Intro to Molecular Biology

Week 1

RAU-BG course

Bioinformatics and Data Science in Oncology

Biology as a science

- Biology is the science that studies life

  - What exactly is life?
  - What are the shared properties that make something “alive”?
  - How do those various living things function?
  - How do we organize the different kinds of organisms so that we can better understand them?
  - How did this diversity arise and how is it continuing?
  - How is information processed in living organisms?
  - How does molecular interactions function in health and disease?
  - How does genetic information passes to generations?
  - etc.

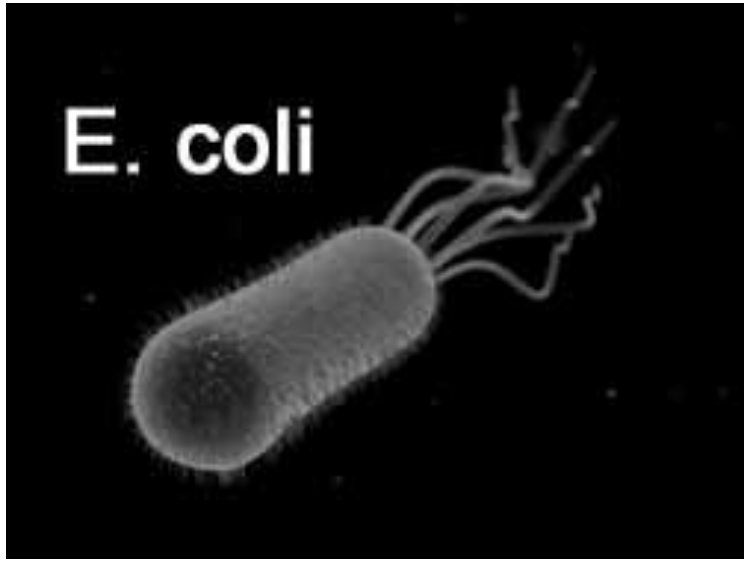
Properties of Life

1. **Order**
2. **Sensitivity or response to stimuli**
3. **Reproduction**
4. **Growth and development**
5. **Adaptation**
6. **Regulation/Homeostasis**
7. **Energy processing**

Order

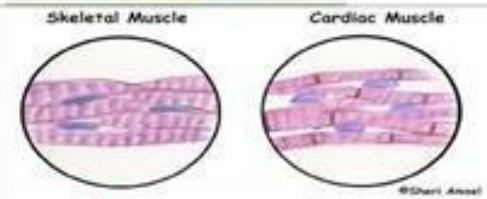
- **A Cell is the basic unit of life**
- All living organisms are highly organized structures that consist of **one or more cells**

Single-cell organisms



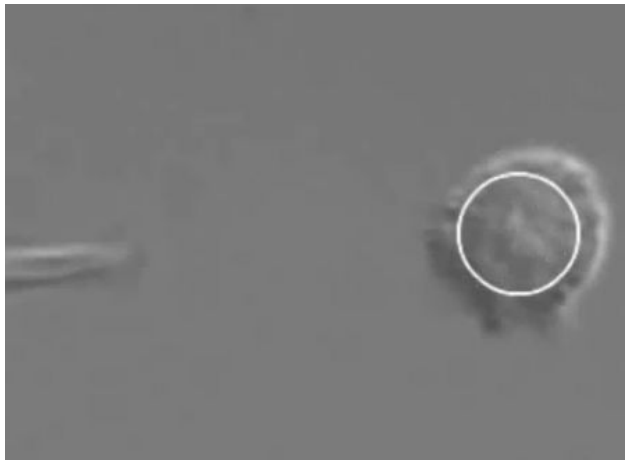
Multicellular organisms

Levels of Organization of Living Things

Cell	Basic unit of structure and function in living things.	
Tissue	In plants and animals, a group of cells that work together to do a specific job.	
Organ	In an organism, structure made of two or more different tissues which have a specialized function. Example: lungs.	
Organ System	Group of organs that work together to do a specific job. Example: digestive system	
Organism	A living thing	

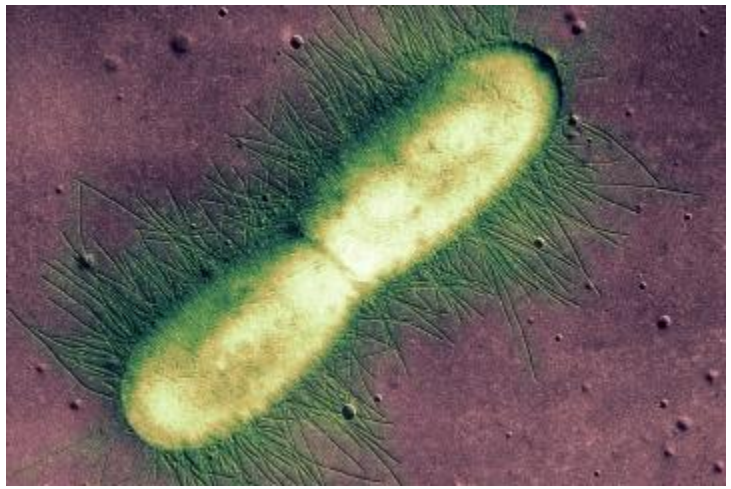
Sensitivity or response to stimuli

- **Sensitivity is a ability of a living organism to change in response to stimuli**
- Organisms respond to diverse stimuli. light, chemicals, pressure, etc
- Movement toward a stimulus is considered a **positive response**, while movement away from a stimulus is considered a **negative response**



Reproduction

- All living organisms produce copies of themselves
- They can do this.
  - **Asexually**. by simple division of cells (e.g. bacteria divide to produce two new cells)
  - **Sexually**. by producing specialized reproductive cells
- During reproduction, genetic material (DNA) is passed to the offspring
- The offspring will belong to the same specie and will have characteristics similar to the parent



Growth and development

- Organisms grow and develop according to specific instructions coded in their genes

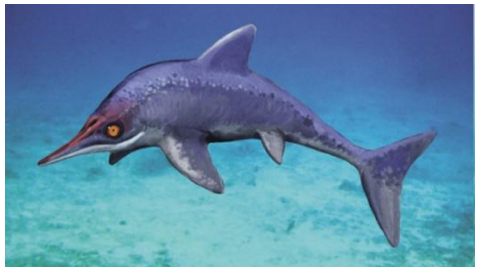
- Genes provide instructions that will direct cellular growth and development

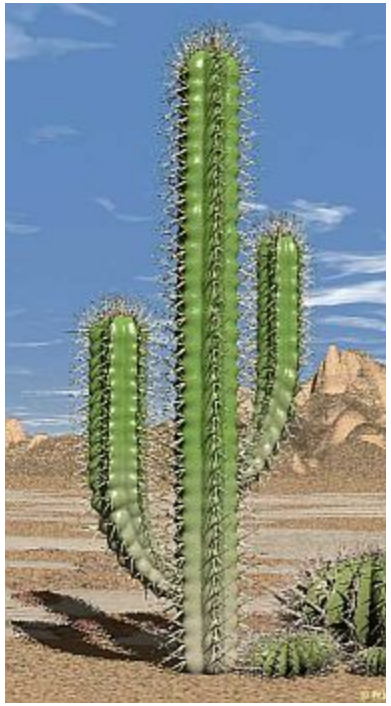
The Riddle of the Sphinx

What goes on four legs in the morning, on two legs at noon, and on three legs in the evening?

Adaptation

- All living organisms exhibit a “fit” (adapt) to their environment due to evolution
- Adaptations enhance the organism's ability to survive and reproduce
- Adaptations are not constant





The last survivor

Tardigrade (water bear)
Length - 0.5 mm

able to survive for up to 30 years without food or water

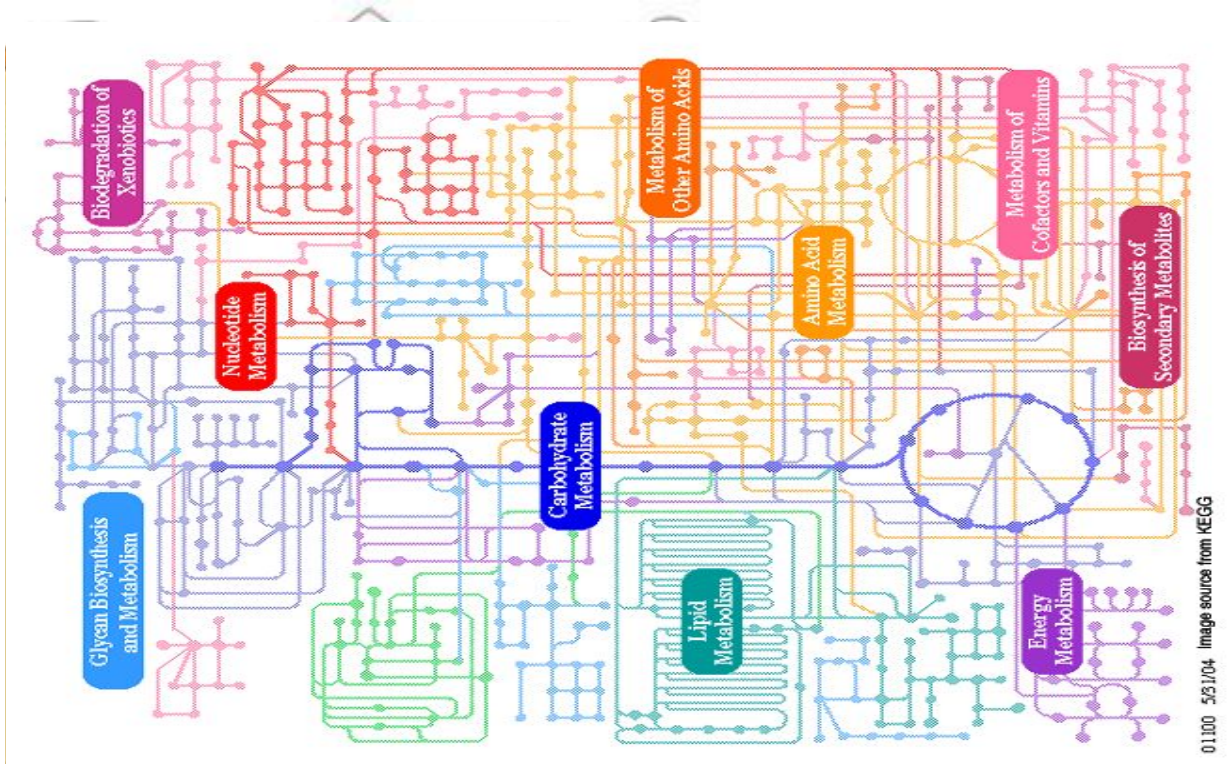
can withstand temperatures down −272 °C and up 150 °C

able to survive ionizing radiation

able to survive in vacuum

Regulation

- organisms are complex and require multiple regulatory mechanisms to coordinate internal functions
  - transport of nutrients, response to stimuli, coping with environmental stresses



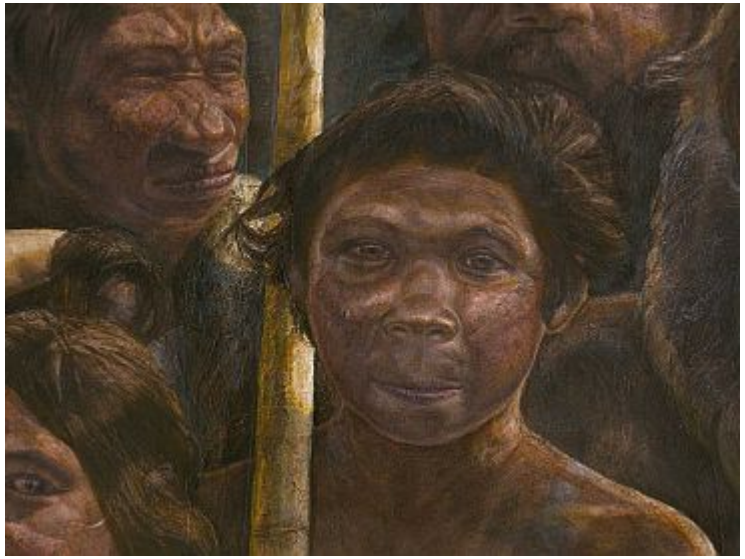
Metabolic pathways

This is complex!!!

Homeostasis/Regulation

- the ability of an organism to maintain constant internal conditions
  - many organisms regulate their body temperature in a process known as thermoregulation

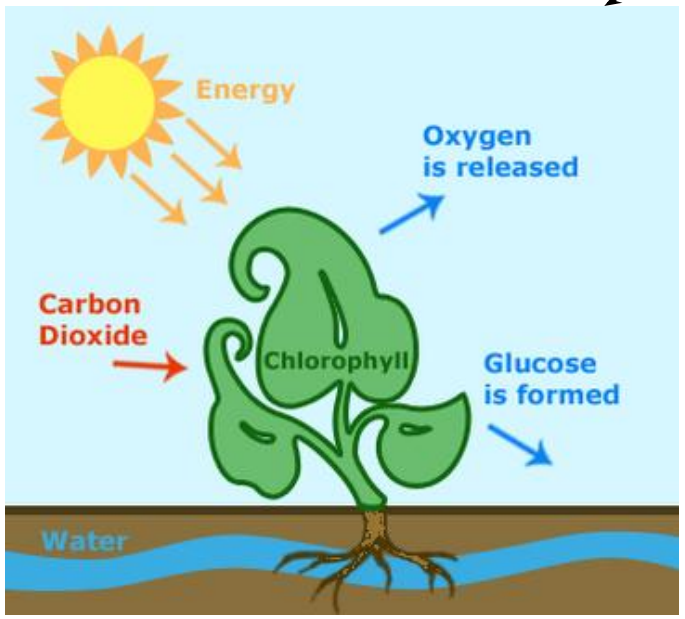
VS

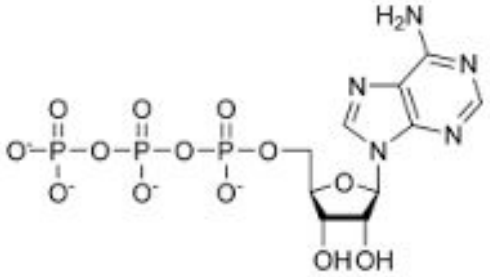


Energy processing

- All the organisms use a source of energy for their life activities.
- Energy from the Sun may be captured and stored in the form of chemical energy (photosynthesis)
- The chemical energy stored in food is utilized to perform life activities

Two main sources of energy





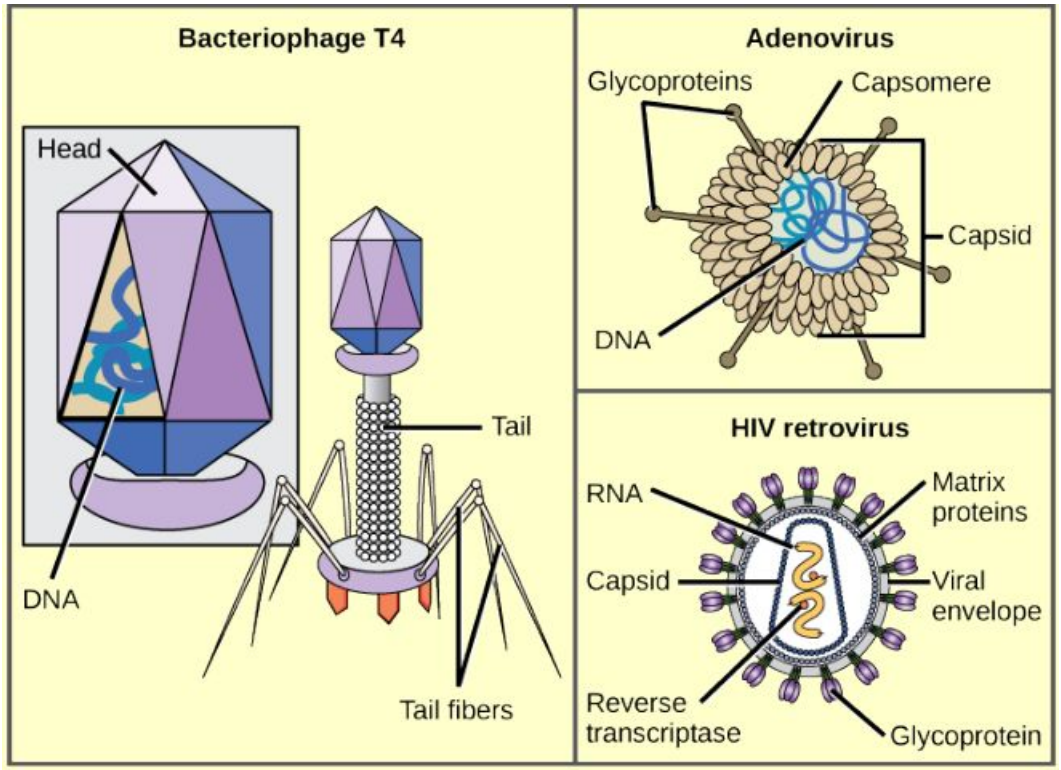
Properties of life

It’s not enough to have any of these properties.

A living organism should possess ALL of them.

Viruses are NOT living organisms

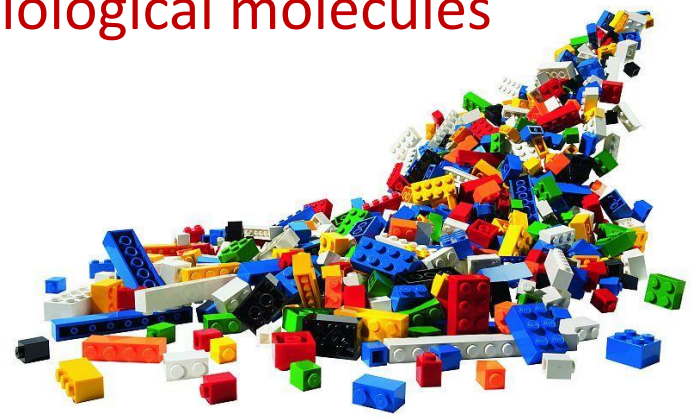
- A virus is a complex assembly of molecules – it does not have a cellular organization
- A virus consists of a **genetic material (DNA or RNA)**, and an **outer protein coating or capsid**



Chemical foundation of life

Molecules of life

- Biological universe is diverse, but uniform
- Biological systems are composed from same chemical molecules and employ same principles of organization
- Diversity is ensured by arrangement in assembly of biological molecules



The most abundant elements in living organisms

H, Hydrogen

N, Nitrogen

O, Oxygen

S, Sulfur

P, Phosphorus

C, Carbon

Atoms combine to form molecules by forming

Bond, ... Chemical Bond

Chemical bonds

Atoms form **chemical bonds by losing or gaining electrons in order to reach stable configuration** of their outermost shells

Types of chemical bonds

Strong bonds.

1. Ionic bonds
2. Covalent bonds

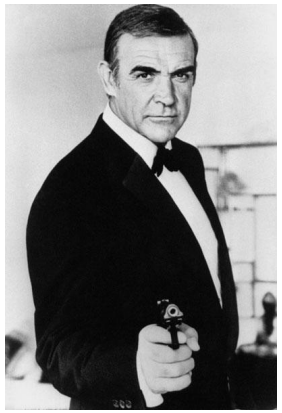
Weak bonds.

1. Hydrogen bonds
2. Electrostatic forces
3. van der Waals Interactions

They have high bond energies, meaning it takes a lot of energy to break them.

They result in the formation of distinct molecules or lattice structures.

They usually have shorter bond lengths.



Strong Bond

Weak Bond

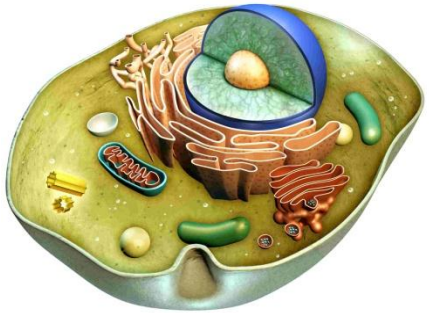
They have lower bond energies compared to strong bonds.

They are responsible for the physical properties of substances, like boiling points, melting points, and solubilities.

They are usually longer in terms of bond length compared to strong bonds.

They play a crucial role in biological systems, especially in the structure and function of large molecules like proteins and DNA.

The molecules of life.
what makes up a cell?



Small molecules

Macromolecules (polymers)

Inorganic

Organic

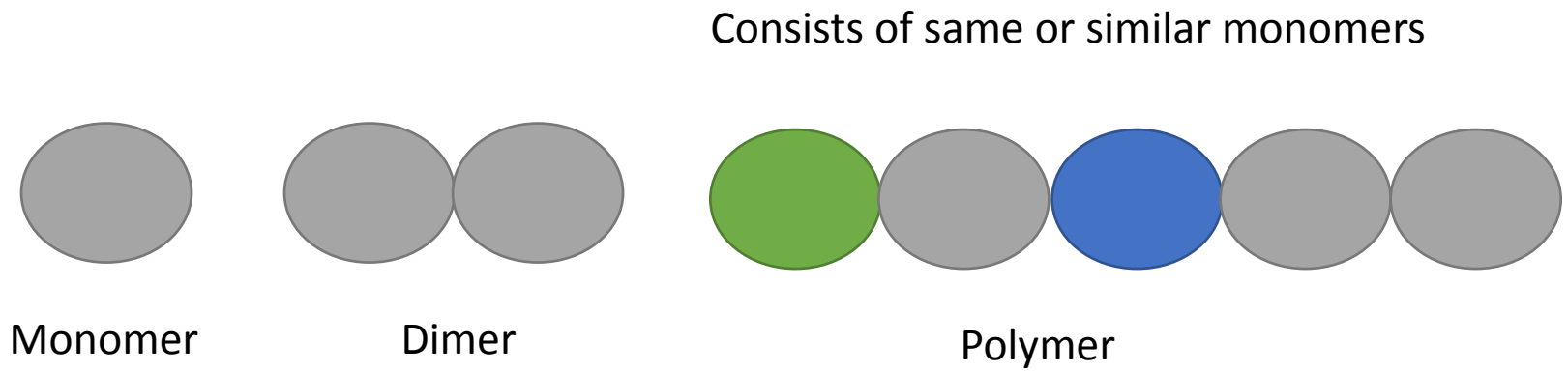
Water

Water

Biological macromolecules - polymers

- Small organic molecules (**amino acids**, **nucleotides**, **sugars**) called **monomers** can join to form **polymers**, also called **macromolecules** through repetitions of single type of chemical reaction

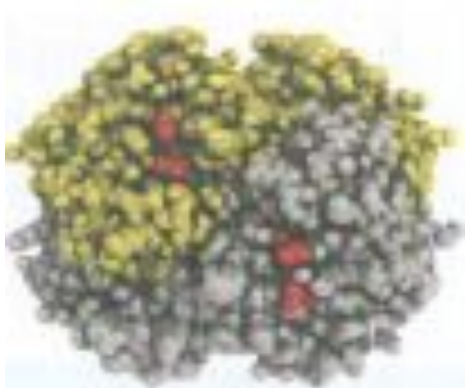
Biomolecules are formed by **covalent bonds**



Polymers

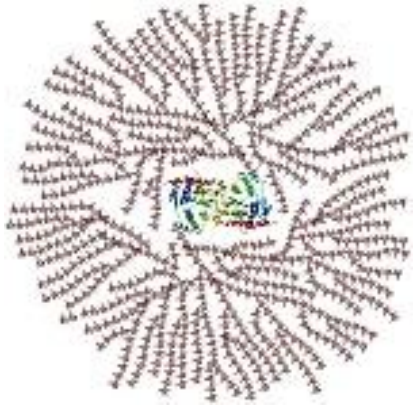
- **biological macromolecules are large molecules, necessary for life, that are built from** smaller organic molecules
- Cell produces four major types of macromolecules.

Proteins



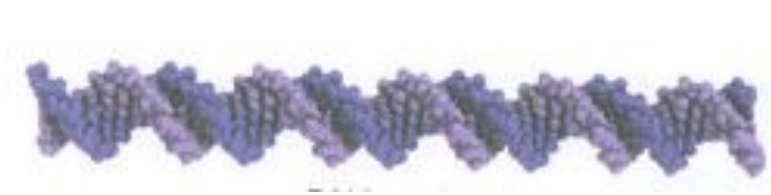
insulin

Polysaccharides

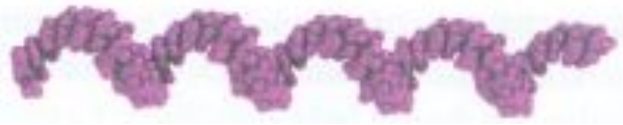


Glycogen

Nucleic acids



DNA



RNA

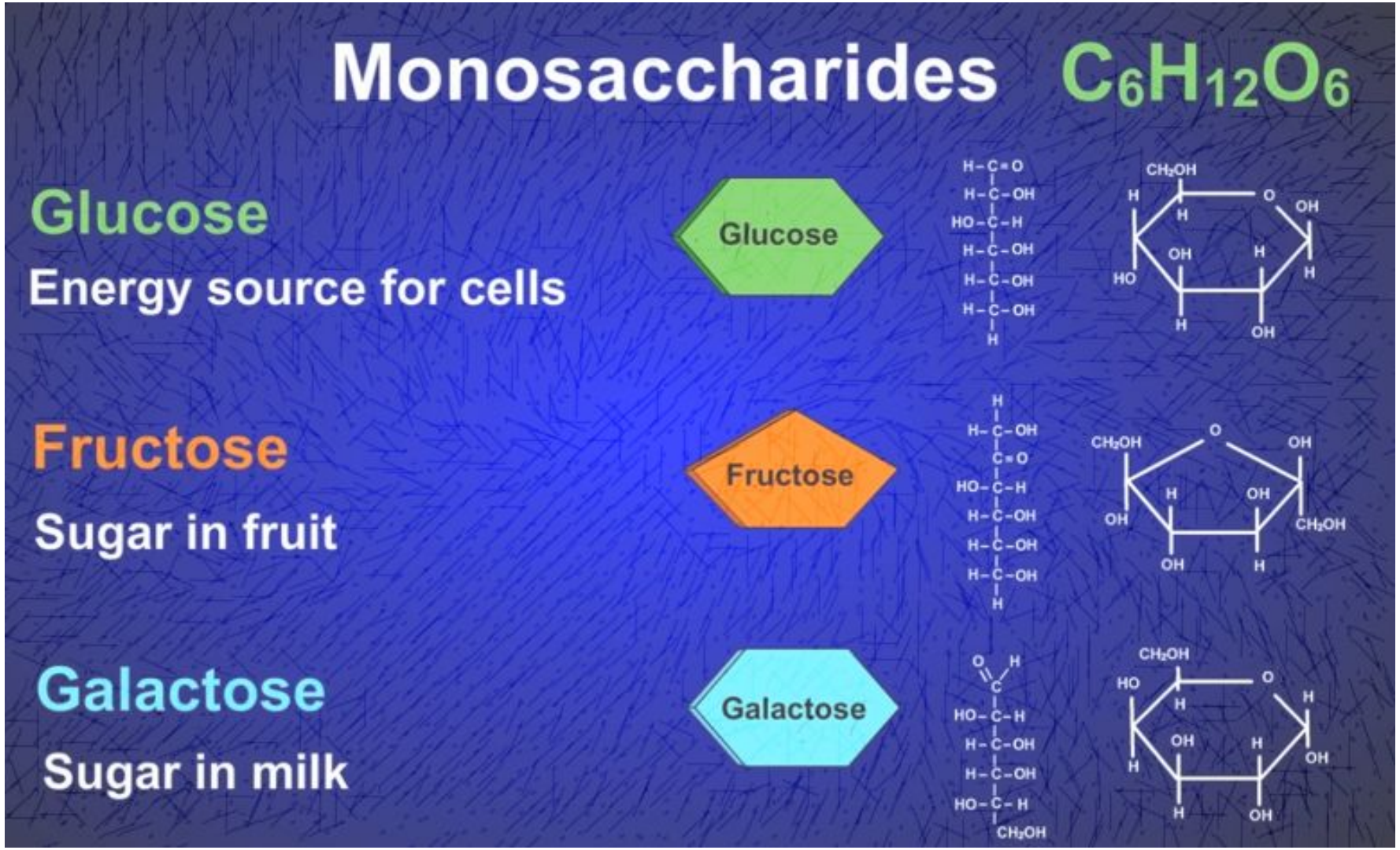
Carbohydrates

- Are essential part of our diet

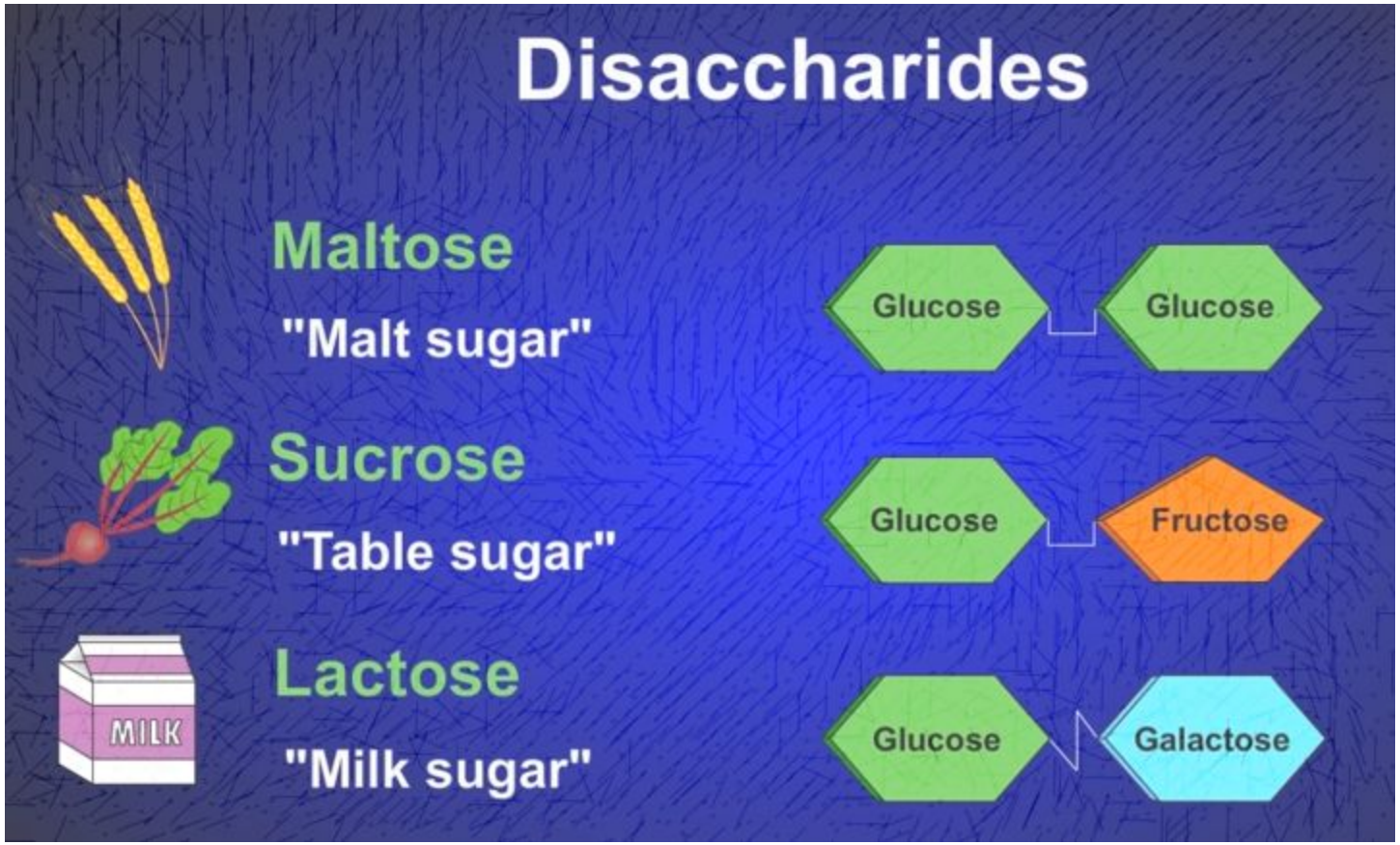
- **Carbohydrates** can be represented by the general formula $\mathbf{(CH_2O)_n}$ **–** this is where the name come from.

https://www.youtube.com/watch?v=LeOUIXbFyqk

Monosaccharides



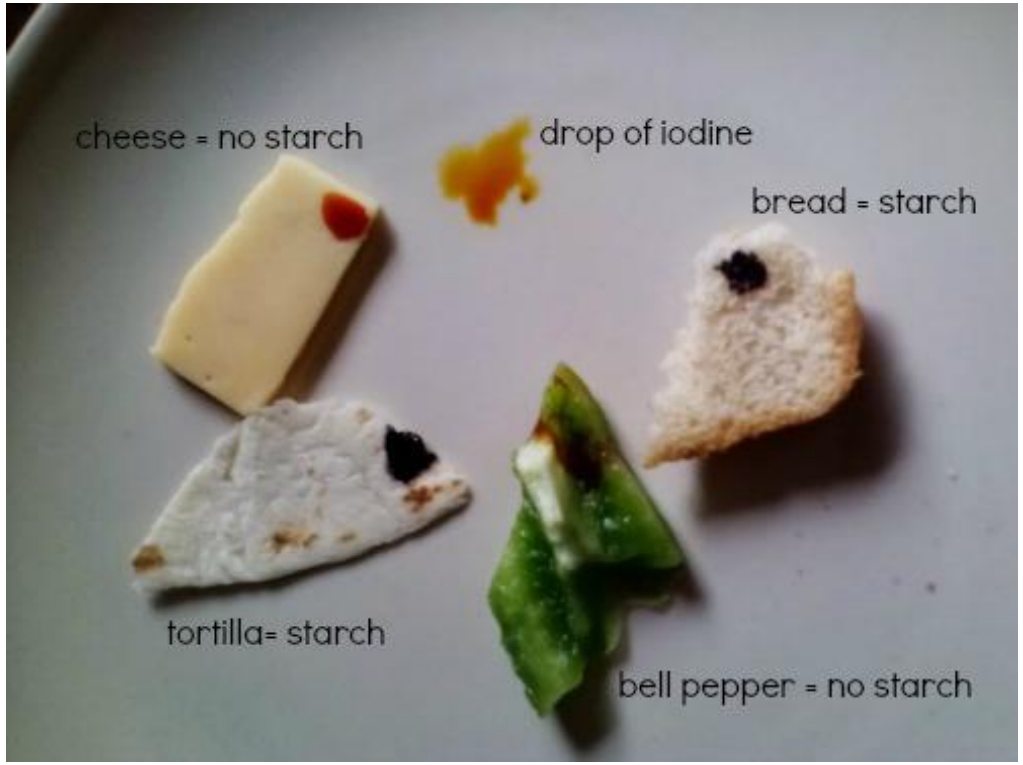
Carbohydrates



Starch

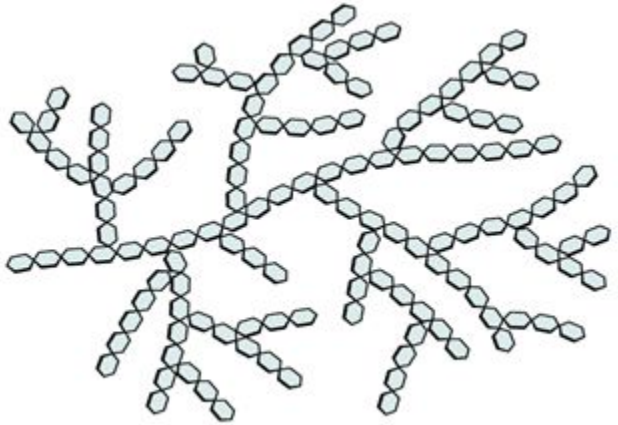
- **Starch** is made up of glucose monomers that are joined by a bond that we can digest
- The bond is called α 1-4 or α 1-6 glycosidic bonds, but you don't need to know this.

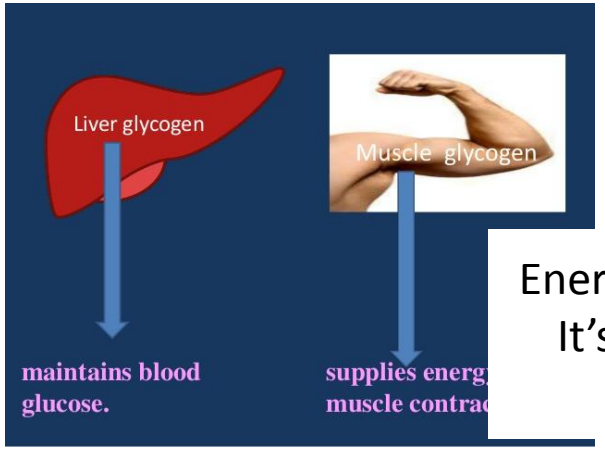
Energy storage for plants



Glycogen

- **Glycogen** is the storage form of glucose in humans and other vertebrates
- Glycogen is the animal equivalent of starch and is a highly branched molecule usually stored in liver and muscle cells
- Whenever blood glucose levels decrease, glycogen is broken down to release glucose in a process known as glycogenolysis

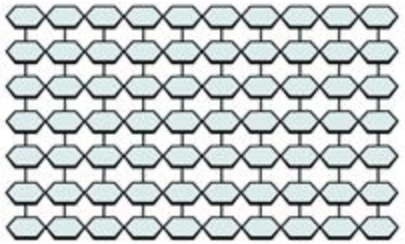


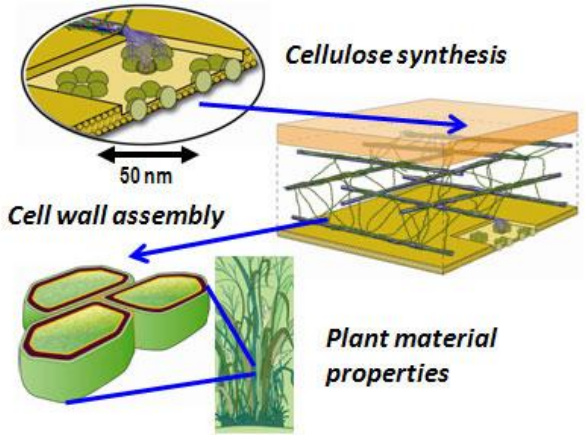


Energy storage for animals. It's more branched and faster to break

Cellulose

- Cellulose is the most abundant natural biopolymer
- Cellulose is made up of glucose monomers that are linked by bonds that we cannot digest.
- The cell wall of plants is mostly made of cellulose. The bonds give cellulose its rigidity and high tensile strength





Structural role. rigid exoskeleton of plants. Most organisms are unable to break the cellulose bonds.

Functions of carbohydrates

- **Energy Source.** The primary role of carbohydrates is to provide energy. Once consumed, carbohydrates can be converted into glucose, which can then be used by our cells for energy.
- **Energy Storage.** Plants store excess glucose in the form of starch, whereas animals store it in the form of glycogen. These storage forms can be broken down into glucose when needed for energy.
- **Structural Role.** Some carbohydrates serve as structural molecules. The plant cell wall is made up of cellulose, a polymer of glucose.
- **Cell Identification and Signaling.** Glycoproteins and glycolipids, found on the surface of cell membranes, play roles in cell recognition, signaling, and adhesion. They are formed by the attachment of carbohydrate chains to proteins and lipids.
- **Precursor Molecule.** Carbohydrates serve as precursor molecules in the synthesis of certain amino acids and other cellular components.
- **Dietary Fiber.** Certain carbohydrates, especially polysaccharides like cellulose, act as dietary fiber in our diet. They are not digestible by human enzymes but play a vital role in maintaining gut health, aiding in digestion.
- **Protection and Lubrication.** Mucins are glycoproteins that contain a significant amount of carbohydrates. They are found in mucus and other secretions, providing lubrication and protection to various surfaces in the body.

Lipids

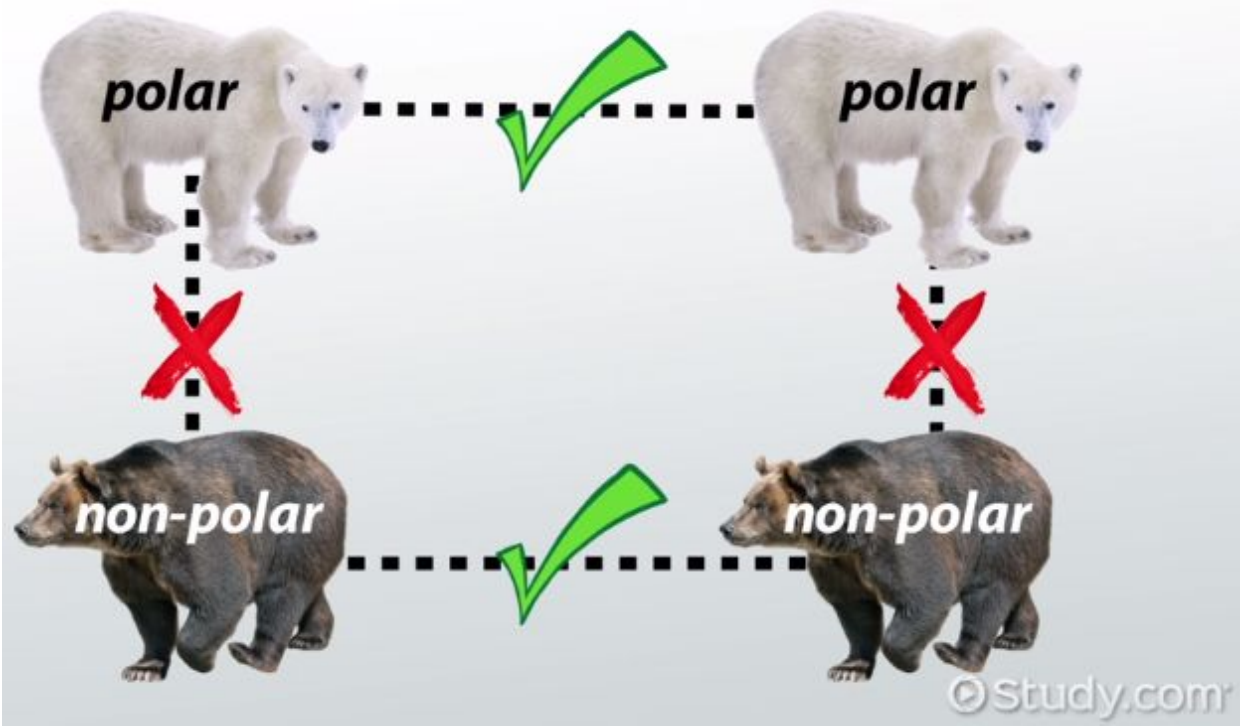
- Lipids include a diverse group of compounds that are largely nonpolar in nature and thus do not dissolve in water.

- Lipids include
  - Fats,
  - Oils,
  - Waxes,
  - Phospholipids,
  - Steroids.

Polar and non-polar molecules

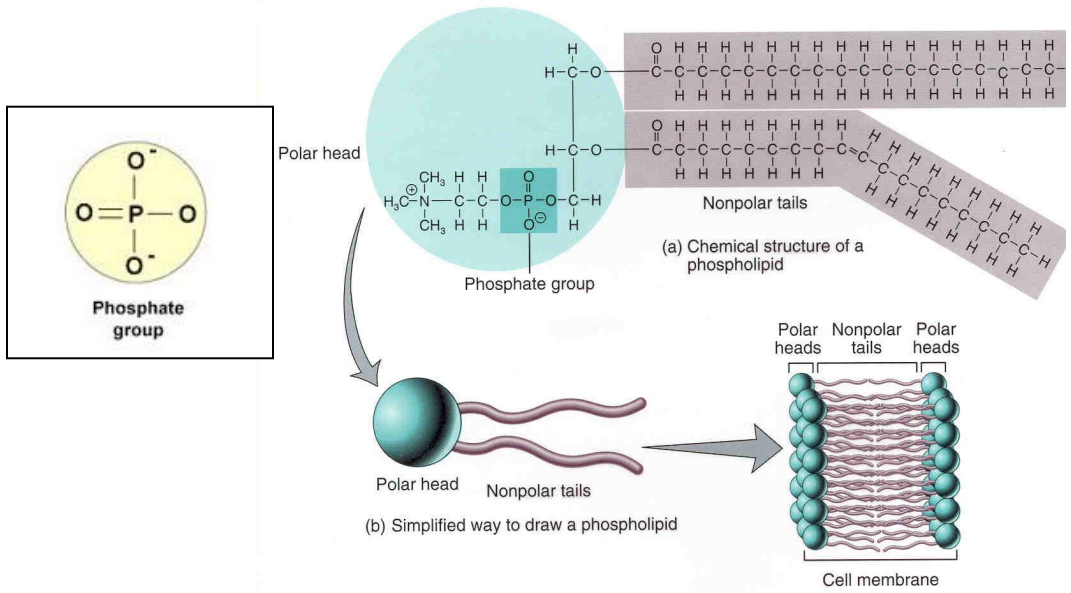
Polar molecules **(e.g. sugar, alcohol, salt …)** dissolve in water. They are **hydrophilic. Hydro – water, philos – love, affinity**

Non-polar molecules ***do not !!!!*** dissolve in water
They are **hydrophobic.**
Hydro – water,
phobia – fear



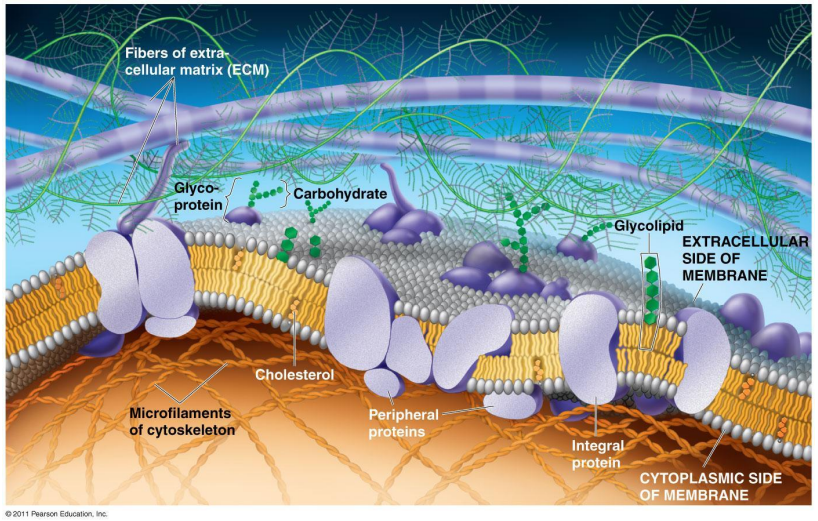
Non-polar molecules (**e.g. fats**) dissolve in **non-polar solvents** (benzene, chlorophorm, toluene)

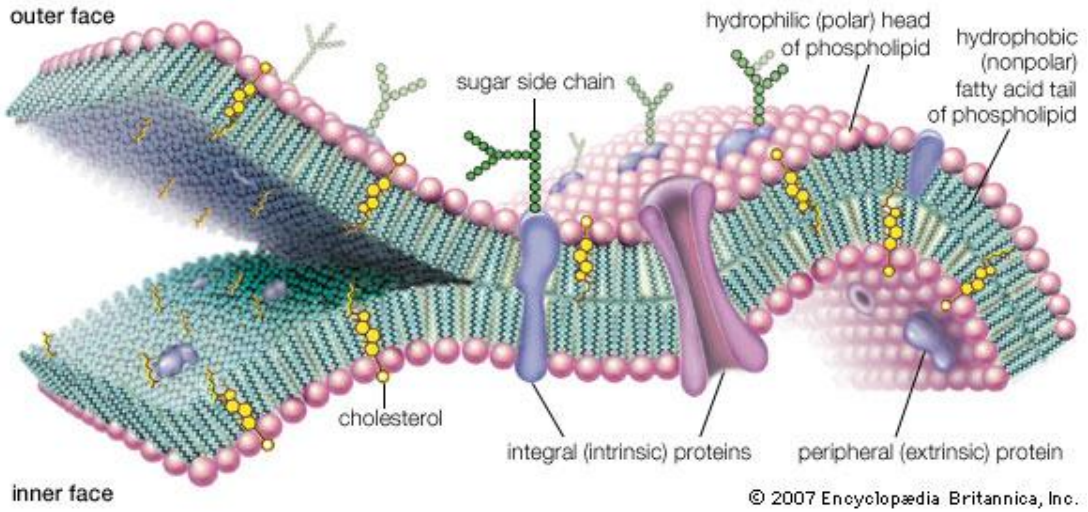
Phospholipids



Phospholipids are made by replacement of a fatty acid chain in triglycerides with a **phosphate group** to which additional functional groups can be attached.

They are major constituents of the **plasma membrane**, the outermost layer of animal cells.

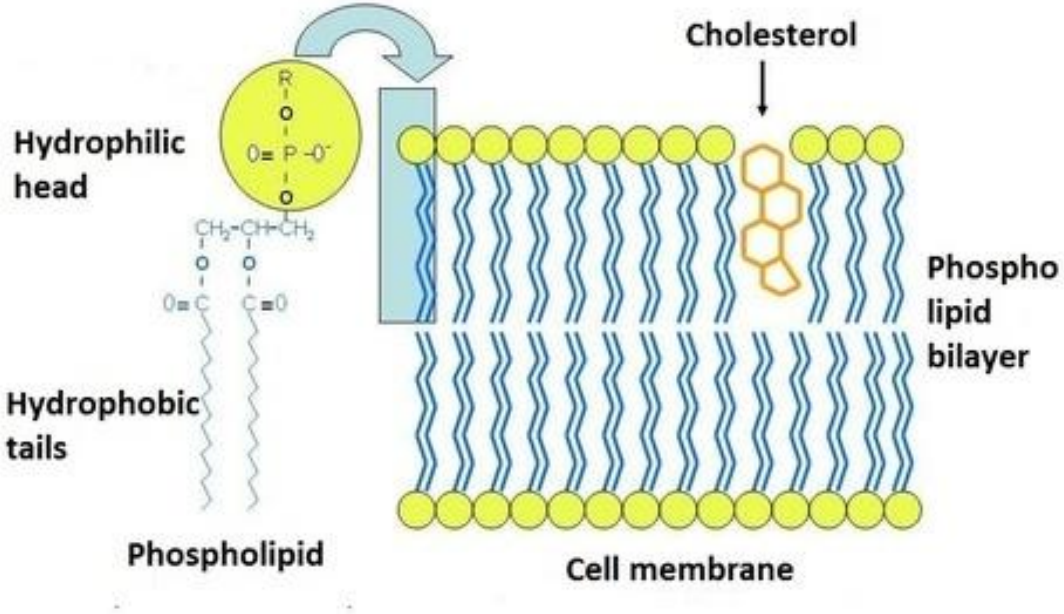




Membrane phospholipids have hydrophilic heads and hydrophobic tails, which is the basis of the membrane properties.

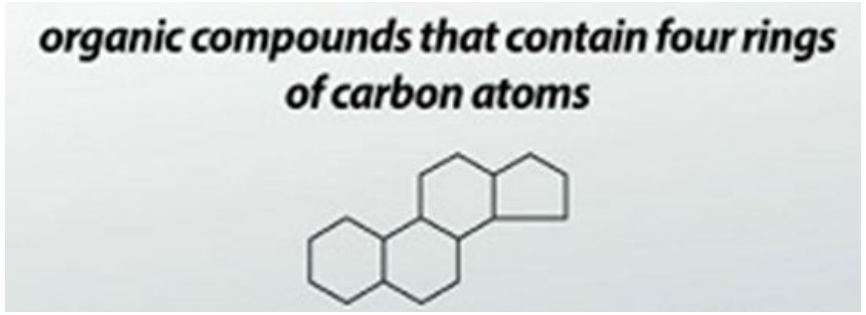
A phospholipid is an **amphipathic** molecule, meaning it has a **hydrophobic** and a **hydrophilic** part

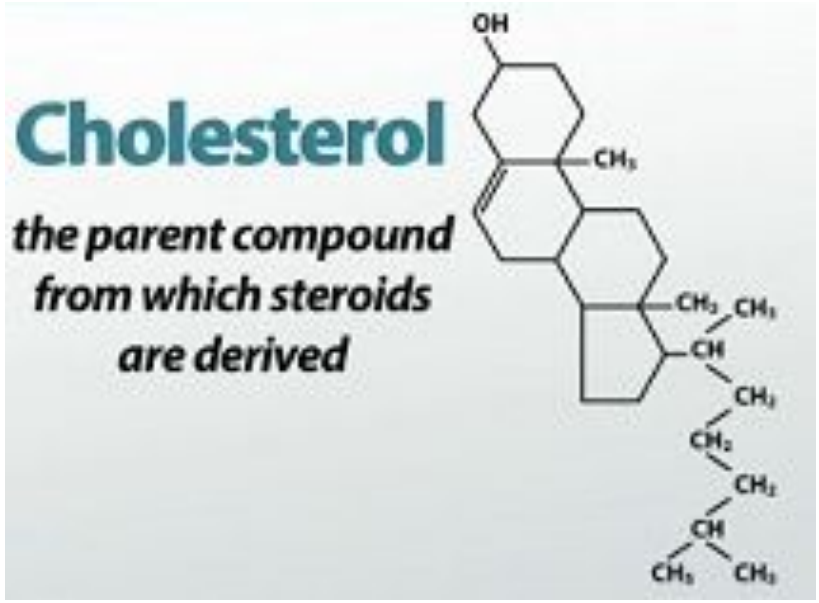
Phospholipids are responsible for the fluidic and dynamic nature of the plasma membrane and its selective permeability.



https://www.youtube.com/watch?v=Qqsf_UJcfBc

Steroids

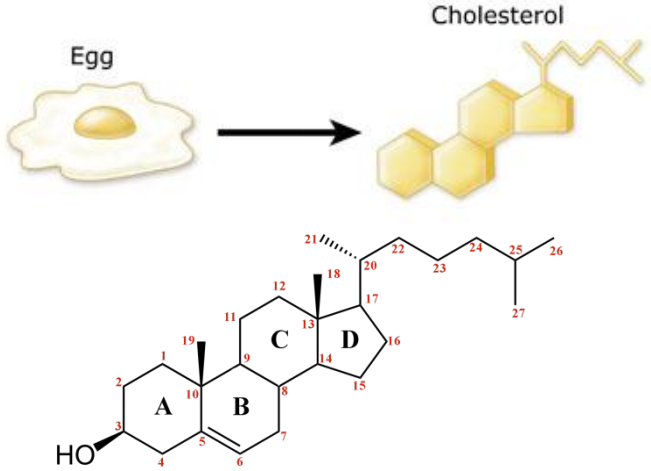




- **Steroids** have a fused ring structure
- They are hydrophobic and insoluble in water
- All steroids have four linked carbon (and tail)
- Cholesterol is the most common steroid
- Is a precursor of steroid hormones such as testosterone and estradiol, vitamin D
- Is a component of plasma membrane
- Participates in transport and cellular communication

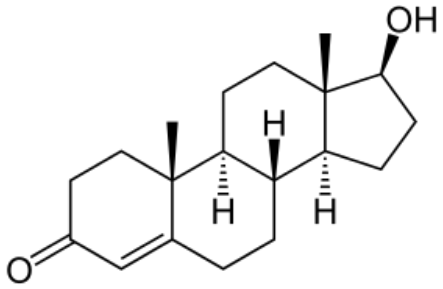
Steroids

Cholesterol

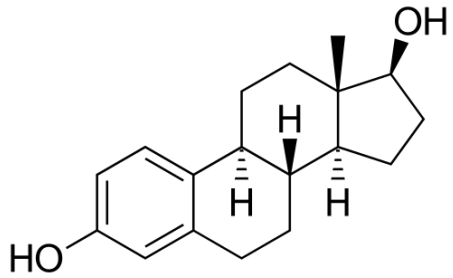


Sex hormones

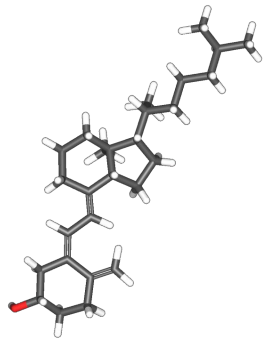
Testosterone



Estrogen

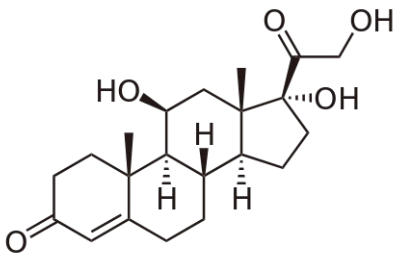


Vitamin D

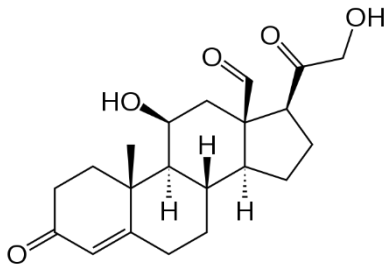


Other hormones (Corticosteroids)

Cortisol.
immunosupression



Aldosterone.
blood pressure



Function of lipids

- **Energy Storage.** Lipids, particularly triglycerides, are efficient energy storage molecules (twice the amount of energy per gram as compared to carbohydrates or proteins). Excess energy is stored primarily as fat in adipose tissue.
- **Cell Membrane Structure.** Phospholipids are major components of the cell membrane.
- **Signaling Molecules.** Certain lipids function as signaling molecules. Steroid hormones are involved in a wide range of physiological processes, including development, metabolism, and immune responses.
- **Vitamin Absorption and Storage.** Some vitamins are lipid-soluble, which means they are absorbed along with fats in the diet and stored in fatty tissues. Examples include vitamins A, D, E, and K.
- **Cofactors for Enzymes.** Some lipids serve as essential cofactors for certain enzymes, enabling them to perform their functions.
- **Digestion and Absorption.** Bile acids, which are derived from cholesterol, aid in the emulsification and digestion of dietary fats in the intestines.
- **Barrier Function.** In the skin, lipids form a barrier in the stratum corneum, preventing excessive water loss and protecting against harmful substances from the environment.
- **Insulation and Protection.** Fat stored in the subcutaneous layer serves as insulation, helping to regulate body temperature. Adipose tissue also acts as a cushion, protecting internal organs from mechanical trauma.

Reading

Concepts of Biology

Chapter 1, sections 1.1

Chapter 2, sections 2.1, 2.3

Homework

Chapter 1 (page 25-26), questions 1, 2, 3, 4

Chapter 2 (page 55), questions 3, 8, 9, 10, 11, 12, 15