Introduction to Biochemistry

Anatomy of an atom:
An atom has a nucleus (with neutrons, protons) and electrons

Electronegativity of an atom:
Electronegativity is a measure of an atom's attraction for electrons in a bond.

Hydrogen Bond:
Electropositive hydrogen partially shared with two electronegative atoms

Hydrophobic forces:
pushing nonpolar surfaces out of hydrogen-bonded water network

Atomic composition of four building-block elements:

Carbon	☙ Form backbones of organic molecules ☙ Can form four bonds with other atoms
Nitrogen	☙ Component of all proteins and nucleic acids
Oxygen	☙ For Cellular respiration ☙ Found in most organic compound ❖ Food (Be more specific: Glucose)
Hydrogen	☙ Presence in all organic compounds ☙ For acid-base balance

These four elements that make up the human body.

Some Elements / Ion our human body

Na	☙ Major cation in tissue fluid → Vital for **fluid balance** ☙ Vital for **conduction of nerve impulses**
Mg	☙ **Needed in Blood** ☙ Needed in other body tissue ☙ Vital as a **co-enzyme**
P	☙ Part of **nucleic acids** ☙ **Structural part of Bone and Cell walls** ☙ Vital in **energy transfer**
S	☙ Part of **Most proteins** ☙ **Activation of Enzymes**
Cl	☙ Major anion in tissue fluid ☙ **Vital for fluid balance** ☙ Part of NaCl and **gastric juice**
K	☙ Vital in **nerve function** ☙ Affect **muscle contraction** ☙ Fluid and Electrolyte Balance

Ca	☙ Structural Component of Bones and Teeth ☙ Acid-base balance ☙ **Muscle Contraction** ☙ **Nerve Impulse** ☙ **Blood Clotting**
F	☙ **Incorporated into the tooth enamel & bone structure**
Cr	☙ **Maintain blood sugar level /** (Insulin)
Mn	☙ It is a co-factor for enzymes → found in liver, kidney and mitochondria ☙ **maturation of red blood cells**
Zn	☙ needed in saliva for the taste buds ☙ vital for growth → sexual development ☙ Vital in protein synthesis and cell division
I	☙ Part of thyroid hormones

Although those elements are less common in our body, they are essential for body functions and metabolisms

Major feature of Chemical Reaction:

☙ Energy is conserved by first law of **Thermodynamic**
- Energy cannot be created or destroyed → Total Energy of a system and its surroundings is constant
- For any cyclic reaction is no net change in the reaction

Some Example of Important Reaction:

- First reaction in glycolysis is a coupled reaction to ATP conversion to ADP.
  - ✧ Glucose → Glucose-6-phosphate, at the same time ATP is converted into ADP + Phosphate Group

Some Example of Hydrolysis reaction:

- Proteins/Polypeptide are hydrolyzed to amino acids
- Fats are hydrolyzed to fatty acids and glycerol
- Starch and complex sugars (glycogen) are hydrolyzed to simple sugar (glucose/galactose)
- Anions of weak acids dissolve in water to give basic solution.

$$CH_3COO^- + H_2O \rightarrow CH_3COOH + OH^-$$

☙ Kinetic of a reaction = Rate of the reaction
- Enzymes/Catalyst can change the rate of the reactions → Speed up reaction
  - For Positive Enzymes/Catalyst: It can lower the activation energy of the reaction

☙ Classification of Chemical Reaction:
- By Type of reactants:
  - Redox reaction
  - Acid-base reaction
    - **The Bronsted-Lowry theory**: *An acid is defined as a proton donor and a base as a proton acceptor*
    - The Arrhenius theory
    - The Lewis theory
- By the reaction outcome:
  - Condensation → Water is formed during combination of the reactants
    - Combining 2 molecules (either the same or different) with the elimination of a stable small molecule
  - Hydrolysis → Water is used to break the bond

Introduction to Water:

- The two hydrogen atoms each share a pair of electrons with the oxygen by covalent bonding
  - Uneven distribution of electron density → Water is polar

Oxygen atom in water molecule	Partial negative charge
Hydrogen atom in water molecule	Partial positive charge

  - Hence, the partial positive charge Hydrogen can be attracted by the neighboring partial negative charge oxygen atom. → Hydrogen Bond is formed due to the electrostatic attraction
- When dissolving a solute (e.g: NaCl) into water:
  - Hydration shells surrounding anions and cation
    - Na^+ and Cl^- are hydrated
- When dissolving a solute (e.g: Alcohol) into water:
  - Alcohol form hydrogen bond with the water molecule.
- Unique Physical Properties of water is due to the hydrogen bonding:
  - High heat of vaporization / Specific Heat
  - Strong Surface tension
  - A near universal solvent
  - Hydrophobic effect
  - Ionization of water, pH = pOH = 7
- Important information of solution and solute:
  - A liquid mixture in which minor solute is uniformly distributed within the solvent.
- Important information of suspension:
  - Particles are dispersed throughout the bulk of a fluid.
    - Example: Blood

Building Blocks of Life:

Lipid	Sugar	Nucleic Acid	Proteins

Introduction to Lipids:

Common Type of Lipids:

Triglyceride → Fatty Acid and Glycerol	■ For long term storage (Fuel Molecule) ■ For Making Cholesterol
Phosphoacylglycerols	■ cell membrane (Phospholipids)
Sphingolipids	■ Enriched in the Central Nervous System (CNS) ■ Tissue development ■ Cell recognition ■ Adhesion (黏附) ■ Act as receptors for toxins
Steroid (a cyclical chemical)	■ Energy metabolism ■ Reproduction ■ Homeostasis

Difference between Oil and Lipid:

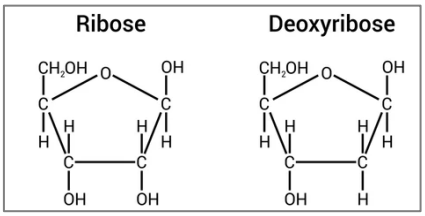
Fat	■ Saturated or fewer double bond ■ Fewer cis structure [No Trans structure] → High MP
Lipidc	■ A large number of double bond → Unsaturated ■ A large number of cis structure → Low MP

Introduction to Phospholipids

$$\text{Phospholipids} = \text{Phosphorus} + 2\text{Fatty Acids} + \text{Alcohol} + \text{Glycerol}$$

Introduction to Sugar (Monosaccharides and Disaccharides):

- Definition of Monosaccharides:
  - Monosaccharides, which cannot be hydrolyzed to simpler compounds, generally have three to six carbons with a carbonyl group at either the terminal carbon or the carbon adjacent to it. Generally, all other carbons have OH groups bonded to them
- More about Monosaccharides:



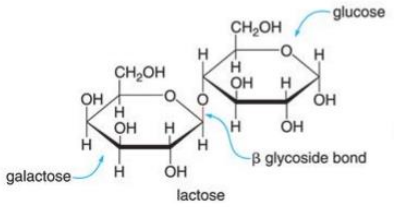
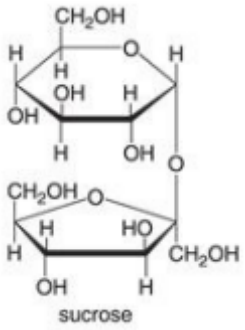
  - Triose = Monosaccharides has 3 Carbons:
    - *L-glyceraldehyde* and *D-glyceraldehyde*, and *dihydroxyacetone*,
  - Tetrose = Monosaccharides has 4 Carbons:
    - *D-Erythrose*, *D-Threose* and *D-Erythrulose*
  - Pentose = Monosaccharides has 5 Carbons:
    - ***Ribose*** (a Petose/核糖) is a constituent of RNA.
  - Hexoses = Monosaccharides had 6 Carbons:
    - Hexoses acts as building blocks of other compounds such as starch.

$$2\ \text{Monosaccharides} \rightarrow \text{Disaccharides} + H_2O\ \ (\text{Linkage is } \mathbf{Glycosidic\ Bond})$$
$$3 \text{ or more Monosaccharides} \rightarrow \text{Polysaccharides}$$

    - Hexoses can form dihexose (like sucrose) by a condensation reaction that makes **1,6-glycosidic bond**.
- Common Example of Monosaccharides:

D-Glucose	D-Galactose	D-Fructose

- Common Example of Disaccharides:

Lactose	Galactose Ring + Glucose Ring Lactose is not appreciably sweet 2 six-membered Ring Joined by 1→4-β-glycosidic bond	
Sucrose	The Disaccharide found in sugarcane Most common in nature One Six-membered and one five membered rings Bonded by 1,6-glycosidic bond	

Introduction to Sugar (Polysaccharides):

- Glycogen:
  - A polymer of glucose containing α-glycosidic bonds
  - As a storage of energy in Liver and Muscle
  - Has an **extensive branched structure**
    - Glucose units are hydrolyzed from the ends of glycogen → Metabolism → Energy
- Cellulose / As a Digestive Fiber for human:
  - Provide Support and rigidity to wood, plant stems and grass
  - Unbranched Polymer (repeating glucose by 1→4-β-glycosidic linkage)
  - Cannot be digested by human
- Amylose / A type of Starch:
  - Has an unbranched skeleton of glucose molecules with 1→4-α-glycoside bonds
  - Numerous of OH groups ⇒ leading to greater water solubility than cellulose.
- Amylopectin / A type of Starch
  - Similar to Amylose
  - Contains Branching along the chain.

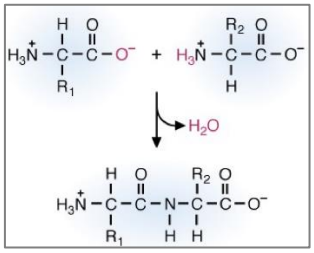
$$\text{Amylose/Amylopectin} + H_2O \rightarrow \text{Glucose (Catalyzed by Amylase)}$$

Introduction to Protein:

General Structure of Amino Acid & Peptide Bond

$$\text{Amino Group} + \text{Carboxyl Group} \rightarrow \text{Amino Acid}$$

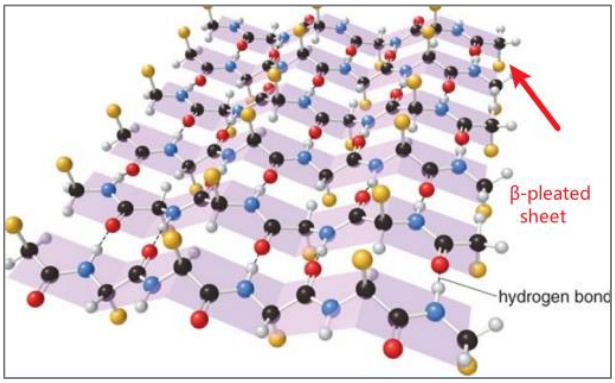
- Do Notice that: One end is COO^- and one end is $R - NH_3^+$
  - By Condensation: A water is removed, and Peptide bond is formed. (Whole compound is neutral.)

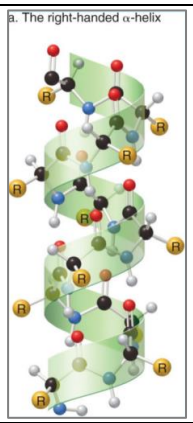


Primary structure of Proteins – Only one poly peptide chain

- Definition:
  - Particular sequence of amino acids that is joined together by peptide bond
- Focus on the structure of Amide Bond

Secondary Structure Proteins – 2 Polypeptide Chains

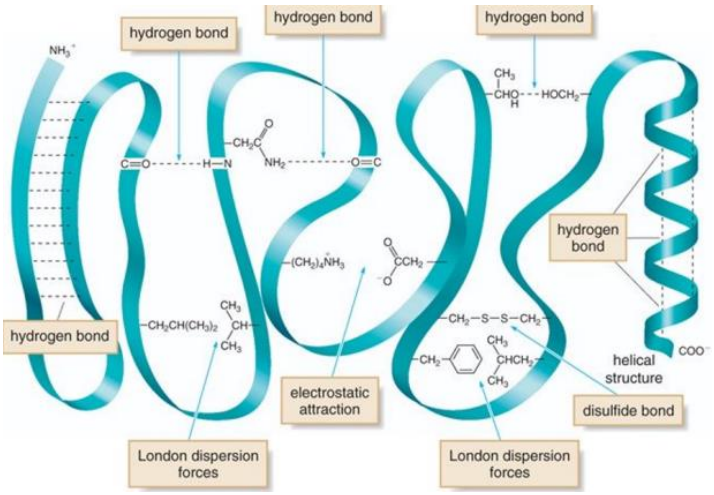




- **α-helix and β-pleated sheet**
- Focus on the NH Bond and CO Double Bond
- The Secondary Structure of Proteins is **formed by the hydrogen bond.**

Tertiary Structure of Proteins – 3 Polypeptide Chains

- Many kinds of intramolecular forces that stabilize polypeptide chains.
  - Including: London Dispersion Forces (Van de Waal's force)



Example:

- Amino acids that contain hydroxyl (OH) and amino groups (NH2) in their side chains ⇒ Hydrogen Bond
- Nonpolar C-C and C-H bonds are stabilized by VDW.

Quaternary Structure of Proteins - More than 3 Polypeptide Chains

- The shape adopted when two or more folded polypeptide chains come together into one protein complex.

n Polypepetide Chains (Subunit) → Quanternary Protein

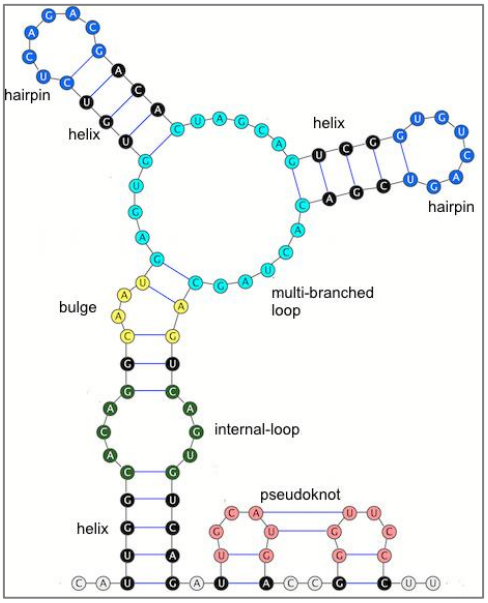
Example: Hemoglobin

Introduction to Protein Complex (Quaternary Structure of Proteins):

Globular	- Coiled into compact shapes - The surface is hydrophilic - Enzymes and Transport Proteins are in this shape - Thus, soluble in blood
Fibrous	- Long, Linear, Compacted Polypeptide Chain - Rod / Sheet Shape - Insoluble in Water - Provide Strength and Protection to tissue or cells

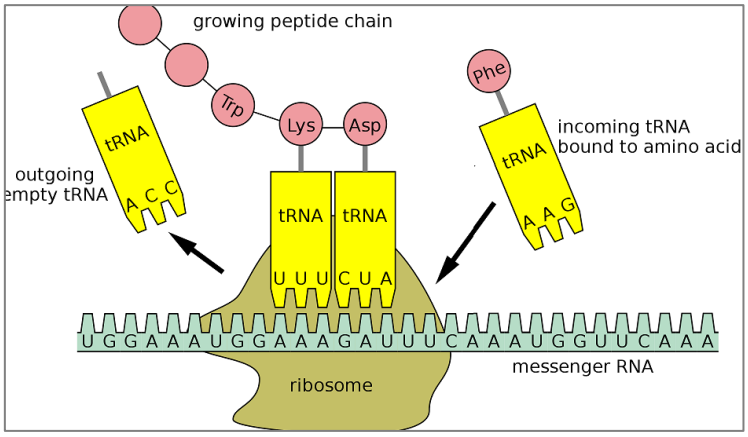
Introduction to RNA (Nucleic Acid):

- Single Strands → Less stable than DNA
- RNA can form secondary structure
  - Hairpin Loops
  - 3D Structure



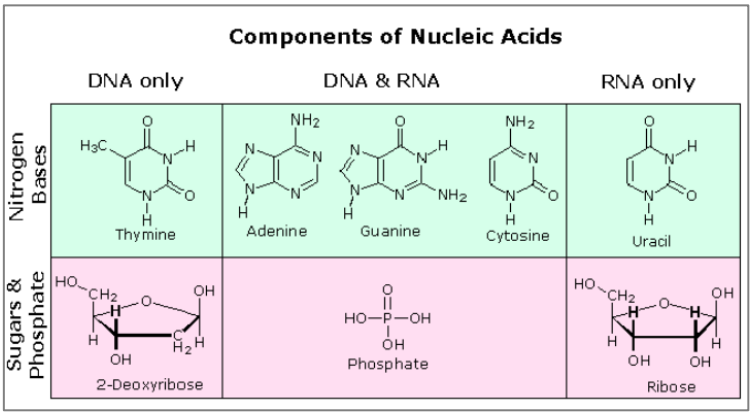
Some common type of RNA:

mRNA (Messager RNA)	★Corresponds to the genetic sequence of a gene ★Read by a ribosome (rRNA) ⇒ synthesizing a protein.
rRNA (Ribosomal RNA)	★Non-coding RNA ⇒ Carries out protein synthesis in ribosomes ★Essential to all cells
tRNA (Transfer RNA)	★Carry an amino acid to ribosome

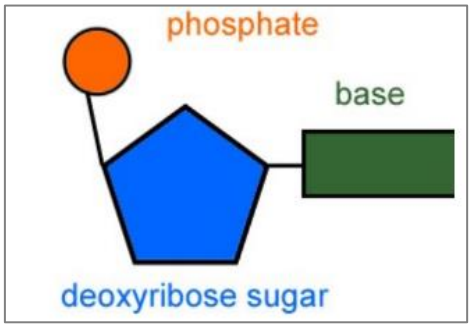


Nucleic Acid – Introduction to Nucleoids and DNA:

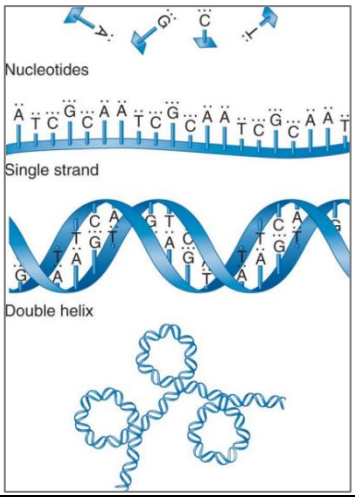
- Component of Nucleic Acid



- Basic Structure of Nucleotides in DNA



- The Bases of Nucleotides:
  - A = adenine
  - G = guanine
  - C = cytosine
  - T = thymine (Only Presence in DNA)
  - U = uracil (Only Presence in RNA)
- Introduction to the relationship between the Nucleoids and the DNA/RNA
  - Nucleotides (monomer) ⇒ linked in linear manner ⇒ a strand of DNA / RNA
  - Two strands of DNA/RNA ⇒ A double helix structure
  - DNA would always interact with another strand of DNA to form double helix.
  - RNA may not interact with another strand to from double helix structure.
- The Complementary base Pairing of DNA / RNA
  - For DNA: A-T, C-G.
    Adenosine must pair with thymine (Paired/Bonded by 2 Hydrogen Bonds)
    Cytosine must pair with guanine (Paired/Bonded by 3 Hydrogen Bonds)
  - For RNA: A-U, C-G
    Adenosine must pair with Uracil
    Cytosine must pair with guanine



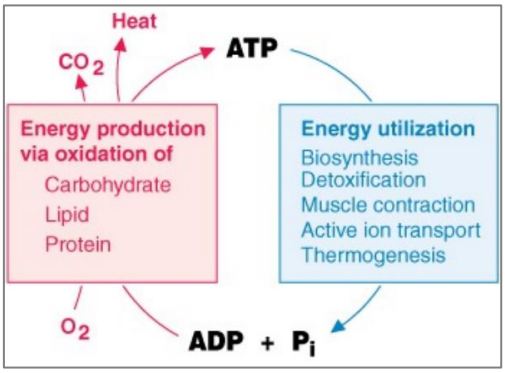
Major Classes of dietary fuels:

Major Fuels from food:

Carbohydrate	Proteins	Fats

oxidation of these fuels to CO_2 and H_2O → Heat + ATP (*adenosine triphosphate*)

How ATP is used:



The energy - generating pathways are shown in red;
The energy -utilizing pathways in blue

Different Forms of Body Fuel Stores:

Fats	☙ Major Fuel Store ☙ Store in Adipose tissues ☙ Accumulate in hips, thighs and abdomens
Carbohydrates	☙ Smaller fuel stores ☙ Stores as Glycogen in liver and muscles
Proteins	☙ From Large muscle masses in particular ☙ Used when we are fasting

Introduction to metabolism:

Metabolism = all chemical reactions involved in maintaining the living state of the cells and the organism.

There are two type of metabolism: **Catabolism** and **Anabolism**

- ☙ Catabolism
  - ■ To break down molecules
- ☙ Anabolism
  - ■ To build up molecules from building blocks