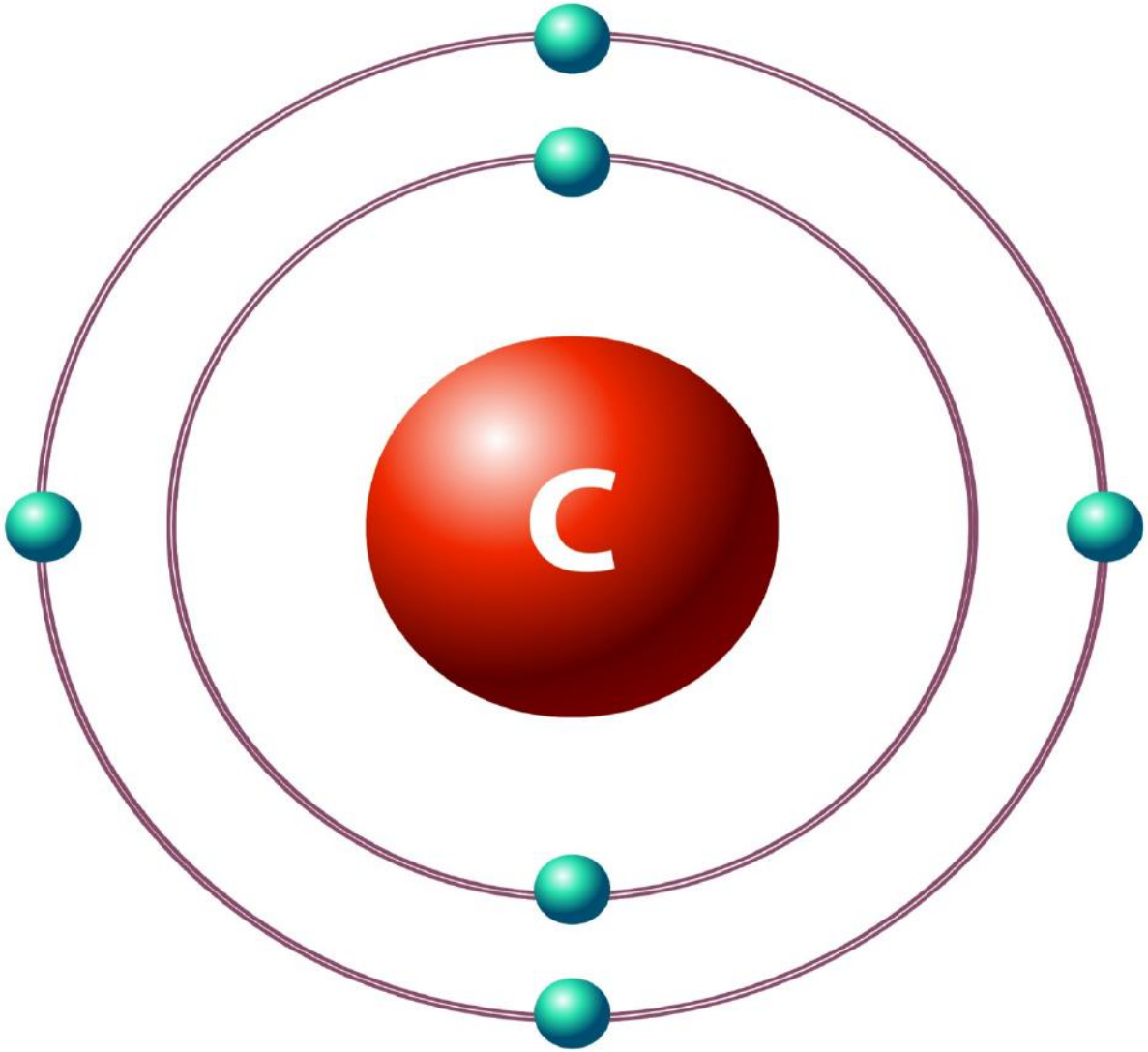
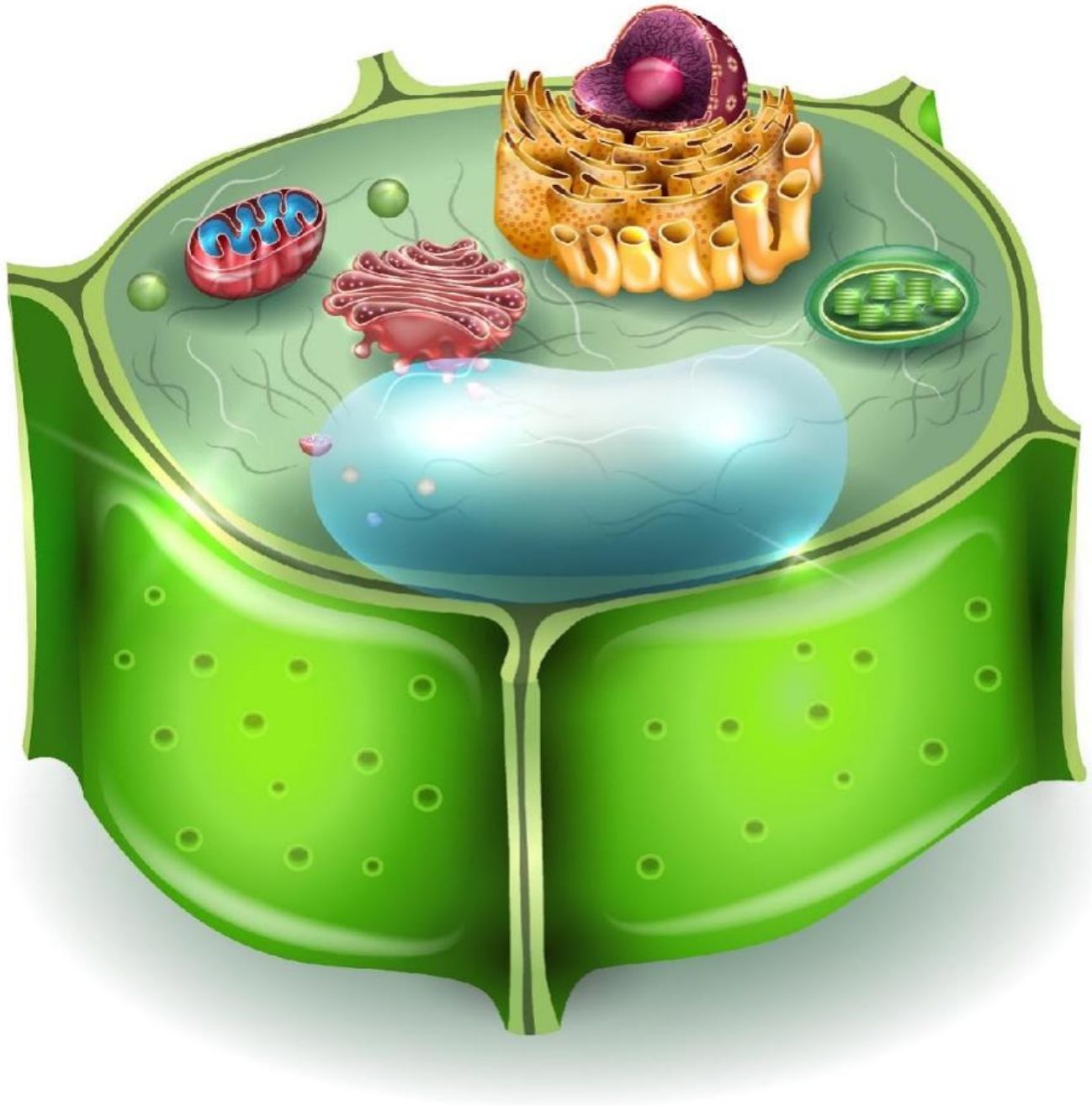
1. Molecular & Cellular Biology

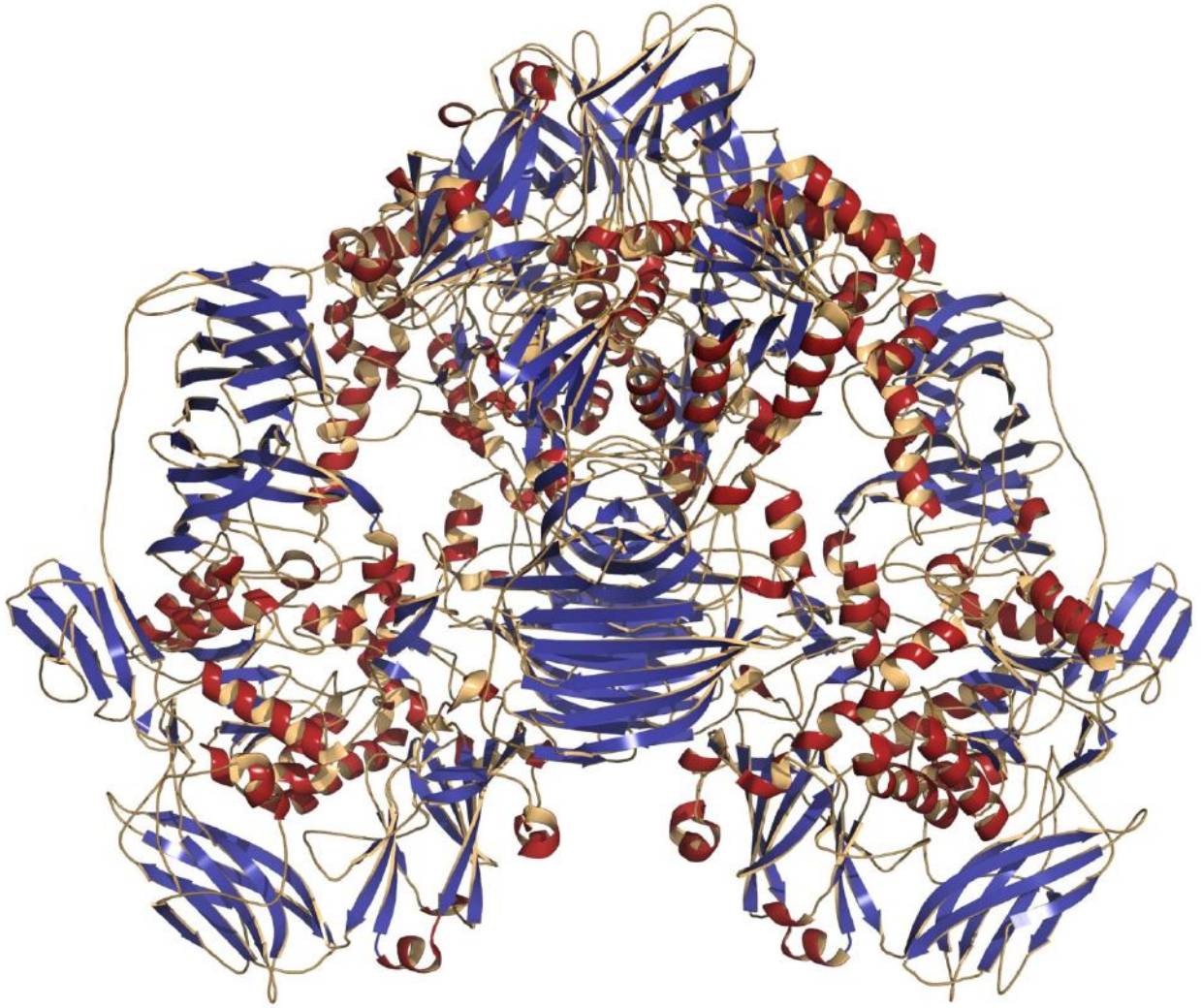
1.1 Chemical Composition of Organisms



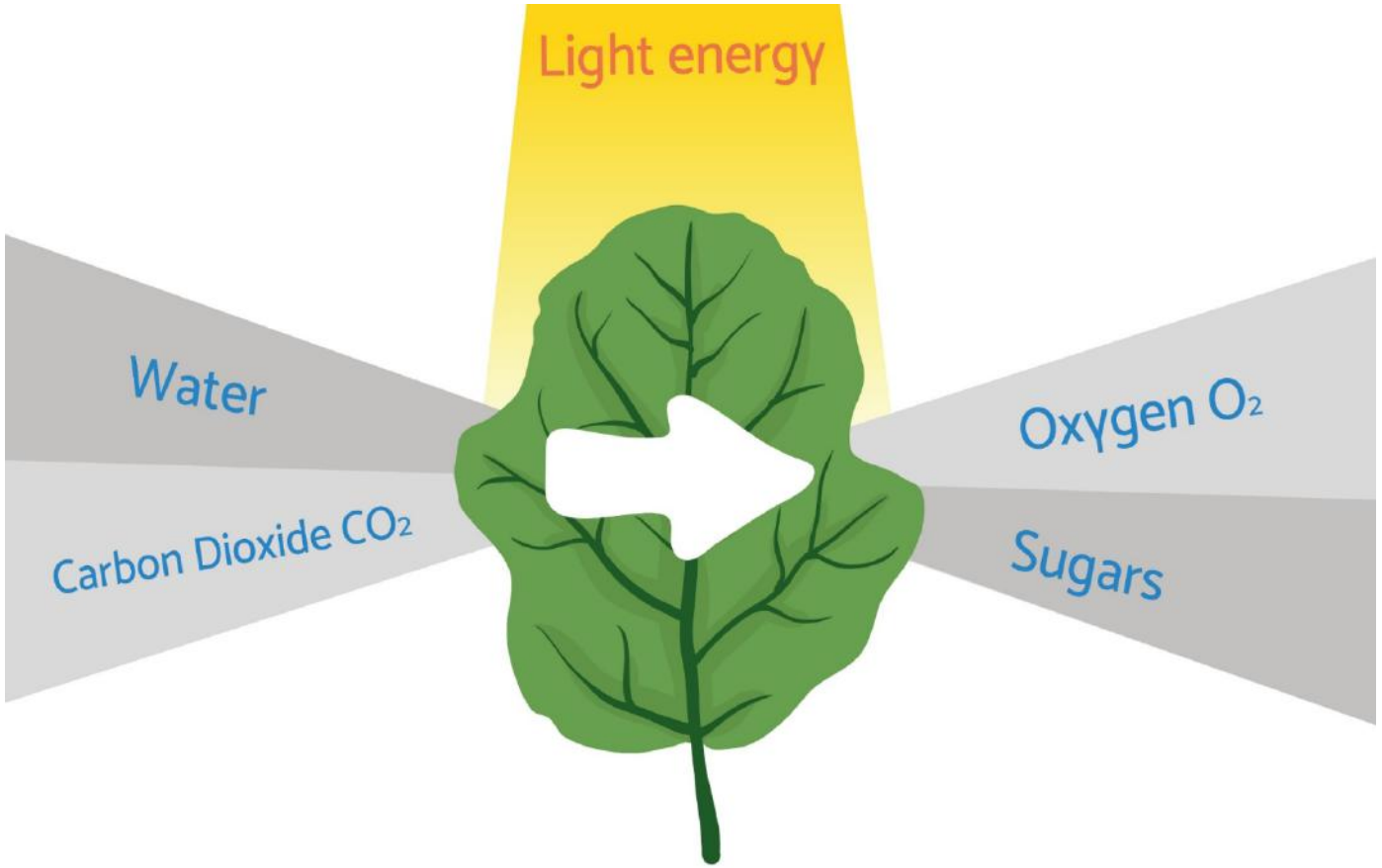
1.2 Cells



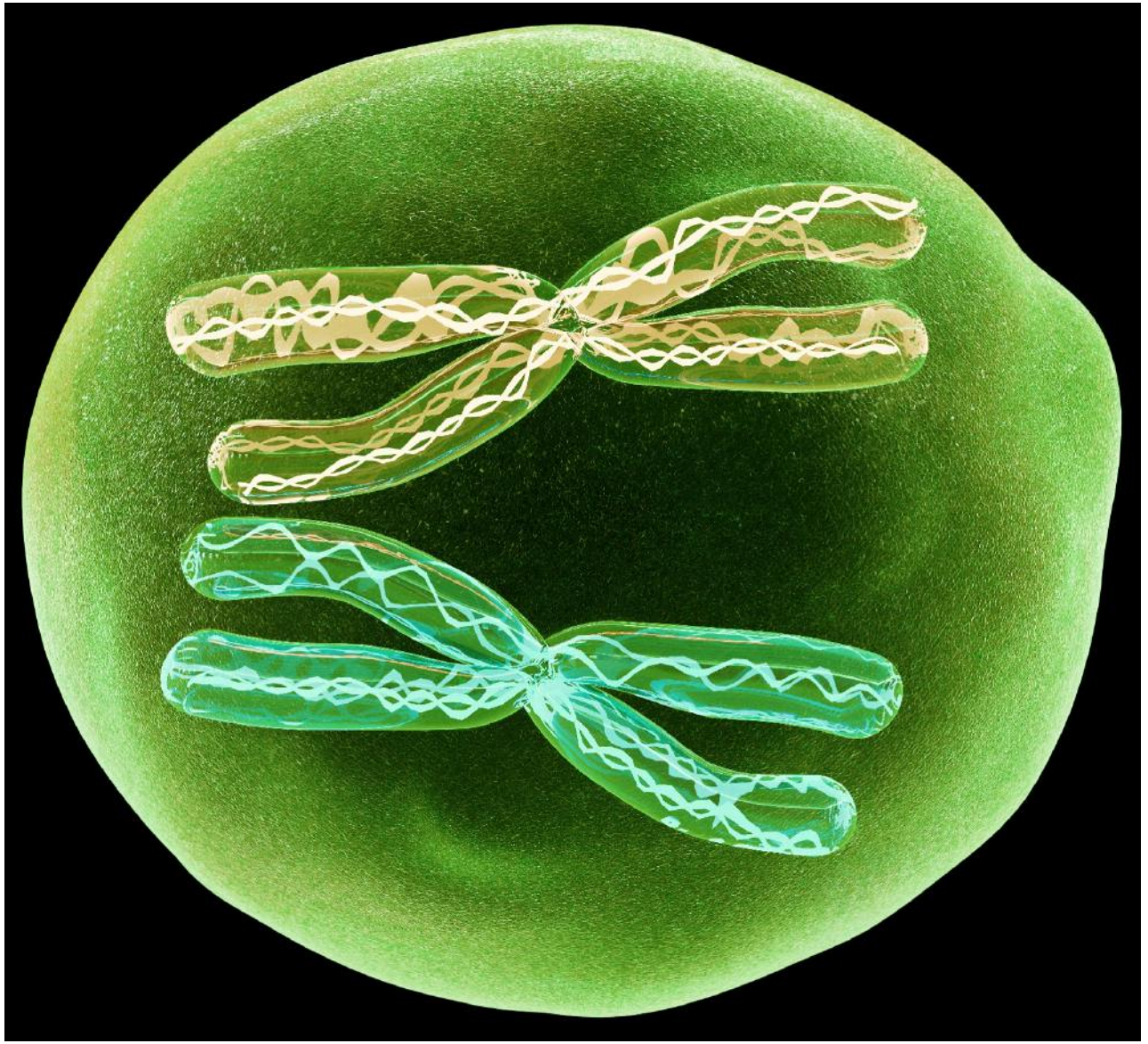
1.3 Enzymes



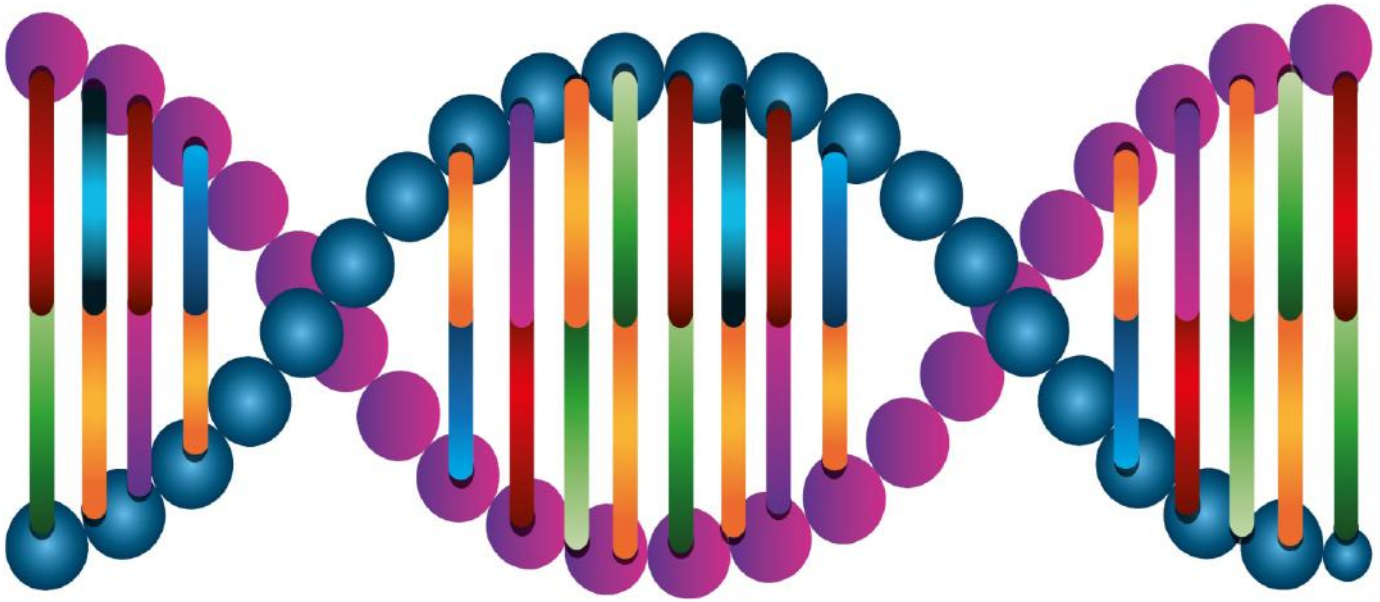
1.4 Energy Transformations



1.5 Cell Division



1.6 Chemical Nature of the Gene



1.1 Chemical Composition of Organisms

Chemistry of Biology

1.1.1 Reactions & Bonds

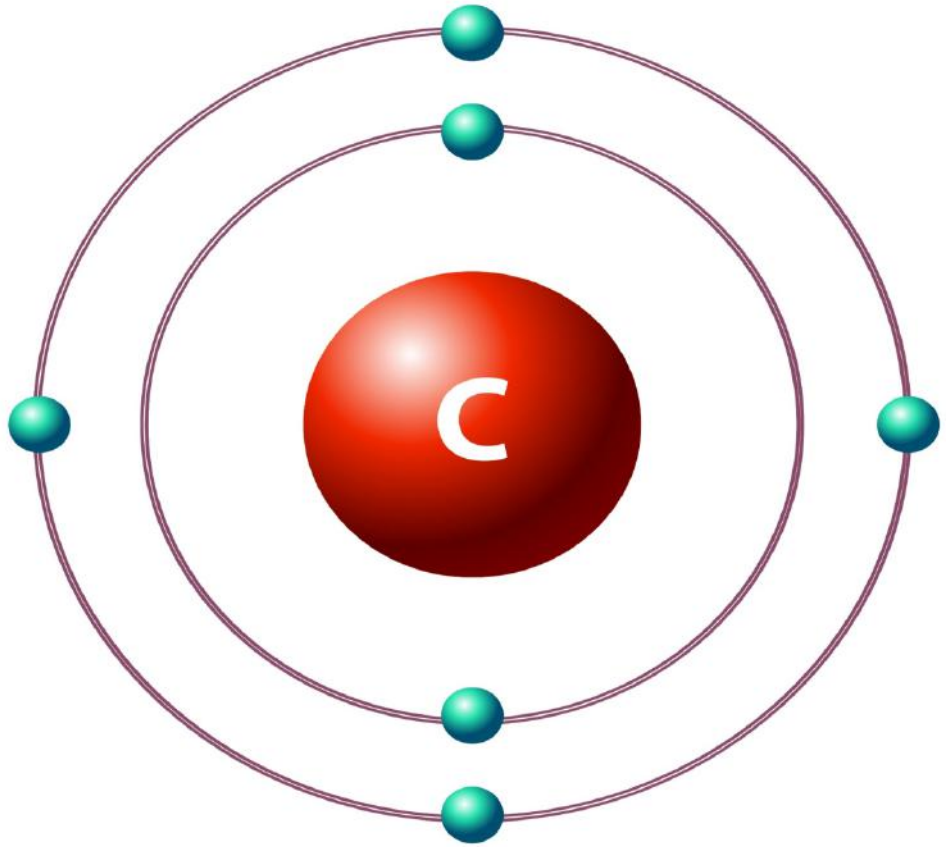
1.1.2 Properties of Water

1.1.3 Organic Molecules

1.1.4 Origin of Life

1.1.1 Reactions & Bonds

- matter & elements
- atoms
- types of bonds
- chemical reactions
- energy

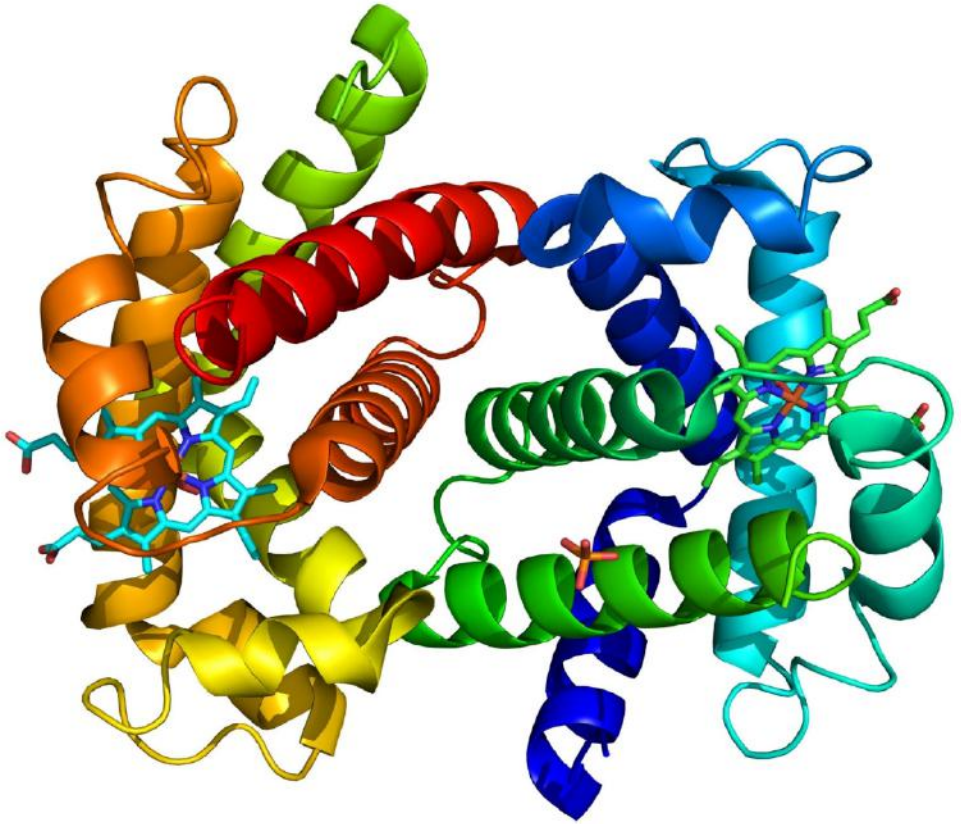


1.1.2 Properties of Water

- what makes water special
- acids & bases
- the pH scale

1.1.3 Organic Molecules

- what makes a molecule organic
- carbohydrates
- lipids
- proteins
- nucleic acids



1.1.4 Origin of Life

- when & where did living things first appear
- what were the first living things
- how did life evolve from simple to complex
- evidence for current hypotheses

1.1.1 Simple Chemical Reactions and Bonds

Matter & Elements

Matter: anything that takes up space & has mass, made of elements

- rocks
- gases
- kittens

Elements: cannot be broken down to other substances

- Carbon
- Oxygen
- Hydrogen

Elements

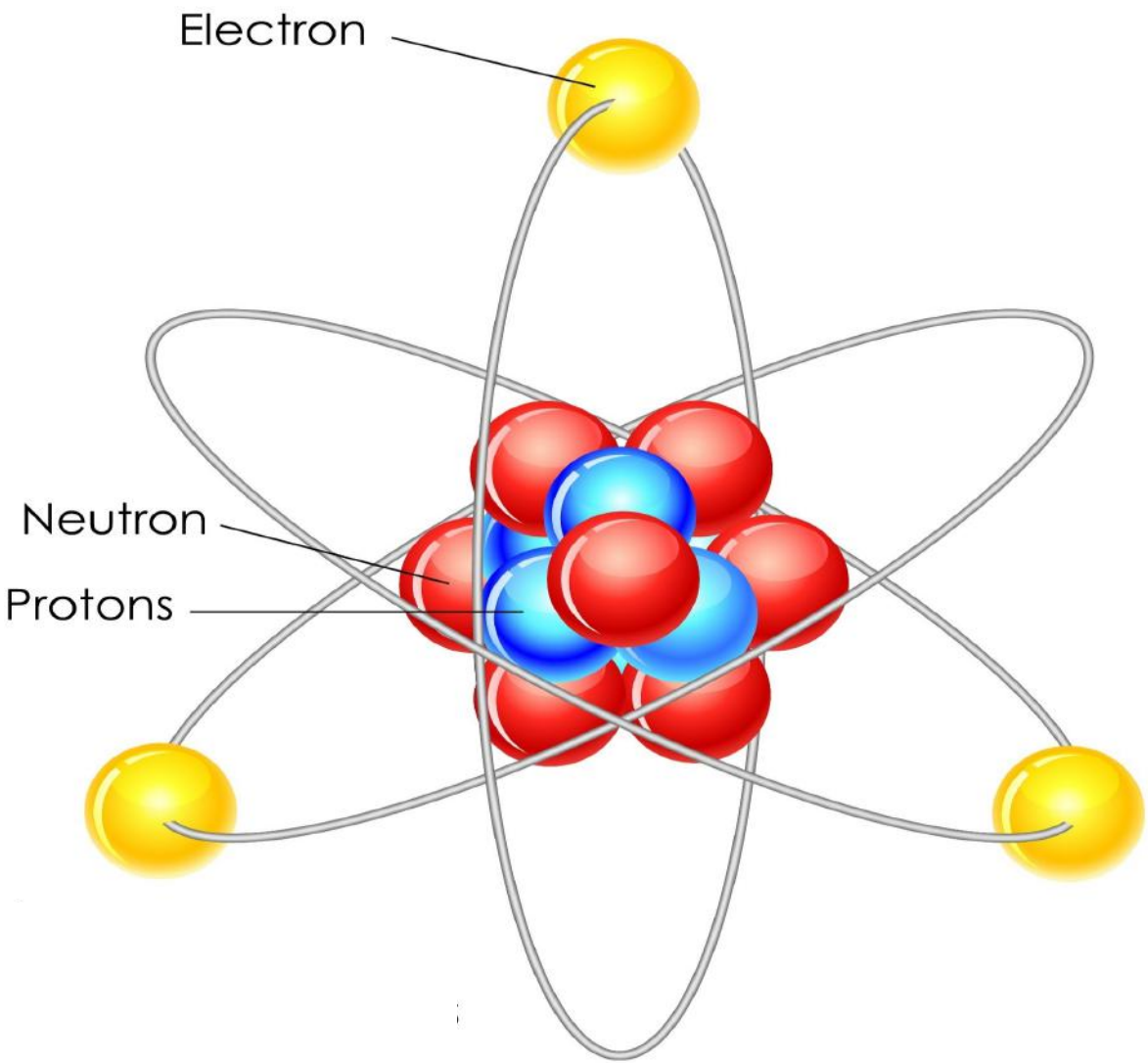
Atom: smallest unit of matter w/ element's properties

Each element has unique atoms, composed of three types of subatomic particles

- **neutrons (0)**
- **protons (+)**
- **electrons (-)**

.

An Atom



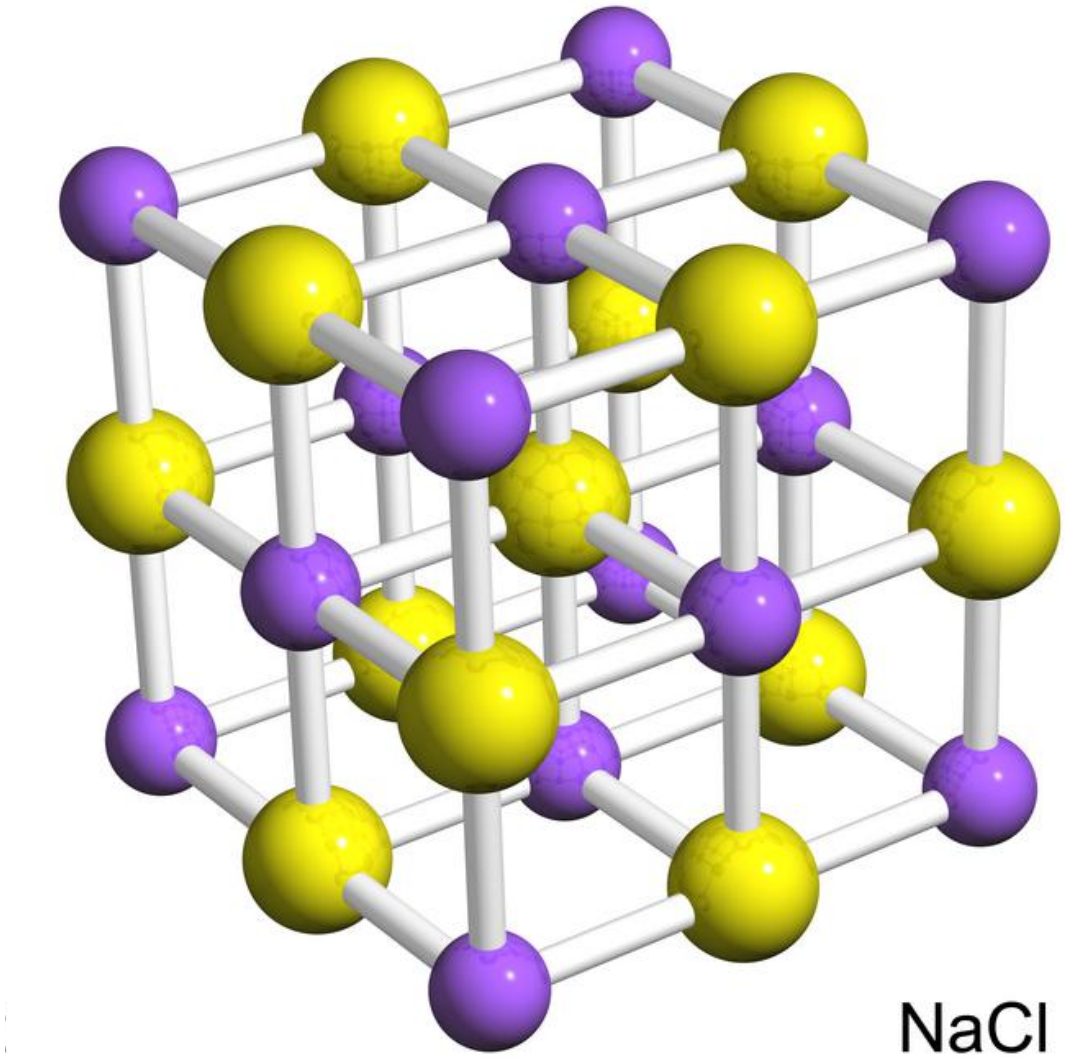
Elements

Compound: 2+ *different* elements combined in fixed ratio

- **table salt (NaCl)**

Molecule: 2+ *same or different* elements combined in fixed ratio

- **oxygen gas**



Electrons

Electrons found orbiting in *shells*

Valence shell: outermost shell, "valence electrons"

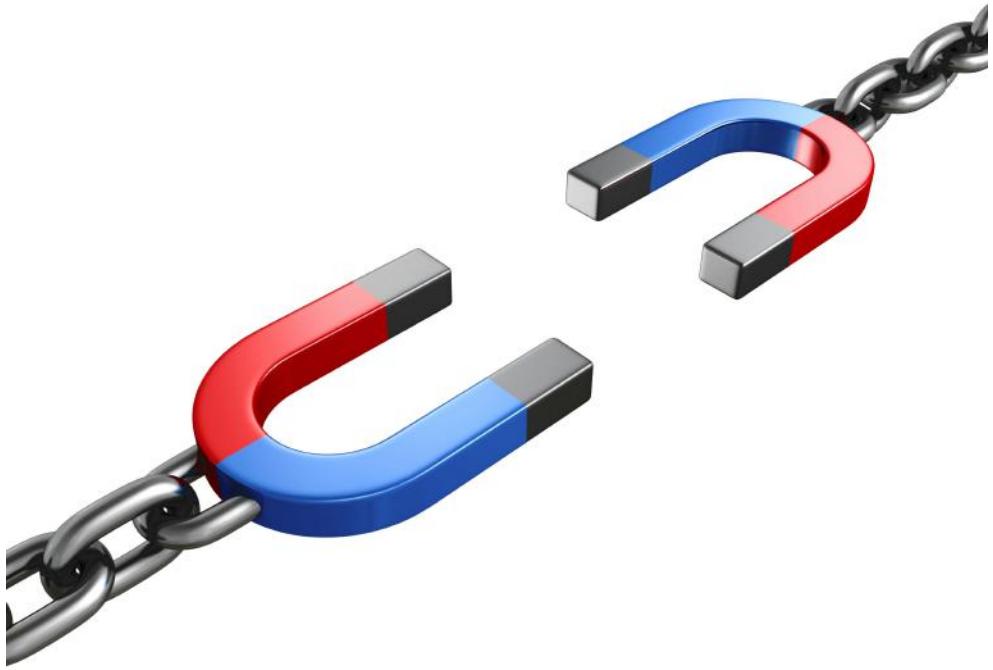
Only valence electrons interact w/ other atoms

Atoms most reactive if valence shell incomplete .

Chemical Bonds

Attractions that keep atoms close together

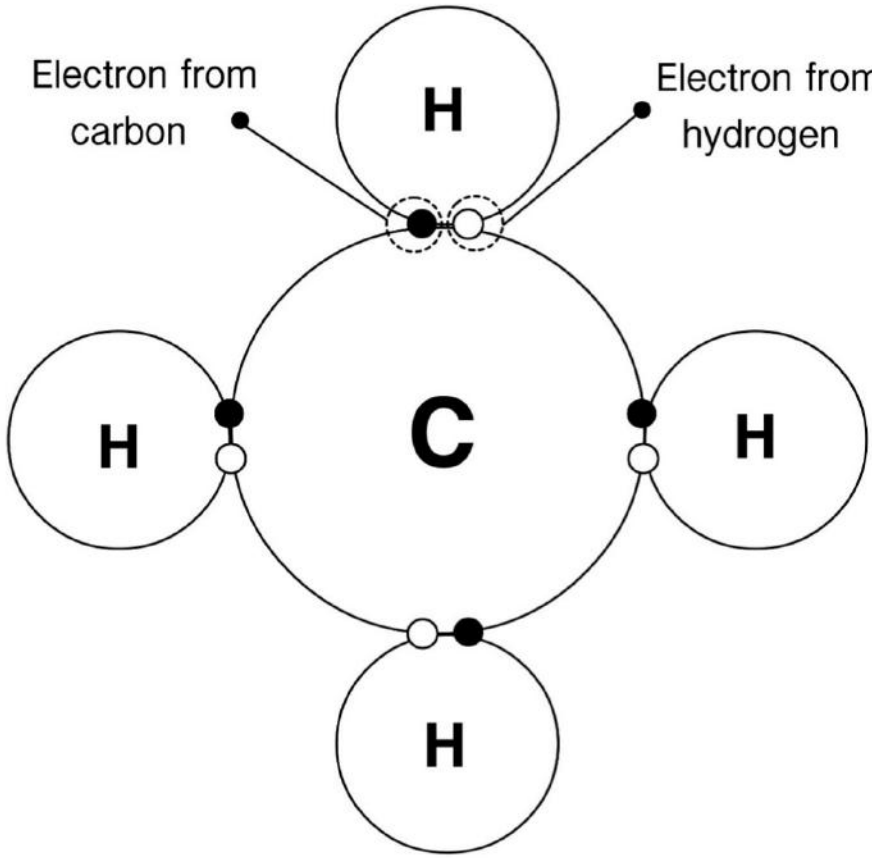
Protons & electrons attract like magnets



Chemical Bonds- Covalent

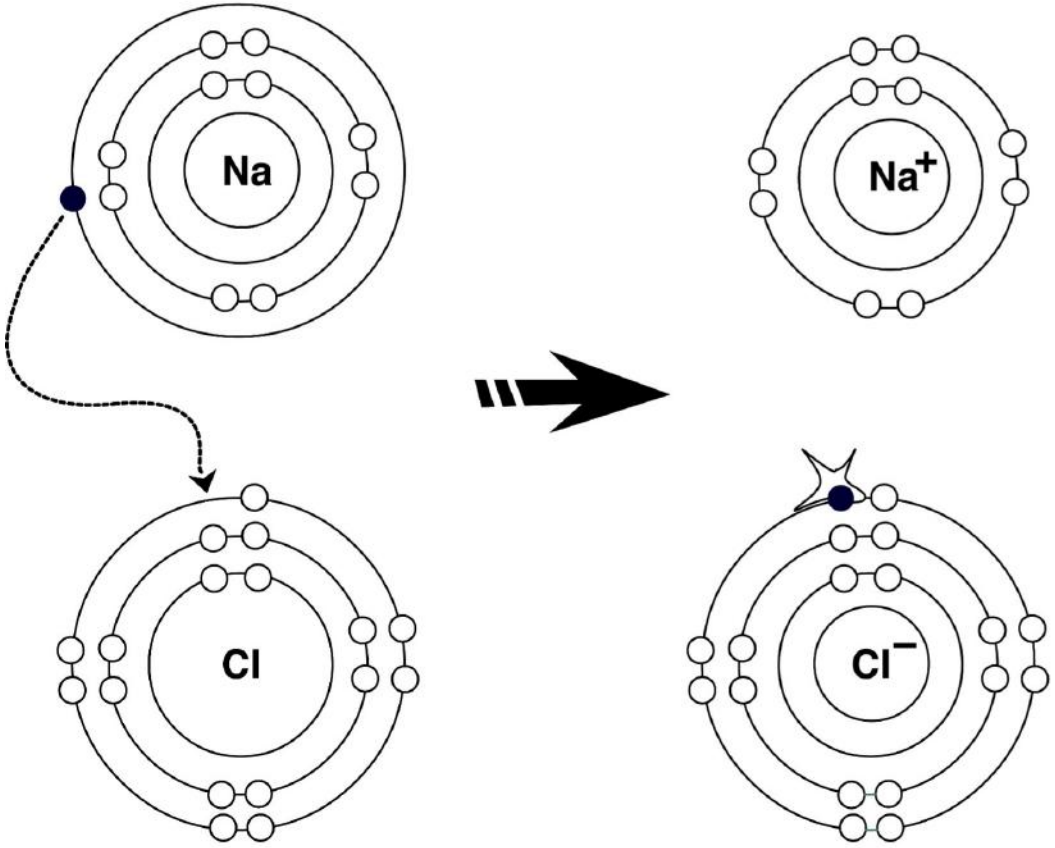
Sharing pair of electrons, strong bonds

1. **nonpolar: sharing is equal**
2. **polar: sharing is unequal, creates partial charges (poles)**



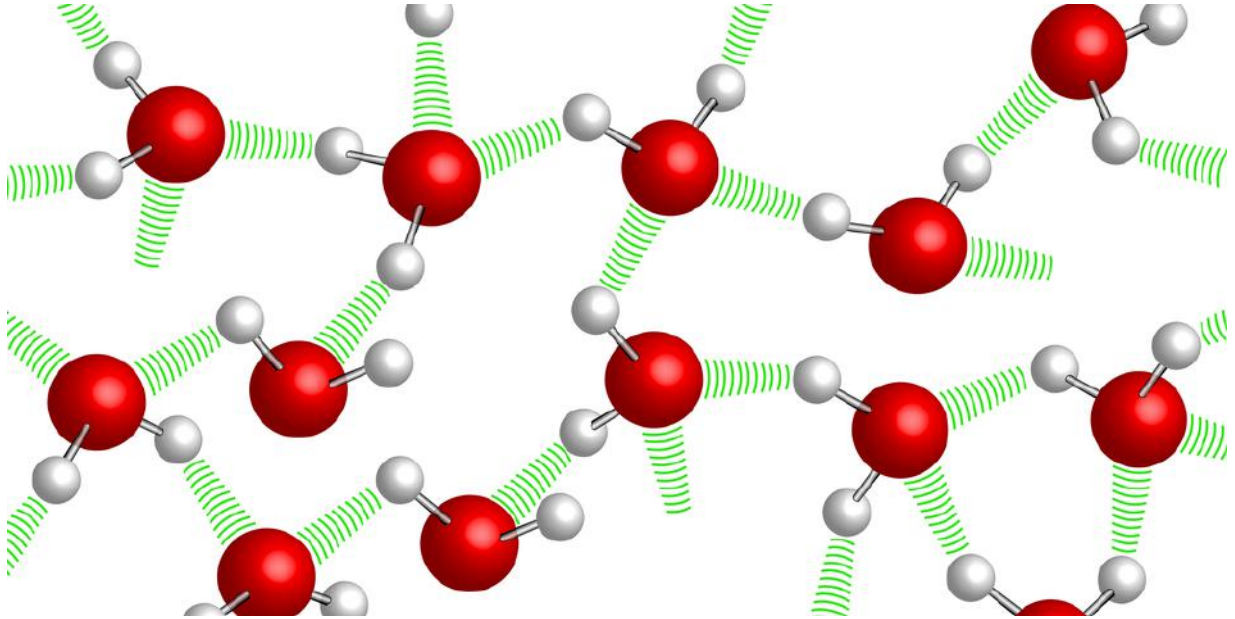
Chemical Bonds- Ionic

One atom (anion) steals electron, other atom (cation) loses electron, strong bonds



Chemical Bonds- Hydrogen

Form between poles of H and O in water molecules, weak bonds



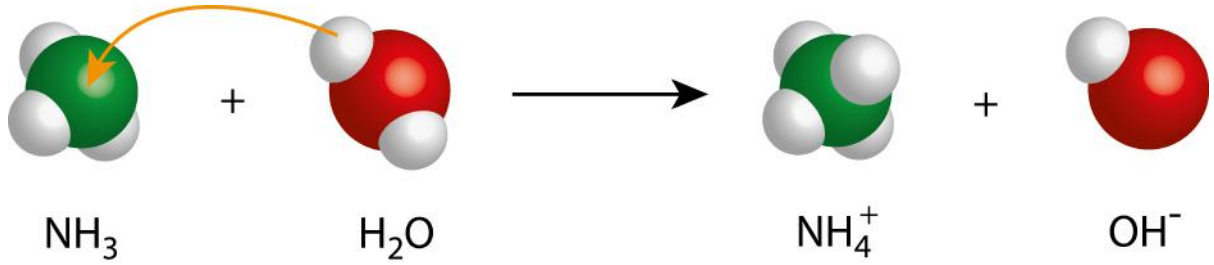
Chemical Reactions

Make and break chemical bonds

Reactants "react" together, start of reaction

Products are "produced," end of reaction

$$A + B \leftrightarrow C$$



Energy

1st Law of Thermodynamics: energy cannot be created or destroyed

2nd Law of Thermodynamics: reactions tend to increase disorder (make enrgy less available for cells)

Endothermic reactions take energy

Exothermic reactions release energy

1.1.2 Properties of Water

Properties of Water

All 3 states

Solid less dense than liquid

Adhesion, cohesion, & surface tension

Universal solvent

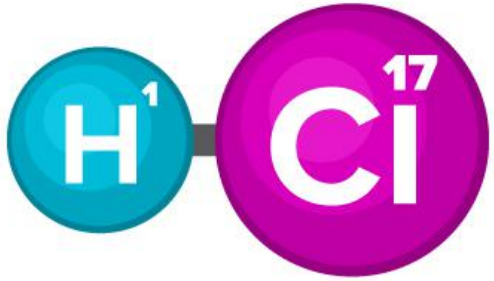
High specific heat

Evaporative cooling

Acids & Bases

Acids: dissolve in water & increase relative H^+ ion concentration in the solution

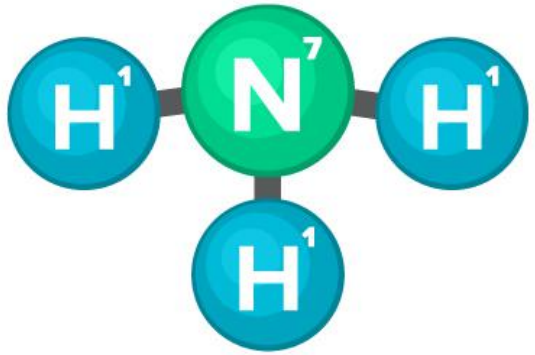
$$HCl \leftrightarrow H^+ + Cl^-$$



Hydrochloric acid

Bases: dissolve in water & decrease the H^+ ion concentration in the solution

$$NH_3 + H^+ \leftrightarrow NH_4^+$$



Ammonia

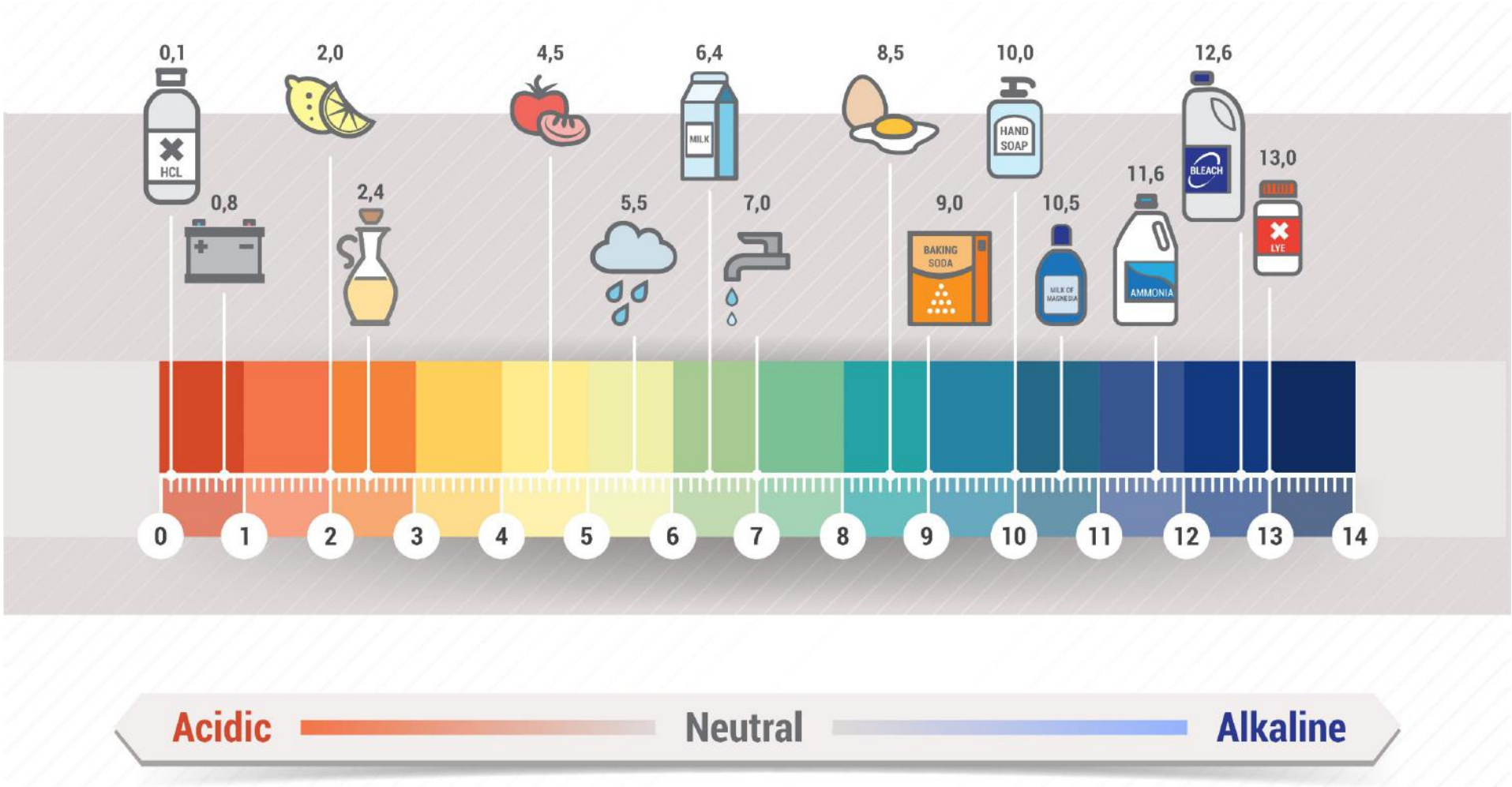
Acids & Bases

pH scale shows relative amount of H^+ ion concentration

- **smaller # means more acidic**
- **larger # means more basic**
- **7 is neutral**

Buffers can be added to bring pH to 7

The pH Scale


0,1
HCL
0,8
2,0
2,4
4,5
5,5
6,4
MILK
7,0
8,5
9,0
BAKING SODA
10,0
HAND SOAP
10,5
MILK OF MAGNESIA
11,6
AMMONIA
12,6
BLEACH
13,0
LYE
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Acidic
Neutral
Alkaline

1.1.3 Chemical Structure of Organic Molecules

Organic Molecules

Any molecule containing carbon is called “organic”

Can contain other molecules- oxygen, hydrogen, nitrogen...

Made of building blocks called *monomers*

Many monomers linked together form *polymer* (whole molecule)

Organic Molecules

4 Classes:

1. carbohydrates
2. lipids
3. proteins
4. nucleic acids .

Carbohydrates

Made only of carbon, oxygen, and hydrogen

Monomer name: monosaccharide, example is glucose

Polymer name: polysaccharide, example is starch

Lipids

Grouped together b/c of hydrophobic properties

Common lipids:

- **waxes- water barrier**
- **fats- energy storage**
- **phospholipids- cell membranes**
- **steroids- hormones**

Proteins

Monomer name: amino acid

Polymer name: polypeptide (protein)

Peptide bond: holds amino acids together

Many functions:

- **most enzymes**
- **defense- antibodies**
- **muscle- fibers**

Nucleic Acids

Monomer name: nucleotide

Two types:

1. **deoxyribonucleic acid (DNA)**
2. **ribonucleic acid (RNA)**

Primary function: information storage

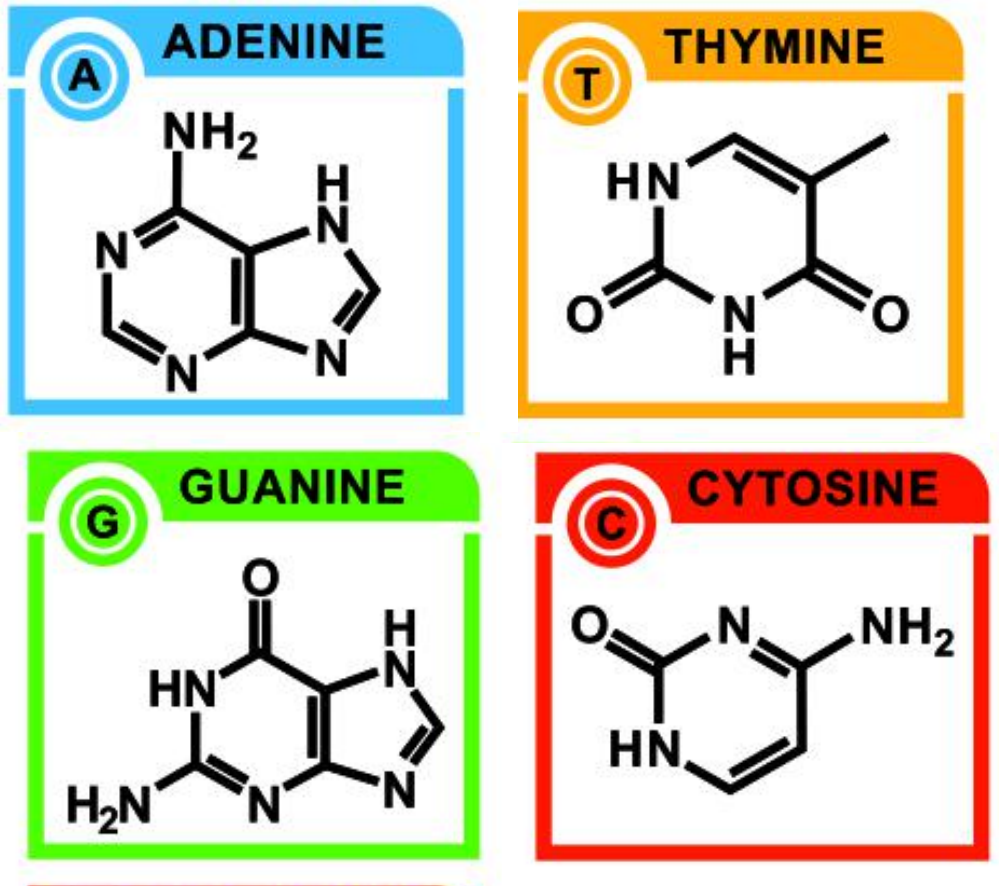
Nucleotides

Nucleotides are made of:

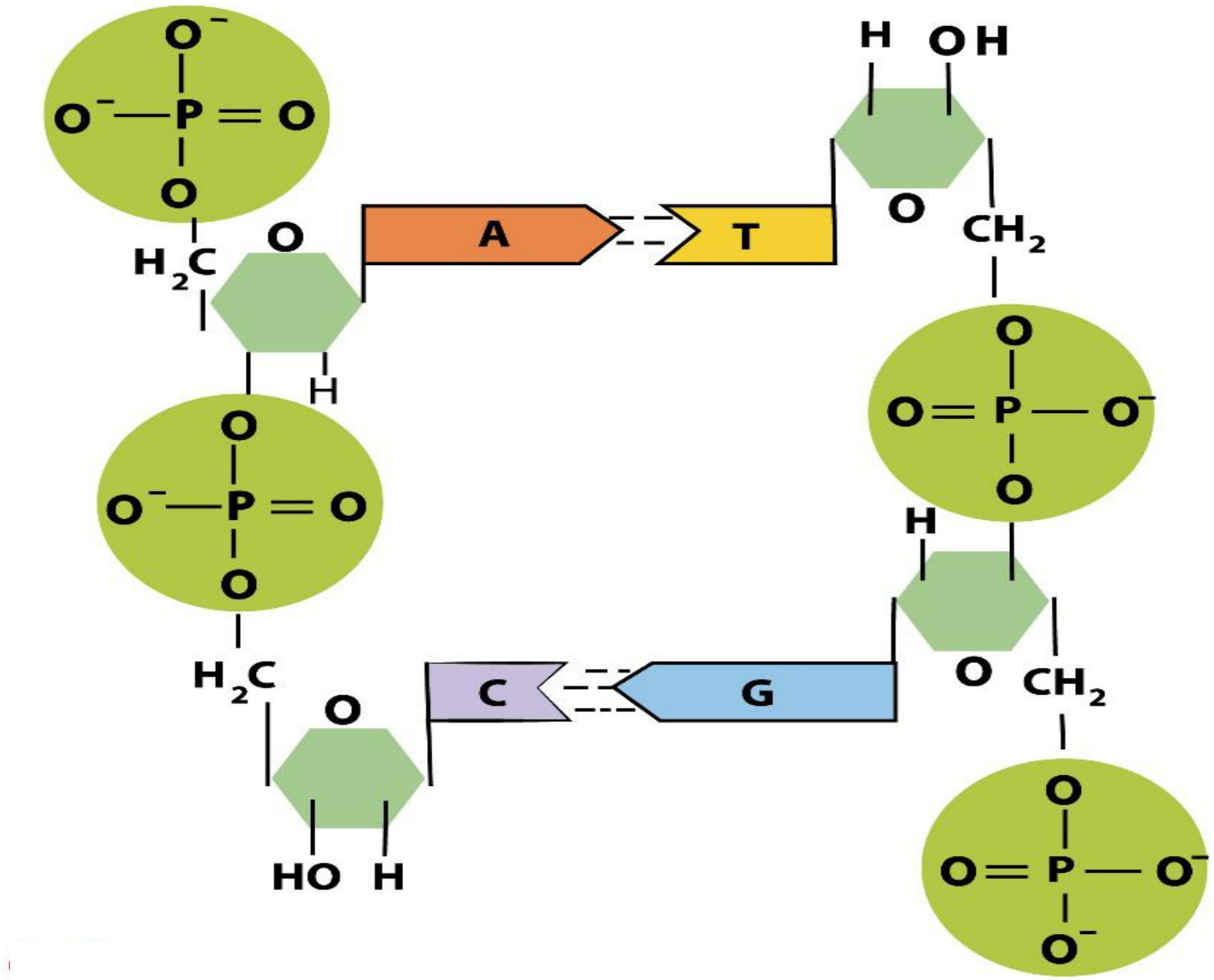
1. 1 Nitrogen base
    - adenine (A)
    - thymine (T, only in DNA)
    - uracil (U, only in RNA)
    - cytosine (C)
    - guanine (G)

2. 1 Sugar (deoxyribose or ribose)

3. 1 Phosphate group



Nucleotides



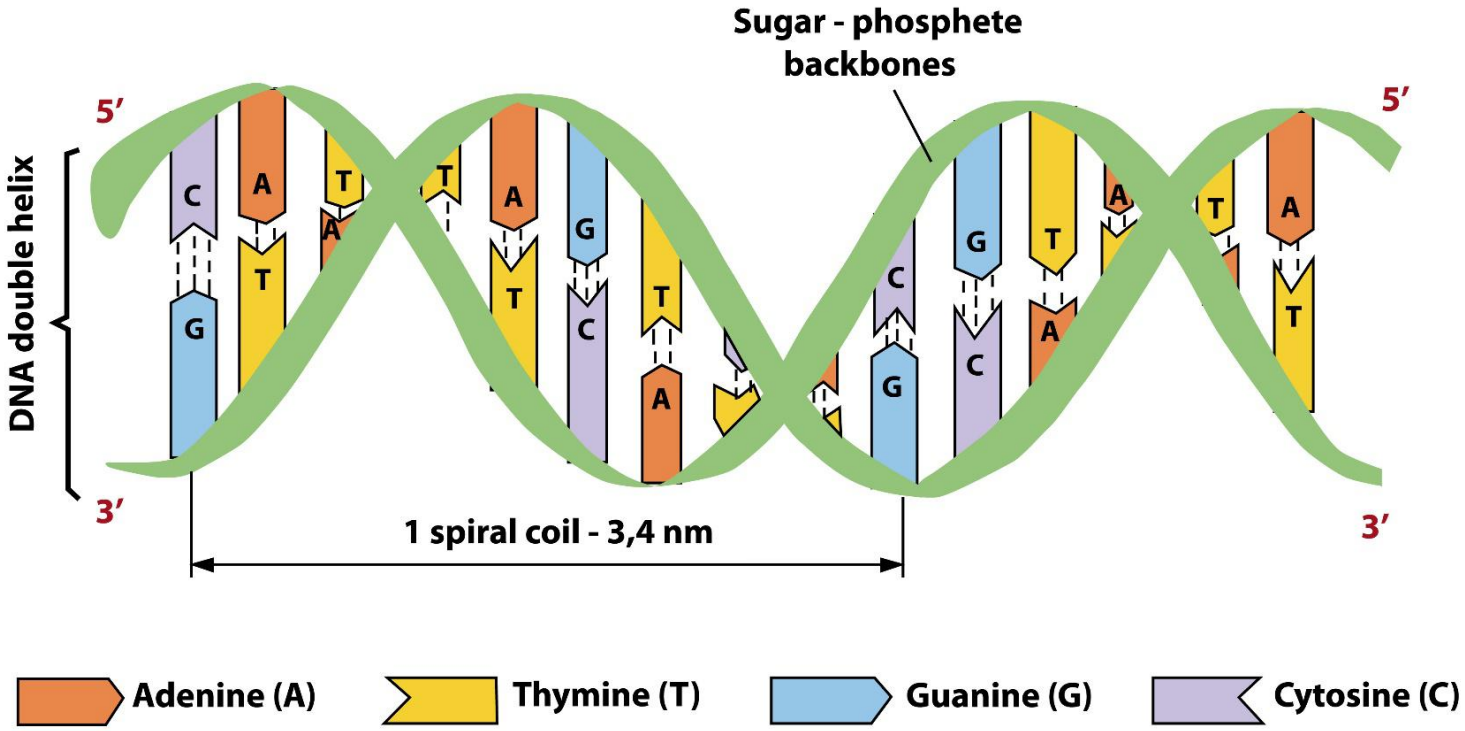
Nucleic Acids

Sugar-phosphate "backbone" forms

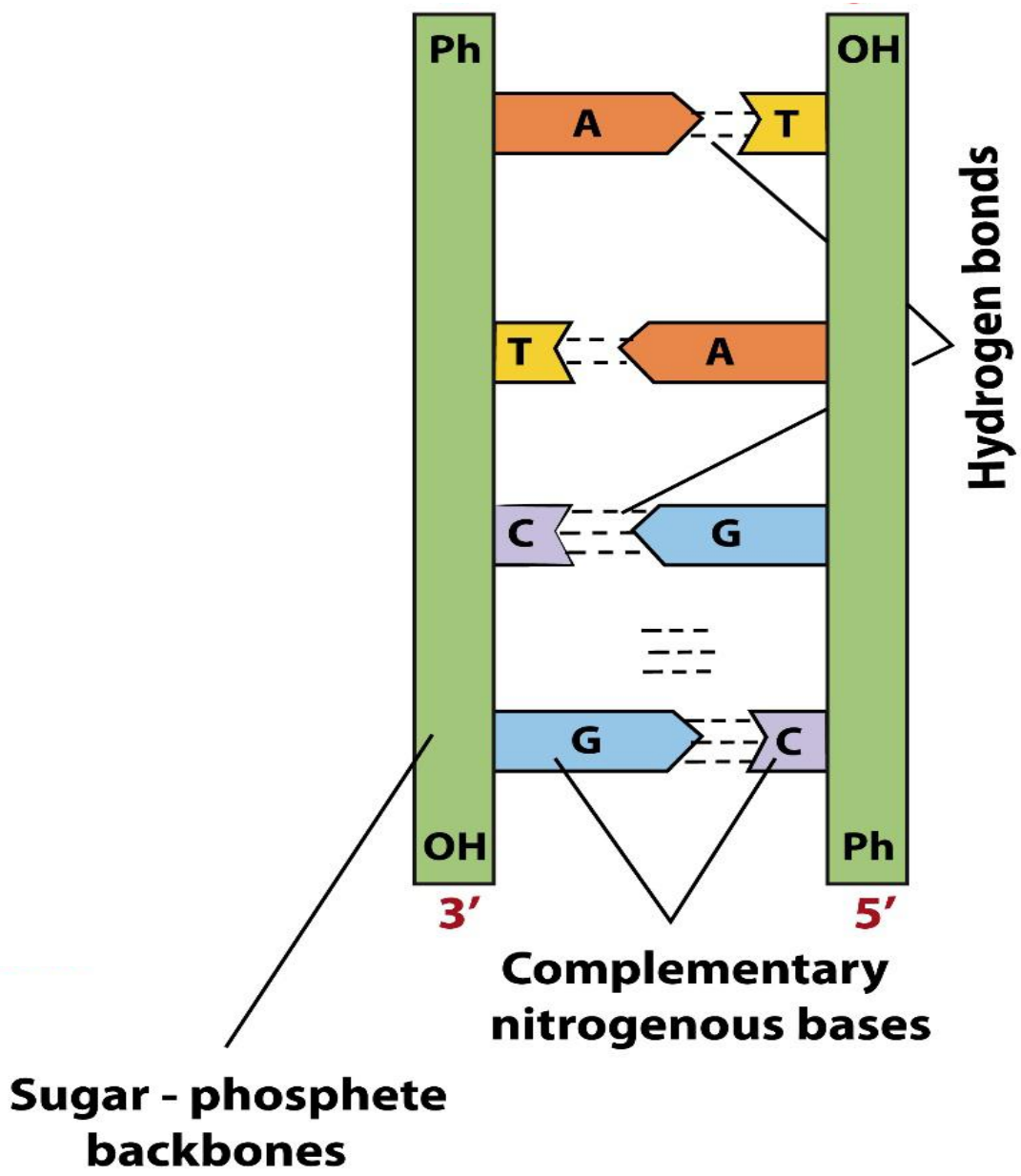
Nucleotides paired (called a base pair), so that DNA or RNA strands are complimentary

- **A-T or A-U**
- **C-G**

Base pairs joined in center by hydrogen bonds



Nucleic Acids



1.1.4 Origin of Life

When and Where

Fossils suggest life evolved 3.5 million years ago

Bacteria & similar organisms

Likely places:

- **deep sea vents**
- **hot springs**
- **tide pools**

From Simple to Complex

Evolution of life happened in steps, each building on those previous

1. simple organic molecules
2. some molecules able to replicate
3. membranes, cell division
4. metabolism

First Living Things

Many lines of evidence of common ancestry

- **cell membranes**
- **metabolism**
- **DNA**
- **fossils**

Tree of life has patterns of evolution from simple to complex

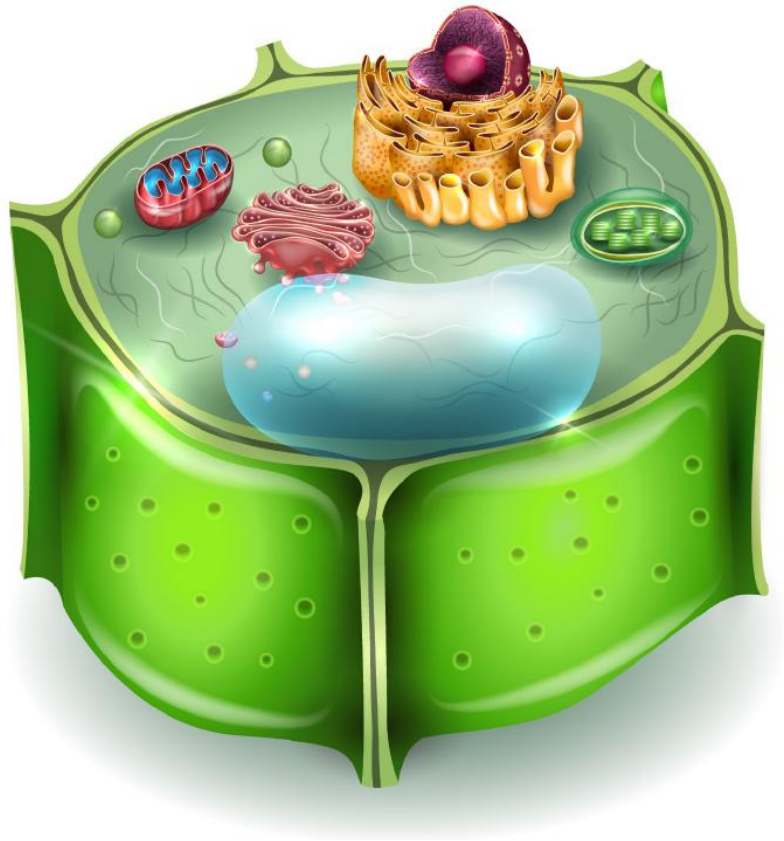
1.2 Cells

The smallest units of life

1.2.1 Structure & Function of Cell Organelles

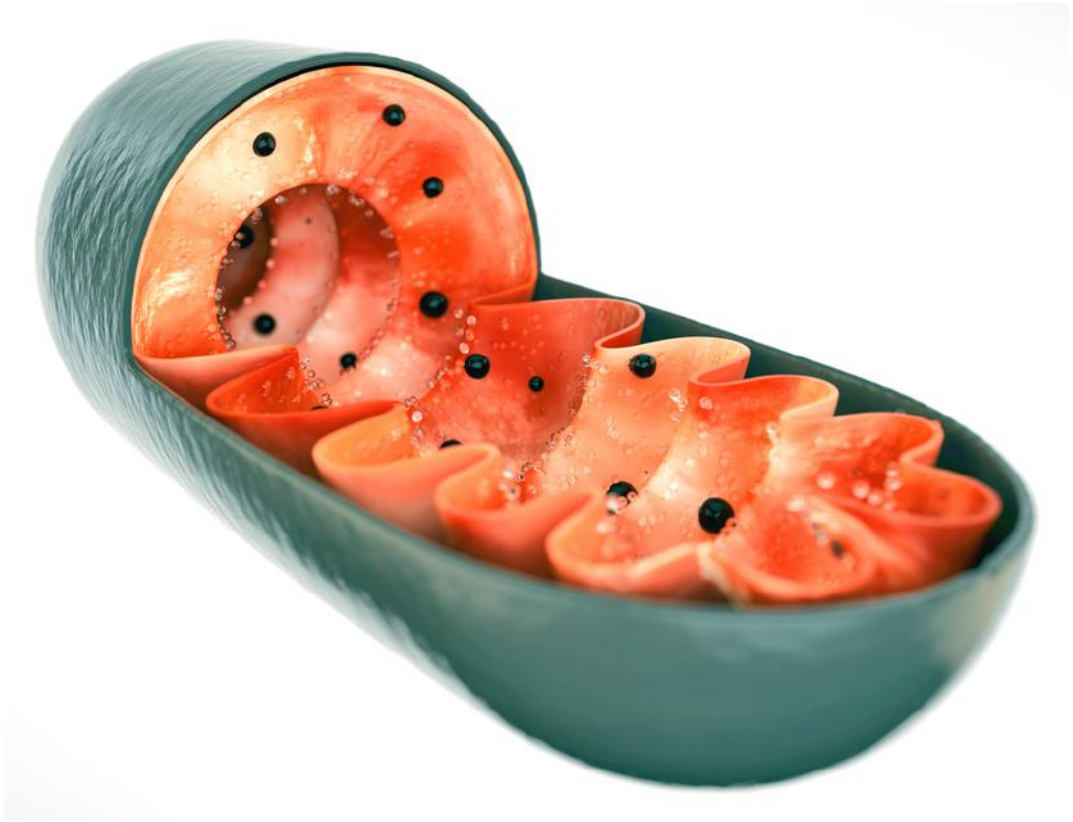
1.2.2 Properties of Cell Membranes

1.2.3 Comparison of Prokaryotic & Eukaryotic Cells



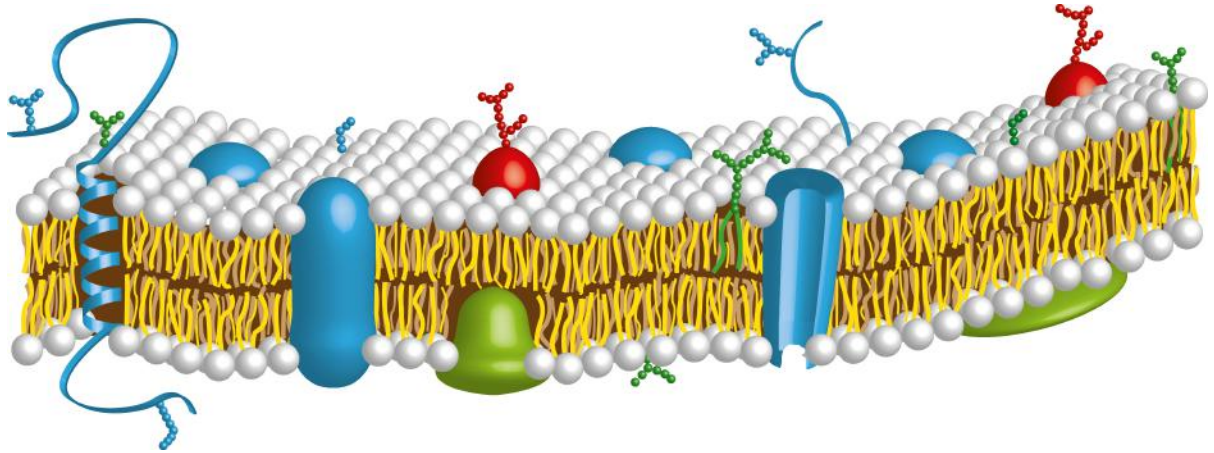
Structure & Function of Cell Organelles

- cell basics
- cytoplasm & cell membrane
- nucleus
- ribosomes
- endoplasmic reticulum
- Golgi apparatus
- mitochondria & chloroplasts
- cytoskeleton
- cell wall



Properties of Cell Membranes

- membrane basics
- selective permeability
- transport basics
- passive transport
- active transport



Comparison of Prokaryotic & Eukaryotic Cells

- cells basics
- prokaryotic cell characteristics
- eukaryotic cell characteristics

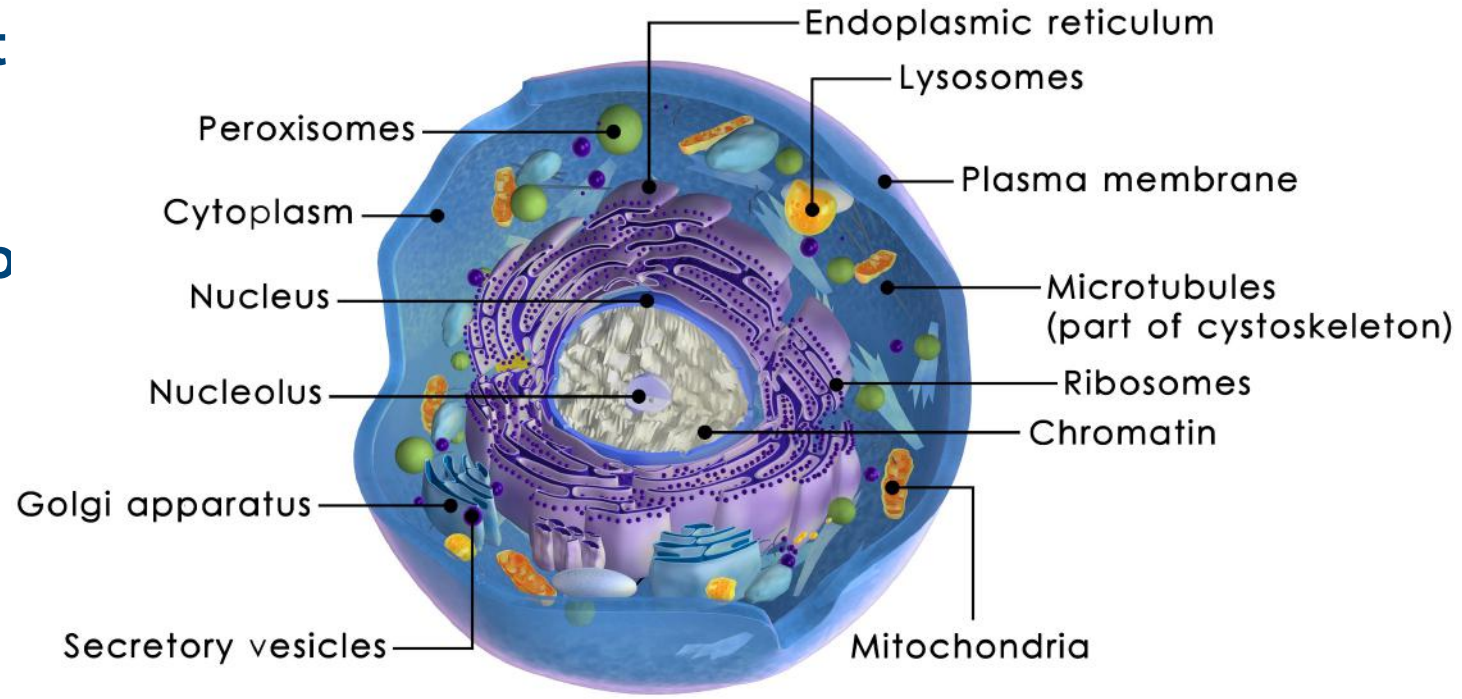
1.2.1 Structure & Function of Cell Organelles

Cells

Smallest collection of matter that be alive

All organisms made of one or mo cells

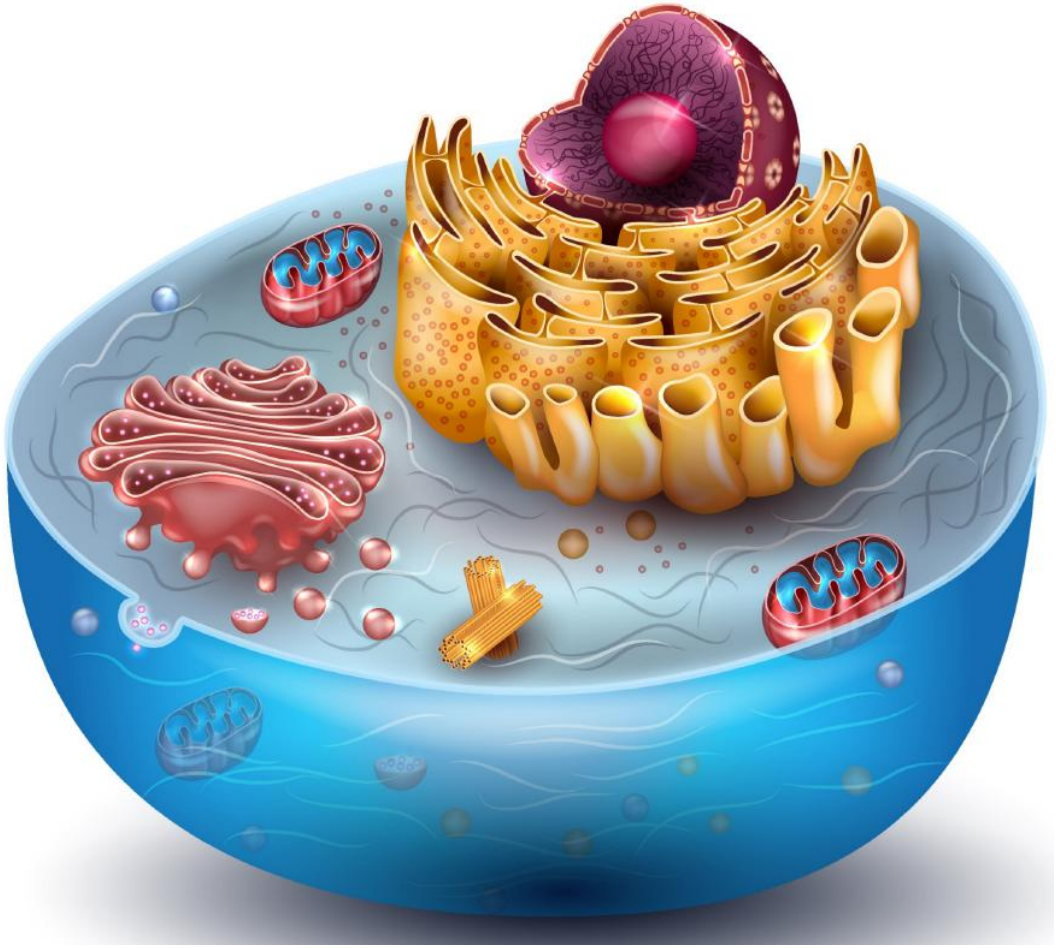
- **single-celled**
- **multicellular**



Cytoplasm & Cell Membrane

Cytoplasm: jelly-like substance in which all organelles are suspended

Cell membrane: lipid layer surrounding cell

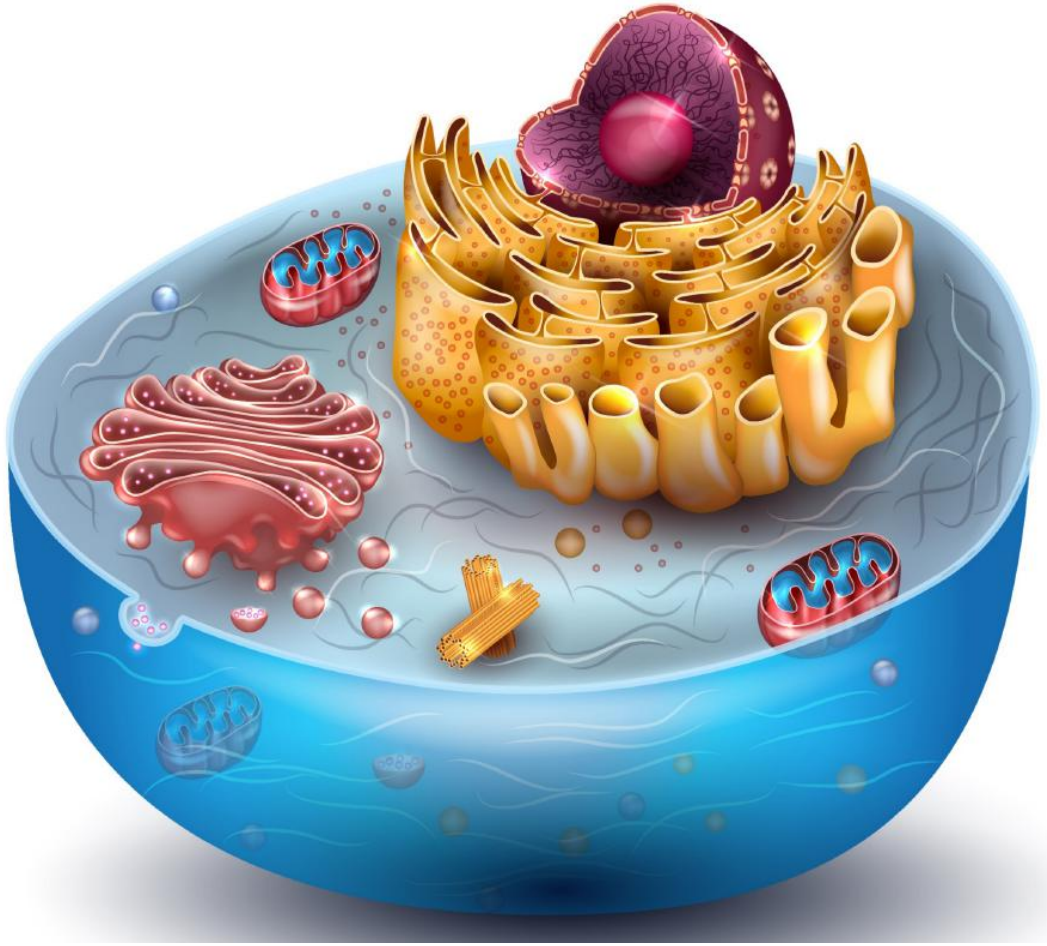


Nucleus

“Command center”

Stores, protects most of DNA

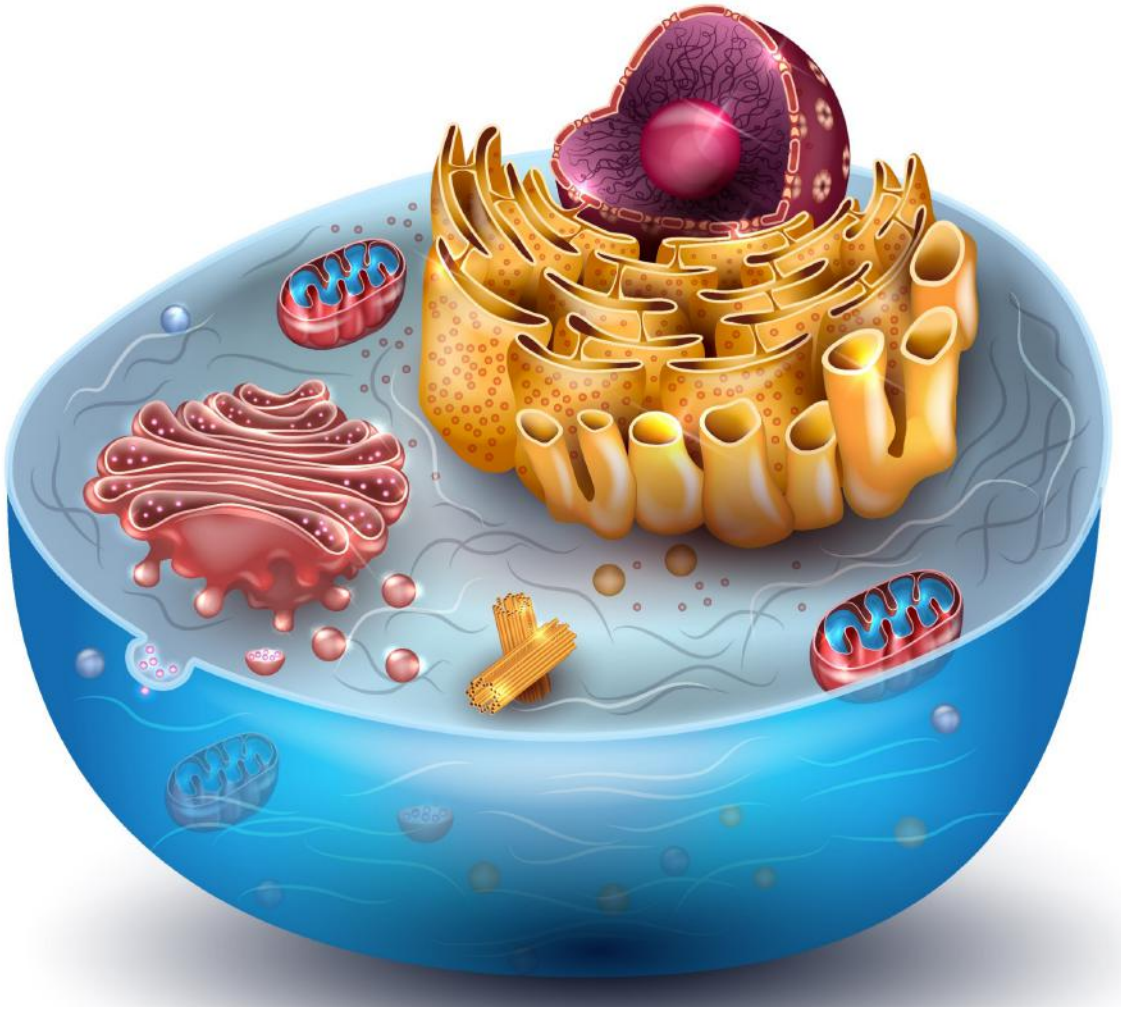
Nucleolus makes RNA & ribosomes



Ribosomes

Protein factories- use DNA instructions to make proteins

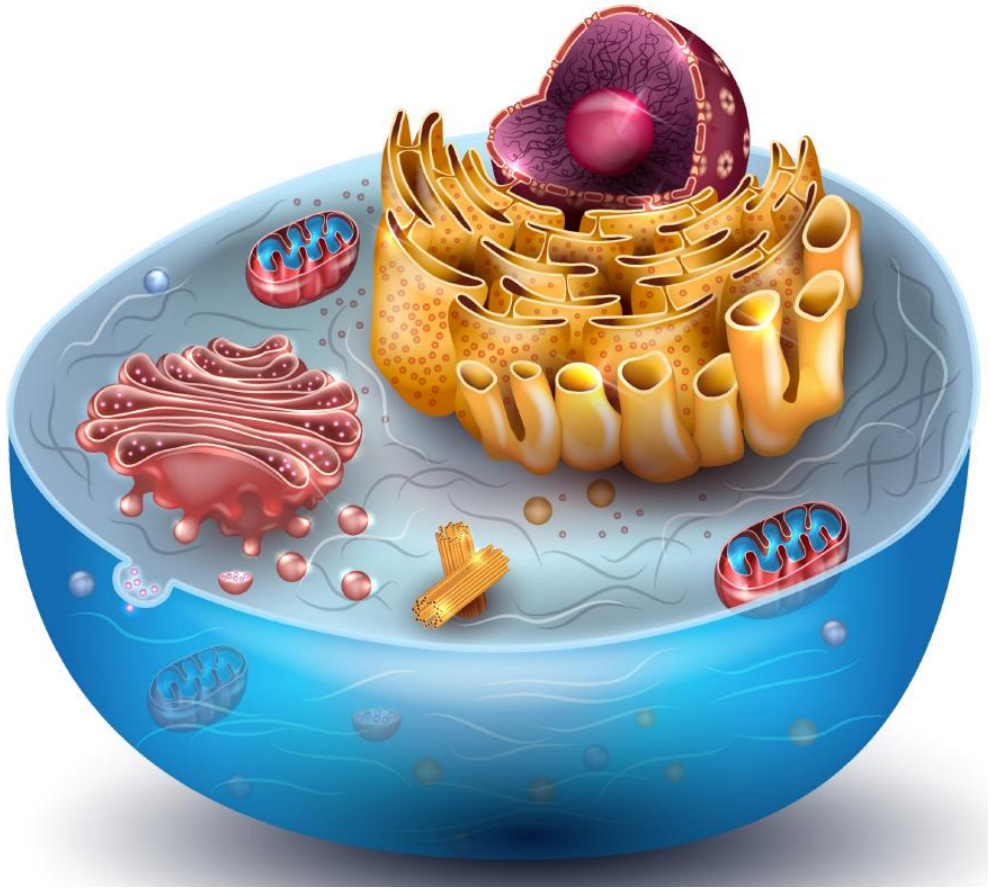
Made of RNA & proteins



Endoplasmic Reticulum

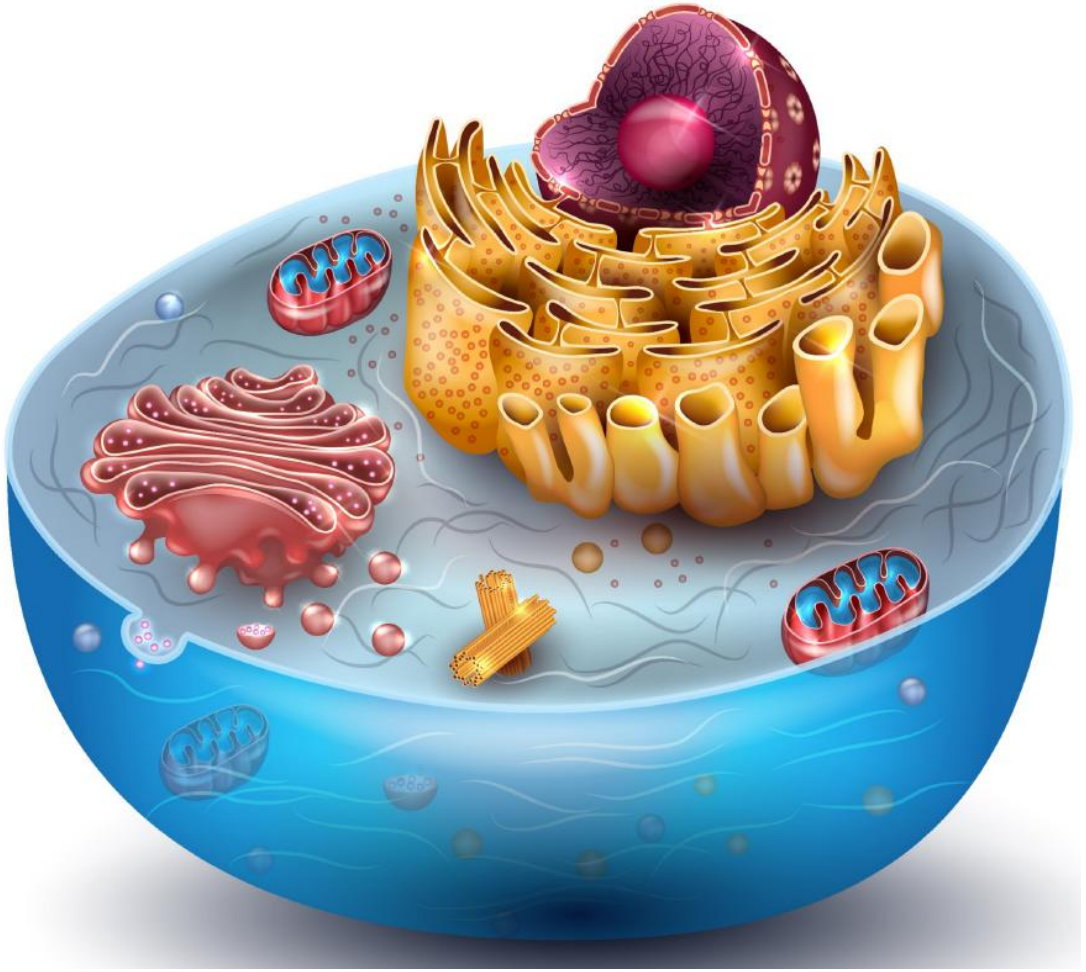
Functions:

- **makes lipids**
- **detox**
- **makes secretory proteins & membrane**



Golgi Apparatus

Functions: receiving, sorting, modifying, and shipping center for ER products



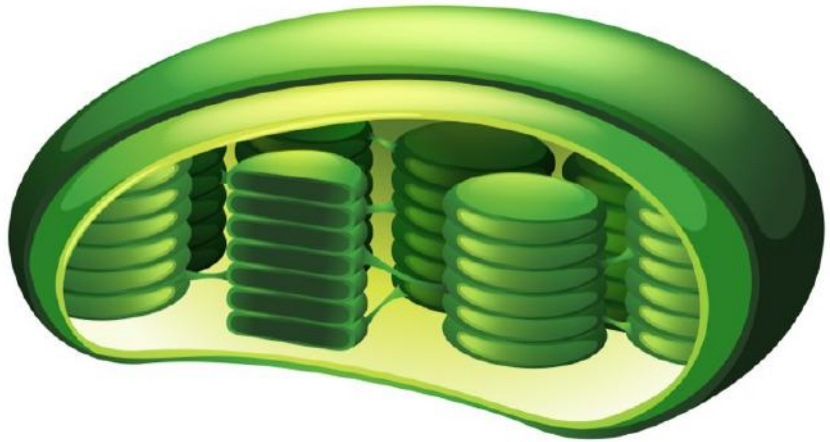
Mitochondria & Chloroplasts

Both have:

- **their own DNA & ribosomes**
- **double-membrane**
- **somewhat autonomous**

Mitochondria: site of cell respiration (converts food to energy molecules)

Chloroplasts: site of photosynthesis (converts sunlight into food)



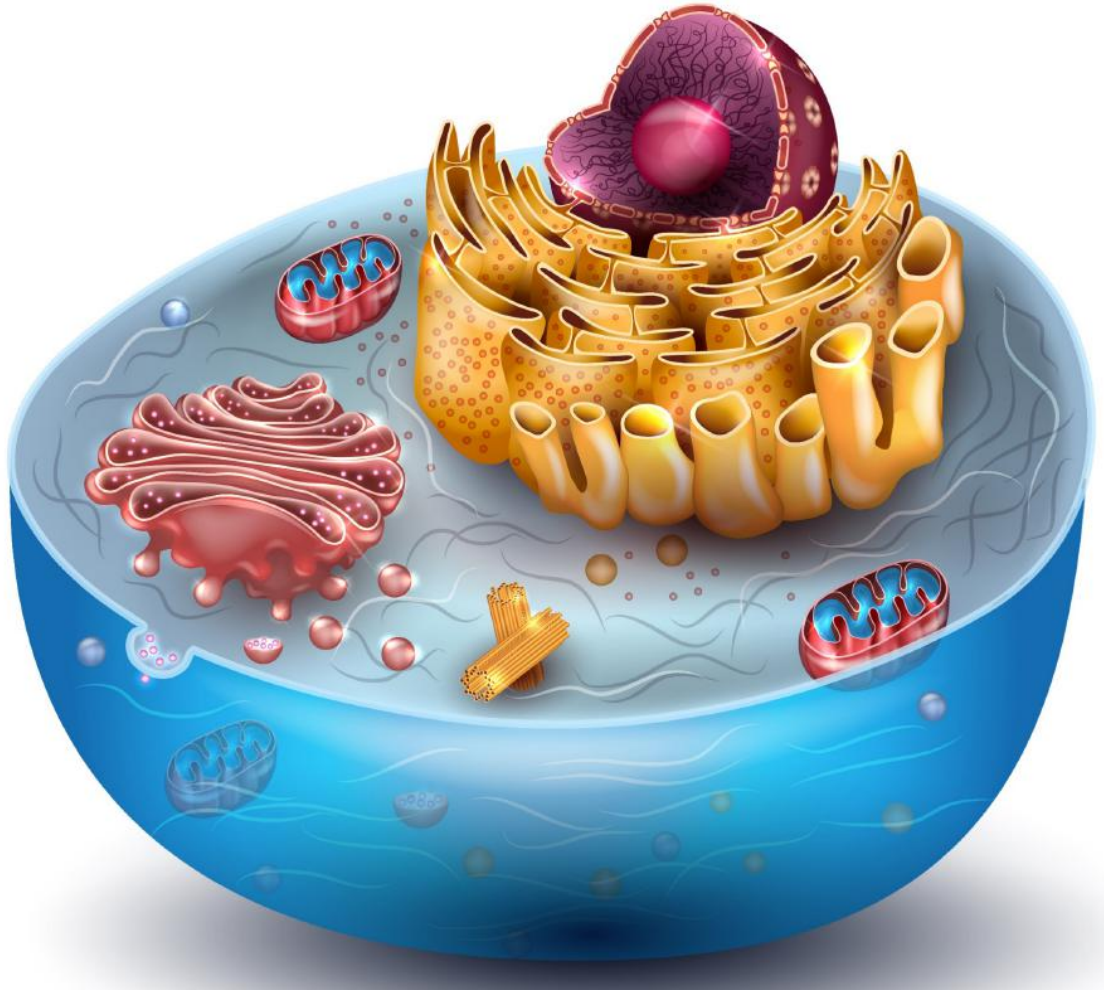
Cytoskeleton

Support scaffolding for cells

Duties:

- **cell shape, muscle movement, highways, organizing cytoplasm, locomotion**

Centrosomes: organizes some of cytoskeleton, & cell division



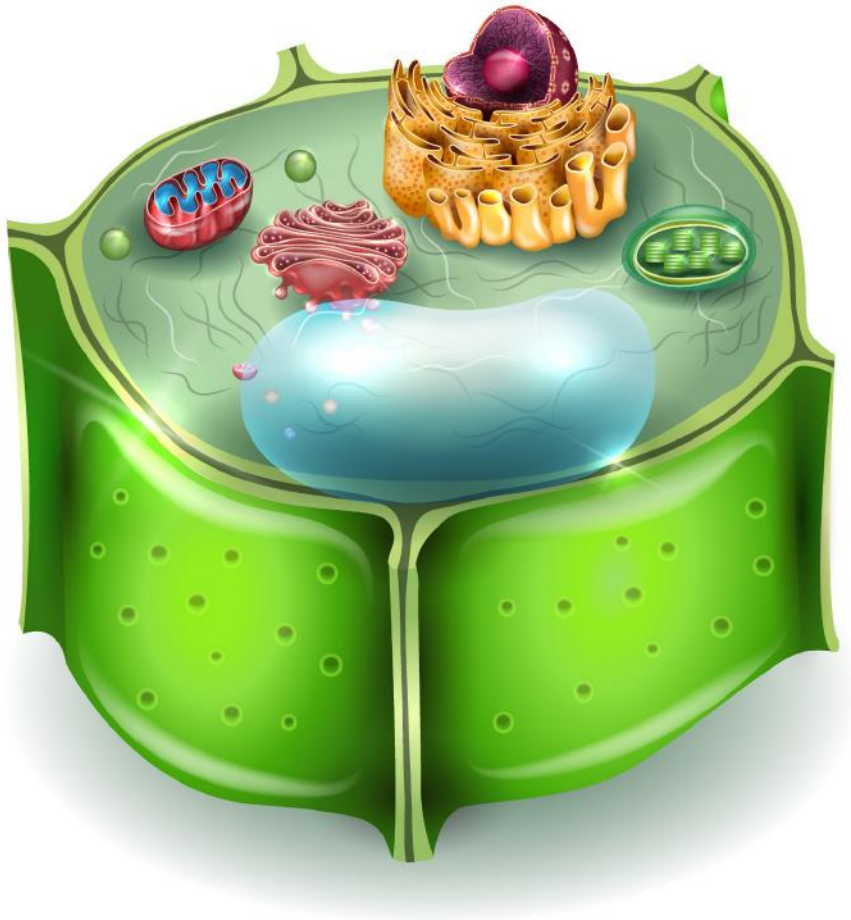
Cell Wall

Found in plants, fungi, bacteria

Rigid, structural support

Common components:

- cellulose
- pectin
- chitin



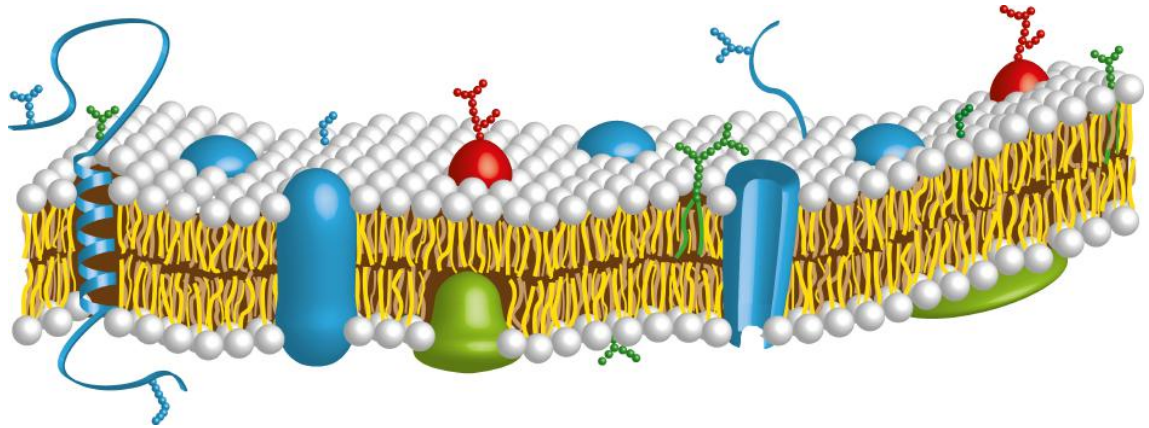
1.2.2 Properties of Cell Membranes

Membranes

Boundary b/w inside of cell & surroundings

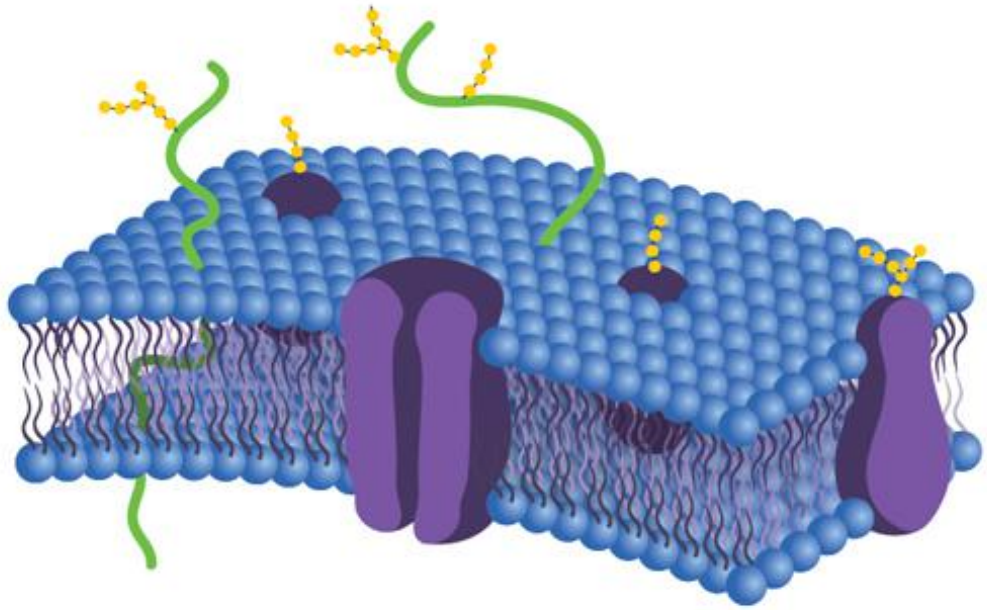
Selectively permeable

Phospholipid bilayer w/ proteins, other lipids, hybrid molecules



Selective Permeability

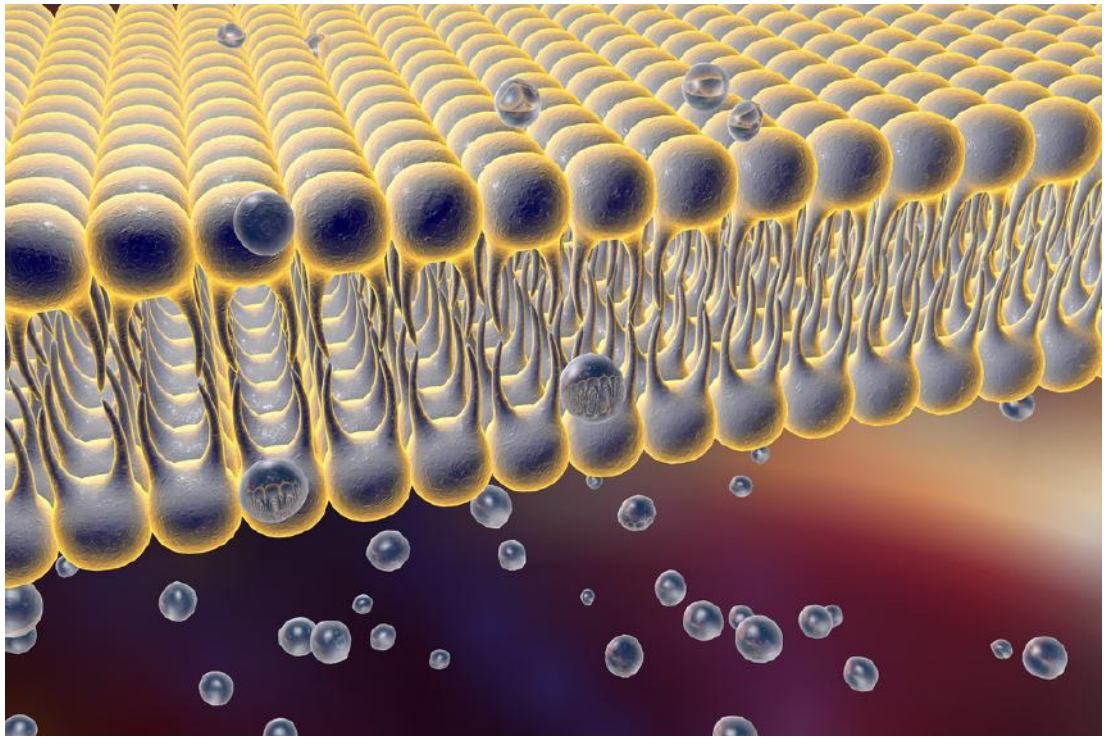
Membranes regulate cell traffic by only allowing some things to pass freely, transporting others, preventing still others



Membrane Transport

Passive transport: diffusion across membrane; no energy required; sometimes need “doorway” protein (which is in membrane)

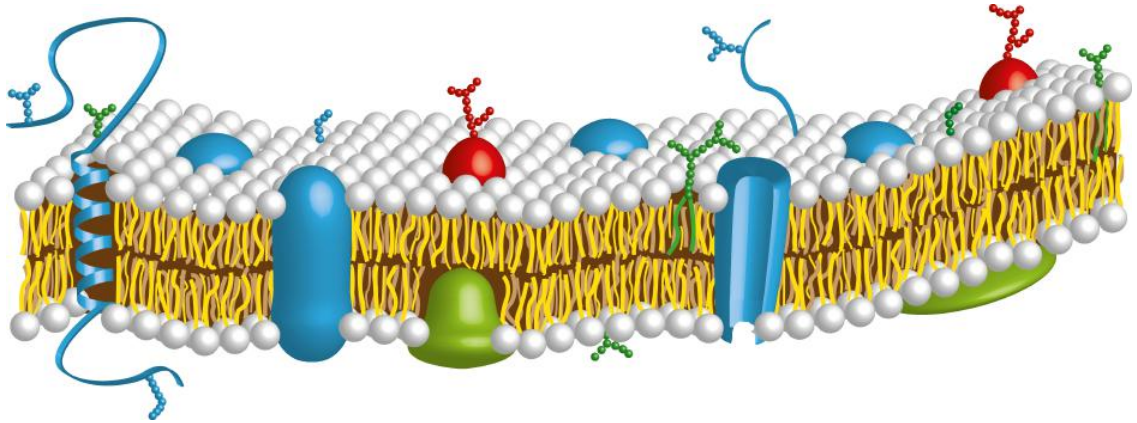
Active transport: movement across membrane requiring energy and “doorway” protein



Passive Transport: Diffusion

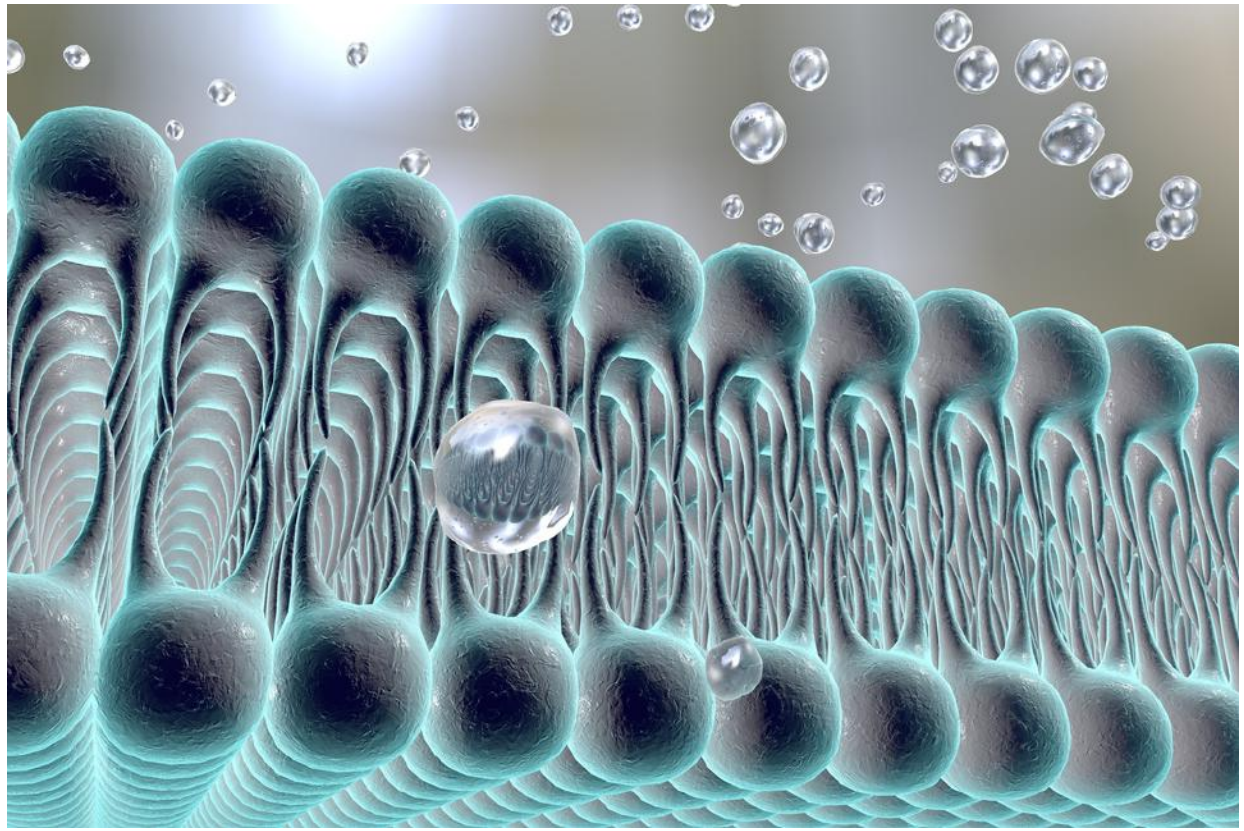
Movement of molecules from higher to lower concentrations

- **each molecule moves randomly**
- **no energy required; spontaneous**



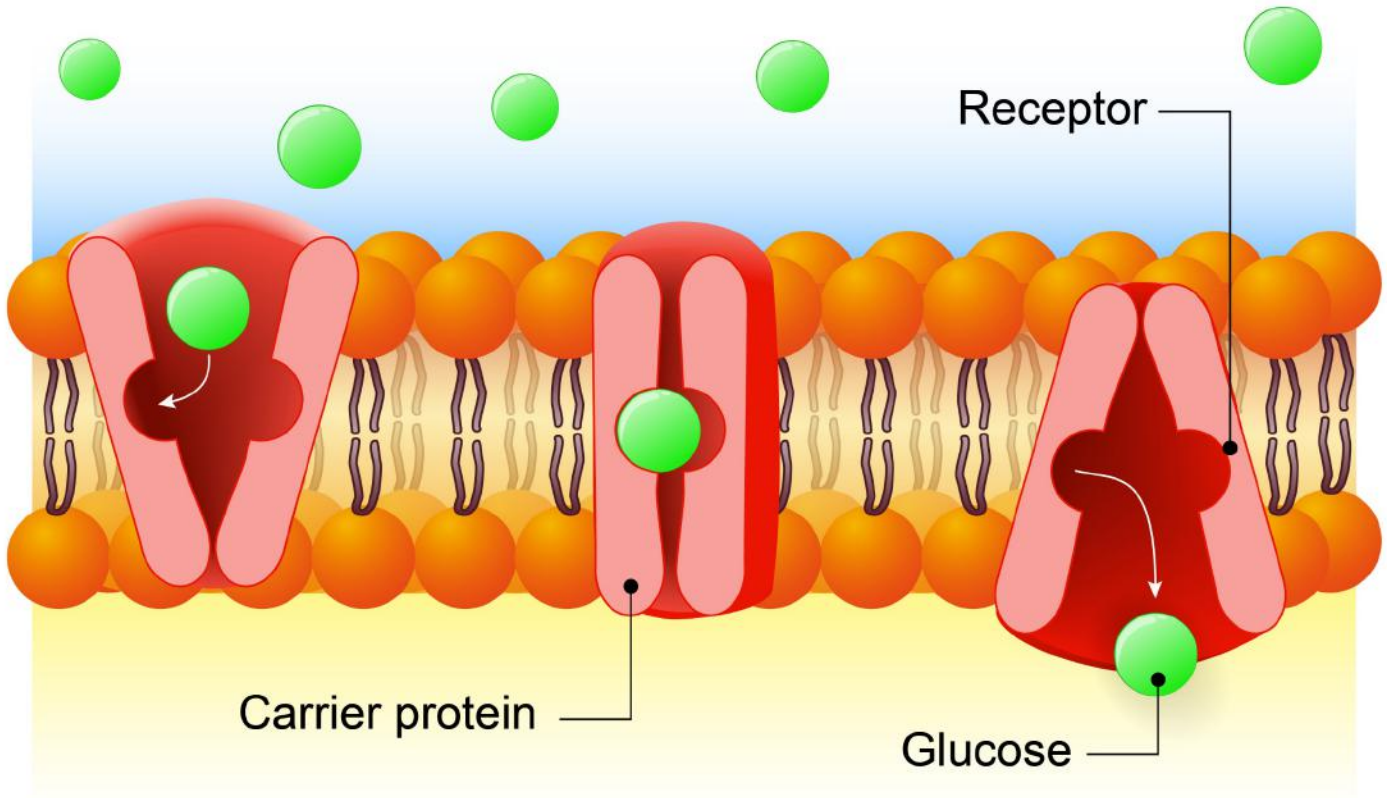
Passive Transport: Osmosis

Diffusion of water across membrane from higher to lower concentrations



Passive Transport: Facilitated Diffusion

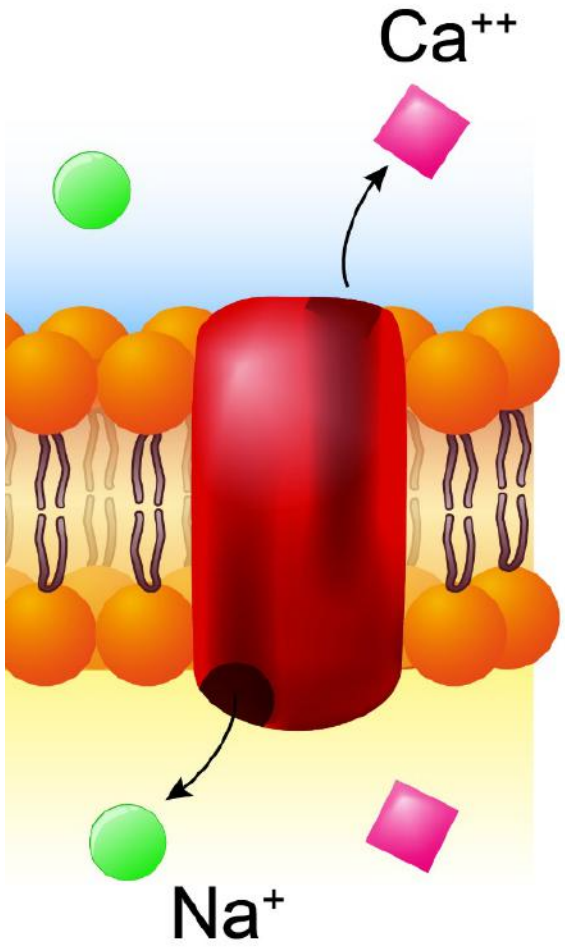
Diffusion w/ help of "doorway" proteins- very specific



Active Transport

Requires energy and "doorway" protein

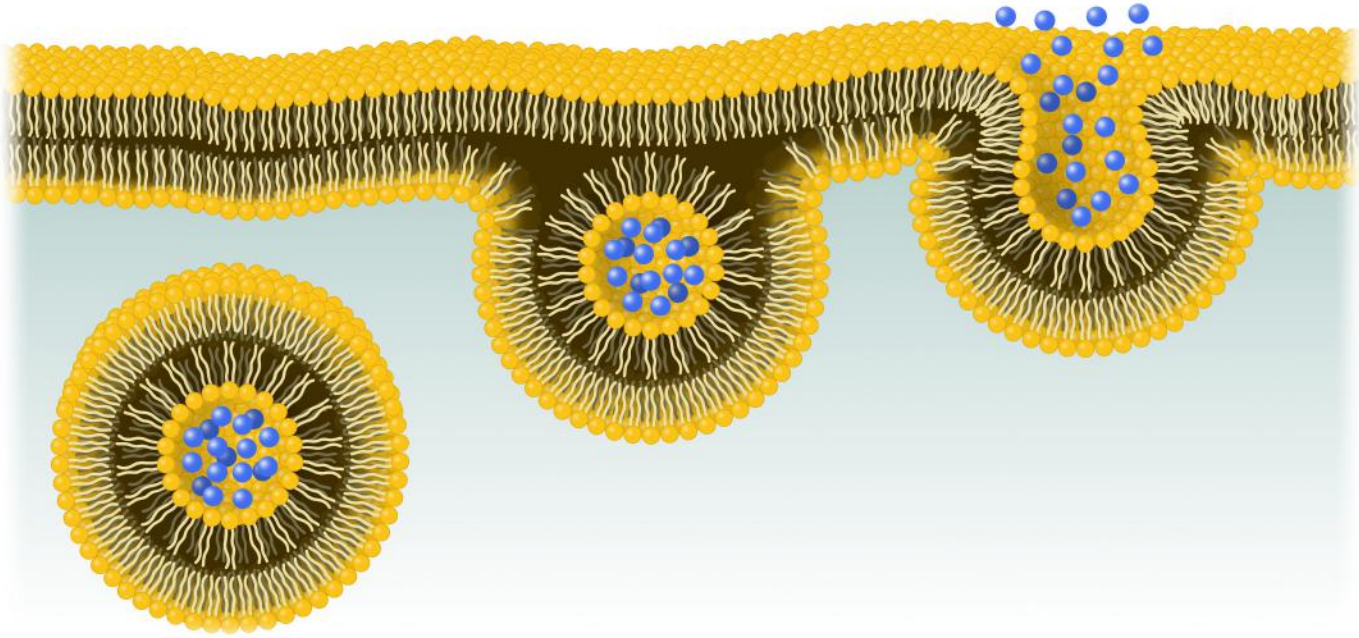
Useful for moving molecules against their concentration gradients



Active Transport: Bulk Transport

Large molecules can't pass through membrane

- **Exocytosis: leaving the cell through vesicles**
- **Endocytosis: entering cell through vesicles**



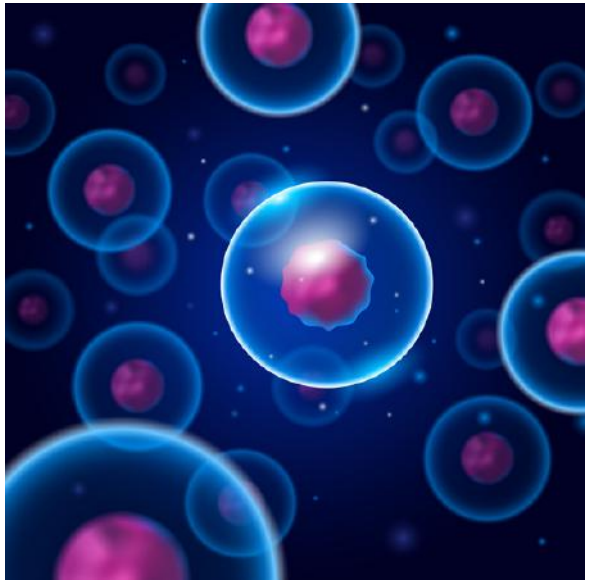
1.2.3 Comparison of Prokaryotic and Eukaryotic Cells

Cells

Two types of cells:

1. Prokaryotic
2. Eukaryotic

All living things are either prokaryotes or eukaryotes



Prokaryotic Cells

Bacteria & Archaea

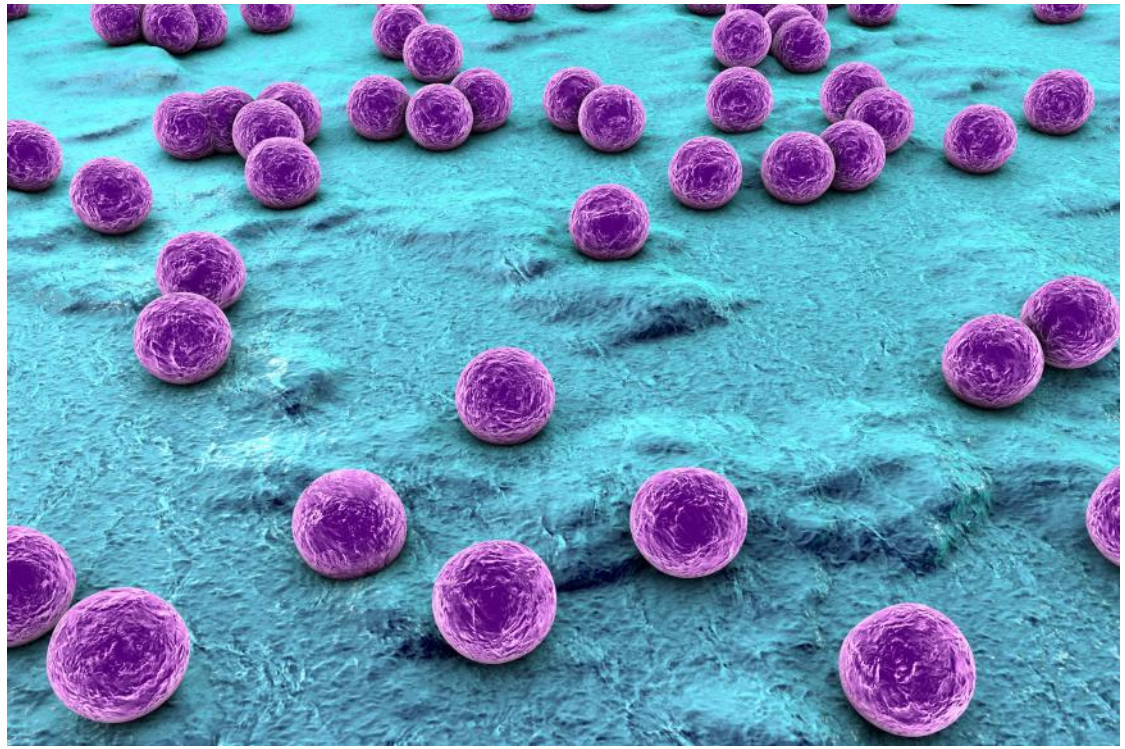
Most ancestral living things

Like all cells, they have:

- cell membrane
- cytoplasm

Unlike eukaryotic cells, they have:

- no nucleus
- no organelles



Prokaryotic Cells

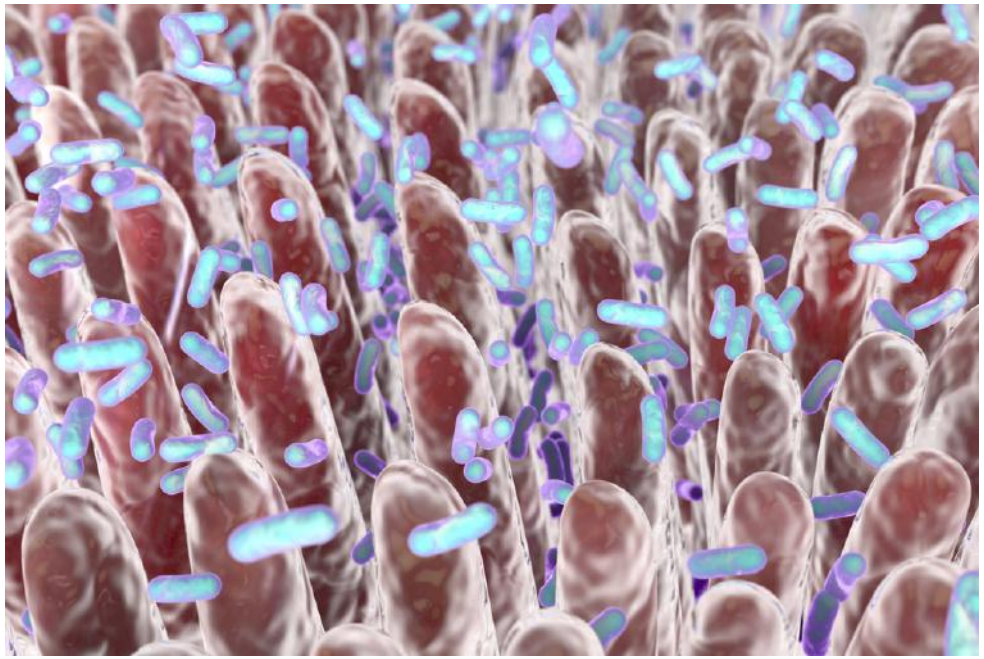
All prokaryotes are unicellular

Some have a cell wall and/or locomotor structures

Most abundant living things on planet

Some helpful (gut), some harmful (infection)

Many shapes, all very small



Lyme disease bacteria

Eukaryotes

Animals, plants, fungi, protozoans, etc.

Evolved from prokaryotes

Like all cells, they have:

- cell membrane
- cytoplasm

Eukaryotes

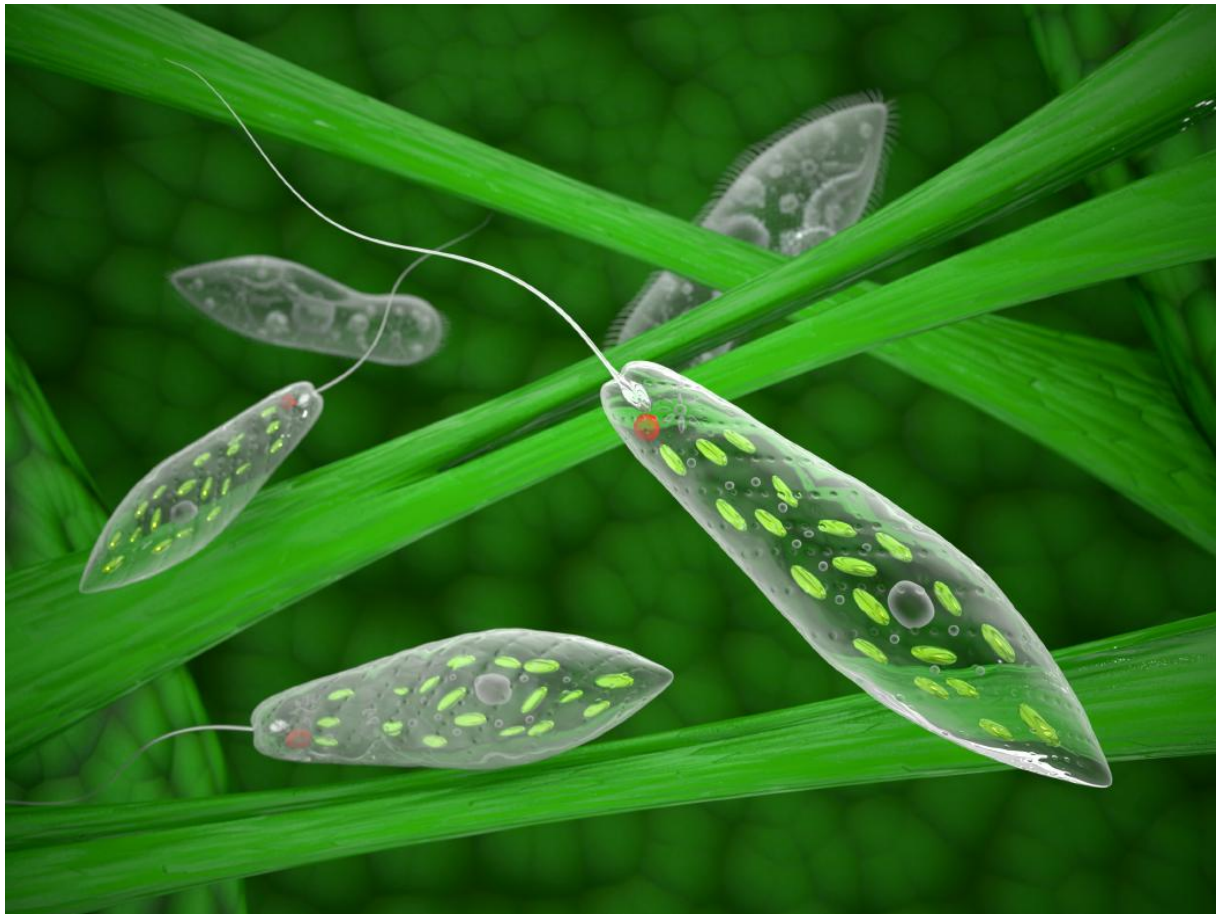
Unlike prokaryotes, they all have:

- **internal organelles like nucleus, mitochondria, etc.**
- **DNA in nucleus**

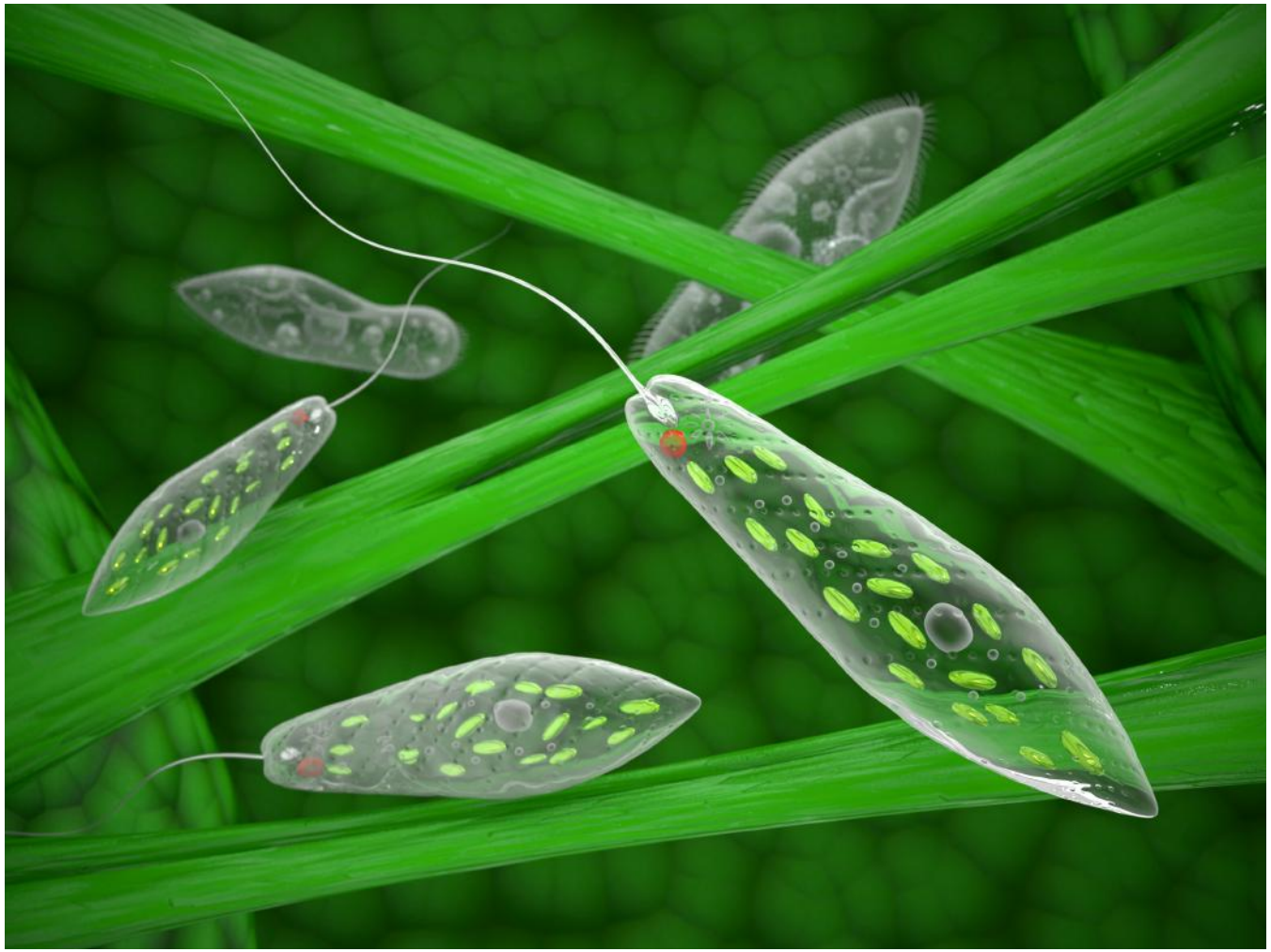
Some have:

- **cell walls**
- **locomotor structures**

Unlike prokaryotes, they can be uni- or multicellular



Eukaryotes



1.3 Enzymes

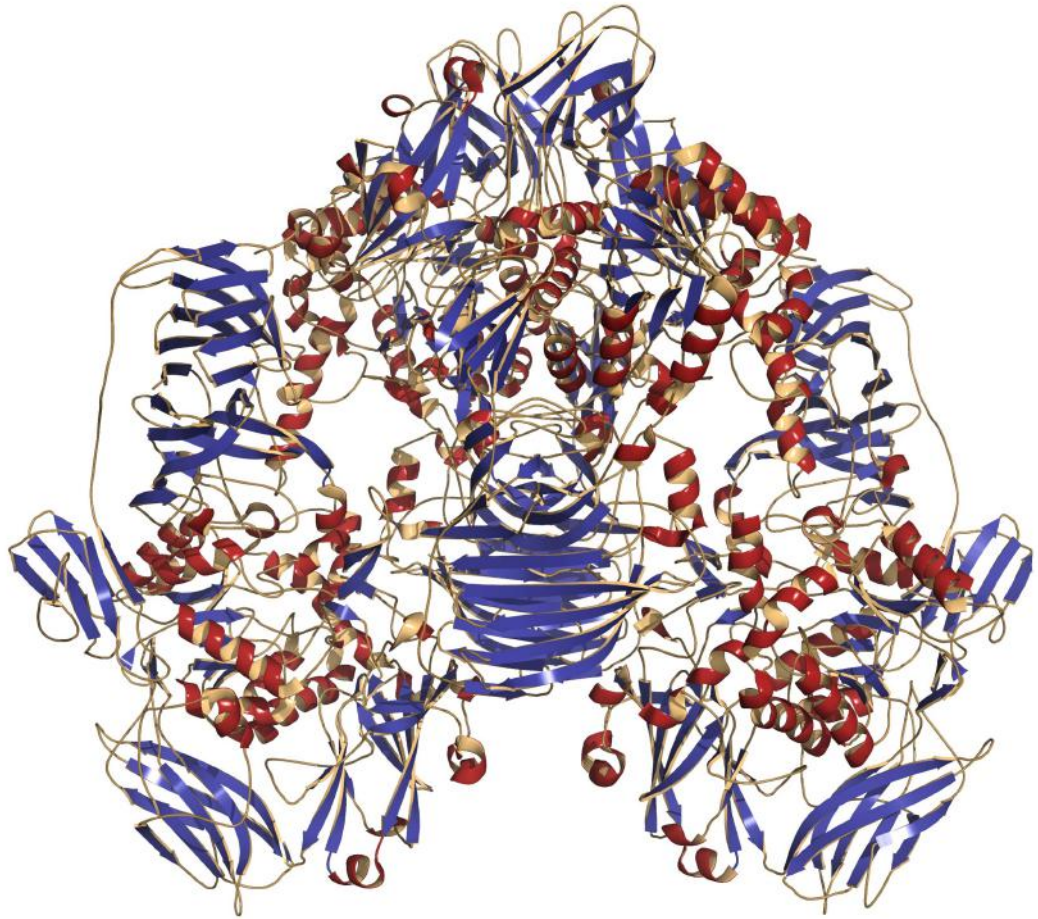
Enzymes

1.3.1- Enzyme-Substrate Complex

1.3.2- Roles of Coenzymes

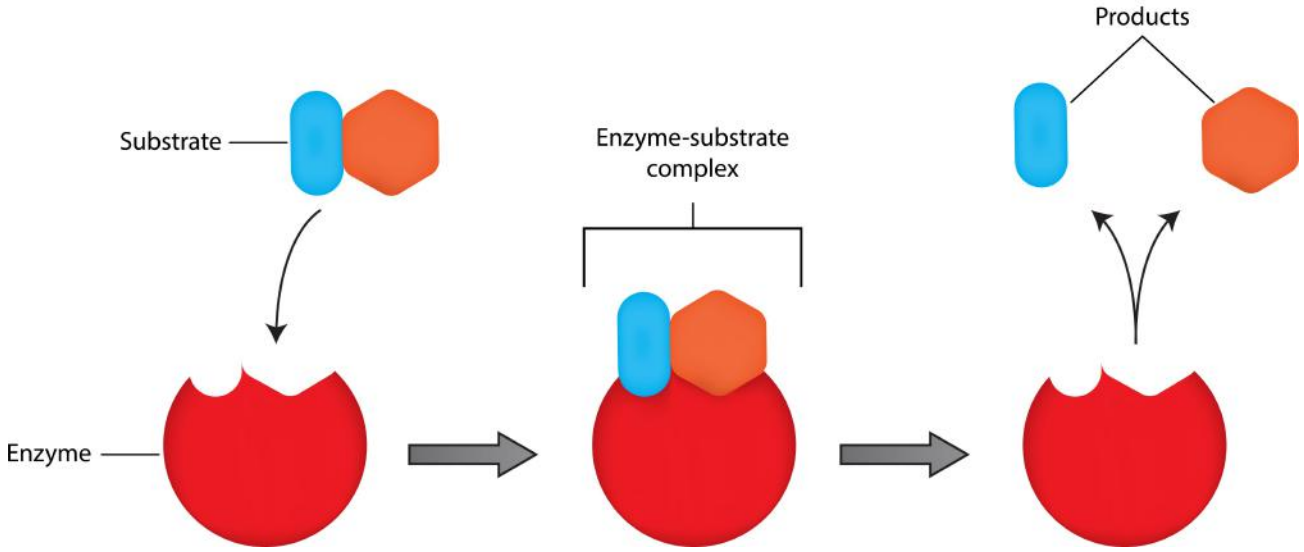
1.3.3- Inorganic Cofactors

1.3.4- Inhibition & Regulation



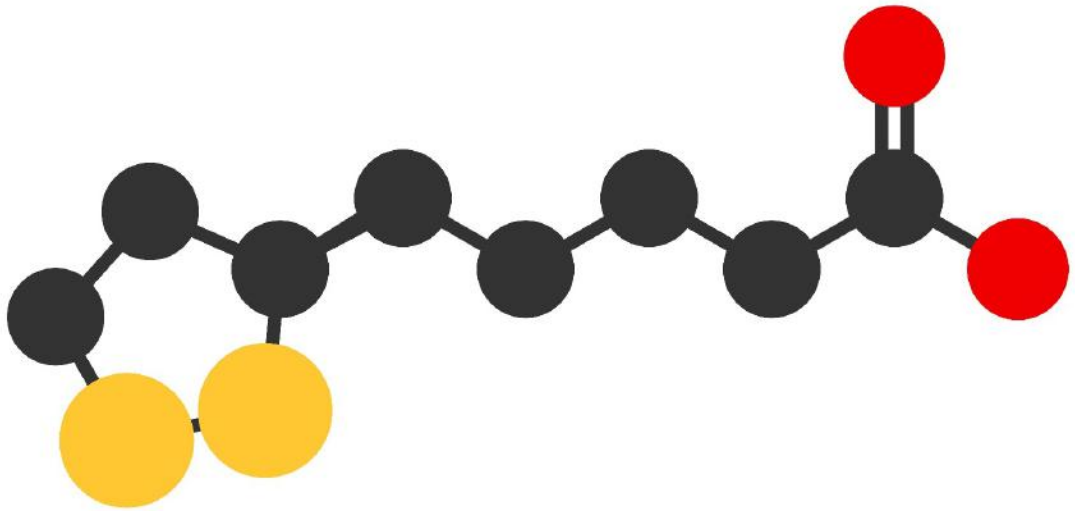
Enzyme-Substrate Complex

- activation energy
- enzymes as catalysts
- substrates & active sites



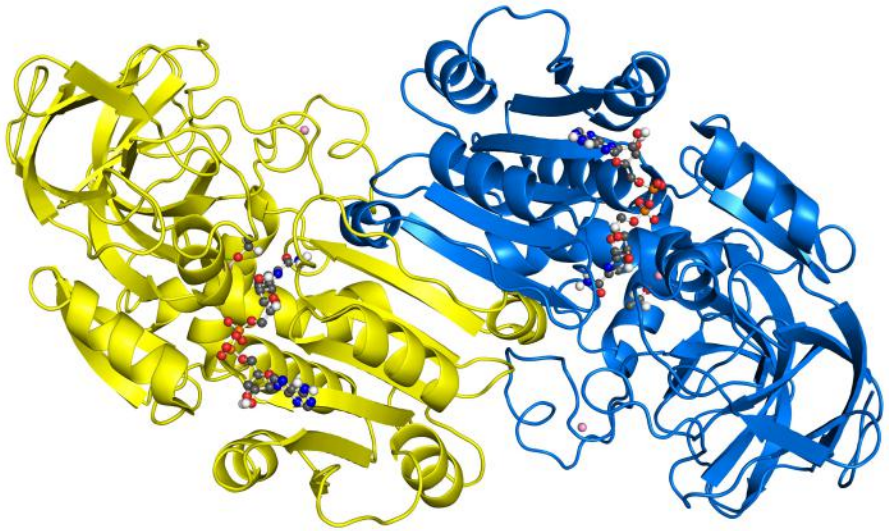
Roles of Coenzymes

- cofactors
- coenzymes



Inorganic Cofactors

- cofactors & coenzymes
- examples of inorganic cofactors



Inhibition & Regulation

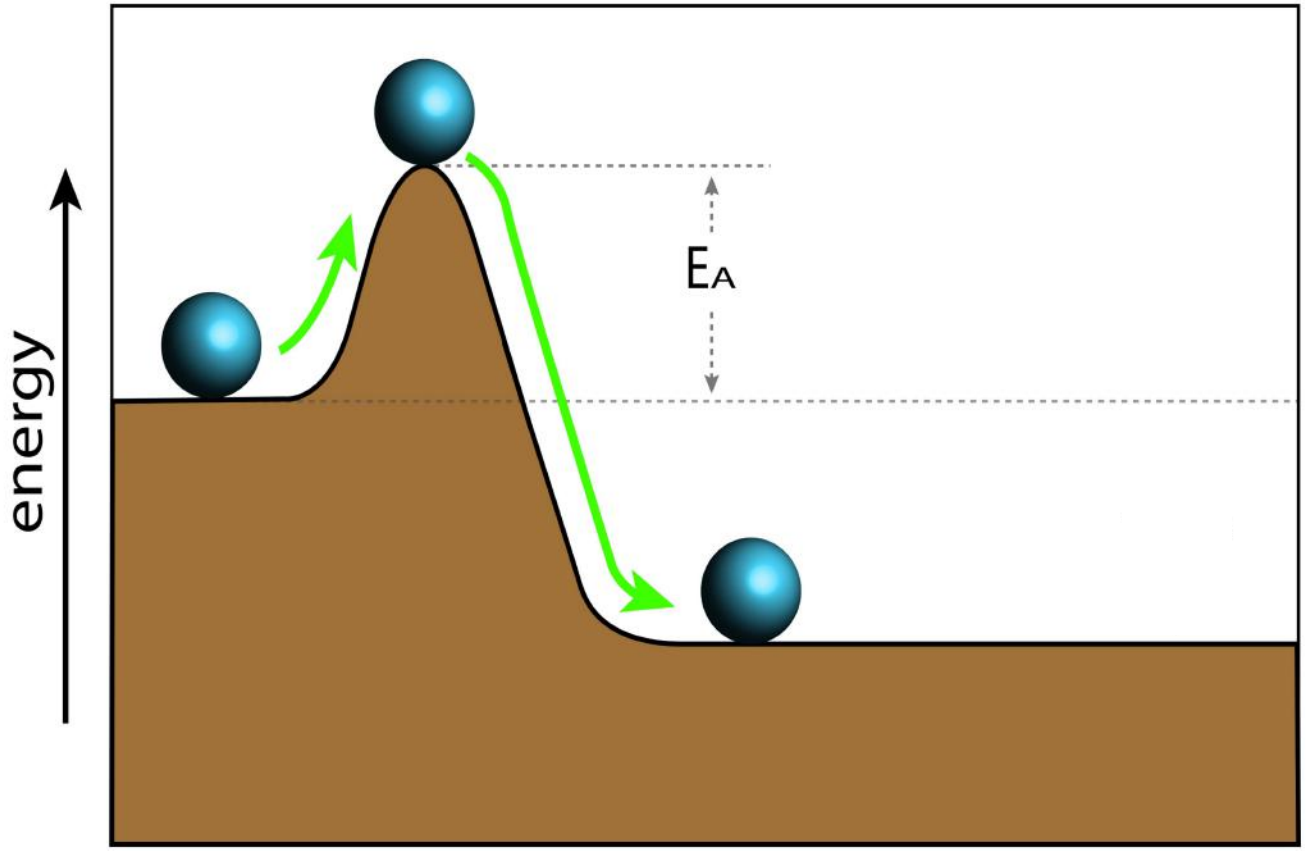
- molecular inhibitors
- environmental inhibition
- regulation
- methods of regulation

1.3.1 Enzyme- Substrate Complex

Activation Energy

Any reaction has an initial energy barrier, called *activation energy* (E_a)

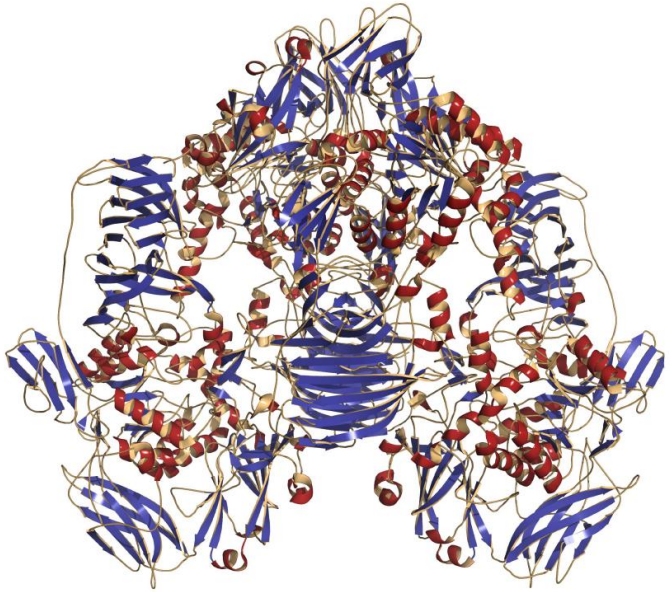
- before new bonding can occur, existing chemical bonds must be broken
- rate of reactions determined by E_a

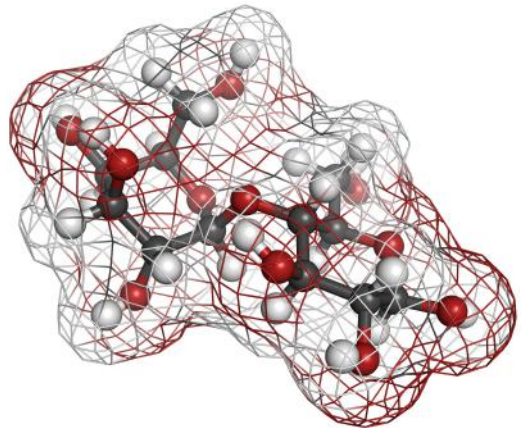


Enzymes

Enzymes **are proteins that act as *catalysts*, which make reactions happen faster by lowering E_a (without being changed/ used themselves)**

Example: lactase and lactose



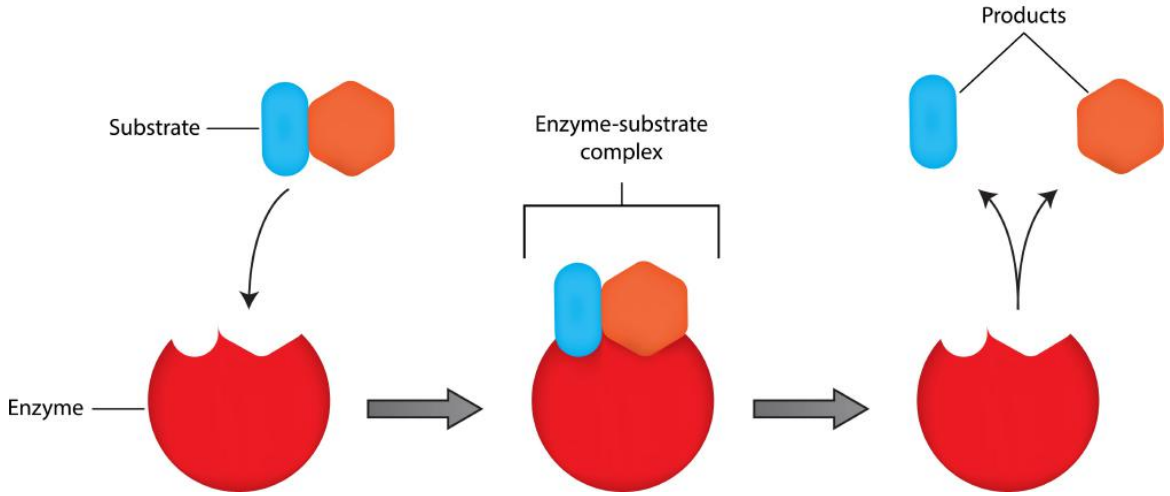


Enzymes

The molecule an enzyme interacts with is called a *substrate*

An enzyme's *active site* is the location where it interacts with the substrate

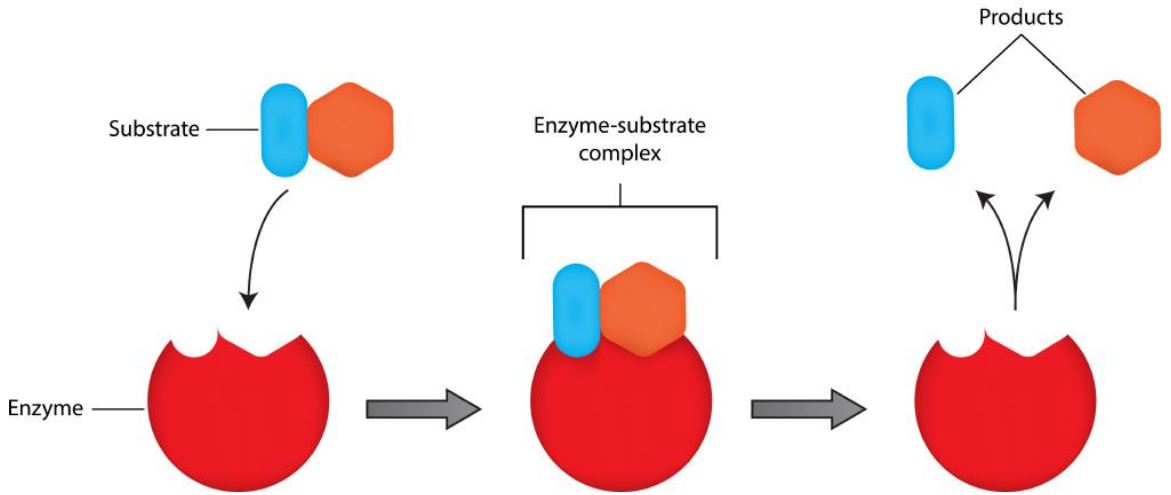
Enzyme and substrate fit together like hand in glove, forming an enzyme-substrate complex



Enzymes

Some enzymes break substrates into smaller pieces

Other enzymes join two substrates together into one molecule



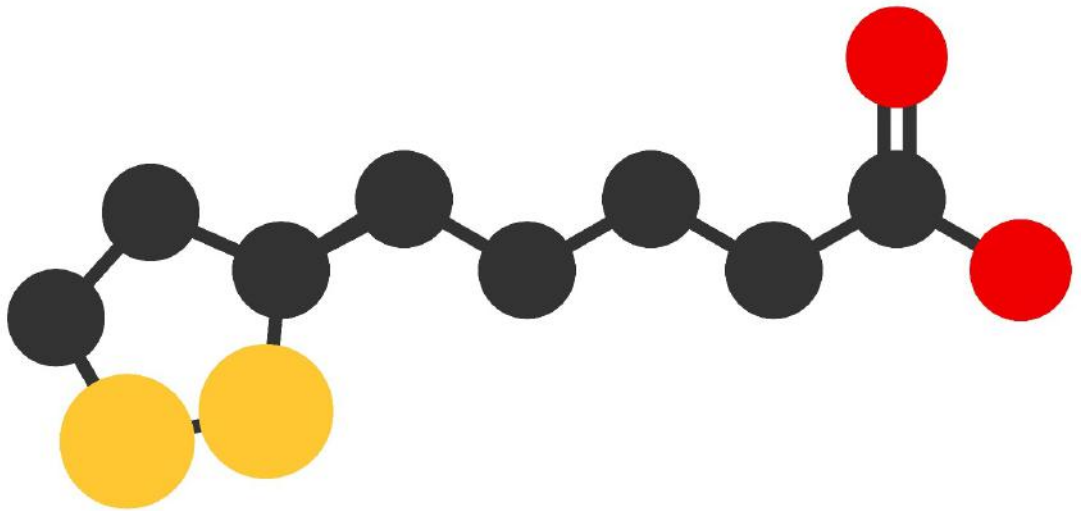
1.3.2 Roles of Coenzymes

Coenzymes

Some enzymes need help from other molecules called cofactors

Cofactors can be inorganic (metals) or organic (coenzymes)

These bind to the enzyme's active site and help form the enzyme-substrate complex

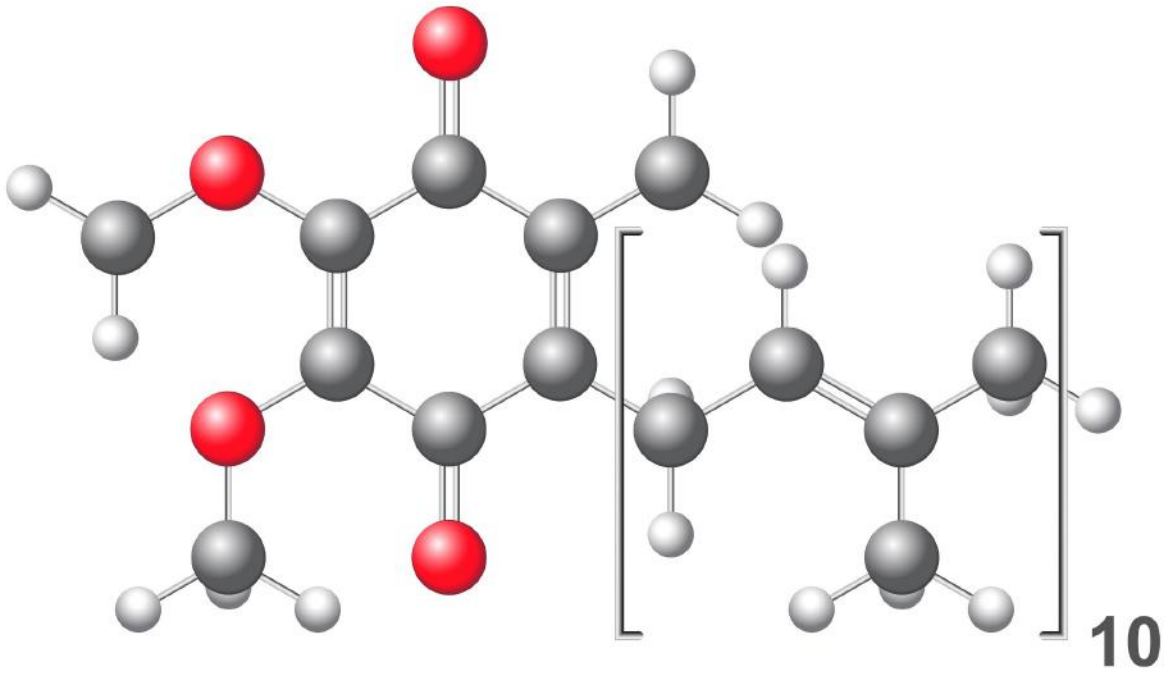


Coenzymes

Commonly vitamins (Ex: coenzyme Q_{10}, Vitamin B_6)

Two types:

- Cosubstrates are detachable
- Prosthetic groups are permanent

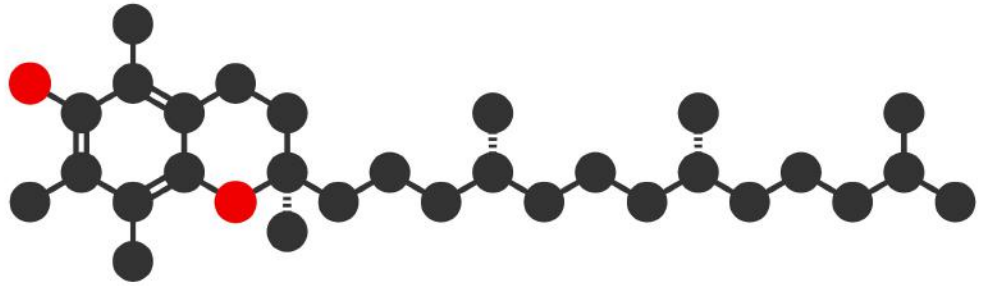


1.3.3 Inorganic Cofactors

Inorganic Cofactors

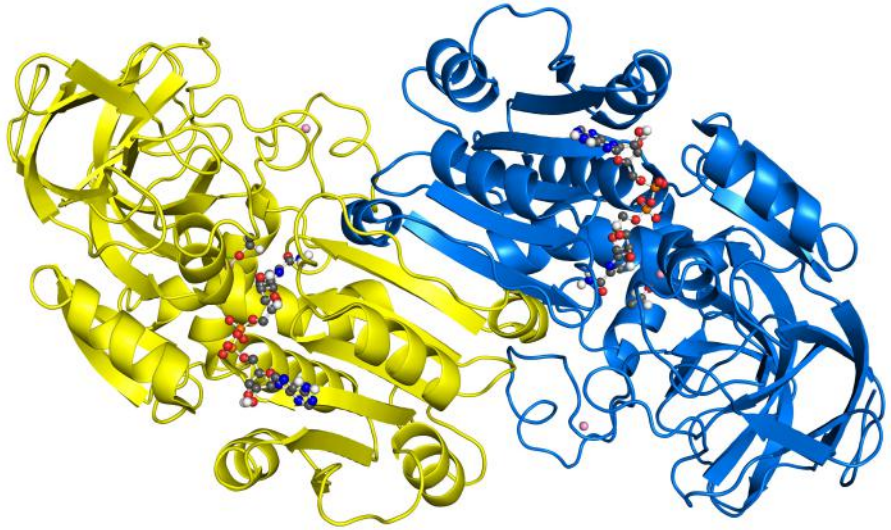
- Cofactors are non-protein molecules that are necessary for some enzymes to function properly

- Organic cofactors are called *coenzymes* (see module 1.3.2)



Cofactors

- Inorganic cofactors are usually metal ions
  - Fe^{2+}
  - Mn^{2+}
  - Zn^{2+} (Ex: with alcohol dehydrogenase, below)

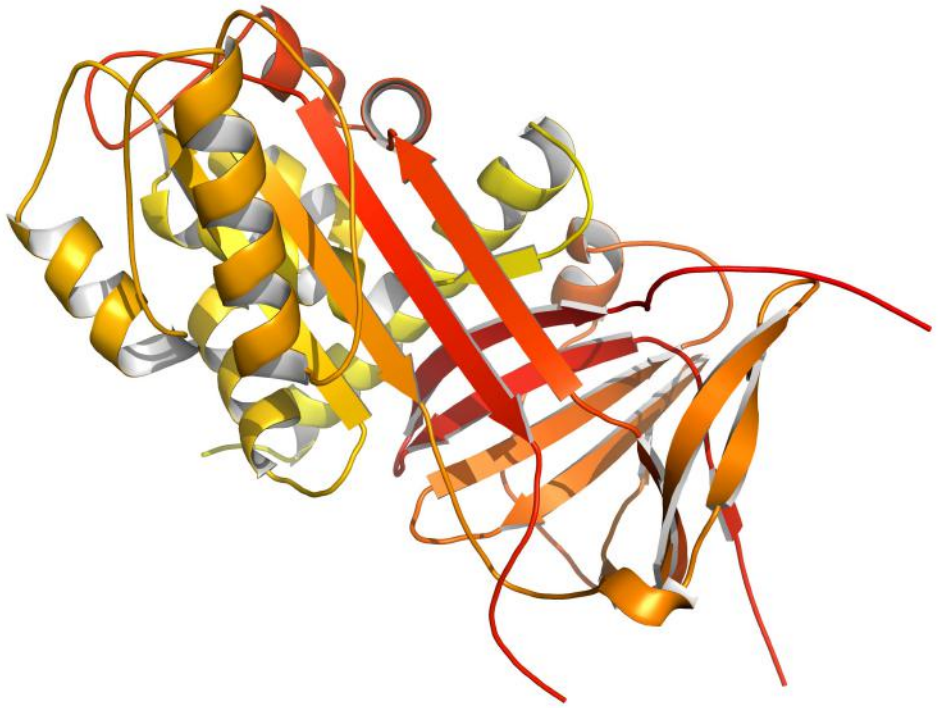


1.3.4 Inhibition & Regulation

Inhibition

- Inhibitors: molecules that compete with substrates for enzymes' active sites
    - Sit in the active site, blocking it so enzyme & substrate cannot interact
    - Attach to enzyme outside active site, but change shape of active site so it doesn't work

- Example: a2-antiplasmin (below) stops enzymes from dissolving blood clots, helpful for treating bleeding disorders like hemophilia



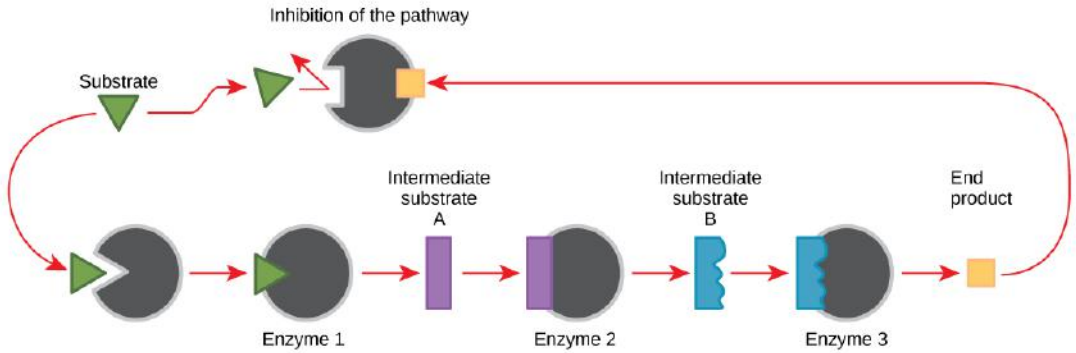
Inhibition

- Enzyme activity is also inhibited when the shape of the enzyme active site is changed by the environment, causing it to stop working
    - temperature
    - pH

- Denaturation: change in enzyme shape that makes it stop working

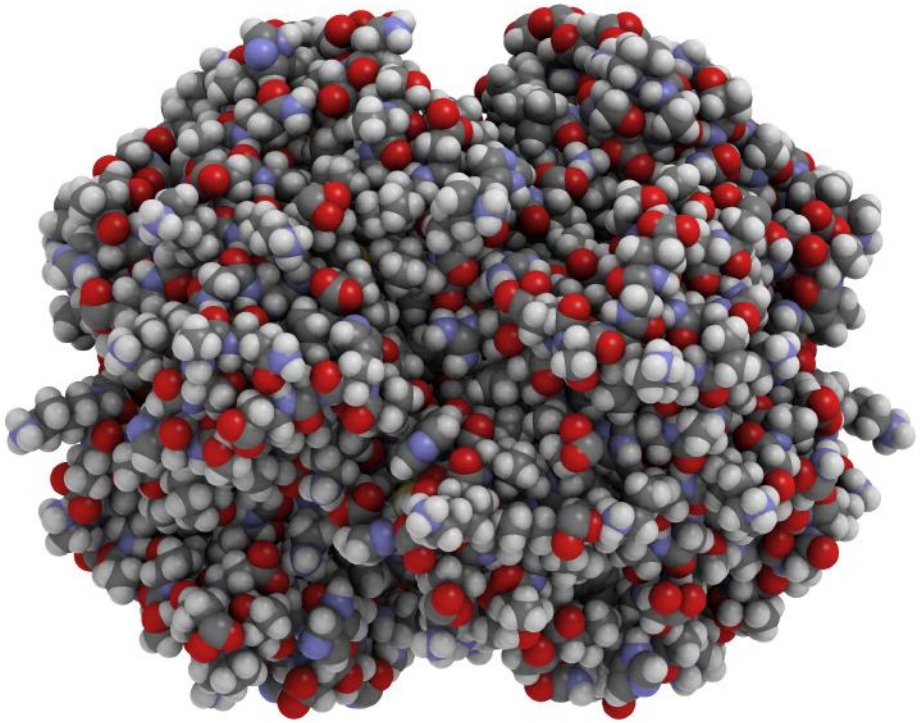
Regulation

- Regulation: when a cell controls the action of its own enzymes
- Two common methods of enzyme regulation:
  - 1. product of reaction inhibits enzyme
    - reaction slows as product increases
    - Example: production of energy molecule ATP decreases as its concentration increases



Regulation

- Two common methods of enzyme regulation:
  - 2. regulator molecules control shape of enzyme active site
    - causes it to fit with substrate or not, depending on what cell needs
    - Example: oxygen is regulator of hemoglobin, changing active site shape when it's attached

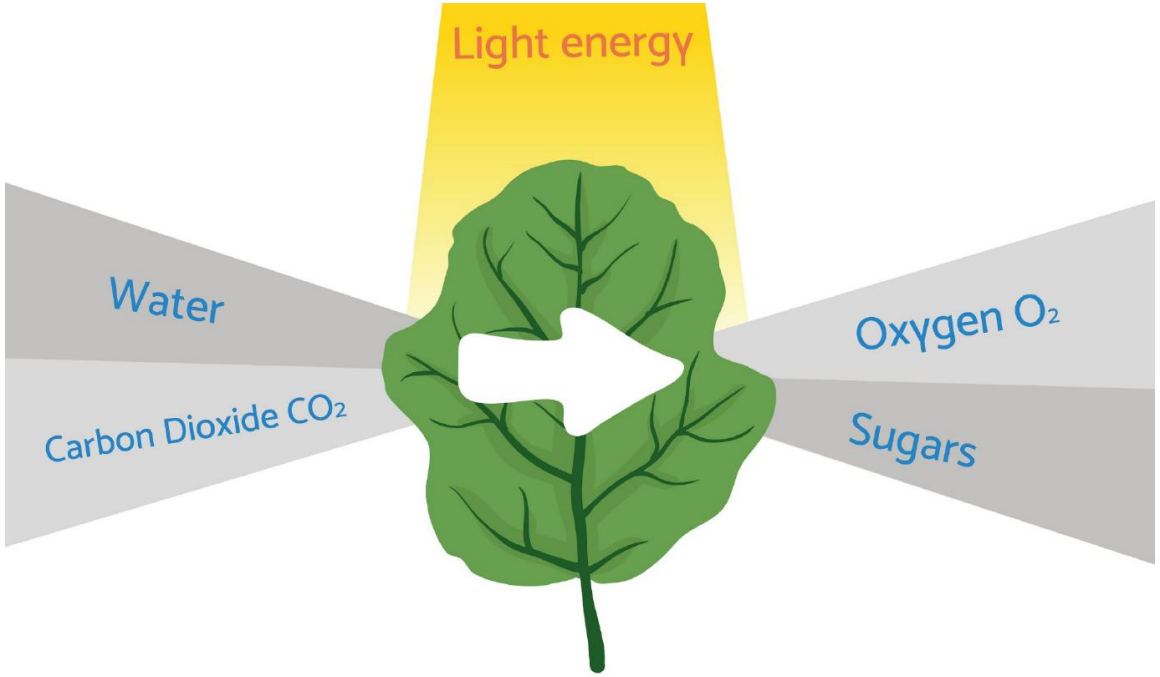


1.4 Energy Transformations

Energy Transformations

1.4.1- Cellular Respiration

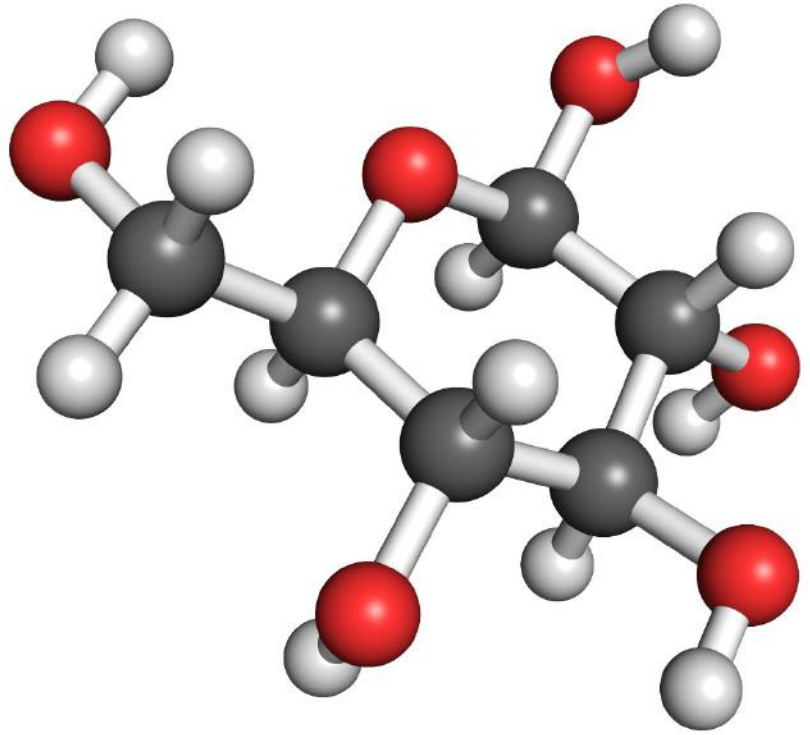
1.4.2- Photosynthesis



$$6CO_2 + 6H_2O \xrightarrow[\text{Chlorophill}]{\text{Light energy}} C_6H_{12}O_6 + 6O_2$$

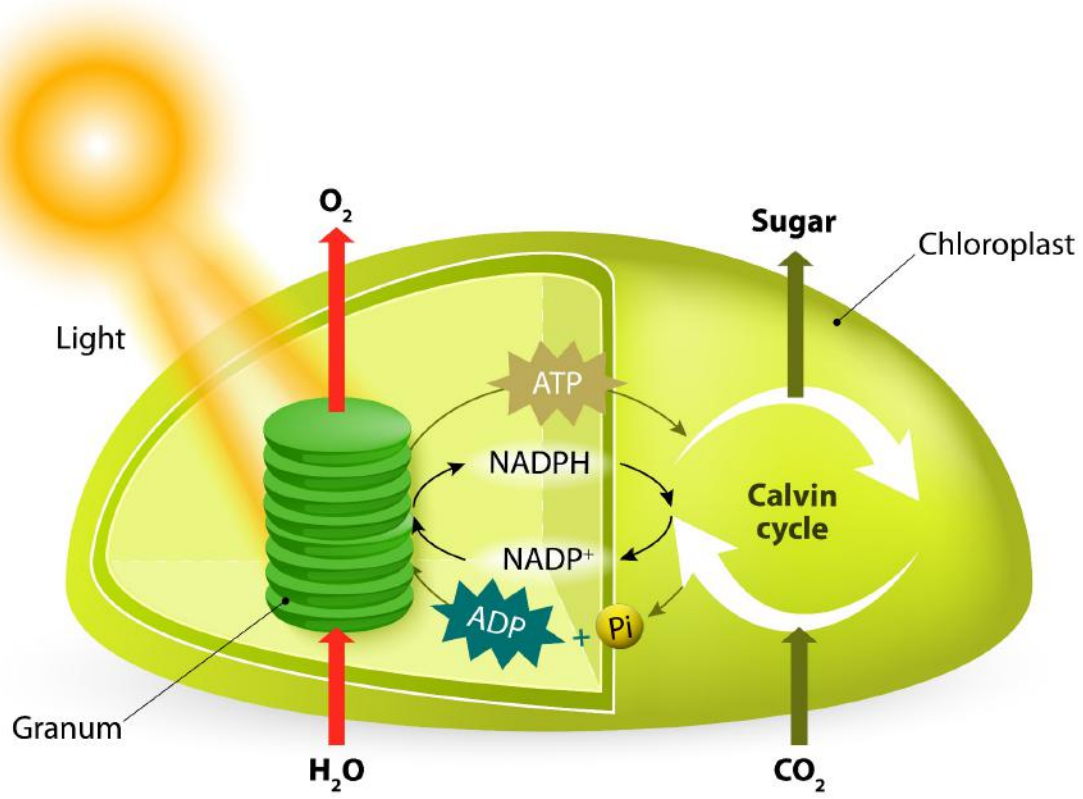
Cellular Respiration

- overview
- glycolysis
- aerobic respiration
  - pyruvate oxidation
  - citric acid cycle
  - electron transport chain
- anaerobic respiration



Photosynthesis

- overview
- light reactions
- dark reactions



1.4.1 Cellular Respiration

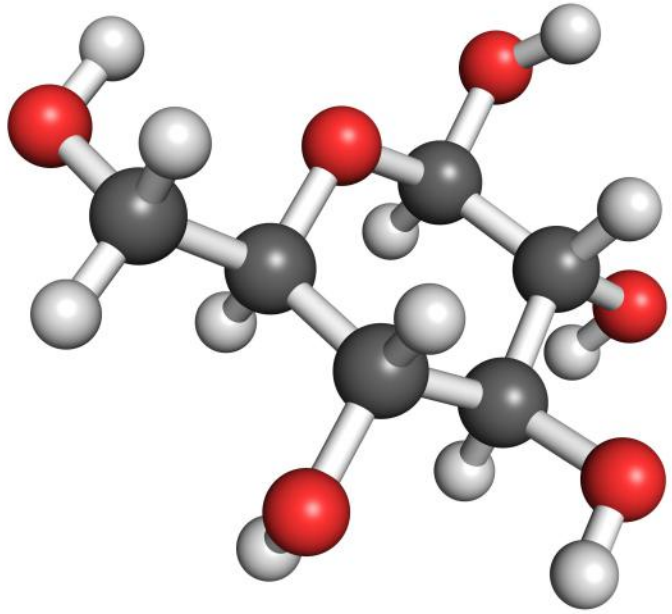
Cellular Respiration

Cells convert ‘food’ (glucose, below) into energy molecule ATP in all organisms

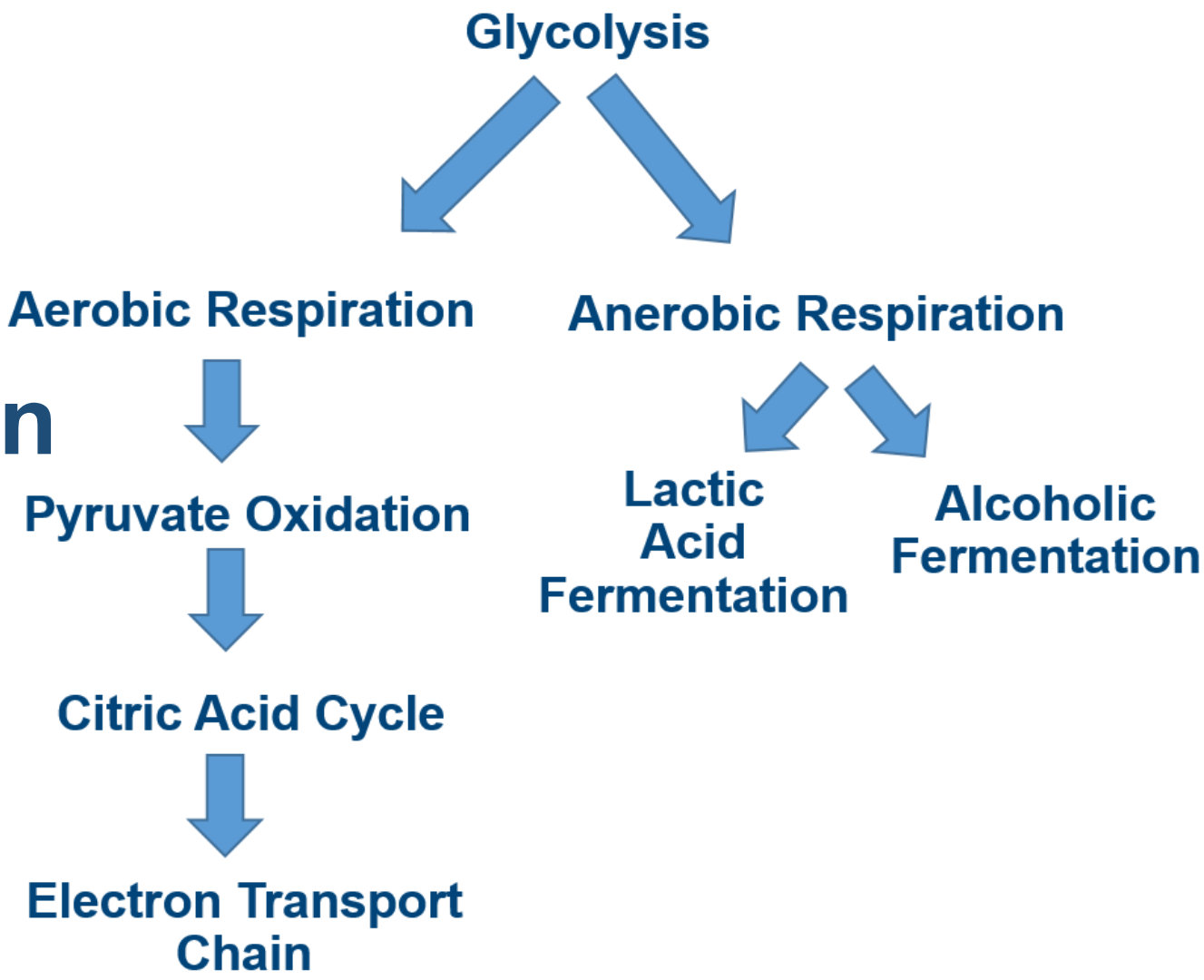
ATP used any time energy needed in organism

Two types:

- **Aerobic (with oxygen)**
- **Anaerobic (without oxygen)**



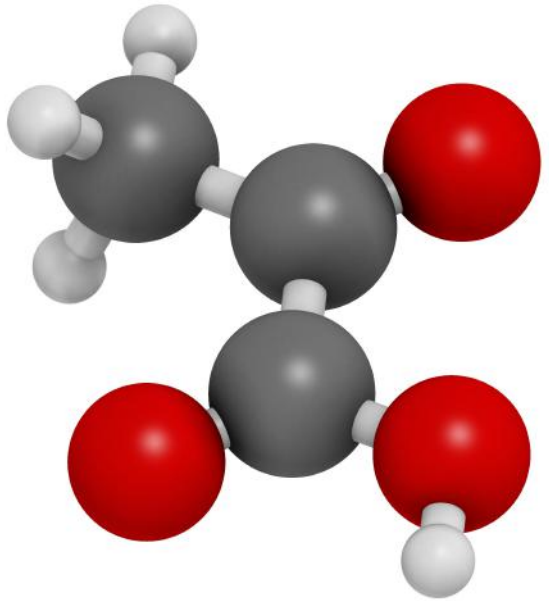
Cellular Respiration



Glycolysis

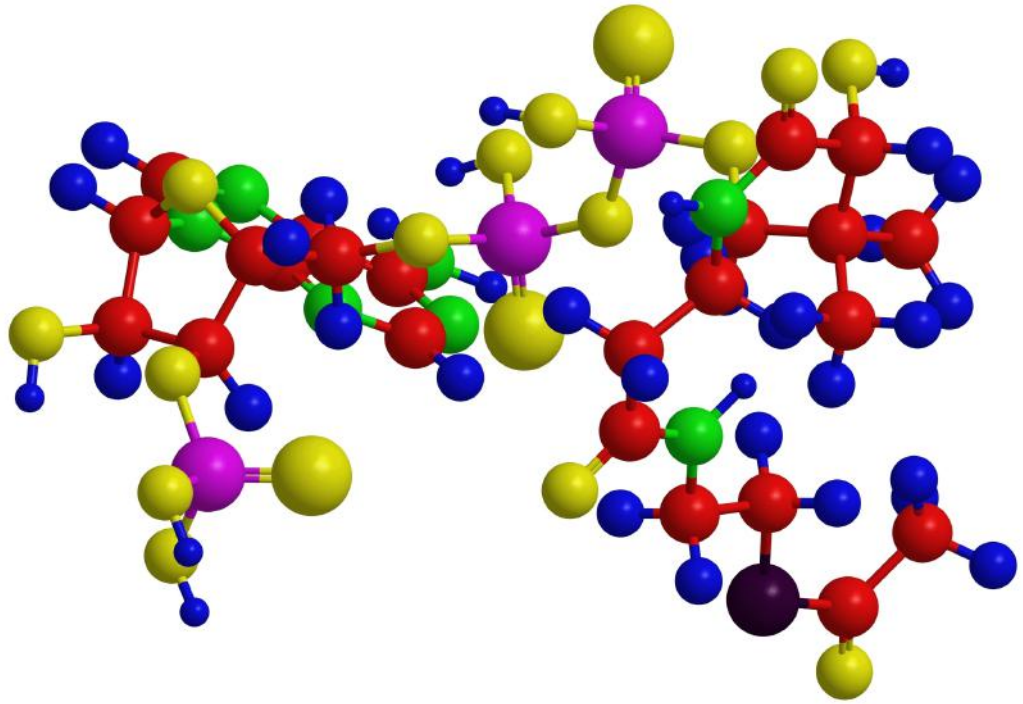
Glycolysis is first step in all organisms, whether doing aerobic or anaerobic respiration

- same in all organisms
- glucose split and used to make 2 molecules of pyruvate and 2 net ATPs
- Pyruvate (below) goes to Pyruvate Oxidation pathway



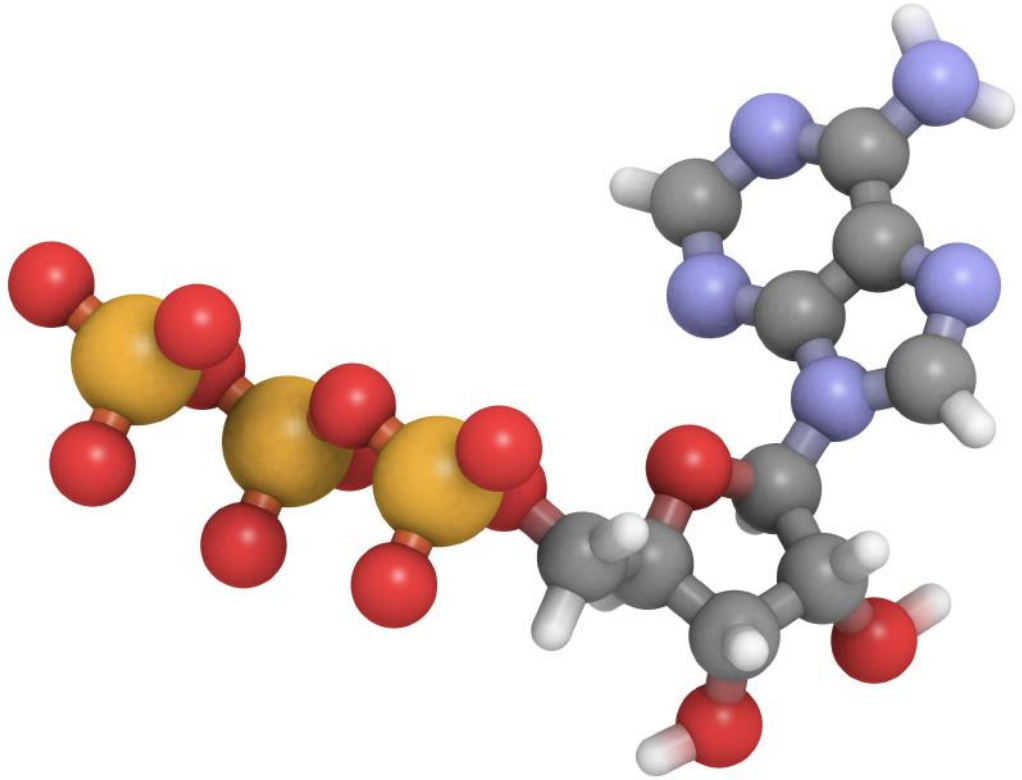
Aerobic Respiration: Pyruvate Oxidation

- Pyruvate converted to Acetyl CoA (below), then goes to Citric Acid cycle



Aerobic Respiration: Citric Acid Cycle

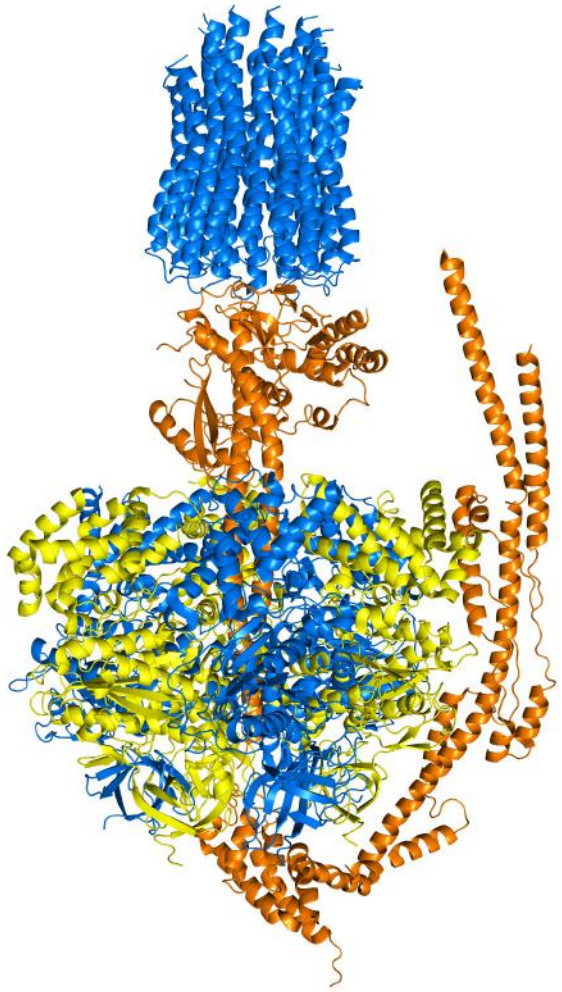
Acetyl CoA converted into different molecules, a little ATP produced (below), other molecules produced that are used in electron transport chain



Aerobic Respiration: Electron Transport Chain

Electrons and molecules from the citric acid cycle help in the production of ATP

Makes the most ATP of all respiration pathways: about 32



Anaerobic Respiration

Conversion of pyruvate (from glycolysis) to ATP without oxygen

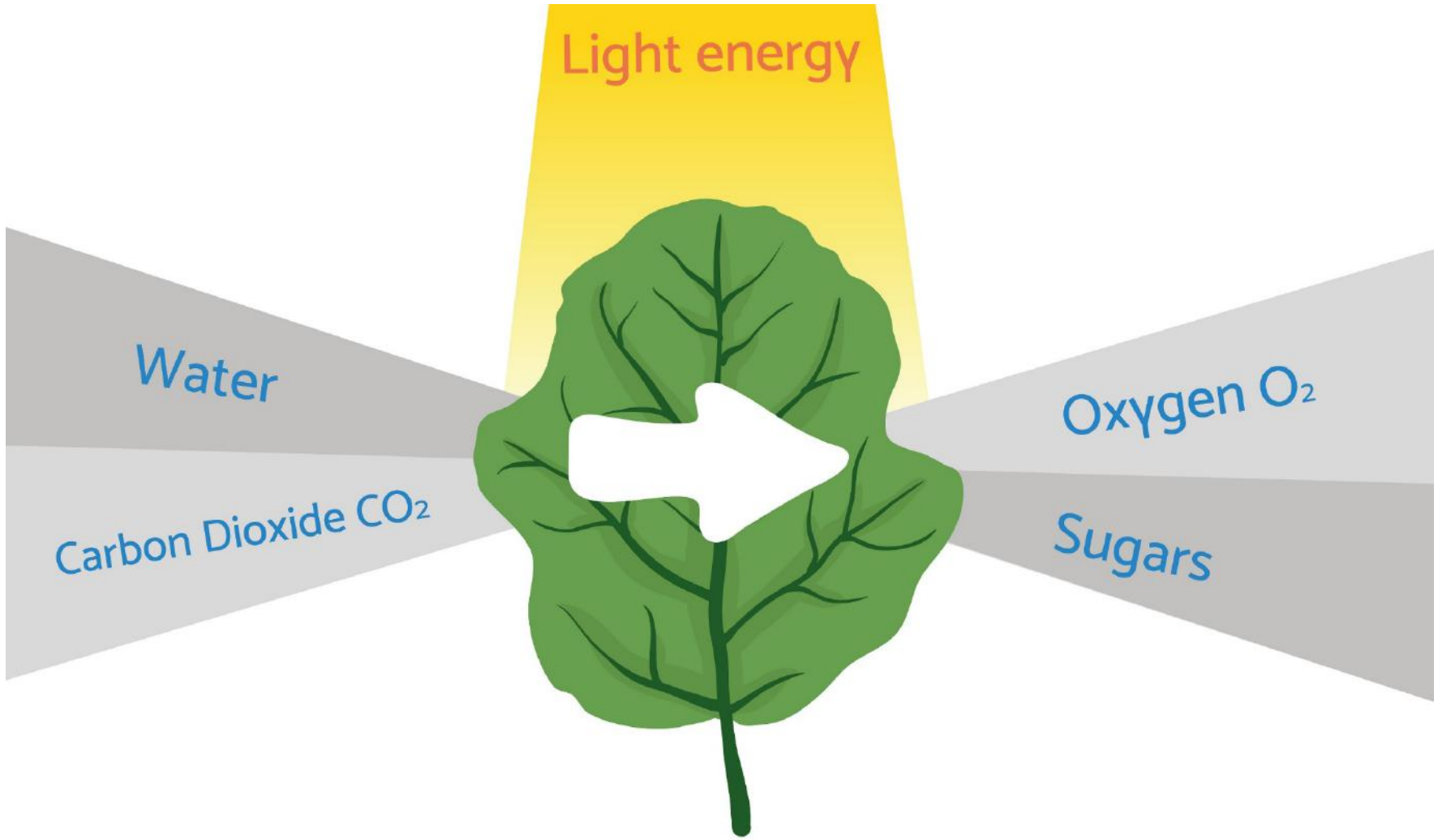
1. Lactic acid fermentation: lactic acid is byproduct (causes muscle burn after hard exercise)
2. Alcoholic fermentation: ethanol is byproduct (important for alcoholic drinks)

Produces very little ATP

1.4.2 Photosynthesis

Photosynthesis Overview

Converts energy from sunlight into glucose that is used in cellular respiration to form ATP



$$6CO_2 + 6H_2O \xrightarrow[\text{Chlorophill}]{\text{Light energy}} C_6H_{12}O_6 + 6O_2$$

Photosynthesis

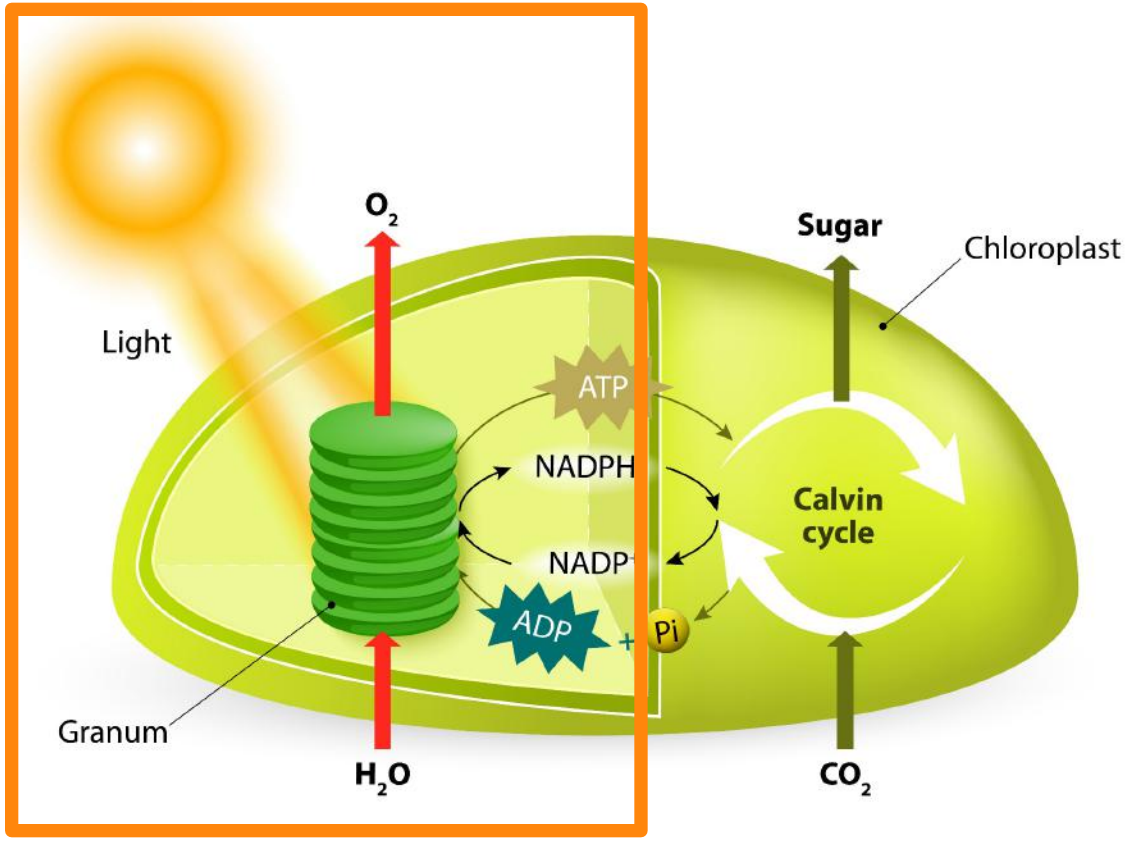
Two processes:

1. Light reactions harvest sunlight
2. Dark reactions make glucose

Light Reactions Overview

Take place in thylakoid membrane

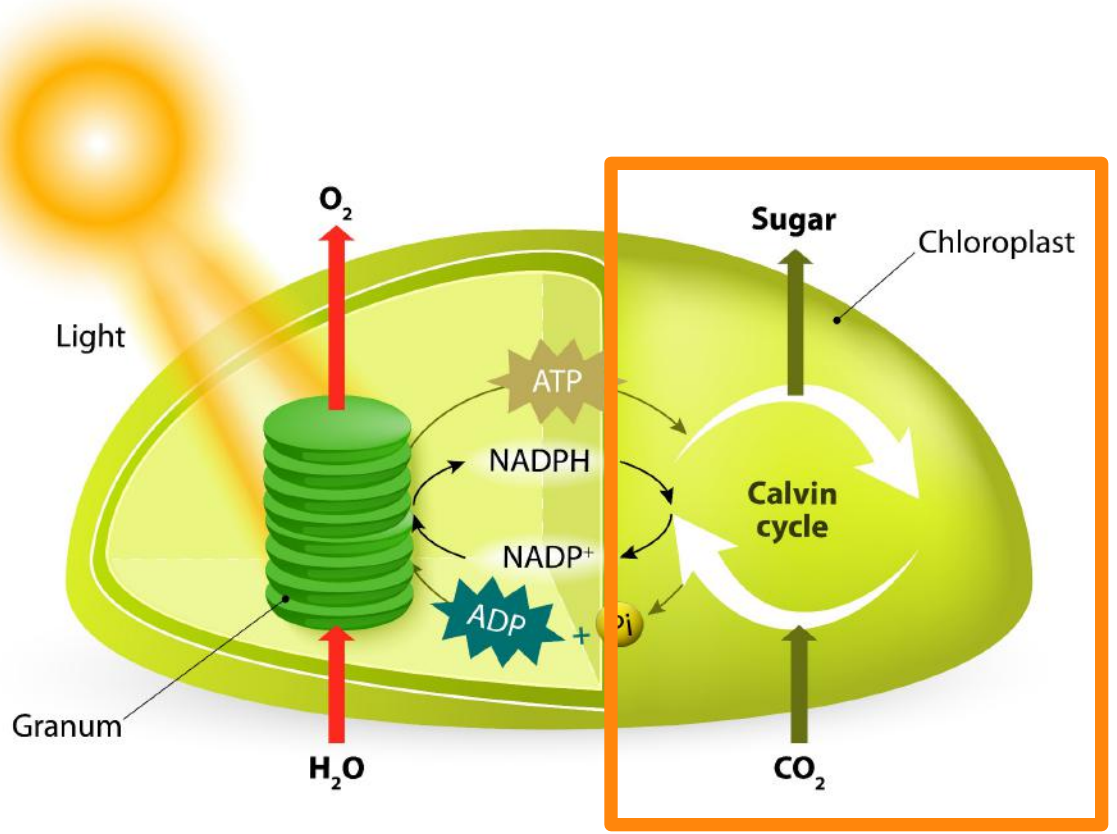
1. **Capture/use light as energy source**
2. **Produce ATP & other molecules for dark reactions**
3. **Produce O_2 as byproduct**



Dark Reactions

Take place in stroma

- Use ATP from light reactions
- Use CO_2 from air
- Make molecules used in light reactions
- Produce glucose that is used in cellular respiration

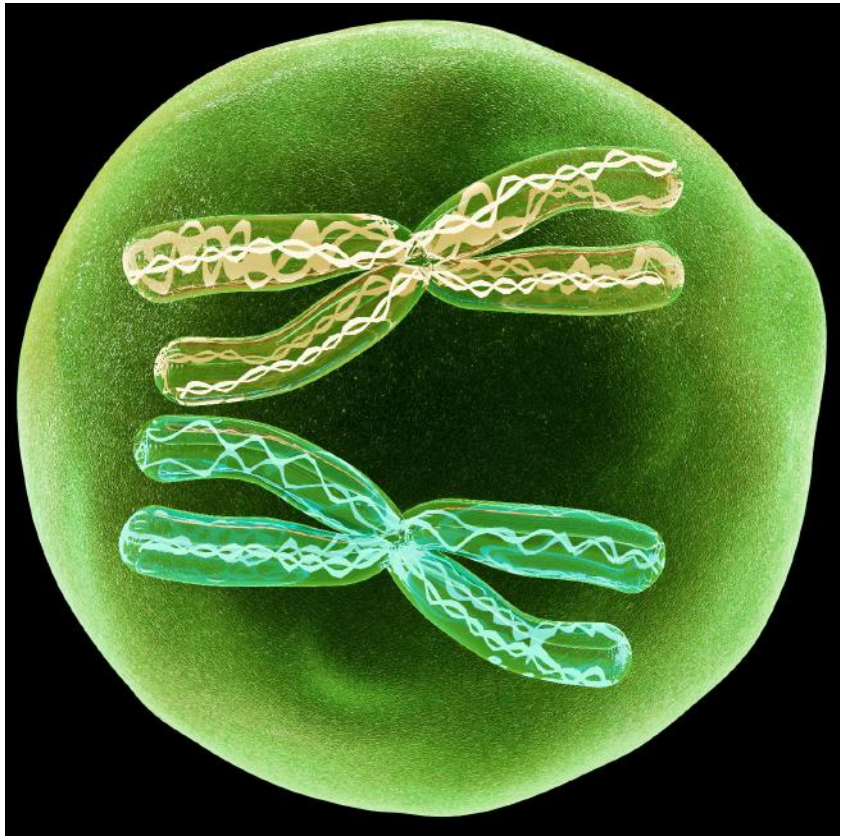


1.5 Cell Division

Cell Division

1.5.1- Structure of Chromosomes

1.5.2- Mitosis, Meiosis, Cytokinesis

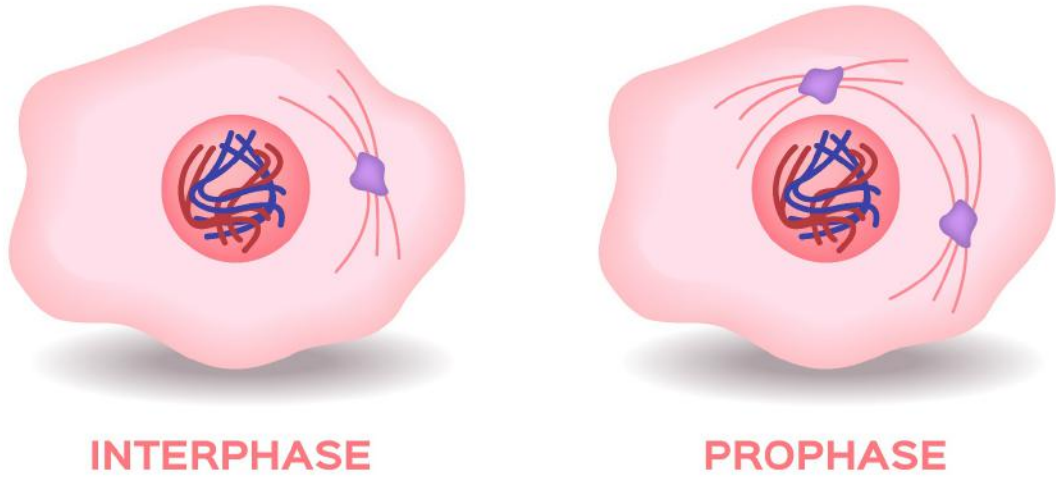


Structure of Chromosomes

- what are chromosomes?
- chromosome terminology
- homologous chromosomes
- ploidy
- karyotypes

Mitosis, Meiosis, Cytokinesis

- cell cycle
- stages of mitosis
- stages of meiosis



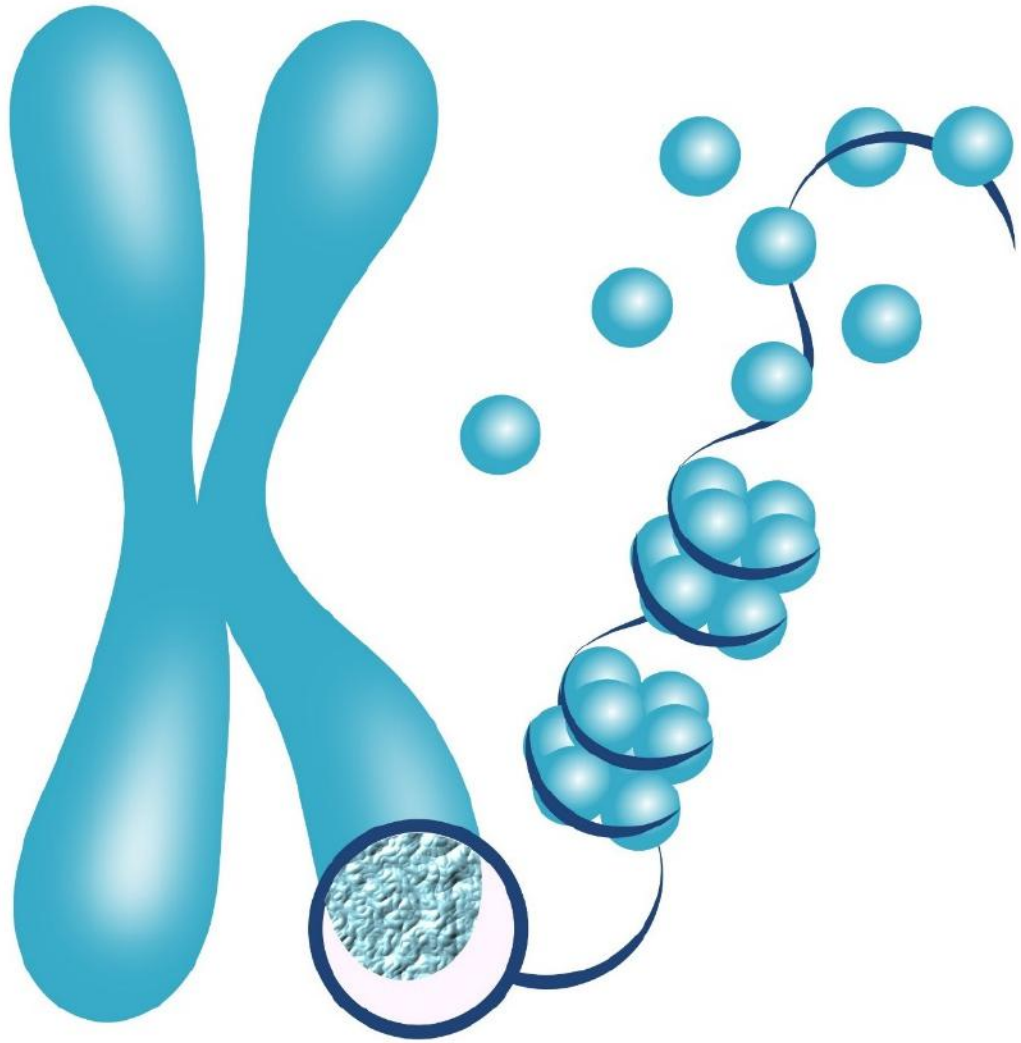
1.5.1 Structure of Chromosomes

Chromosomes

Chromatin: How DNA exists most of the time, unwound like a pile of yarn

Chromosome: DNA wound up, only happens right before mitosis

- **DNA wound around proteins called histones**
- **each group of histones w/ DNA is called a nucleosome**



Chromosome Terms

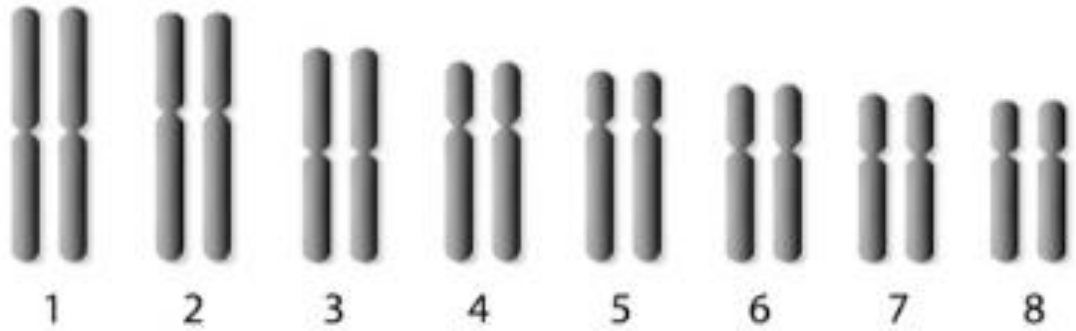
Sister chromatids: copies of each other, made before mitosis

Centromere: visible constriction, holds chromatids together

Homologous Chromosomes

Homologous chromosomes

- **have genes coding for the same characteristics, in the same locations (loci)**
- **roughly the same size and shape**
- **pair up before mitosis**



Homologous Chromosomes

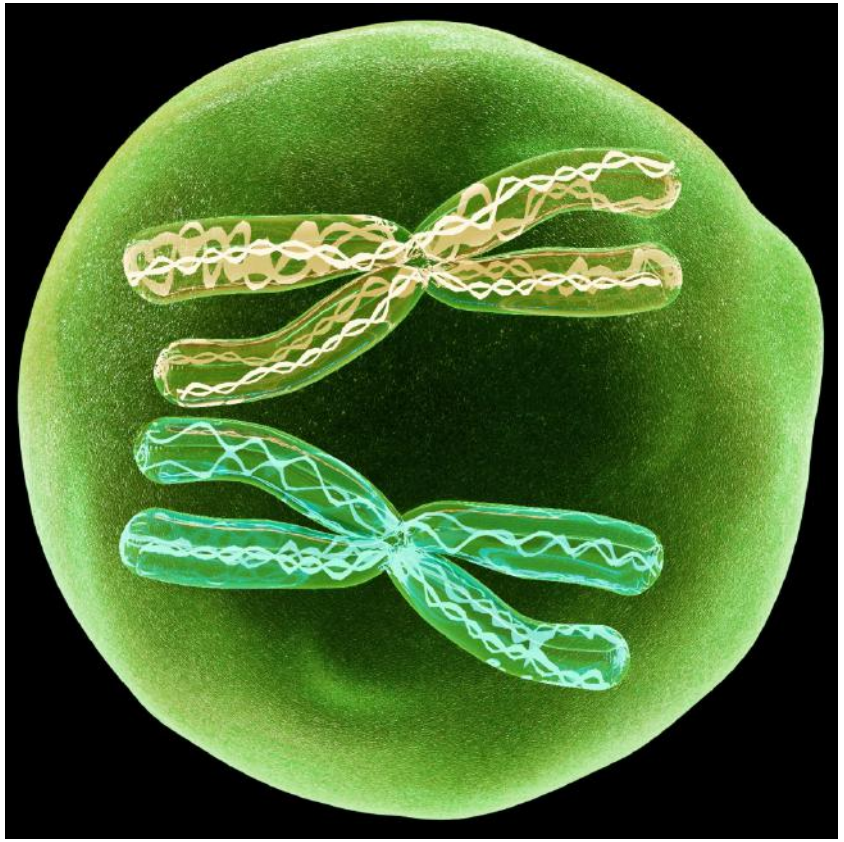
Alleles: variations of the same gene, found on homologous chromosomes.

- **Example: in a gene coding for hair color, one allele for black hair, another for blonde hair**

Ploidy

Denotes number of copies of genes/ chromosomes in organism, abbreviated as a number and the letter “n”

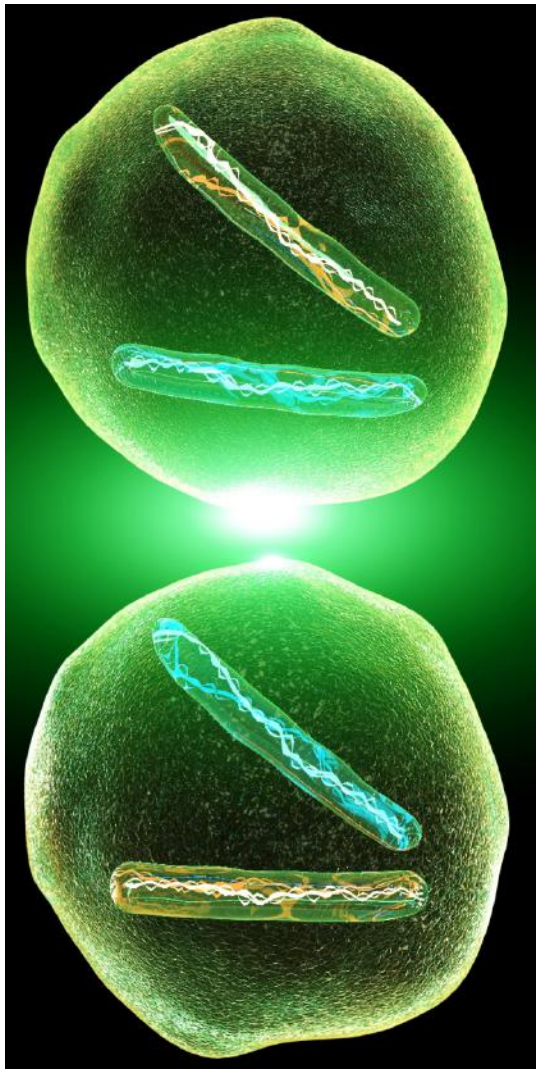
- Haploid: 1n, having 1 copy of each gene
- Diploid: 2n, having 2 copies of each gene



Ploidy

From the moment of fertilization, humans are 2n

Only our sperm & eggs are haploid (1n)

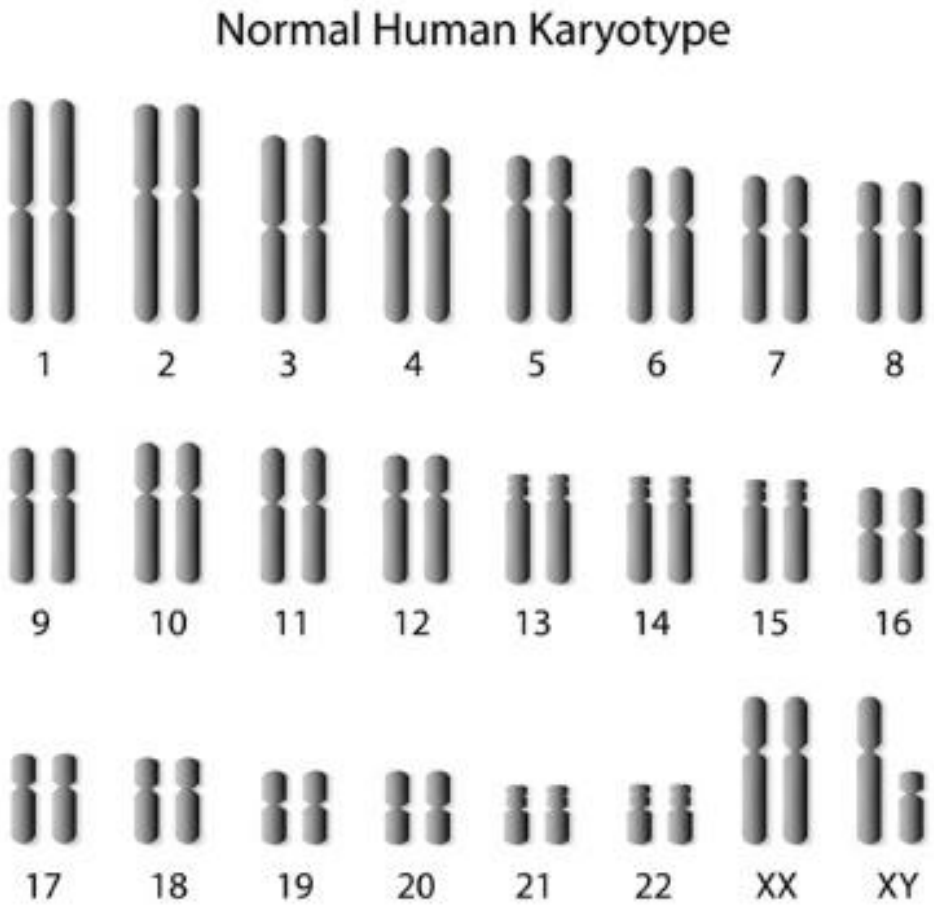


Karyotype

Karyotype: picture of chromosomes

For humans, 2n=46

Sex chromosomes are #23



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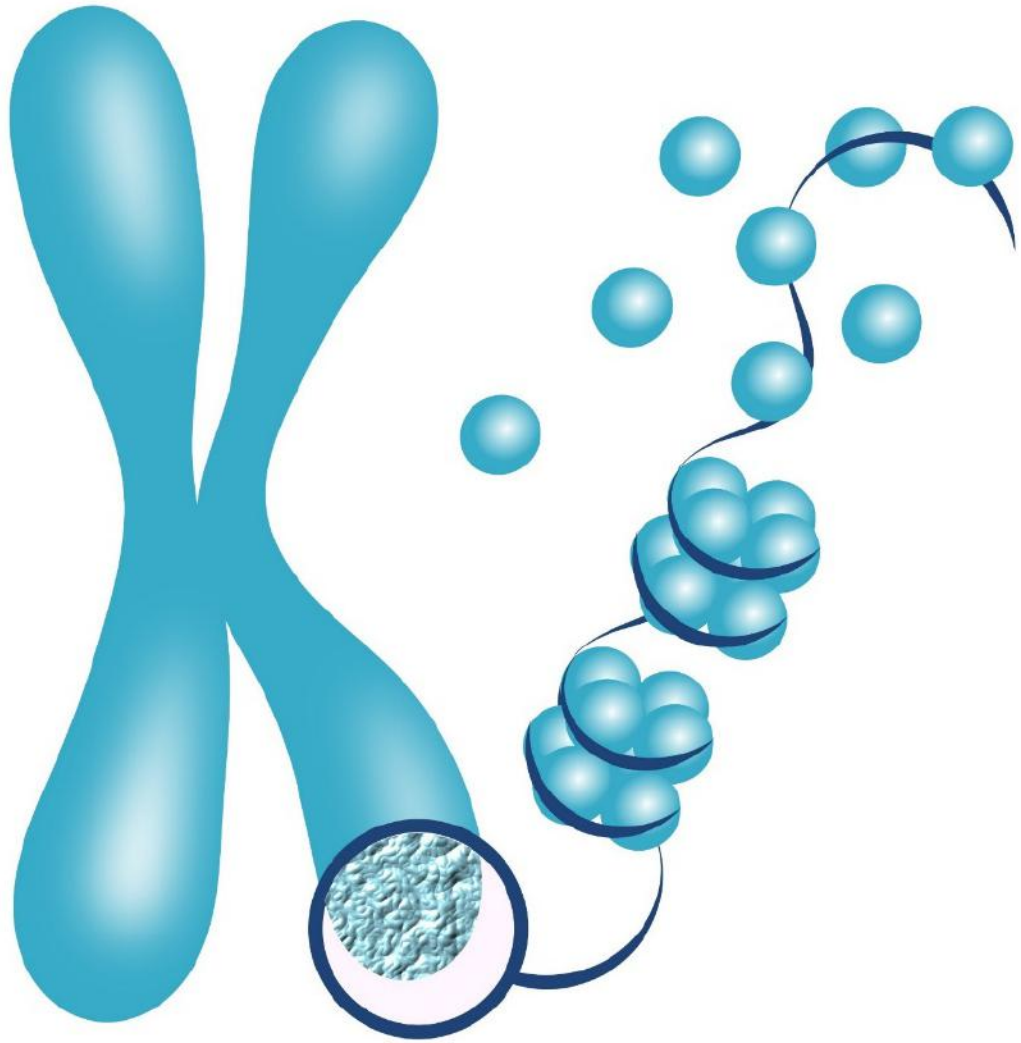

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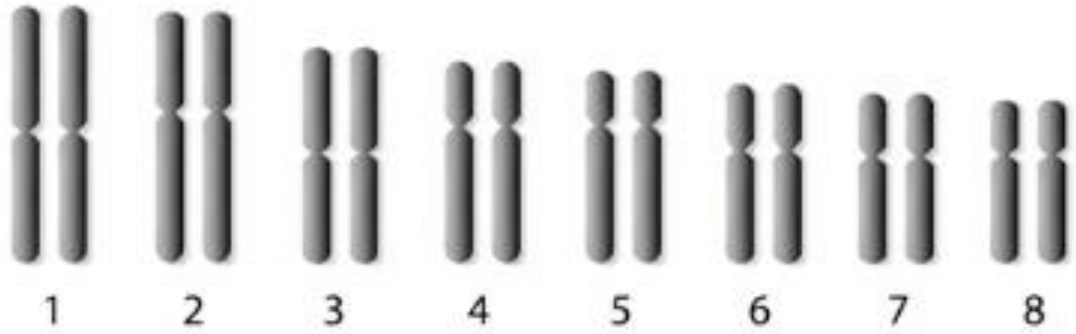

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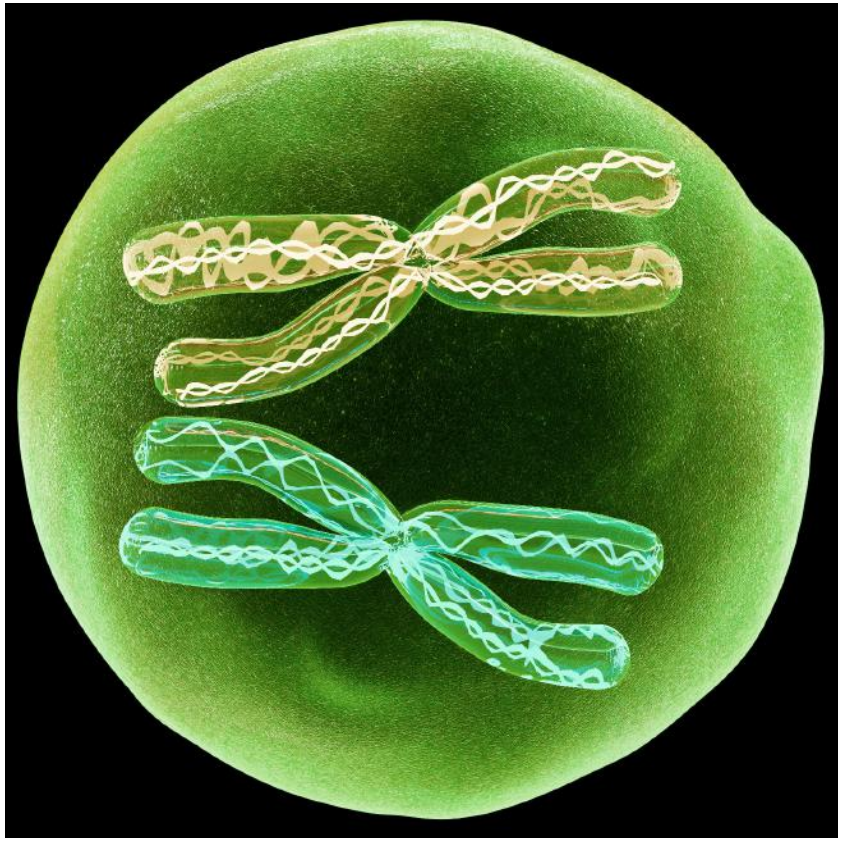
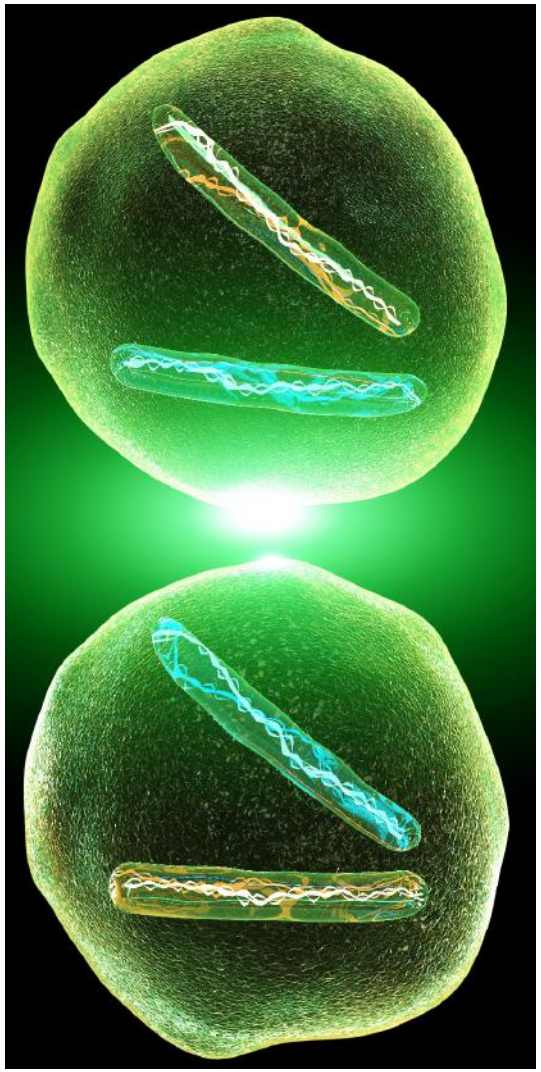


Ploidy

From the moment of fertilization, humans are 2n

Only our sperm & eggs are haploid (1n)

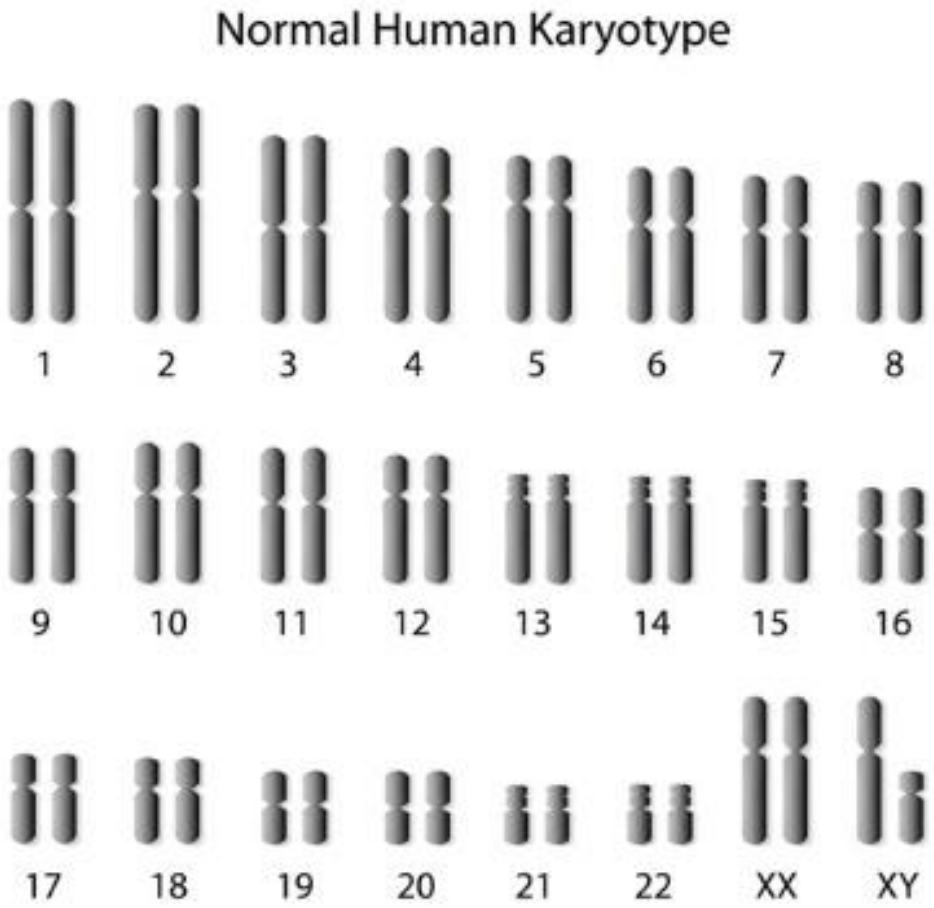


Karyotype

Karyotype: picture of chromosomes

For humans, 2n=46

Sex chromosomes are #23



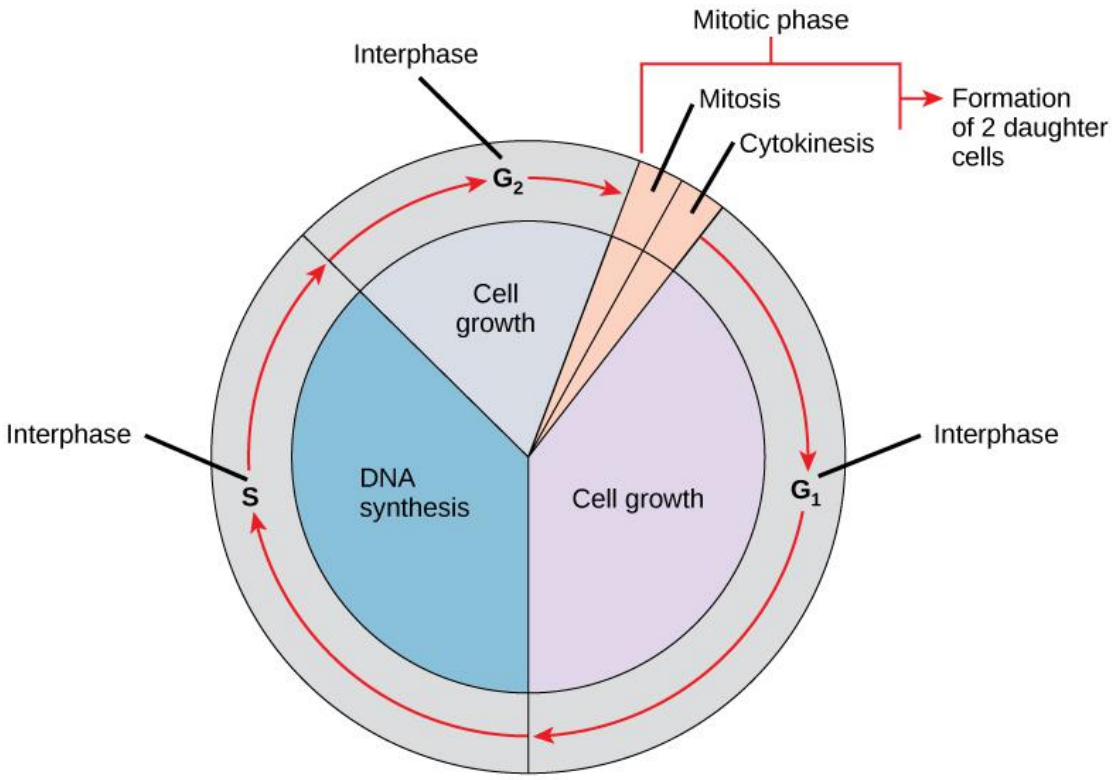
1.5.2 Mitosis, Meiosis, Cytokinesis

Cell Cycle

Interphase: 90% of cell's life, DNA is copied

- G_1
- S
- G_2

Mitotic Phase: Parent cell splits into 2 identical daughter cells



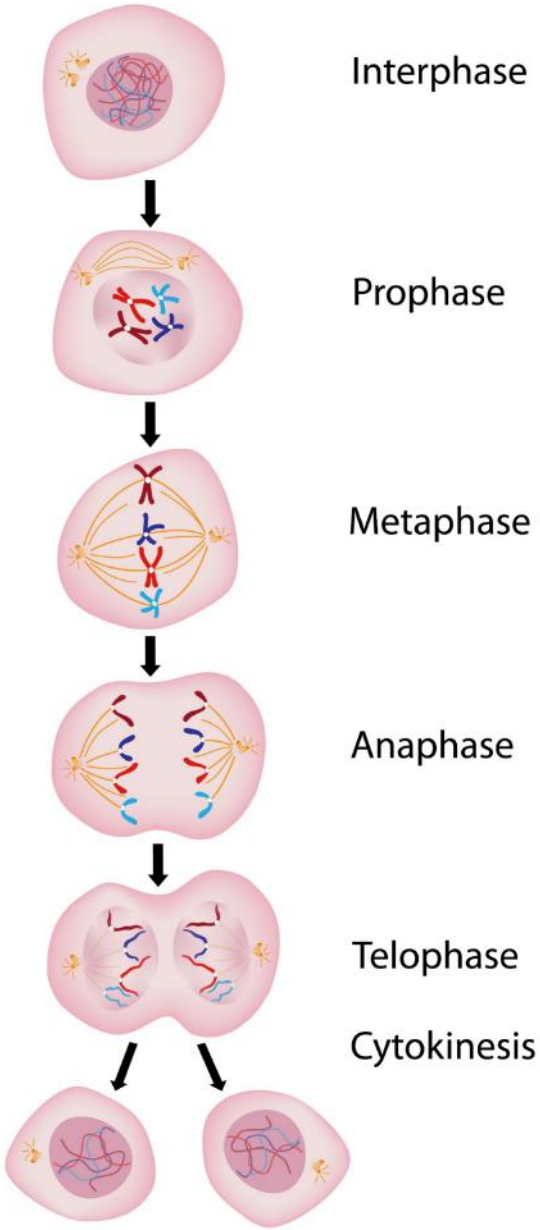
Mitotic Phase

Mitosis (PMAT)

1. **Prophase- chromosomes condense**
2. **Metaphase- chromosomes align on metaphase plate**
3. **Anaphase- chromosomes pulled to poles**
4. **Telophase- chromosomes decondense**

Cytokinesis: parent cell splits into 2 identical daughter cells (2n)

Mitotic Phase



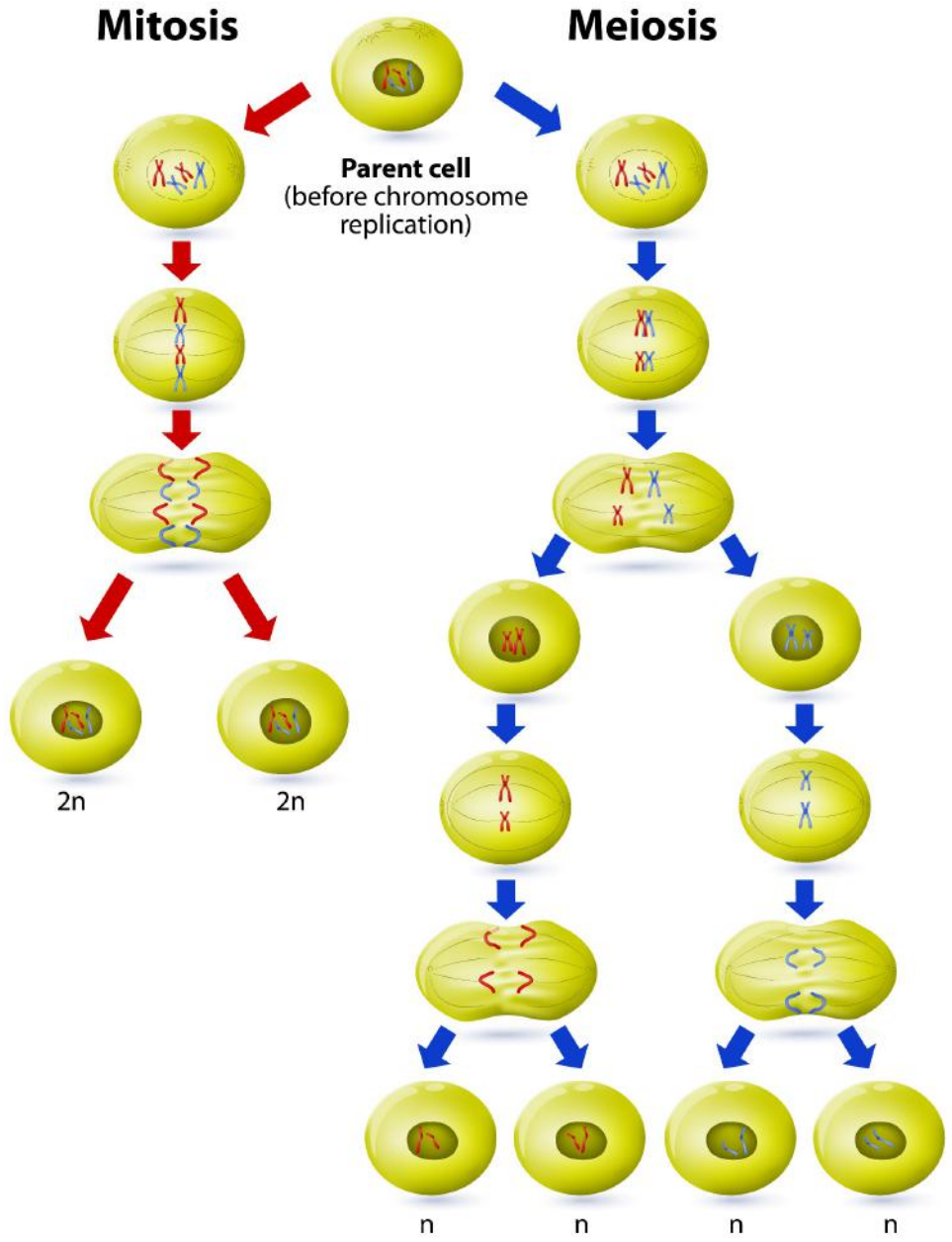
Meiosis

Forms 4 unique 1n cells, sperm in testes & eggs in ovaries

2 Parts:

1. **Meiosis I**
2. **Meiosis II**

Meiosis


Mitosis
Meiosis
Parent cell
(before chromosome
replication)
2n
2n
n
n
n
n

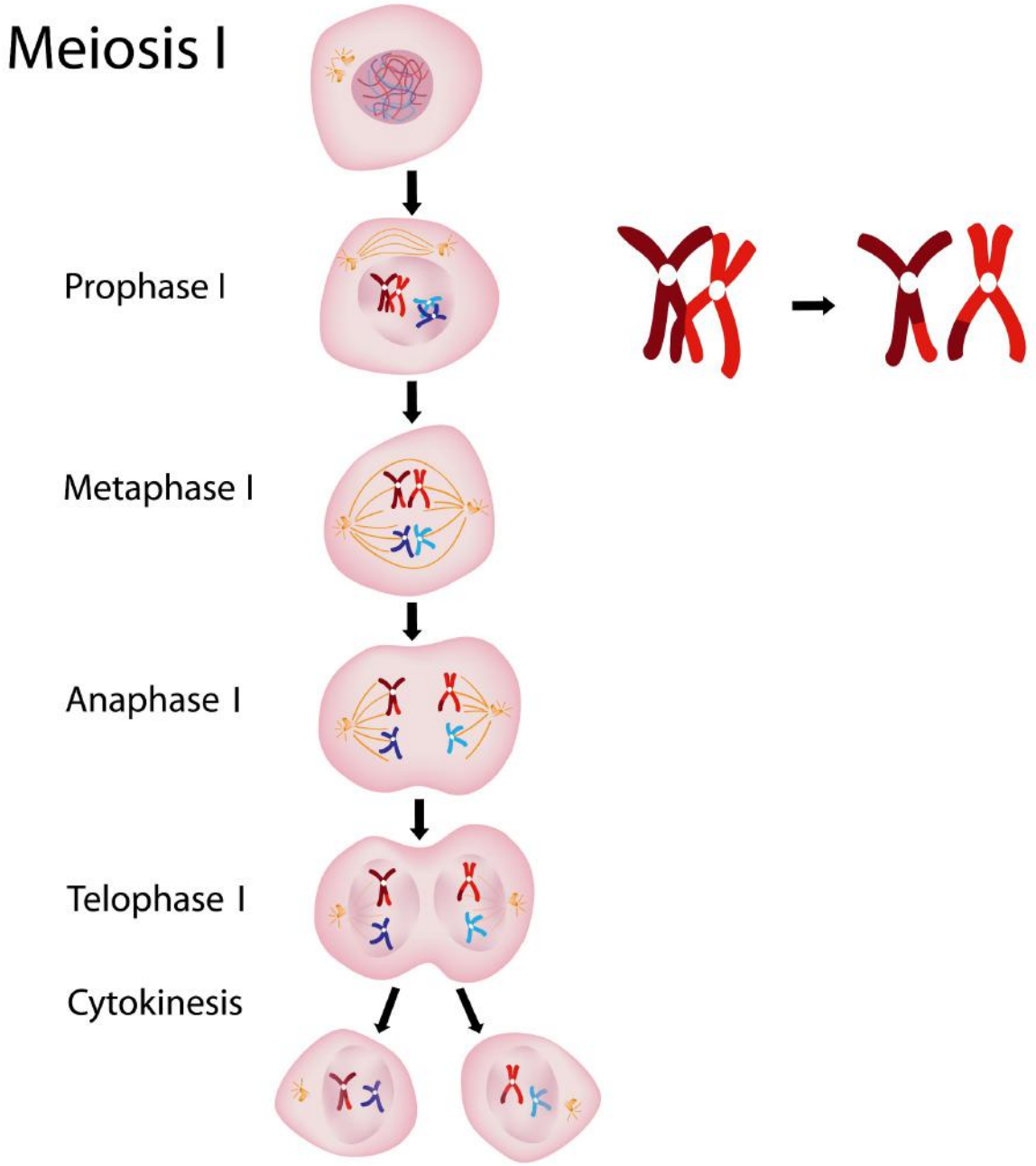
Meiosis I

Stages in same order, do the same things as in mitosis w/ one difference

- **Prophase I**
- **Metaphase I**
- **Anaphase I**
- **Telophase I**
- **Cytokinesis**

Important difference: crossing over occurs during Prophase I, new combinations result

Meiosis I

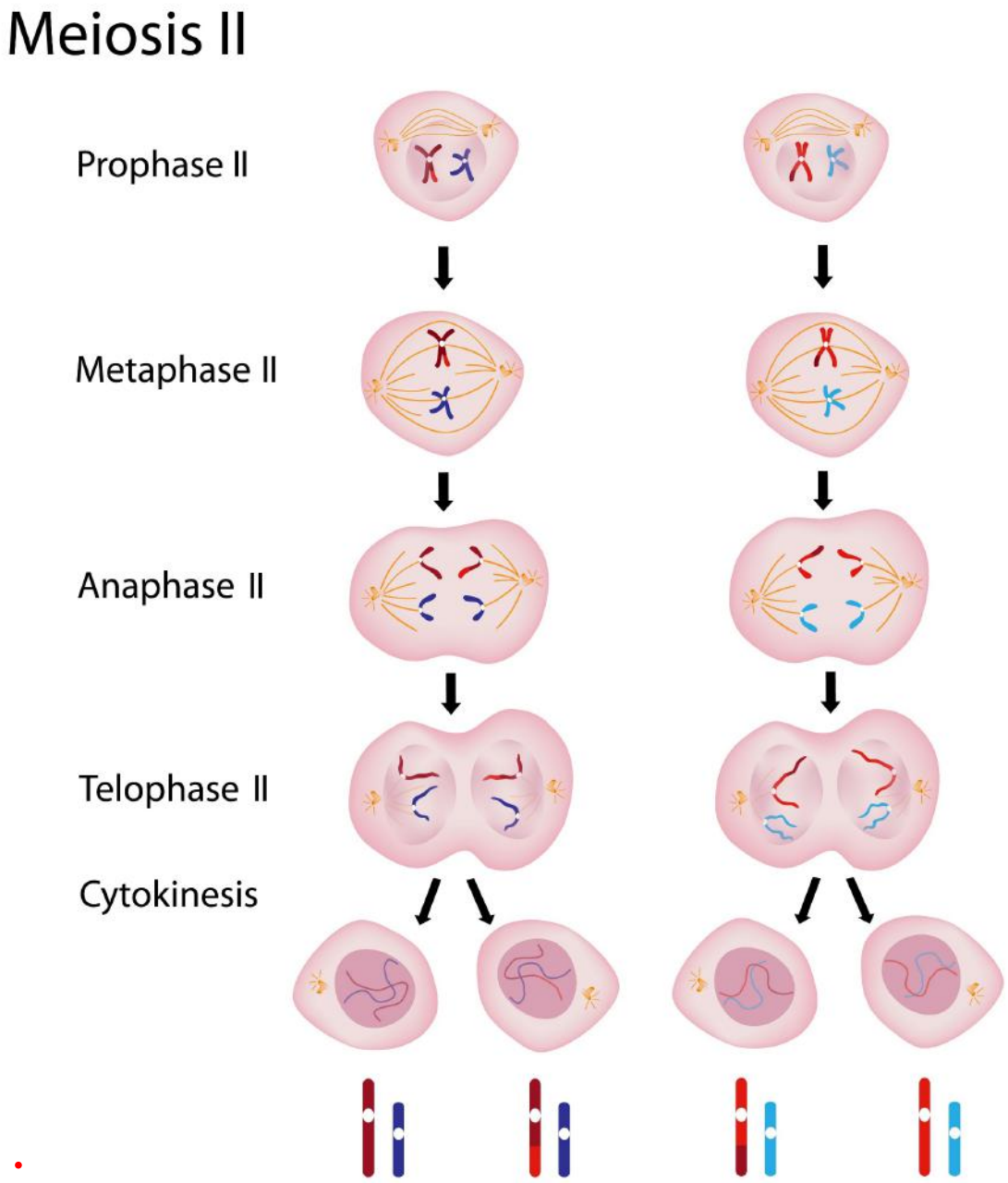

Meiosis I
Prophase I
Metaphase I
Anaphase I
Telophase I
Cytokinesis

Meiosis II

Same as in mitosis & Meiosis I, but chromosomes have been through crossing over

End product is four haploid cells, instead of the 2 that result from mitosis & Meiosis I

Meiosis II


Meiosis II
Prophase II
Metaphase II
Anaphase II
Telophase II
Cytokinesis

1.6 Chemical Nature of the Gene

Genes

1.6.1- Watson-Crick Model of Nucleic Acids

1.6.2- DNA Replication

1.6.3- Mutations

1.6.4- Control of Protein Synthesis

1.6.5- Structural & Regulatory Genes

1.6.6- Transformation

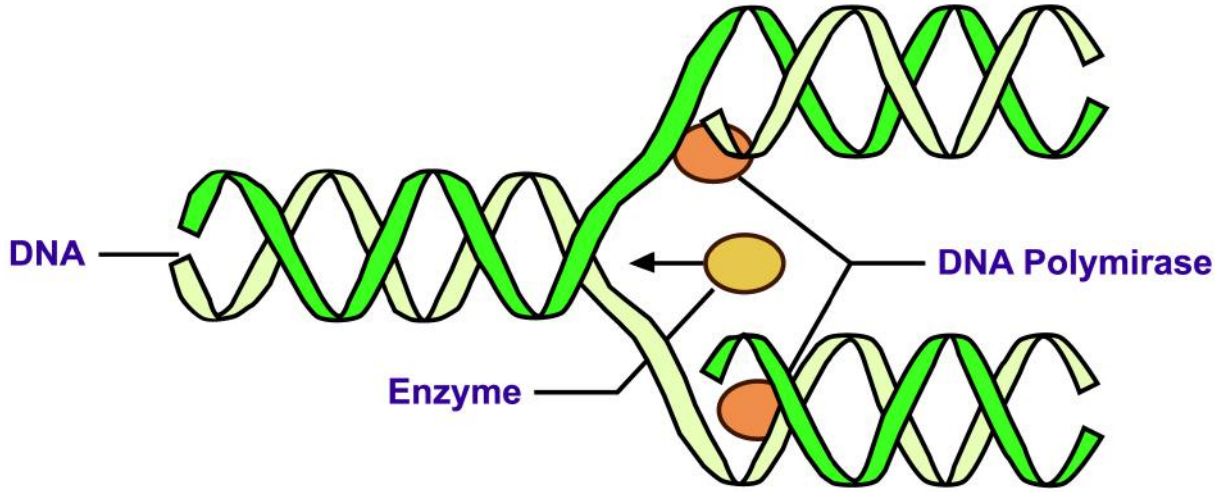
1.6.7- Viruses

Watson-Crick Model of Nucleic Acids

- discoveries before Watson & Crick
- the Watson-Crick model

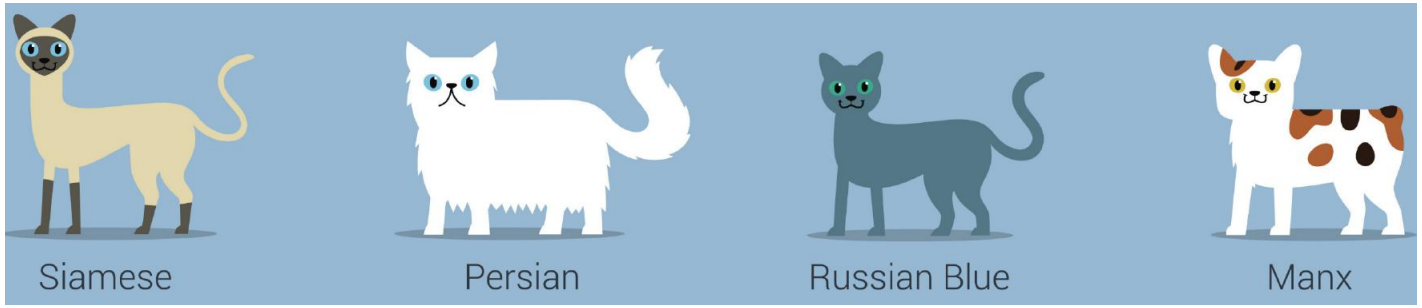
DNA Replication

- DNA as blueprint
- each strand a template
- process
- end product



Mutations

- what are they
- causes
- types



Control of Protein Synthesis

- genes & protein synthesis
- transcription
- translation

Structural & Regulatory Genes

- types of genes/ proteins
- structural genes/ proteins
- regulatory genes/ proteins

Transformation

- bacterial genes
- transduction
- transformation

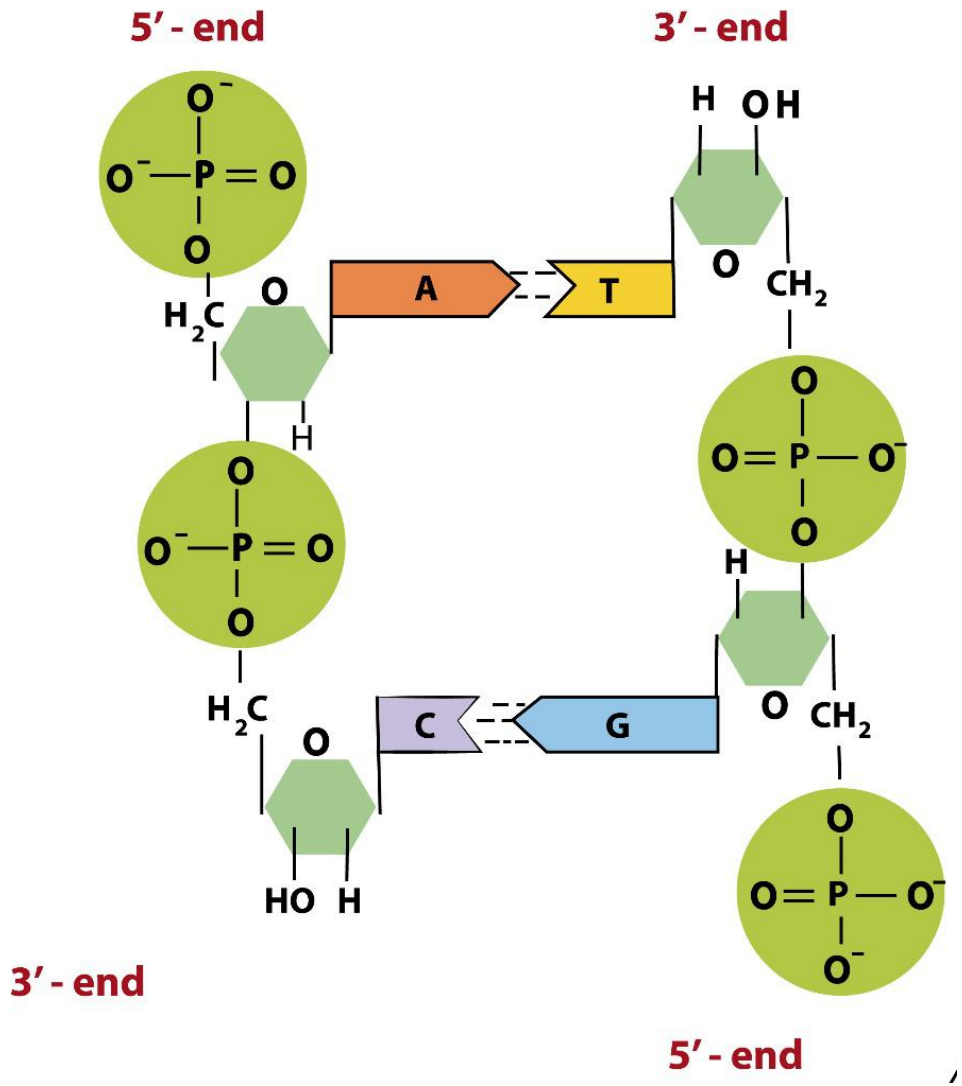
Viruses

- are they alive
- structure
- how they work

1.6.1 Watson-Crick Model of Nucleic Acids

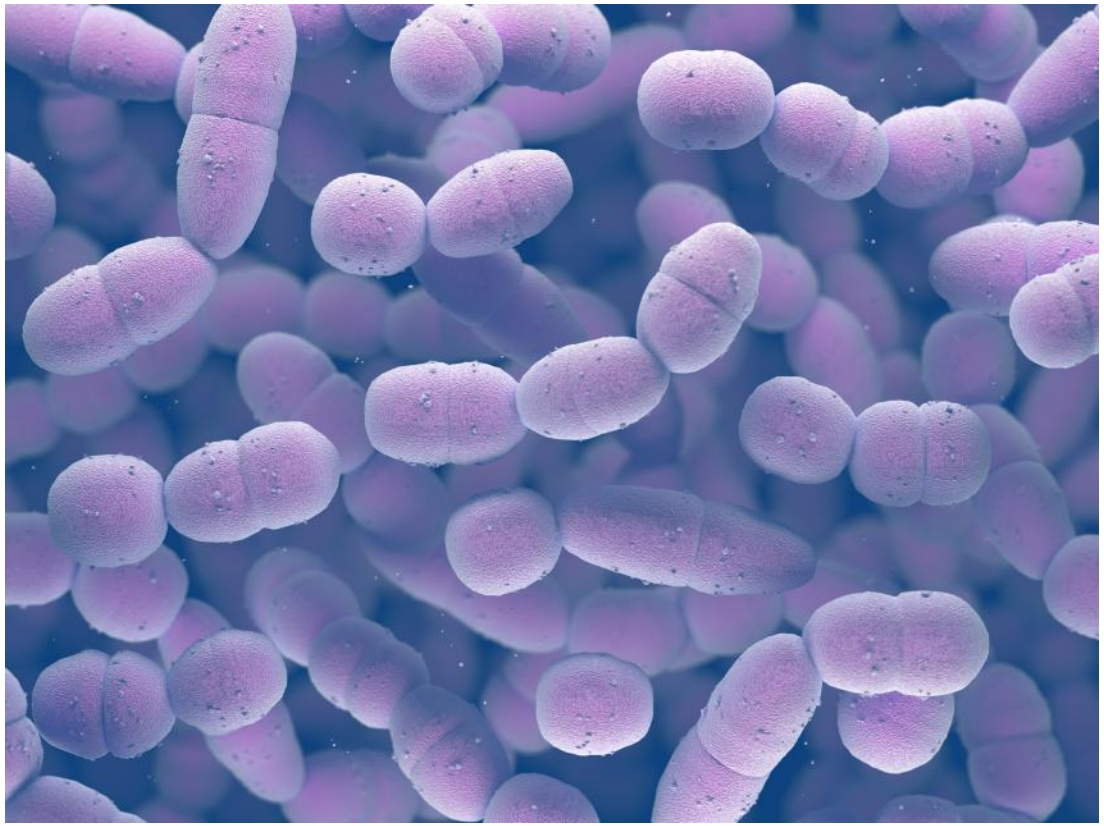
Discoveries Before Watson & Crick

Friedrich Miescher (1860s): discovered phosphate-rich chemicals in white blood cell nuclei


5′ - end
3′ - end
A
T
C
G
3′ - end
5′ - end

Discoveries Before Watson & Crick

Frederick Griffith (1920s): some kind of molecule transformed pneumonia bacteria from harmless to lethal

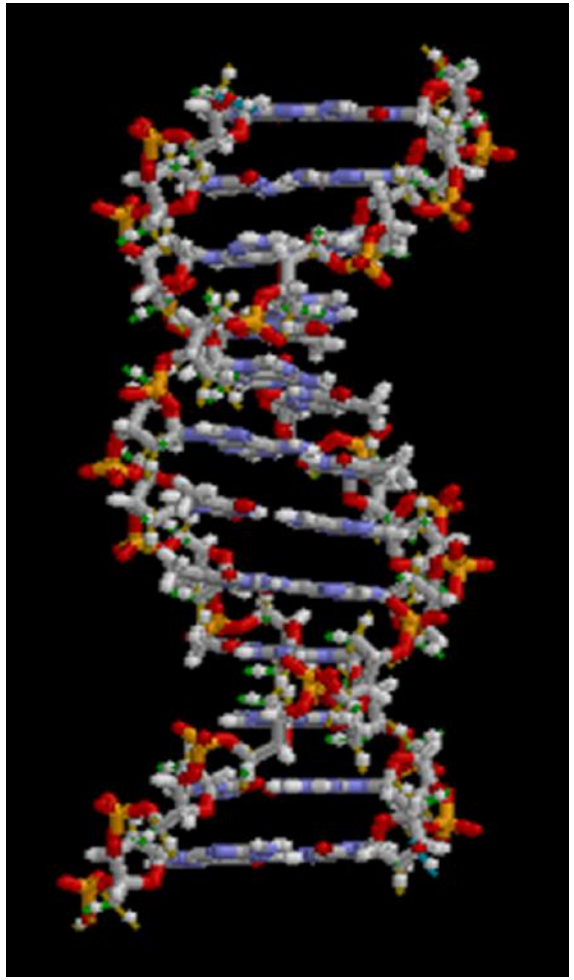


Discoveries Before Watson & Crick

Avery, MacLeod, McCarty (1940s): DNA was the transforming molecule

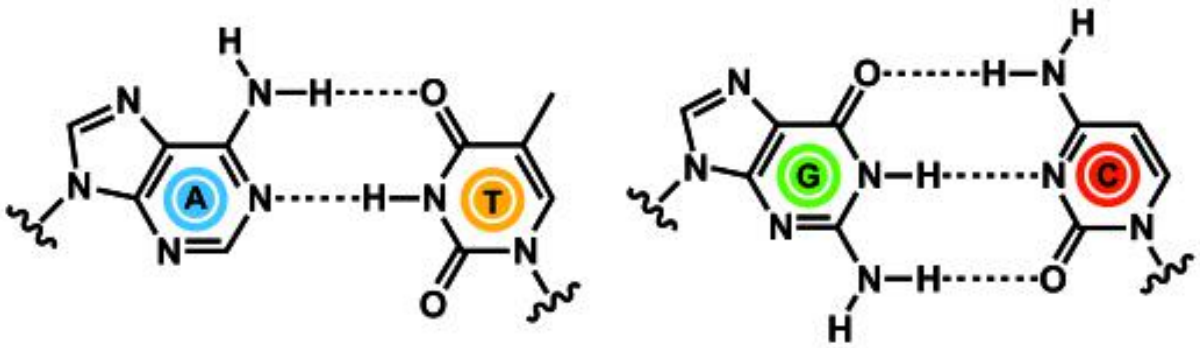
Discoveries Before Watson & Crick

Chase & Hershey (1950s): DNA (not proteins) the genetic material



Discoveries Before Watson & Crick

Erwin Chargaff (1950s): A=T and C=G



Discoveries Before Watson & Crick

Rosalind Franklin (1950s): X-ray crystallography showed helical structure

Watson-Crick model of nucleic acids

James Watson & Francis Crick (1950s): A-T bond was the same length as the C-G bond, leading to double-helix

Watson & Crick published their model in 1953

1.6.2 DNA Replication

The Blueprint

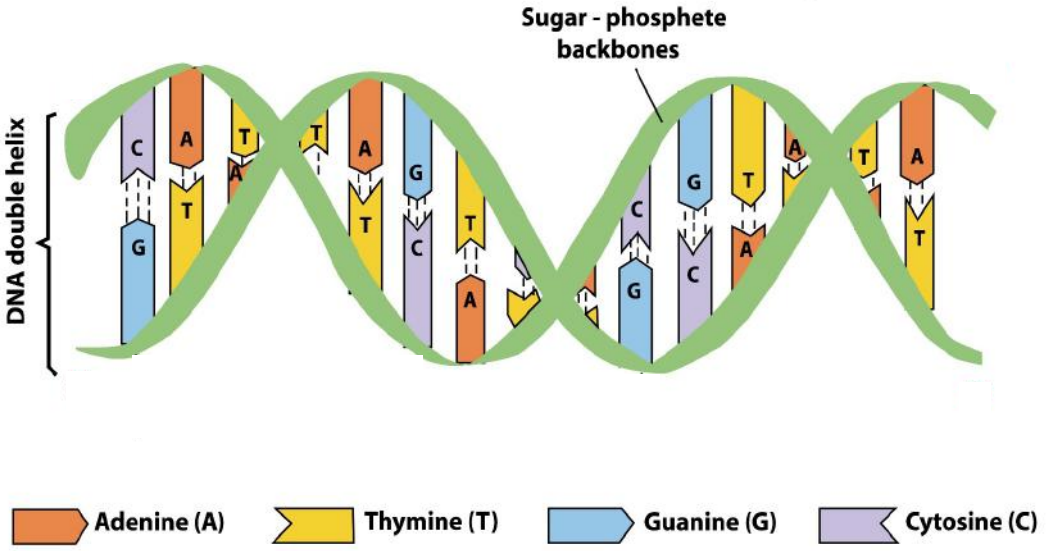
DNA is the “blueprint” for everything cells make and do

Before mitosis, a cell must copy DNA, so each daughter cell gets an identical copy

DNA replication- making the copy

Each Strand a Template

The base pairing rule (A=T and C=G) means each DNA strand can be a template for a new strand



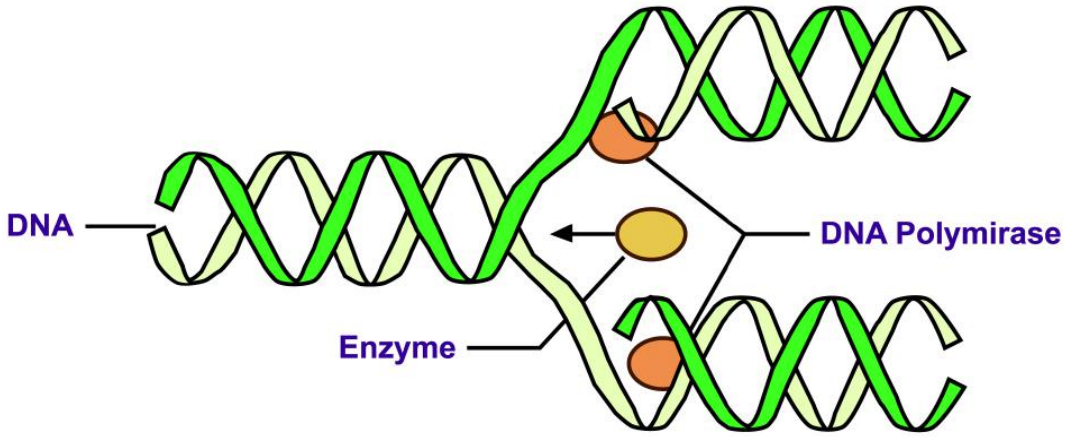
The Process

Steps:

1. The enzyme *helicase* breaks bonds b/w nucleotides on the two DNA strands, unwinding the double helix

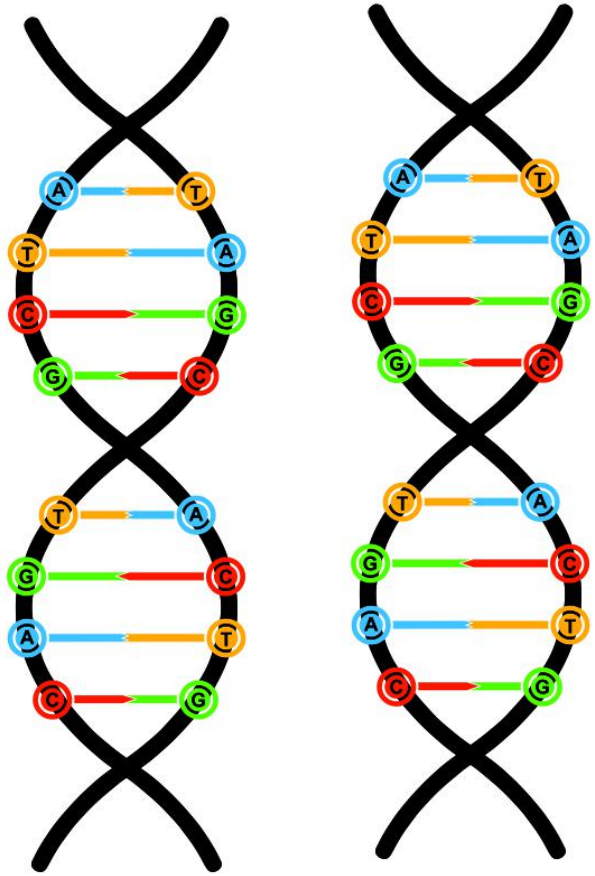
2. The enzyme *DNA polymerase* reads the sequence of nucleotides on one DNA strand (*template strand*)

3. Polymerase builds a new strand by matching nucleotides to those on template strand



The End Product

When polymerase is finished, two identical double helices have been formed



1.6.3 Mutations

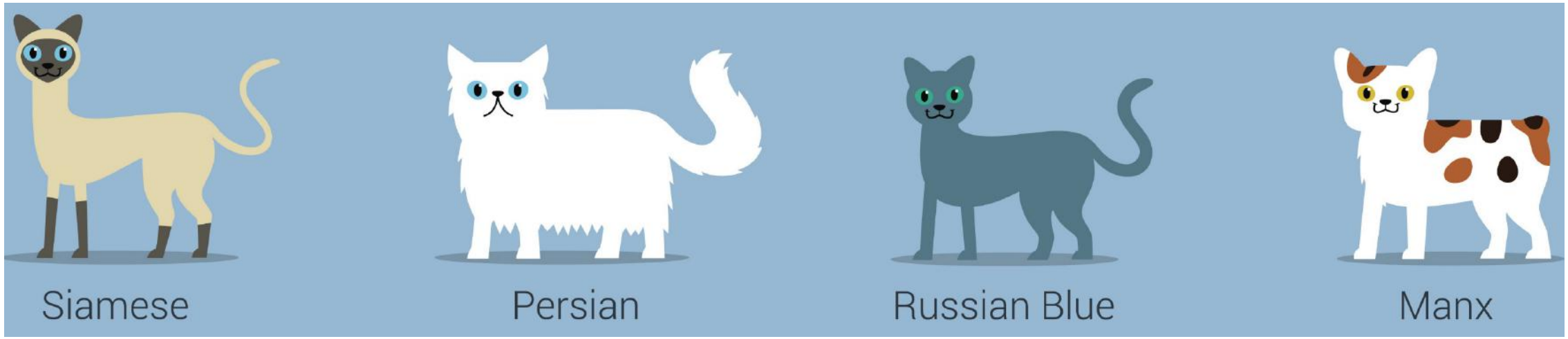
Mutations

Ultimate source of new genes

Can be beneficial or detrimental

Called genetic disorder if detrimental
(i.e. sickle-cell disease)

Mutations



Causes

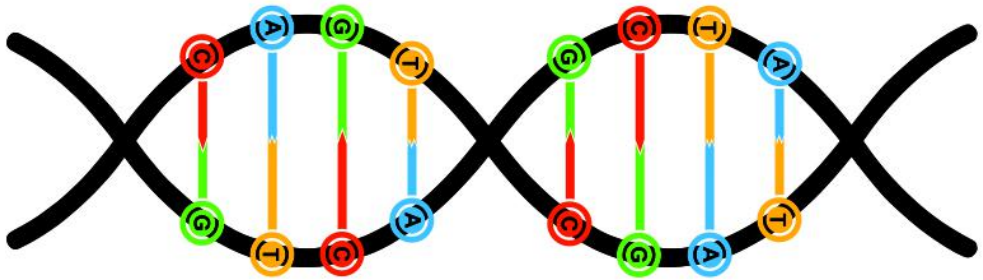
1. Accidents during replication or transcription

2. Exposure to carcinogens (like radiation)

Mutation Types

1. Substitutions: when the wrong nucleotide is used (i.e. A instead of C)

2. Frameshifts: an extra nucleotide added or essential one deleted



1.6.4 Control of Protein Synthesis

Genes & Protein Synthesis

Gene: segment of DNA that is blueprint for specific protein

Genes control protein synthesis

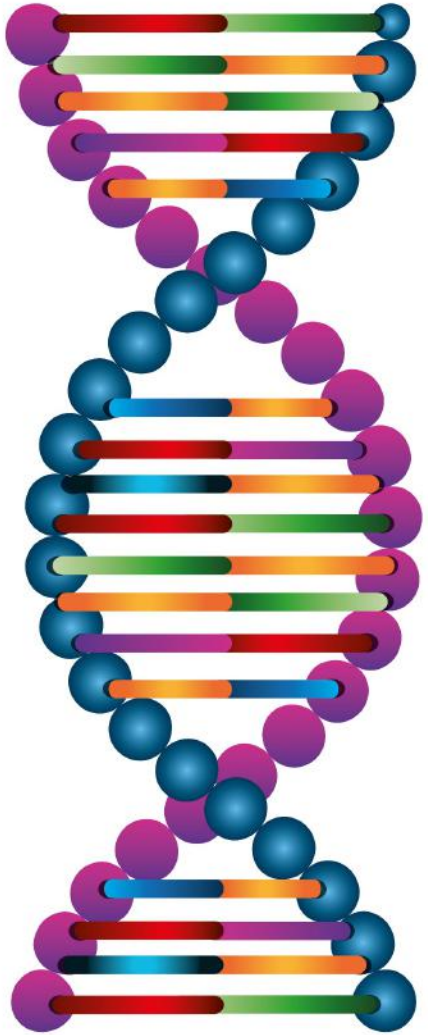
Two stages:

1. **Transcription**
2. **Translation**

Transcription

Gene copied from DNA into RNA format (U instead of T)

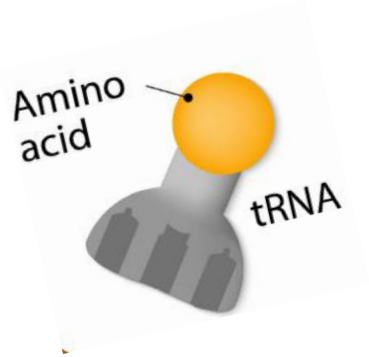
mRNA- messenger RNA, takes message to cytoplasm for translation

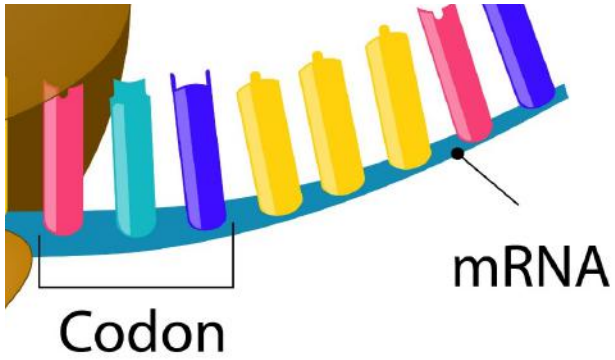


Translation

Sets of 3 nucleotides on mRNA form *codons*, which are complimentary to sets of *anticodons* on transfer RNA (tRNA)

tRNA carries amino acids from cytoplasm to ribosomes

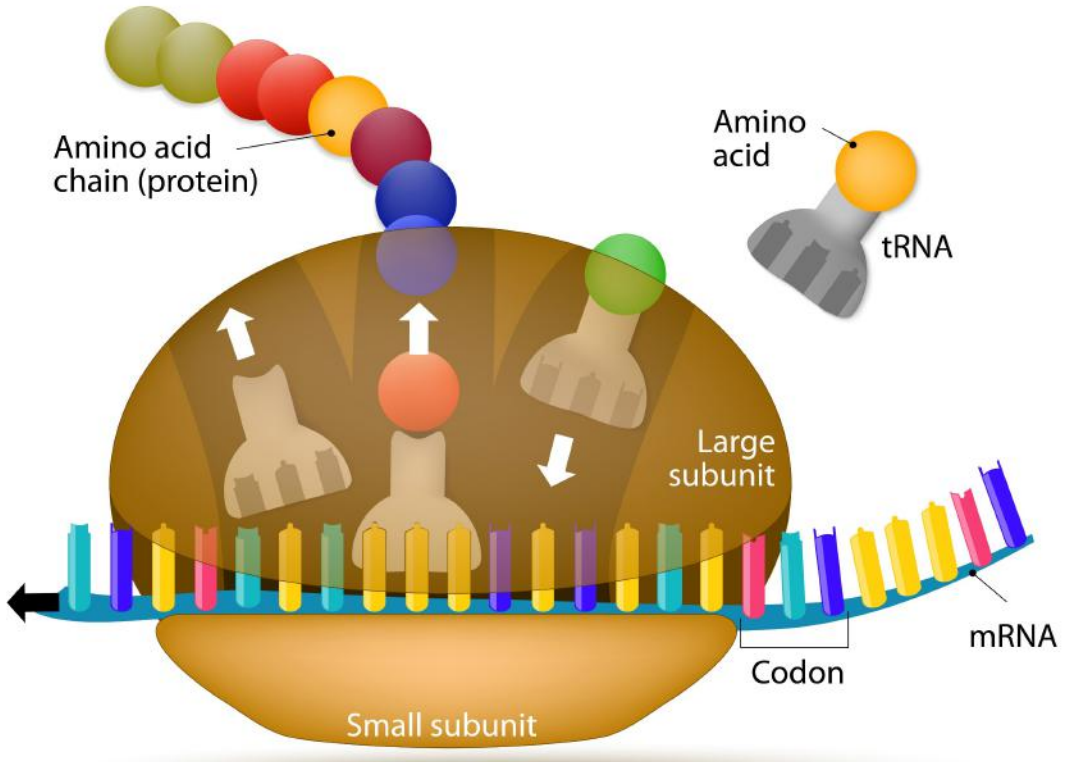




Translation

Ribosomes match anticodons to codons

Attached amino acids are joined to form proteins

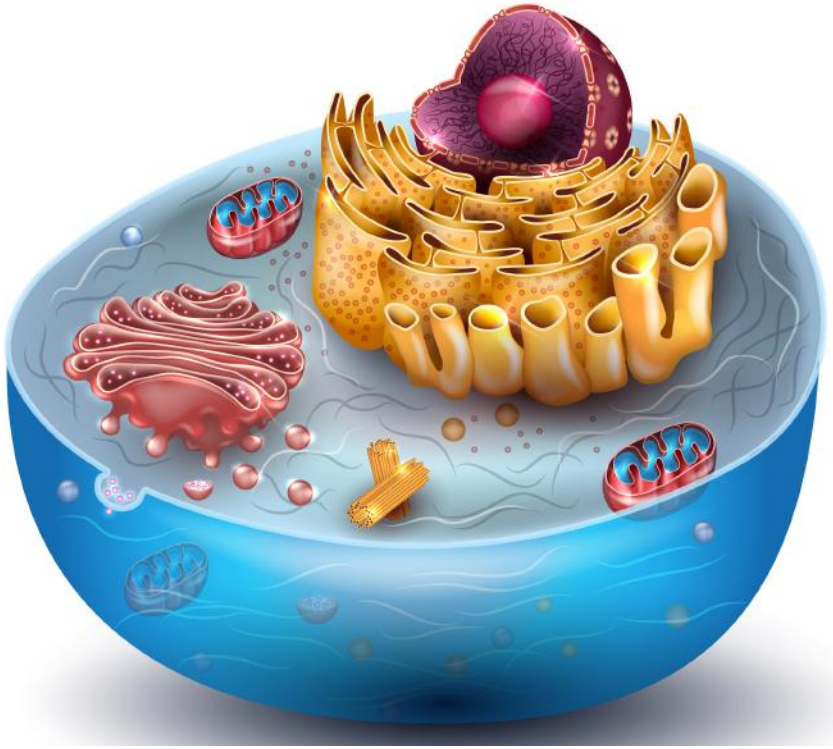


1.6.5 Structural & Regulatory Genes

Two Types of Proteins

Genes code for production of two types of proteins:

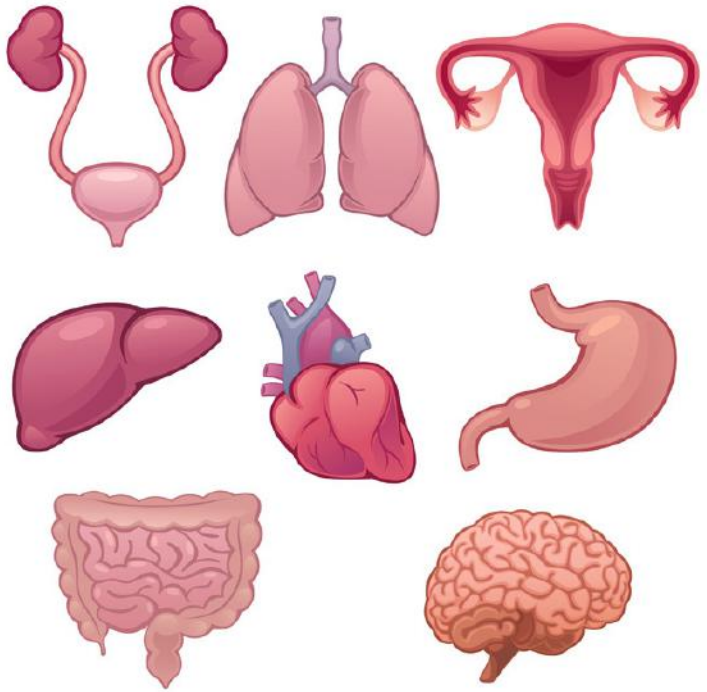
1. Structural
2. Regulatory



Structural Genes

Structural genes code for structural proteins, which form things like:

- **organs**
- **cell walls**
- **cytoskeleton**



Regulatory Genes

Regulatory genes code for regulatory proteins which do things like:

- regulate growth
- control development
- start or stop transcription of certain genes

1.6.6 Transformation

Bacterial Genes

Remember that bacteria are prokaryotes, no nucleus

DNA can be changed more easily, one reason why they can become resistant to medication quickly

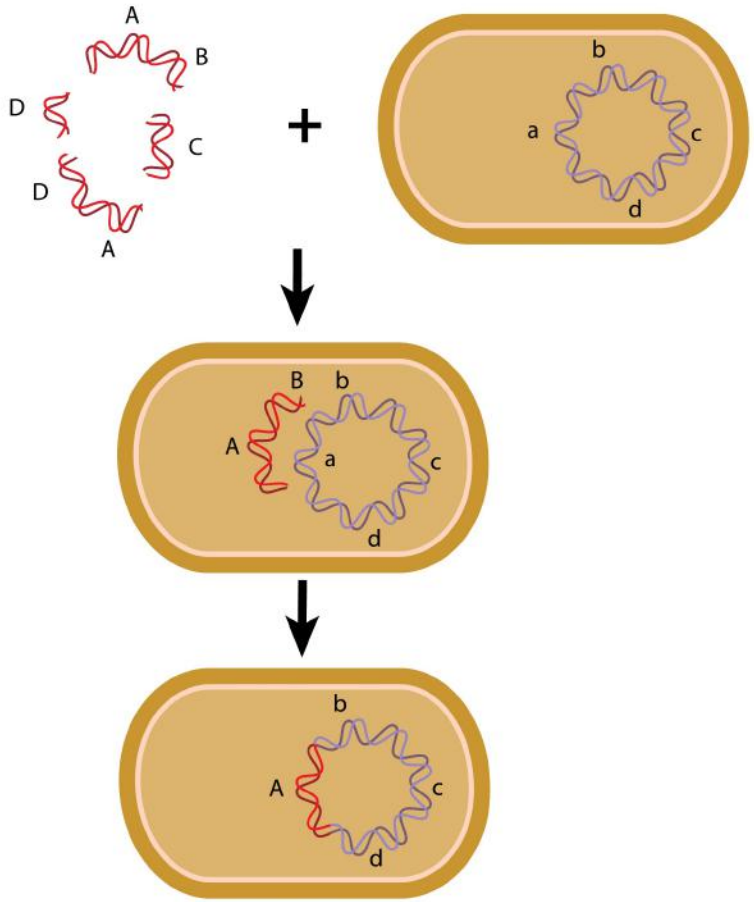
1. Transduction
2. Transformation

Transduction

A virus can put genes from one bacterium into another

Transformation

Bacteria can incorporate bits of DNA from environment into their own genes



1.6.7 Viruses

Are They Alive?

Scientists disagree

- have their own DNA or RNA
- can only reproduce in host cells
- no metabolism

A single virus: particle or virion

Structure

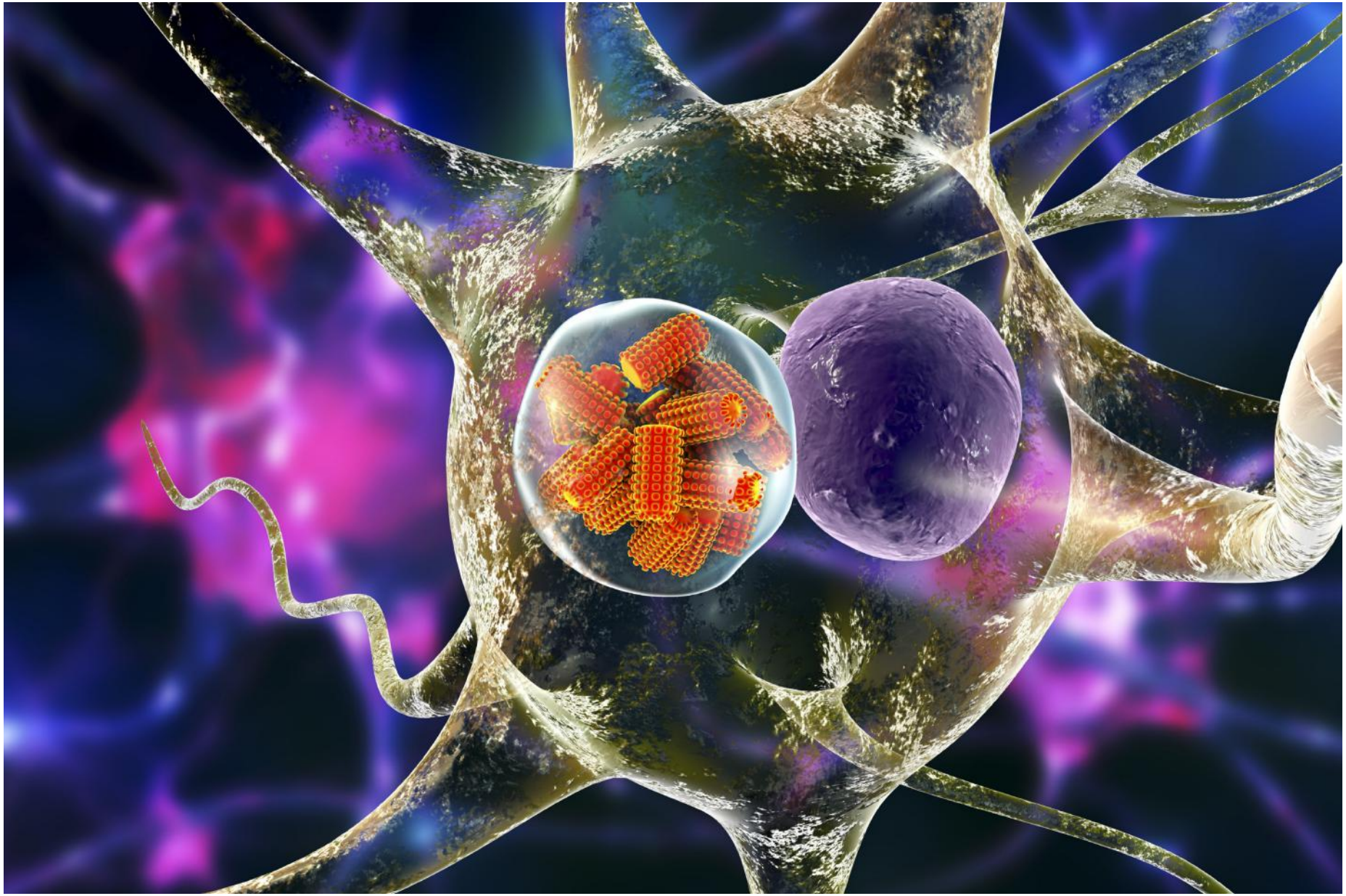
Much smaller than smallest bacteria

All are composed of:

- **Capsule**
- **DNA or RNA**

Some have enzymes, attachment structures

Rabies

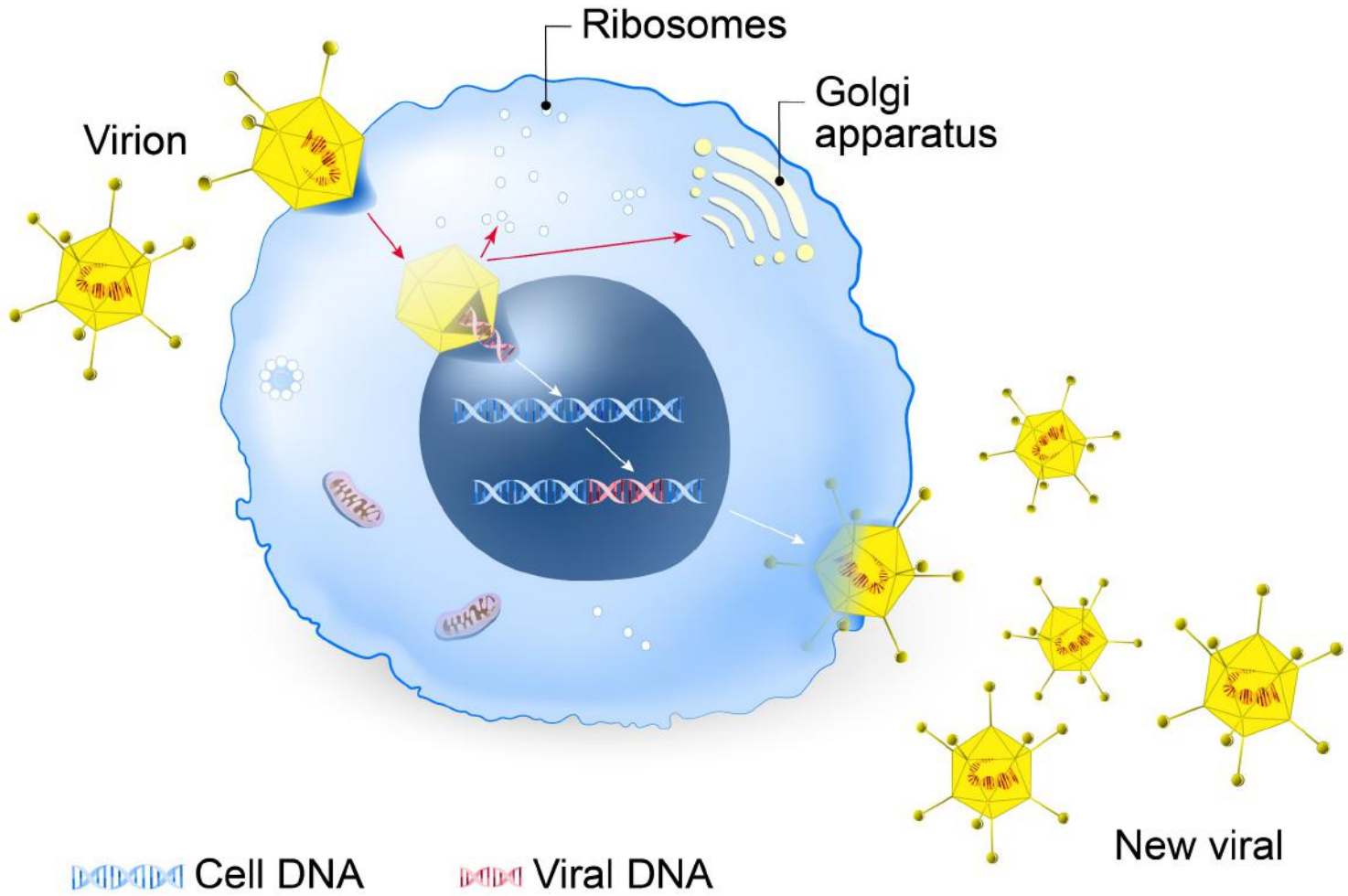


How Do They Work?

A viral “infection” involves:

1. A virus invades a living cell (host)
2. Takes control of DNA replication, sometimes transcription & translation
3. Gets host cell to make more of itself

Some viruses program the host’s immune system to stop working or attack itself


Ribosomes
Golgi apparatus
Virion
New viral
Cell DNA
Viral DNA