Chemistry of the Body, Chapter 2

Outline of class notes

After studying this chapter you should be able to:

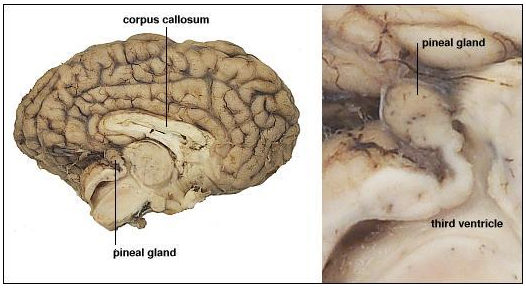
1. Define the terms elements and atoms and be able to list the main elements that make up 99% of the human body.
2. Describe the important properties of water.
3. Describe the following: Acid vs. a base; pH scale; normal blood pH and what can happen when there are deviations; buffers.
4. Describe the 4 organic molecules that make up the human body.
5. Explain the characteristics of carbohydrates, lipids, proteins, and nucleic acids.
6. Describe the characteristics of the following disorders: atherosclerosis; scurvy; keloids; Creutzfeldt-Jakob disease or Kuru.
7. Describe the characteristics of enzymes
8. Discuss the Clinical Applications from the study guide and assigned Applications to Health.

Chemistry of the Body, Chapter 2

- **Does Turkey Make you Sleepy?**
- **Elements and Atoms**
- **Inorganic Chemistry**
  - Importance of H2O
  - pH
- **Organic Molecules**
  - Four major classes of organic molecules: Proteins, Lipids, Carbohydrates, Nucleic Acids

Does Turkey Make You Sleepy?

- Turkey contains relatively high levels of the amino acid **tryptophan**.
  - **Tryptophan** is used to make **serotonin** – a neurotransmitter that plays a role in mood and can create a feeling of well-being and relaxation.
    - **Serotonin** can be converted to **melatonin** which is produced (usually at night) within the brain by the **pineal gland**.
  - **Melatonin** is thought to promote sleepiness and regulate our **circadian rhythms** (24-hour cycle in the physiological processes of living beings) and its release is slowed when light enters the eyes
- Most protein rich foods such as meats and dairy products contain high levels of tryptophan.
- Fish contains higher levels of tryptophan than turkey
- **Answer:**



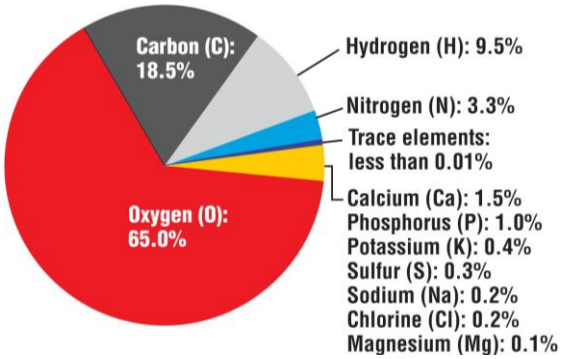
Elements and Atoms

- **Element:** Substance that cannot be broken down to
  - An **atom** is the smallest unit of an element that still retains the properties of that element.
  - Know the symbols for these 14 essential Elements

C	Carbon	**Na**	Sodium
H	Hydrogen	**K**	Potassium
O	Oxygen	**S**	Sulfur
N	Nitrogen	**Mg**	Magnesium
P	Phosphorus	**Cl**	Chlorine
Ca	Calcium	**Fe**	Iron
I	Iodine	**Zn**	Zinc

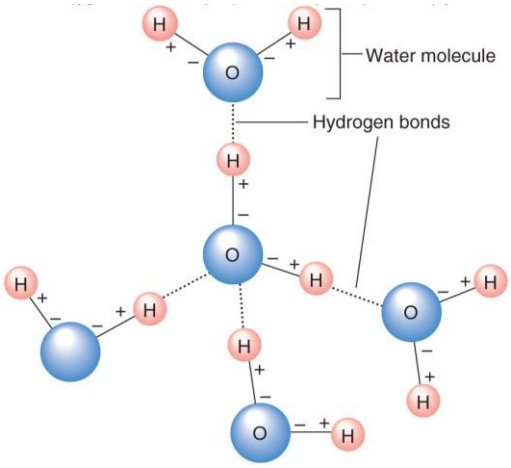
Chemical Composition of the Body

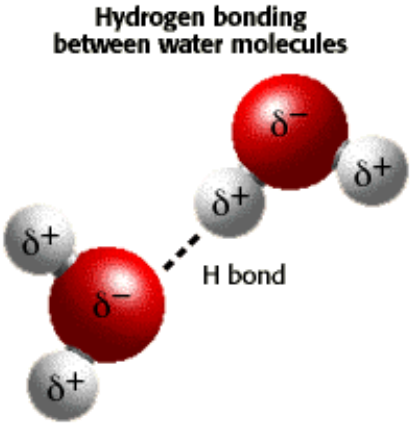
- There are 118 known elements.
  - ~
- C, H, O, N, Ca, P make up 99% of our body



Hydrogen Bonds

- **Hydrogen bonds**
  - Weak bond that forms between a partially positive hydrogen atom of one polar molecule that is attracted to the partially negative atom of another polar molecule.
  - Ex: Hydrogen bonds exist between adjacent water molecules. The H^+ of one H_2O molecule is attracted to the oxygen of another H_2O molecule.
  - Hydrogen bonds give water its unusual properties.



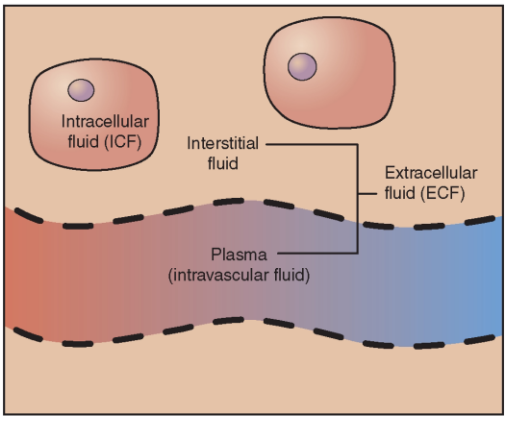


Properties of Water

- Properties of water that make it vital to life include:
  - **Participation in chemical reactions:** Chemical reactions occur in water and water molecules can participate in some reactions.
  - **Excellent Solvent**: Water dissolves a number of ions and molecules
  - **Lubrication:**
    - Ex: Within joints; between organs within the ventral body cavities.
  - **High heat capacity**: Absorbs and releases heat very slowly - helps the body to redistribute heat via circulating blood.
    - Sweat evaporation on the skin takes large quantities of heat and helps to cool the body via perspiration.

Distribution of Water in the Human Body

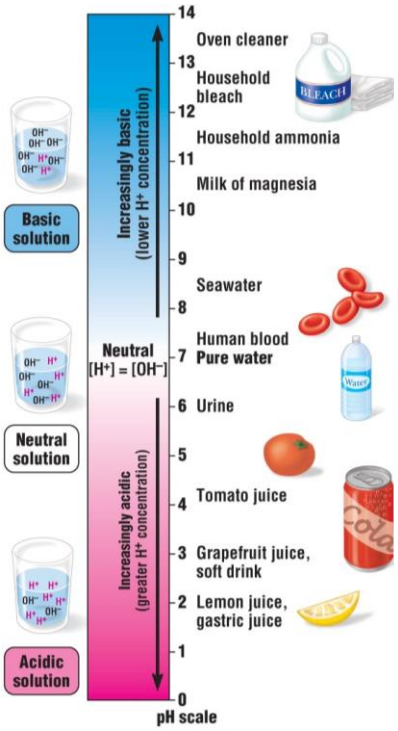
- About
  - 2/3 of this water is found within your cells referred to as ***intracellular fluid (ICF)***
  - The other 1/3 is outside your cells so we call it ***extracellular fluid (ECF)***



Acids and Bases

- **Acid:** A substance that

- **Base:** A substance that usually releases hydroxide ions (OH-) in water.

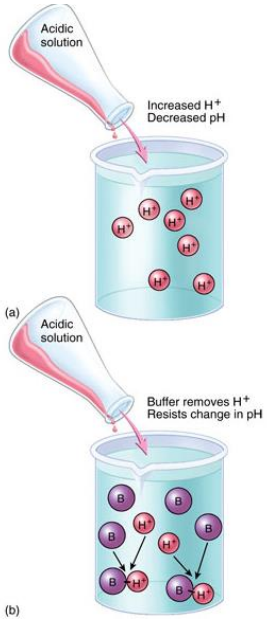


The pH Scale

- **pH scale:** Used to measure the hydrogen ion (H+) concentration in a solution, but is commonly used to measure the degree of the acidity or the alkalinity of a solution.
  - Scale ranges from 0 to 14
  - The **"p"** stands for power and **"H"** stands for hydrogen ions, thus it can be viewed as the **power of Hydrogen**.
  - The pH scale is **logarithmic** which means that moving one unit either way on the pH scale results in a **10 fold** change in the degree of alkalinity or acidity.
  - A change of one unit on the pH scale represents a **10-fold** change in H+ concentration
    - Example: A solution of pH 6.0 has 10 times more H+ than a solution with a pH of 7.0
- **Neutral solution** (pH = 7): contains equal number of H+ and OH- ions
- **Acidic solution** (pH less than 7): contains more H+ than OH- ions
- **Alkaline or basic solution** (pH greater than 7): contains less H+ than OH- ions
- **Important!!**
  - As the pH value becomes smaller, the solution is **more acidic**
  - As the pH value becomes larger, the solution is **more basic or alkaline**

Humans and pH

- The normal pH range for
  - **Acidosis** is a condition that results if blood pH drops below 7.35.
    - The nervous system becomes depressed, and the individual becomes disoriented and possibly comatose
  - **Alkalosis** is a condition that results of blood pH rises above 7.45.
    - The nervous system becomes over excitable and the individual may be extremely nervous and have convulsions.



Buffers

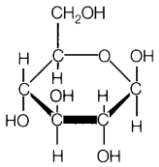
- **Buffers:**
  - Buffers absorb excess H+ and OH- ions as they are added to a solution and then return them when they are needed.
- Can You think of a buffer that is commonly used?
- , otherwise known as baking soda, is used in antacids such as Alka-seltzer and Rolaids to neutralize excess hydrochloric acid in the stomach.

Organic Molecules

- **Organic Chemistry**
  - Four major classes of organic molecules: **Carbohydrates, Lipids, Proteins,** and **Nucleic Acids**

Carbohydrates

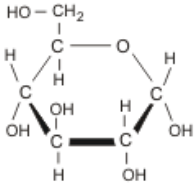
- **Carbohydrates:** Are composed of carbon, hydrogen and oxygen atoms and include sugars and starches



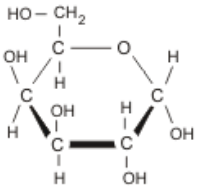
  -
  - The ratio of C:H:O is nearly 1:2:1, meaning that for every carbon atom there are two hydrogen and 1 oxygen atom
    - The ending "<u>hydrate</u>" was given since the hydrogen and oxygen occur in a 2:1 ratio, the same as in water

Classification of Carbohydrates

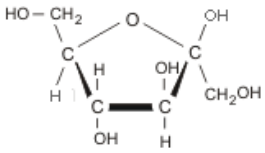
- The classification of carbohydrates is
  - **<u>Monosaccharides</u>** (simple sugars)
    - Contain 3 to 7 carbon atoms
    - Examples: **glucose** ($C_6H_{12}O_6$) – blood sugar, **fructose** ($C_6H_{12}O_6$) – fruit sugar, and **galactose** ($C_6H_{12}O_6$), which are all <u>isomers.</u>
      - **<u>Isomers</u>** are chemicals that have the same formula, but differ in their arrangement of atoms.



Glucose

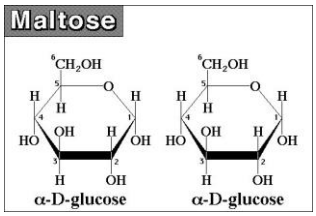


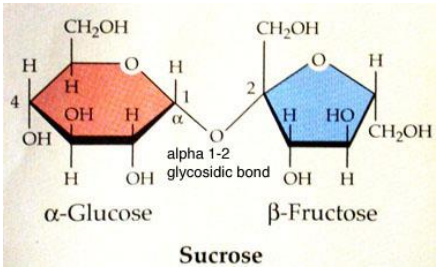
Galactose

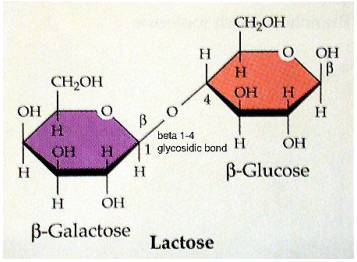


Fructose

- **<u>Disaccharides (two sugars)</u>**
  - Are two
  - Examples include **Maltose** (glucose – glucose), **sucrose** or table sugar (glucose – fructose), and **lactose** or milk sugar (glucose – galactose).





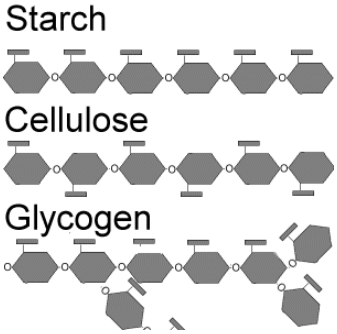


Lactose Intolerance

- **Lactose intolerance**:
  - The enzyme **lactase**, produced by the cells of the small intestine, breaks down the disaccharide **lactose (milk sugar)** into glucose and galactose.
  - Bacteria in the large intestine use the undigested lactose and cause the uncomfortable symptoms, such as bloating, gas, and diarrhea

Classification of Carbohydrates (cont)

- **Polysaccharides:** Consist of many monosaccharides bound in long chains.
  - **Polysaccharides** of <u>glucose</u> consist of:
    - **<u>Glycogen:</u>** storage form of
      - Large glycogen stores occur in the liver and skeletal muscles
      - Cells can break down glycogen into glucose molecules and use glucose for energy.
    - **<u>Starch:</u>** storage form of



Lipids

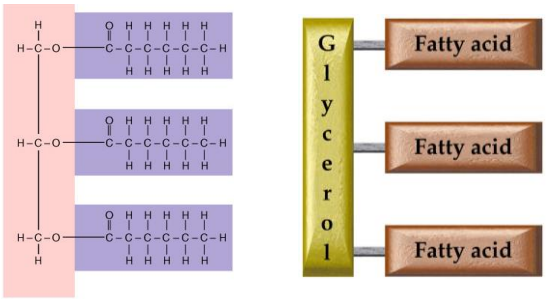
- **Lipids** are hydrophobic substances that dissolve in nonpolar solvents, such as alcohol or acetone, but not in polar solvents such as water.
  - **Hydrophopic** (water fearing) – substances that do not mix well with water.
- Four important types of lipids are: **fats and oils, waxes, phospholipids,** and **steroids**

Fats: Function/Classification

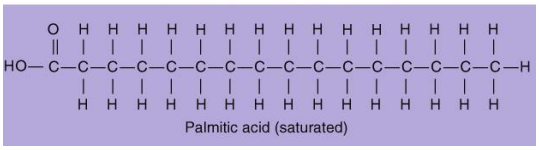
- **Function** as energy storage molecules, cushion vital organs, and provide insulation to keep you warm.
- Fats and oils are classified into three major groups depending on their chemical structure:
  1.
  2. (polyunsaturated and monounsaturated)
  3. (partially hydrogenated – chemically altered fats found in manufactured foods).

Fats: Structure

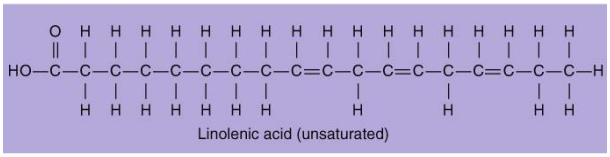
- Building blocks of fats are **glycerol** and **fatty acids**
  - **Triglycerides** have three fatty acids bound to a glycerol molecule and are the most common type of fat molecules



  - Fatty acids differ according to their length and degree of saturation
    - **Saturated fatty acids** contain
      - Sources include meat, whole milk, cheese, butter, coconut oil, and palm oil.



    - **Unsaturated fatty acids** have fewer than the maximum number of hydrogen atoms.
      - **Monounsaturated fats** have one double covalent bond. Include olive and peanut oils.
      - **Polyunsaturated fats** have two or more double covalent bonds. Include safflower, sunflower, corn, and fish oils.



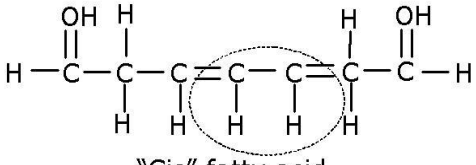
Simple Rule for Rating Fats

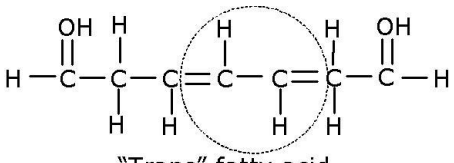
- Fats that are liquid at room temperature are more unsaturated than fats that are solid at room temperature.
  - The lower the temperature that a fat becomes solid, the less saturated it is.

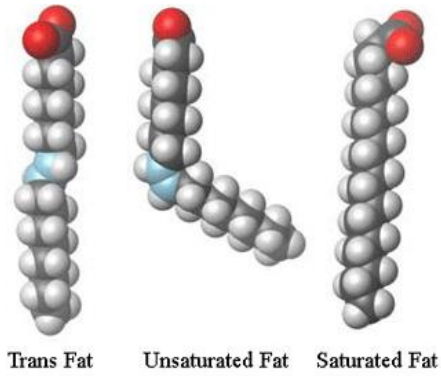
Trans Fats

- **Hydrogenation**: Process by which hydrogen is added to unsaturated fats (vegetable oil) to make them more saturated.
  - Process improves texture and shelf life of foods.
  - Example:

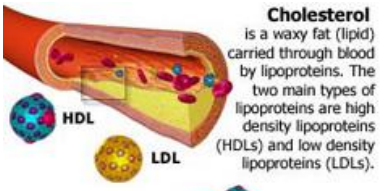
- **Trans fat:** During hydrogenation a certain percent of the fats can become trans fats.
  - In the normal *Cis'* configuration, hydrogen atoms on the same side of the double bond.
  - In the trans configuration: Hydrogen atoms on different sides of the double bond.

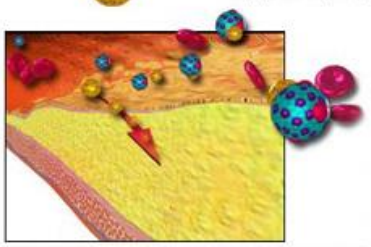






- **Trans fats are unhealthy**
  - **Raise LDL**, or bad cholesterol.
  - **Lower HDL**, or good cholesterol, actually making them worse for the body than saturated fat.
  - Appear to **increase blood triglyceride levels** and increase the risk for <u>atherosclerosis</u> and heart disease.





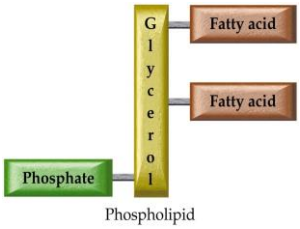
HDLs (good cholesterol) carry LDLs (bad cholesterol) away from artery walls. LDLs stick to artery walls and can lead to plaque build-up (atherosclerosis).

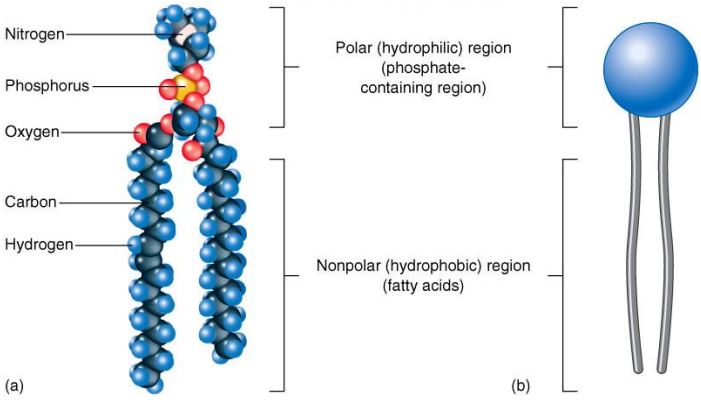
Atherosclerosis

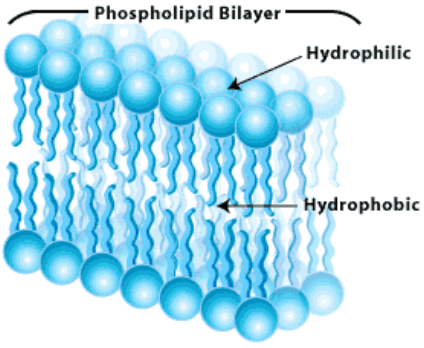
- Condition in which lipid-containing deposits called **plaque** build up in the walls of blood vessels, reducing blood flow and increasing risk of **heat attacks** and **strokes**.
  - <u>Triglycerides</u> and <u>cholesterol</u> are incorporated into <u>**lipoproteins**</u> for transport within the blood
    - <u>**H**</u>**igh density Lipoproteins**: (<u>**H**</u>appy Lipoproteins)
    - <u>**L**</u>**ow density lipoproteins**: (<u>**L**</u>ousy Lipoproteins) carry cholesterol to cells and can deposit in the arterial walls.

Phospholipids

- <u>**Phospholipids**</u> are like a triglyceride in which a phosphate containing molecule has replaced a fatty acid.
  - They contain
  - The **fatty acids** in a phospholipid are nonpolar and insoluble in water or hydophobic (water fearing)
  - The **phosphate** group makes the phospholipid polar and therefore soluble in water or hydrophillic (water loving)
  - Molecular aspects of phospholipids make them crucial components of cellular membranes



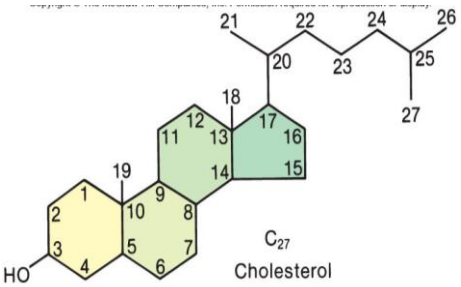


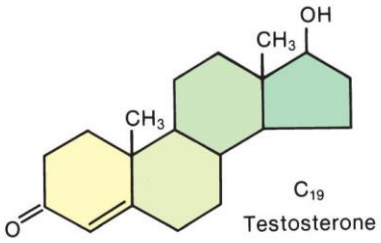


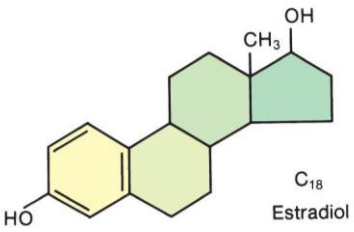
Steroids

- **Steroids** classified as

  - **Steroids** are composed of carbon atoms bound together into four ring-like structures.
  - **Cholesterol** is the parent molecule (precursor) from which many other steroids are synthesized
    - Component of bile salts: increase fat absorption in the intestine
    - Reproductive hormones: estrogen, progesterone, and testosterone.
      - **Anabolic steroids** are synthetic variants of testosterone
    - Cholesterol is an important component of cell membranes – provide rigidity.







Proteins

- **Proteins** are the most abundant organic components of the human body (about 20% of the body weight)
- Proteins provide a variety of essential functions
  - **Support:** Structural proteins (e.g. keratin, collagen) provide framework for cells, tissues, and organs.
  - **Movement:** Contractile proteins (actin and myosin) are responsible for muscle contraction
  - **Transport:** Lipids, respiratory gasses, and several hormones are carried in the blood attached to transport proteins (globular proteins).
  - **Defense:** Antibodies and the immune system
  - **Enzymes:**

What disorder results from improper formation of collagen protein?
Answer:

- **Characteristics:** Joint and muscle aches, bleeding gums, loose teeth, a ots or hemorrhages on the skin
- **Cause:**

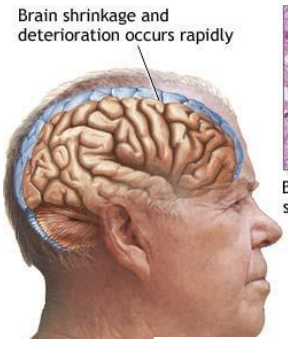
  - Vitamin C is required by key enzymatic reactions for proper **collagen** formation.
- **Treatment:** Ingest foods (fruits/vegetables) with vitamin C

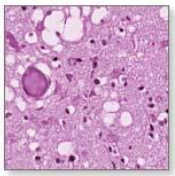
Keloids

- **Keloid:** Overgrowth of a Scar. Excessive **collagen** formation, used in wound repair
  - Non contagious
  -
- **Cause:** Damage to skin. Can be something as simple as ear piercing, pimple, or scratch
  - Reason for excessive growth is unknown
- **Treatment:** Remove the scar completely, but there is a 50% probability the Keloid will return.

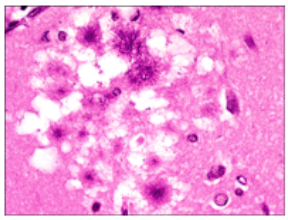
Prions: Protein Folding Gone Bad

- **Prion Proteins** are thought to cause:
  - **Mad Cow Disease** (Bovine Spongiform Encephalopathy), **Scrapie** (sheep), and its human counterpart **Creutzfeldt-Jakob disease** and **Kuru**.
- **Prions** are pathogenic variants of a protein normally produced in nerve cells and found on the cell surface.
  -
  - Rouge prions force normal prion proteins to change shape and become pathogenic.
  - Prions can arise spontaneously, through mutation or be passed along when an animal eats infected nervous-system tissue.





Brain section showing spongiform pathology characteristic of Creutzfeldt-Jakob



nvCJD cerebral cortex showing the "florid" plaques that consist of vacuoles (spongiform degeneration) containing amyloid plaques

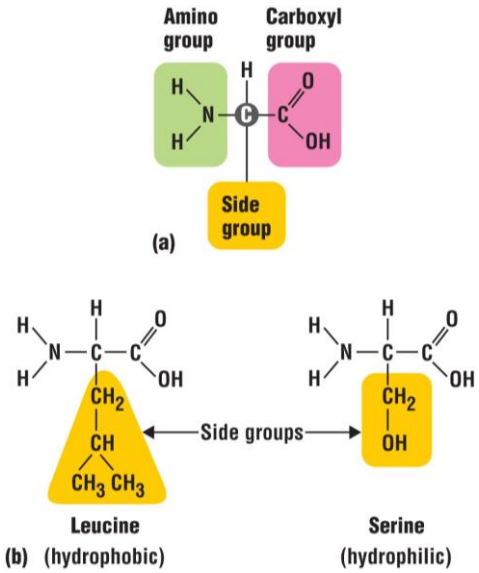
Prions: Mode of Entry

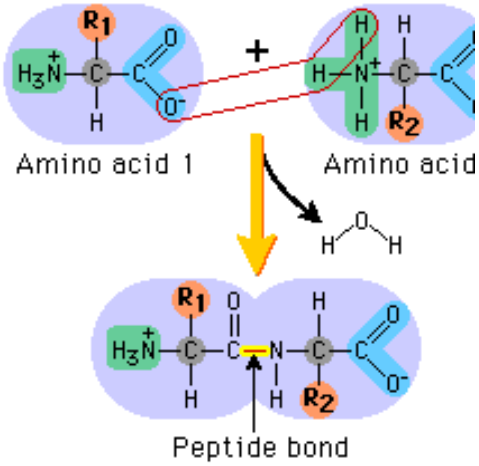
- **Prions** are thought to enter the body form the intestines then travel to the brain along the axons of neurons
- **Prions** cause formation of **amyloid plaques** in the brain, eventually killing the nerve cell.cause formation of

Building Blocks of Proteins

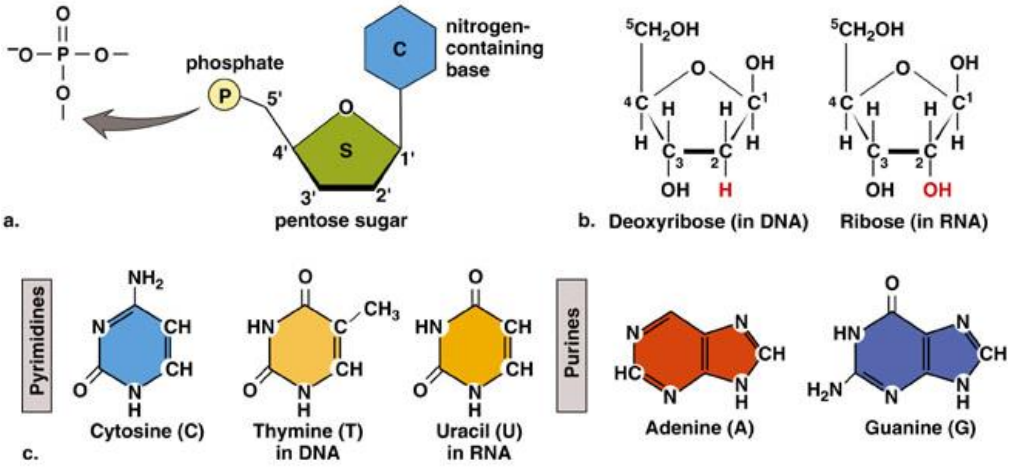
- **Amino acids (AA)** are the building blocks of proteins
  - There are **20 different AA** of which **8 are essential** (meaning the body is unable to synthesize these and must be supplied by diet).
  - Each amino acid consists of a central carbon to which four groups are attached:
    (1)
    (2)
    (3) a carboxyl group (-COOH)
    (4) a **variable group** (**side groups**) designated as "R", which gives that AA special chemical properties and distinguishes one AA from another.

Peptide Bonds:





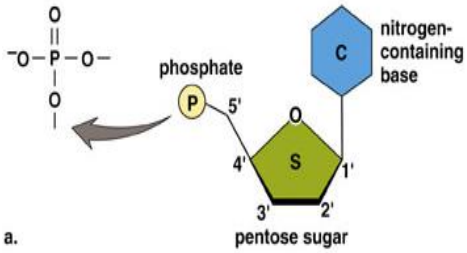
Nucleotide Structure



Nucleic Acids

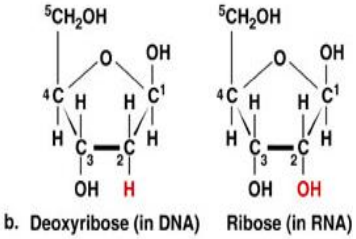
- **Nucleic acids:**.
  - Are information storage molecules that provide the directions for building proteins and involved in the transmission of energy.
  - Are the only organic compounds <u>capable of replicating themselves</u>
  - Nucleic acids Include:
    - Deoxyribonucleic acid (DNA)
    - Ribonucleic acid (RNA)
    - Adenosine triphosphate (ATP).

Nucleic Acids are made from Nucleotides



- **Deoxyribonucleic acid (DNA)** and **Ribonucleic acid (RNA)** consist of long chains (polynucleotides) of chemical monomers called **nucleotides**.
- A **nucleotide** consists of three main parts:
  1.
  2. **A sugar** (<u>ribose</u> in RNA or <u>deoxyribose</u> in DNA)
  3. **A nitrogenous base**: either adenine (abbreviated A), guanine (G), cytosine (C), thymine (T), or uracil (U).

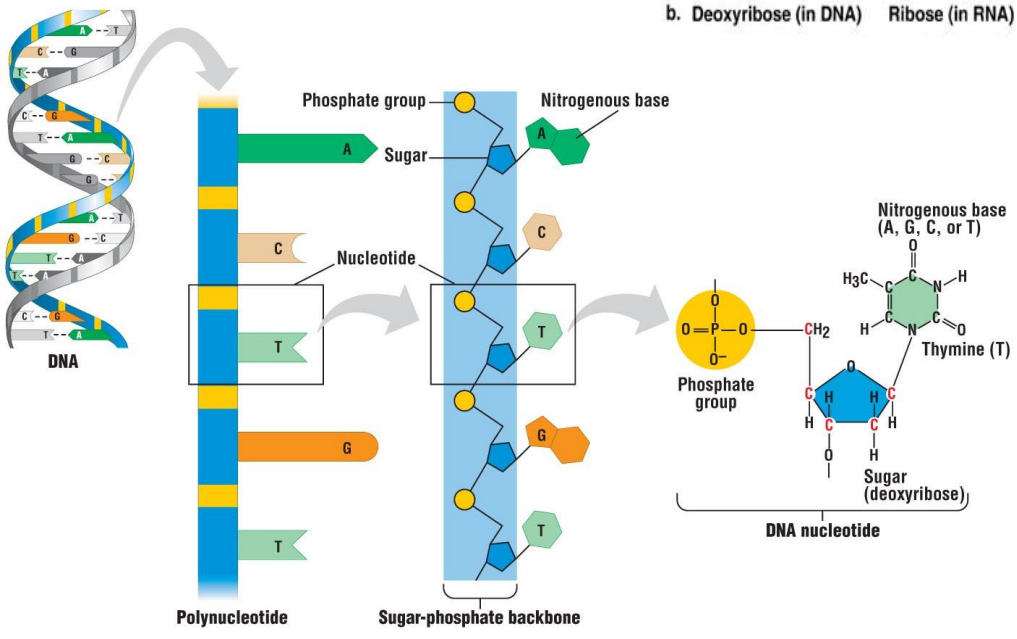
Sugar Component of Nucleotides



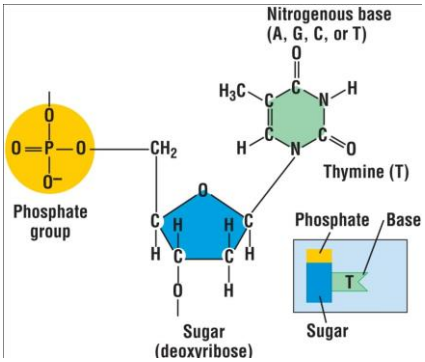
- **RNA**
  - The ribose sugar has an extra –OH group compared with the deoxyribose sugar (deoxy means “without oxygen).
- **DNA**

Sugar-phosphate backbone

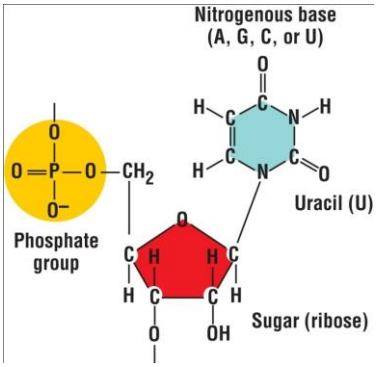
- The nucleotides are joined together by a **sugar-phosphate backbone**.
  - Repeating pattern of sugar-phosphate-sugar-phosphate make up the **sugar phosphate backbone**.



Deoxyribonucleic Acid (DNA)



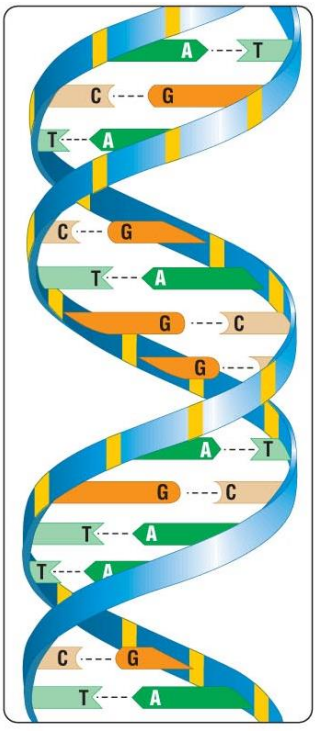
- DNA is found in the nucleus of cells and contains the genes that directs the cell's activity.
- The four nucleotides found in DNA:
  -
  - Are thymine (T), cytosine (C), adenine (A), and guanine (G).
- **DNA** functions to store genetic information and direct the production of proteins.
  - A **gene** is a sequence of DNA nucleotides that serves as a blueprint for the
  - **Genes** determine the rate and type of chemical reactions that occur in cells by controlling enzyme structure and thus cellular activity.



Ribonucleic Acid (RNA)

- **RNA** functions in
  - RNA is single stranded
- The four nucleotides found in RNA:
  - Are cytosine (C), adenine (A), guanine (G) and uracil (U).
  - RNA has **uracil (U)** in place of **thymine**
    - Uracil is structurally very similar to thymine

Base Pairing within DNA



- Base pairing of DNA is as follows
  - Adenine (A) pairs with
  - Guanine (G) pairs with
- The model of DNA is like a rope ladder twisted into a spiral.
  - DNA is double stranded
  - The sides of the ladder represent the sugar-phosphate backbone
  - The rungs represent the paired bases

Test Your Knowledge

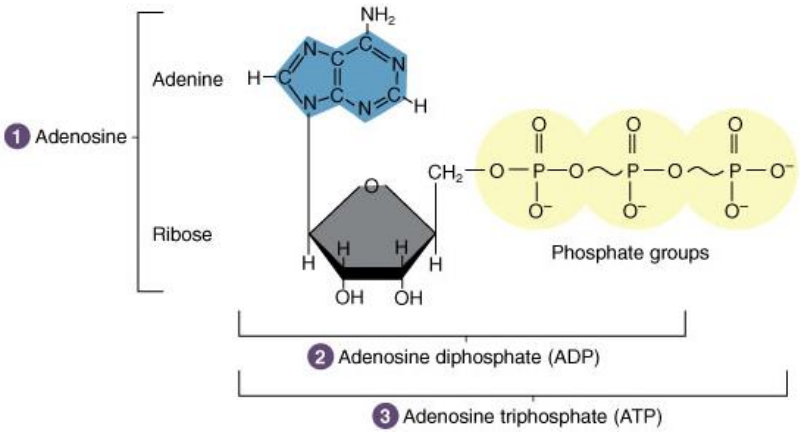
- Compare the structure of DNA and RNA

	Type of sugar	Types of bases
DNA		
RNA		

Adenosine Triphosphate (ATP)

- **ATP** consists of adenosine (ribose and adenine) and three

- The potential energy stored in the covalent bonds of the phosphate groups provides the energy used in nearly all of the chemical reactions within cells.
- **ATP** is called the energy currency of cells because it is capable of both storing and providing energy.



Enzymes Highlights

Enzymes:

-
- Speed up chemical reactions by lowering the activation energy
-

- Molecular interaction analogous to a “lock-and-key” model.
- Enzymes are very specific in their function

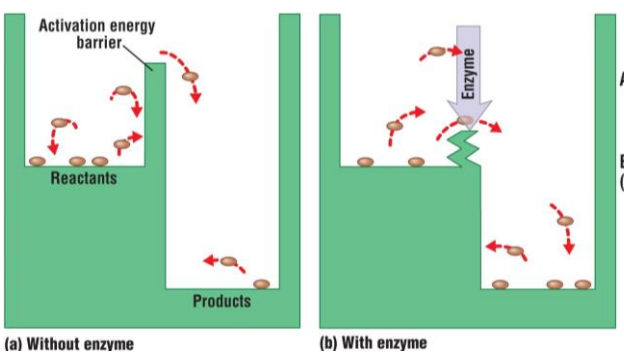
Enzyme Function

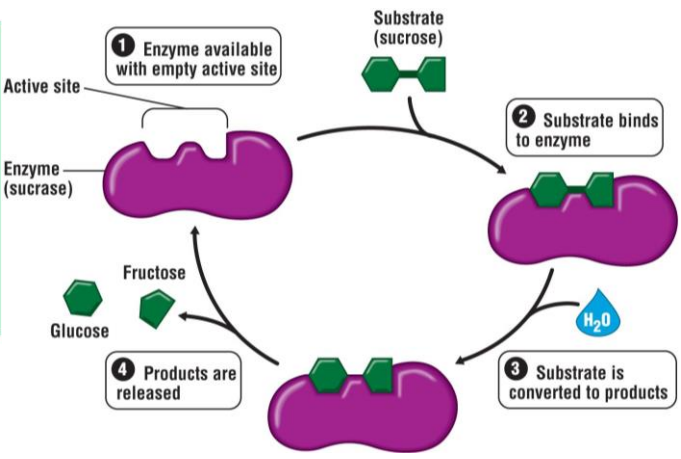
- **Enzymes** are proteins that speed up (catalyst) chemical reactions in the body.
  - Enzymes function by lowering the **Activation energy,** which is the energy necessary to start a chemical reaction.
  - **Enzymes** arrange the **substrates** (**reactants**) in the right orientation so that they react to form a product or be broken apart
  - **Enzymes** are usually not destroyed during a reaction and can be used over and over again.
  - Enzyme names usually end in –ase.
    Example:

Active Site

- **Enzymes** have a specific shape (confirmation) with

  - These pockets are the enzymes **<u>active site</u>**
- Specific **substrates** have a shape that allows them to fit into the active site known as the “**lock-and-key**” model of enzyme action.





Conditions that affect Enzyme Activity

- Concentration of enzyme or substrate
- Extreme pH values can change the enzyme's shape (**denature**) and make it less effective.
- Low temperatures slow enzymatic reactions – as temperatures increase the rate of the reaction also increases to a point.
- At a few degrees above body temperature (37°C or 98.6°F) there is a decrease in activity and high temperatures **denature** enzyme shape and permanently stop its activity.