RU RMT 2
Anatomy and Physiology
Lecture 3
Cell Bio Chemical Level

Water as a Solvent

In a chemical **solution:**

A substance (called the **solute)** dissolves in a liquid (called the **solvent).** The solvent is typically water.

There are 2 types of solutes:

1. **Hydrophillic solutes**
   * Water loving, dissolve easily in water
2. **Hydrophobic solutes**
   * Water fearing, not soluble in water

Compounds and Solutions

A **compound** is a molecule made of atoms from different elements, bound via chemical bonds.

Organic Compounds

* Always contain carbon, and usually contain hydrogen
* Large molecules, make up a large portion of the human body

Inorganic Compounds

* Lack carbon
* More simple molecules

Mixtures

A **mixture** is a blend of elements or compounds not bound by chemical bonds.

The components of a liquid mixture include:

1. Solute: the solid component of a mixture
2. Solvent: the liquid component of the mixture

Mixtures

Three common liquid mixtures are:

1. **Solutions**
   * Solutes are very small and are evenly dispersed among the solvent molecules
   * Solutes do not settle or accumulate at the bottom
   * Solutes look transparent (eg. saline)
2. **Colloids**
   * Solutes are large enough to scatter light, hence colloid appears translucent or opaque (eg. milk)
   * Solutes do not settle or accumulate at the bottom
3. **Suspensions**
   * Solutes of large enough for sedimentation, therefore a suspension is not transparent (eg. blood)

Percentage and Molarity

Percentage and molarity are two different methods of describing the concentration of solute in a solution.

Percentage gives the relative mass of a solute in a given volume of solution (eg. beer has 5% alcohol)

Molarity relates to the number of molecules in a given volume of solution (measured in moles per litre – mol/L)

Acids and Bases

Acids dissociate into one or more hydrogen ions (H+) when dissolved in water

Bases dissociate into one or more hyroxide ions (OH--) when dissolved in water.

Acid--Base Balance: The Concept of pH

Biochemical reactions are very sensitive to even small changes in acidity or alkalinity

The more hydrogen ions (H^+) that are dissolved in a solution, the more acidic the solution becomes, while the more hydroxide ions (OH^-) dissolved in a solution, the more basic (alkaline) is the solution

Acid--Base Balance: The Concept of pH

The acidity or alkalinity of a solution is denoted as pH, and is measured on a scale of 0--14.

* **pH 7:** Neutral (concentration of H+ and OH-- are equal
* **pH < 7:** Acidic Solutions (more H+ than OH--)
* **pH > 7:** Alkaline (Basic) Solutions (more OH-- than H+)

The pH values of different parts of the body, particularly the blood, is maintained within narrow limits by the presence of buffer systems.

Carbohydrates

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Carbohydrates

* Carbohydrates are a large group of organic compounds present in the body
* Carbohydrates consist of the elements carbon (C), hydrogen (H), and oxygen (O)
* They are mainly used to provide energy in the body
* Ex: Glycogen, starches and cellulose

Carbohydrates

Carbohydrates are divided into three major groups based on their size, and include:

1. Monosaccharides
2. Disaccharides
3. Polysaccharides

Monosaccharides

Monosaccharides (mono= one, sacchar = sugar)

* Simple sugars that contain about 3--7 carbon atoms
* Ex. Glucose and galactose

Disaccharides

Disachharides (di= two)

* Simple sugars formed from the combination of two monosaccharides
* Ex. Lactose is formed by glucose and galactose

Polysaccharides

Polysaccharides (poly = many)

* Combination of 10's to 100's of monosaccharides
* The major polysaccharides include:
  * Glycogen
  * Starches
  * Cellulose

Glycogen

Glycogen

* It is composed entirely of glucose molecules and present only in humans and animals
* It is stored in the liver and skeletal muscles
* It is released into the blood as glucose when needed

Starches

Starches

* It is a major carbohydrate and is found only in plants
* It is composed entirely of glucose molecules
* It is found in foods such as pasta and potatoes

Cellulose

Cellulose

* It is also composed entirely of glucose molecules and is found only in plants
* It cannot be digested by humans and so provides roughage

Lipids

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Lipids

* In lean adults, lipids make up about 18--25% of body mass

* Lipids contain carbon, hydrogen and oxygen (lipids are organic compounds)

* Most lipids are insoluble in water (hydrophobic)

Fatty Acids

* Fatty acids are the simplest form of lipid

* Fatty acids are the building blocks which are used to form larger lipids, specifically triglycerides and phospholipids

* Lipids can be catabolized (broken down) to generate cellular energy (ATP)

Fatty acids

There are two types of Fatty acids:

1. Saturated fatty acids

* Contain only single, covalent bonds between the carbon atoms of the hydrocarbon chain

2. Unsaturated fatty acids

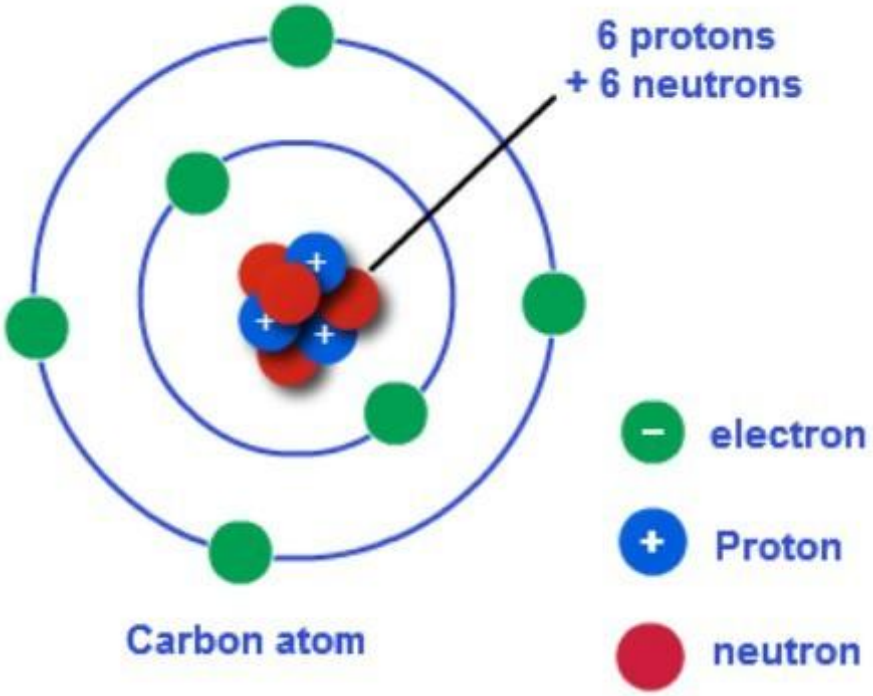
* Contain one or more double, covalent bonds between the carbon atoms of the hydrocarbon chain

Covalent Bonds Reviewed

Covalent bonds occur when atoms share electrons to complete their valance shells.

Covalent bonds between atoms can be **single**, with two electrons shared; **double**, with four electrons shared; or **triple bonds**, with six electrons shared.

Carbon Reviewed



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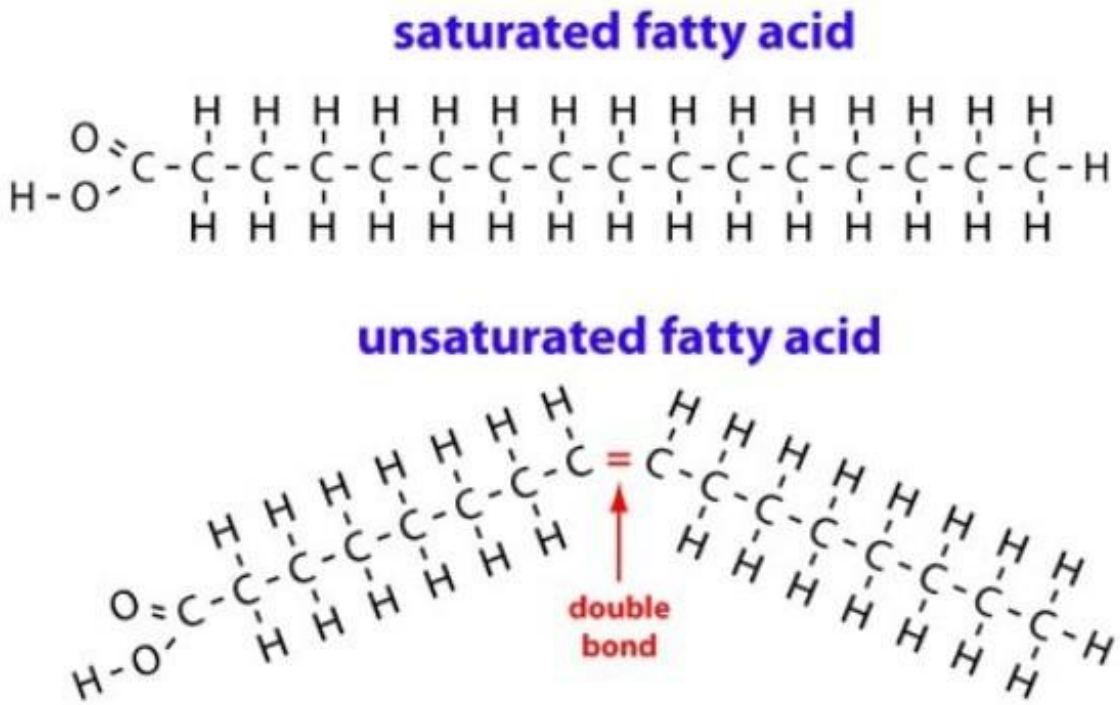
Fatty acids



Unsaturated Fatty Acids

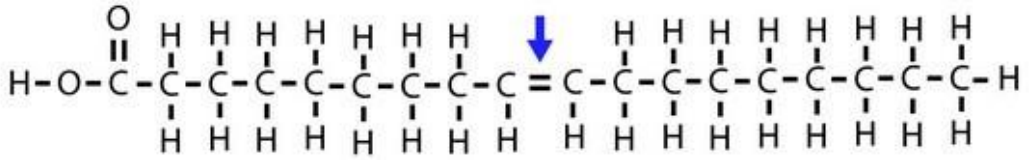
There are two types of unsaturated fatty acids:

1. Monounsaturated
   * One double bond in the hydrocarbon chain

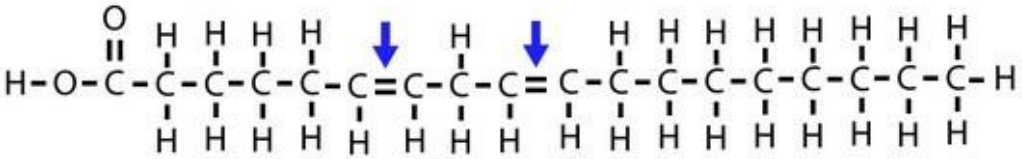
2. Polyunsaturated
   * More than one double bond in the hydrocarbon chain

Unsaturated Fatty Acids

Oleic acid - Monounsaturated fatty acid



Linoleic acid - Polyunsaturated fatty acid



Triglycerides

* Triglycerides are the most plentiful lipids in the body and the diet
* Simply put, triglycerides are fat in the blood
* Triglycerides can be broken down to provide energy (providing more than twice as much energy per gram compared to carbohydrates and proteins)
* Excess dietary carbohydrates, proteins and fats are all stored as triglycerides in adipose (fat) tissue

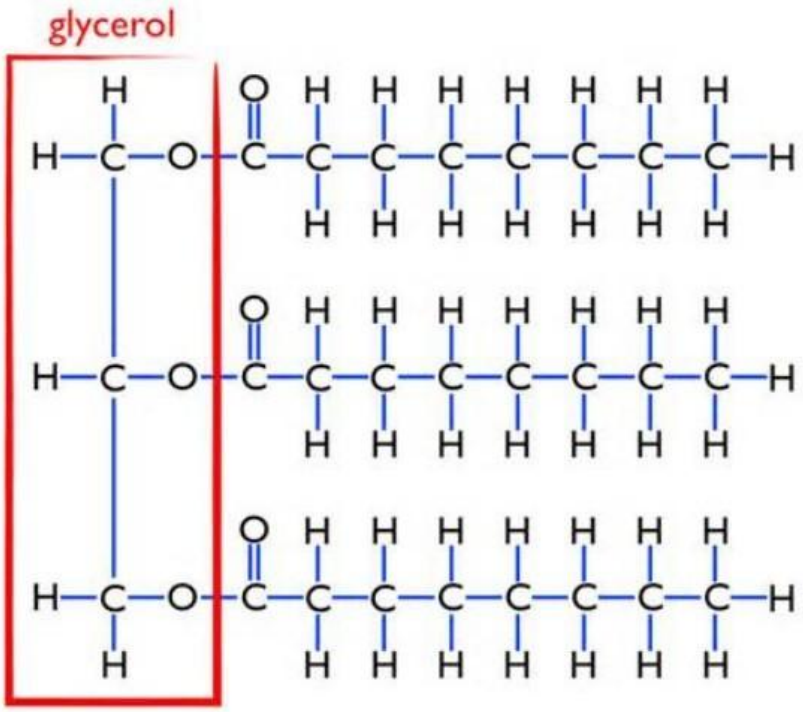
Triglycerides

Each triglyceride molecule consists of:

* One glycerol molecule
* Three fatty acids

Triglycerides can be either solids or liquids at room temperature

Triglycerides



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Triglycerides: Fat

1. Saturated fats

* Solid at room temperature
* Meat and animal products (butter, cheese), coconut oil, processed foods (cookies, cakes, chips)

2. Unsaturated fats

i. Monounsaturated fats

* Eg. olive oil, avocados, nuts

ii. Polyunsaturated fats

* Eg. vegetable oils, fish, nuts and seeds
* Omega 3s (reduce triglycerides in blood)

Triglycerides: Fat

3. **Trans fat**

* A type of unsaturated fat created via industrial processes (artificial)
* Hydrogen is added to liquid vegetable oils to make them more solid
* The primary dietary source for **trans fats** in processed food is "partially hydrogenated oils."
* eg. margarine, snack foods, baked goods

Phospholipids

Composed of:

* One glycerol molecule
* Two fatty acid chains
* One phosphate group

Steroids

* Steroid hormones are a type of lipid, made from cholesterol
* They have a variety of functions within the body
* The most important steroids are estrogen, progesterone and testosterone involved with the reproductive system

Prostaglandins

These are a group of lipids that have a variety of functions that include:

* Modifying responses to hormones
* Contribute to inflammatory responses
* Dilatation of airways to the lungs
* Regulation of body temperature
* Formation of blood clots

Fatty Acids in Health and Disease

* Essential fatty acids (EFAs) are a group of fatty acids that are essential for human health
* However, they cannot be produced by the human body and must be obtained from foods or supplements
* The most common EFAs include **omega--3 fatty acids**, **omega--6 fatty acids** and **omega--9 fatty acids**
* The benefits of EFAs include:
  * lower total cholesterol (decrease risk of heart disease)
  * increase calcium utilization (improved bone health)
  * improve mental functions (brain health)

Proteins

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Proteins

* Proteins are large molecules that contain carbon (C), hydrogen (H), oxygen (O), nitrogen (N) and sometimes sulphur

* They are more complex in structure than carbohydrates and lipids

Proteins

Function of proteins:

* Structural: collagen and keratin form the structural framework for various body tissues
* Regulatory: function as hormones that regulate processes, control growth and development, and act as neurotransmitters in the NS
* Contractile: myosin and actin allow shortening of muscle cells to produce movement

Proteins

- Function of proteins (cont.):
  - Immunological: antibodies and interleukins provide protection against invading pathogens
  - Transport: hemoglobin carries most oxygen and some carbon dioxide in the blood
  - Catalytic: act as enzymes that regulate biochemical reactions

Amino Acids

- The building blocks of proteins are called amino acids

- Each amino acid consists of:
  - a hydrogen (H) atom
  - three important functional groups attached to a central carbon atom, namely:
    - an amino group ($-NH_2$)
    - an acidic carboxyl group (–COOH)
    - a side chain -- (R group). Different side chains give each amino acid its distinctive chemical identity

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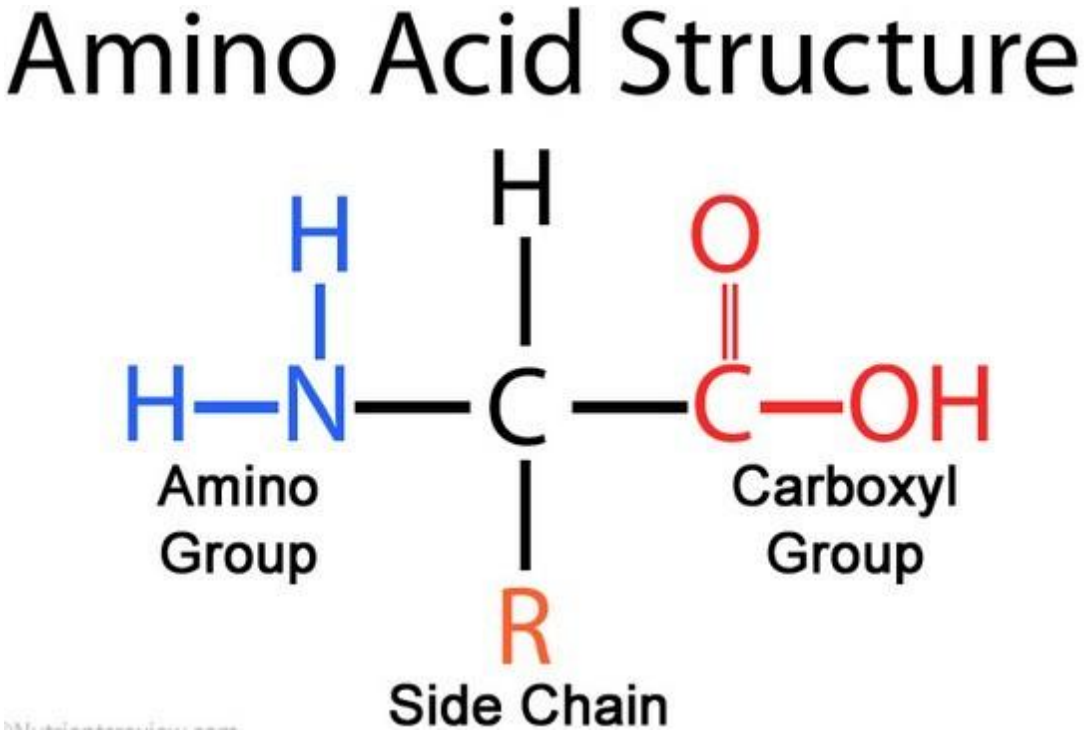
Amino Acids



Proteins

Proteins are chains of amino acids joined by peptide (covalent) bonds:

* **Dipeptides:** formed by combination of two amino acids
* **Tripeptides:** combination of three amino acids
* **Polypeptides:** combination of 10 to more than 2000 amino acids

Proteins

* Proteins are shaped according to their function in the body, and are maintained in that stage by homeostatic mechanisms

* If conditions in the body change, proteins can easily lose their characteristic shape ??this process is known as **denaturation**

Enzymes

* Enzymes are molecules composed primarily or entirely of protein that behave as biological catalysts

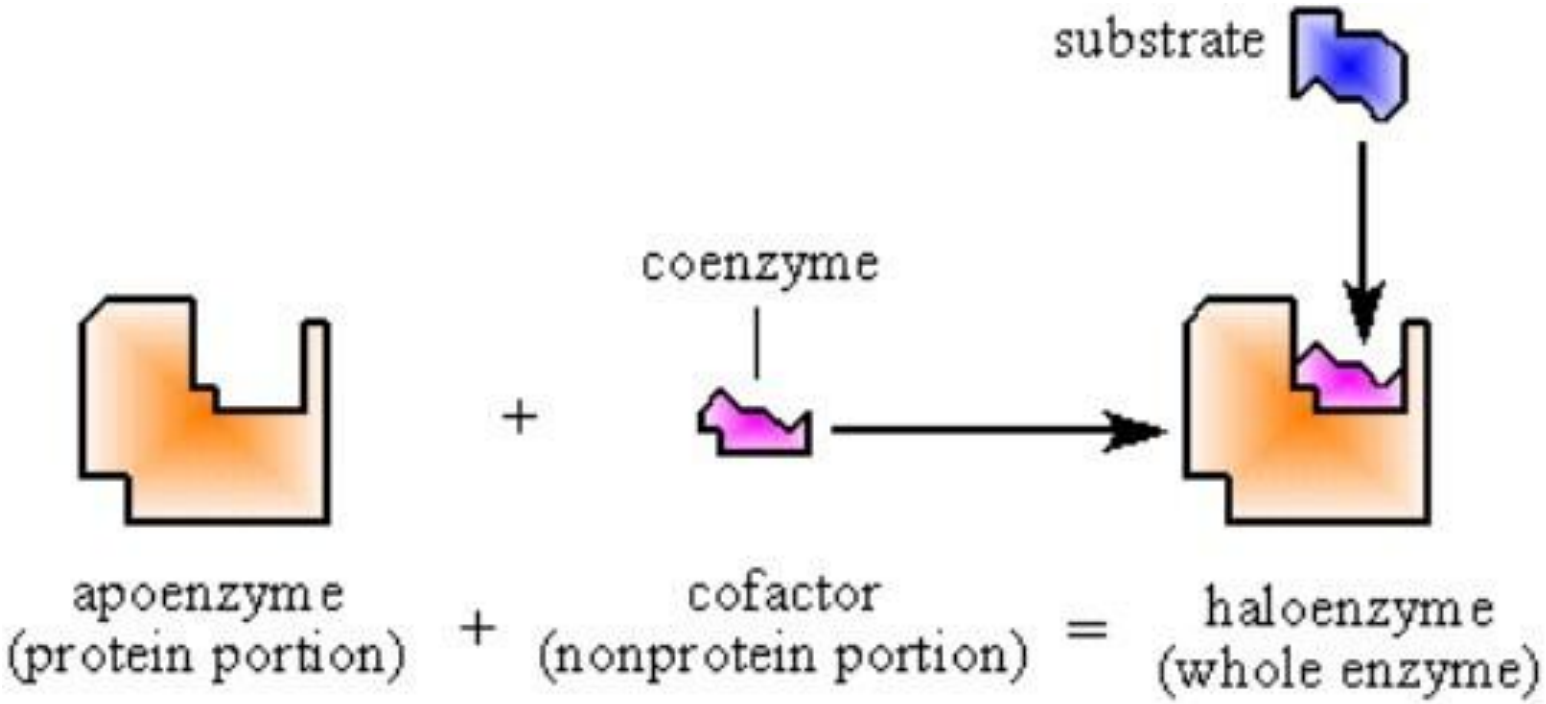
* They alter the rate of chemical reactions without being consumed in the process

* Some enzymes consist entirely of proteins, while others have non--protein portions

Enzymes

* The parts of an enzyme include:
  * **Apoenzyme:** the protein portion of an enzyme
  * **Cofactor:** the non--protein inorganic portion of an enzyme that is necessary for enzymatic function (eg. metallic ions such as zinc and magnesium)
  * **Coenzyme:** the non--protein organic portion of an enzyme that is necessary for enzymatic function (eg. B vitamins)

Enzymes



Enzymes

* The names of enzymes usually end in the suffix –ase and are grouped according to the type of chemical reaction that they catalyze:
  * **oxidases** add oxygen
  * **dehydrogenases** remove hydrogen
  * **ATPases** split ATP
  * **anhydrases** remove water
  * **proteases** break down proteins
  * **lipases** break down triglycerides
  * **amylases** break down carbohydrates

Enzymes

The important properties of enzymes include:

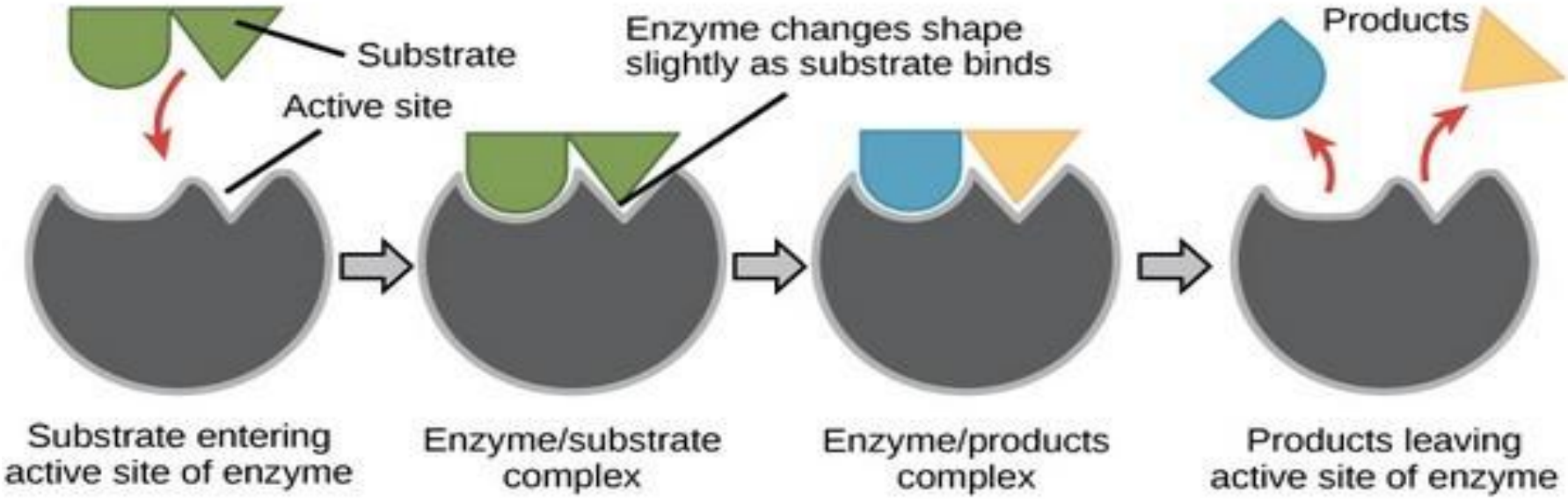
* Enzymes are highly specific
  * Enzymes are only able to bind to specific **substrates** (reactant molecules on which the enzyme acts)
* Enzymes greatly increase the speed of a chemical reaction
  * Enzymes lower **the activation energy** of a chemical reaction
* Enzyme production is controlled by the cellular environment
  * Certain environments will either enhance or inhibit specific enzyme activity

Enzymes

Enzyme activity:

* Substrates bind to the **active site** of the enzyme and create an **enzyme--substrate complex**
* The enzyme drives the reaction (whether a synthesis, decomposition, or reversible reaction)
* The final reaction products move away from the enzyme, which remains unchanged and ready to assist the next reaction

Enzymes



Nucleic Acids

Nucleic acids are large organic molecules containing carbon, hydrogen, oxygen, nitrogen and phosphorus

* They are of two types namely:
  * **Deoxyribonucleic acid (DNA)**
  * **Ribonucleic acid (RNA)**

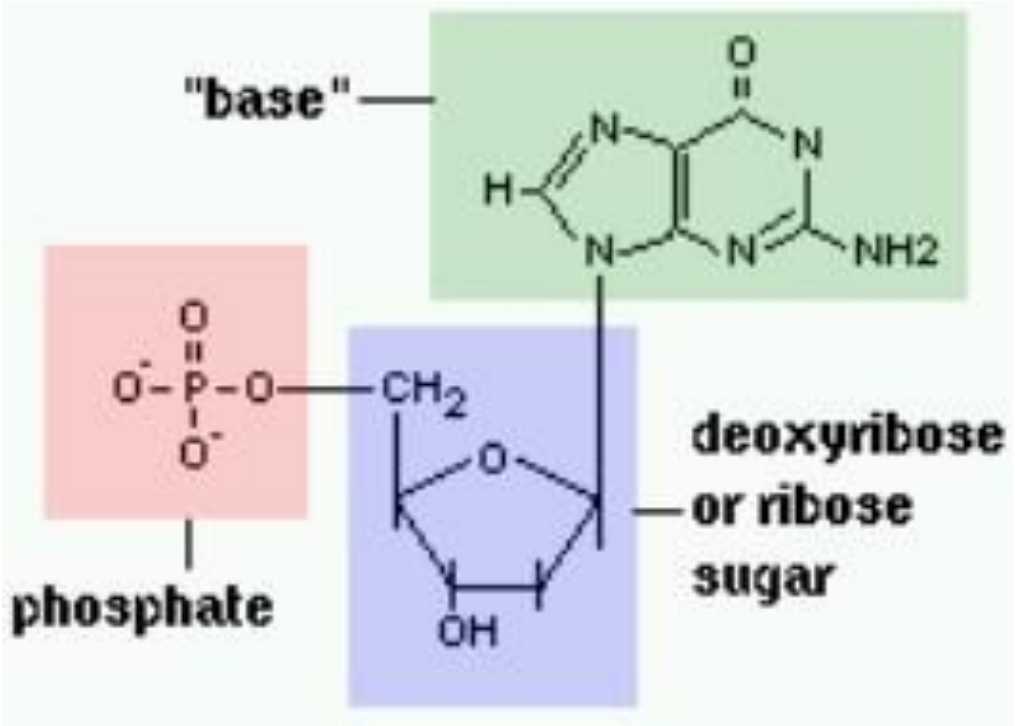
* The building blocks for both DNA and RNA are called **nucleotides.**

Nucleic Acids

Each nucleotide consists of three parts:

1. **Nitrogenous base** (made up of atoms of carbon, hydrogen, oxygen, and nitrogen)
   * Adenine (A)
   * Thymine (T): present only in DNA
   * Cytosine (C)
   * Guanine (G)
   * Uracil: present only in RNA
2. **A carbohydrate molecule** which attaches to each base
3. **Phosphate group**

Nucleic Acids



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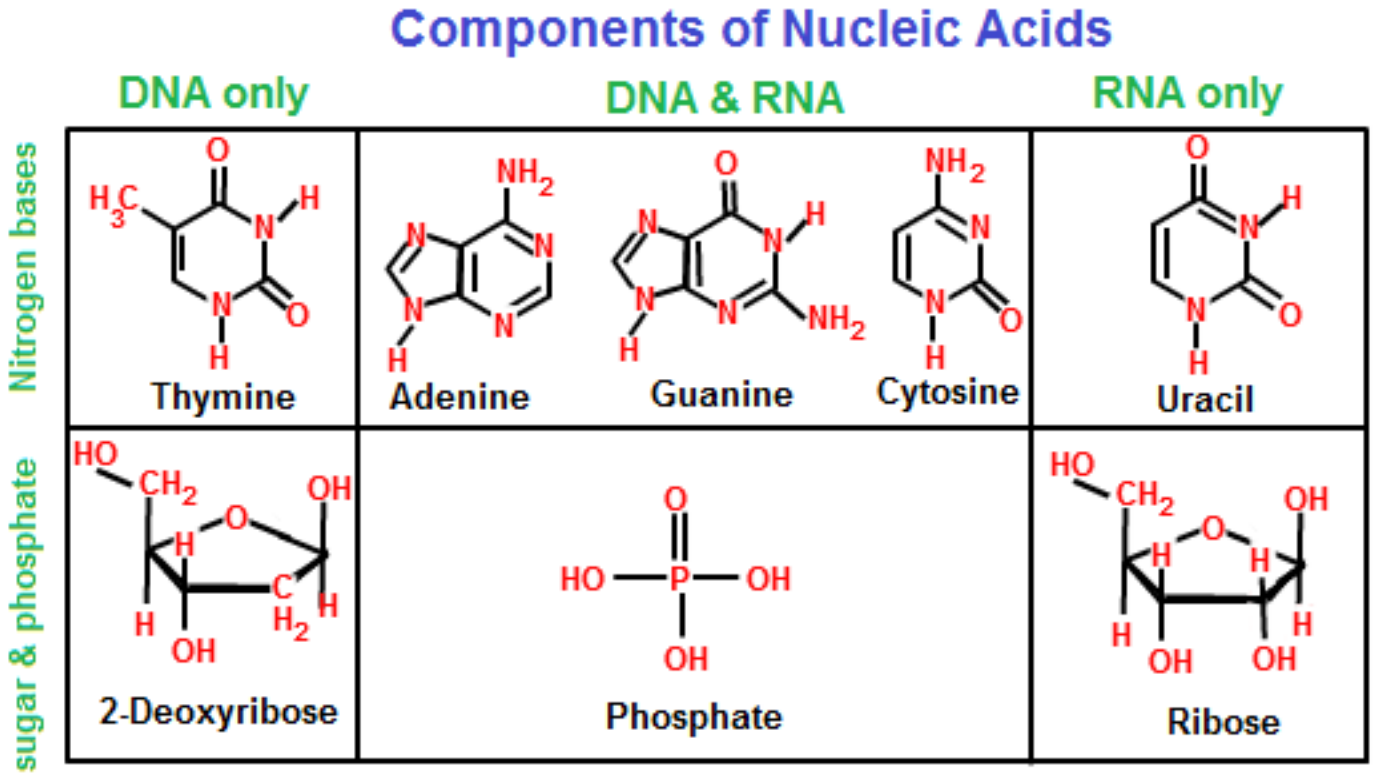
Nucleic Acids



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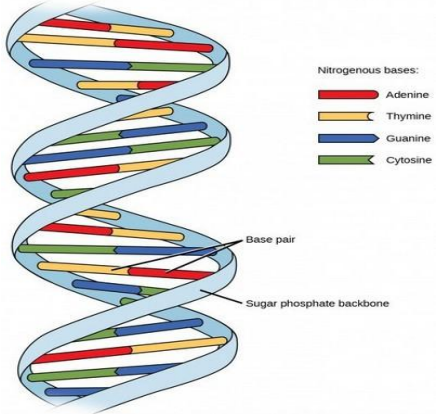
Deoxyribonucleic Acid (DNA)

* DNA is a molecule that carries the genetic code used in the growth, development, functioning and reproduction of all known living organisms
* DNA is inherited from both parents
* Each gene is a segment of a DNA molecule that:
  * Regulates most activities that take place in cells throughout life
  * Determines the inherited traits and hereditary information is passed through DNA when a cell divides

DNA

DNA structure:

* DNA molecule resembles a spiral ladder and this arrangement is known as a **double helix** (ladder)
* the phosphate and sugar molecules form the sides of the ladder
* The paired nitrogenous bases are held together by hydrogen bonds and form the ‘rungs’ of the



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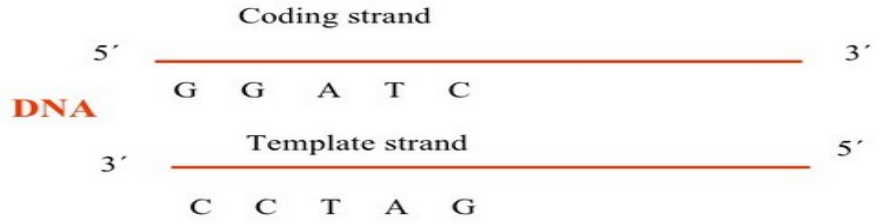
DNA

The pattern of pairing of the nitrogenous bases between adjacent strands is as follows:

* Adenine always pairs with thymine (A--T)
* Cytosine always pairs with guanine (C--G)

* Hence, if the sequence of bases in one strand of DNA is known,, then the sequence of the other (complimentary) strand can be determined

* When DNA is copied, the two strands unwind and each [illegible] the other strand is



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DNA

* A mutation is any change that occurs in the sequence of nitrogenous bases in a DNA strand

* Mutations can result in the death of a cell, cause cancer, produce genetic defects in future generations

Ribonucleic Acid (RNA)

* RNA is a molecule essential in the expression of genes
* RNA relays instructions from the genes (DNA) in order to guide each cell's synthesis of specific proteins using amino acids

* RNA is different than DNA in several aspects:
  * RNA is single--stranded, while DNA is double stranded
  * The carbohydrate in RNA is ribose (as opposed to deoxyribose in DNA)
  * RNA contains the nitrogenous base Uracil (U) instead of thymine (T)

RNA

Cells contain three different types of RNA, each with a different role:

* **Messenger RNA (mRNA)**: directs the synthesis of proteins
* **Ribosomal RNA (rRNA):** joins with ribosomal proteins to make ribosomes
* **Transfer RNA (tRNA):** transfers amino acids and hold them in place on a ribosome until it is incorporated into a protein during translation

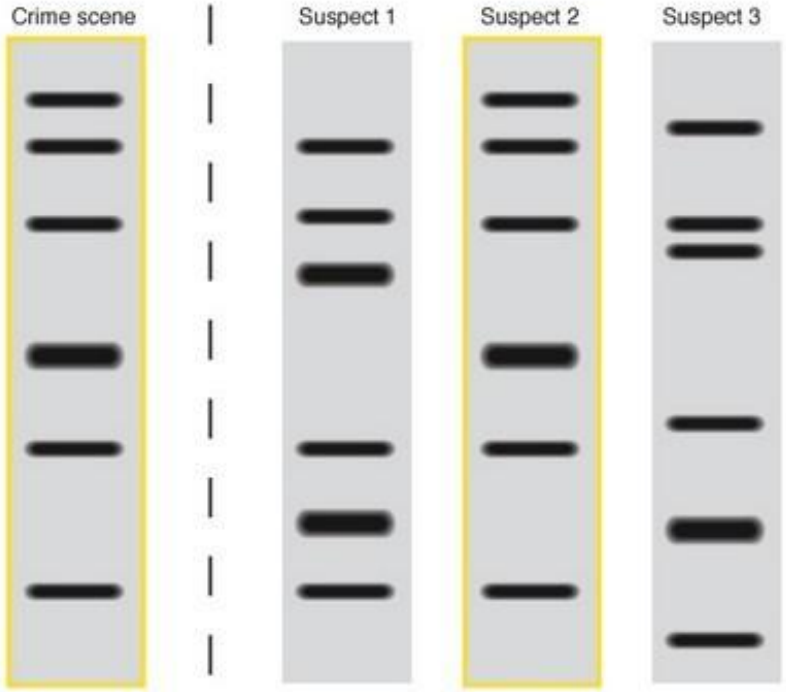
RNA

Messenger **RNA** (mRNA) carries the genetic information copied from DNA in the form of a series of three--base code "words," each of which specifies a particular amino acid. Transfer **RNA** (tRNA) is the key to deciphering the code words in mRNA. ...

Ribosomal **RNA** (rRNA) associates with a set of proteins to form ribosomes.

DNA Fingerprinting

DNA fingerprinting is a laboratory technique used to establish a link between biological evidence and a suspect in a criminal investigation. A **DNA** sample taken from a crime scene is compared with a **DNA** sample from a suspect. If the two **DNA** profiles are a match, then the evidence came from that suspect.



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Adenosine Triphosphate

* Adenosine triphosphate (ATP) is the principal energy-- storing molecule in the body

* ATP transfers energy (gained in exergonic catabolic reactions) to power cellular activities that require energy (endergonic reactions)

ATP

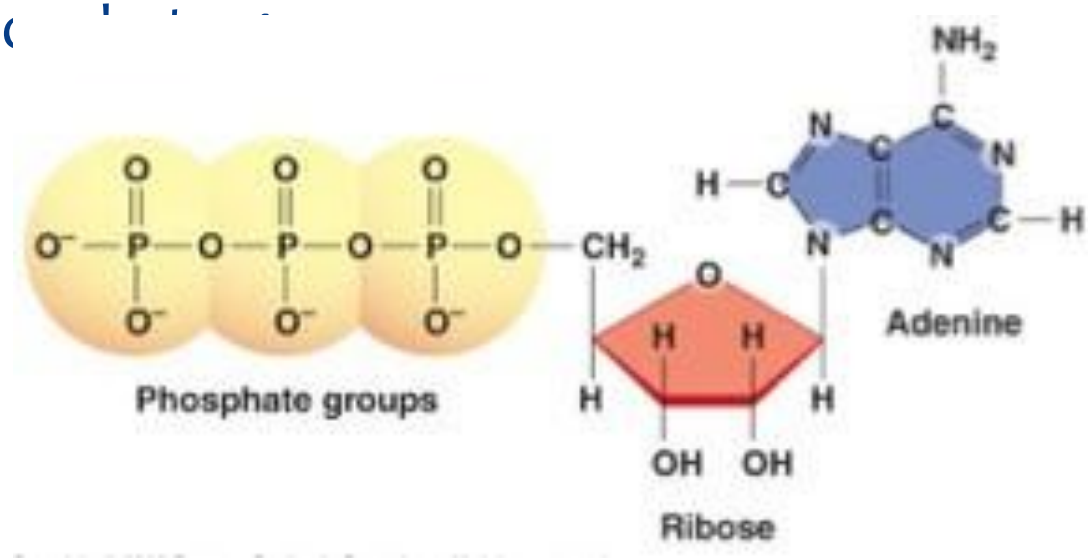
Some of the cellular activities for which ATP provides energy include:

* muscular contractions
* chromosome movement during cell division
* organelle movement within cells
* membrane transport processes
* synthesis reactions

ATP

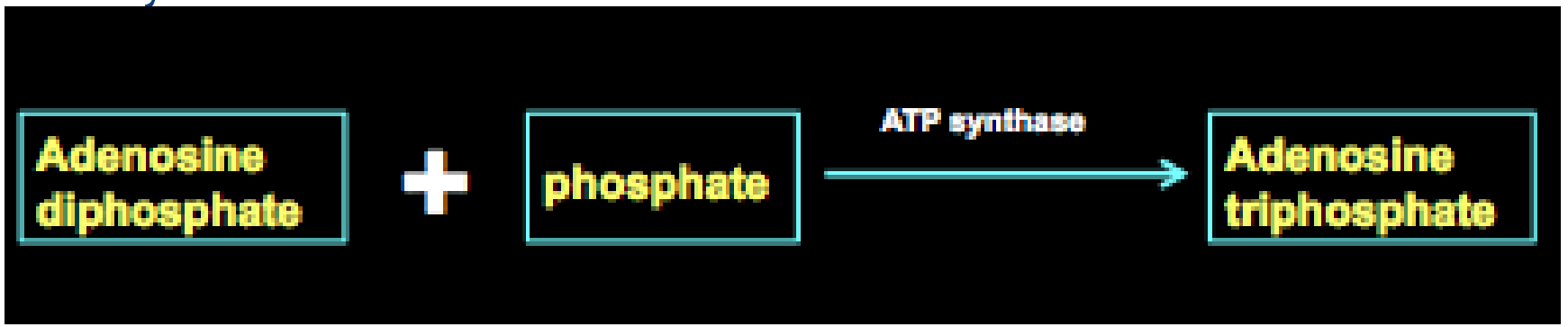
ATP consists of:

* Adenosine
  * composed of the amino acid adenine and the carbohydrate ribose
* three ph



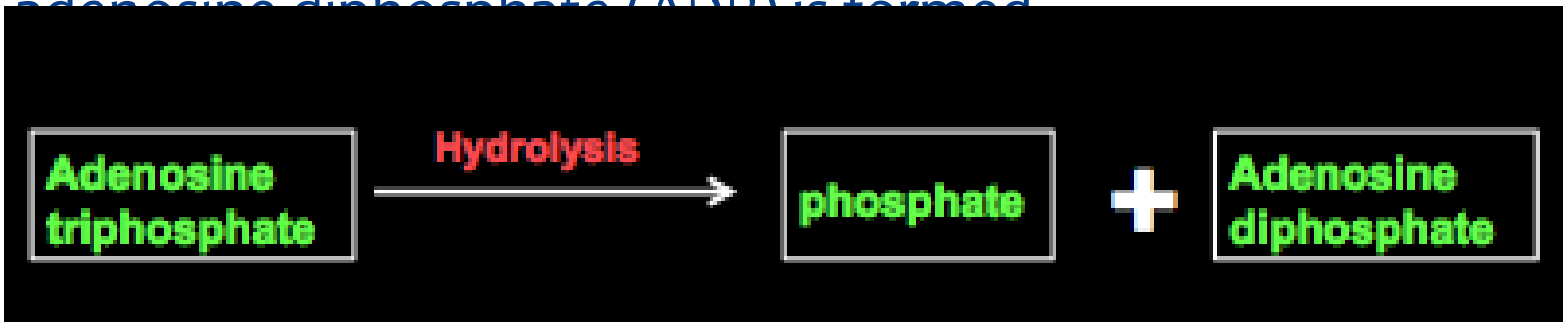
ATP

* ATP is manufactured from adenosine diphosphate (ADP) by the addition of a phosphate group
  * this reaction is catalyzed by the enzyme ATP synthase



ATP

* When a water molecule is added to ATP, a hydrolysis reaction takes place and the third phosphate group is removed
* Energy is liberated during this process and adenosine diphosphate (ADP) is formed



ATP

* ATP supply is limited at any given time, and has to be replenished constantly

* The energy needed to attach a phosphate group to ADP is supplied by catabolism of glucose in a process called cellular respiration

* Released energy gets stored in the last bond of the third phosphate group

Cellular Respiration

Cellular respiration is the process of obtaining energy from food and there are two forms of cellular respiration namely, aerobic and anaerobic

Aerobic respiration

* Aerobic respiration occurs in the presence of sufficient oxygen
* Glucose is completely broken down into CO_2 and water
* Each glucose molecule is broken down to produce 36 molecules of ATP

Cellular Respiration

Anaerobic respiration

* Anaerobic respiration is a series of reactions that do not require oxygen
* Glucose is partially broken down by catabolic reactions into lactic acid
* Each glucose molecule is broken down to produce 2 molecules of ATP