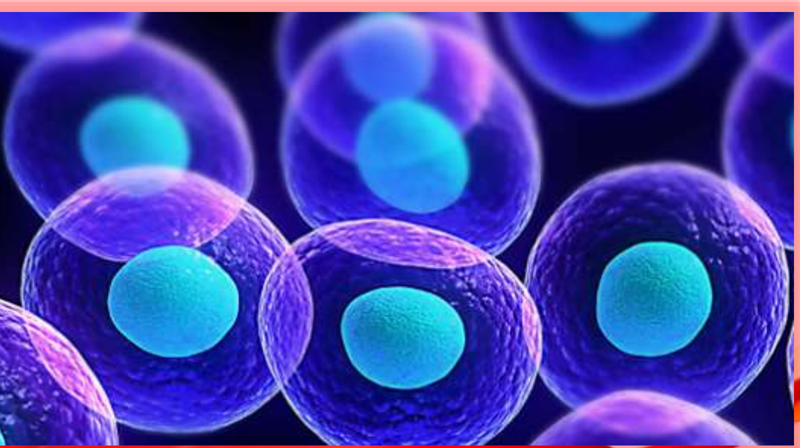
UNIT 2: PROCESSES THAT SUSTAIN LIFE

TWO CHAPTERS:

- Chapter 3
- Chapter 4

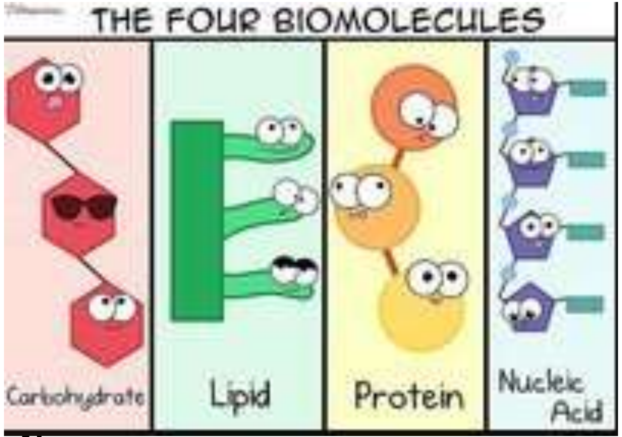


UNIT 2 OPENER – PROCESSES THAT SUSTAIN LIFE

- *In this unit, we will explore the following topics:*
  - Biochemistry of life
  - Development and improvement of the microscope as it relates to the study of biology
  - Cell theory – types of cells, cell structures, cell transport methods

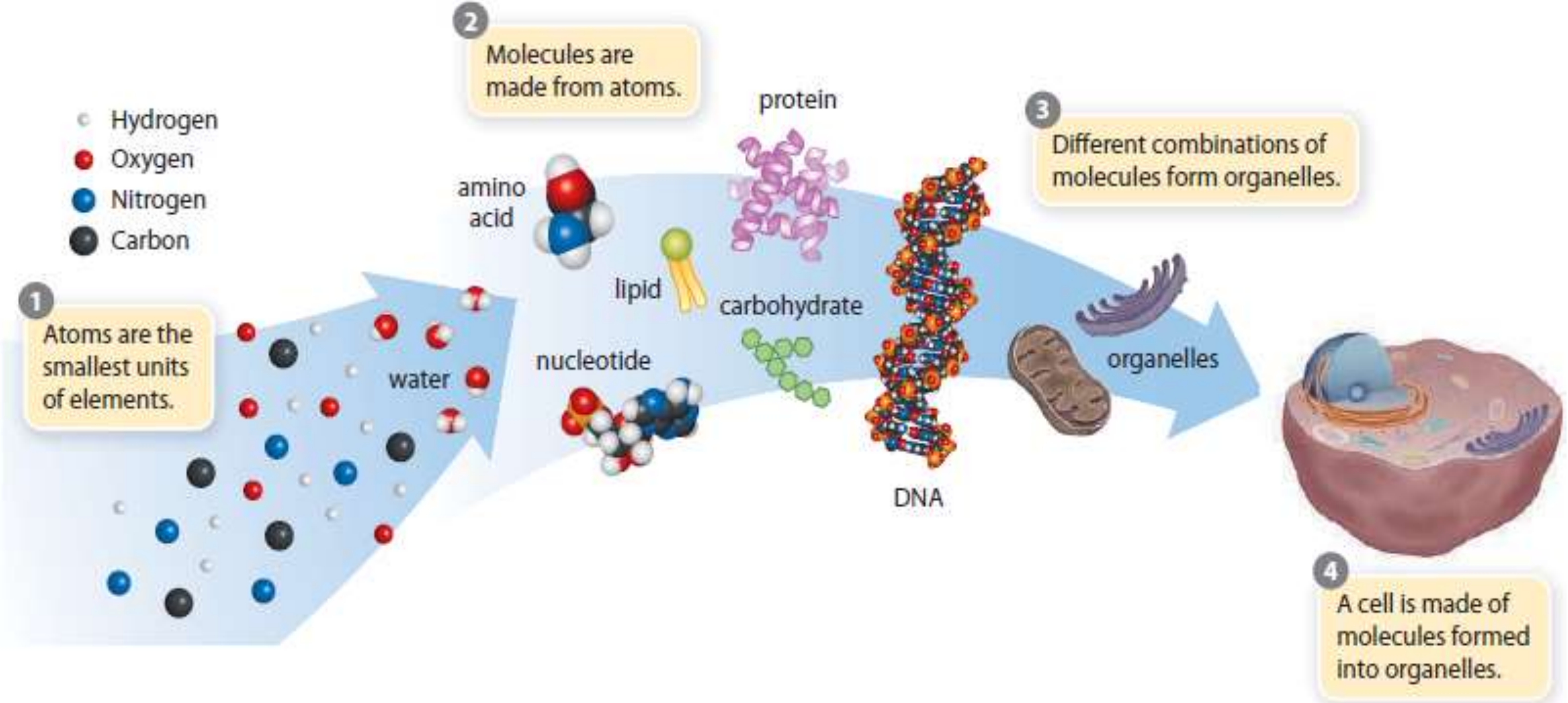
CHAPTER 3 – MOLECULES IN CELLS: BUILDING BLOCKS OF MATTER

- *Chapter 3 will focus on Biological Molecules in Cells:*
  - *3.1 Chemistry Fundamentals* ✓
  - *3.2 Molecules of Life* ✓
  - *3.3 Enzymes (**not in Unit 2**)*
  - This chapter goes into greater detail than needed for Biology 2201, so keep that in mind when independently reading.



3.1 – CHEMISTRY FUNDAMENTALS

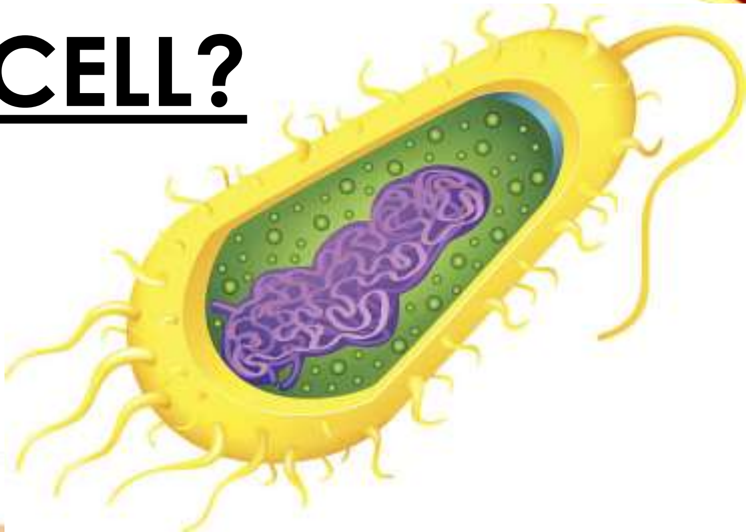
- In this section, we will highlight the connection between **chemistry** and **cellular function**.



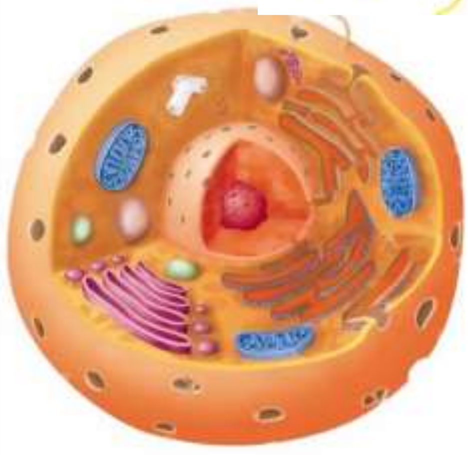
3.1 – CHEMISTRY FUNDAMENTALS

- What is **Biochemistry**? CLIP (stop at 2 min)
  - A field of science that combines the disciplines of **biology** and **chemistry**.
  - It is the study of the **activity and properties of molecules** that are **important to living systems and cells**.

WHAT IS A CELL?

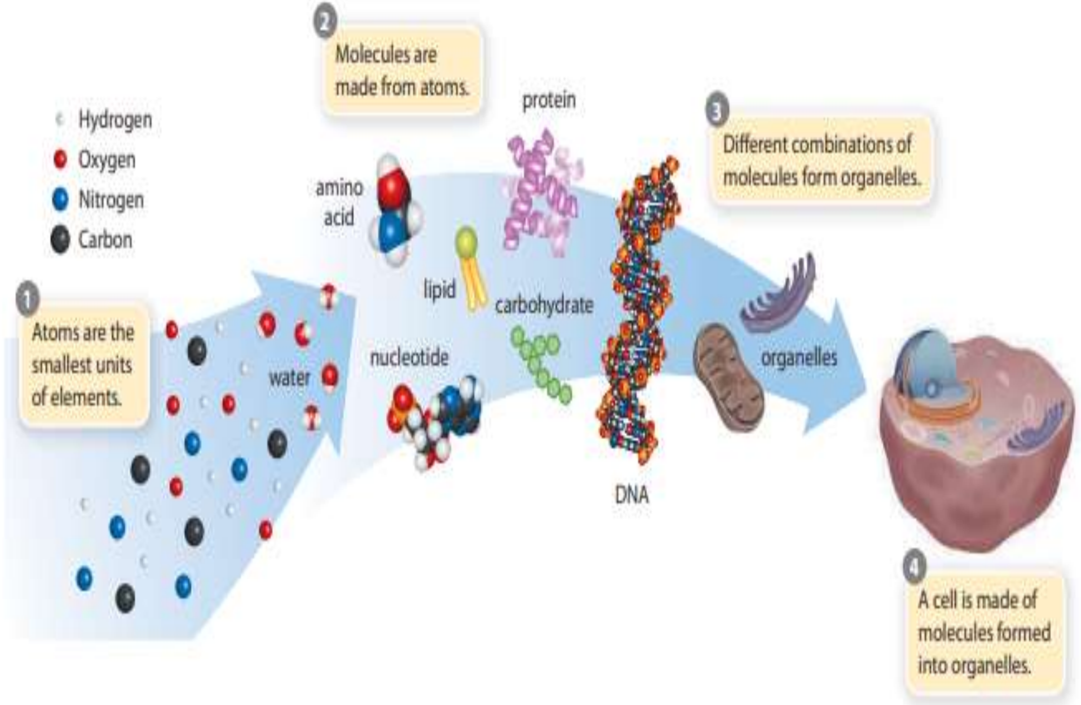


- The **building blocks of life.**
- The cell is the **smallest unit of life** that can exist on its own.
- All **living things are made up of cells**. (***unicellular*** or ***multicellular***).



WHAT IS A CELL? . . .

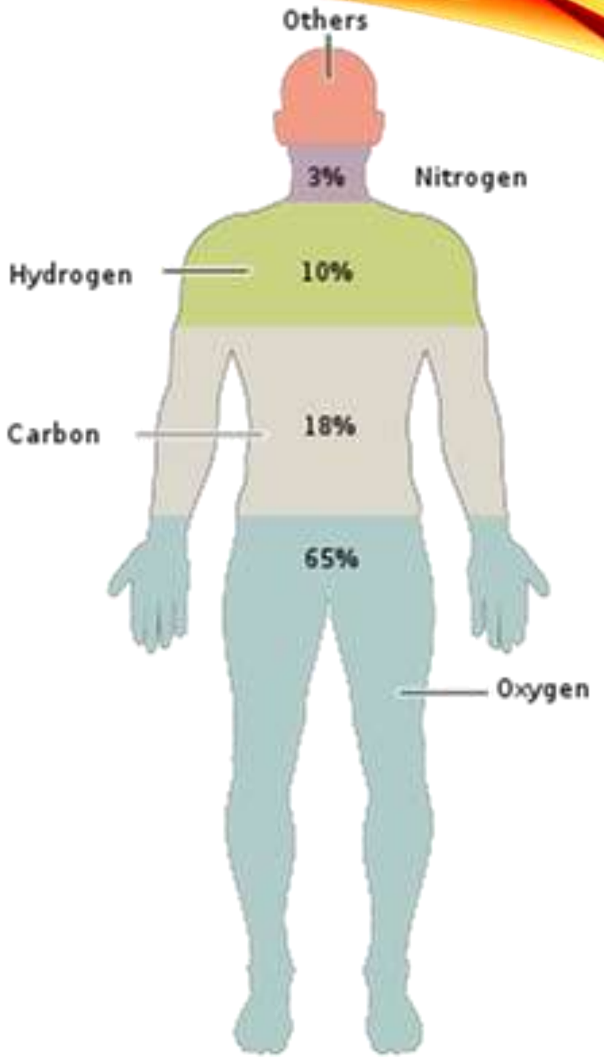
- To understand cells and cell function, we need to become more familiar with their basic components: **elements and compounds**.
- A brief review of Chemistry is required.



ELEMENTS

- All the matter that makes up living organisms is made up of one or more **elements** from the periodic table.
- **25 elements** are essential to life.
- Living things are composed almost entirely (**96 % of the human body**) of 4 elements:

  - **hydrogen (H)**
  - **oxygen (O)**
  - **nitrogen (N)**
  - **carbon (C)**



ELEMENTS . . .

Trace Elements found in our body:

- **iron (Fe)**
- **iodine (I)**

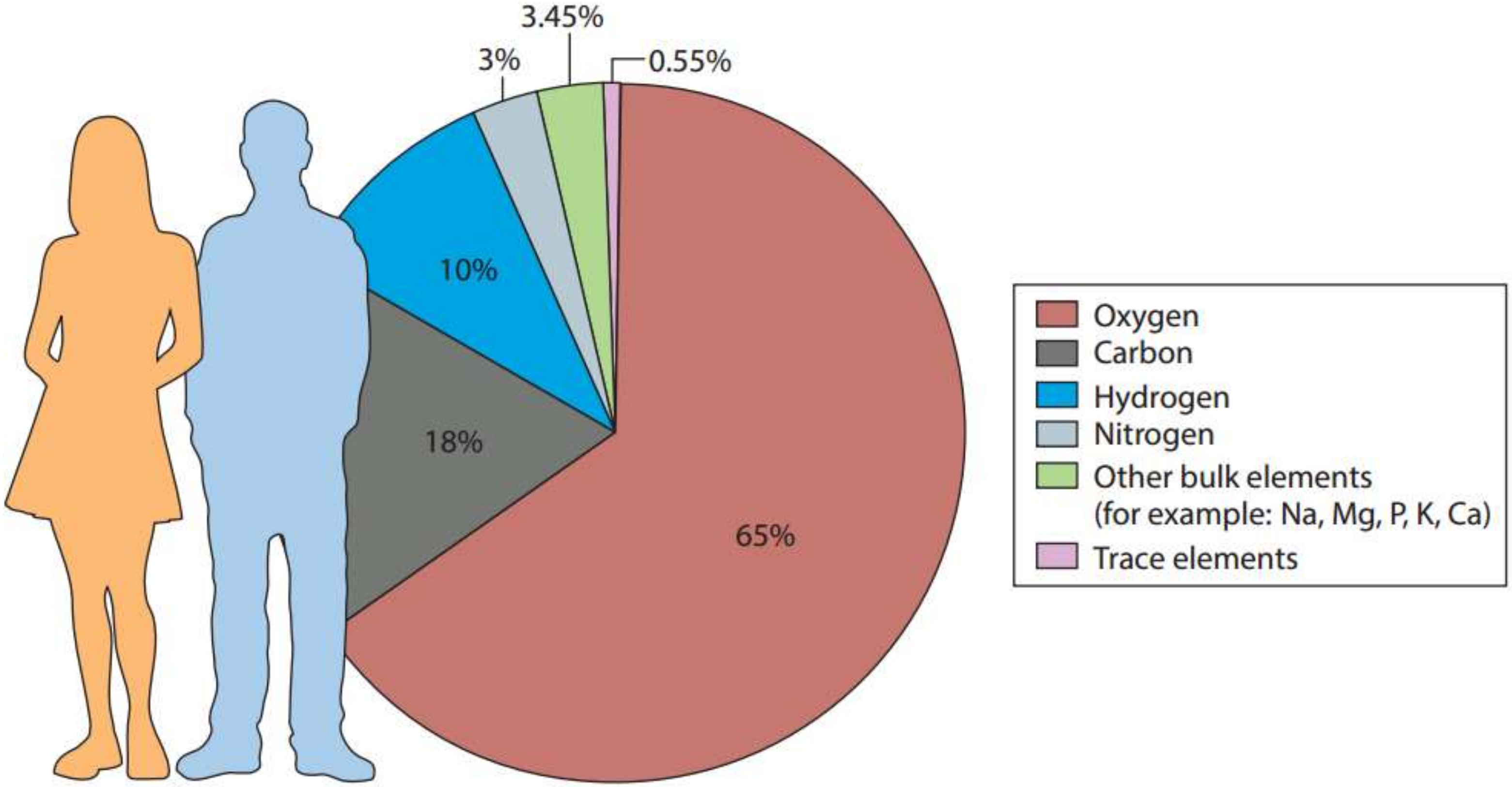
0.55%

Bulk Elements found in our body:

- **sodium (Na)**
- **magnesium (Mg)**
- **phosphorus (P)**
- **potassium (K)**
- **calcium (Ca)**

3.45%

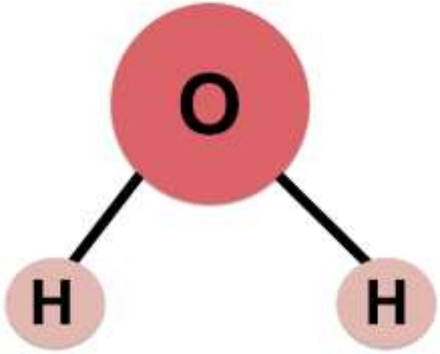
ELEMENTS . . .

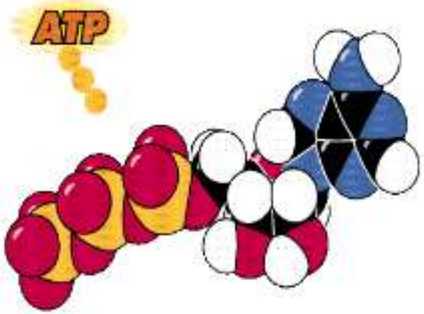

3.45%
3%
0.55%
10%
18%
65%
Oxygen
Carbon
Hydrogen
Nitrogen
Other bulk elements
(for example: Na, Mg, P, K, Ca)
Trace elements

COMPOUNDS

- Most elements found in your body are not in their **pure form** but are chemically combined together as **compounds** (usually **molecules**).
- Molecules are a type of chemical compound that have **covalent bonds**.

- Examples include:





- **Water (H_2O)**
- **Carbon dioxide (CO_2)**
- **Oxygen (O_2)**
- **DNA (deoxyribonucleic acid)**
- **ATP (adenosine triphosphate)**

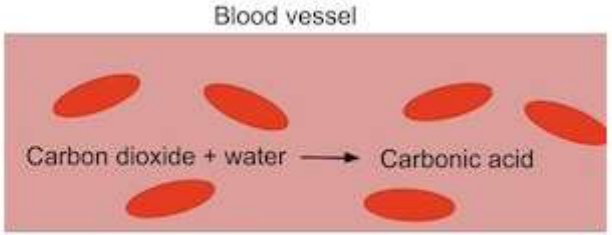
IONS

- Ions are **charged particles** and take part in **many biological processes** (ex: the beating of your heart or messages transmitted to and from the brain).

- Ions that are **dissolved in the body's fluids** are called **electrolytes** and include:
  - **sodium (Na^+)**
  - **potassium (K^+)**
  - **hydrogen (H^+)**
  - **calcium (Ca^{2+})**
  - **iron (Fe^{2+})**
  - **phosphate (PO_4^{3-})**
  - **chloride (Cl^-)**
  - **iodide (I^-)**

CHEMICAL REACTIONS

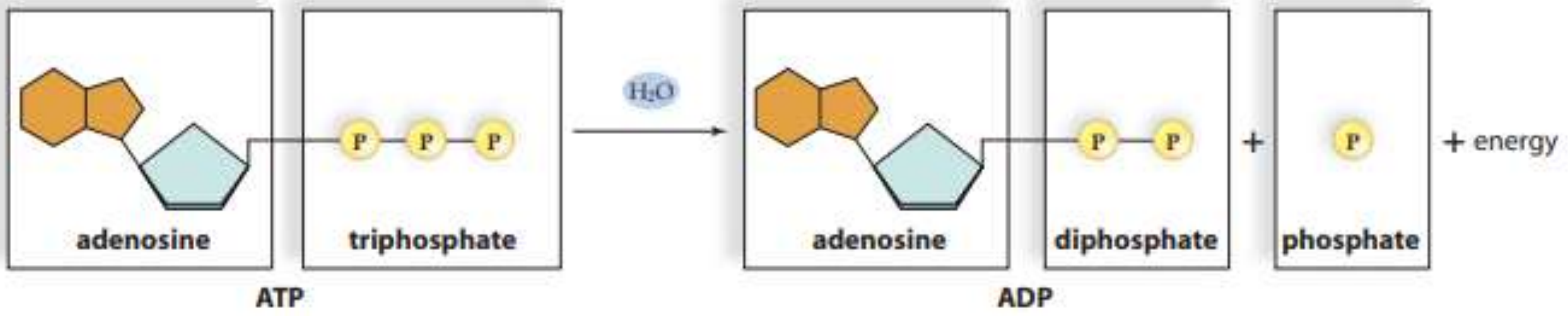
- In a chemical reaction, elements and compounds **are rearranged** to form **different substances with different properties**.
- In the process, **reactant** bonds **break** and **product** bonds are **formed**.
- ***Energy*** is either **released** or **absorbed**.
- **Living systems** depend on **chemical reactions** and **energy changes** that occur in cells.

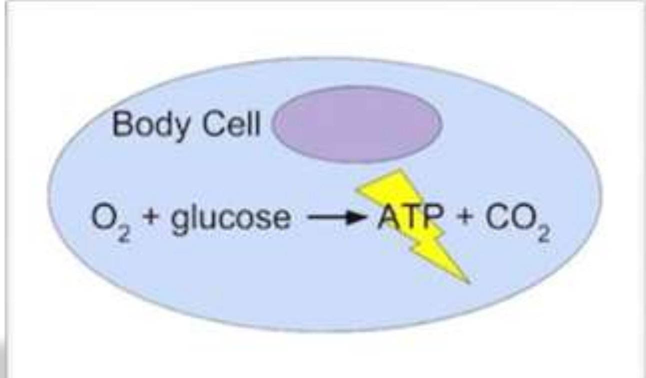


Carbon dioxide is converted to carbonic acid in the blood to keep you alive

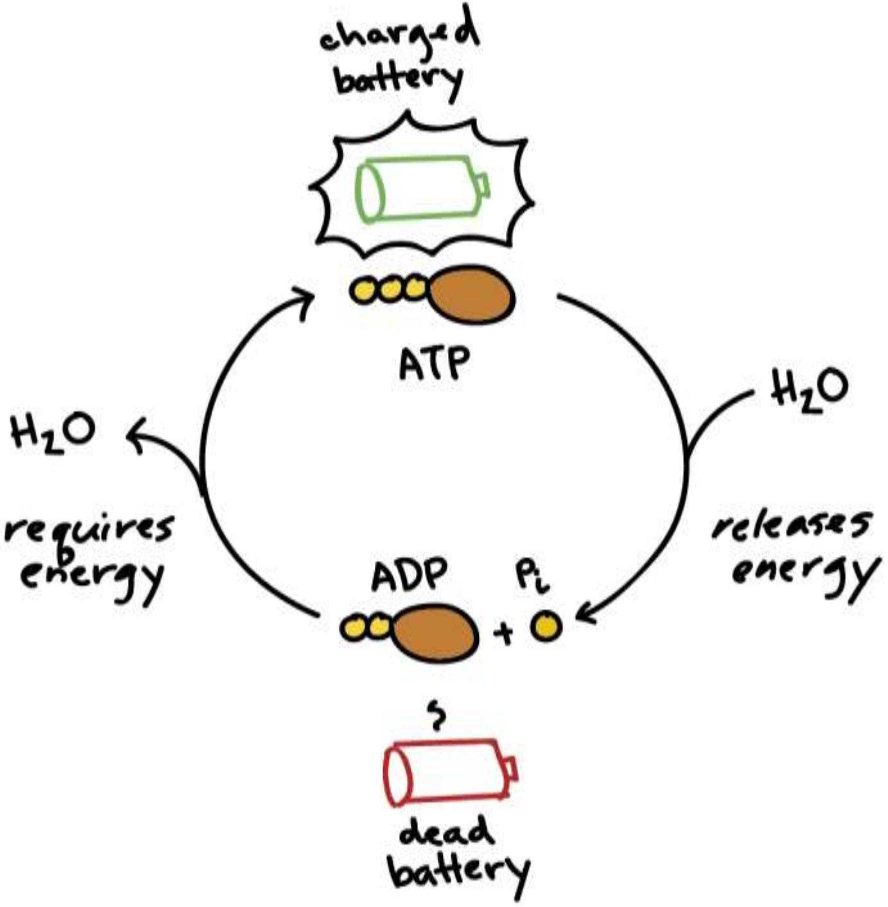
CHEMICAL REACTIONS . . .

- For example, **ATP** (adenosine triphosphate) is an **energy-carrying biological molecule**.
- It is considered by biologists to be the **energy currency of life**.
- It **stores the energy** to do just about everything we need to do in life.





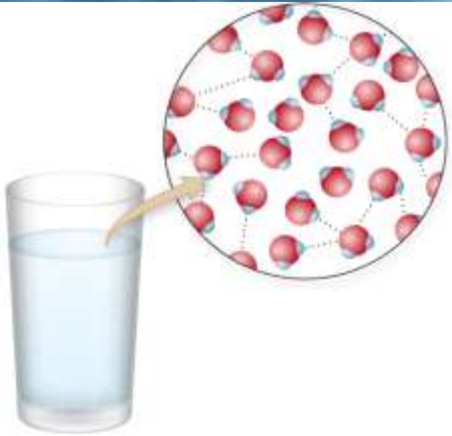
Equation for cellular respiration

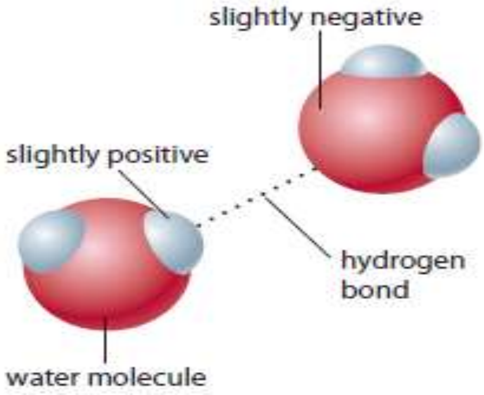


FOCUS ON WATER

CLIP

- No organism on Earth can live without **water.**
- Water is a **polar molecule**, meaning that it has a **slightly positive charge** on one end, and a **slightly negative charge** on another end.





FOCUS ON WATER

What is the role of water in living systems ?

1. **Provides a medium for most chemical reactions.**
2. **Transports dissolved substances throughout the system.**
3. **A reactant in many of life's chemical reactions.**
4. **Regulates temperature.**

Table 3.1 Water's Unusual Properties

Property	Explanation	Example(s)
Water dissolves many substances.	"Like dissolves like." Because water is a polar molecule, it dissolves compounds made of ions or polar molecules.	Water provides a medium in which substances can undergo chemical reactions in living systems. Within living systems, water solutions (such as blood plasma) transport dissolved substances to where they are needed. 
Water regulates temperature.	Water has a strong ability to resist temperature changes. It takes more heat to raise water's temperature than it takes for most other liquids. Also, a lot of heat is required to change water from a liquid to a gas.	When sweat evaporates from skin, water molecules must absorb energy to escape into the air. When they evaporate they absorb thermal energy from the body. This cools the body and thus helps to regulate body temperature. 
Water expands as it freezes.	Ice is less dense than liquid water. As water freezes, the ice floats on the surface of the denser liquid water below.	When the air temperature drops, a small amount of water freezes at the lake's surface. A solid cap of ice forms, which traps heat in the water below, preventing the water from freezing further and protecting aquatic organisms from freezing. 

Water takes part in life's chemical reactions.	Nearly all of life's chemical reactions occur in the watery solution that fills and bathes cells. In addition, water is either a reactant in or a product of many of life's chemical reactions.	In photosynthesis, plants use the Sun's energy to assemble food using carbon dioxide and water. Oxygen, which nearly all organisms require, is released.	
Water is cohesive.	Hydrogen bonds contribute to a property of water called *cohesion*—the tendency of water molecules to stick together. The water molecules at the surface of water hold together so strongly that they form a "skin" at the surface.	Surface tension allows insects, such as this water skimmer, to literally walk on water.	
Water adheres to other substances.	Water also demonstrates *adhesion*, an attraction to the molecules of other substances. Adhesion provides an upward force on water and counteracts the pull of gravity.	Adhesion causes water molecules to stick to the inner surface of a glass tube or the water-conducting vessels in a plant. When evaporation draws water out from a plant's leaves, the remaining water in the stem is pulled up by adhesion and cohesion.	

FOCUS ON WATER

CLIP

- Water is referred to as the **UNIVERSAL SOLVENT** as it dissolves so many substances (**solutes**).
- But there are many things that water **does not dissolve**.
- Scientists divide substances into two categories based on water solubility:
  - **Hydrophobic**
  - **Hydrophilic**

HYDROPHILIC

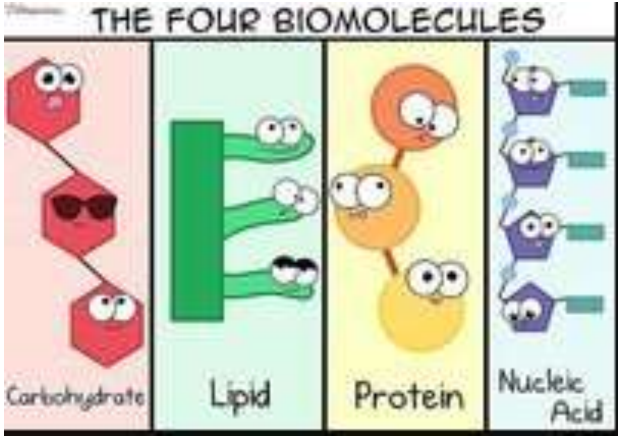
- Hydrophilic = **“water loving”**
- Hydrophilic substances **dissolve in water**.
- Usually **polar molecules** or **ions**.
- Ex:
  - **sugar** or **table salt** in water

HYDROPHOBIC

- Hydrophobic = **"water fearing"**
- Hydrophobic substances **do not** dissolve in water.
- Usually **non-polar** or **molecules**.
- Ex: **fats** or **oils** in water
- Make **protective coatings** in living organisms.

3.2 – MOLECULES OF LIFE

- Macromolecules are **large molecules made up of smaller molecules**.
- The 4 major classes of biological macromolecules are:
  - **Carbohydrates**
  - **Lipids**
  - **Proteins**
  - **Nucleic Acids (will be covered in 3201)**



- Animals obtain macromolecules and other biological molecules **from the food they eat.**

CARBOHYDRATES

Category	Examples	Chemical Structure	Functions(s)
Carbohydrates 	monosaccharides and disaccharides	single and double rings composed of C, H, and O	Provide quick energy
	complex carbohydrates (such as cellulose, starch)	polymers of monosaccharides	Provide structure to cells and organisms; store energy

CARBOHYDRATES CLIP

- A carbohydrate is a biomolecule containing **carbon, hydrogen, and oxygen**.
- Common carbohydrates include **sugars** such as **glucose, sucrose and fructose** as well as **starch** and **cellulose**.
- Carbohydrates are an important source of **energy**.
- *What are some foods that contain carbohydrates?*

CARBOHYDRATES . . .

SUGAR	OTHER NAME	FOOD SOURCES
Glucose	**"Blood Sugar"**	**Fruit, Veggies, Grains**
Sucrose	**"Table Sugar"**	**Table Sugar, Sugar Cane**
Fructose	**"Fruit Sugar"**	**Fruit**
Maltose	**"Malt Sugar"**	**Grains**
Lactose	**"Milk Sugar"**	**Milk**

CARBOHYDRATES . . .

- Carbohydrates include:

1. **Monosaccharides - single sugar**
2. **Disaccharides - two sugars linked**
3. **Polysaccharides - complex sugars (polymers)**

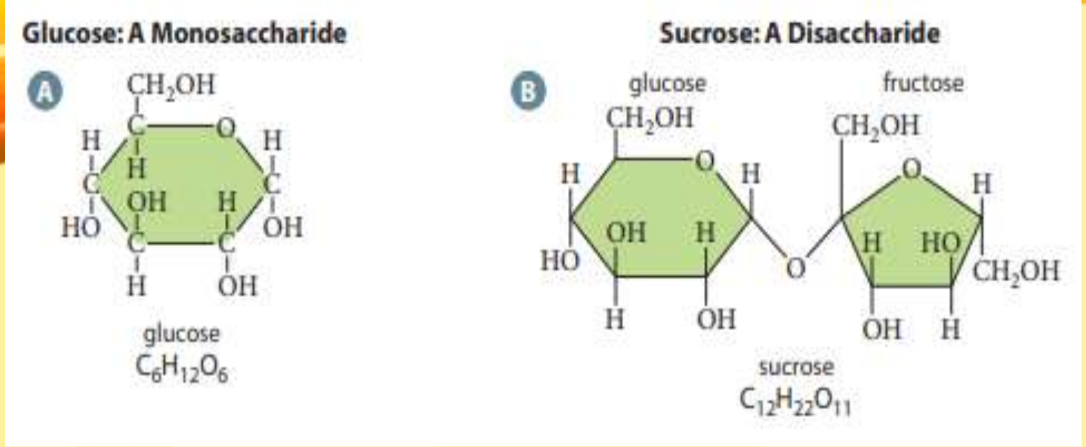
- Monosaccharides and disaccharides are classified as **simple carbohydrates**, also called **simple sugars**. Monosaccharides and disaccharides are **immediate energy sources** .
- In humans, **glucose** provides the body with a source of immediate energy since body cells can easily use it to make **ATP**.

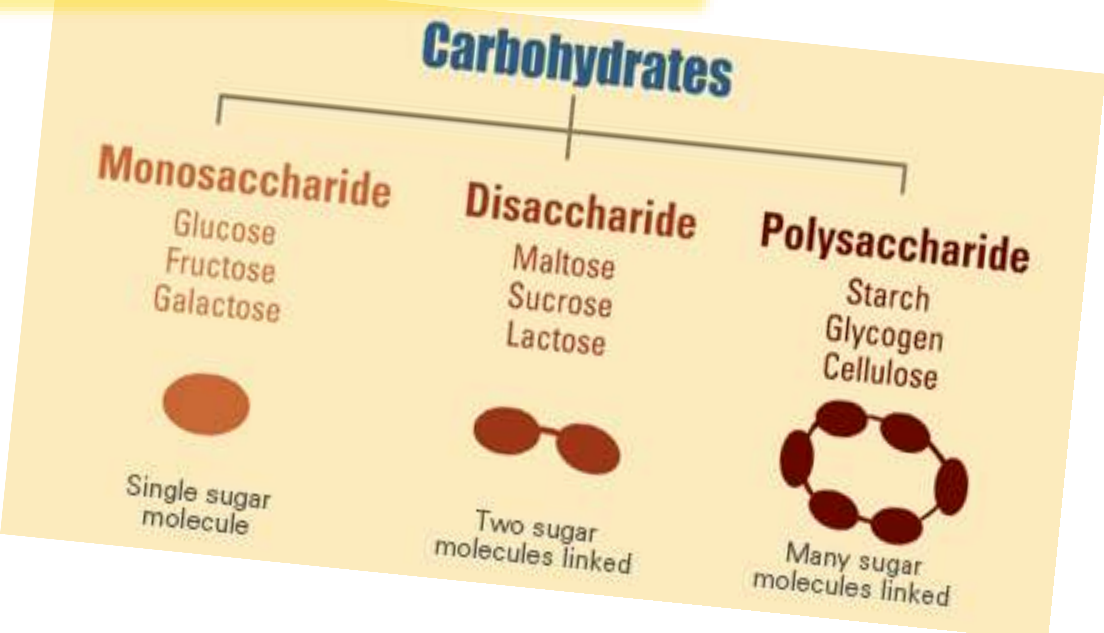
CARBOHYDRATES . . .

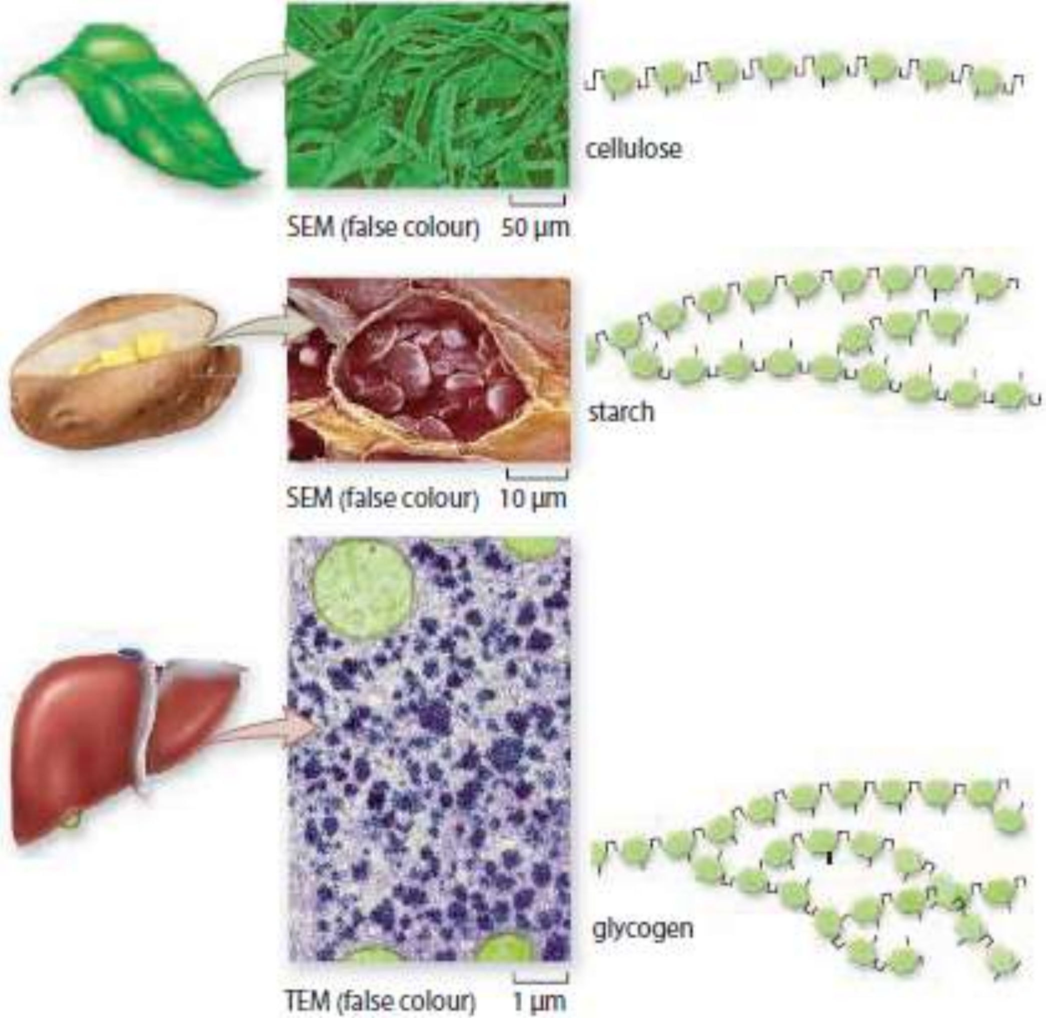
- Monosaccharides also join together to make ***polysaccharides*** ("**many sugars**"), or **complex carbohydrates**.

- Polysaccharides are **polymers** **(long chains of small molecules linked together)** of monosaccharides.

- Polysaccharides are used for **energy storage**.


Glucose: A Monosaccharide
Sucrose: A Disaccharide
A
CH₂OH
glucose
$C_6H_{12}O_6$
B
glucose
fructose
O
sucrose
$C_{12}H_{22}O_{11}$

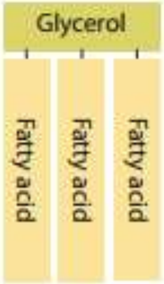

Carbohydrates
Monosaccharide
Glucose
Fructose
Galactose
Single sugar molecule
Disaccharide
Maltose
Sucrose
Lactose
Two sugar molecules linked
Polysaccharide
Starch
Glycogen
Cellulose
Many sugar molecules linked



cellulose
SEM (false colour) 50 µm
starch
SEM (false colour) 10 µm
glycogen
TEM (false colour) 1 µm

LIPIDS

Lipids	triglycerides	glycerol + 3 fatty acids	Store energy
	phospholipids	glycerol + 2 fatty acids + phosphate-containing group	Form major part of biological membranes
	steroids	4 fused rings, mostly C and H	Stabilize animal membranes; act as sex hormones
	waxes	long C-based chains	Various functions, including protection



LIPIDS

- Fats (**aka lipids**) are a diverse group of macromolecules with one property in common: they **DO NOT dissolve in water.** This is because they are **non-polar (hydrophobic).**

- Examples include **fats and oils (ex: nuts, oily fish).**

- Lipids provide more than **twice as much energy** as equal masses of carbohydrate or protein.

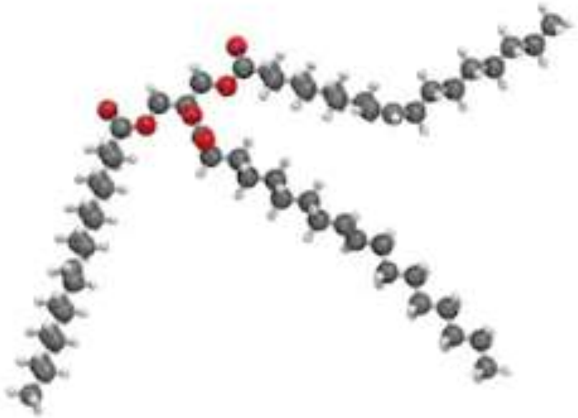
LIPIDS . . .

Lipids include:

1. **Triglycerides**
2. **Phospholipids**
3. **Steroids**

LIPIDS . . .

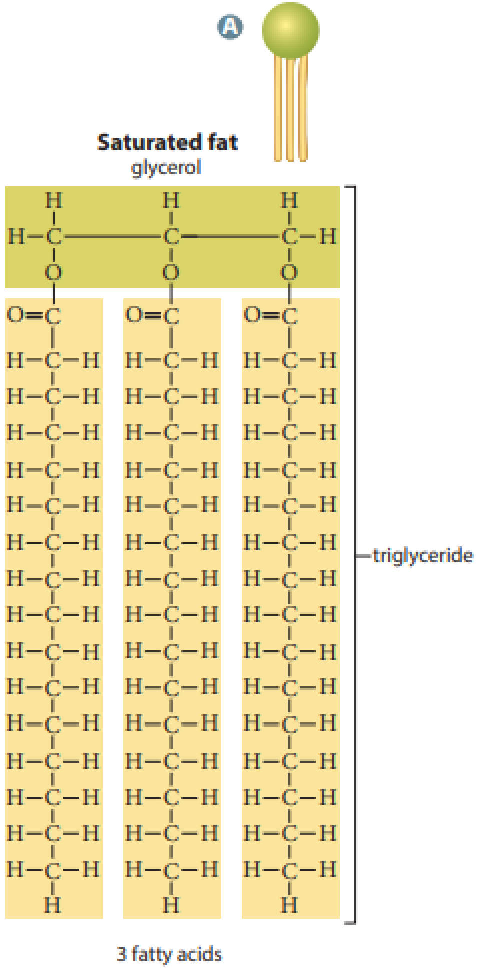
- **Triglycerides**
  - These lipids make up the **fats and oils in our diet**.
  - In cells they are used primarily to **store energy**.
  - A triglyceride is made up of **three long fatty acid chains** bonded to a three-carbon molecule called **glycerol**.
  - Triglycerides can be **saturated** or **unsaturated**.



LIPIDS . . .

Saturated Triglycerides:

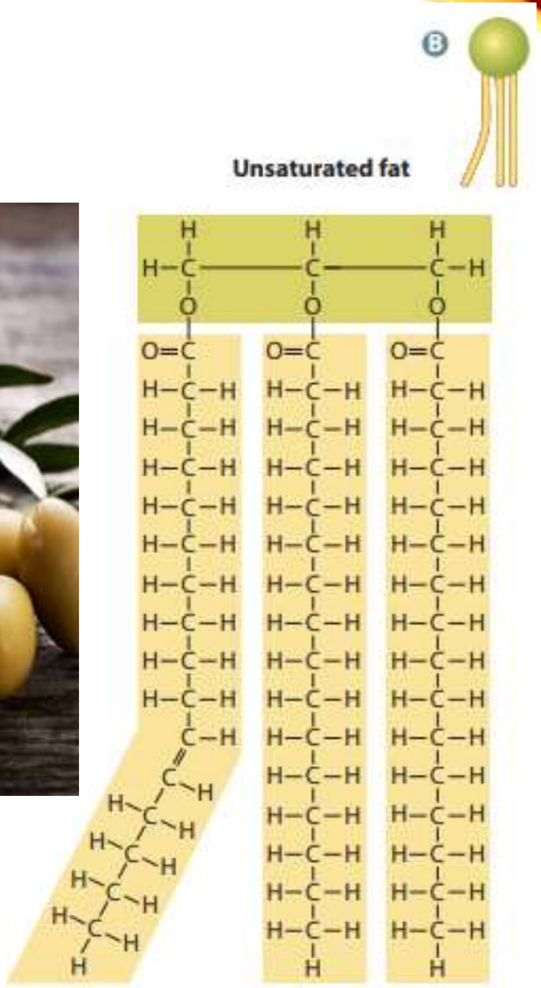
- AKA **saturated fat**
- A saturated fatty acid contains **all the hydrogen atoms** that it possibly can.
- Saturated fats are **solid at room temperature.**

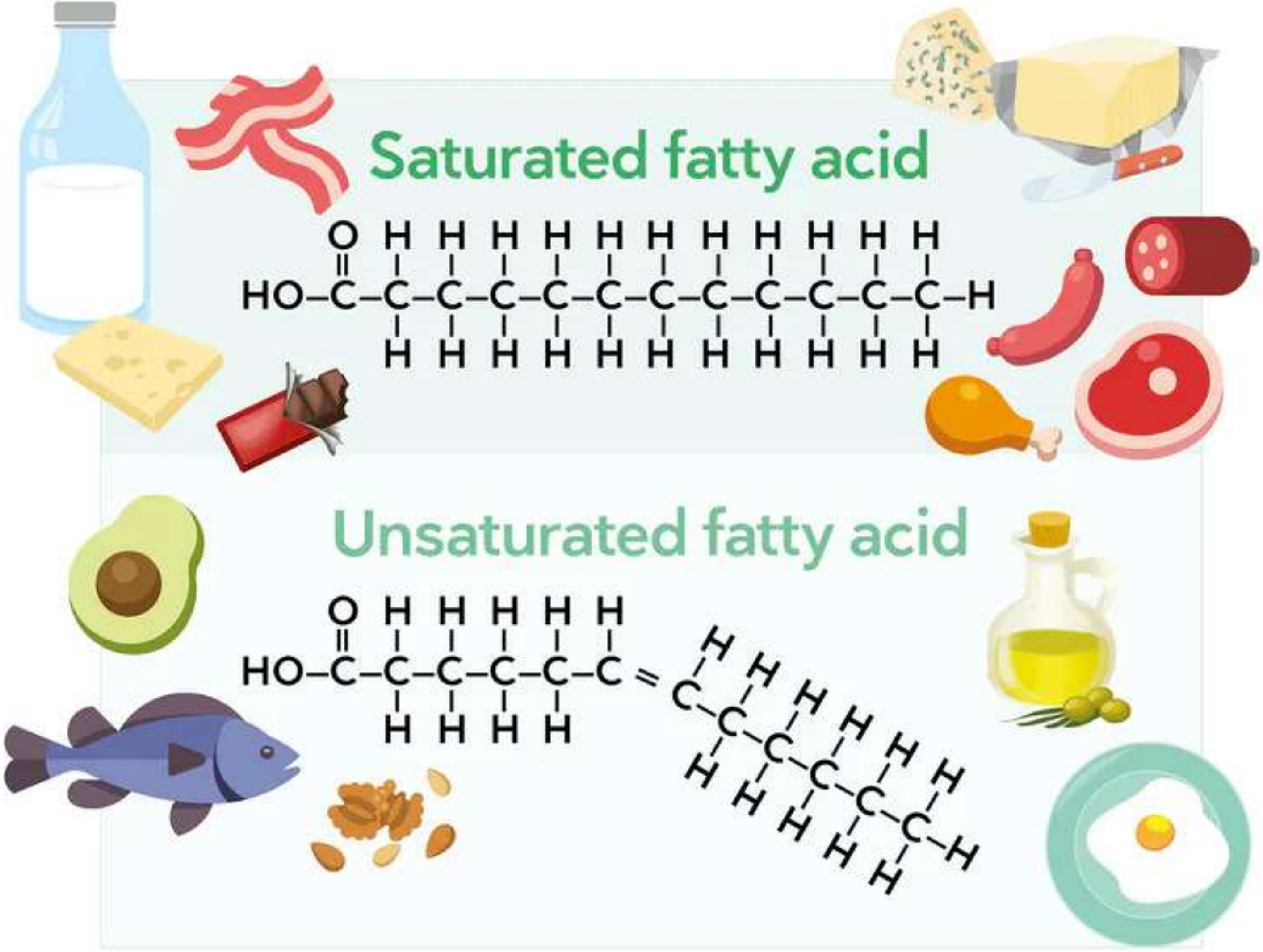


LIPIDS . . .

Unsaturated Triglycerides:

- AKA **unsaturated fats**
- Unsaturated fatty acids have **one or more double bonds** between carbon atoms (**less hydrogen**).
- Unsaturated fats are usually **liquid at room temperature**.

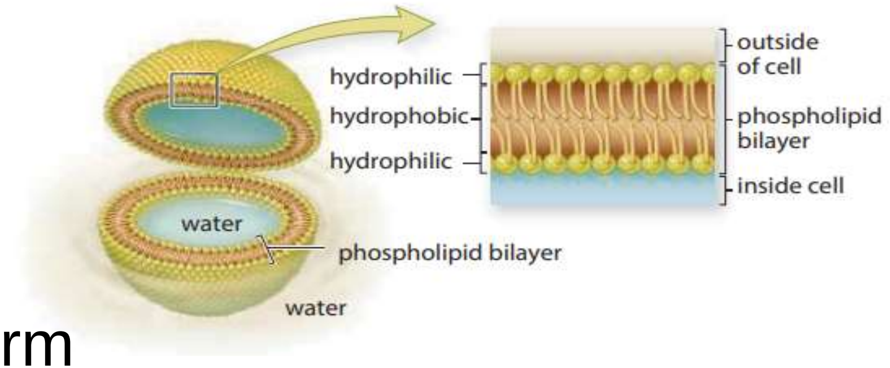



Saturated fatty acid
Unsaturated fatty acid

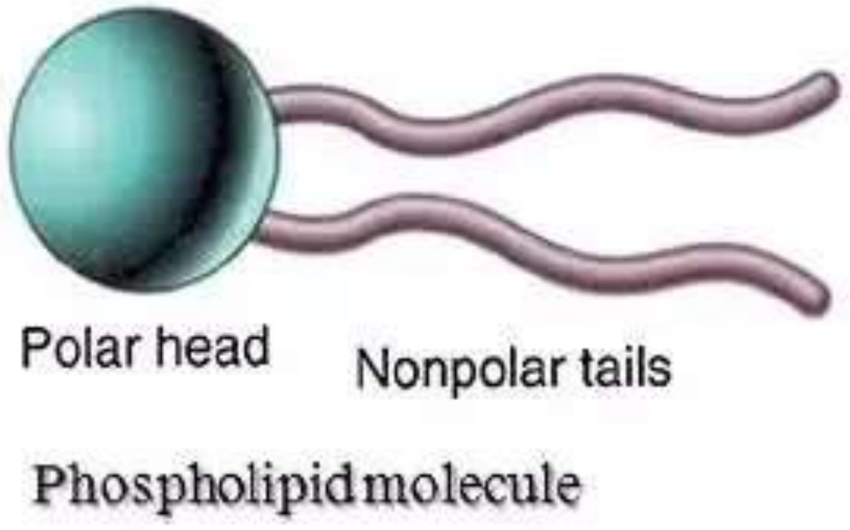
LIPIDS . . .

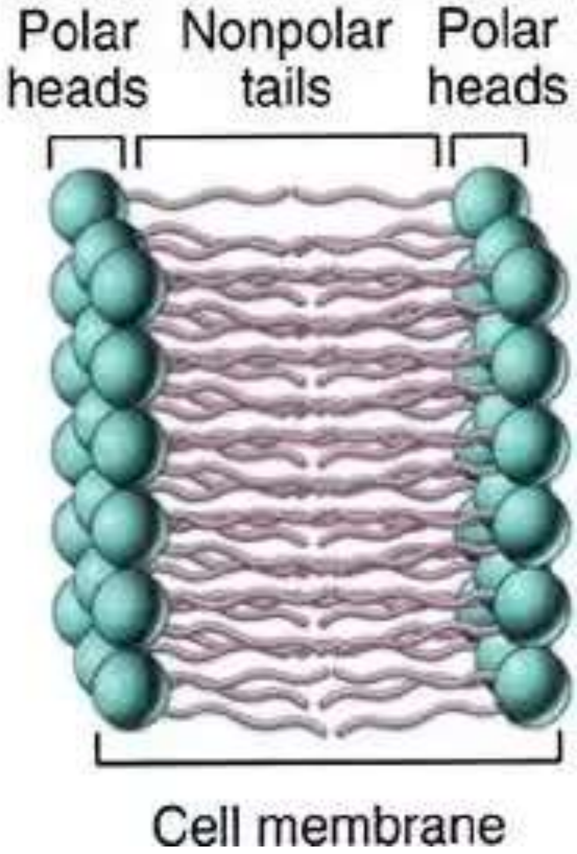
Phospholipids

- Phospholipids have a **hydrophilic head** and **hydrophobic ends**.
- Due to their structure, they form a **double-layered structure** when in water called a **phospholipid bilayer**.
- They are the key component of **cell membranes**.



LIPIDS . . .

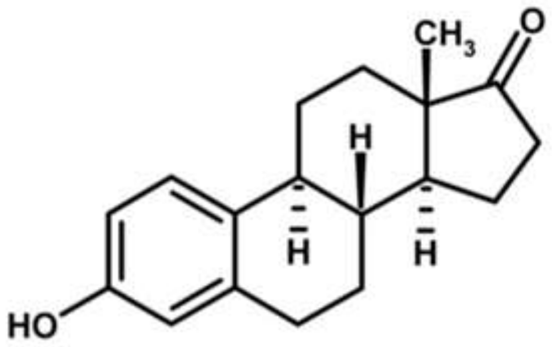

Polar head
Nonpolar tails
Phospholipid molecule


Polar heads
Nonpolar tails
Polar heads
Cell membrane

LIPIDS . . .

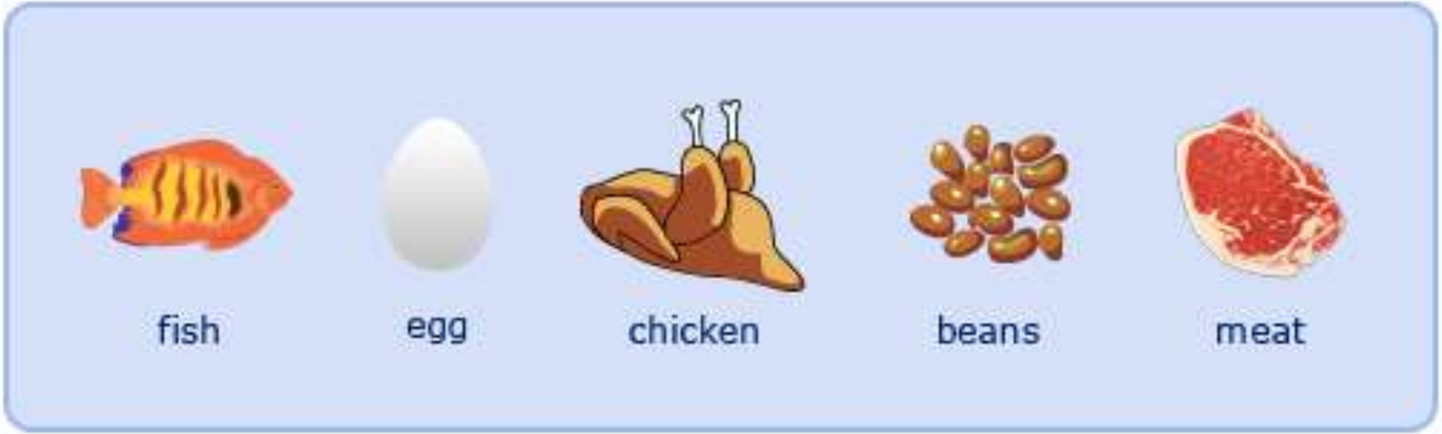
Cholesterol:

- Cholesterol is a **steroid** in animals that **helps keep the cell membranes stable**.
- Animal cells use cholesterol as a **starting material to make other lipids**.
- Ex: testosterone and estrogen



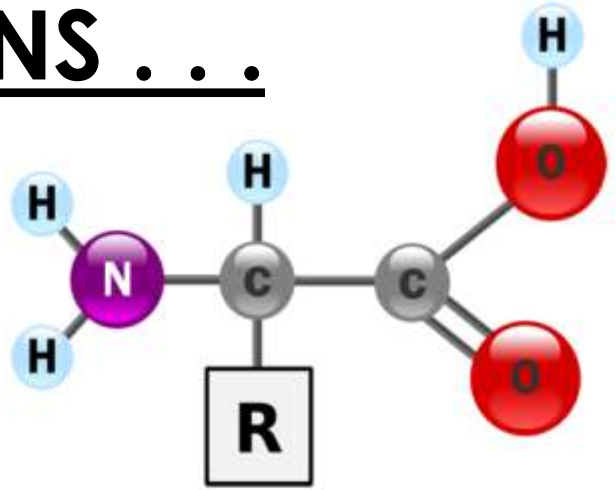
PROTEINS

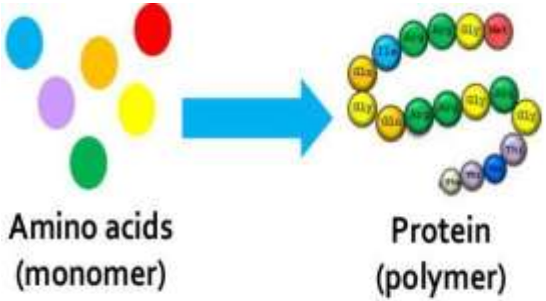
Proteins 	amino acids	polymers of amino acids	Carry out nearly all the functions of the cell



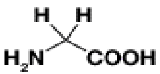
PROTEINS . . .

- Proteins have more roles in the the cell than any other biomolecule.
- **Illness or death** can result if even one type is **missing or faulty**.
- They are **polymers of amino acids**.
- The shape of a protein is determined by the **sequence of amino acids**, which in turn determines the **protein's function**.
- There are **22 different types of amino acids (R groups)** that make up the proteins in all domains of life.



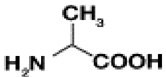


STRUCTURE OF AMINO ACIDS



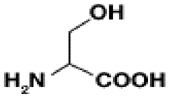
GLYCINE

$C_2H_5NO_2$



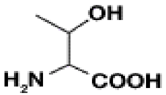
ALANINE

$C_3H_7NO_2$



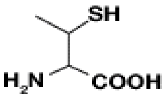
SERINE

$C_3H_7NO_3$



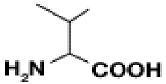
THREONINE

$C_4H_9NO_3$



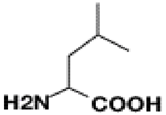
CYSTEINE

$C_3H_7NO_2s$



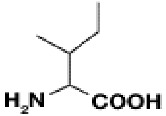
VALINE

$C_5H_{11}NO_2$



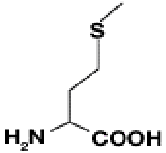
LEUCINE

$C_6H_{13}NO_2$



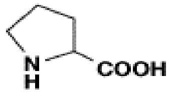
ISOLEUCINE

$C_6H_{13}NO_2$



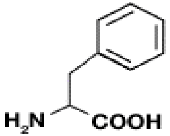
METHIONINE

$C_5H_{11}NO_2S$



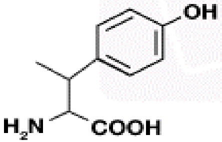
PROLINE

$C_5H_9NO_2$



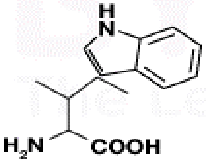
PHENYLALANINE

$C_9H_{11}NO_2$



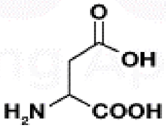
TYROSINE

$C_9H_{11}NO_3$



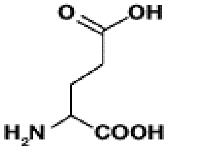
TRYPTOPHAN

$C_{11}H_1N_2O_2$



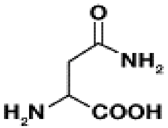
ASPATIC ACID

$C_4H_7NO_4$



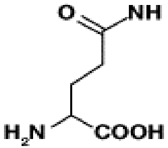
GLUTAMIC ACID

$C_5H_9NO_4$



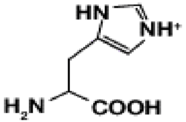
ASPARAGINE

$C_4H_8N_2O_3$



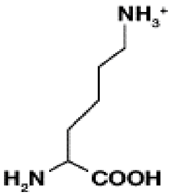
GLUTAMINE

$C_5H_{10}N_2O_2$



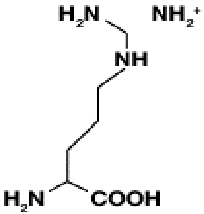
HISTIDINE

$C_6H_9N_3O_2$



LYSINE

$C_6H_{14}N_2O_2$



ARGININE

$C_6H_{14}N_4O_2$

PROTEINS

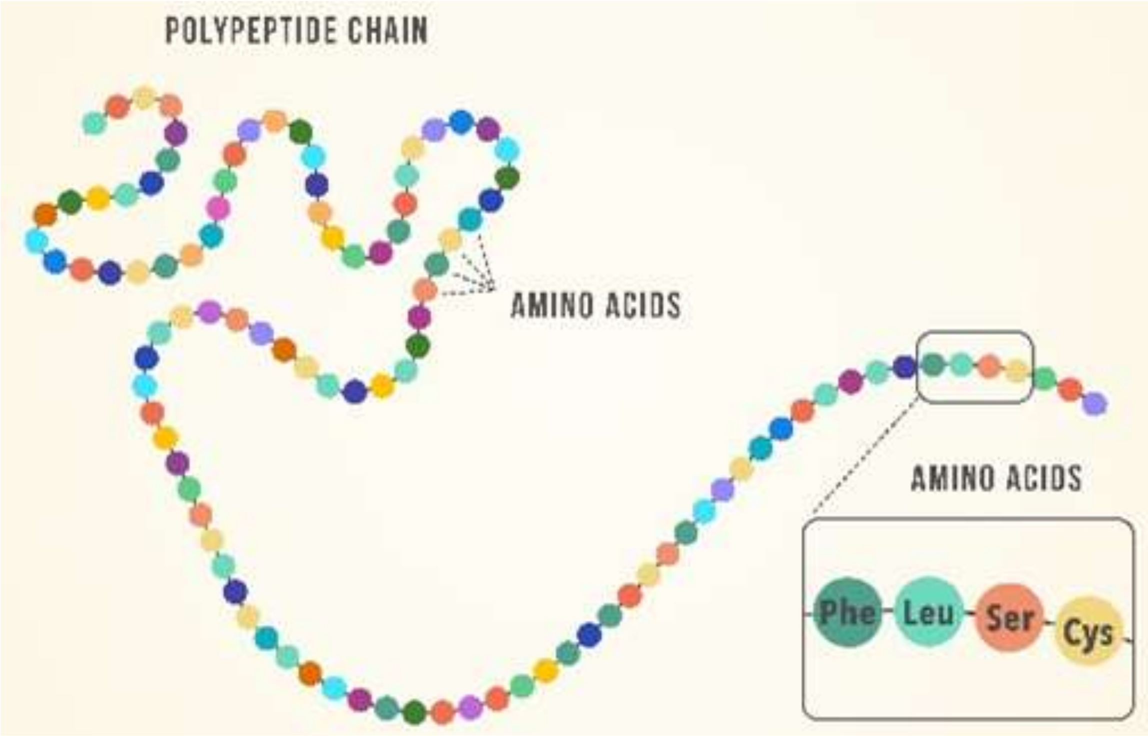
- Proteins have many crucial roles in cells:
    - ***control what enters and leaves a cell***
    - ***carry oxygen in blood***
    - ***aid in blood clotting***
    - ***build hair and fingernails***
    - ***support the body's tissues***
    - ***break apart food molecules***
    - ***allow muscles to contract***
    - ***help cells to communicate***
    - ***defend the body against germs***

Table 3.3 Selected Proteins and Some of Their Functions

Protein(s)	Function
Membrane channel proteins	Transport ions in and out of cells
Hemoglobin	Transports oxygen in blood
Clotting factors	Help blood to clot and thus stop bleeding
Keratin	Forms hair and fingernails and protects skin
Amylase	Breaks down starch
Collagen and elastin	Make up tendons, which attach muscle to bone
Actin and myosin	Make up muscle tissue
Signalling proteins	Act as chemical messengers between cells
Antibodies	Bind to viruses and bacteria that can infect the body

PROTEINS . . .

- Amino acids link together with special bonds called **peptide bonds.**
- A long chain of amino acids is called a **polypeptide**.



HUMAN BIOCHEMISTRY CAREERS

- Examples
  - A researcher tests a new anti-cancer medication on cells grown in the laboratory (Figure 3.1).
  - A technician analyzes a blood sample from an elite athlete for the presence of illegal drugs.
  - A child receives just the right amount of anesthetic to stay safely unaware during an operation.
  - Plant Geneticist A plant's DNA can hold the key to properties such as disease tolerance, seed size, and productivity. Plant geneticists conduct research to understand how changes to this DNA can alter a plant's properties in a desired way. They then apply this knowledge to create new and improved plants. Often working for agricultural and chemical companies, plant geneticists may also conduct research and teach courses at the university level. While a bachelor's degree in a related field such as genetics or biochemistry is the minimum requirement for this career, many plant geneticists have a master's or doctorate degree.

Figure 3.1 Understanding cells has allowed researchers to grow cells in the laboratory. This allows scientists to test products and medications directly on cells and to observe how the cells react.