Module 1: Information Transfer

Lecture 02 The Chemistry of Life

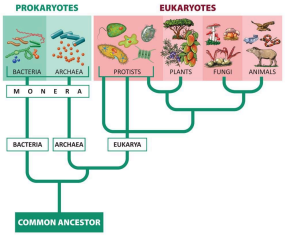
1. Explore the properties of living organisms and appreciate the common origins and makeup of the molecules of life
2. Identify the elements particularly important for life, and define the properties used to describe how they interact
3. Describe the basic structures, chemical properties, and biological functions of the building blocks of life (macromolecules): - Water, carbohydrates (sugars), lipids, nucleic acids, amino acids

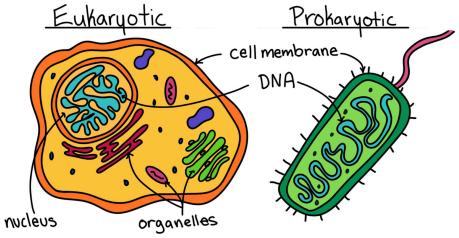
Properties of life

Order - Life is cell-based, complex, and organised
Energy Processing - Plants convert sunlight → chemical energy, animals consume chemical energy
Sensitivity/Response to Stimuli - Detect and react to environment
Reproduction - Pass on genetic material
Growth & Development - Programmed by DNA
Regulation/Homeostasis - Maintain stable internal conditions despite environmental changes
Adaptation - Traits that improve survival in an environment
Evolution - Change in populations over generations

Classifying living things (6-8 kingdoms, 3 domains)

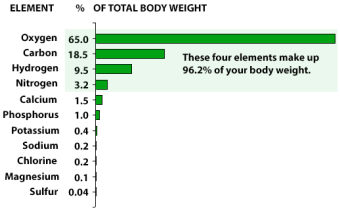
- ➔ 6-8 kingdoms, 3 domains





Essential elements for life

- ➔ Common: C, H, N, O



Molecule: 2+ **atoms** bound by a chemical bond
Compound: 2+ **different** atoms bound
All compounds are molecules (H_2O), but not all molecules are compounds (O_2)

Carbon's Importance

- ➔ Versatile - Bonds with itself + many elements
- ➔ Diverse - Backbone of all major biopolymers
- ➔ Stable - Forms strong covalent bonds

Molecular interactions with water

- ➔ **Hydrophobic -** Water-fearing (non-polar, e.g. C-H)
- ➔ **Hydrophilic -** Water-loving (polar/charged, often O, N, P)
- ➔ **Amphipathic -** Both hydrophilic & hydrophobic parts (e.g. lipids)

Water

Structure: Polar molecule → hydrogen bonding with other water molecules

Functions/Properties which contribute to Earth's suitability for life:

- ➔ Cohesion (sticks to itself)
- ➔ High specific heat & high heat of vaporisation → temp. regulation
- ➔ Expands when frozen
- ➔ Excellent solvent → dissolves polar/charged substances → aids nutrient/waste transport

Carbohydrates (sugars)

Made by Photosynthesis

Monosaccharides: Simplest form of carbohydrate - often in cyclic form (sometimes in linear)

Disaccharides: 2 monosaccharides joined by glycosidic bond (via dehydration synthesis reaction) - broken down by hydrolysis

Polysaccharides: Carbohydrate macromolecules composed of many sugars

Storage: Starch (plants: amylose + amylopectin), Glycogen (animals)

Structure: Building material for structures that protect the cell or the organism → Cellulose (plants), Chitin (arthropods), Peptidoglycan (bacteria)

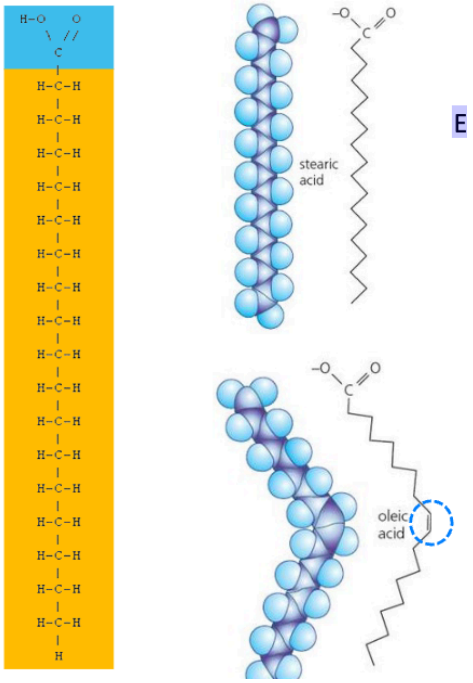
Lipids

Structure

- ➔ Composed of C, H and O
- ➔ Types - Fats, oils, waxes, **steroids**/sterols
- ➔ Large energy release when broken down
- ➔ Simple fatty acids are non-polar molecules made up of a carboxylic acid group (COOH) and a long hydrocarbon tail (R)

Saturated Fats: Every C in the tail is bound to H

Unsaturated Fats: 2 or more C in the tail are not bound to H - Double bond allows for free rotation around C=C bond



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Function

Tryglycerols = Energy stores

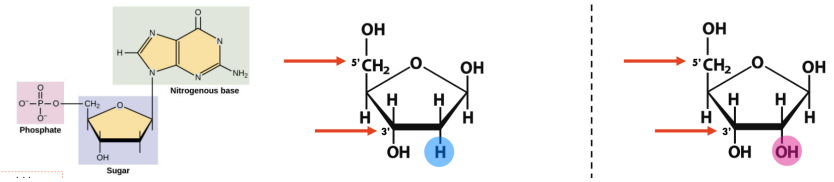
Steroids = signalling molecules

Waxes = Protection and waterproofing

Phospholipids, Glycolipids, Cholesterol = Membrane structure
Membrane lipids (primarily phospholipids) = amphipathic: hydrophilic head (Outside, interact with aqueous environment), hydrophobic tail (Cluster inside where they are shielded)

Nucleic Acids

Nucleotide: phosphate group (negatively charged), sugar (ribose/deoxyribose), nucleobase (A, G, C, T, U)



Functions:

- ➔ Genetic information (DNA/RNA)
- ➔ Energy storage (ATP)
- ➔ Metabolic regulation
- ➔ Signalling (cAMP)
- ➔ Immune function

Nucleoside: Sugar + base only (no phosphate)

Amino acids (Building blocks of proteins)

Structure: Amino group ($-NH_2$), carboxyl group (-COOH), variable side chain (R)
At pH 7: Ionised to $-NH_3^+$ and $-COO^-$ → this is the normal state for amino acids in nature
20 common amino acids - differ in size, charge, polarity

Lecture 03 Biopolymers

1. Describe the main chemical components of nucleic acids and proteins/peptides, as well as their repeating units (backbones, bonds, and sidechains or bases).
2. Identify the conventions of direction/ends of nucleic acids and proteins.
3. Describe the base pairing between nucleobases and appreciate that C/G base pairing is stronger than A/T(U) base pairing in nucleic acids.
4. Describe the double-helical structure of DNA and distinguish DNA from RNA in terms of structure and stability.
5. Describe how the physical and chemical properties of nucleic acids and proteins can be exploited in experimental situations

Nucleic Acids (DNA/RNA)

Monomer: Nucleotide = phosphate, sugar + base (Nucleotides make up DNA/RNA)
Polymer: DNA/RNA
Sugar-phosphate backbone:

- ➔ Nucleotides are linked by covalent ester bonds (phosphodiester bonds) - Always grows 5' to 3'
- ➔ Backbone is negatively charged and hydrophilic

Attaching the Sugar to the Base:

- ➔ The nucleobase (Base) is attached to the pentose ring (sugar) at 1' carbon via N-glycosidic bond
- ➔ Bases provide sequence variation (A, G, C, T/U)

Base pairing

- ➔ A = T (DNA) / U (RNA) → 2 H-bonds
- ➔ G ≡ C → 3 H-bonds (stronger, more stable)
- ➔ There should be a 1:1 stoichiometric ratio of purine (A,G) and pyrimidine (C,T,U) bases