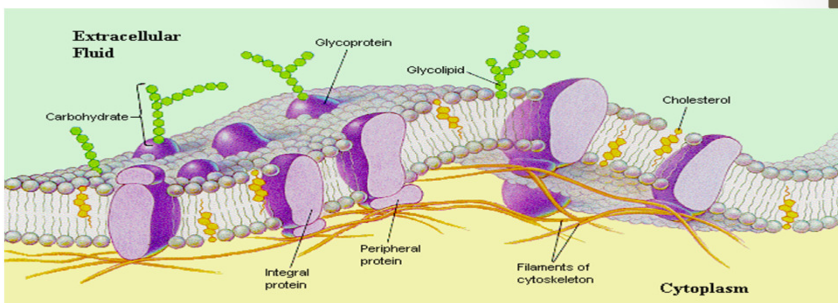
Cell Membrane Structure

- **Lipids**
  - Phospholipids – Composed of a hydrophilic head and two hydrophobic tails.
  - Cholesterol – Regulates the rigidity of the membrane over different temperature ranges.
- **Proteins**
  - **Channel or Gate proteins** – Serve to allow materials in and out of the cell. These proteins are often specific to certain molecules.
  - **Glycoproteins** – Proteins that have a carbohydrate chain on them. Often involved in immune response helping cells to identify one another.
- Together these make up the phospholipid bilayer. – Made up of 2 layers





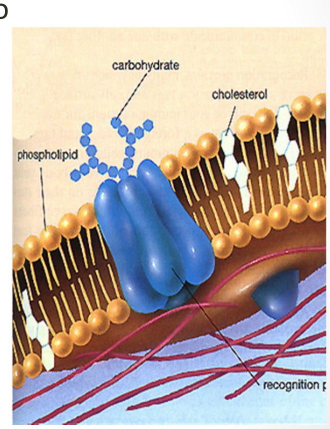
Fluid Mosaic Model



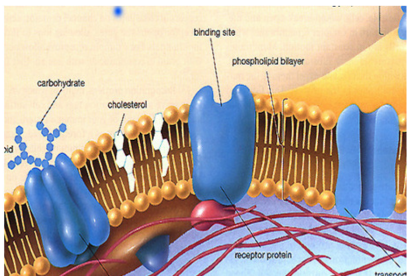
- This describes the idea that the membrane has a fluid-like consistency that allows each phospholipid to move independently throughout the membrane. Lipids can move in laterally or flip-flop.
- All membrane components can move freely as if floating on the surface of the ocean
- The membrane is able to change shape without damaging the cell

Cholesterol in the Membrane

- Allows the animal cell membrane to exist in a wide variety of temperatures
- Warmer temperatures
  - Maintains rigidity of the bilayer – holds it together preventing it from melting
- Colder temperatures
  - Keeps the membrane fluidic, flexible and functional – prevents cell death from a frozen membrane
- Note
  - Plant cells have a different lipid with a similar function



Membrane Proteins



- Have a variety of functions, and cells may have several types on their membrane surface
- Some functions
  - Cell-cell recognition
  - Transport
  - Receptor sites
  - Structural support to cytoskeleton

What are Proteins?

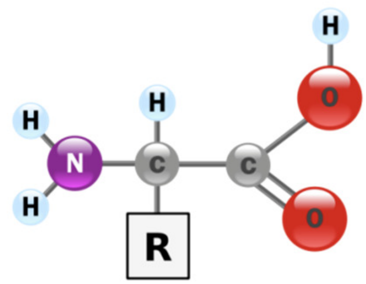
- Similar to lipids and carbohydrates, proteins are composed of carbon, hydrogen and oxygen. However, proteins also contain nitrogen.

- Protein, as you might guess, is mainly found in animal products such as beef, fish, eggs and dairy.

- Protein is also found in some plant sources, like nuts and seeds. It is also found in foods like beans.

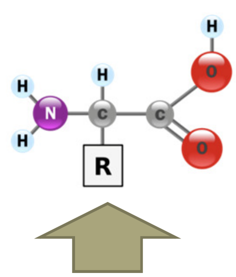
What makes up protein?

- All proteins are made up of tiny structures called **amino acids**.
- All amino acids have a basic structure:
  - A hydrogen
  - A central carbon
  - An amino group(NH_3)
  - An acid group (COOH)



Amino Acids

- Each amino acid has a unique R group, or side group.



- This group is what distinguishes each amino acid from the next.
- There are **20** common amino acids.
  - We will do these more when we study DNA and protein synthesis

Essential Amino Acids

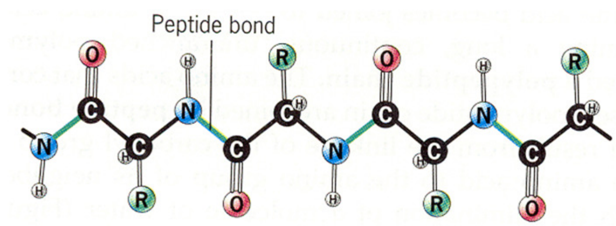
- The human body is able to synthesize (make) 11 of the amino acids on its own, which means you don't need to eat them directly.
- There are 9 essential amino acids. This means that the body CANNOT make these amino acids, so therefore you must get these amino acids from your diet.
- HISTIDINE, ISOLEUCINE, LEUCINE, LYSINE, METHIONINE, PHENYLALANINE, THREONINE, TRYPTOPHAN and VALINE are the essential amino acids.

Formation of Protein

- Amino acids are linked together in a variety of ways to form thousands of different proteins.
- Amino acids are linked together through a **peptide bond.**
- Amino acids are connected to form peptide bonds through DEHYDRATION SYNTHESIS.

Naming Conventions

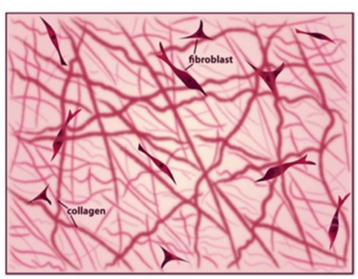
- **Dipeptide**- two amino acids bonded together
- **Tripeptide**- three amino acids bonded together
- **Polypeptide**- Many amino acids bonded together



Roles of Proteins

- Proteins are the building materials for muscles, skin, blood, bone, and almost every other body structure.

- Collagen- a type of protein that is the foundation for bones and teeth, and it also makes up connective tissue (tendons, ligaments, scars).



Proteins in Your Body

- Proteins are needed daily in your body:
  - Muscle cells need protein to grow larger and stronger in response to exercise
  - New proteins are used to synthesize hair and fingernails
  - The lifespan of skin is usually about 30 days. Therefore new cells are required which are mostly made of proteins
  - Cells in the digestive tract are replaced every 3 days!

Sequence Is Everything

- Protein folding is critical, as is the sequence of amino acids!
- If a protein has incorrect amino acids, this may prevent the protein from working properly.
- **Hemoglobin** is a protein in red blood cells that carries oxygen. With just **one** wrong amino acid in hemoglobin, you get **sickle cell anemia.**

The messed up shape of blood cells in people with sickle cell anemia prevents their blood from carrying oxygen properly.

Chemical Reactions and Life

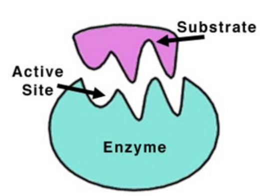
- Inside the human body, as well as all other organisms, there are **millions** of chemical reactions going on **all the time**.

- Chemical reactions that occur in the **cells** of organisms need to occur **quickly**, **accurate,** and **precisely.** Many factors affect the rate of a chemical reaction, but one thing especially helps when we are dealing with living organisms.

Enzymes

- Enzymes are basically catalysts that exist in living organisms. An enzyme's job is to speed up and organize chemical reactions in a cell.
- If you could sum up an enzyme in one sentence, it should be:

- **Enzymes** are protein catalysts that serve in biological reactions.



How do Enzymes Work?

1. Enzyme function is actually very simple. The specific reactants that an enzyme works on are called substrates.
2. When the substrate binds to the enzyme, the entire thing is called the enzyme-substrate complex.
3. The enzyme weakens the bonds of the substrate, allowing the products to form more easily.
4. The products are released from the enzyme, which is then free to bind a new substrate.

Factors Affecting Reaction Rates & Enzyme activity

1. **Temperature** – *an increase in temperature increases the rate of a chemical reaction*.
2. **Concentration** – *a higher concentration of reactants increases the rate of a chemical reaction.*
3. **Surface area** – *an increased surface area increases the rate of a chemical reaction.*
4. **Catalysts** - chemicals may be present that cause reactions to occur, but are not used or involved in chemical reactions.

This orange has a higher surface area than an orange that has not been cut.