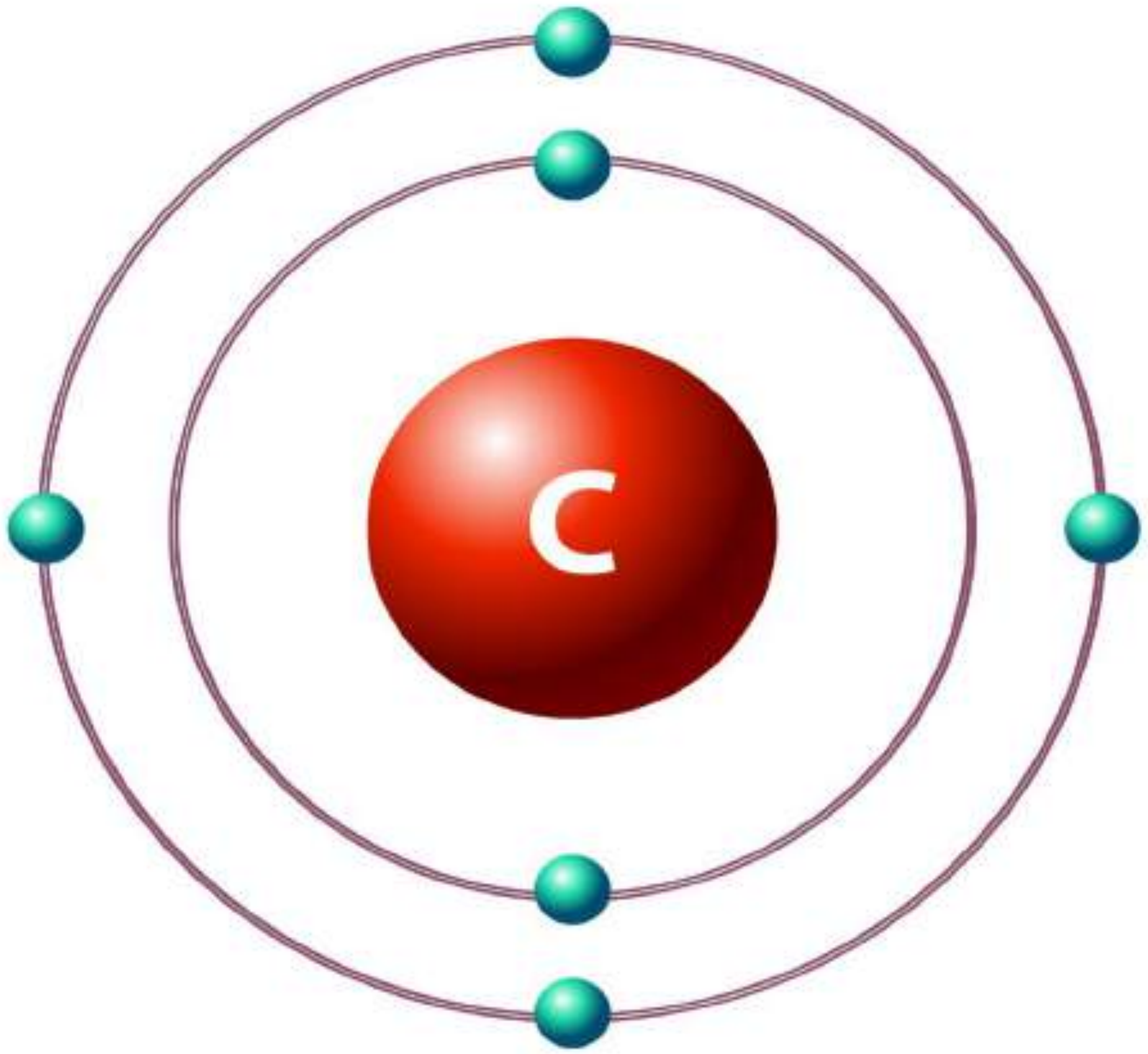
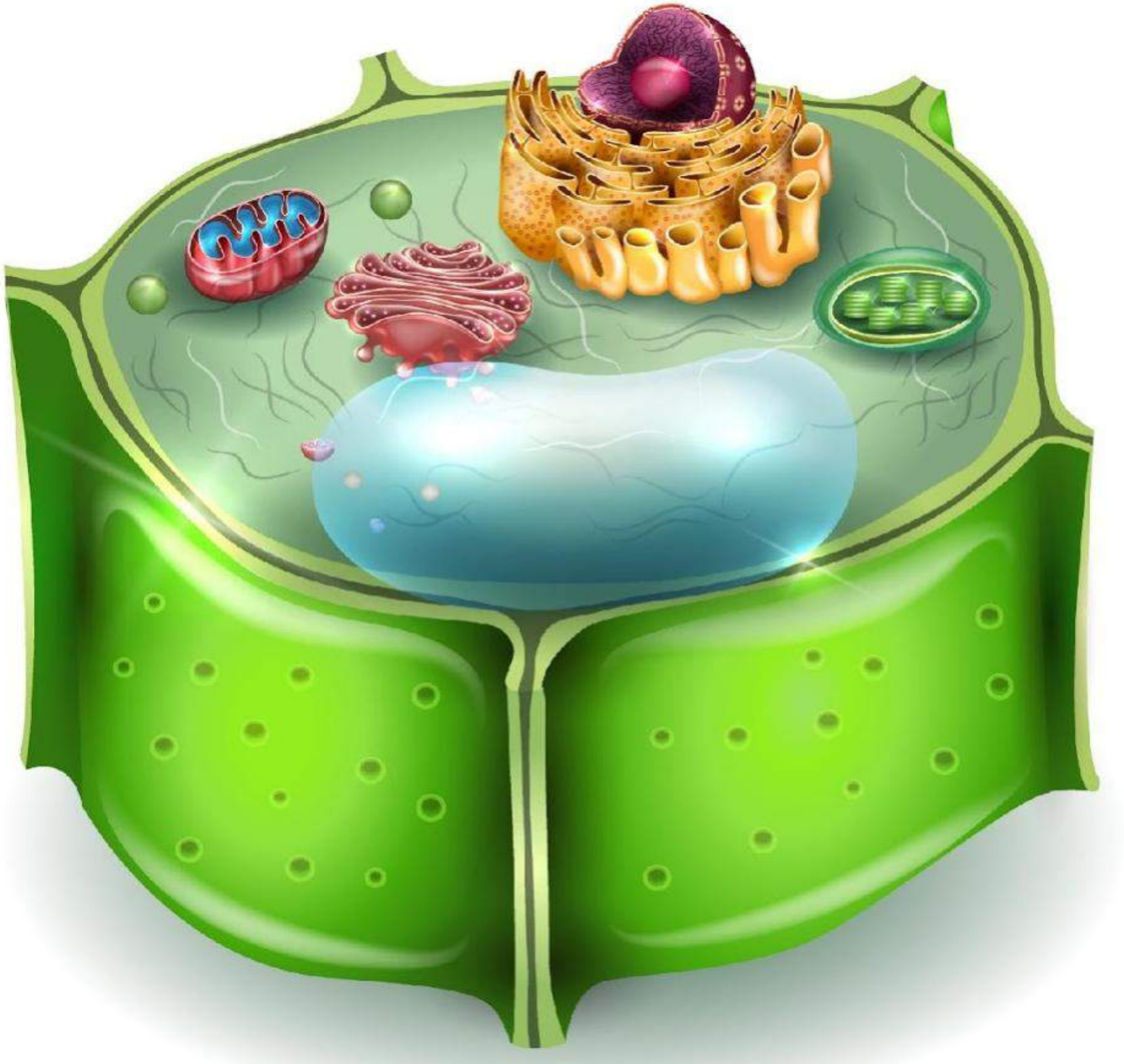
1. Molecular & Cellular Biology

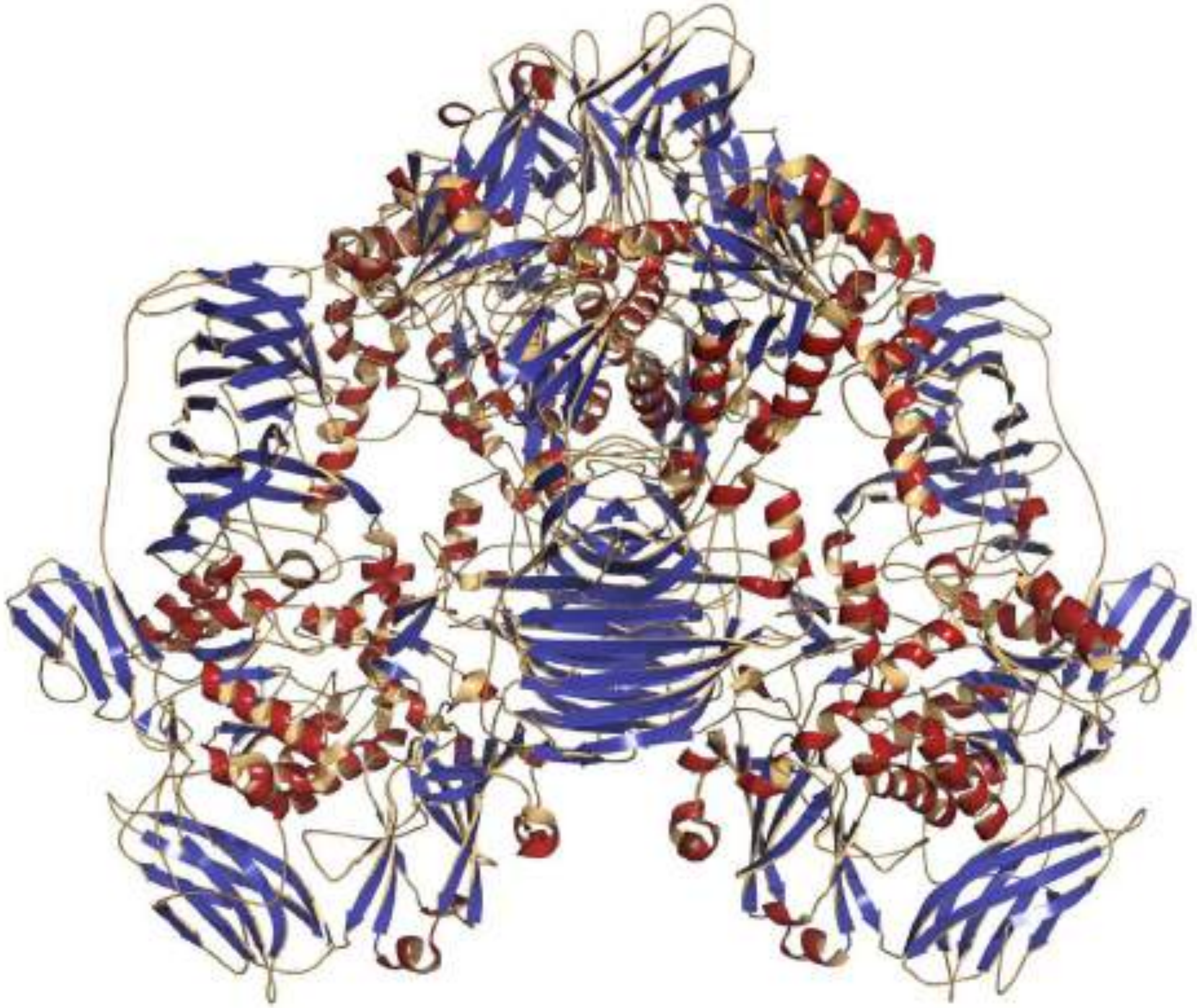
1.1 Chemical Composition of Organisms



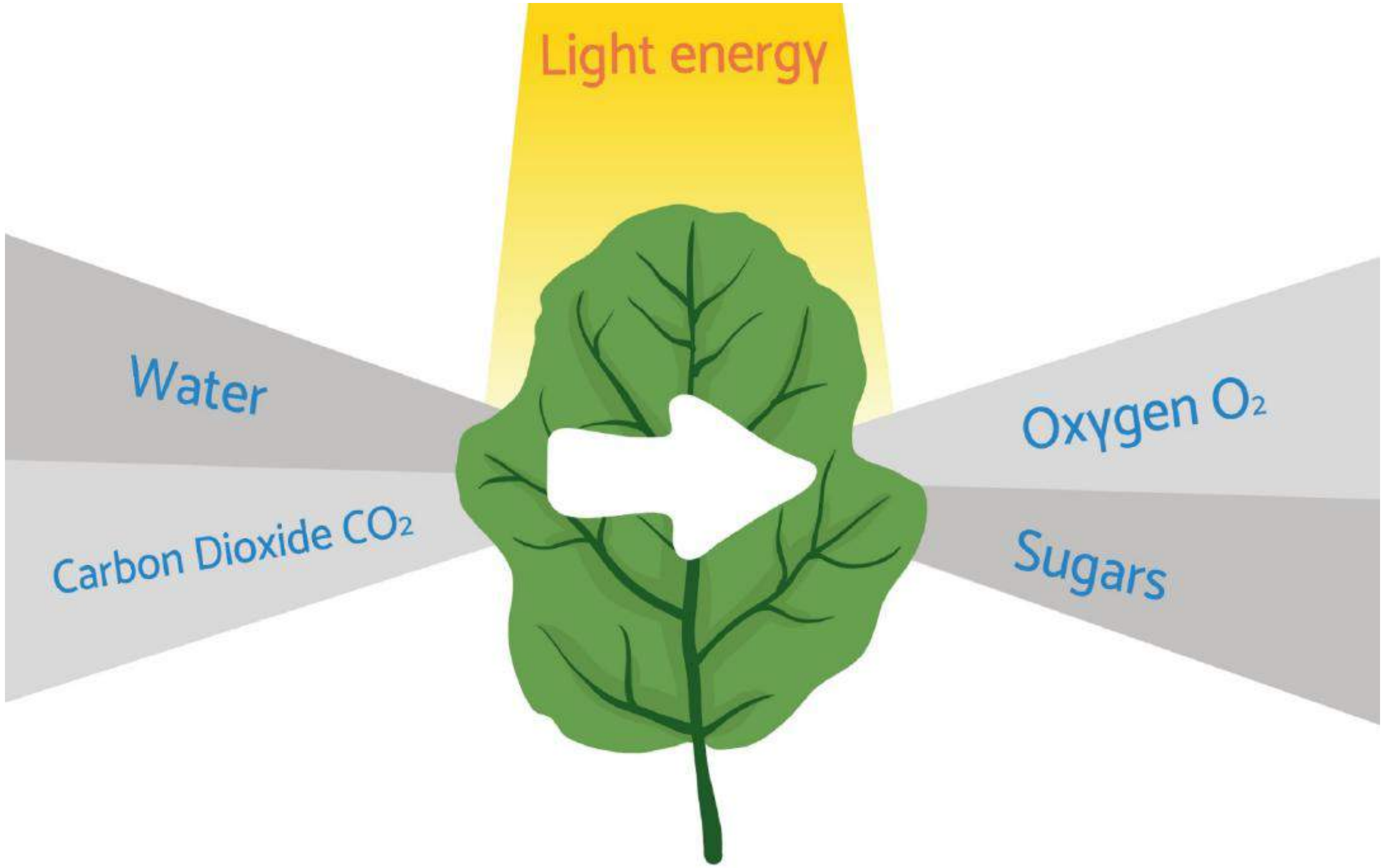
1.2 Cells



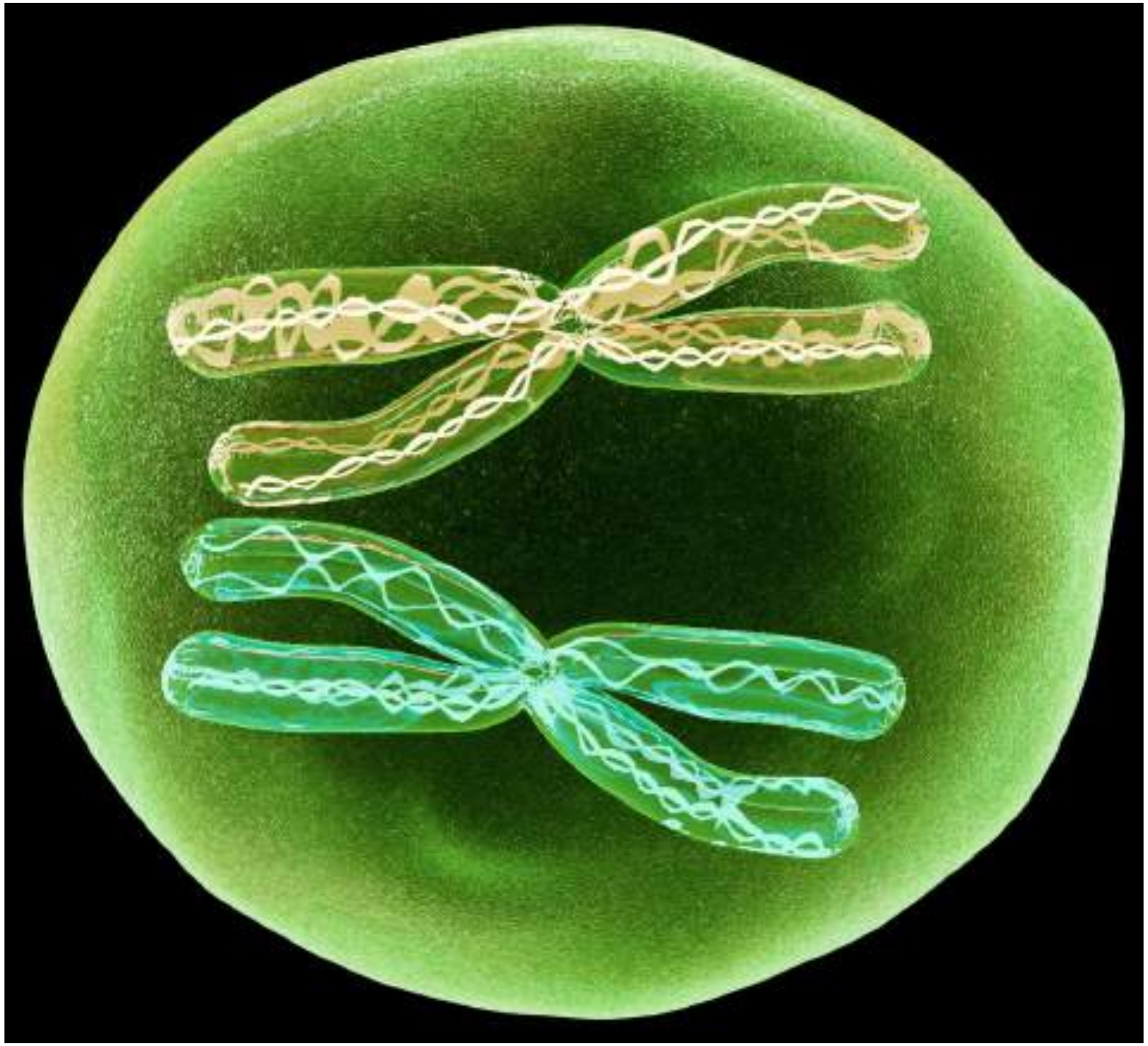
1.3 Enzymes



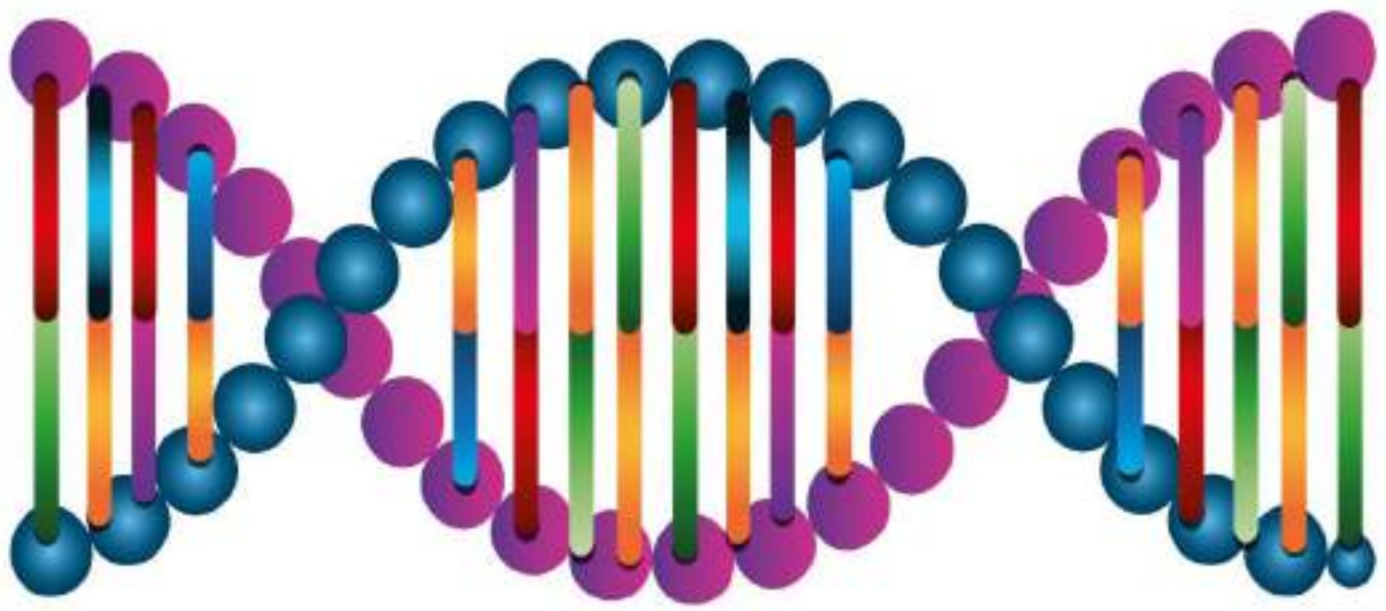
1.4 Energy Transformations



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

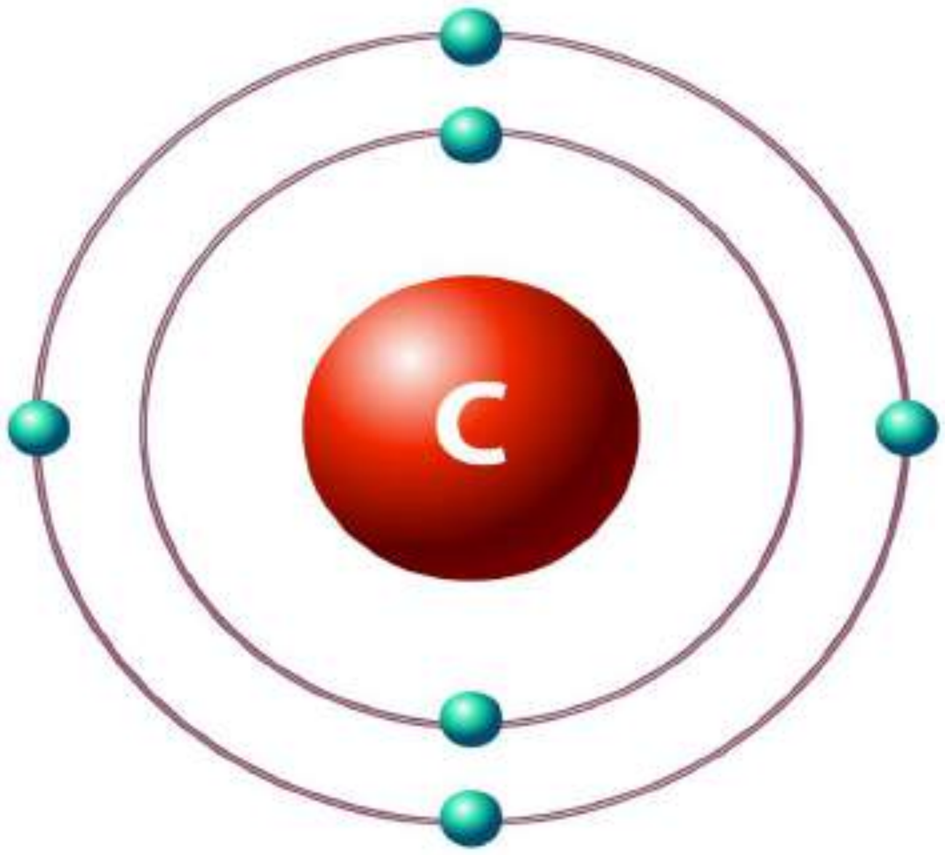
1.1.2 Properties of Water

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

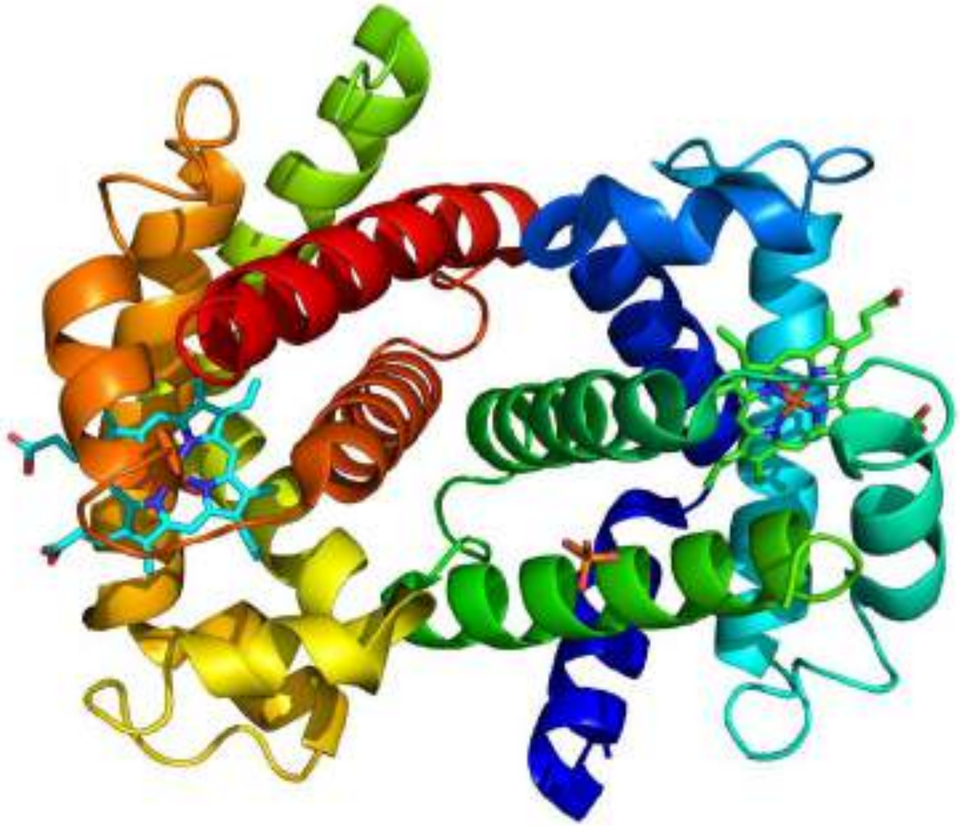


1.1.2 Properties of Water

- 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

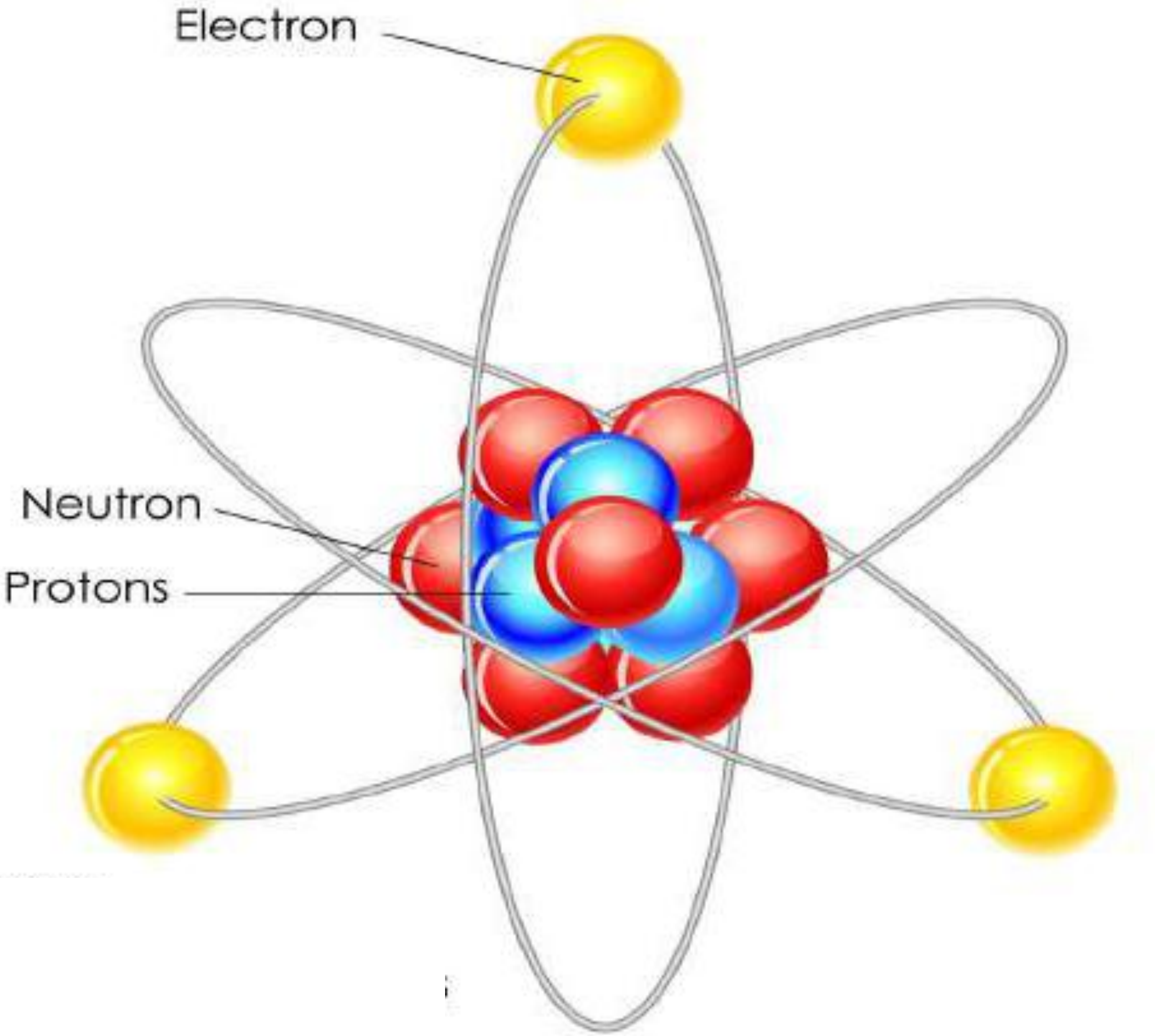
Elements

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



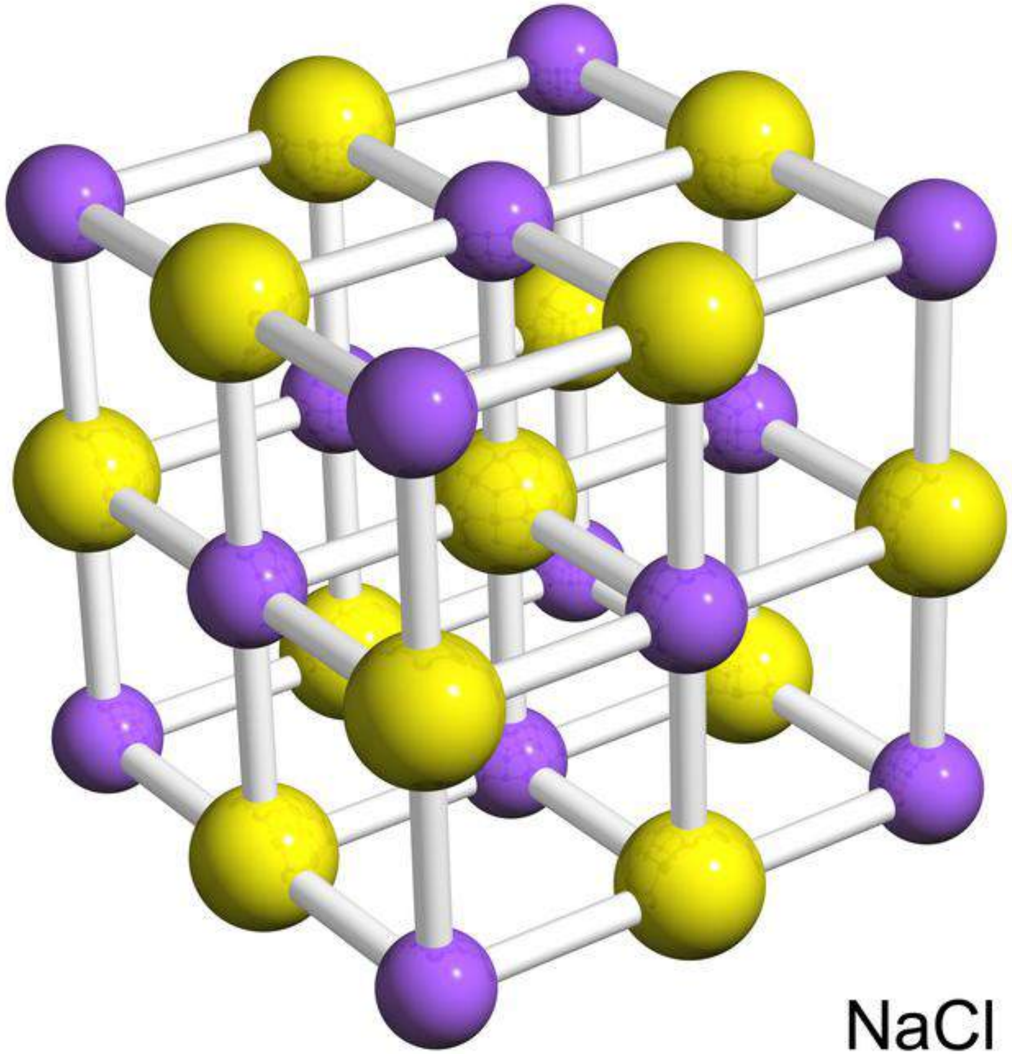
Elements

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"

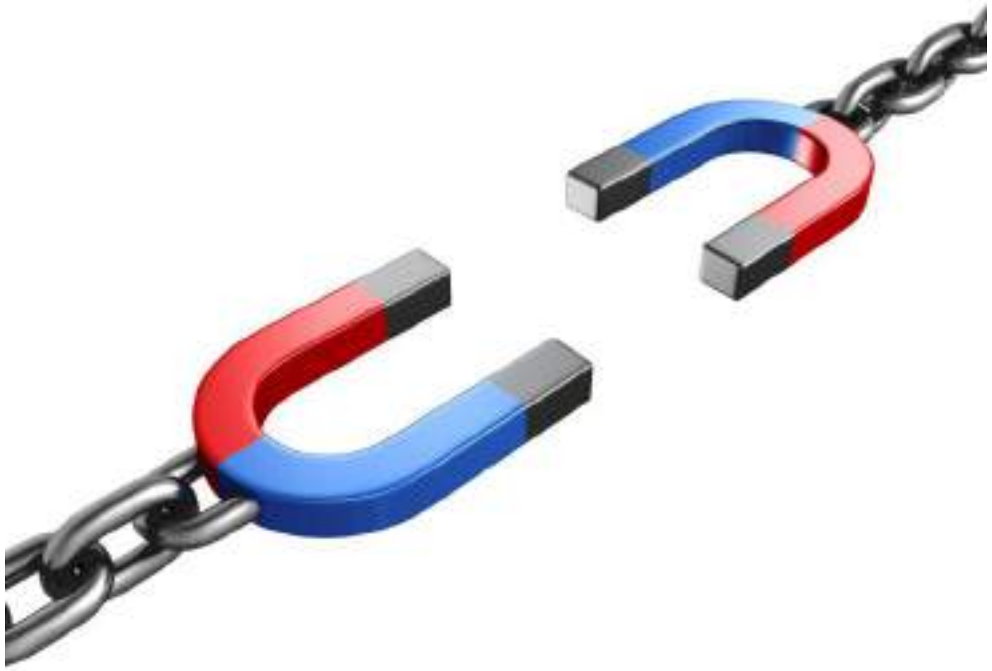
Only valence electrons interact w/ other atoms

Atoms most reactive if valence shell incomplete .

Chemical Bonds

Attractions that keep atoms close together

Protons & electrons attract like magnets

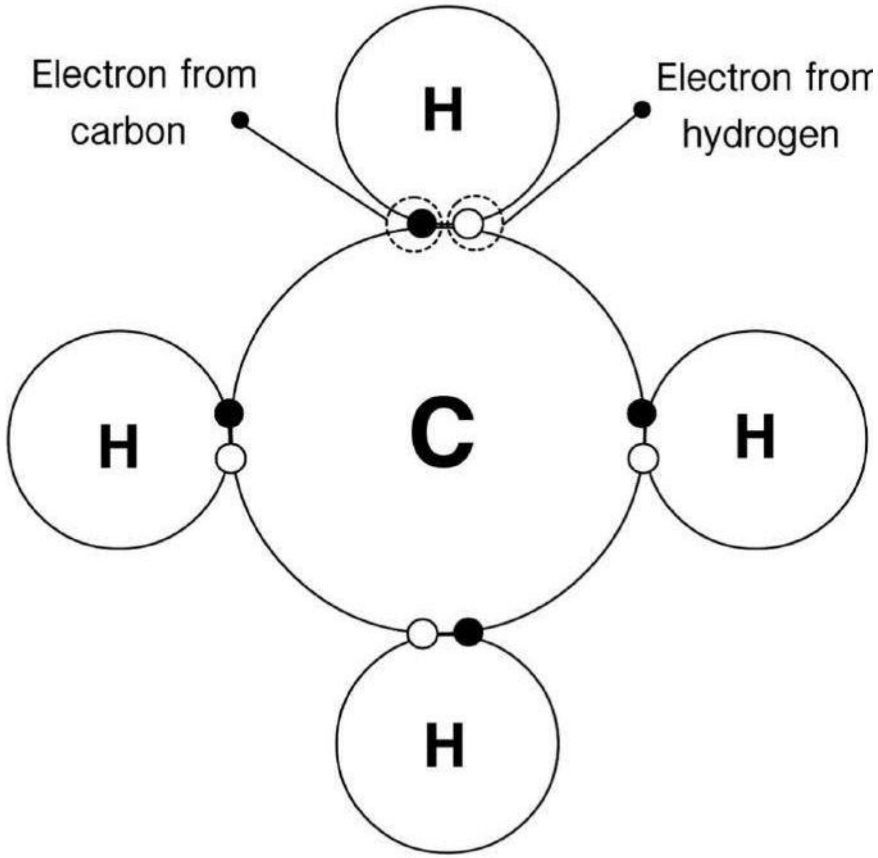


Chemical Bonds- Covalent

Sharing pair of electrons, strong bonds

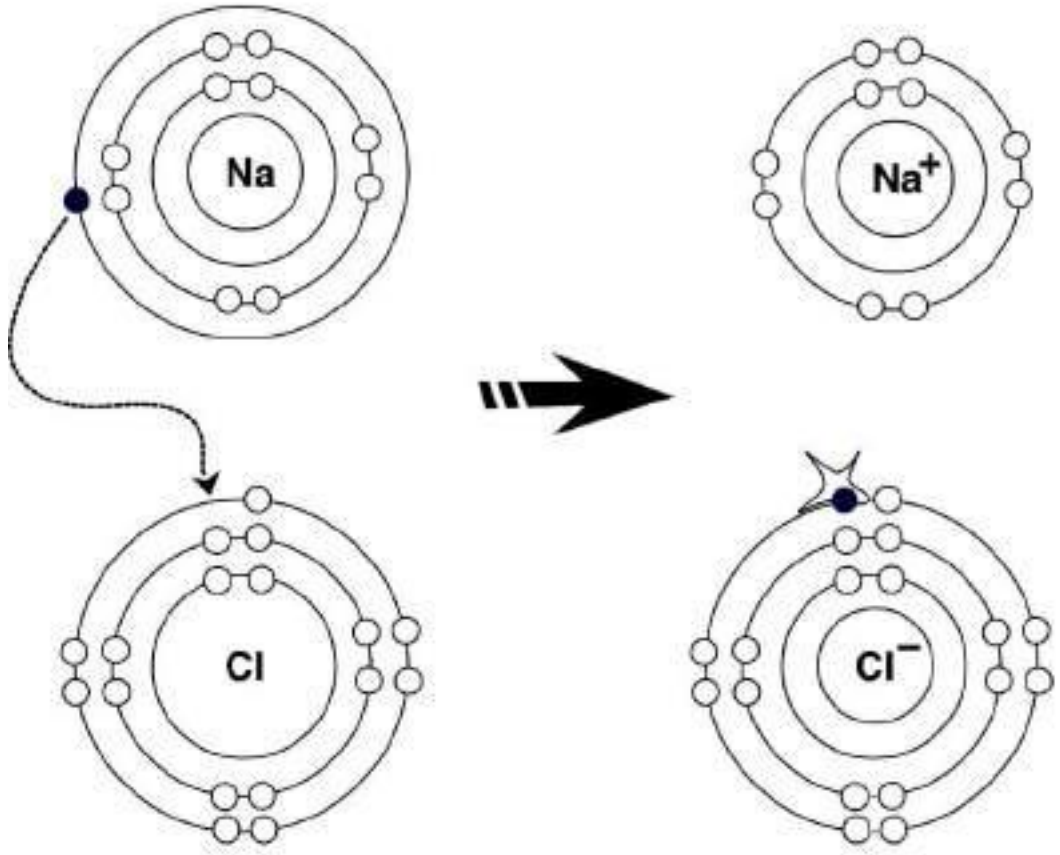
1. **nonpolar: sharing is equal**

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



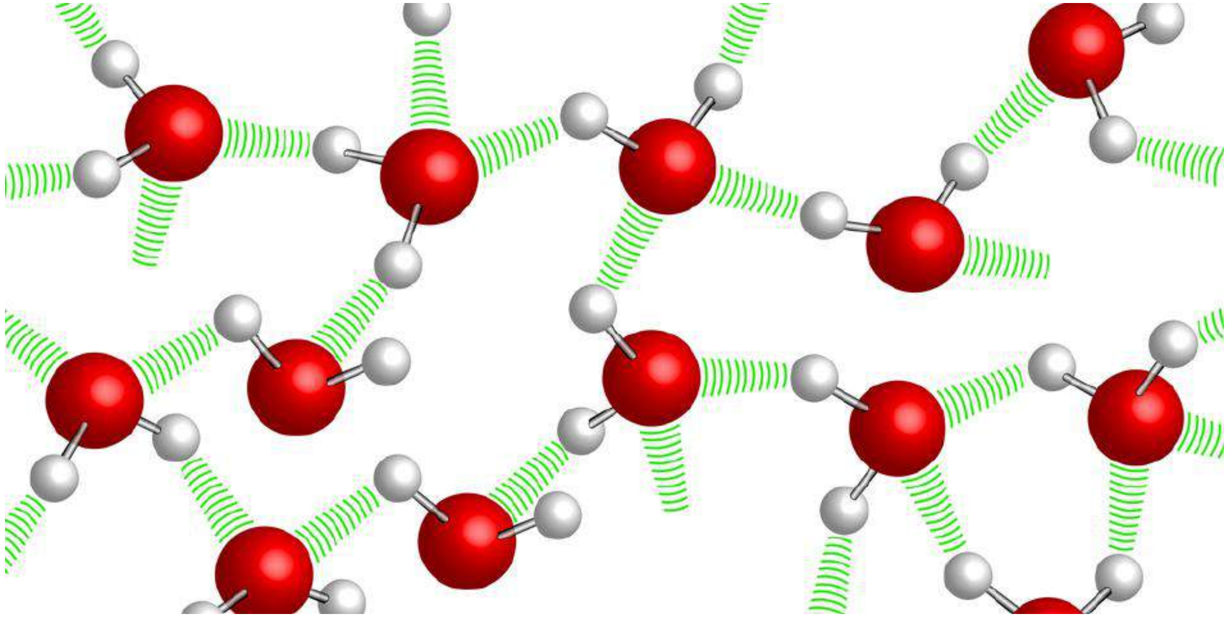
Chemical Bonds- Ionic

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



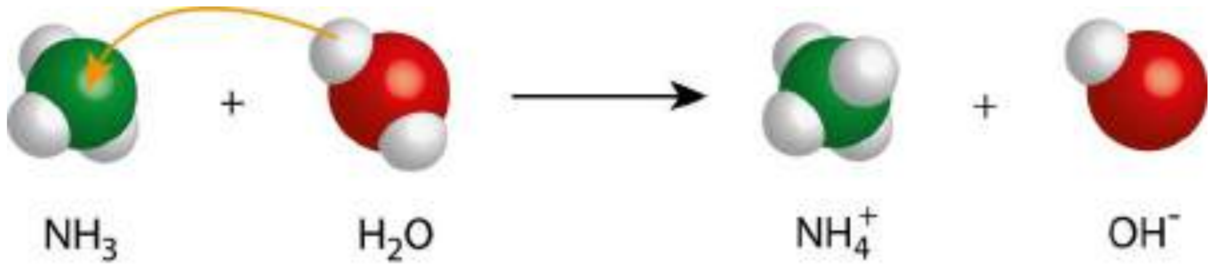
Chemical Reactions

Make and break chemical bonds

Reactants "react" together, start of reaction

Products are "produced," end of reaction

A + B ⟷ 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

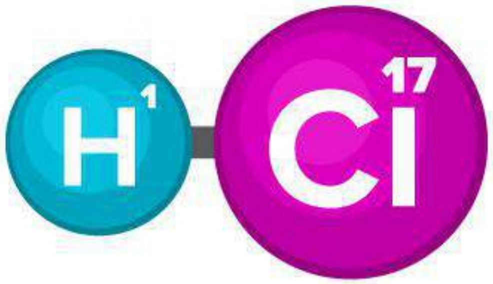
Acids & Bases

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

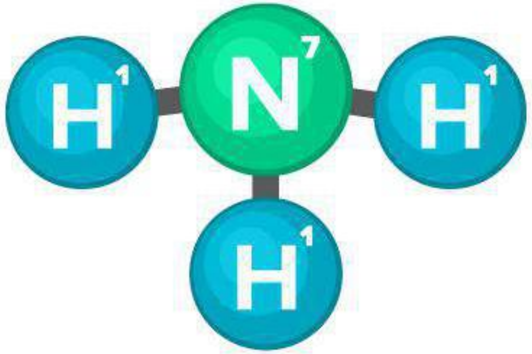
$$HCl \leftrightarrow H^+ + Cl^-$$

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

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



Hydrochloric acid



Ammonia

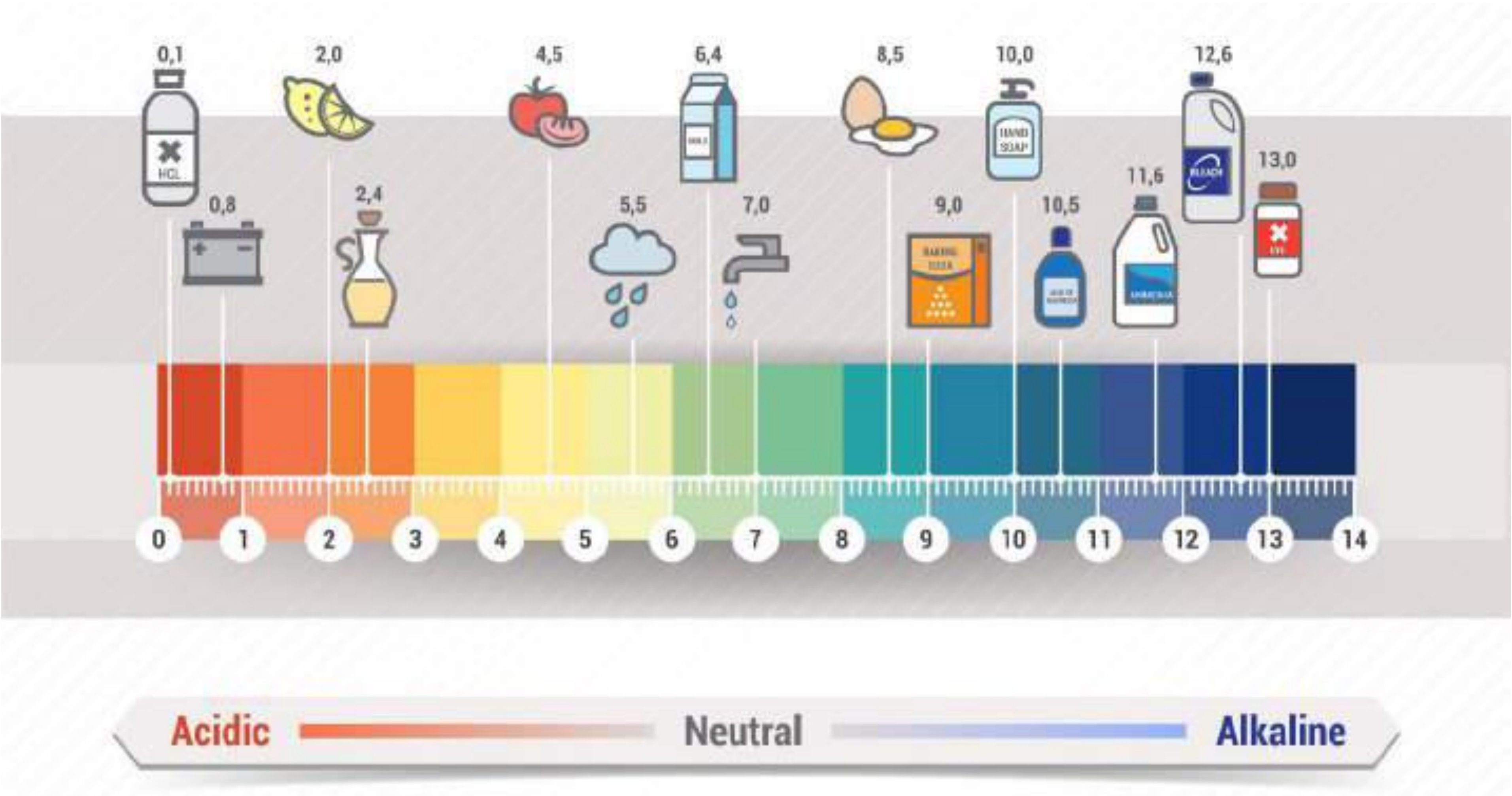
Acids & Bases

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
7,0
8,5
9,0
10,0
HAND SOAP
10,5
11,6
12,6
13,0
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**

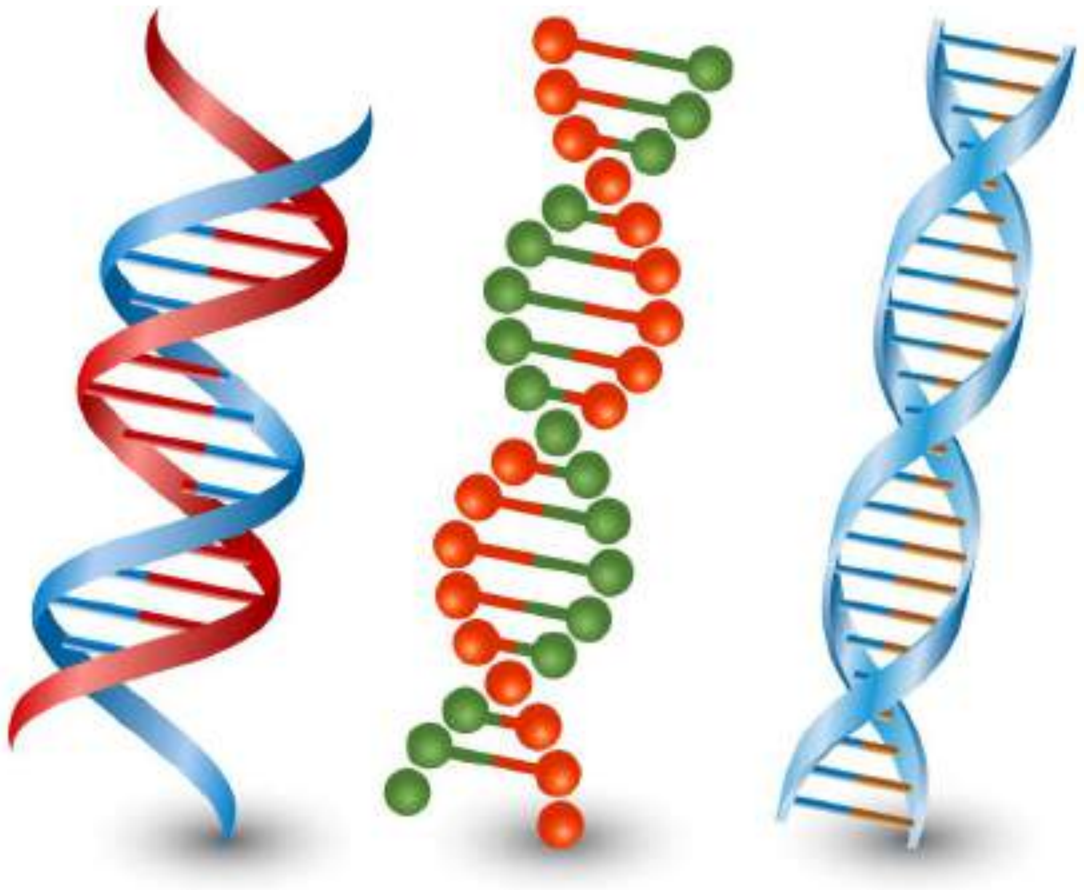
Nucleic Acids

Monomer name: nucleotide

Two types:

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

Primary function: information storage



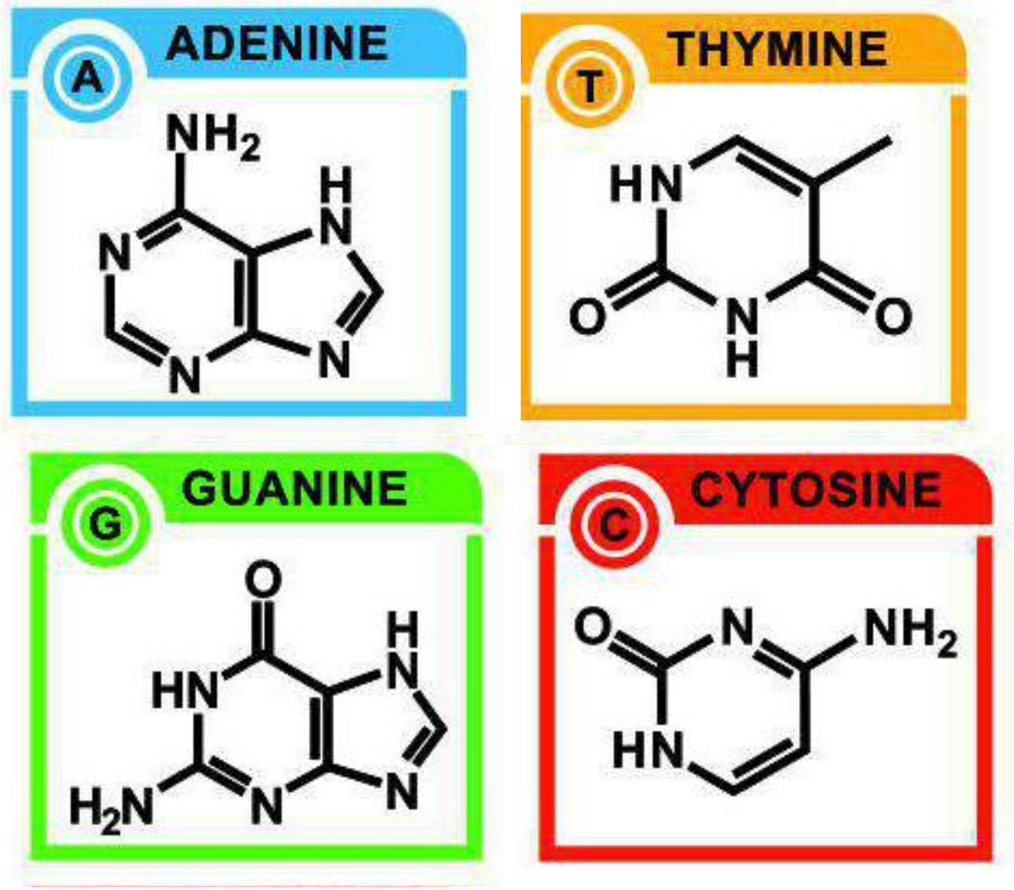
Nucleotides

Nucleotides are made of:

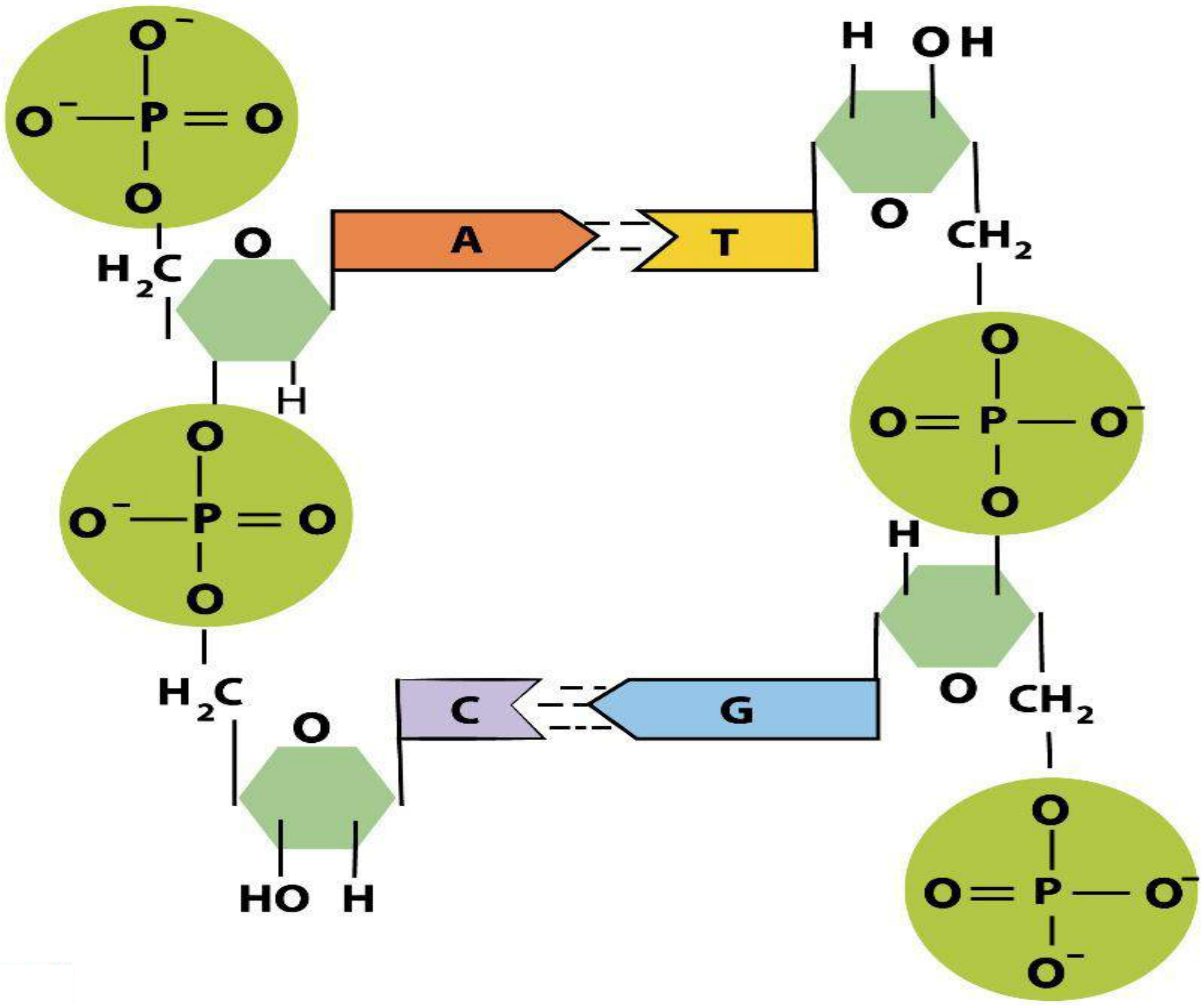
1. 1 Nitrogen base
    - adenine (A)
    - thymine (T, only in DNA)
    - uracil (U, only in RNA)
    - cytosine (C)
    - guanine (G)

2. 1 Sugar (deoxyribose or ribose)

3. 1 Phosphate group



Nucleotides



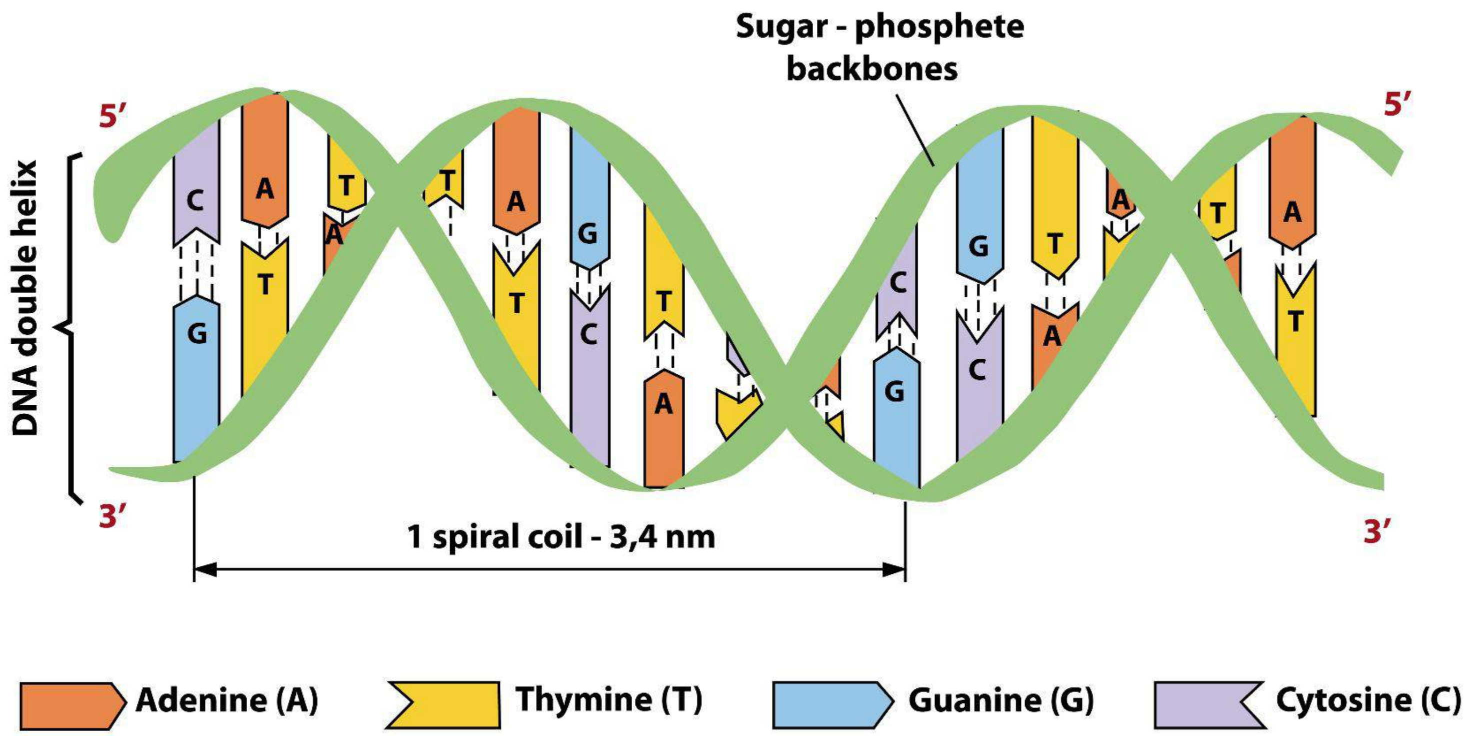
Nucleic Acids

Sugar-phosphate "backbone" forms

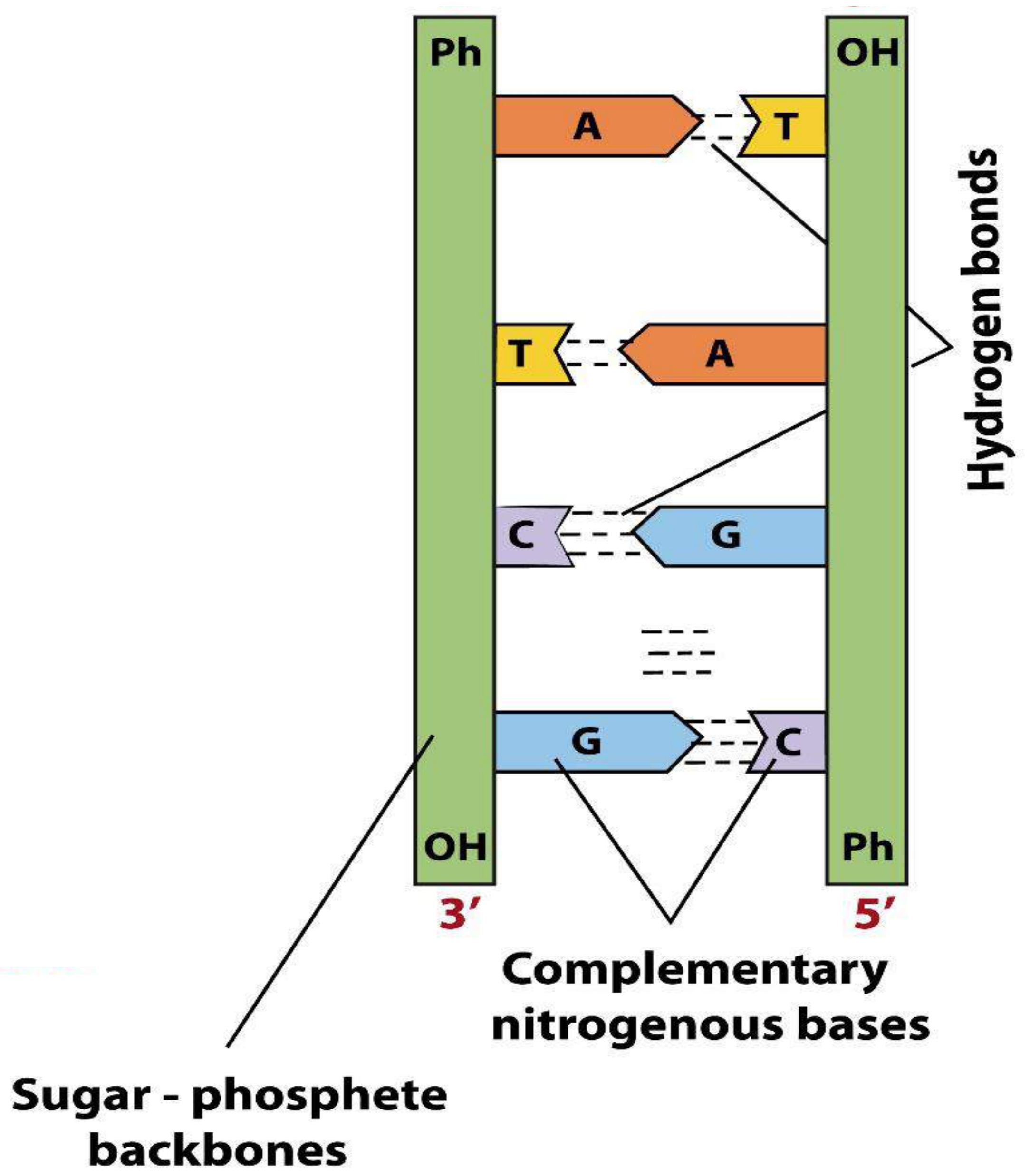
Nucleotides paired (called a base pair), so that DNA or RNA strands are complimentary

- 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

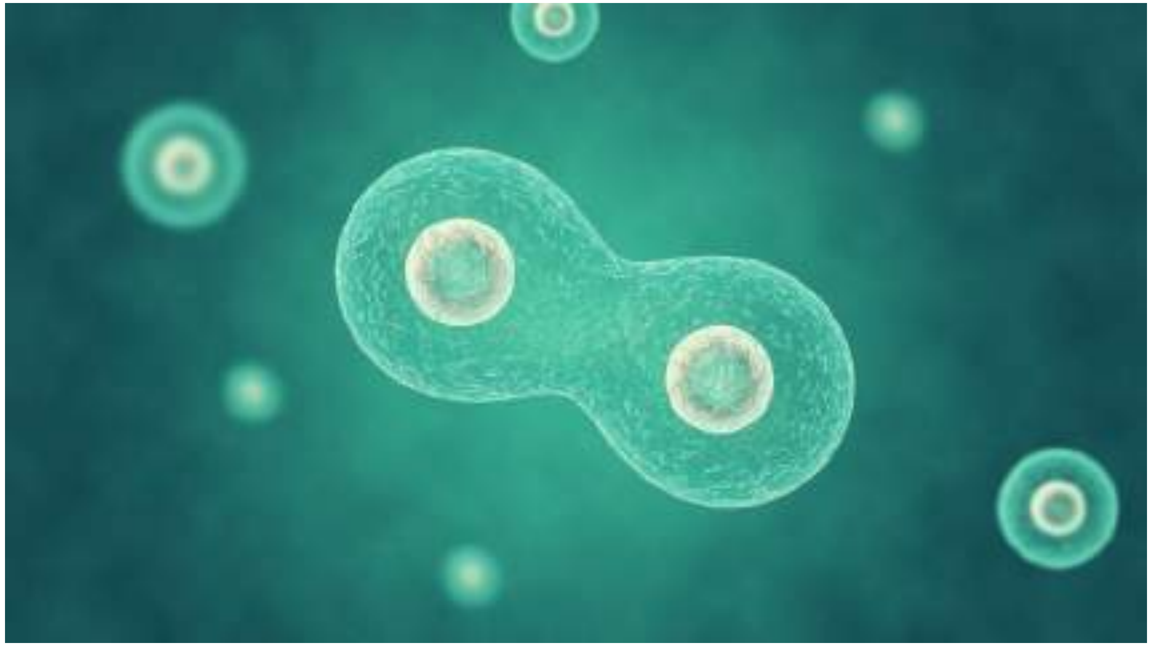
Likely places:

- 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

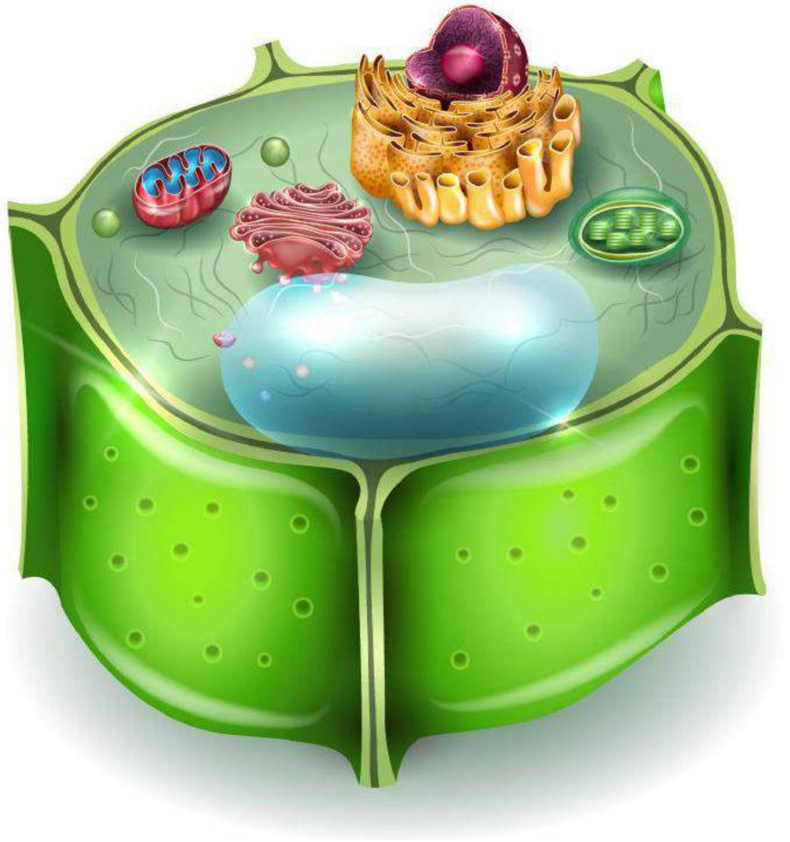
1.2 Cells

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

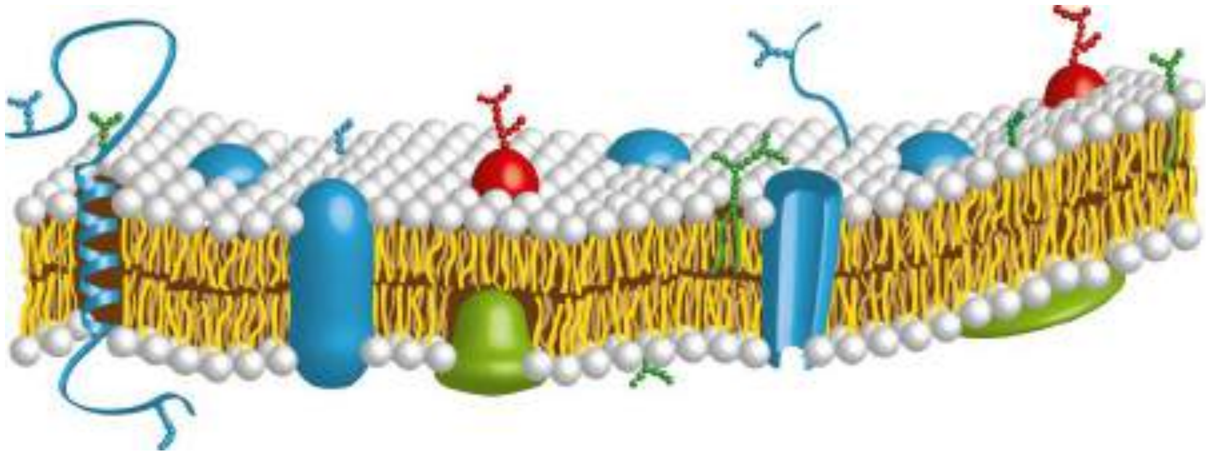


Structure & Function of Cell Organelles

- 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

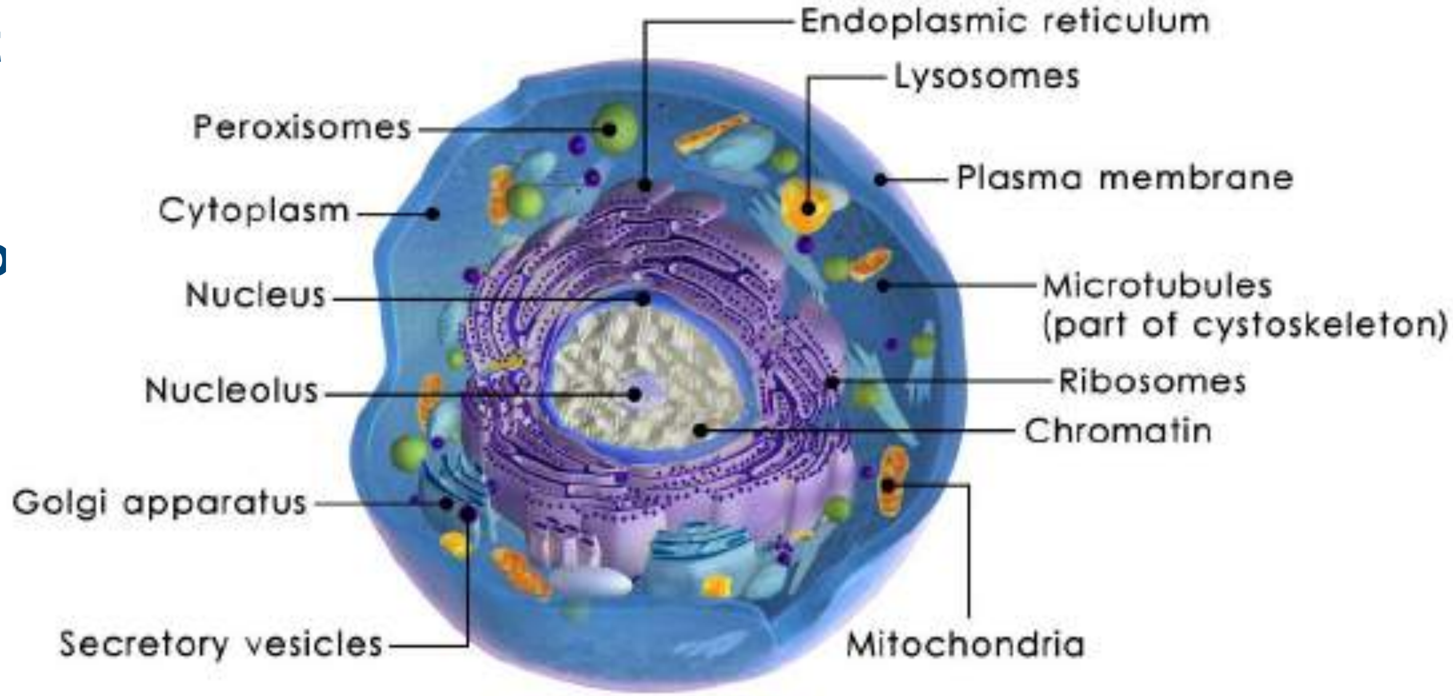
1.2.1 Structure & Function of Cell Organelles

Cells

Smallest collection of matter that
be alive

All organisms made of one or mo
cells

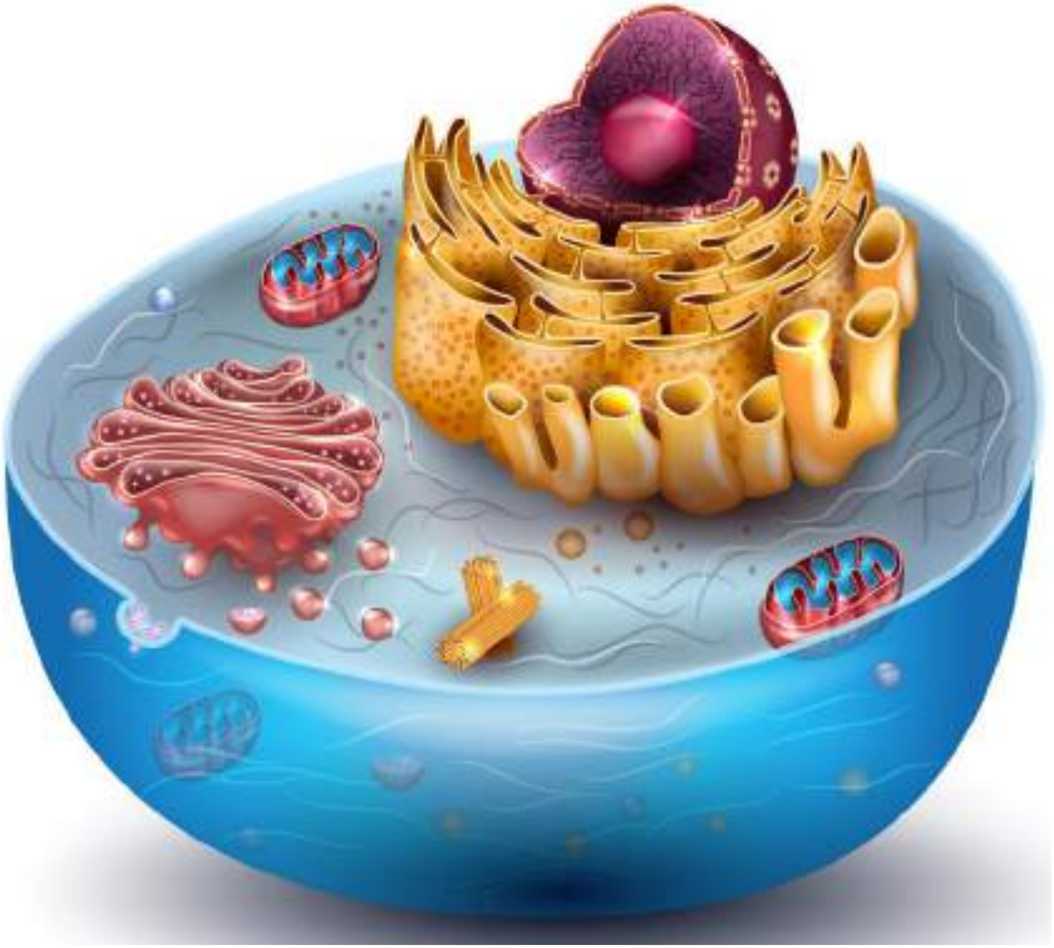
- single-celled
- multicellular



Cytoplasm & Cell Membrane

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

Cell membrane: lipid layer surrounding cell

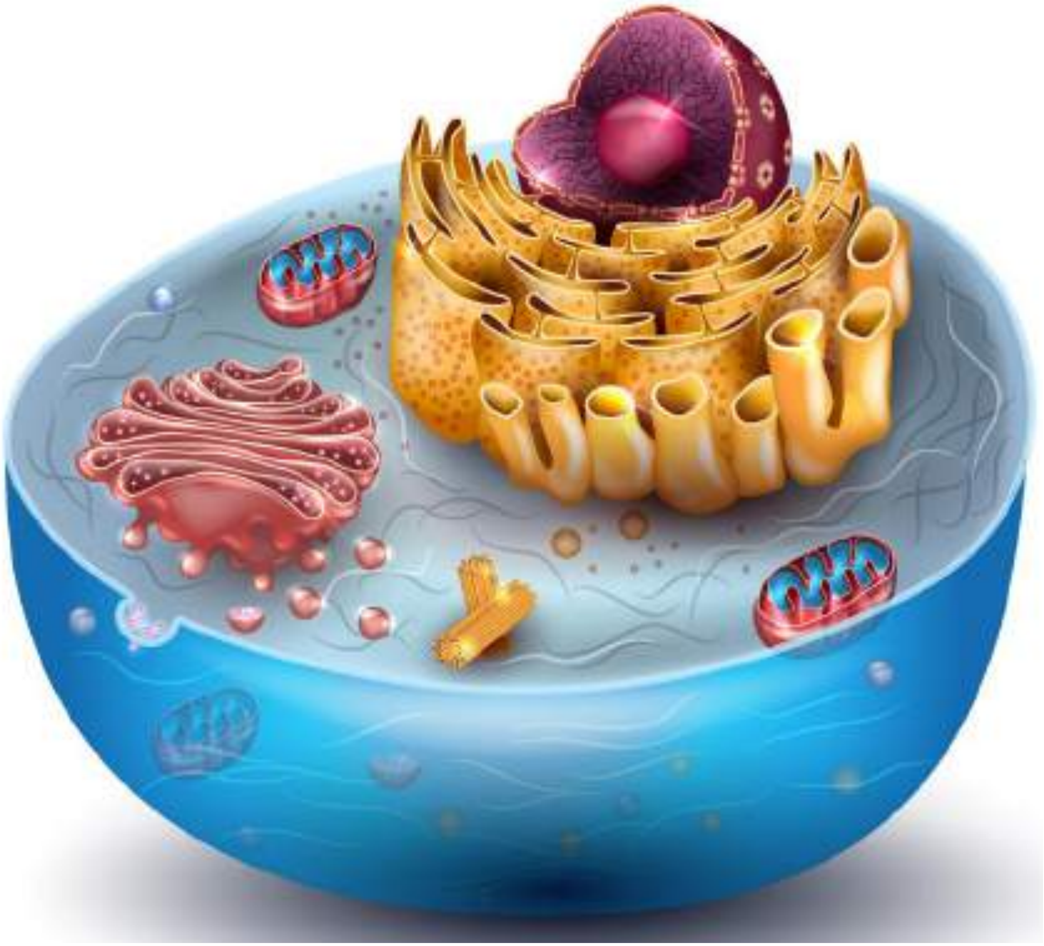


Nucleus

"Command center"

Stores, protects most of DNA

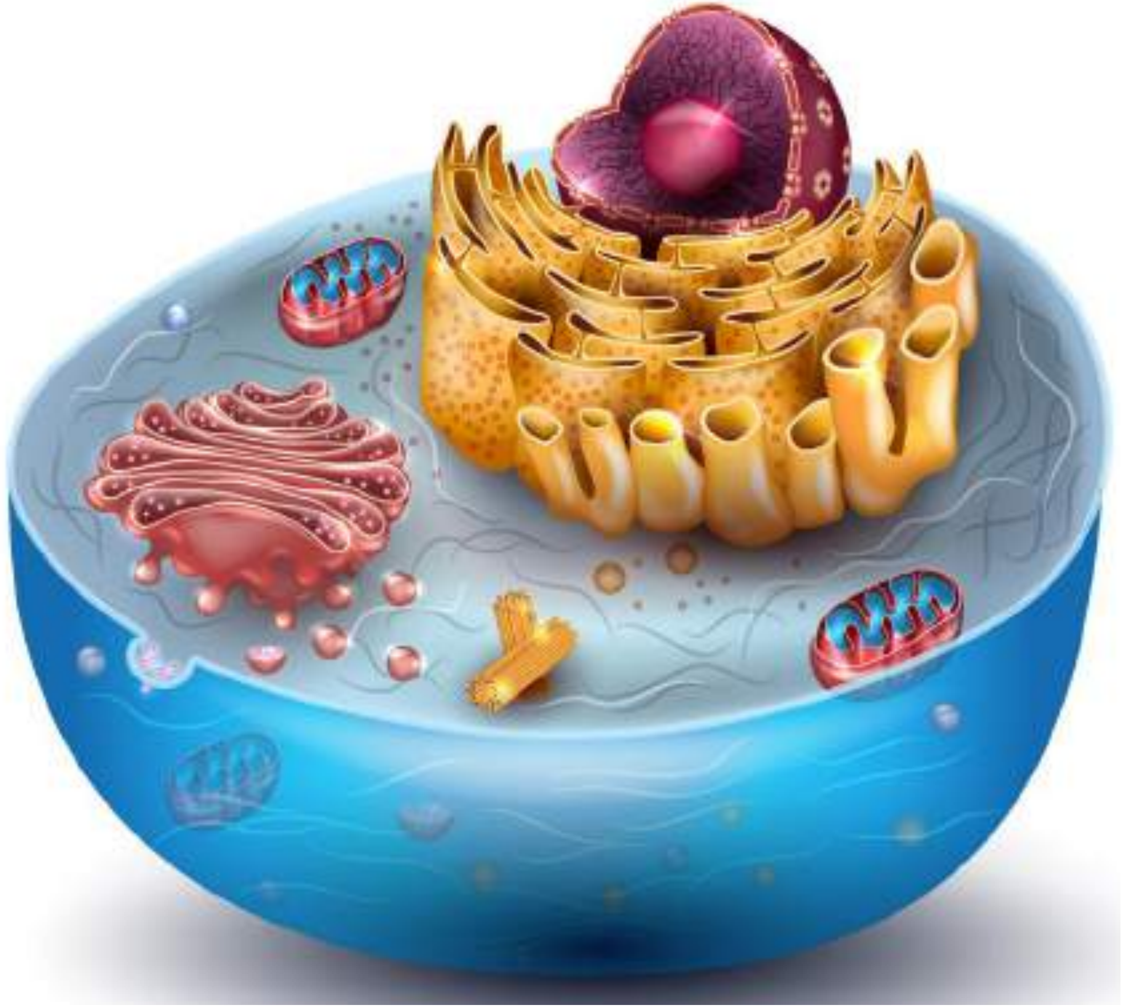
Nucleolus makes RNA & ribosomes



Ribosomes

Protein factories- use DNA instructions to make proteins

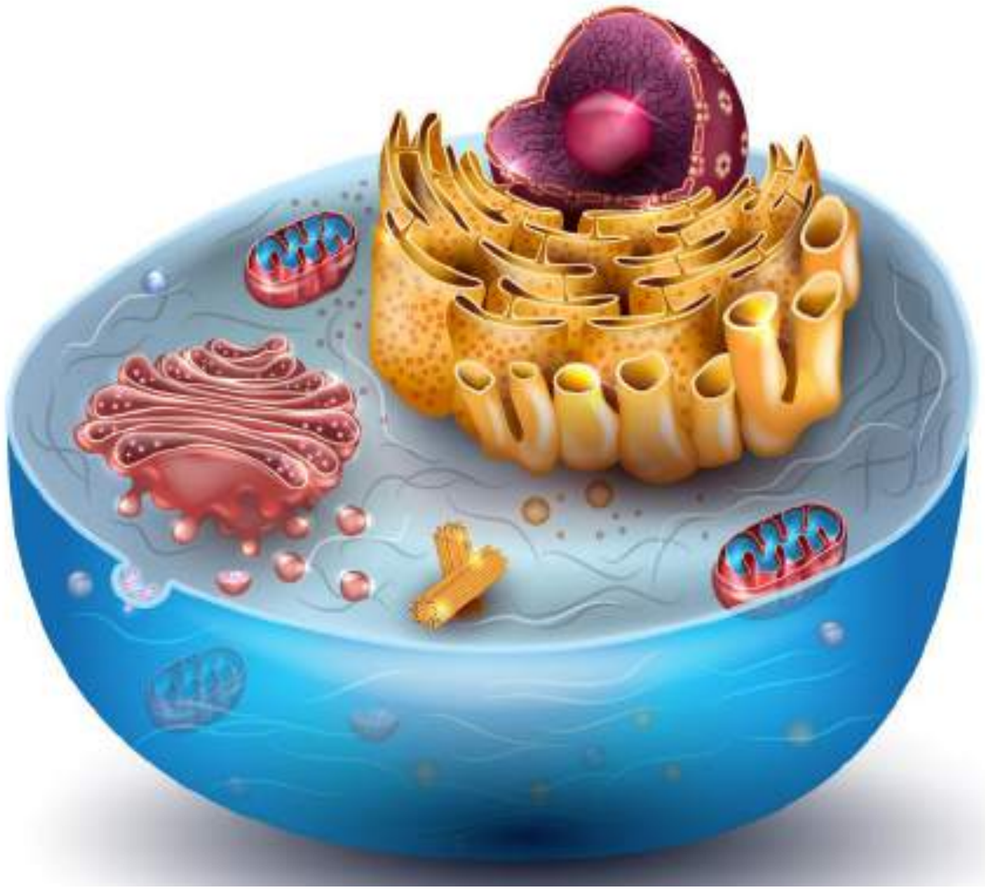
Made of RNA & proteins



Endoplasmic Reticulum

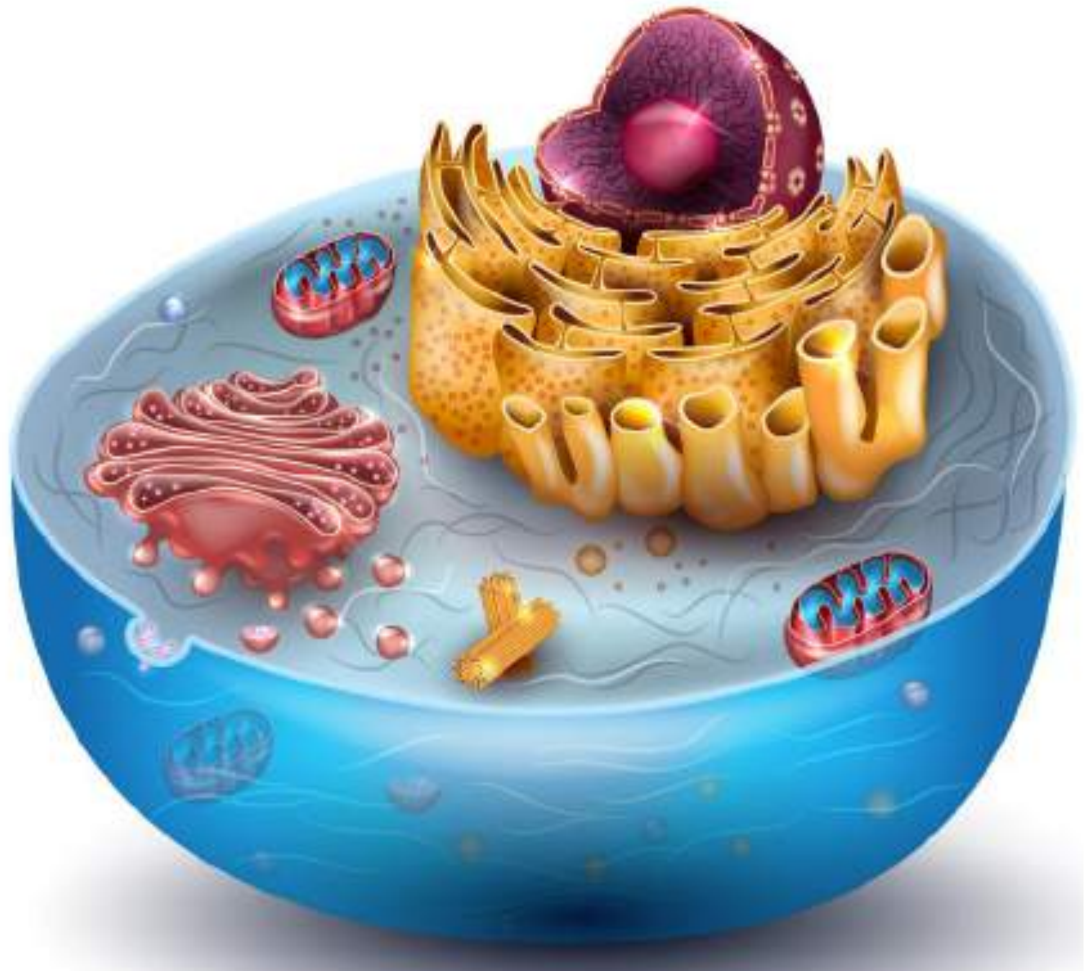
Functions:

- 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)

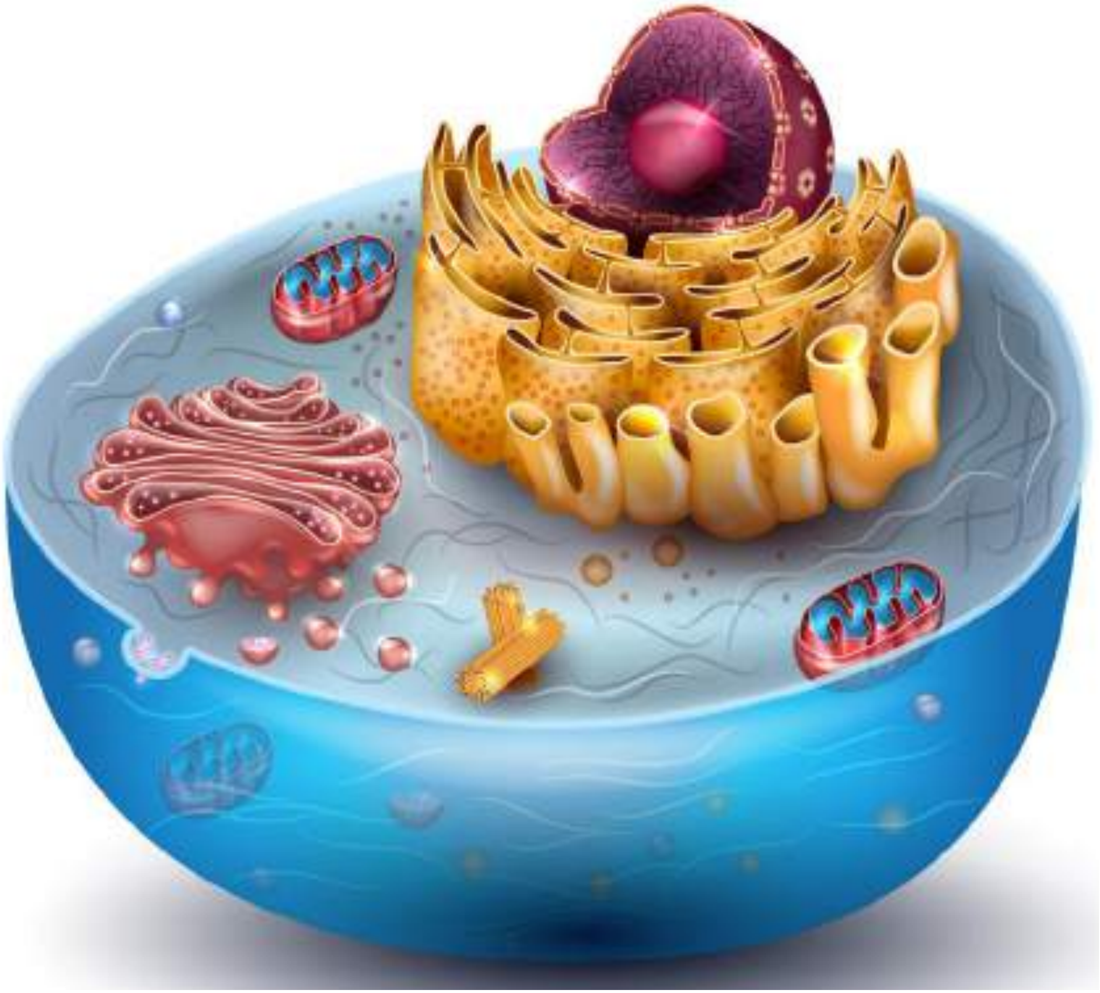
Cytoskeleton

Support scaffolding for cells

Duties:

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

Centrosomes: organizes some of cytoskeleton, & cell division



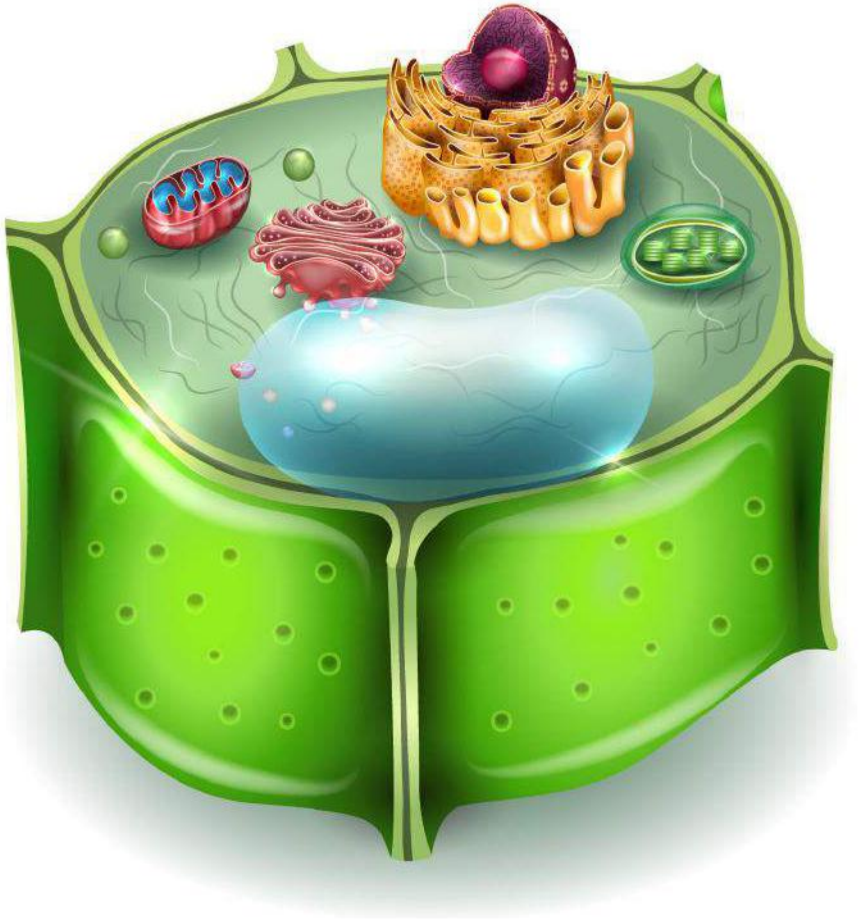
Cell Wall

Found in plants, fungi, bacteria

Rigid, structural support

Common components:

- cellulose
- pectin
- chitin



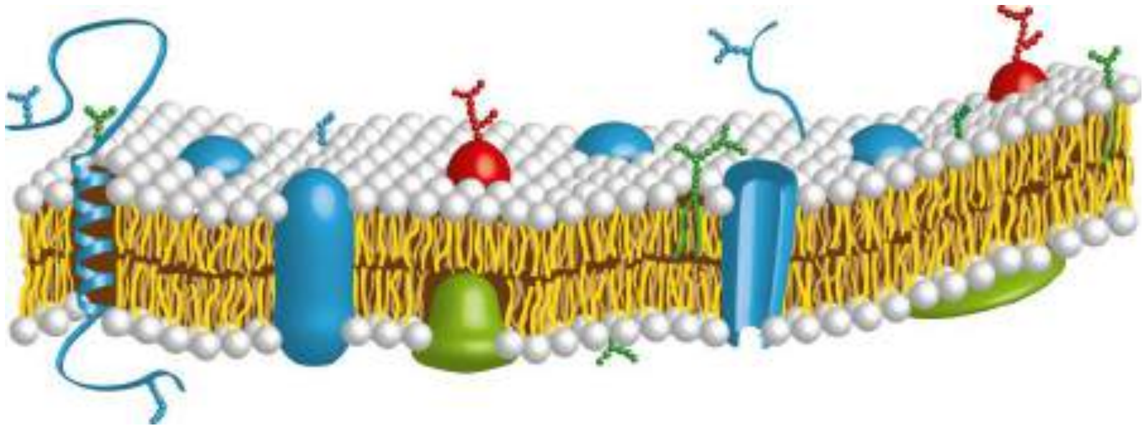
1.2.2 Properties of Cell Membranes

Membranes

Boundary b/w inside of cell & surroundings

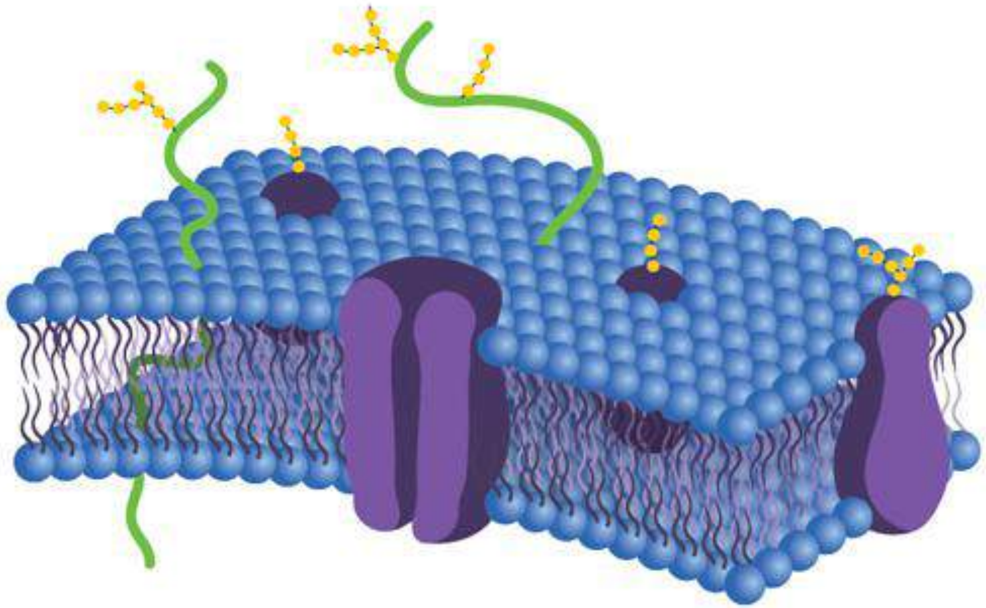
Selectively permeable

Phospholipid bilayer w/ proteins, other lipids, hybrid molecules



Selective Permeability

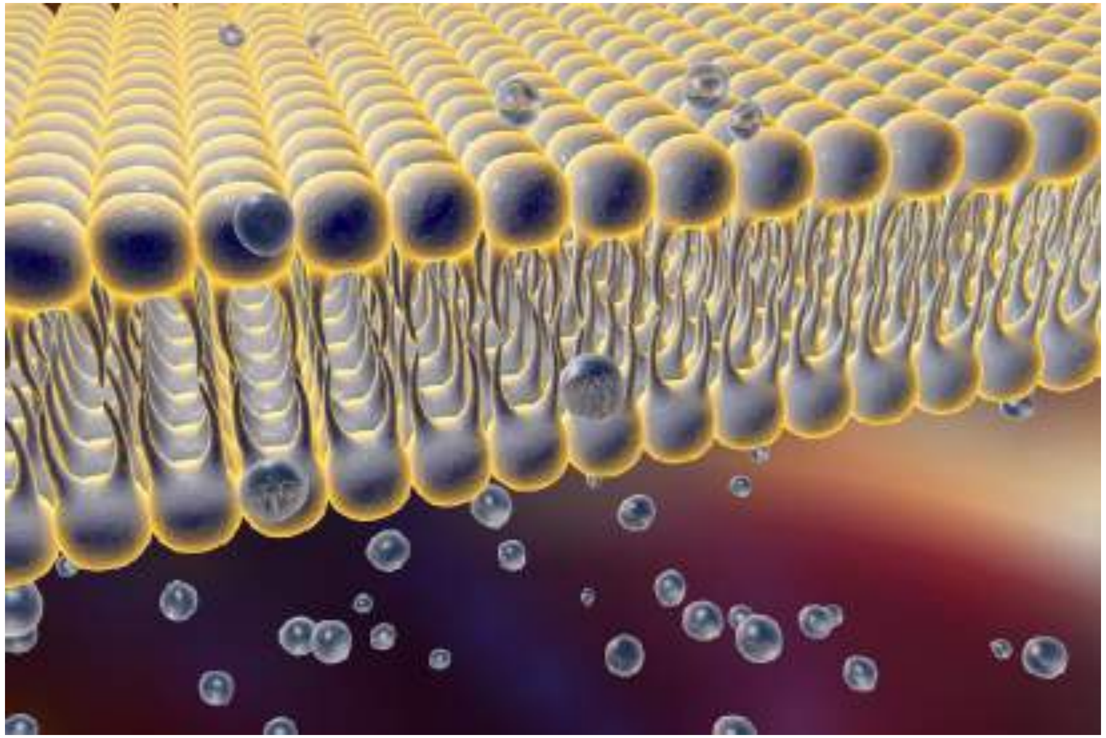
Membranes regulate cell traffic by only allowing some things to pass freely, transporting others, preventing still others



Membrane Transport

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

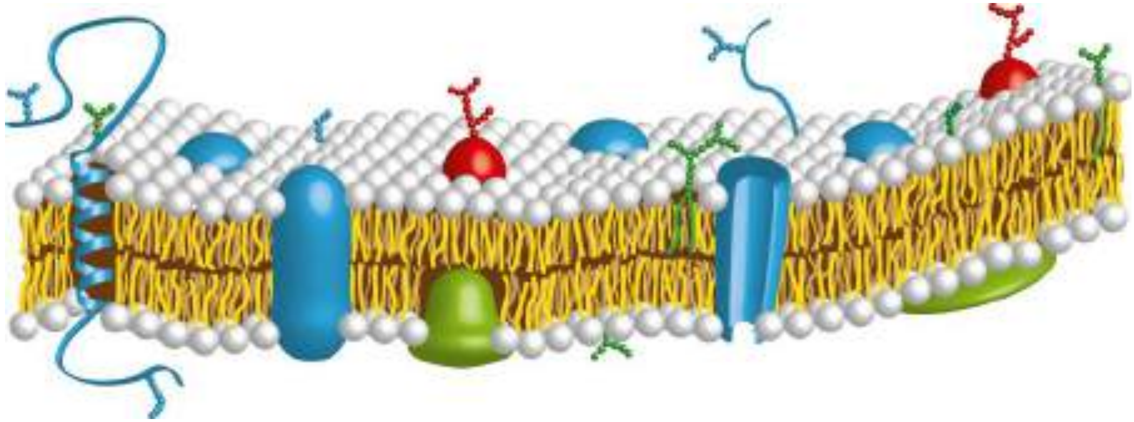
Active transport: movement across membrane requiring energy and “doorway” protein



Passive Transport: Diffusion

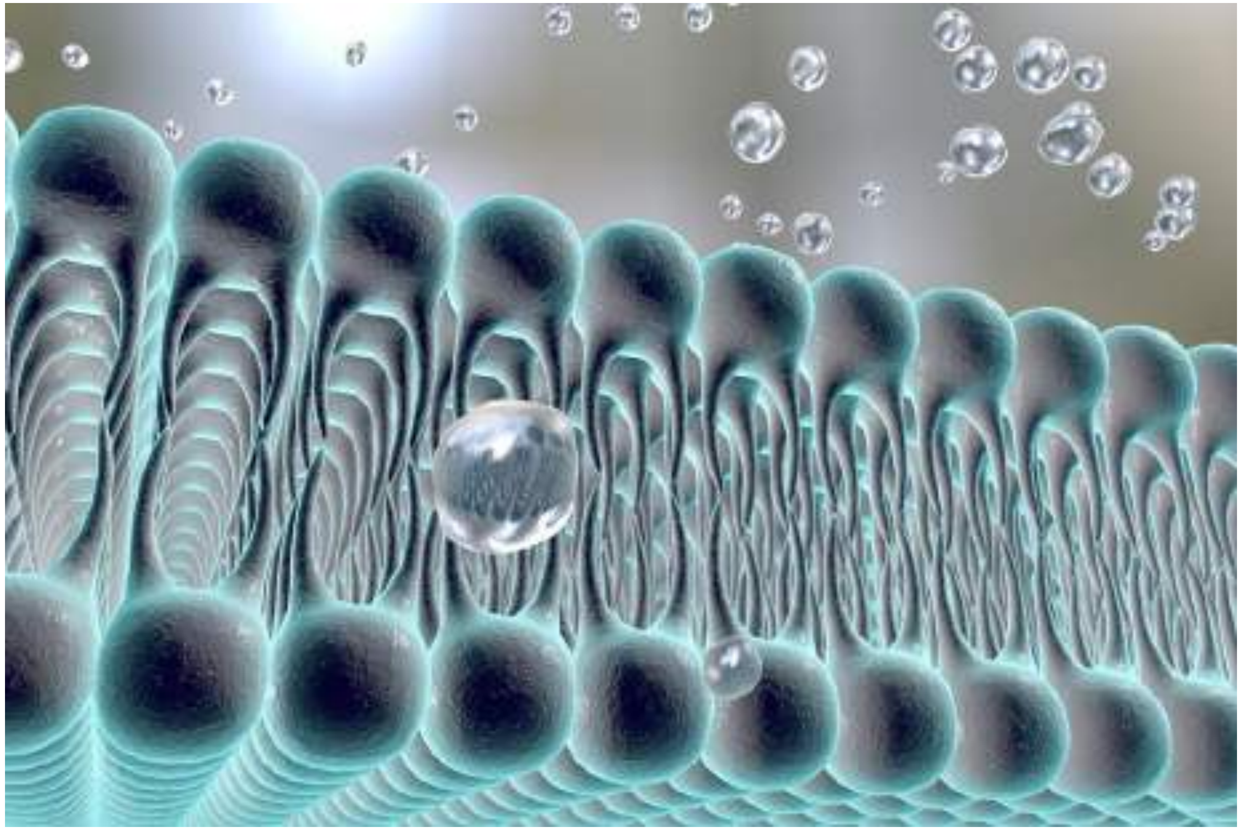
Movement of molecules from higher to lower concentrations

- each molecule moves randomly
- no energy required; spontaneous



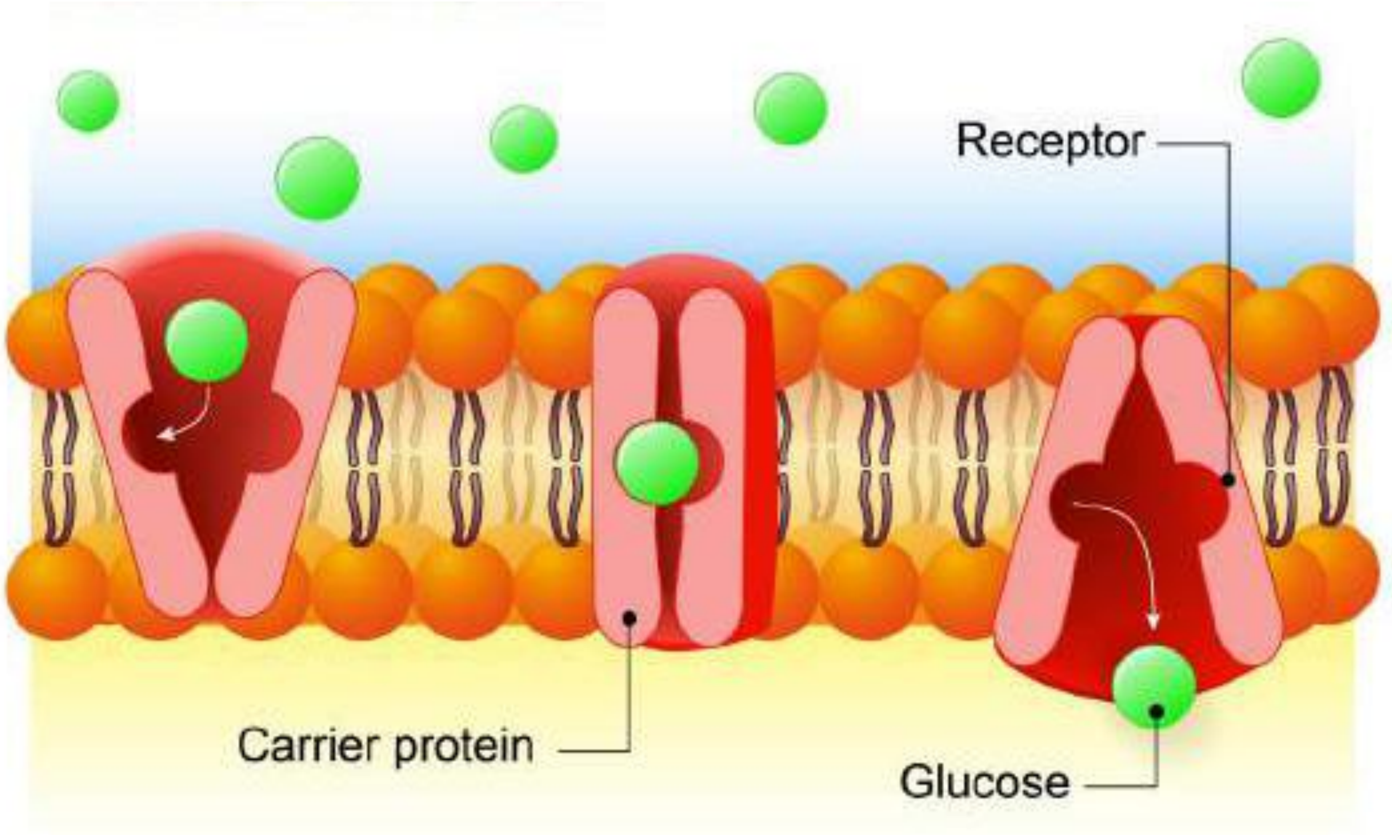
Passive Transport: Osmosis

Diffusion of water across membrane from higher to lower concentrations



Passive Transport: Facilitated Diffusion

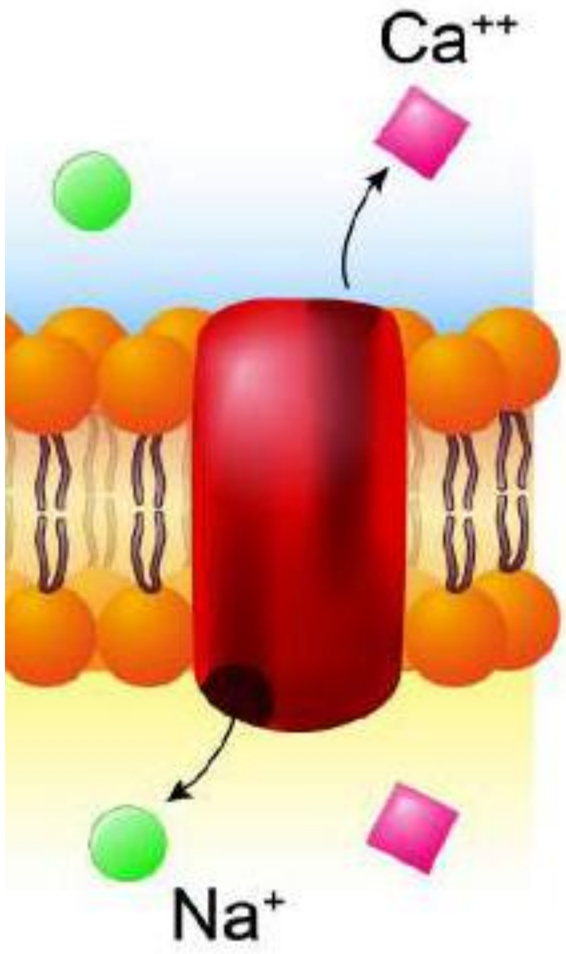
Diffusion w/ help of "doorway" proteins- very specific



Active Transport

Requires energy and "doorway" protein

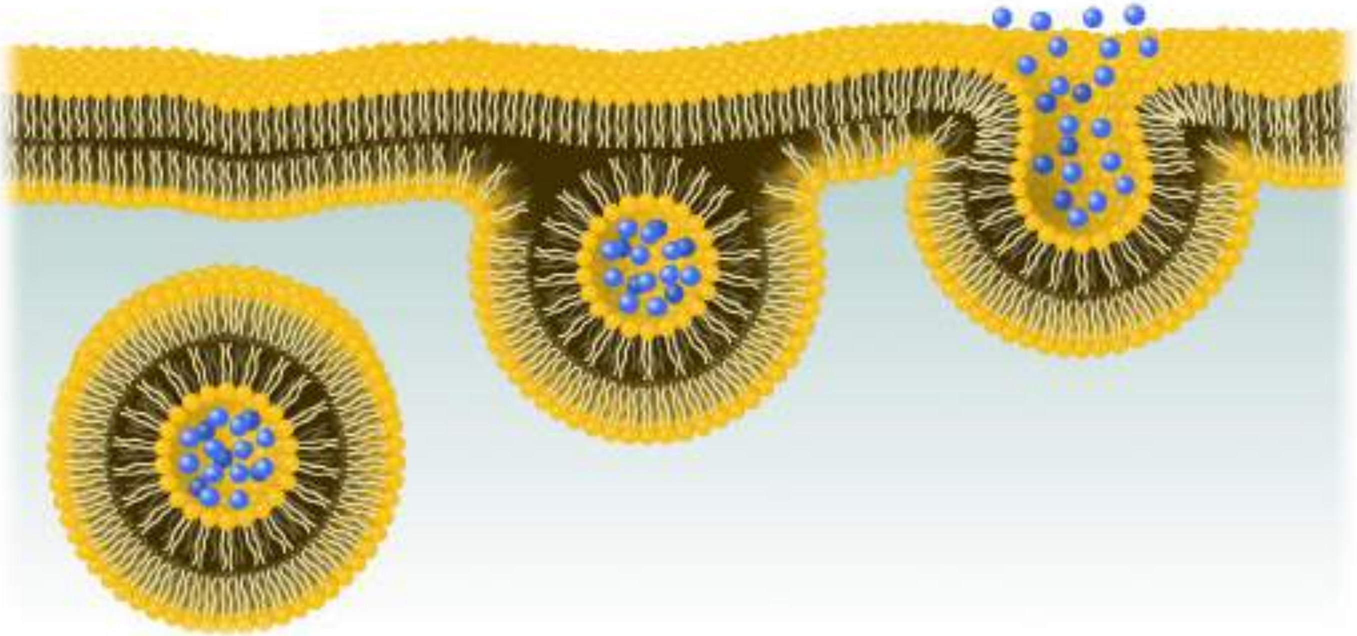
Useful for moving molecules against their concentration gradients



Active Transport: Bulk Transport

Large molecules can’t pass through membrane

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



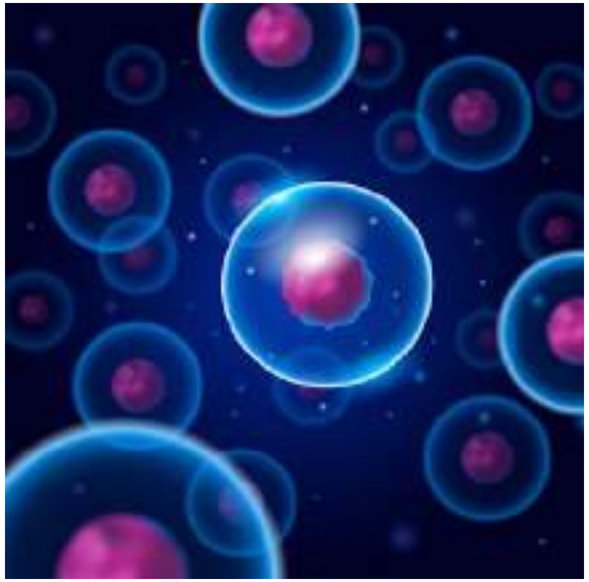
1.2.3 Comparison of Prokaryotic and Eukaryotic Cells

Cells

Two types of cells:

1. Prokaryotic
2. Eukaryotic

All living things are either prokaryotes or eukaryotes



Prokaryotic Cells

Bacteria & Archaea

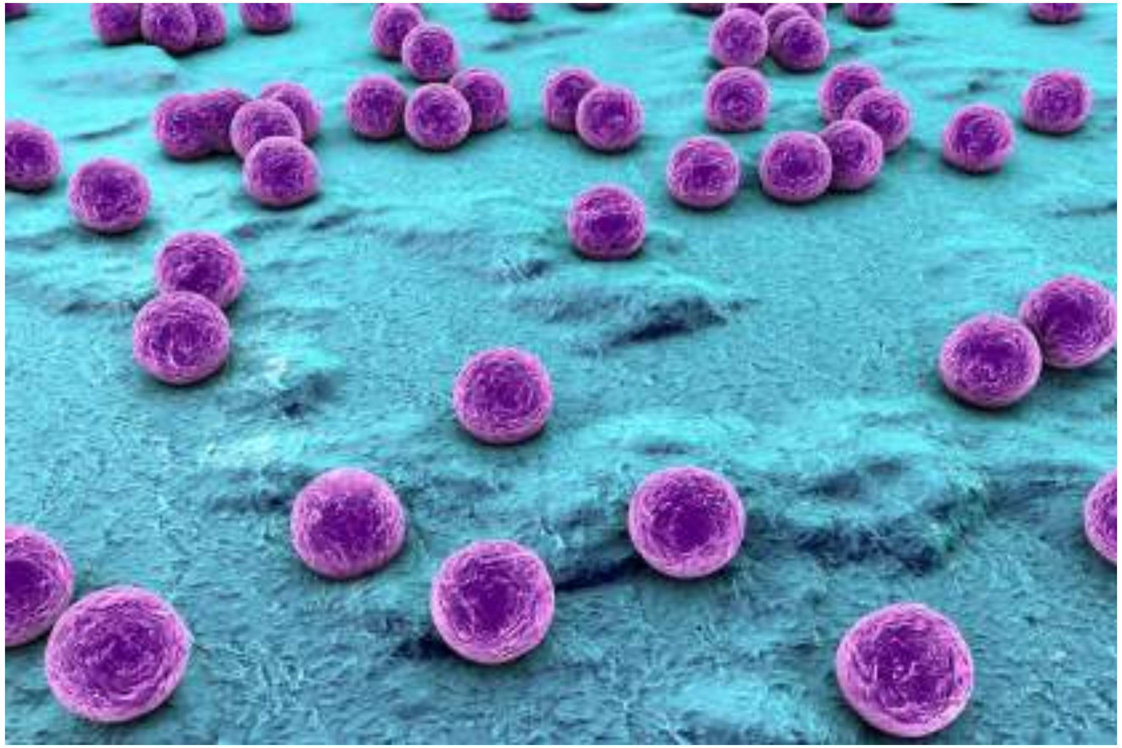
Most ancestral living things

Like all cells, they have:

- cell membrane
- cytoplasm

Unlike eukaryotic cells, they have:

- no nucleus
- no organelles



Prokaryotic Cells

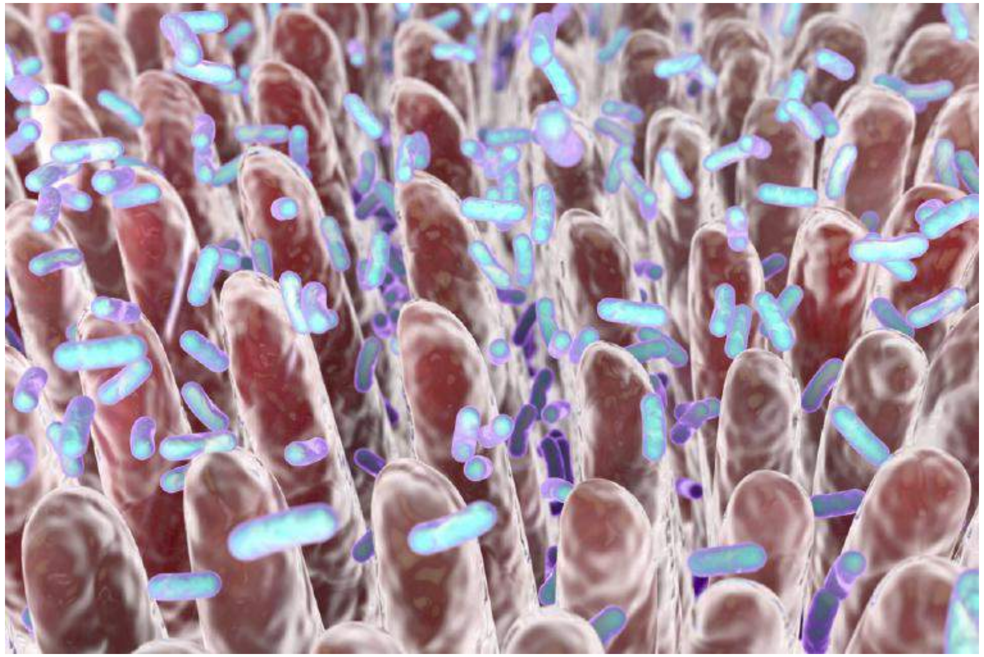
All prokaryotes are unicellular

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

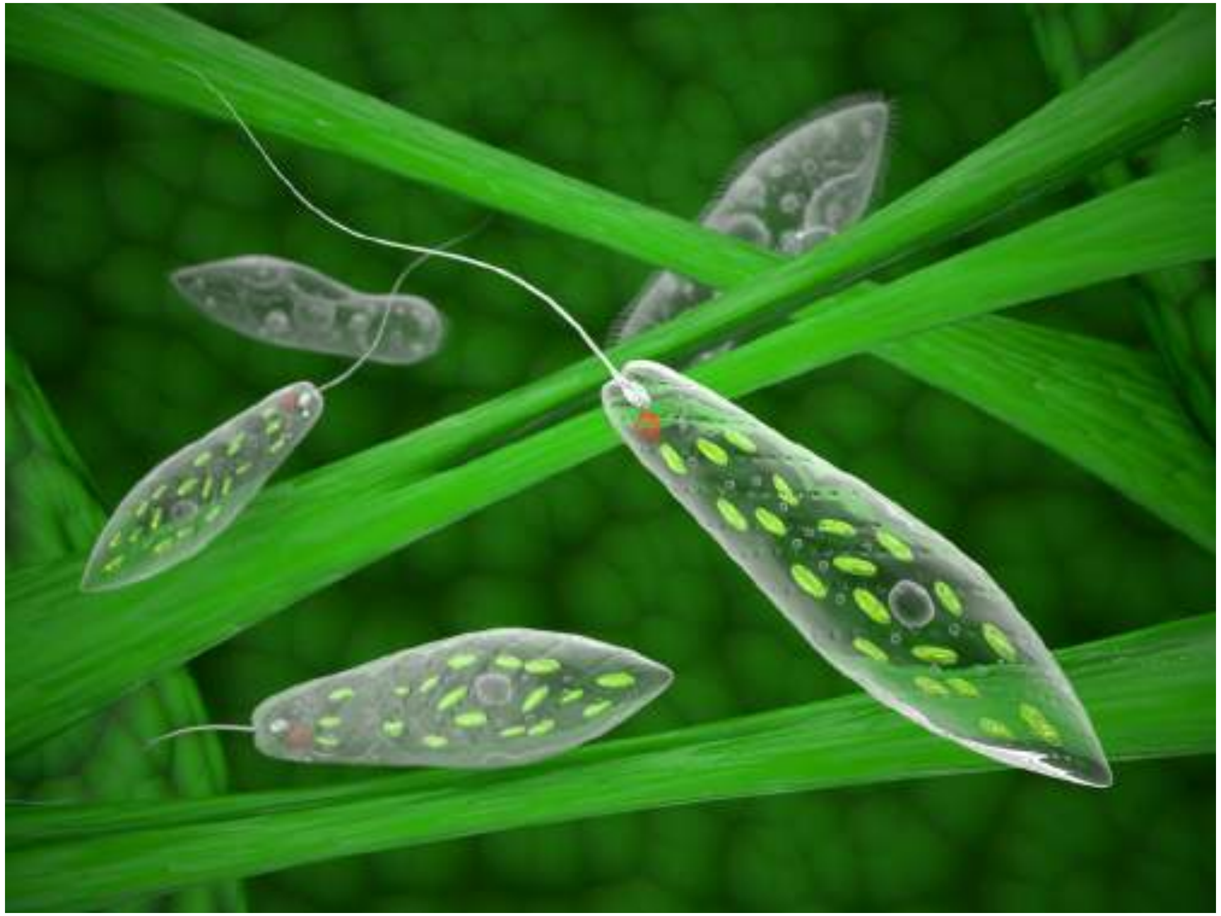
Unlike prokaryotes, they all have:

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

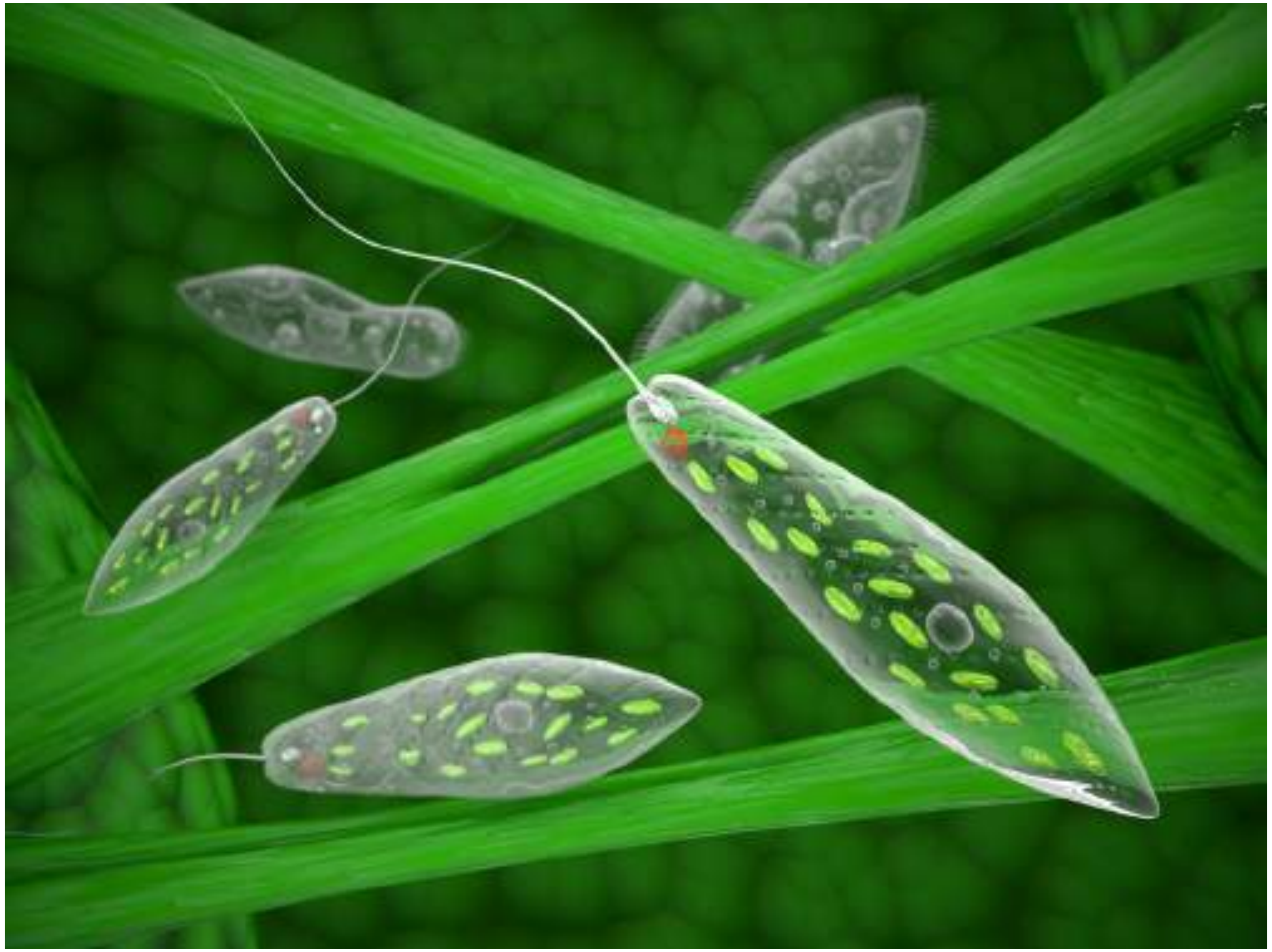
Some have:

- cell walls
- locomotor structures

Unlike prokaryotes, they can be uni- or multicellular



Eukaryotes



1.3 Enzymes

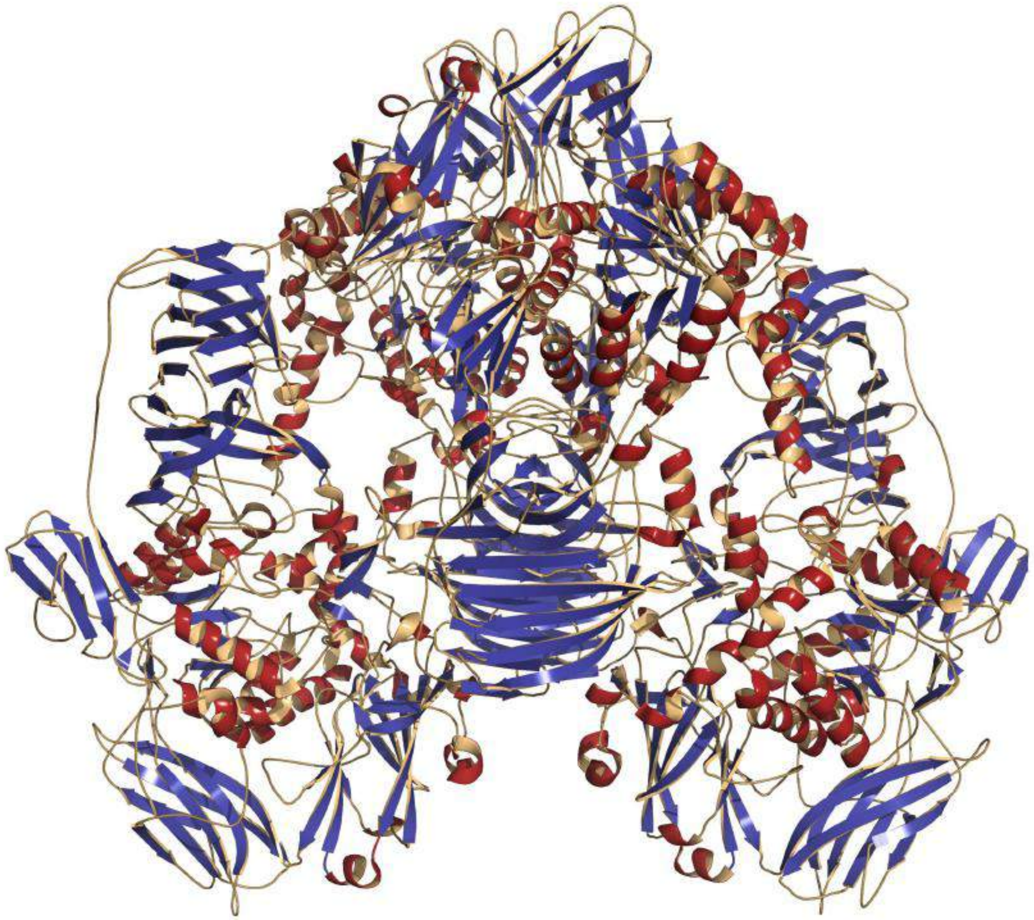
Enzymes

1.3.1- Enzyme-Substrate Complex

1.3.2- Roles of Coenzymes

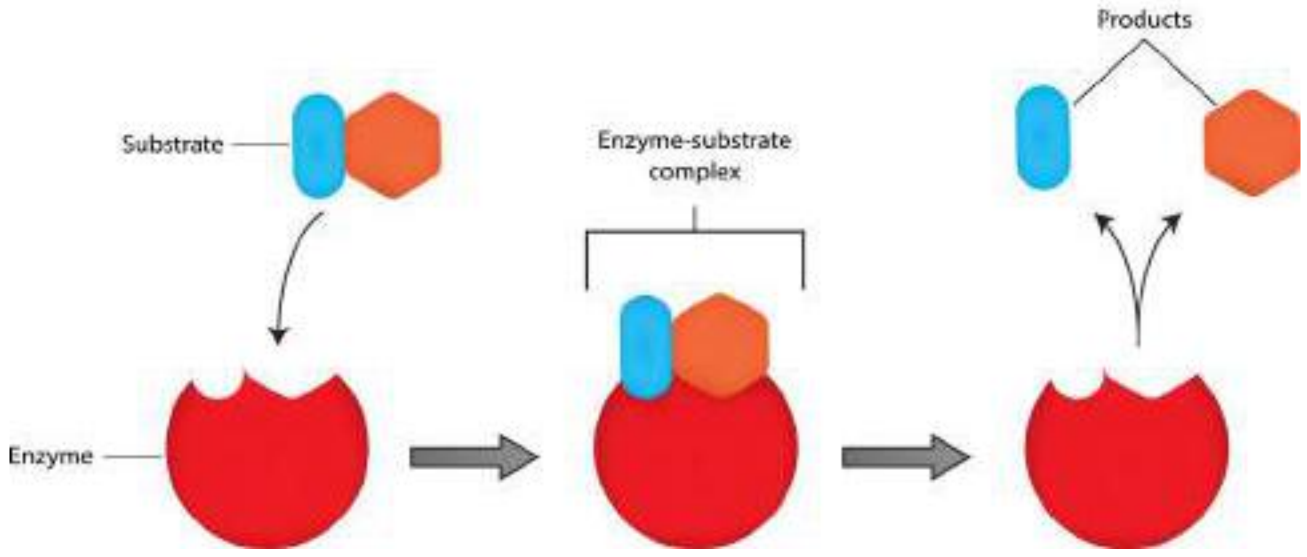
1.3.3- Inorganic Cofactors

1.3.4- Inhibition & Regulation



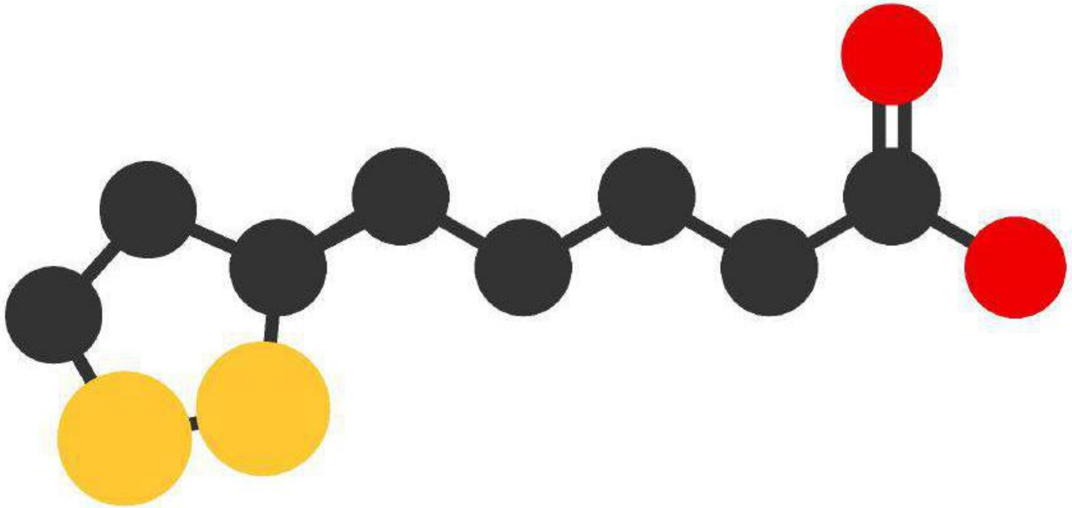
Enzyme-Substrate Complex

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



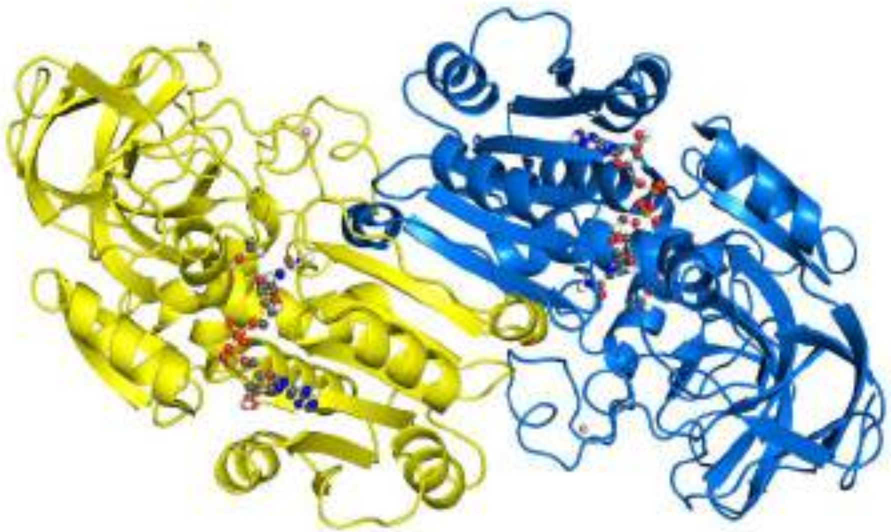
Roles of Coenzymes

- cofactors
- coenzymes



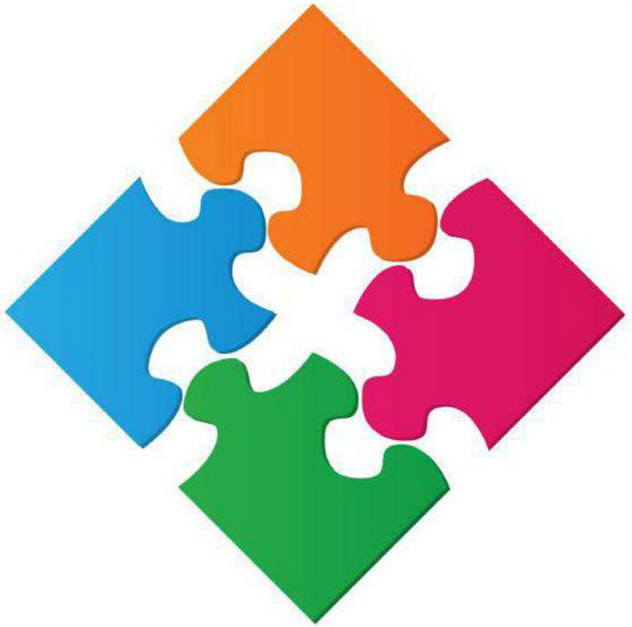
Inorganic Cofactors

- cofactors & coenzymes
- examples of inorganic cofactors



Inhibition & Regulation

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

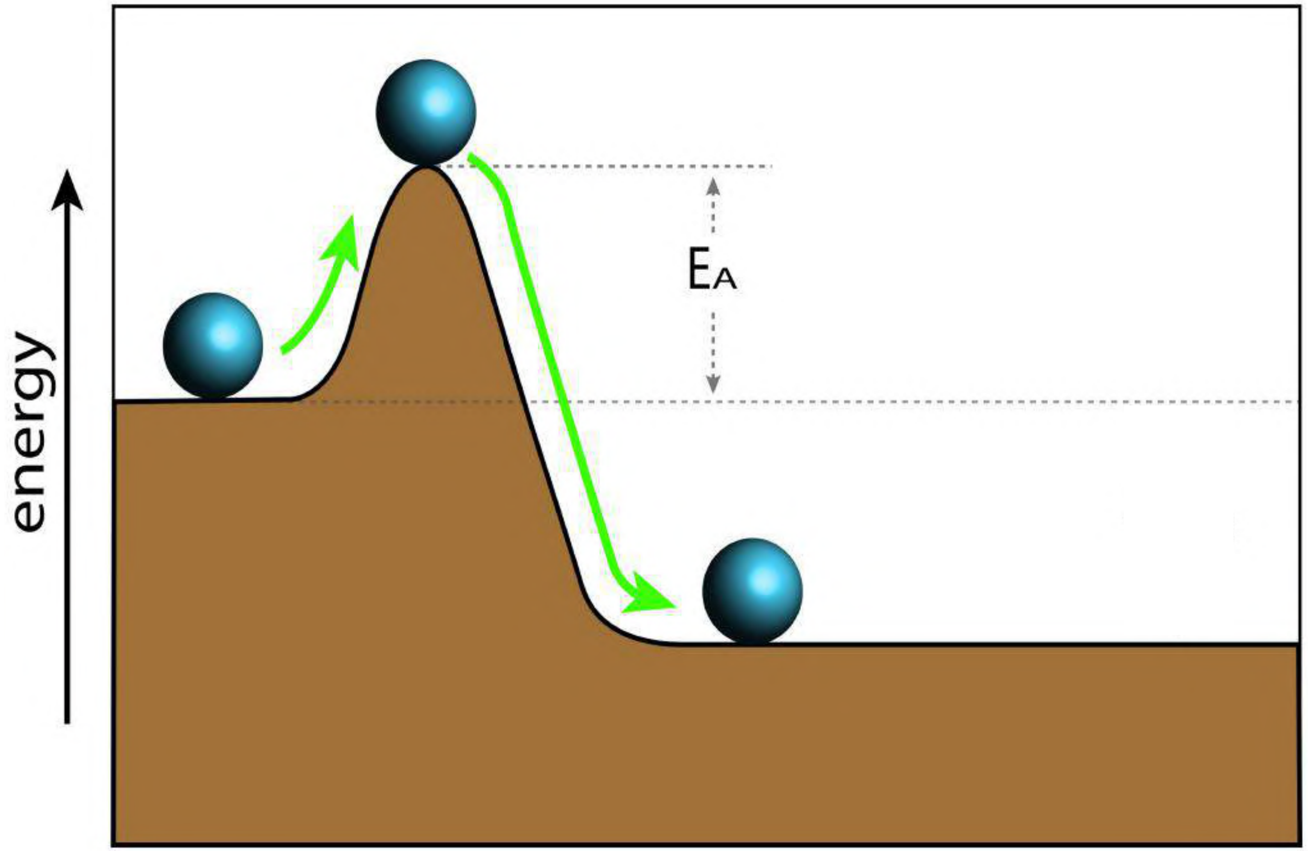


1.3.1 Enzyme- Substrate Complex

Activation Energy

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

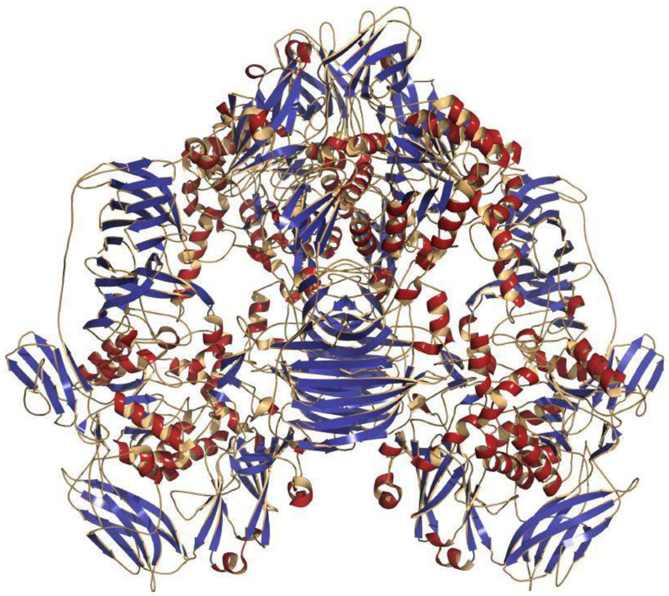
- **before new bonding can occur, existing chemical bonds must be broken**
- **rate of reactions determined by E_a**

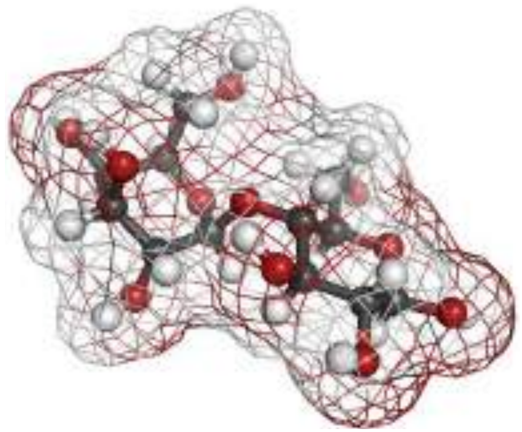


Enzymes

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



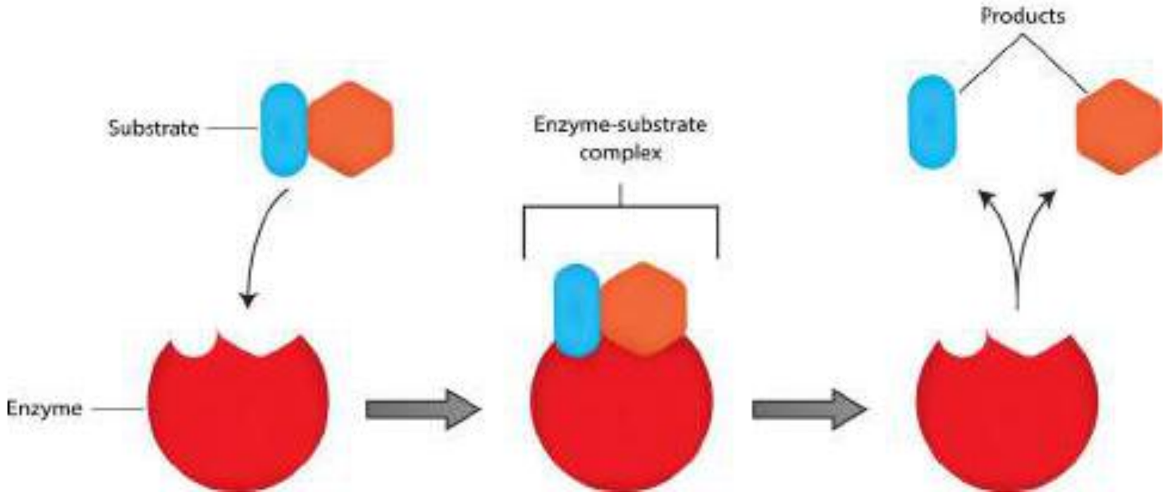


Enzymes

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

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

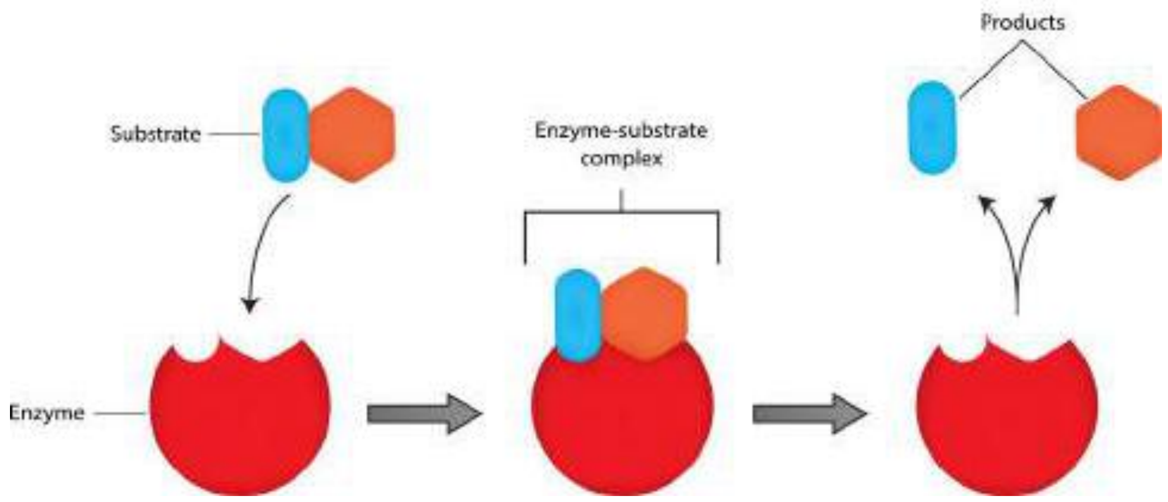
Enzyme and substrate fit together like hand in glove, forming an enzyme-substrate complex



Enzymes

Some enzymes break substrates into smaller pieces

Other enzymes join two substrates together into one molecule



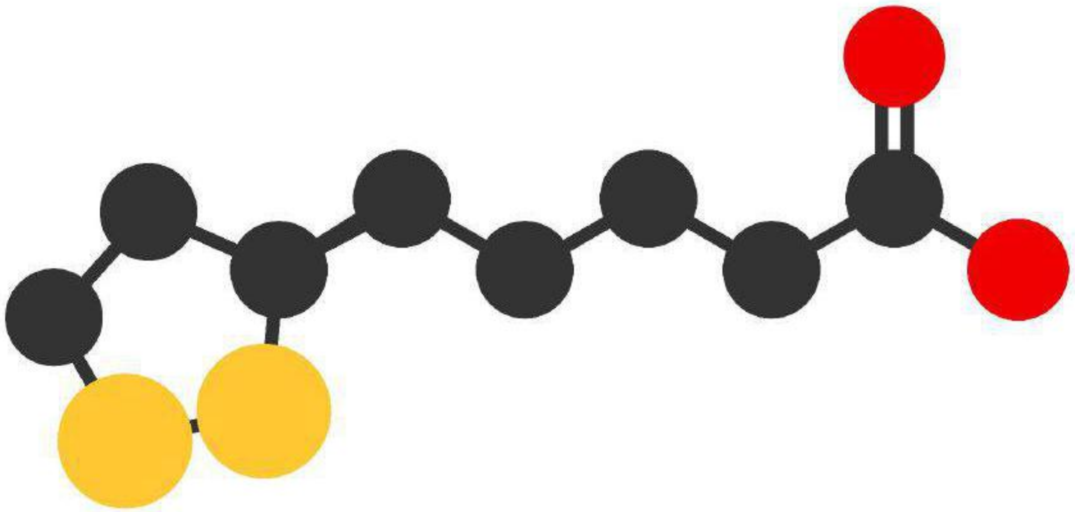
1.3.2 Roles of Coenzymes

Coenzymes

Some enzymes need help from other molecules called cofactors

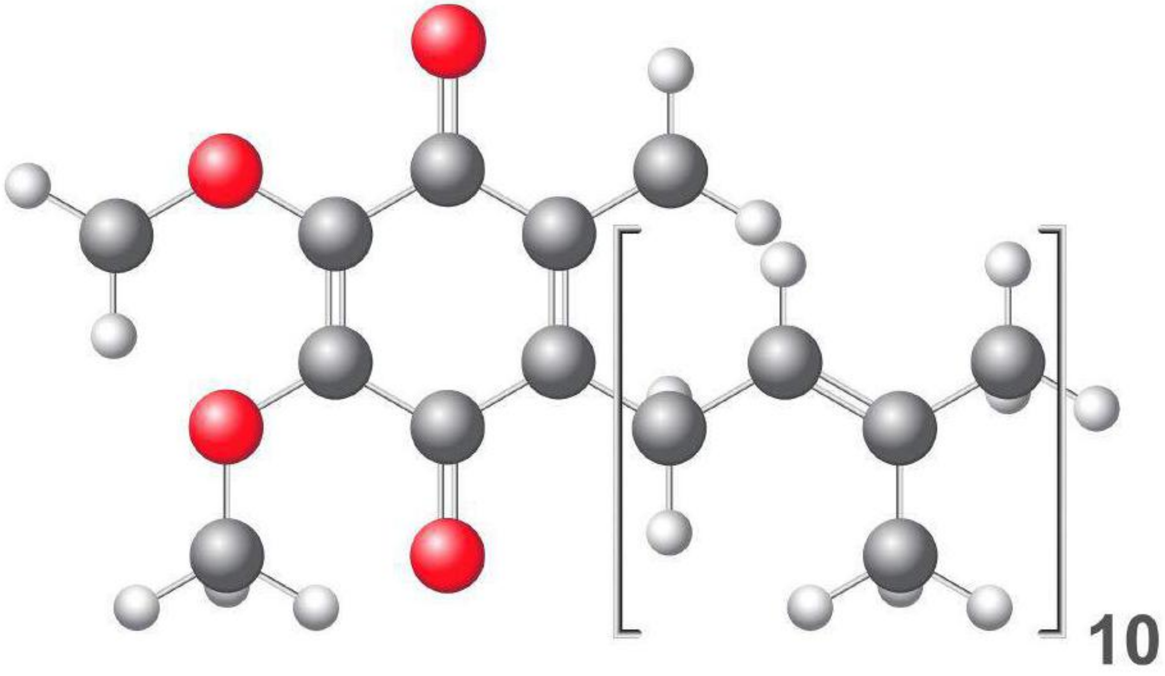
Cofactors can be inorganic (metals) or organic (coenzymes)

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)



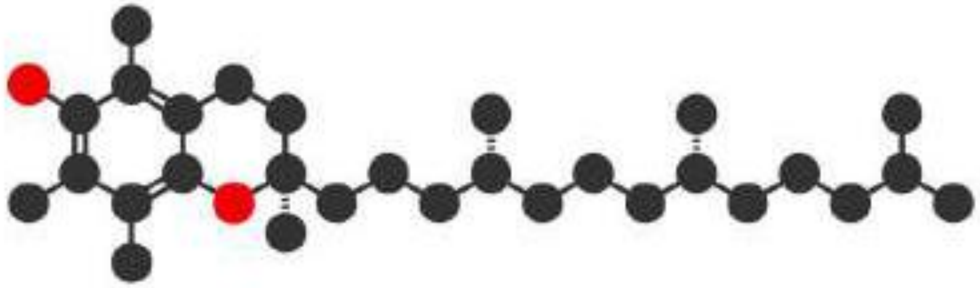
Two types:

- Cosubstrates are detachable
- Prosthetic groups are permanent

1.3.3 Inorganic Cofactors

Inorganic Cofactors

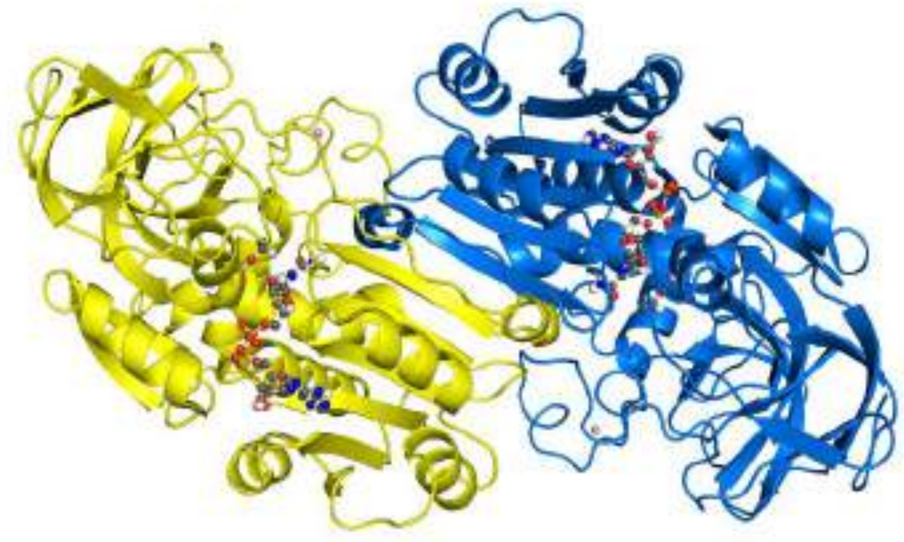
- Cofactors are non-protein molecules that are necessary for some enzymes to function properly



- 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)

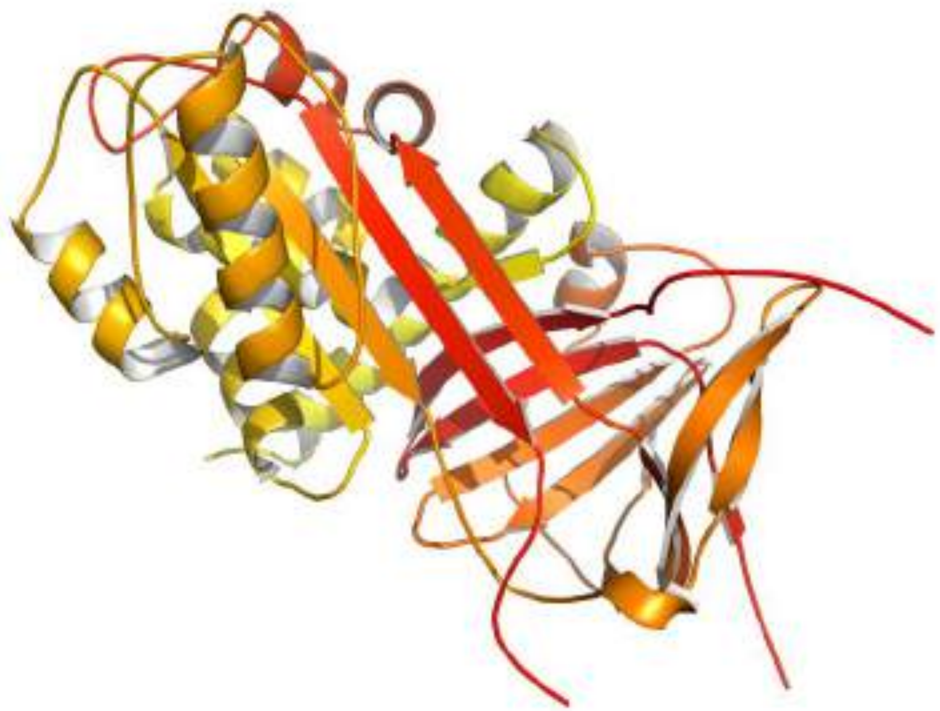


1.3.4 Inhibition & Regulation

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

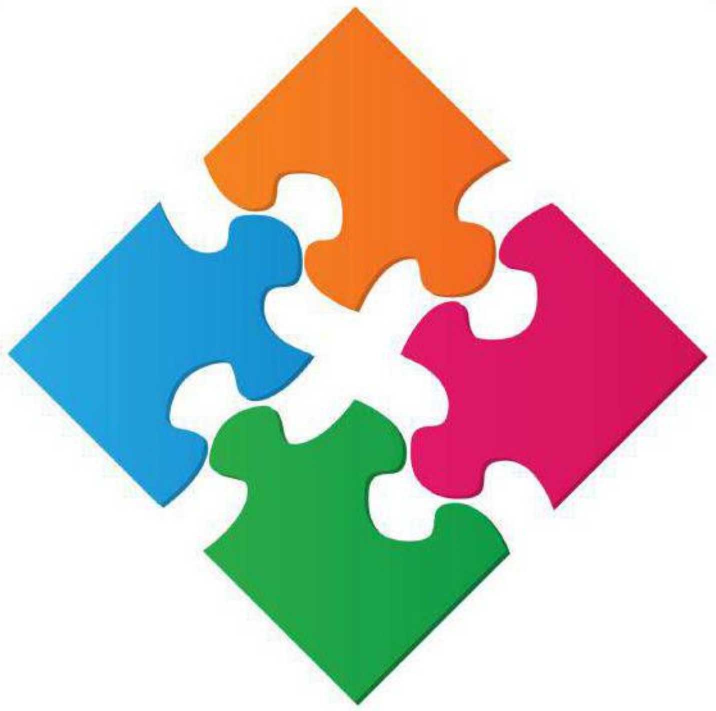
- Example: a2-antiplasmin (below) stops enzymes from dissolving blood clots, helpful for treating bleeding disorders like hemophilia



Inhibition

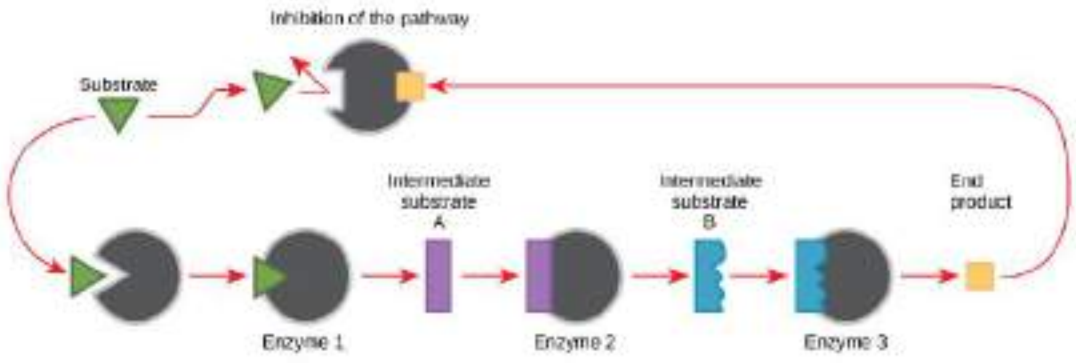
- Enzyme activity is also inhibited when the shape of the enzyme active site is changed by the environment, causing it to stop working
    - temperature
    - pH

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



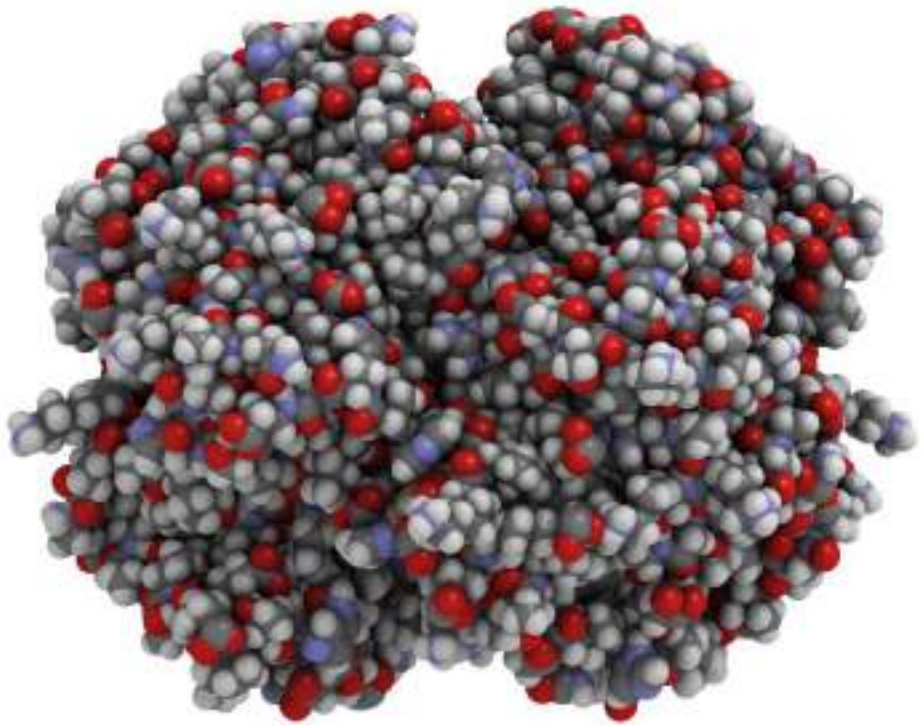
Regulation

- 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

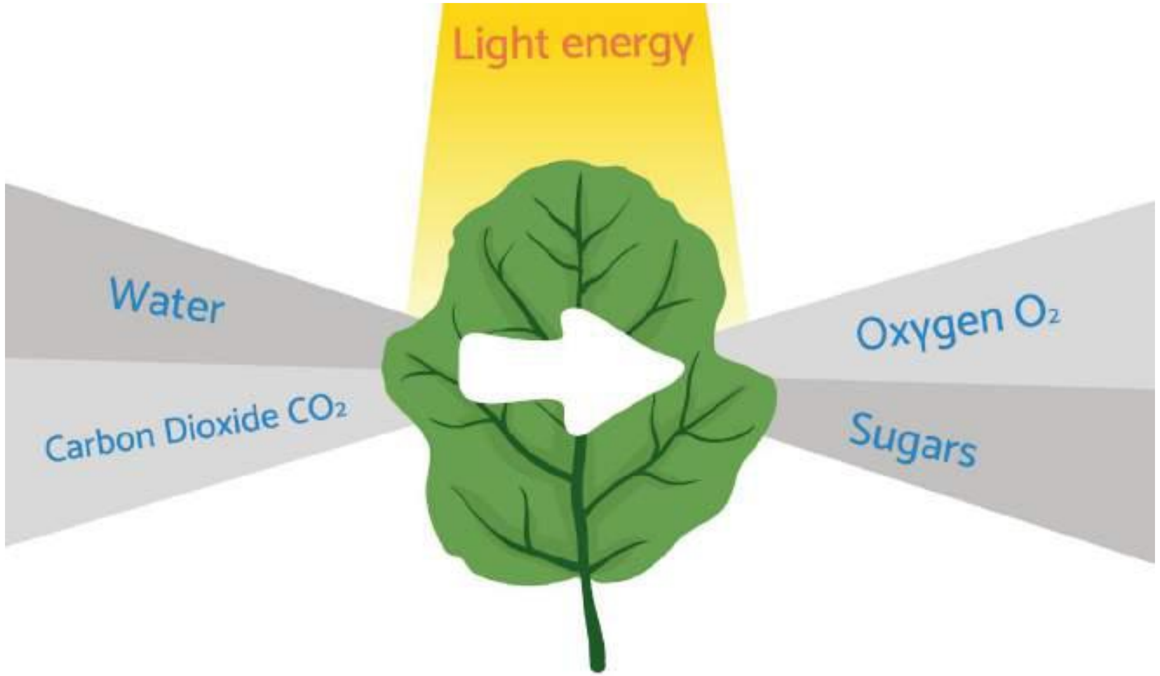


1.4 Energy Transformations

Energy Transformations

1.4.1- Cellular Respiration

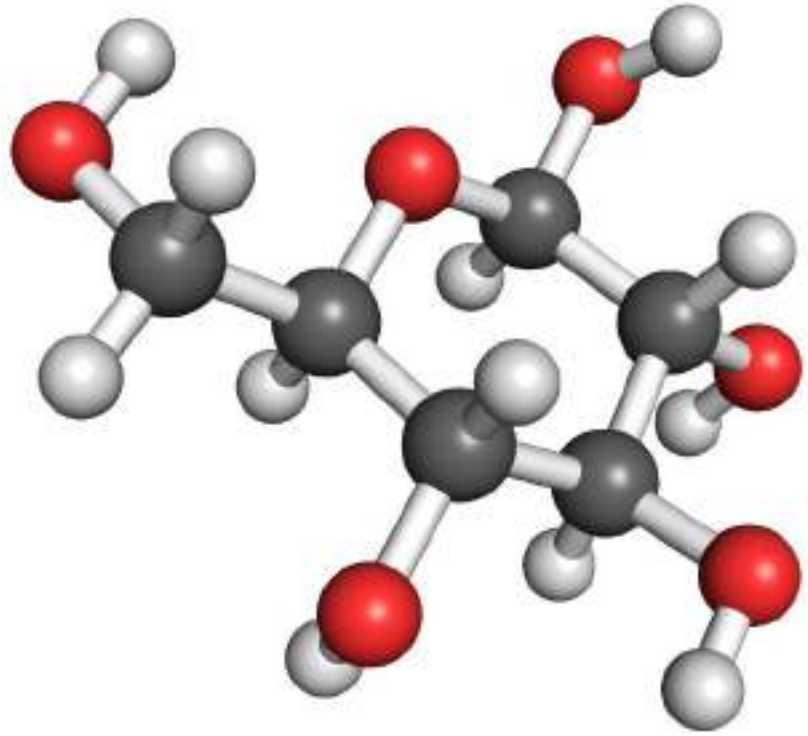
1.4.2- Photosynthesis



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

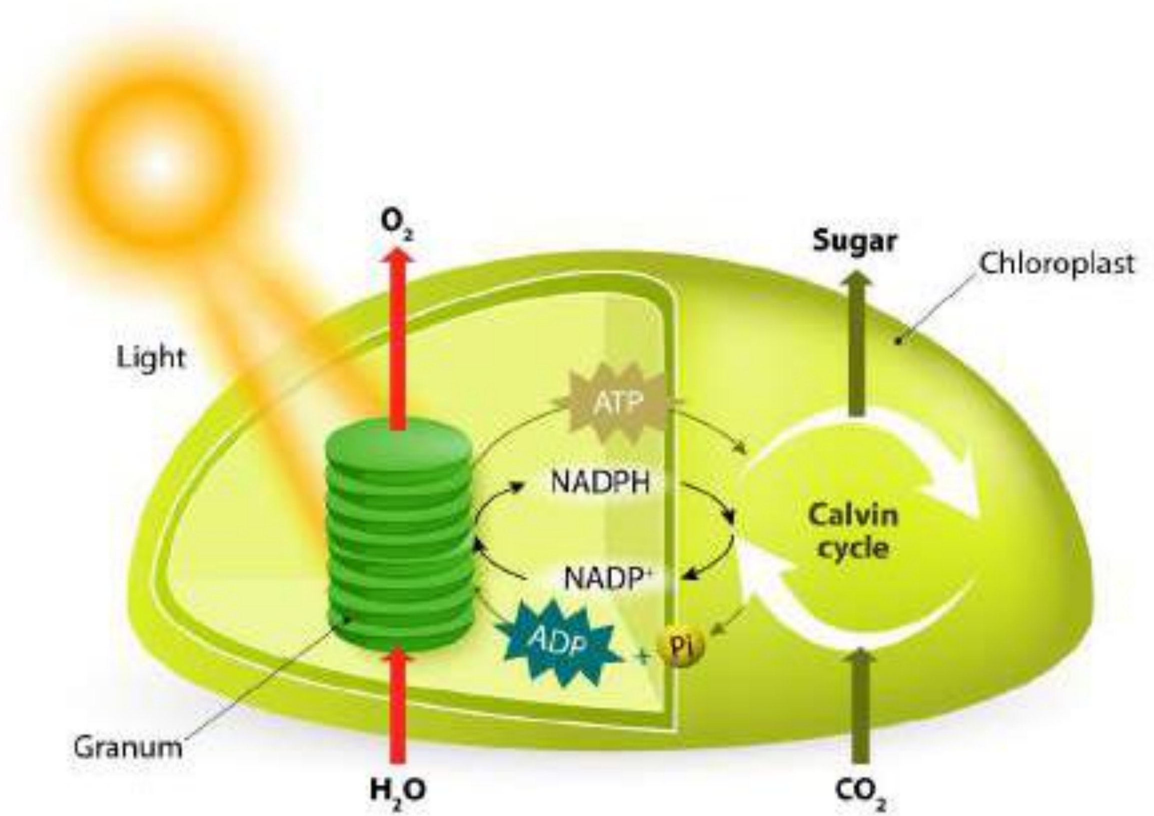
Cellular Respiration

- 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

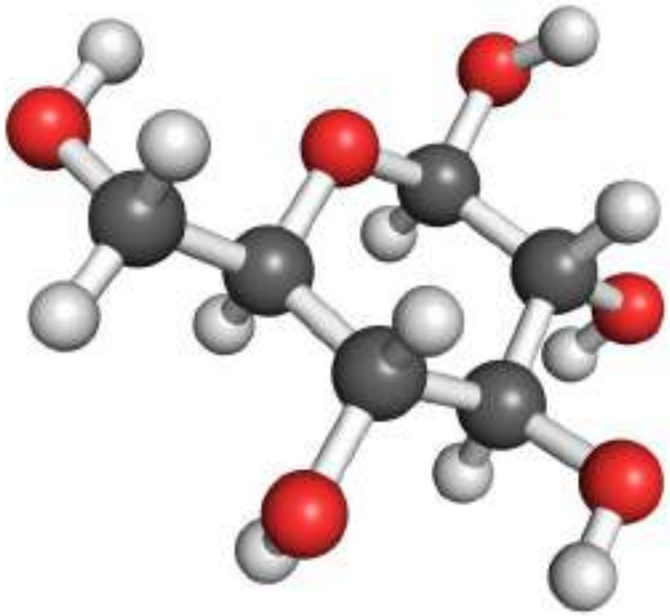
Cellular Respiration

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

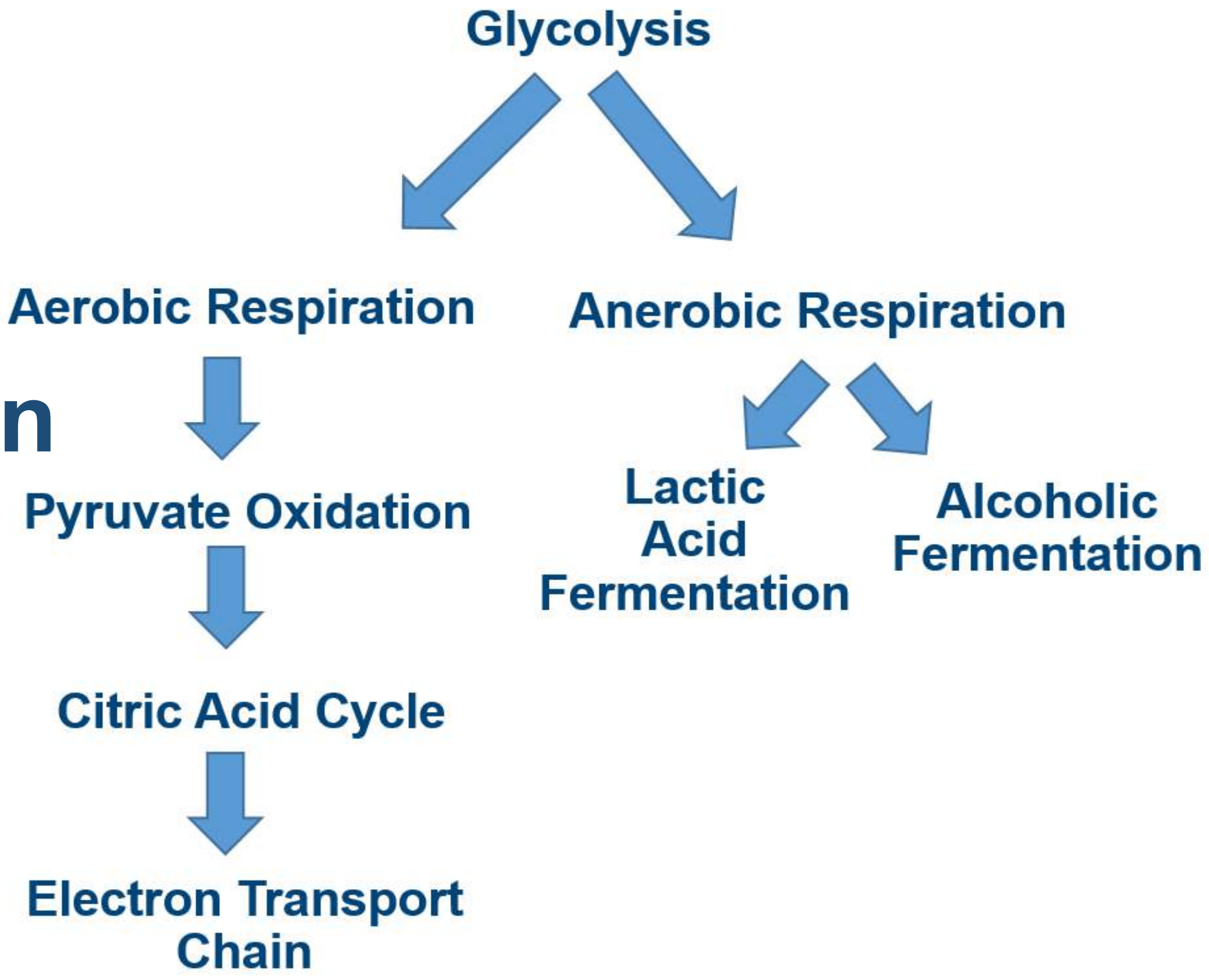
ATP used any time energy needed in organism

Two types:

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



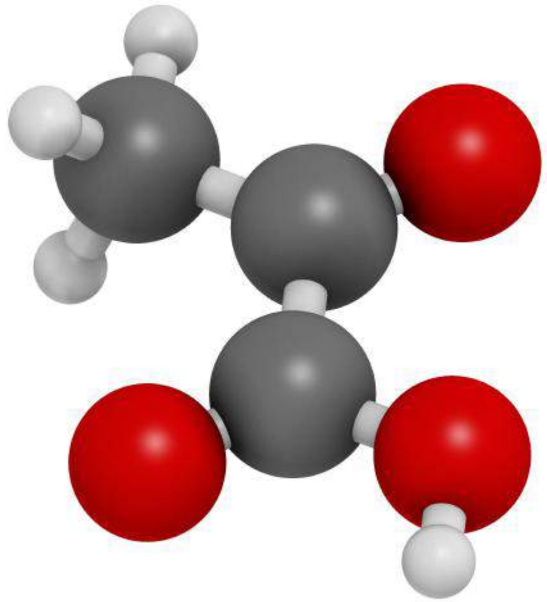
Cellular Respiration



Glycolysis

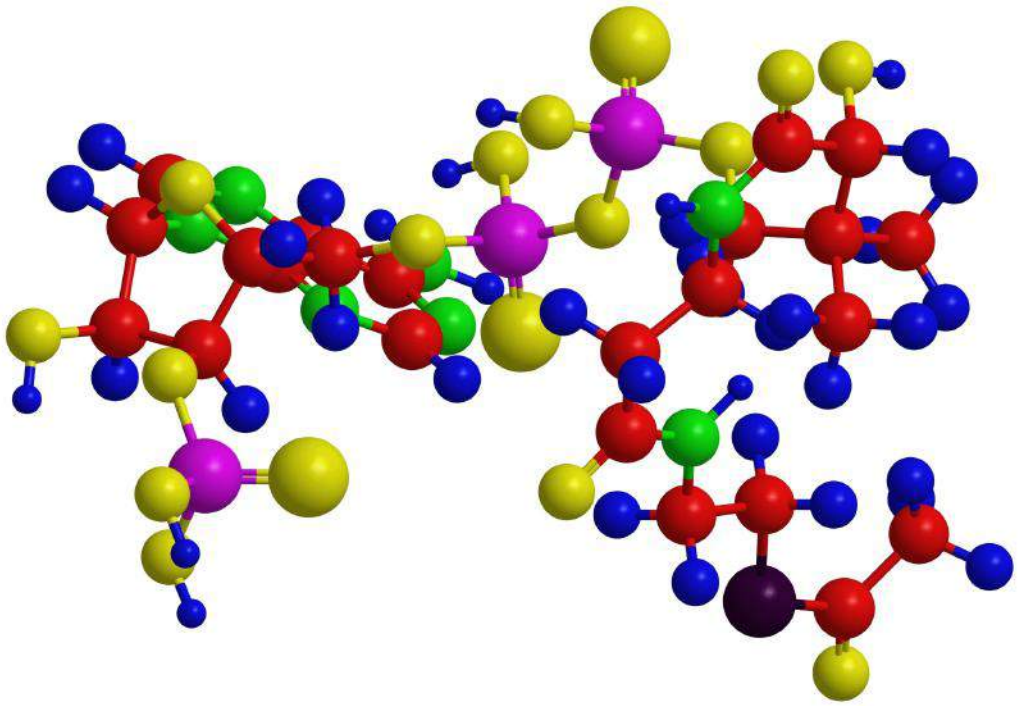
Glycolysis is first step in all organisms, whether doing aerobic or anaerobic respiration

- 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



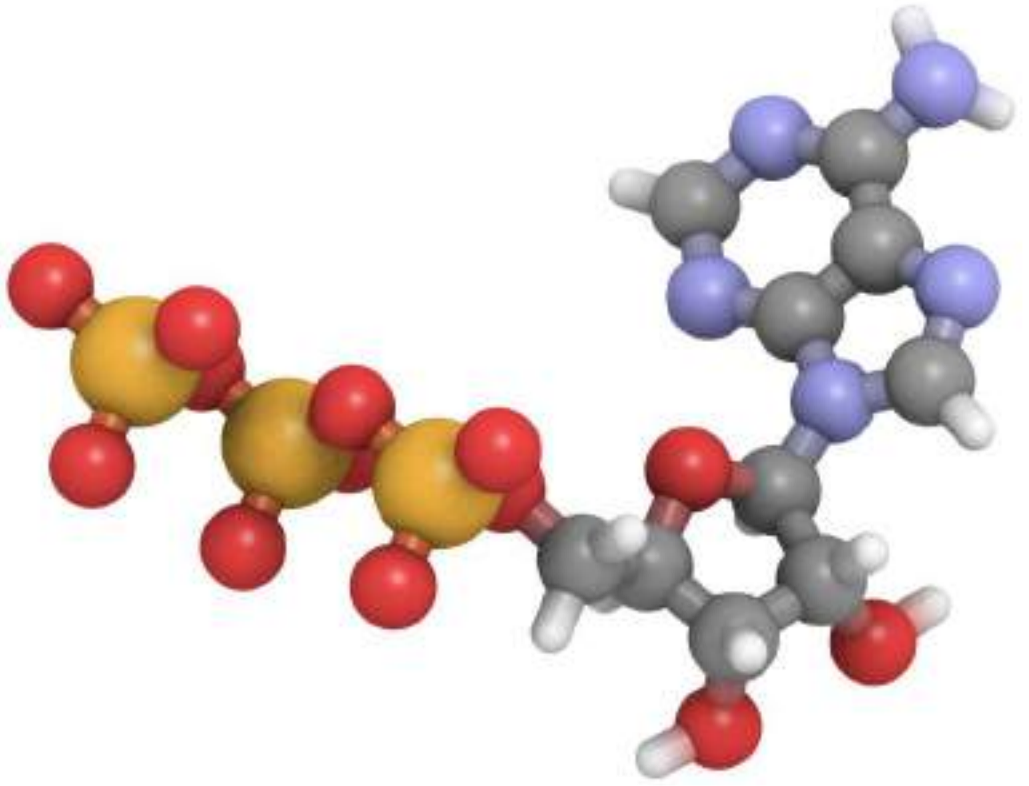
Aerobic Respiration: Pyruvate Oxidation

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



Aerobic Respiration: Citric Acid Cycle

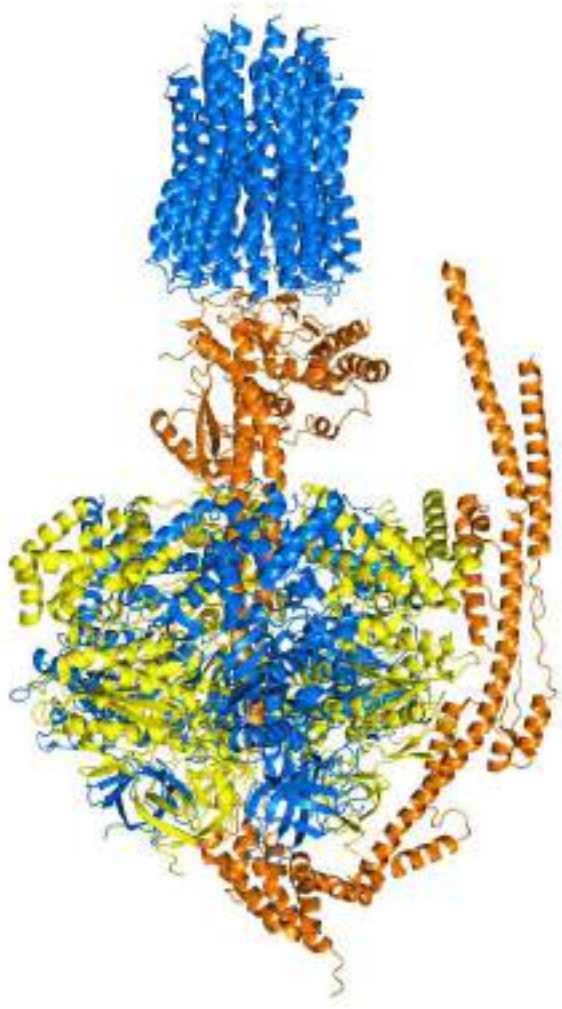
Acetyl CoA converted into different molecules, a little ATP produced (below), other molecules produced that are used in electron transport chain



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

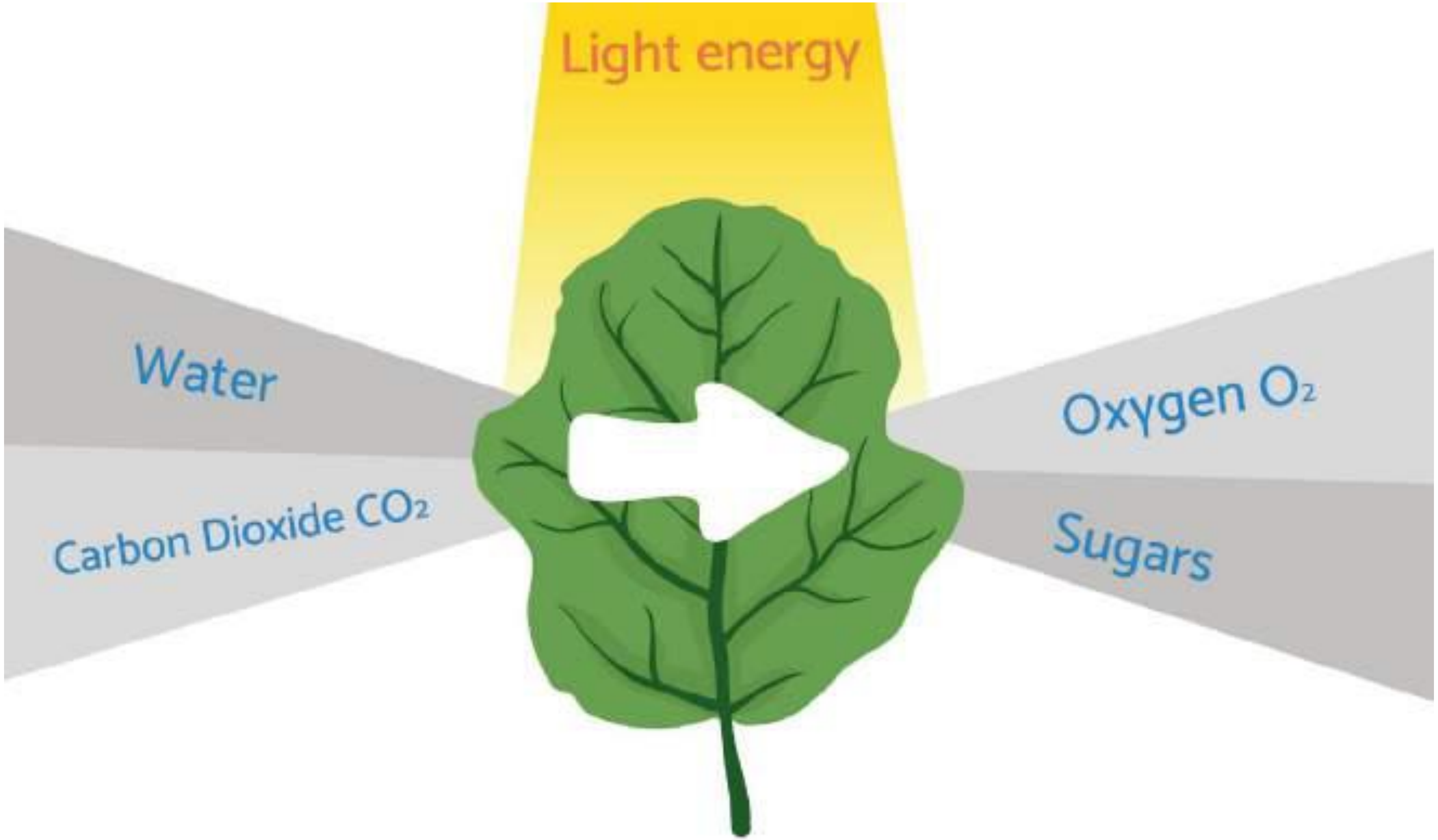
1. Lactic acid fermentation: lactic acid is byproduct (causes muscle burn after hard exercise)
2. Alcoholic fermentation: ethanol is byproduct (important for alcoholic drinks)

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

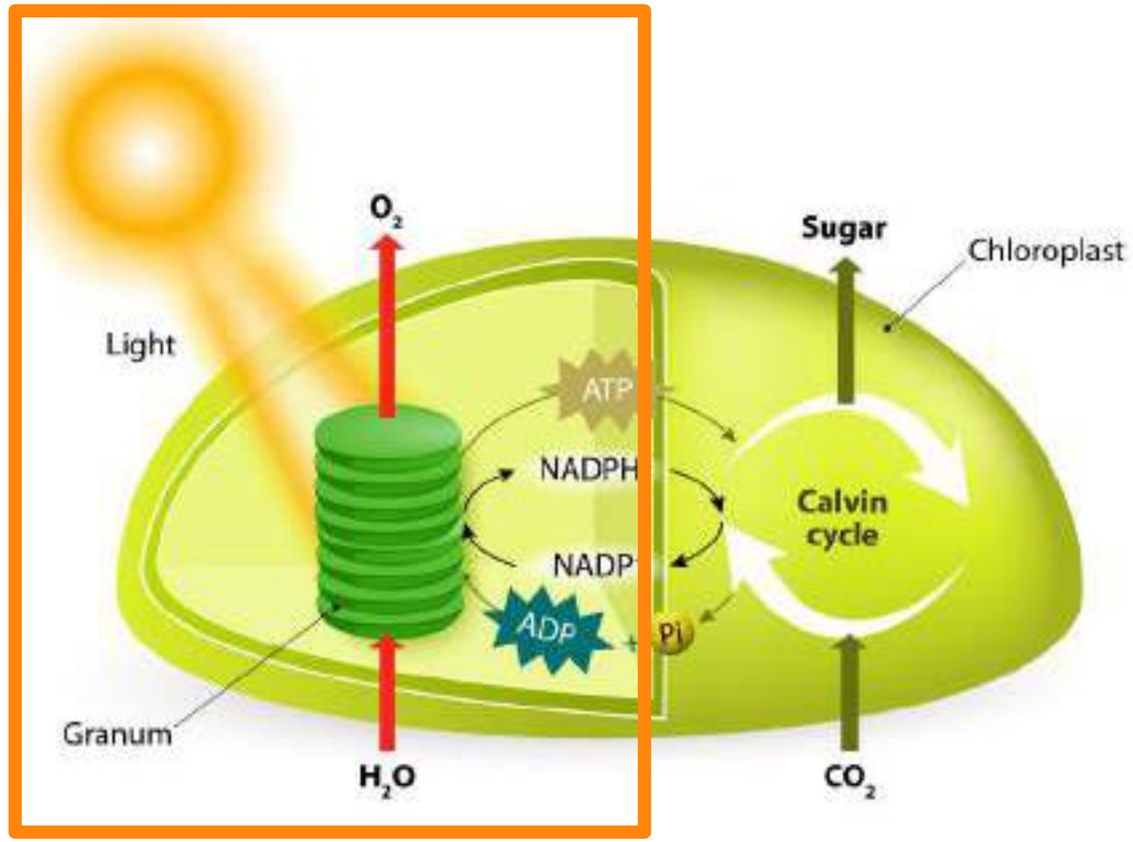
Two processes:

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

Light Reactions Overview

Take place in thylakoid membrane

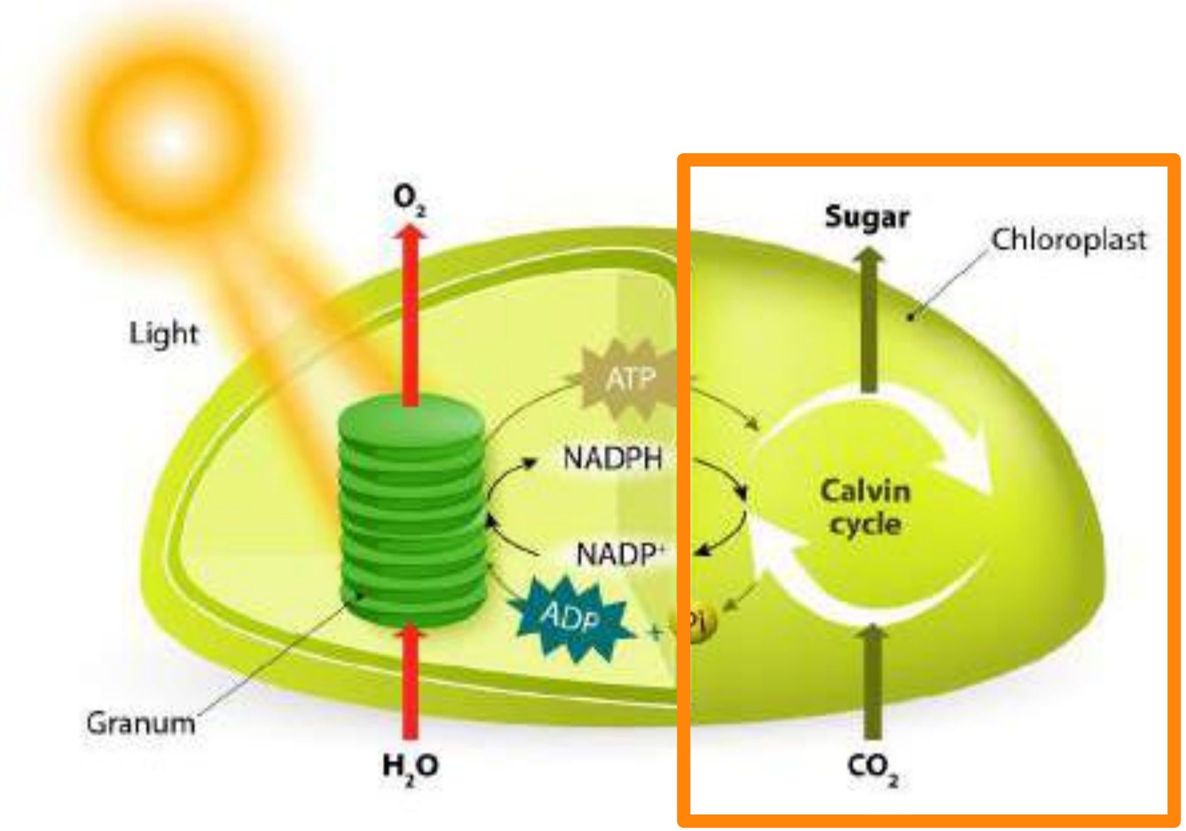
1. Capture/use light as energy source
2. Produce ATP & other molecules for dark reactions
3. Produce O_2 as byproduct



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

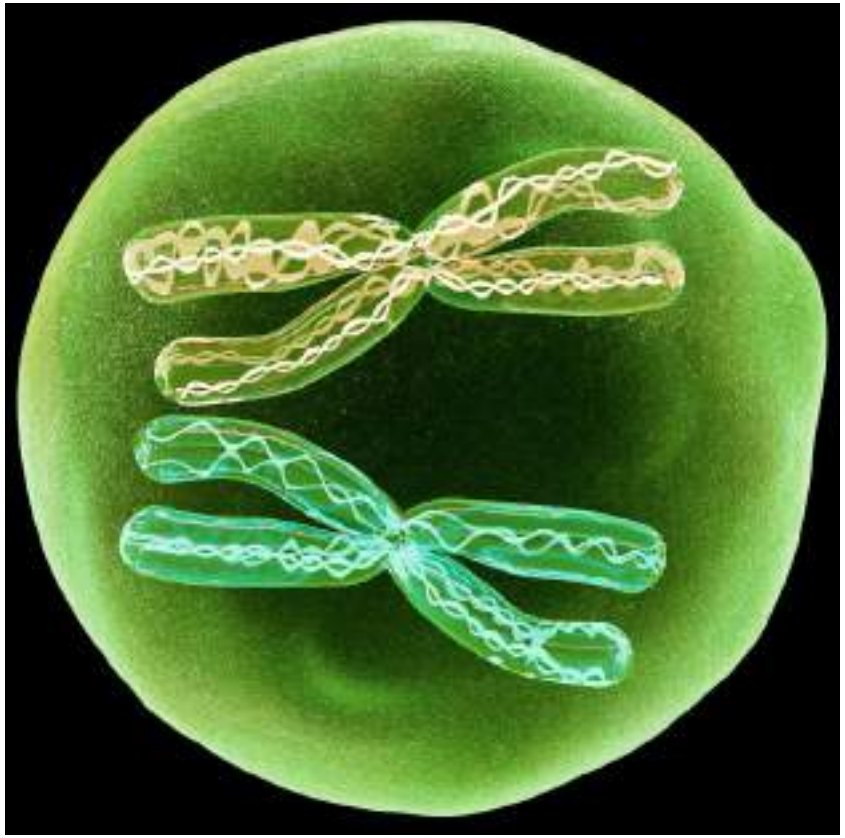


1.5 Cell Division

Cell Division

1.5.1- Structure of Chromosomes

1.5.2- Mitosis, Meiosis, Cytokinesis

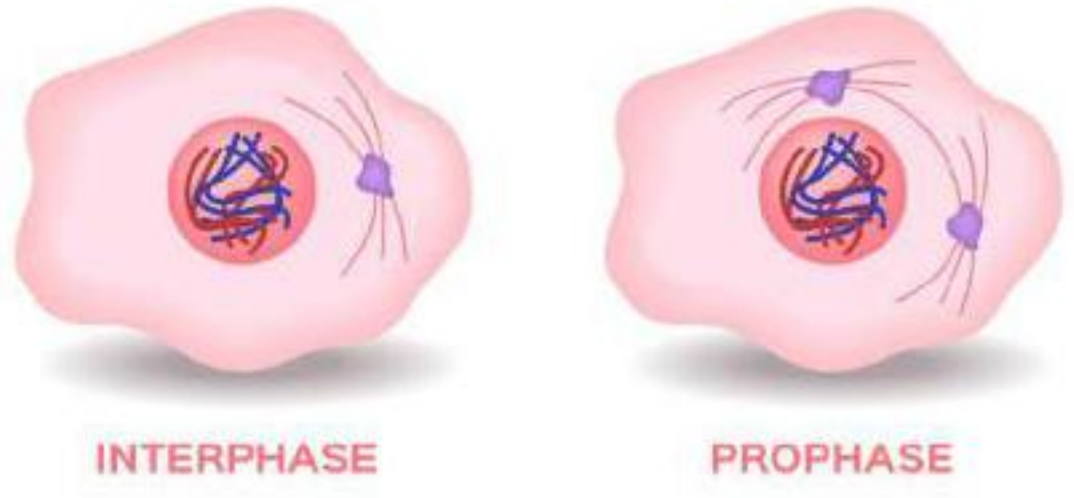


Structure of Chromosomes

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

Mitosis, Meiosis, Cytokinesis

- cell cycle
- stages of mitosis
- stages of meiosis



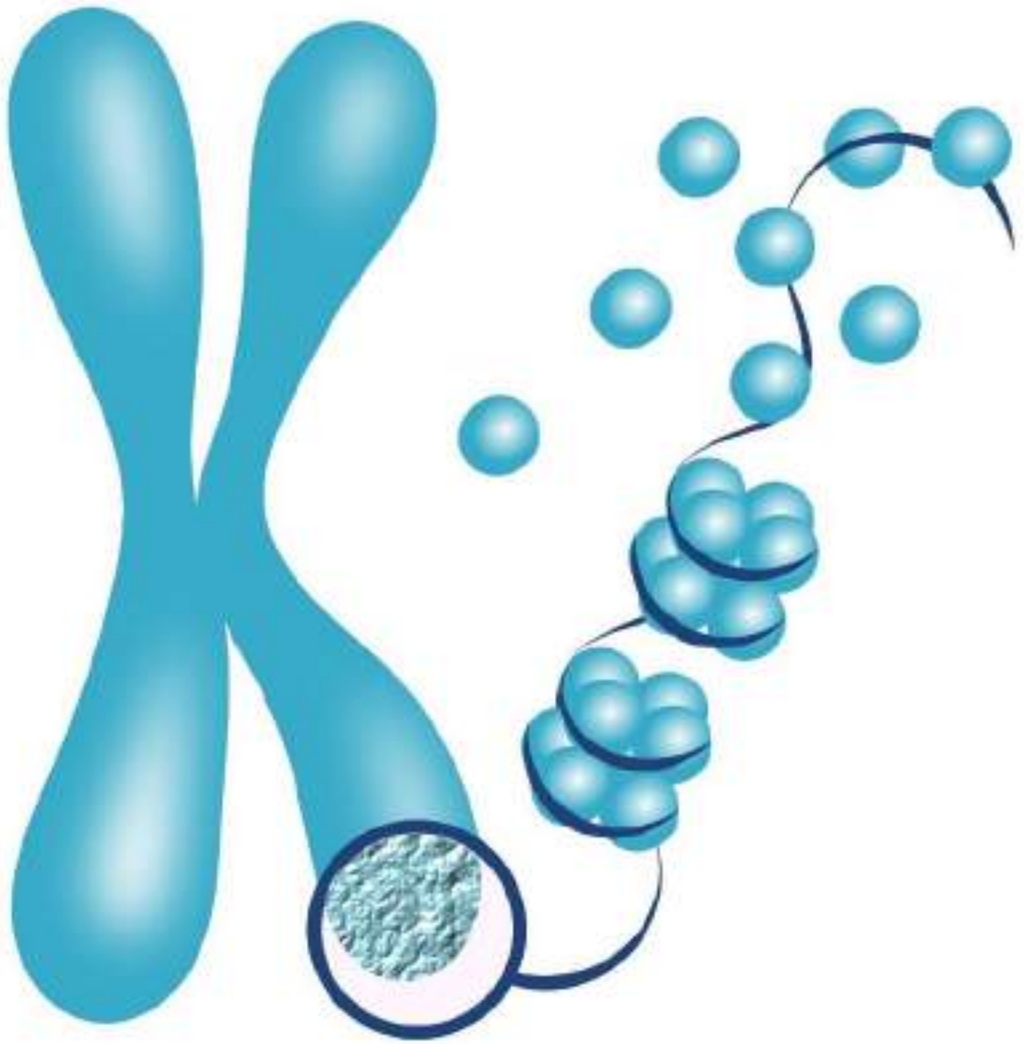
1.5.1 Structure of Chromosomes

Chromosomes

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

Chromosome: DNA wound up, only happens right before mitosis

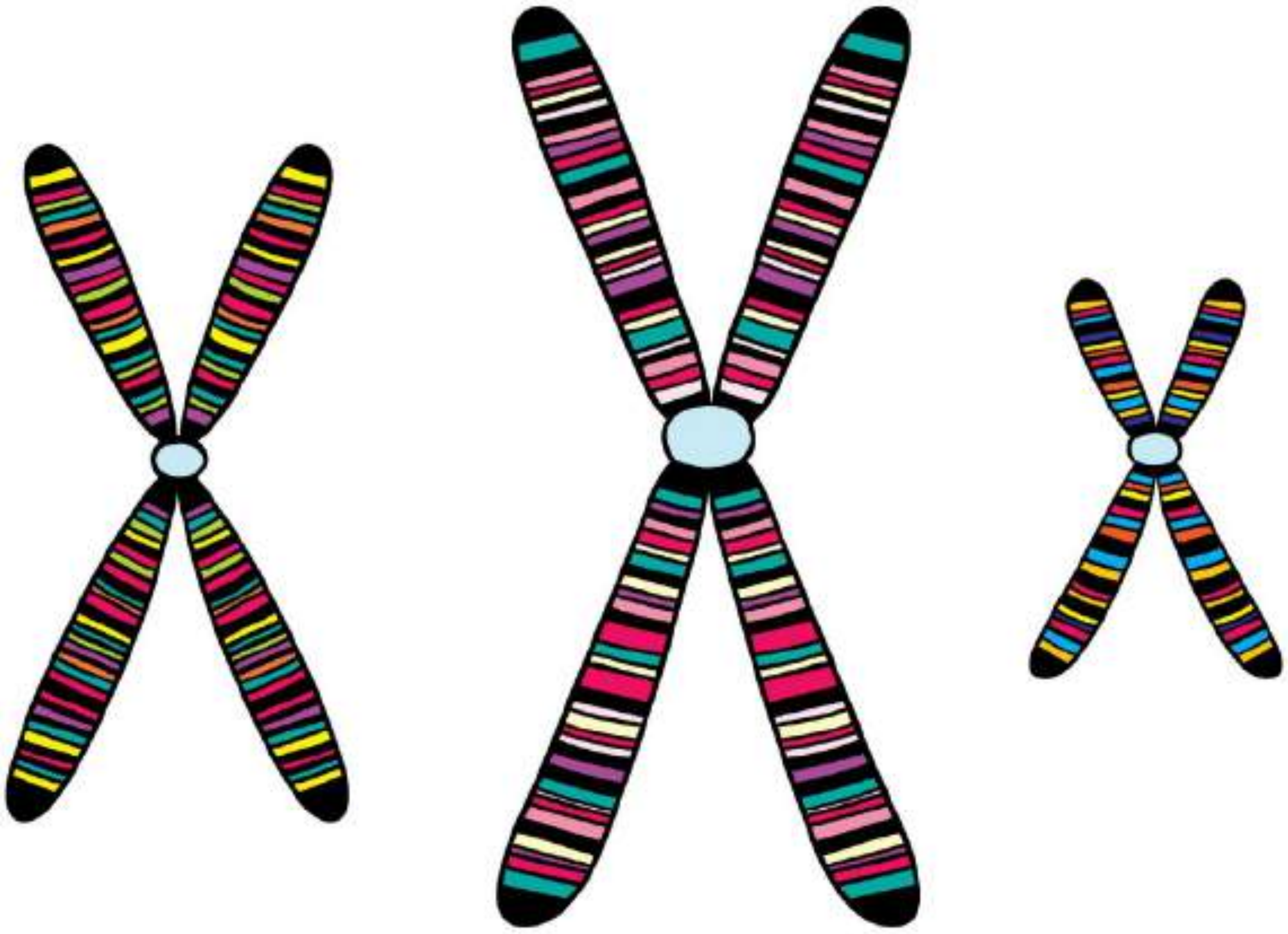
- DNA wound around proteins called histones
- each group of histones w/ DNA is called a nucleosome



Chromosome Terms

Sister chromatids: copies of each other, made before mitosis

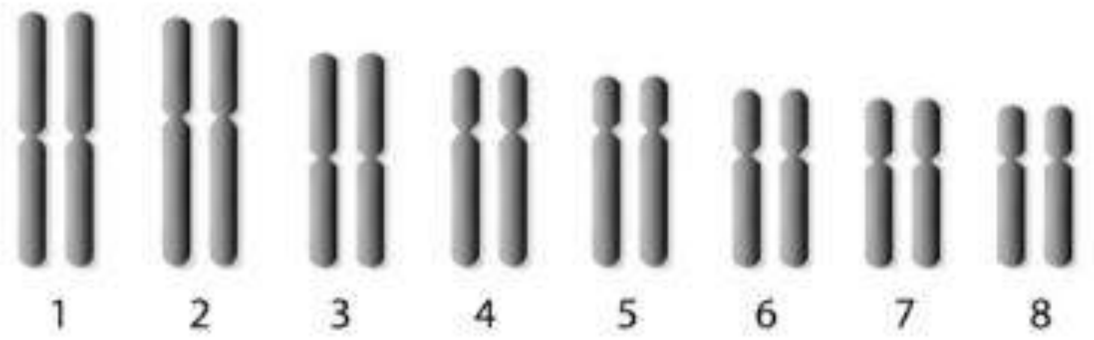
Centromere: visible constriction, holds chromatids together



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

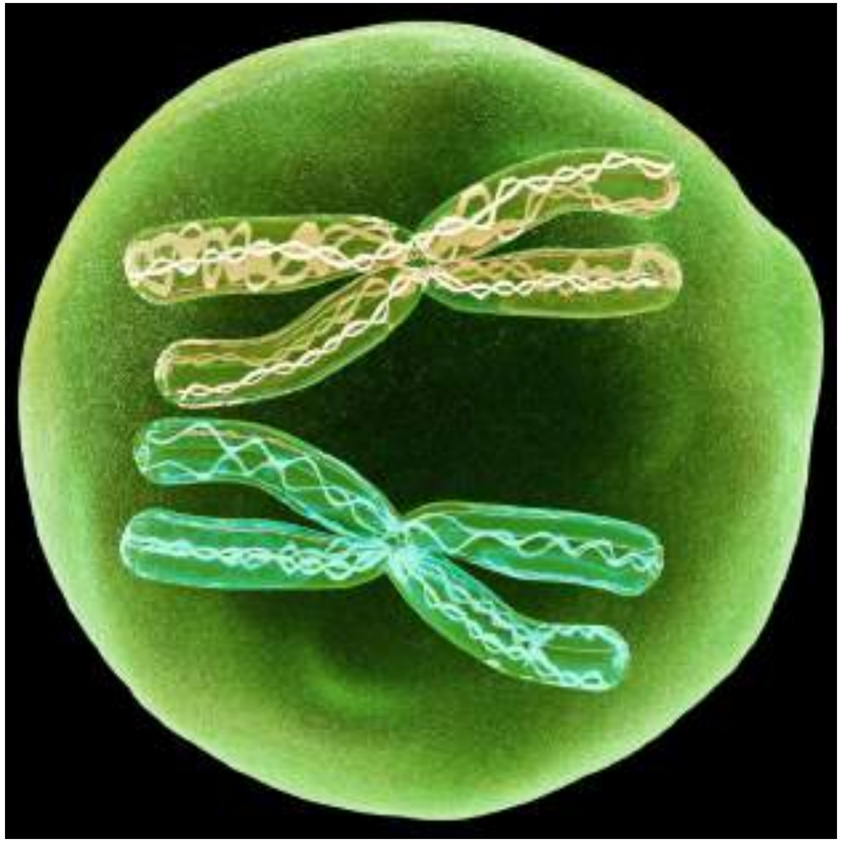
Alleles: variations of the same gene, found on homologous chromosomes.

- 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”

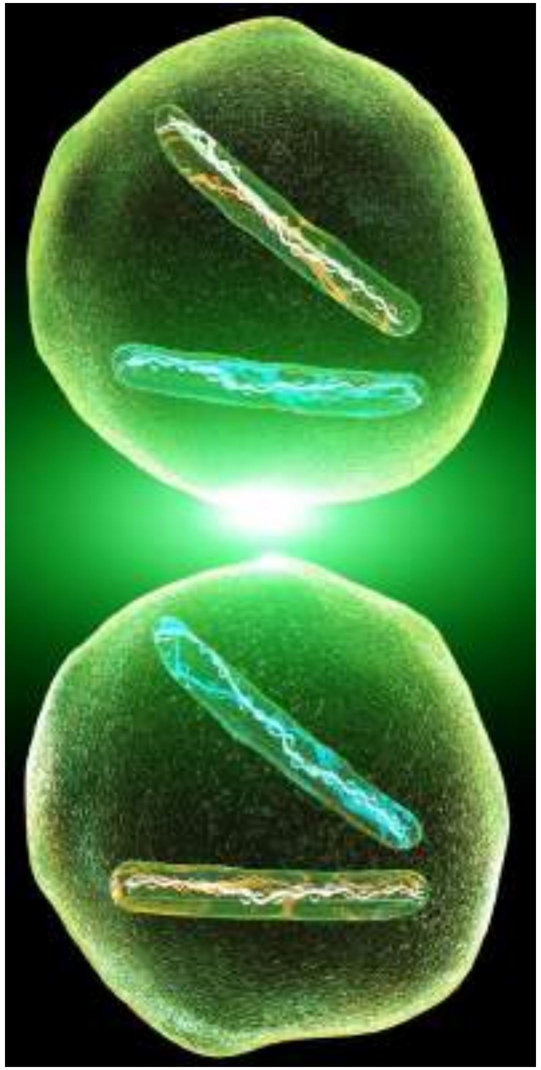
- Haploid: 1n, having 1 copy of each gene
- Diploid: 2n, having 2 copies of each gene



Ploidy

From the moment of fertilization, humans are 2n

Only our sperm & eggs are haploid (1n)

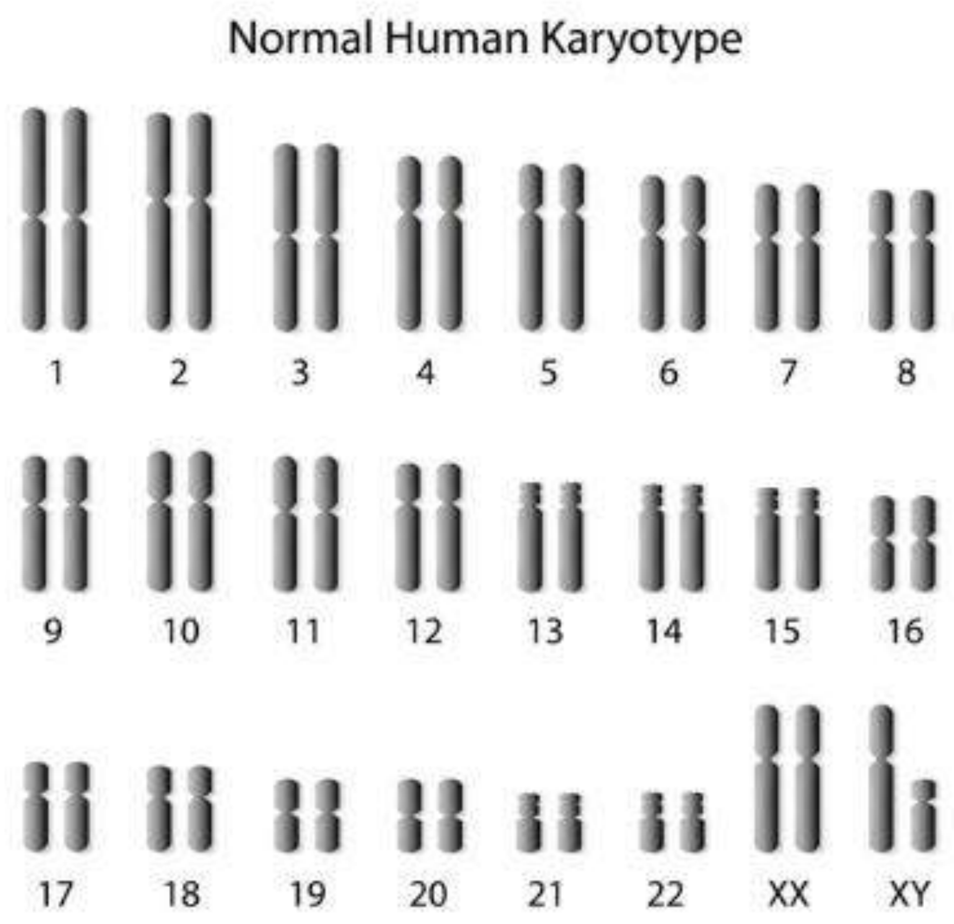


Karyotype

Karyotype: picture of chromosomes

For humans, 2n=46

Sex chromosomes are #23



1.5.1 Structure of Chromosomes

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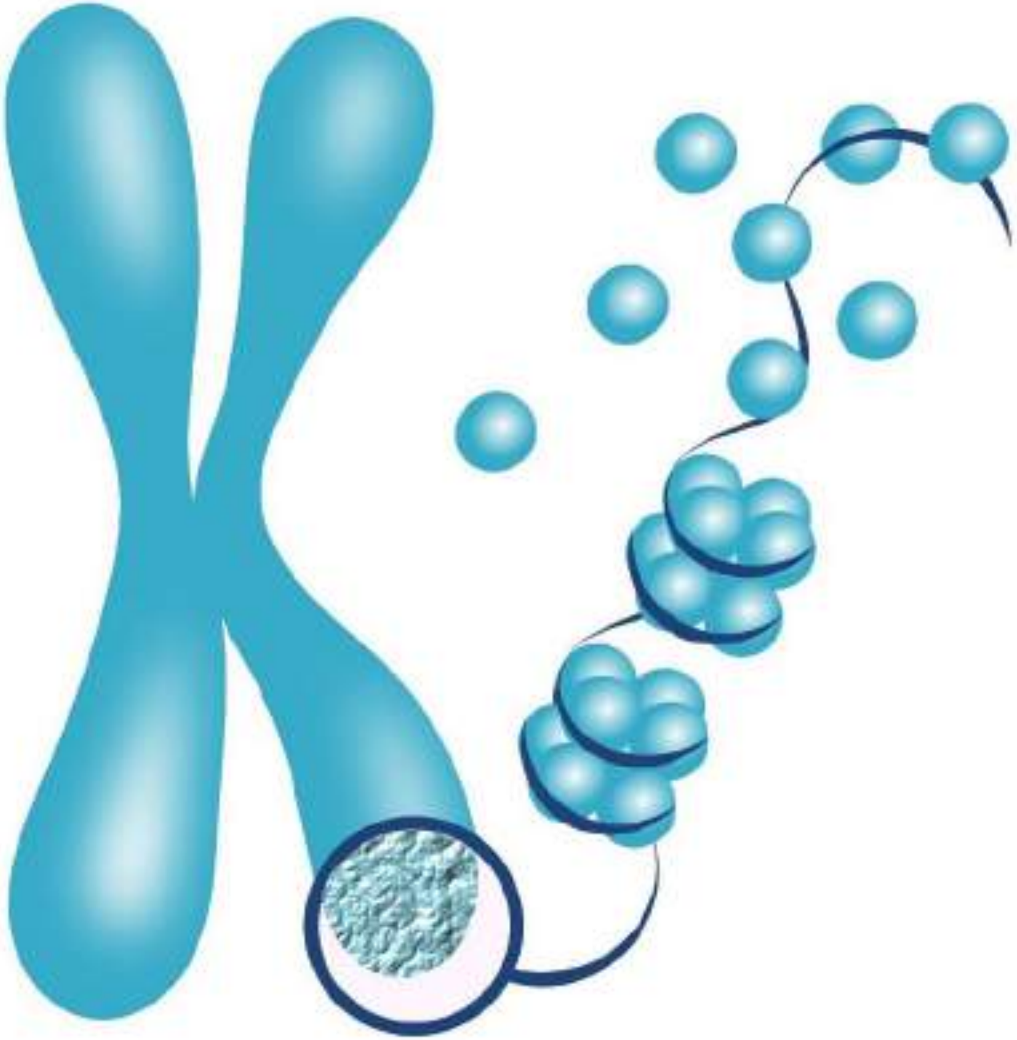

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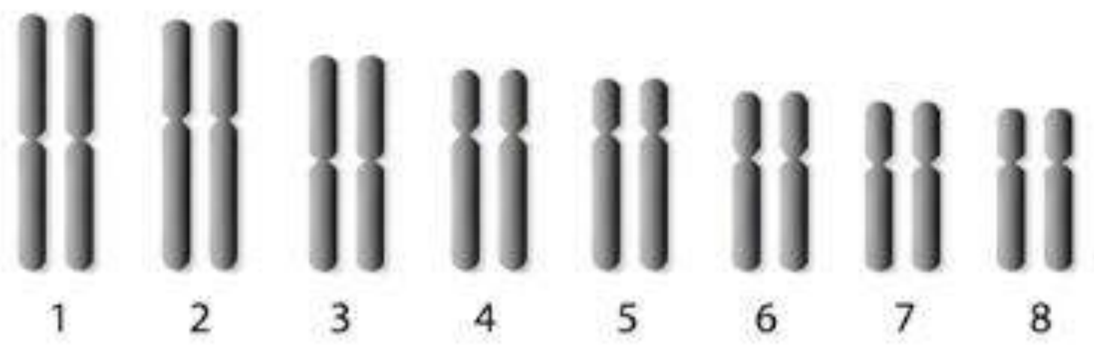

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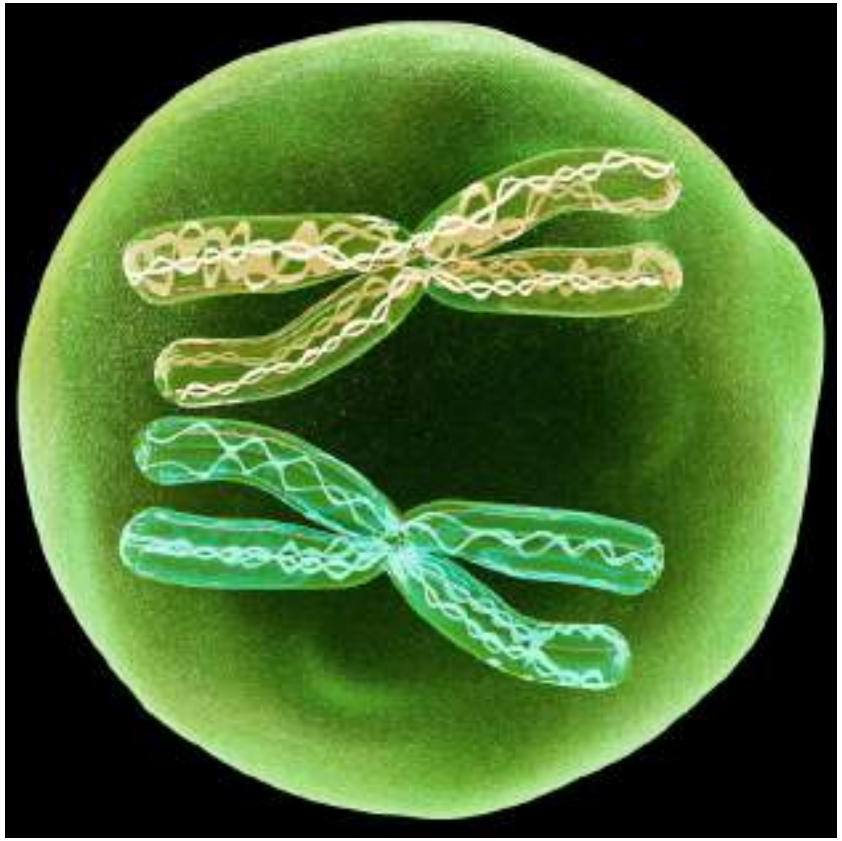

Ploidy

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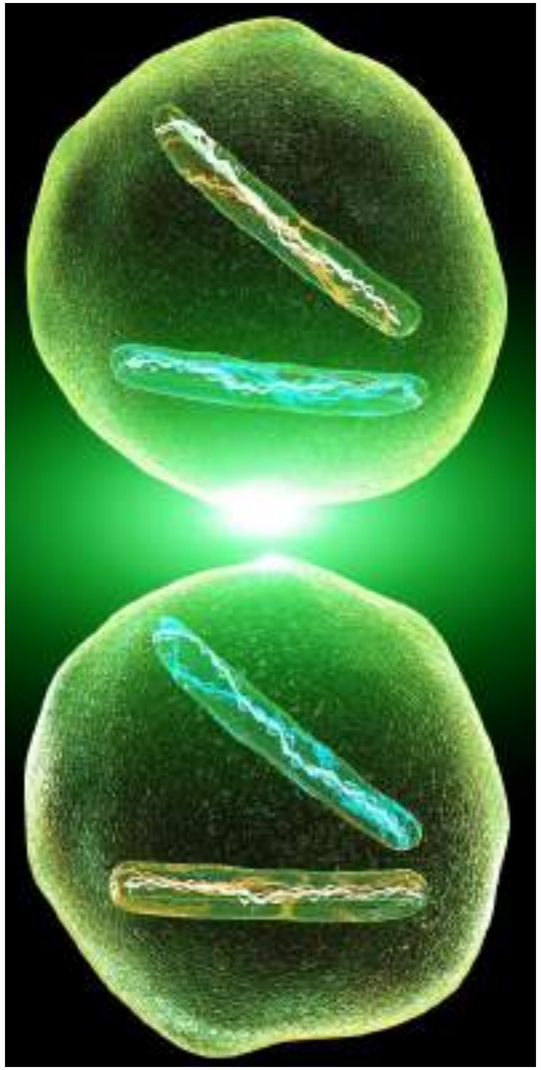
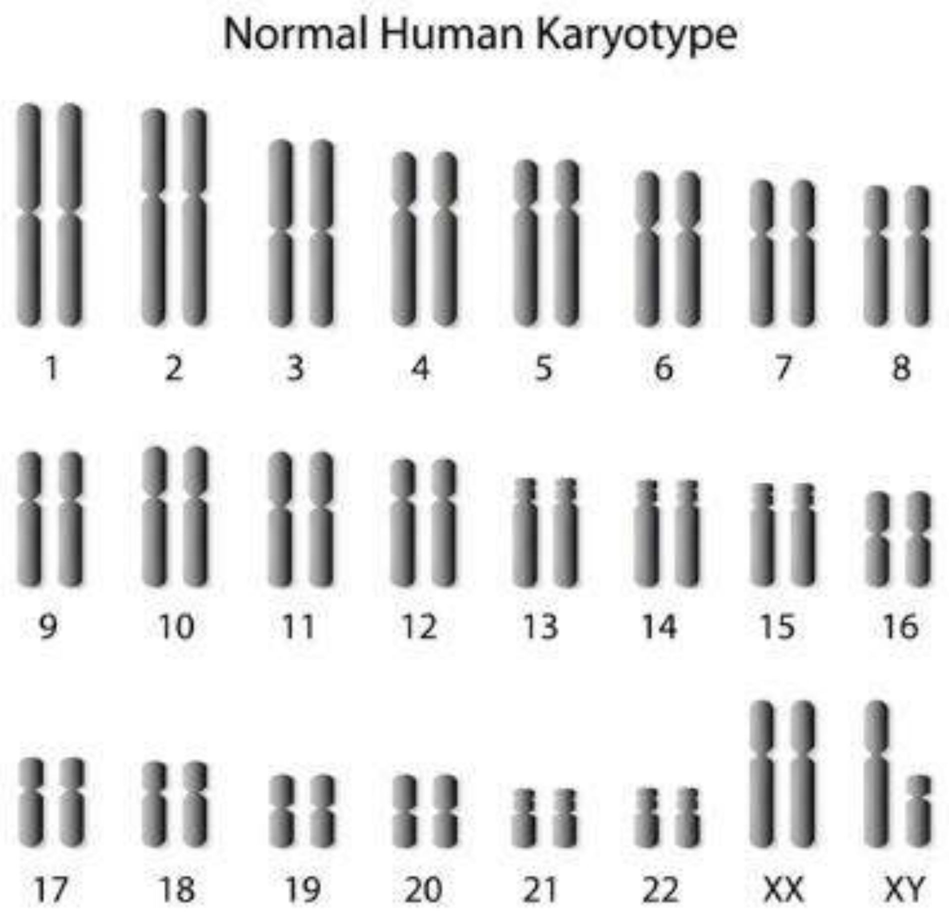
Only our sperm & eggs are haploid (1n)



Karyotype



Karyotype: picture of chromosomes

For humans, 2n=46

Sex chromosomes are #23

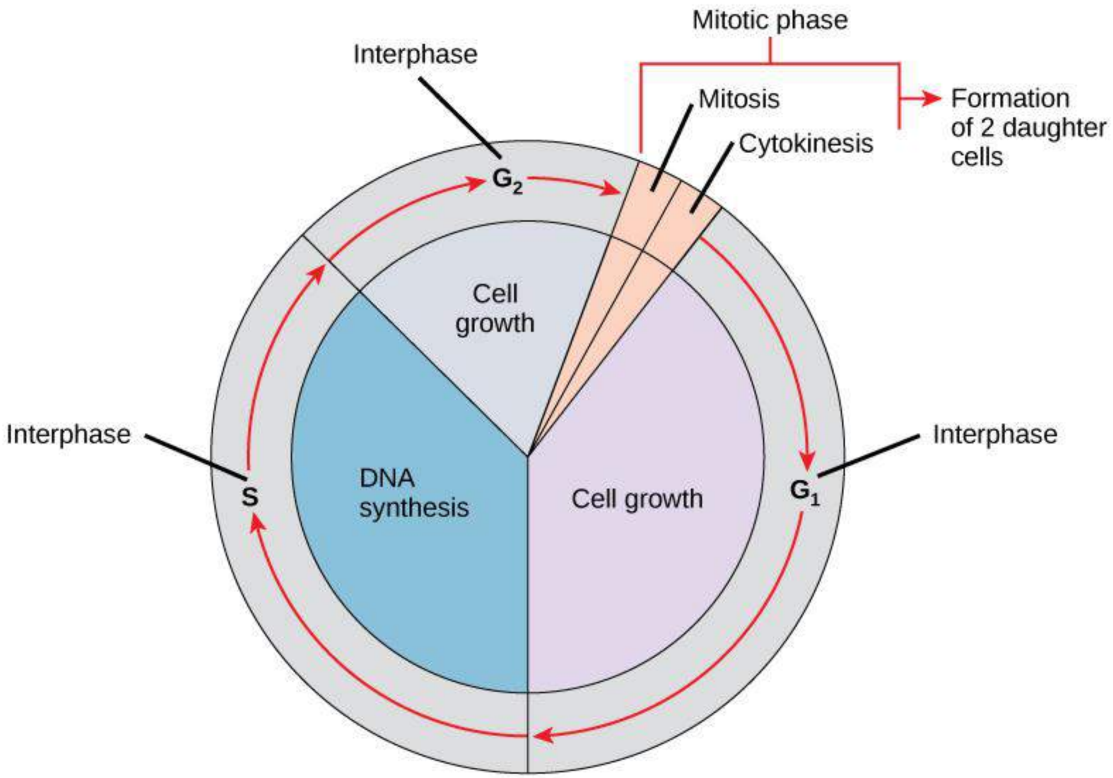
1.5.2 Mitosis, Meiosis, Cytokinesis

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



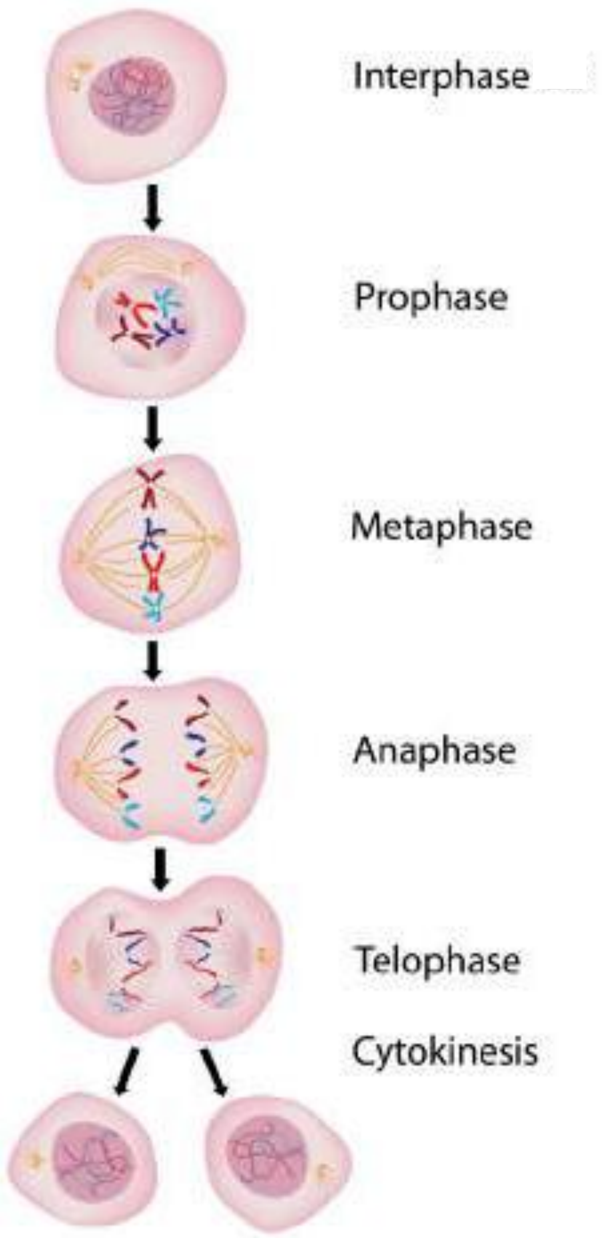
Mitotic Phase

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



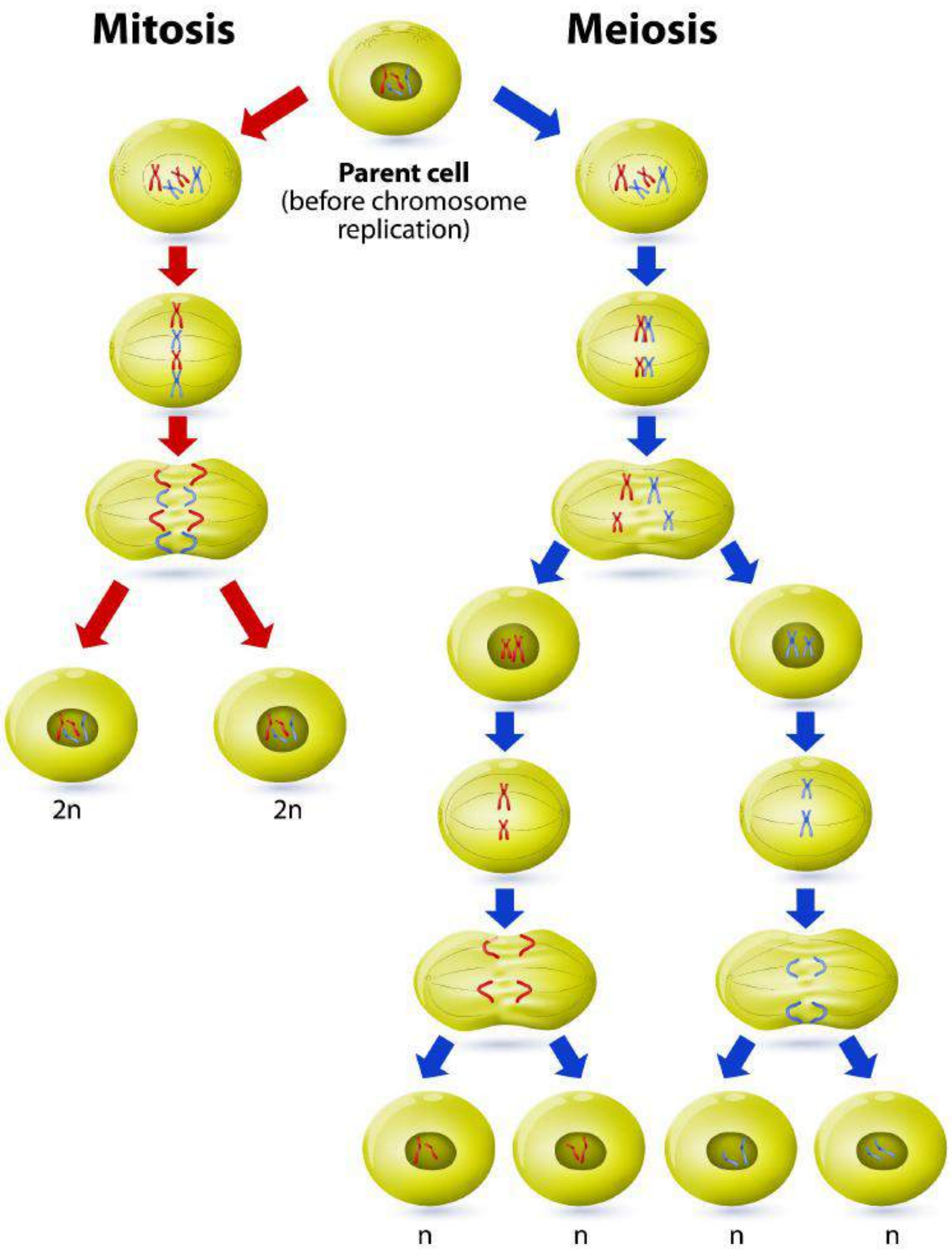
Meiosis

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

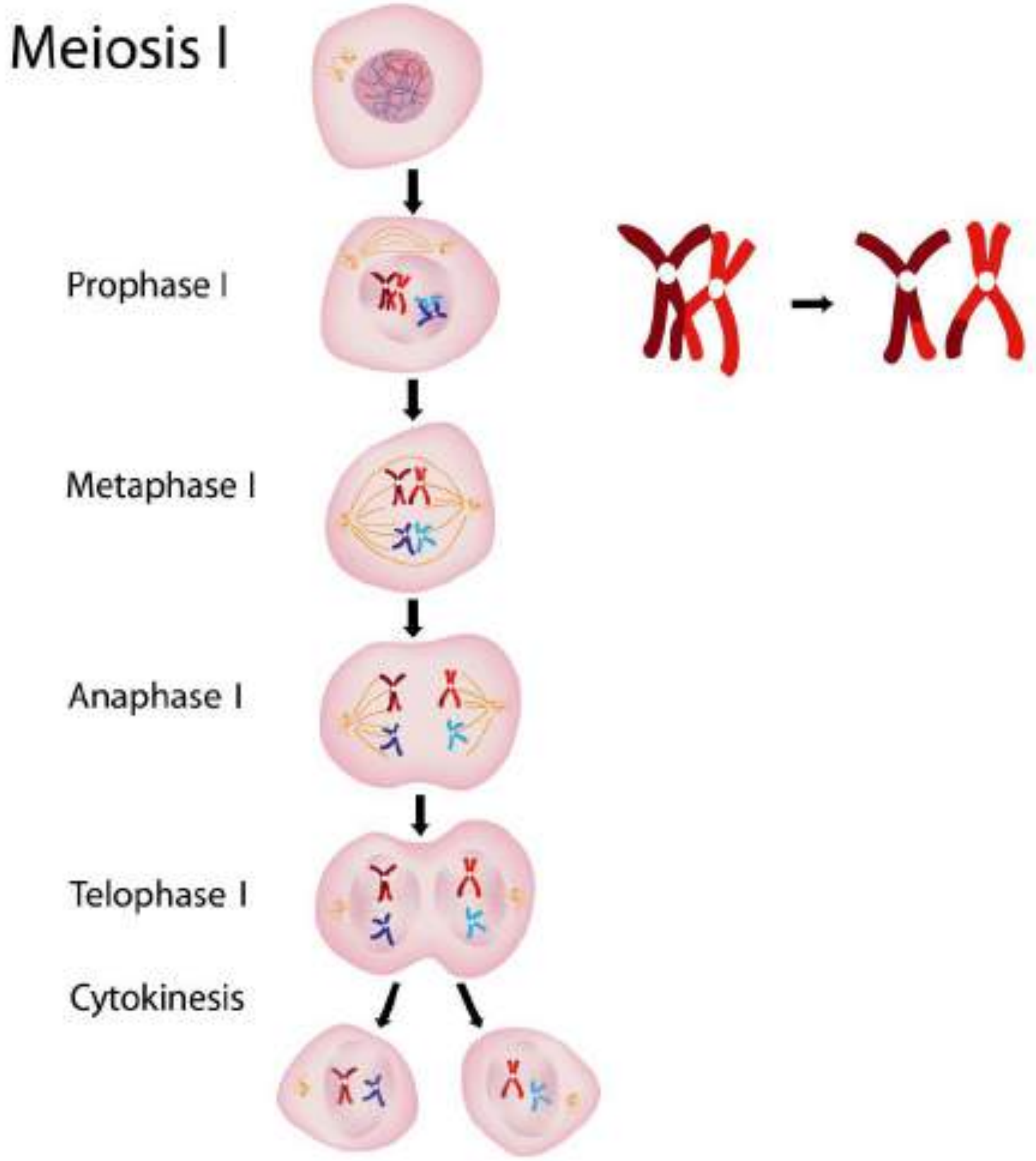
Meiosis I

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

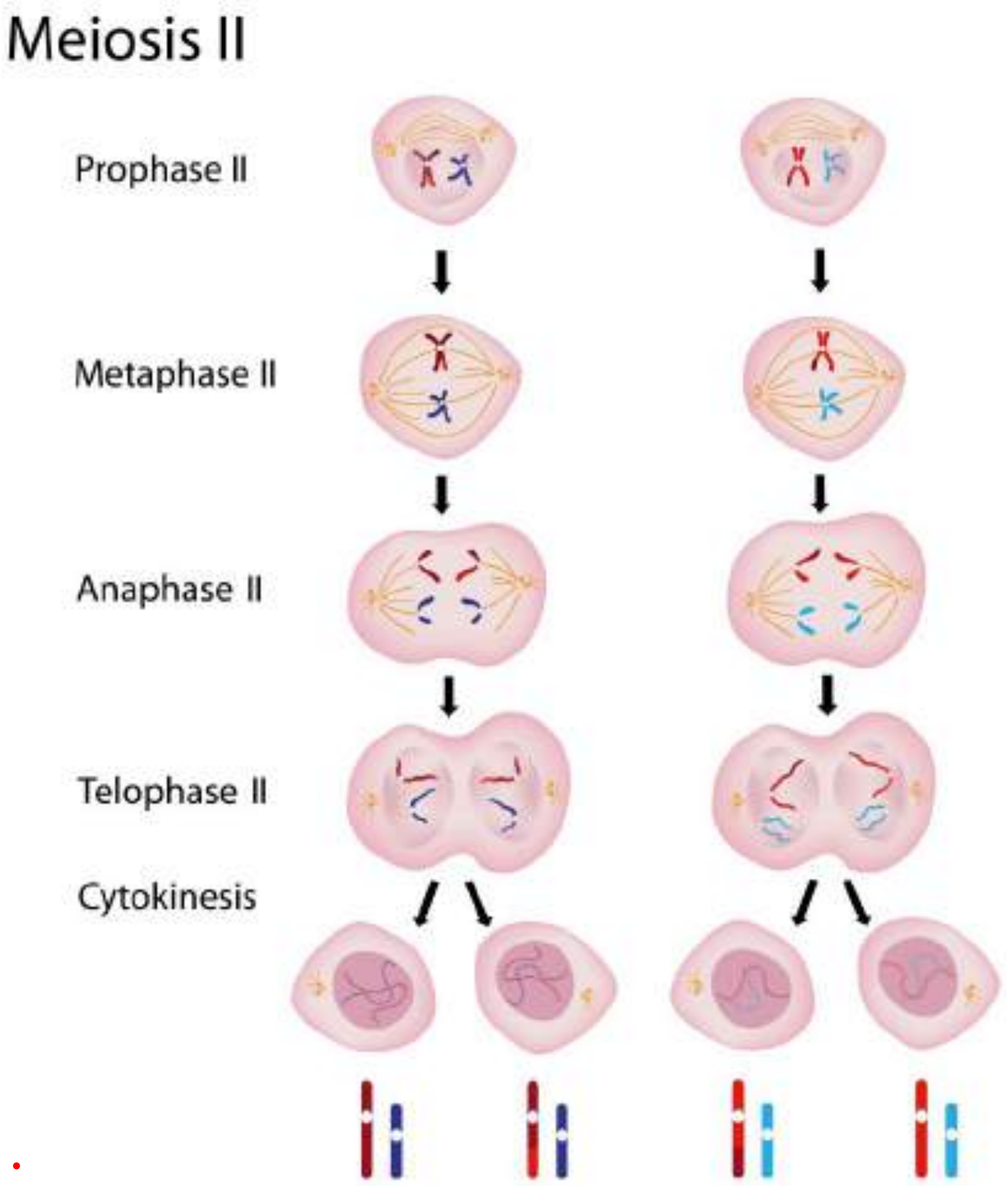

Meiosis I
Prophase I
Metaphase I
Anaphase I
Telophase I
Cytokinesis

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

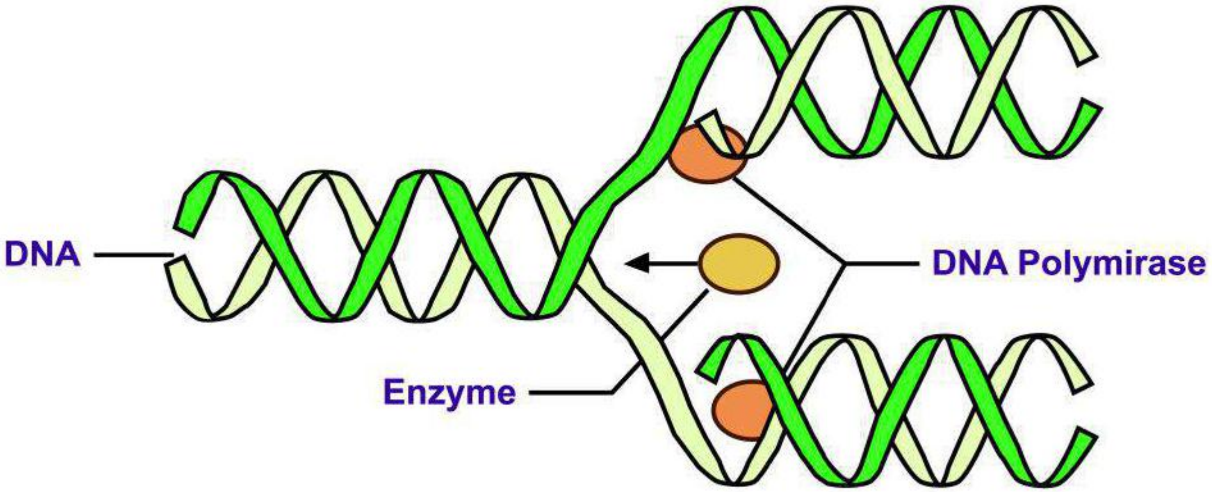
1.6.7- Viruses

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

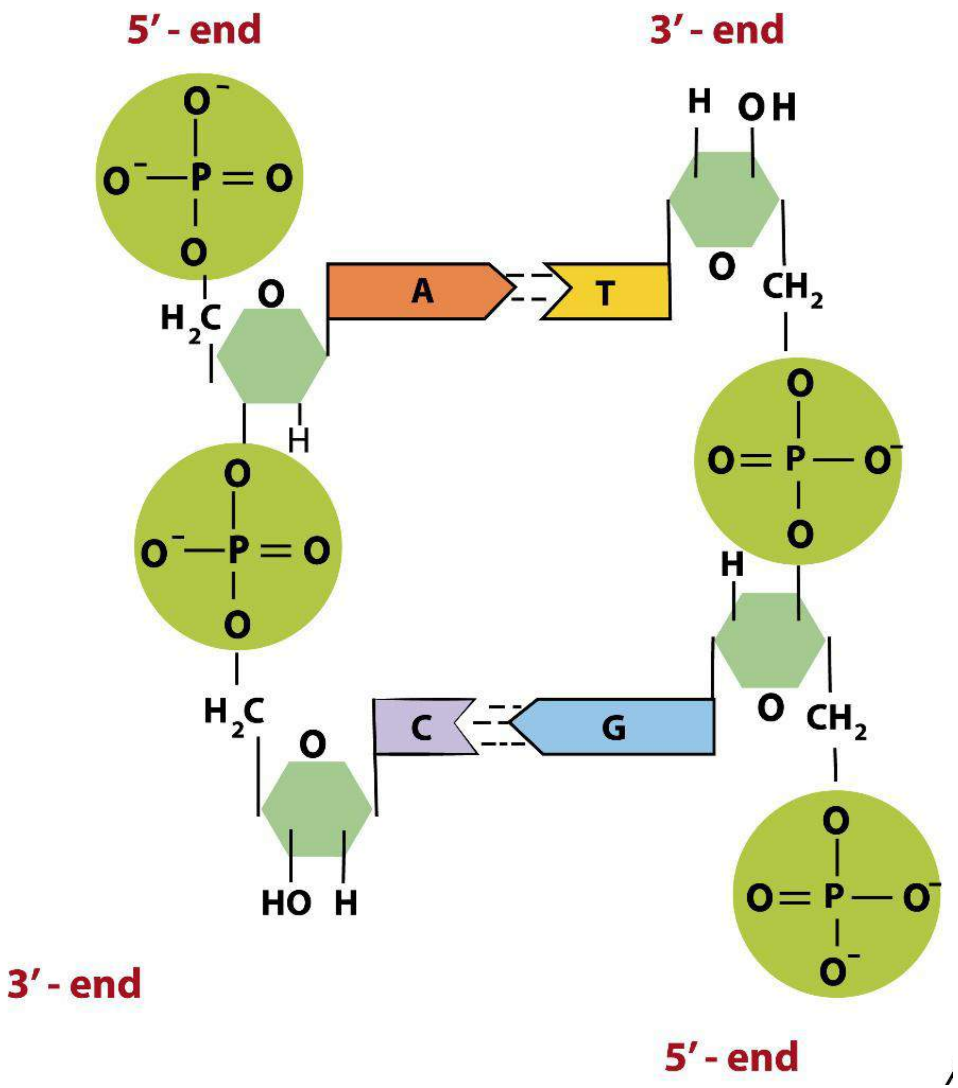
- are they alive
- structure
- how they work

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

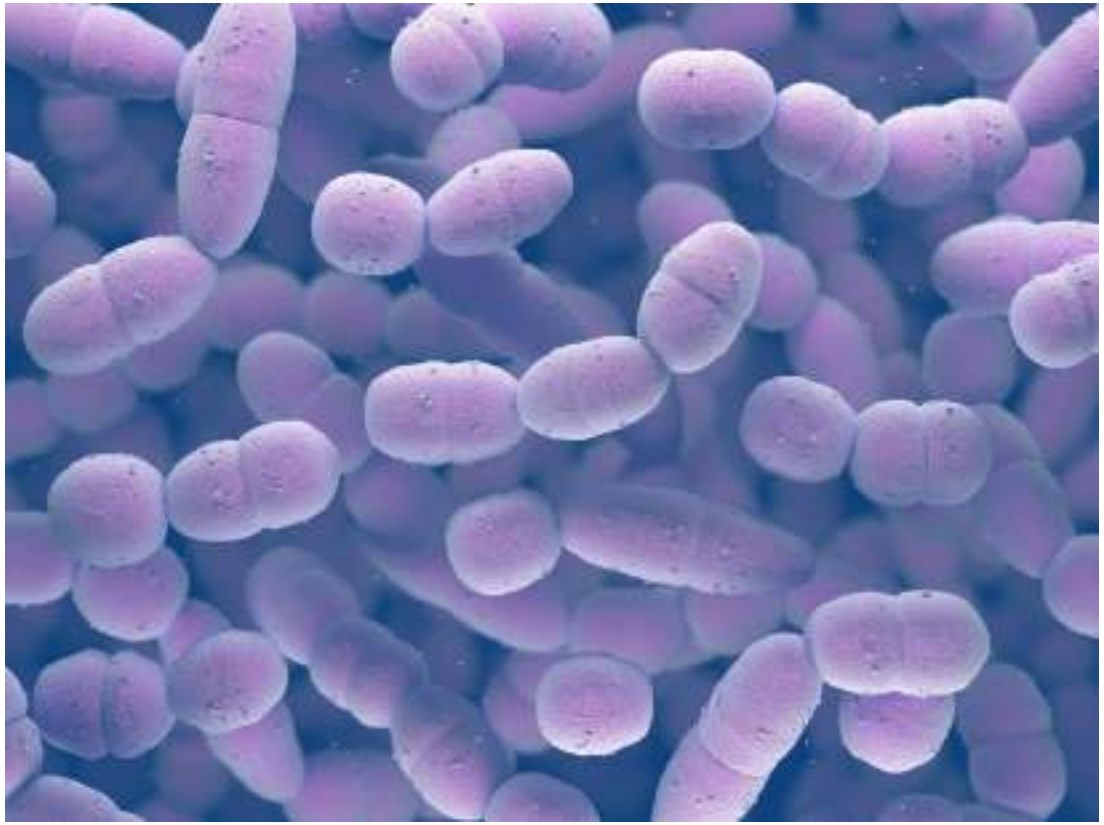
•



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

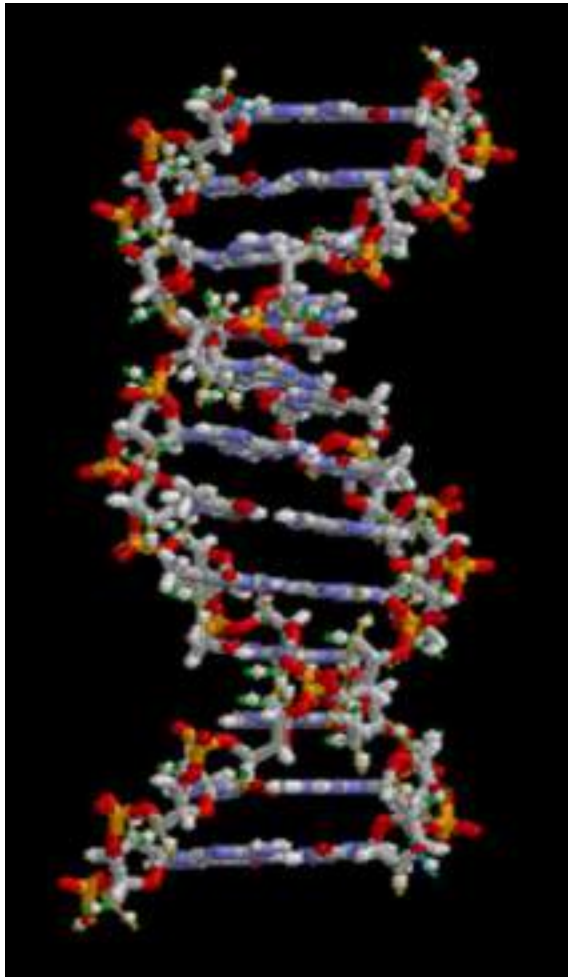


Discoveries Before Watson & Crick

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

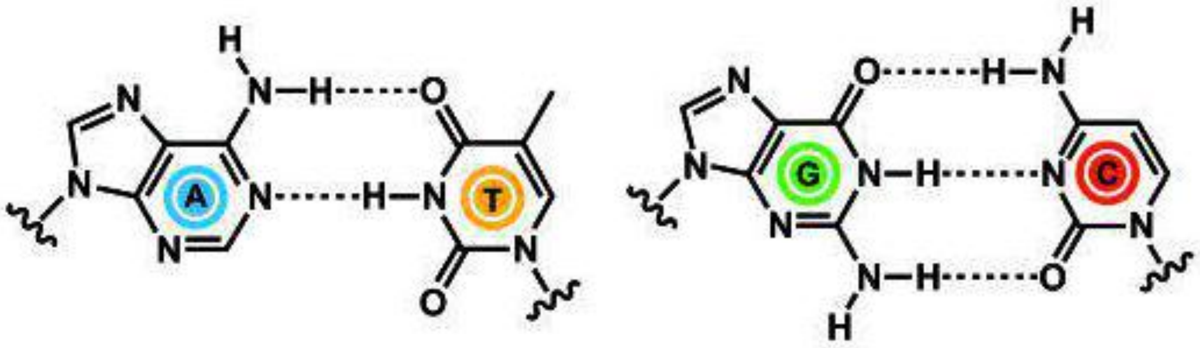
Discoveries Before Watson & Crick

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

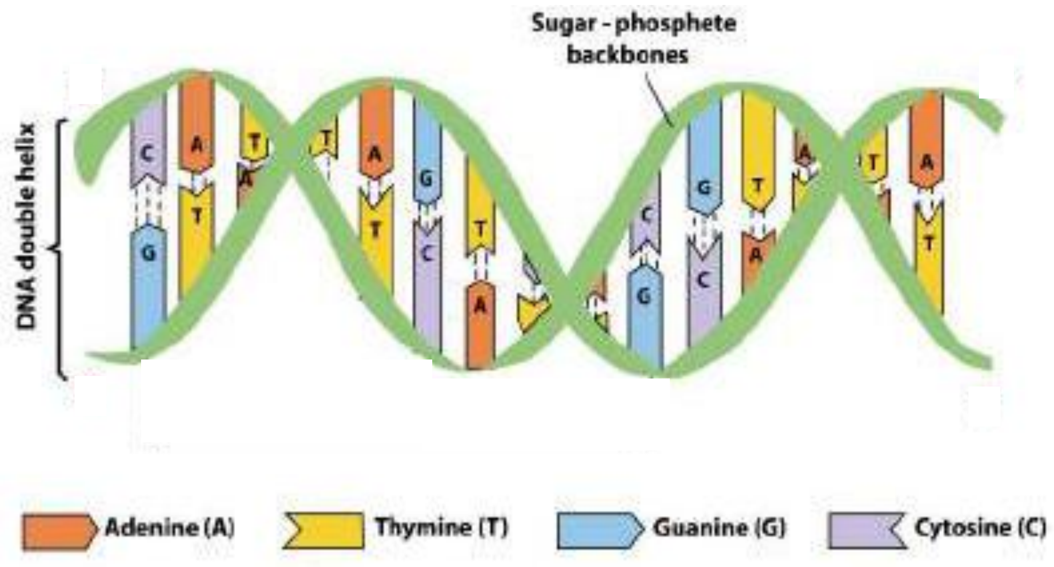
DNA is the “blueprint” for everything cells make and do

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



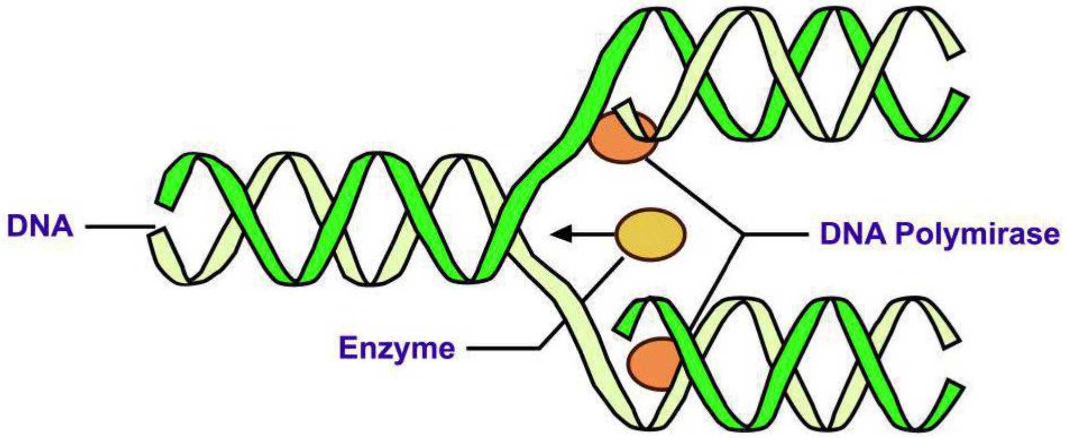
The Process

Steps:

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

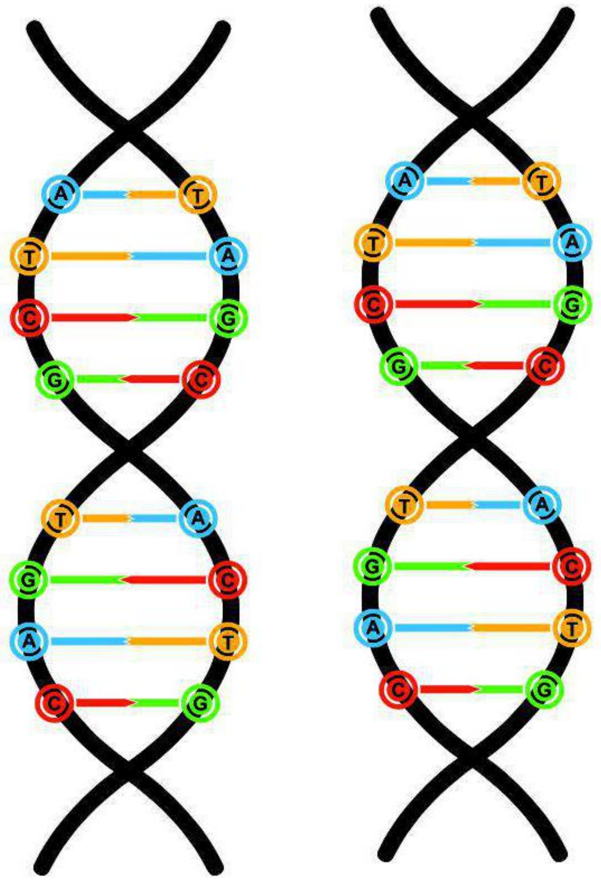
2. The enzyme *DNA polymerase* reads the sequence of nucleotides on one DNA strand (*template strand*)

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

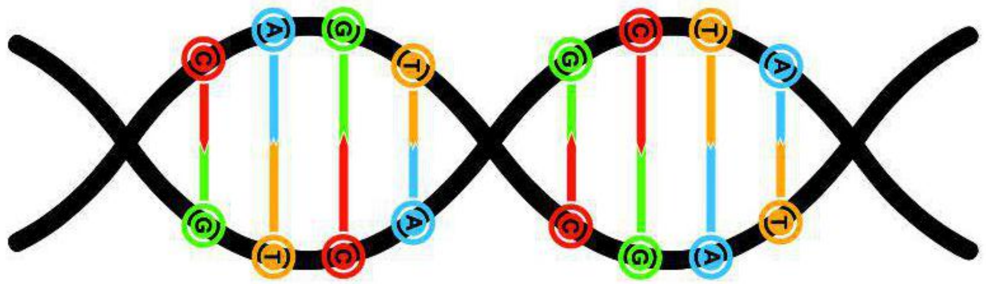
Causes

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

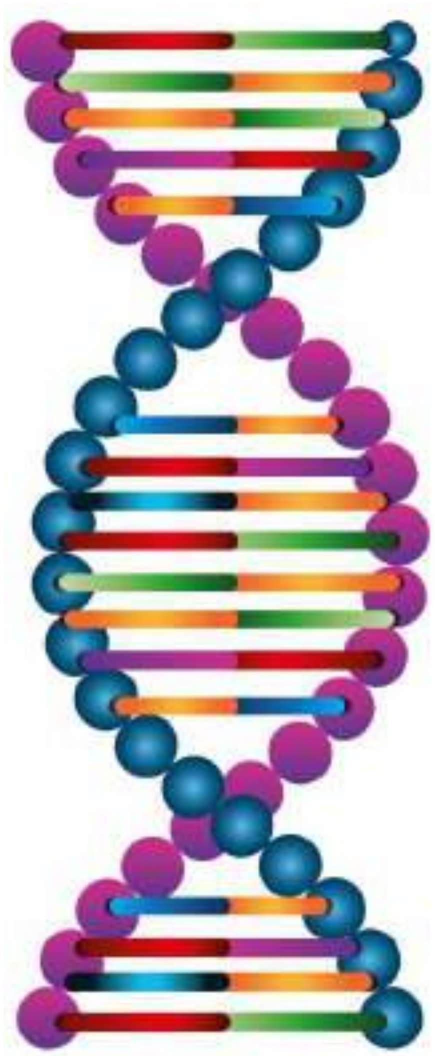
Two stages:

1. Transcription
2. Translation

Transcription

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

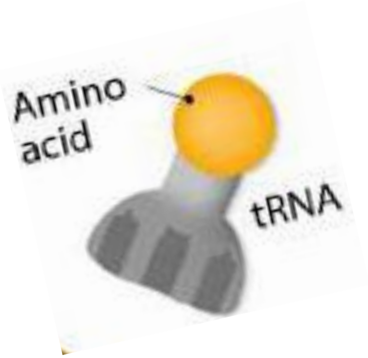
mRNA- messenger RNA, takes message to cytoplasm for translation

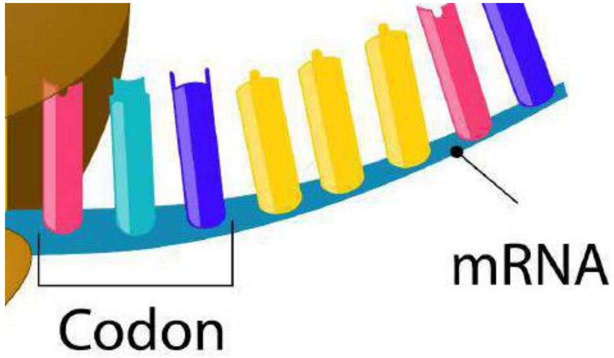


Translation

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

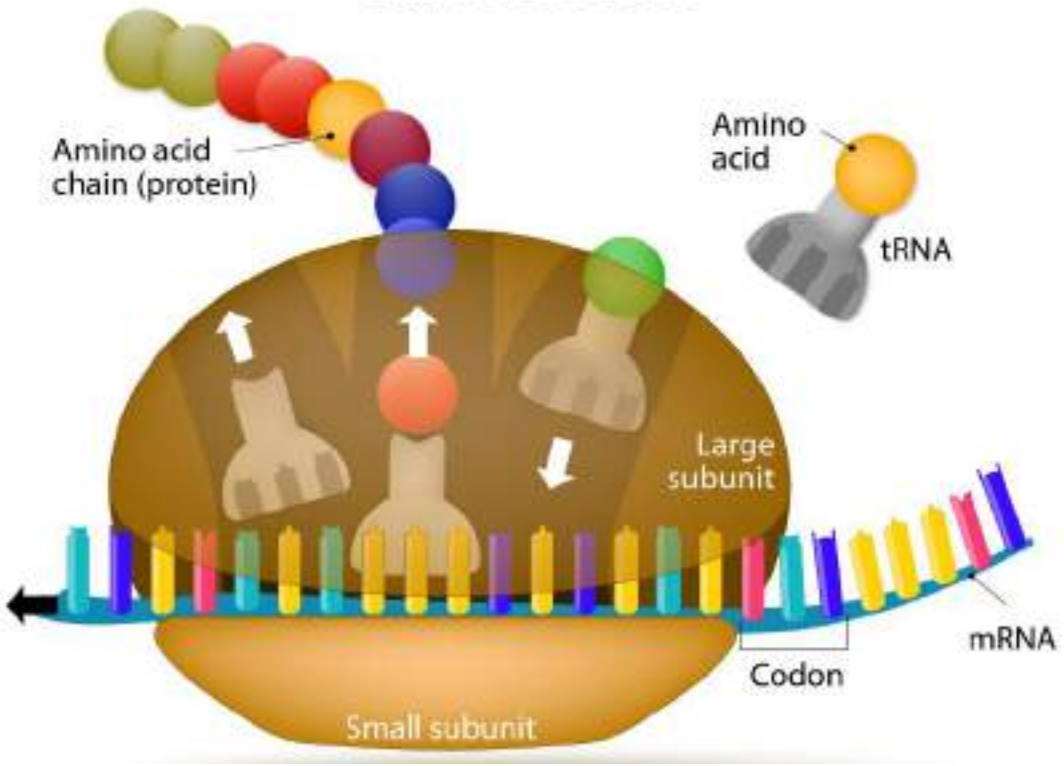




Translation

Ribosomes match anticodons to codons

Attached amino acids are joined to form proteins

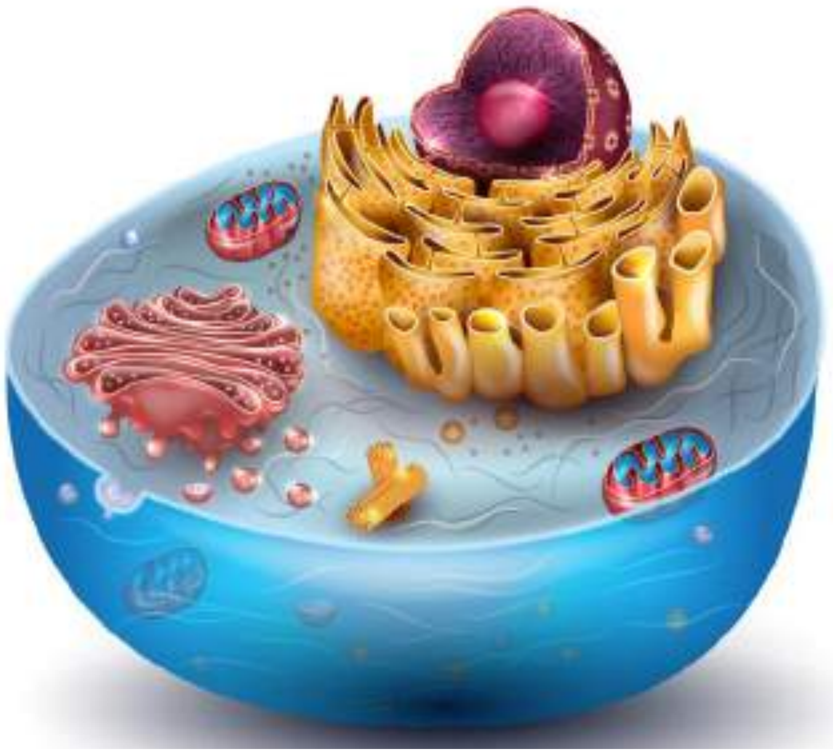


1.6.5 Structural & Regulatory Genes

Two Types of Proteins

Genes code for production of two types of proteins:

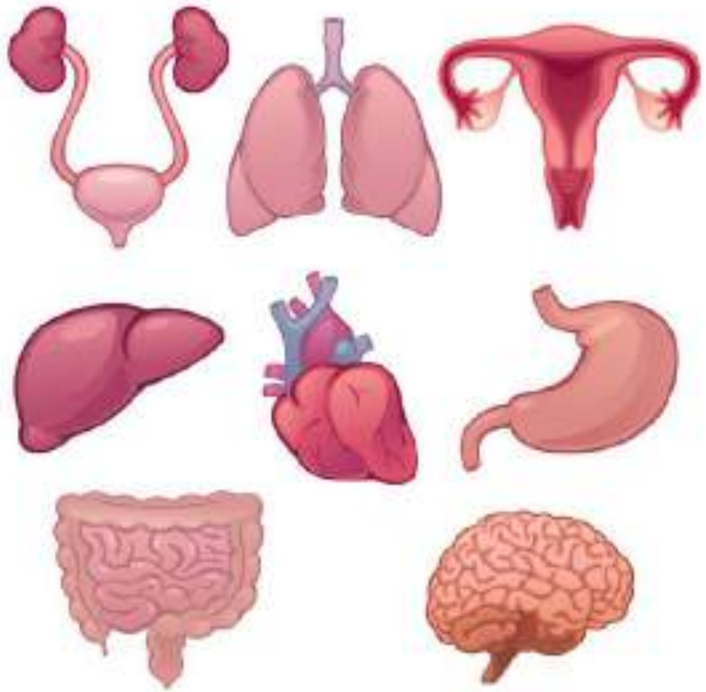
1. Structural
2. Regulatory



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

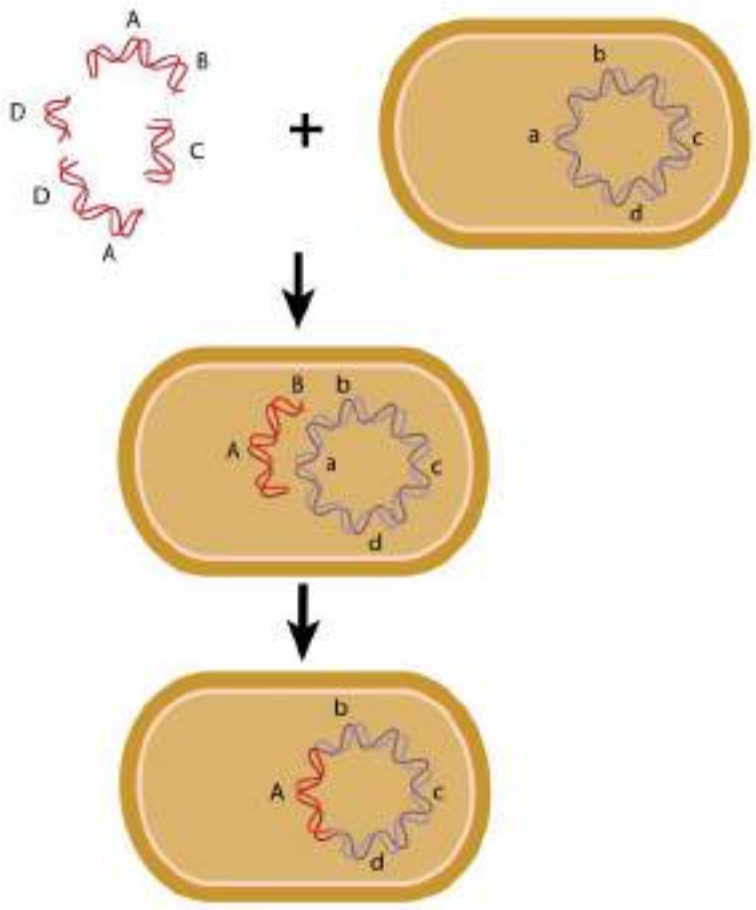
1. Transduction
2. Transformation

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

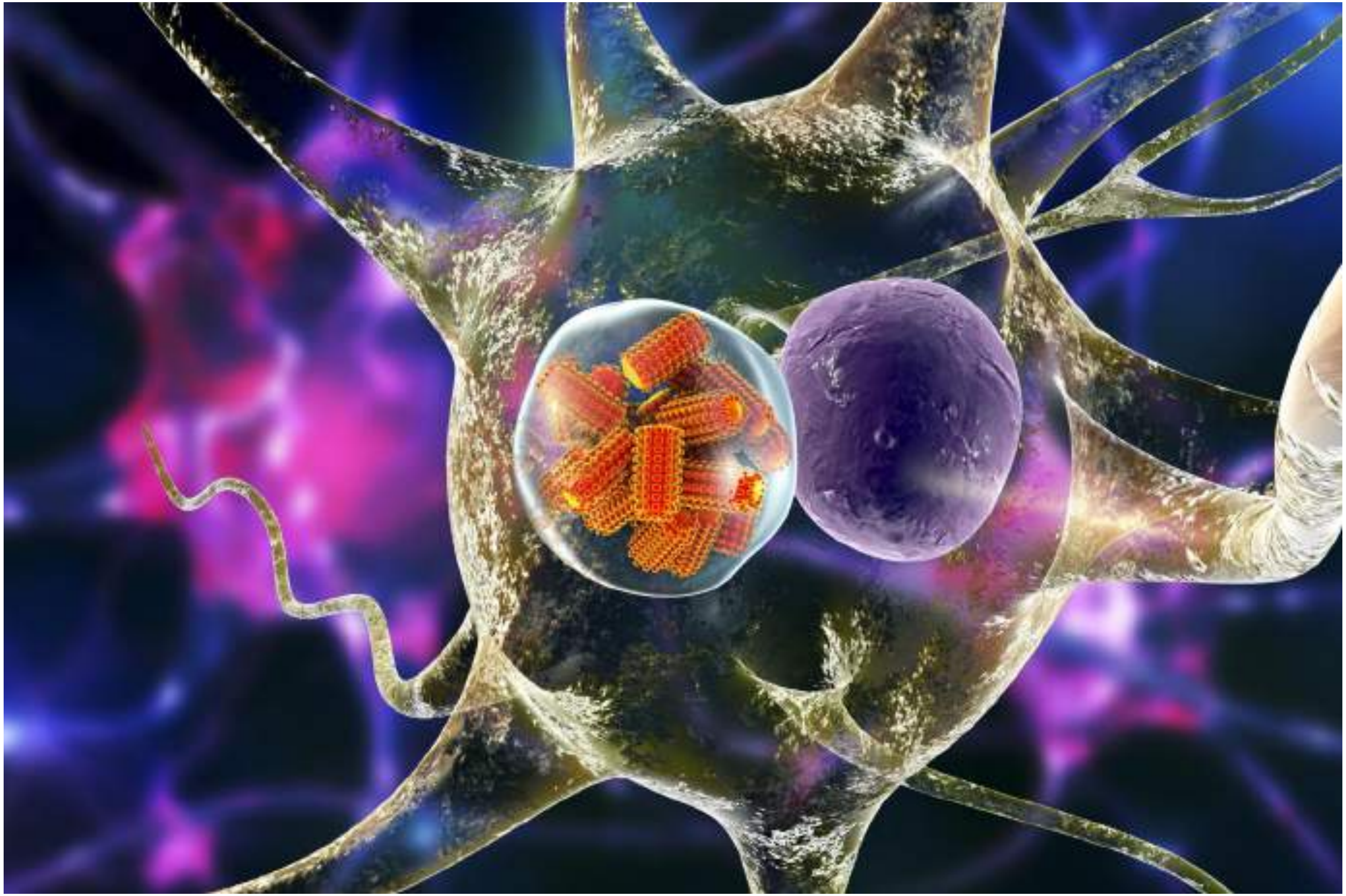
Much smaller than smallest bacteria

All are composed of:

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

Some have enzymes, attachment structures

Rabies

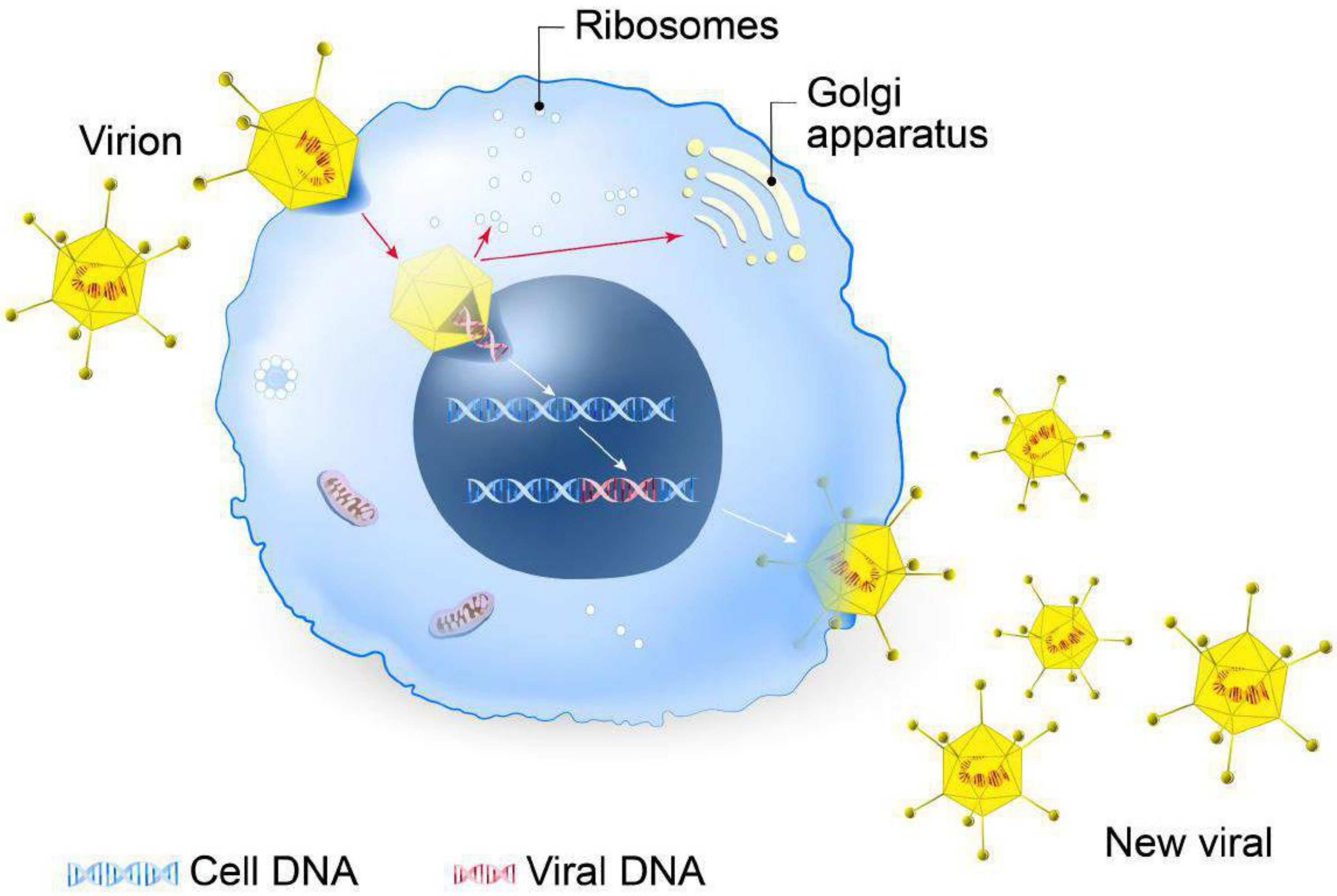


How Do They Work?

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

2. Organismal Biology

Structure & Function in Plants

1- Plant Organs
2- Water & Mineral Acquisition
3- Food Translocation & Storage

Plant Reproduction & Development

1- Alternation of Generations
2- Gamete Formation & Fertilization
3- Growth & Development
4- Tropisms & Photoperiodicity

Structure & Function in Animals

1- Major Systems
2- Homeostatic Mechanisms
3- Hormones in Homeostasis & Reproduction

Animal Reproduction & Development

1- Gamete Formation & Fertilization
2- Cleavage, Gastrulation, Germ Layers, Organ System Differentiation
3- Experimental Analysis of Vertebrate Development
4- Extraembryonic Membranes
5- Formation & Function of Mammalian Placenta
6- Blood Circulation in the Human Embryo

Principles of Heredity

1- Mendelian Inheritance
2- Chromosomal Basis of Inheritance
3- Linkage
4- Polygenic Inheritance

2.1 Structure & Function in Plants

Plant Structure & Function

2.1.1- Plant Organs
2.1.2- Water & Mineral Acquisition and Transport
2.1.3- Food Translocation & Storage

2.1.1

Plant Organs

- shoots
- leaves
- flowers
- fruits
- roots

2.1.2

Water & Mineral Acquisition and Transport

- vascular plants
- vascular tissues
- transport

2.1.3

Food Translocation & Storage

- phloem
- sugar movement
- food storage

2.1.1 Plant Organs

Major Plant Organs

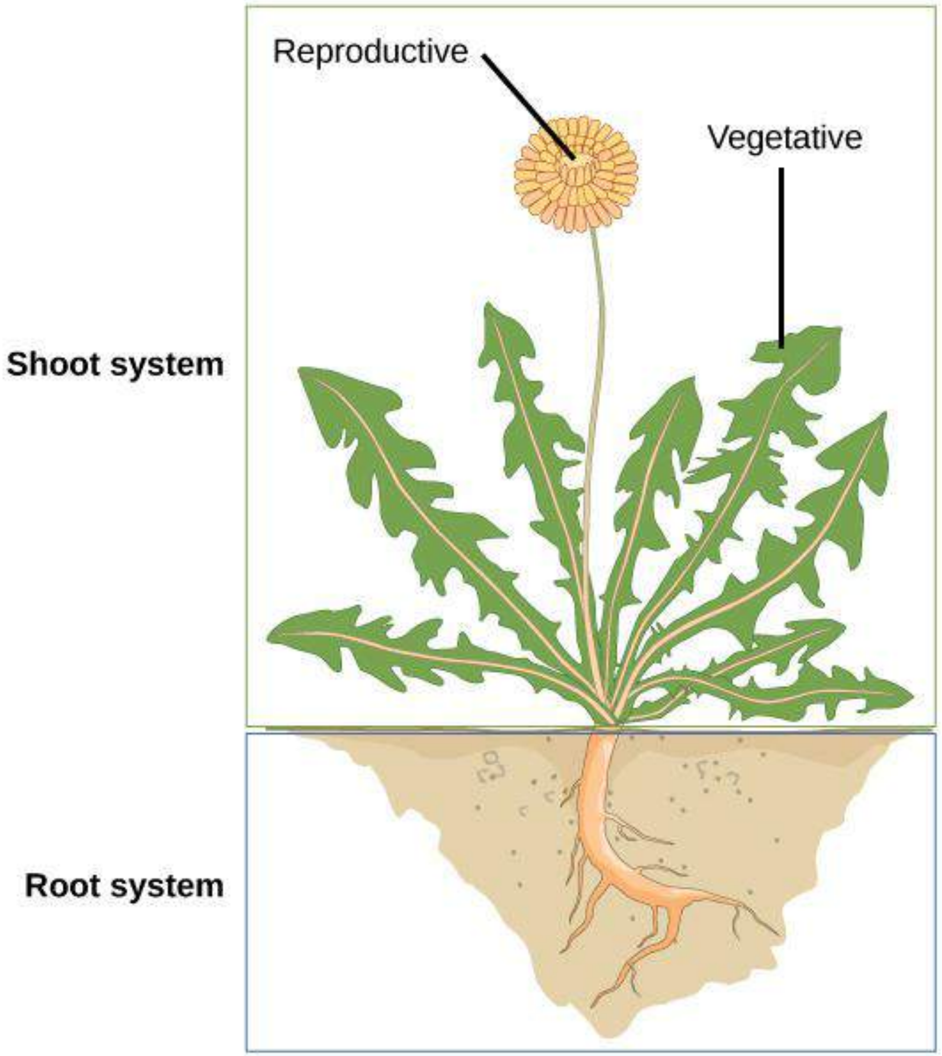
Shoots

Leaves

Flowers

Fruits

Roots



Shoot System

Usually above-ground part of plants

Sometimes has leaves, flowers, fruits

Gathers light & CO_2 for photosynthesis

Leaves

Gather light for photosynthesis

Sometimes modified or absent

Flowers

Only present in angiosperms

Attract pollinators, release pollen

Fruits

Mature reproductive organ

Contain seeds, sometimes tasty flesh

Roots

Absorb water & nutrients from soil

Below-ground organs

Sometimes store energy, water

2.1.2 Water & Mineral Acquisition and Transport

Vascular Plants

Non-vascular plants: no transport tissues; small & inconspicuous

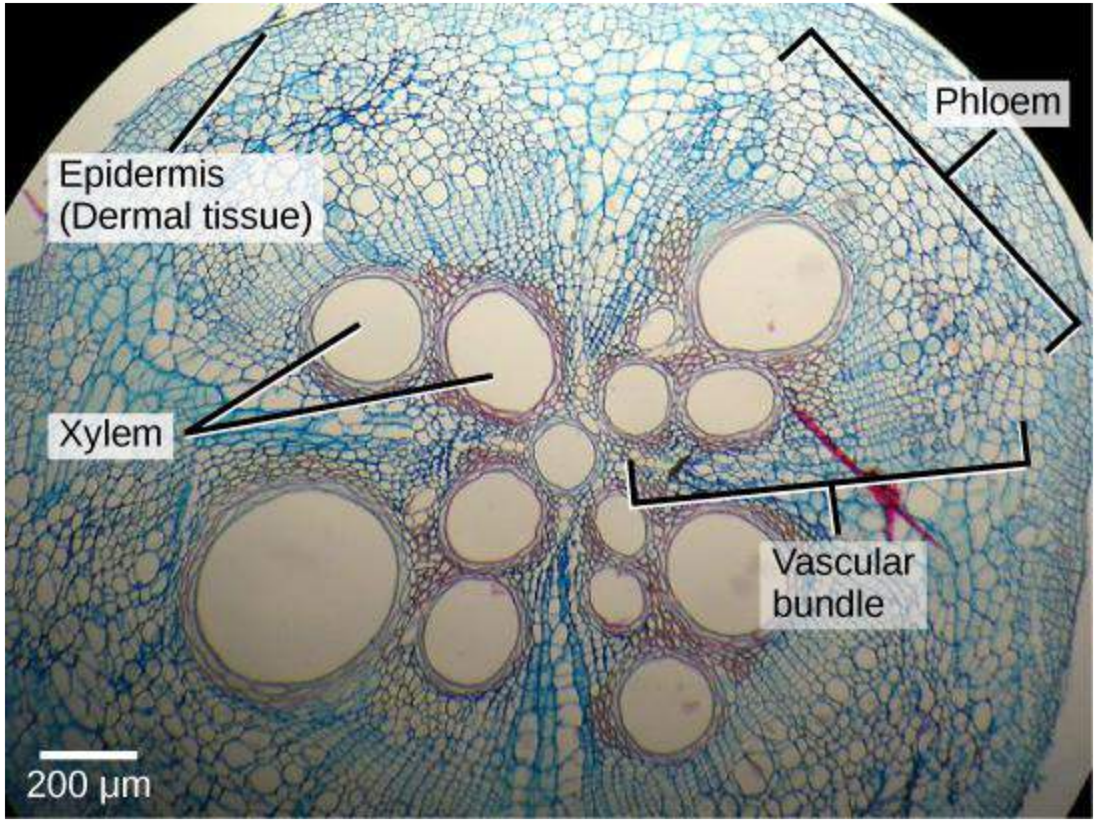
Vascular Plants: plants that have transport vessels for water, sugars, & minerals; most conspicuous plants

- grasses
- trees
- cacti
- herbs...

Vascular Tissues

Specifically for transport

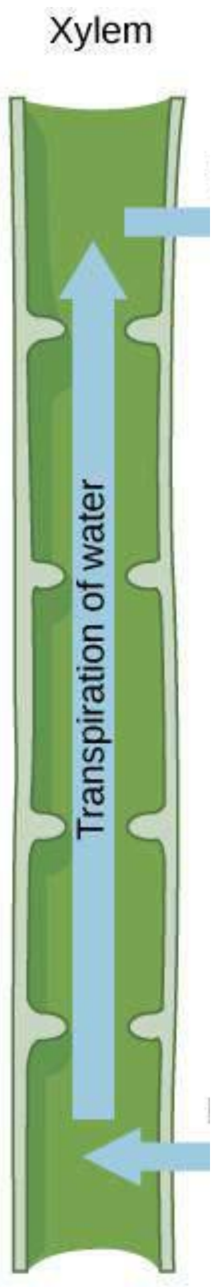
Xylem: transports water & minerals



Transport

Water & minerals diffuse into root cells

Cohesion-tension pulls water & minerals up through plant as water vapor is lost

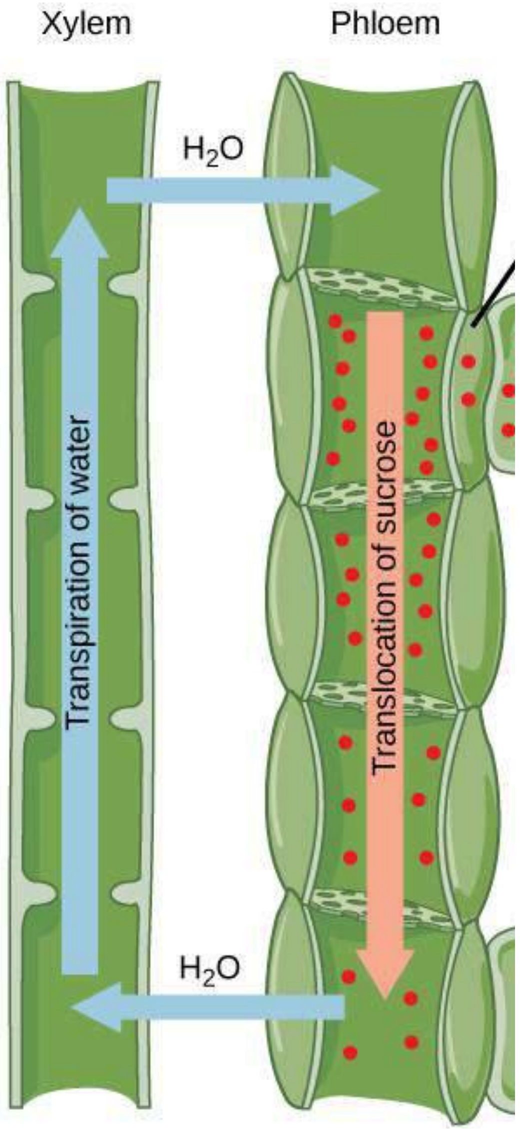


2.1.3 Food Translocation & Storage

Phloem

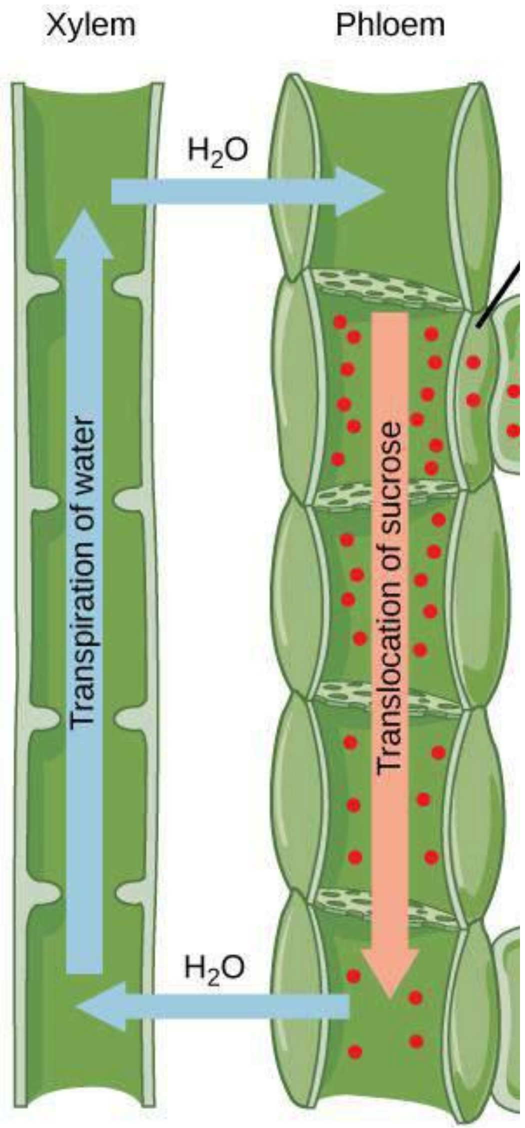
“Food” is sugars made via photosynthesis

Phloem: food transport tissues, shuttle sugars from leaves to rest of plant



Sugar Movement

Sugars build up in phloem, water diffuses in, sugar solution (sap) pushed throughout the plant



Food Storage

Some plants store carbohydrates as starch in stems or roots

- potatoes
- beets
- turnips

2.2 Plant Reproduction & Development

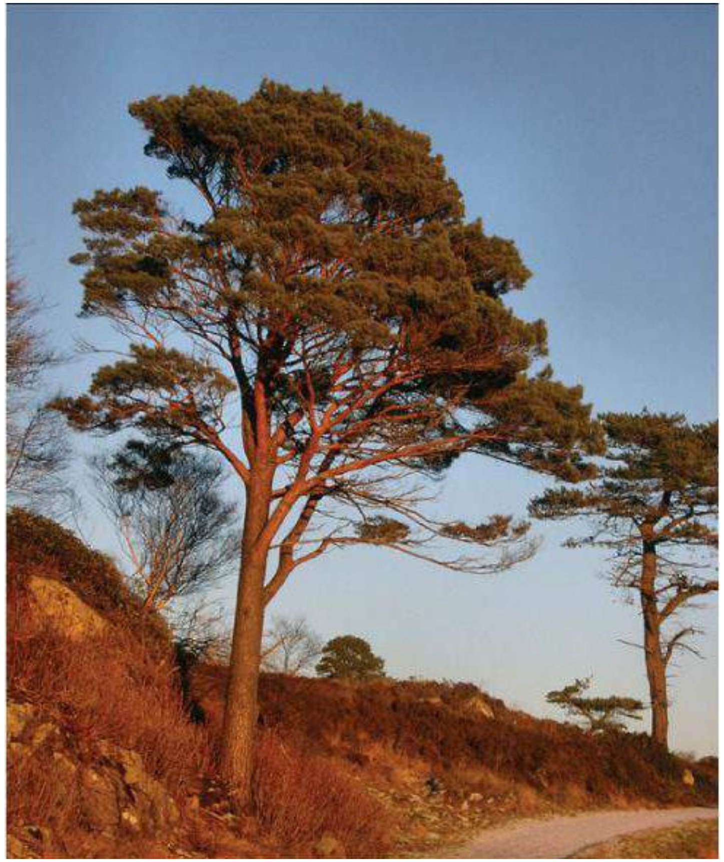
Plant Reproduction & Development

2.2.1- Alternation of Generations
2.2.2- Gamete Formation & Fertilization
2.2.3- Growth & Development
2.2.4- Tropisms & Photoperiodicity

2.2.1

Alternation of Generations

- alternation of phases
- diploid & haploid phases



2.2.2

Gamete Formation & Fertilization

- plant gametes
- plant sperm
- plant eggs
- fertilization in plants

2.2.3

Growth & Development

- plant hormones
- auxins
- cytokinins
- gibberellins
- abscisic acid
- ethylene

2.2.4

Tropisms & Photoperiodicity

- tropisms
- phototropism
- gravitropism
- thigmotropism
- photoperiodicity

2.2.1 Alternation of Generations

Alternation of Phases

The plant’s life cycle is an alternation of haploid and diploid phases

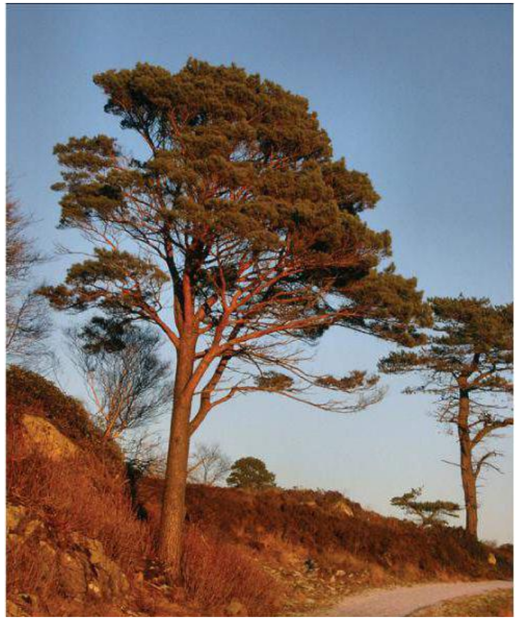
Both phases can undergo mitosis

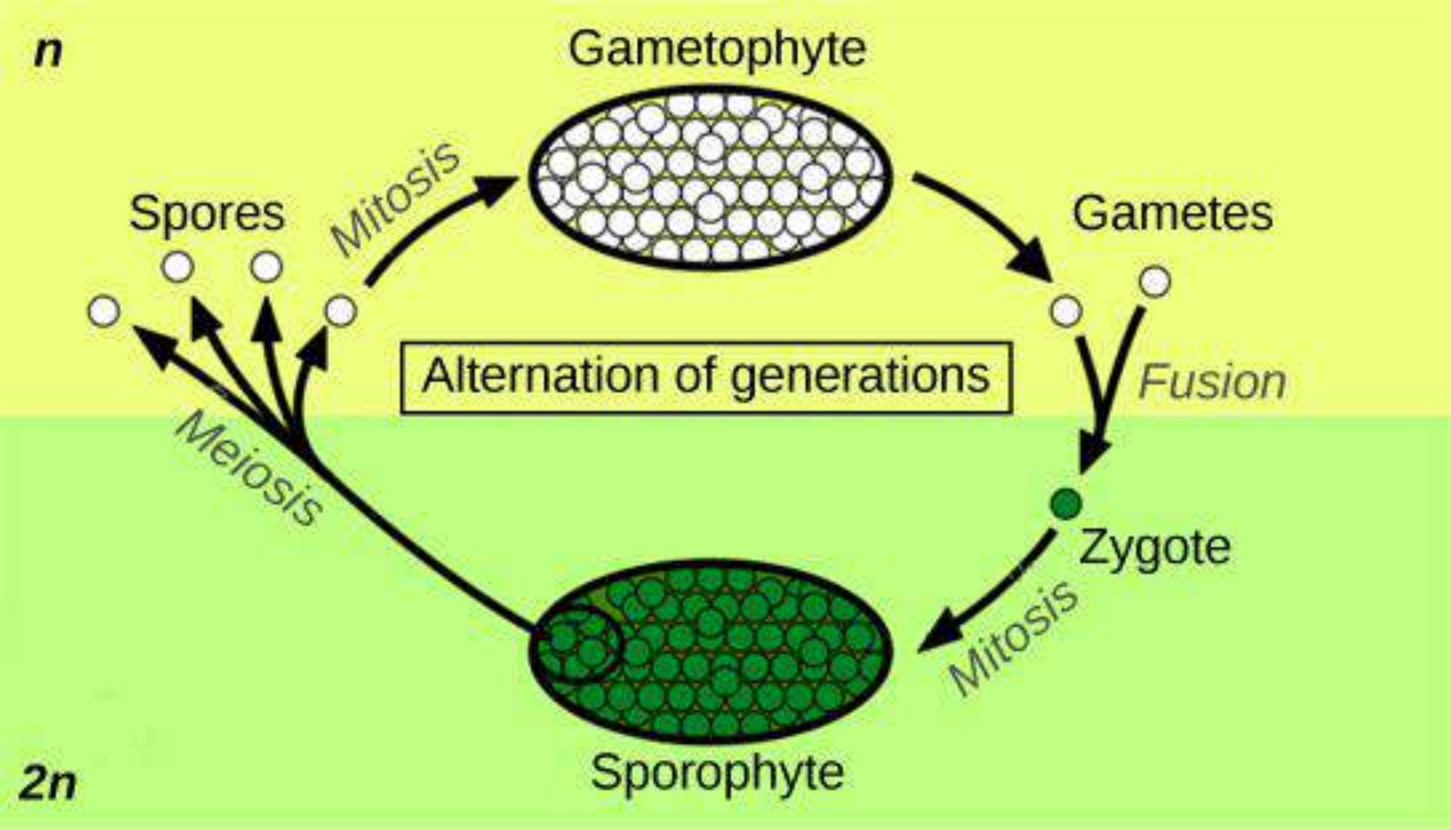
Sporophyte dominant in most plants, but depends on species

Diploid & Haploid Phases

Sporophyte (ex: pine tree): diploid phase, produces spores via meiosis, which grow into gametophytes via mitosis

Gametophyte (ex: inside pine cones): haploid phase, produces gametes via mitosis, which fuse to form new diploid individual (a sporophyte)




n
Gametophyte
Spores
Mitosis
Gametes
Alternation of generations
Fusion
Meiosis
Zygote
Mitosis
2n
Sporophyte

2.2.2 Gamete Formation & Fertilization

Plant Gametes

Gametes in plants are named like gametes in animals:

- male gamete: sperm
- female gamete: egg
- zygote: fused sperm & egg (fertilized egg)
- embryo: growing zygote (more than a few cells)

Plant Sperm

Formed by male gametophyte

Produced in large numbers, leave to join eggs

Transmittal depends on species:

- swimming in plants from wet areas
- non-swimming & packaged inside pollen grains in other plants

Plant Eggs

Formed by female gametophyte

Produced in small numbers, larger

Transmittal uncommon (they stay put)

Fertilization in Plants

Similar to fertilization in animals- male & female gametes fuse to form zygote

In seed plants (ex: pines, roses) sperm must grow through female plant tissue to reach ovaries w/ eggs

In seedless plants (ex: mosses, liverworts) it’s simpler

2.2.3 Growth & Development

Plant Hormones

Function similarly to animal hormones, transported in vascular system

Control most aspects of growth & development

Often several interact

Auxins

Promote shoot elongation

Produced mostly in shoot tips; transported only from tip to base of shoot

Cytokinins

Stimulate cytokinesis

Produced in actively growing tissue: roots, embryos, fruits

Gibberellins

Affect cell division & elongation, fruit growth, seed germination

Young roots & leaves major sites of production

Abscisic Acid

Slows growth, often antagonizing actions of growth hormones

Ratio of ABA to growth hormones determines whether growth occurs

Ethylene

Produced in response to stresses...
- drought
- flood
- injury

And as part of normal life cycle
- fruit ripening
- programmed cell death

2.2.4 Tropisms & Photoperiodicity

Tropism

Any growth response that results in plants growing towards or away from stimuli

Phototropism

Response to light

Positive: plant organs grow toward light, most often seen in shoots

Negative: plant organs grow away from light, most often seen in roots

Gravitropism

Response to gravity

Roots display positive gravitropism

Shoots display negative gravitropism

Response occurs as soon as seed germinates & organs grow in appropriate direction no matter how seed is oriented when it lands

Thigmotropism

Response to touch

Comes in several forms

- trees in windy habitats grow short & thick
- plants that use objects for climbing
- plants that close when touched

Photoperiodicity

Physiological response to relative lengths of night & day

Affects growth & development

- time of year for growing
- time of year for flowering

2.3 Structure & Function in Animals

Structure & Function in Animals

1- Major Systems
2- Homeostatic Mechanisms
3- Hormones in Homeostasis & Reproduction

Major Systems

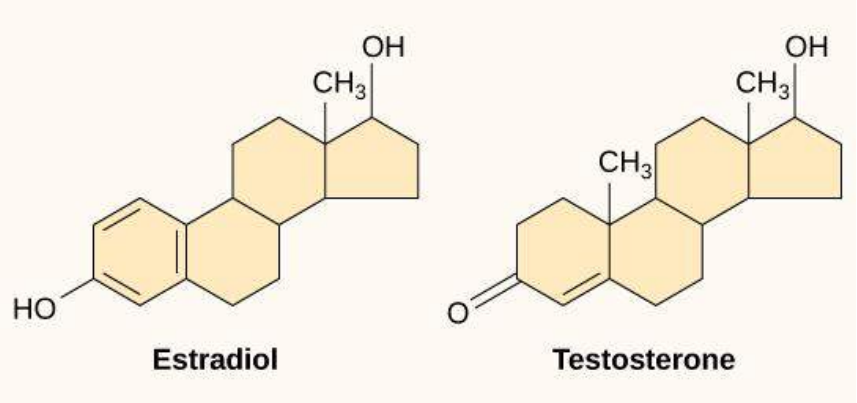
- the animal body
- digestive
- respiratory
- circulatory
- musculoskeletal
- nervous
- excretory
- immune

Homeostatic Mechanisms

- homeostasis
- homeostatic components
- feedback mechanisms
- thermoregulation

Hormones in Homeostasis & Reproduction

- endocrine system
- what is a hormone?
- endocrine glands
- hormones as signals
- hormones in reproduction



2.3.1 Major Systems

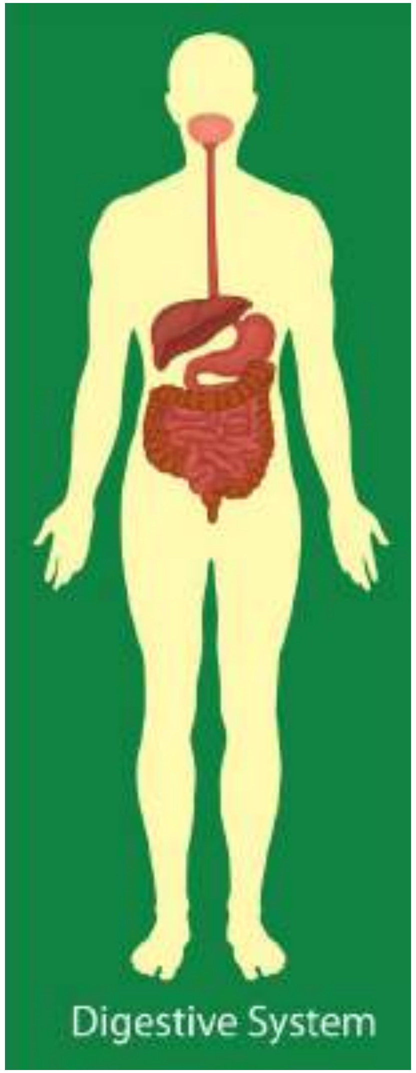
The Animal Body

Highly complex "machine" with numerous processes occurring simultaneously & systems cooperating to maintain life

Mostly controlled by hormones, but affected by environment

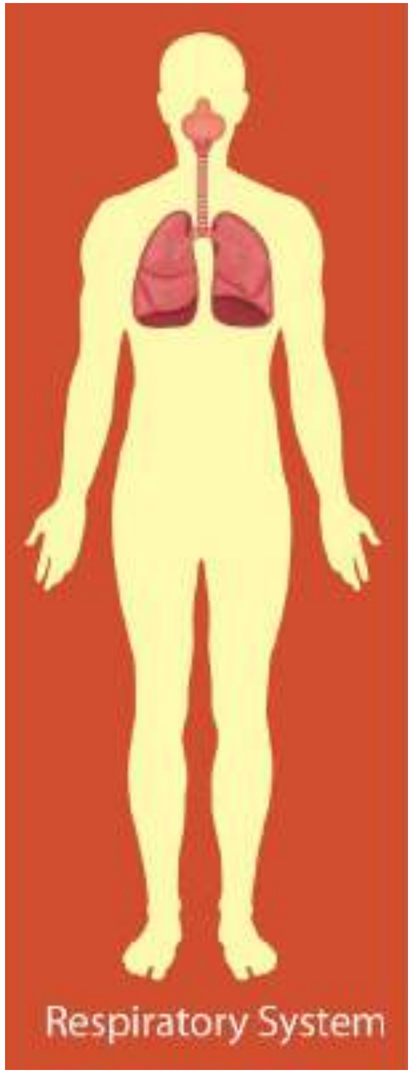
Digestive System

Processes ingested food & drink



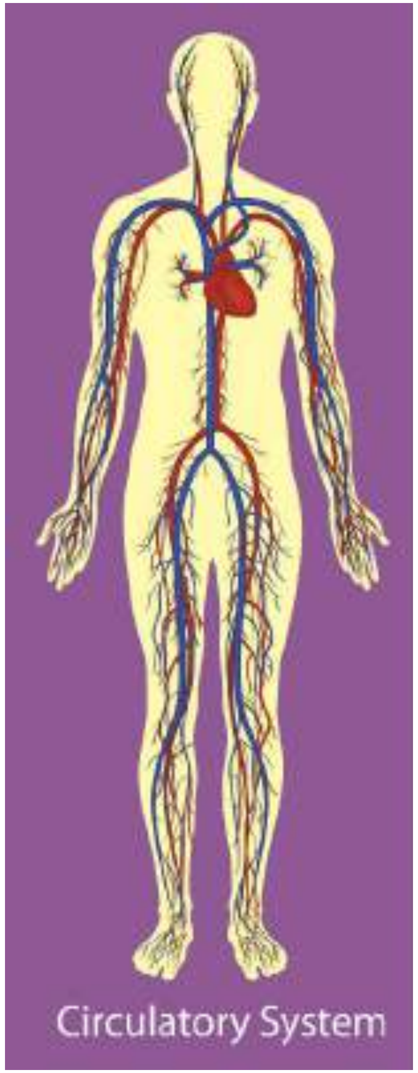
Respiratory System

Responsible for intake
of essential gases,
release of waste gases



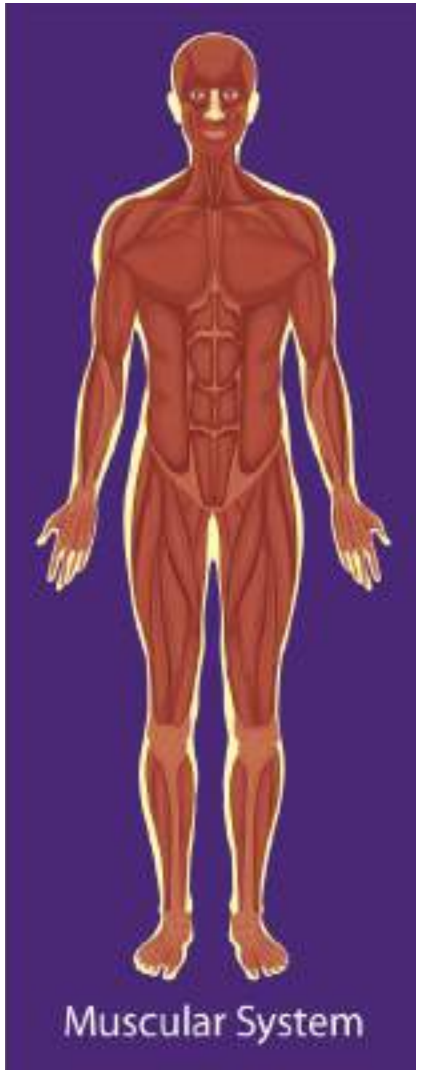
Circulatory System

Moves gases, nutrients, hormones throughout body



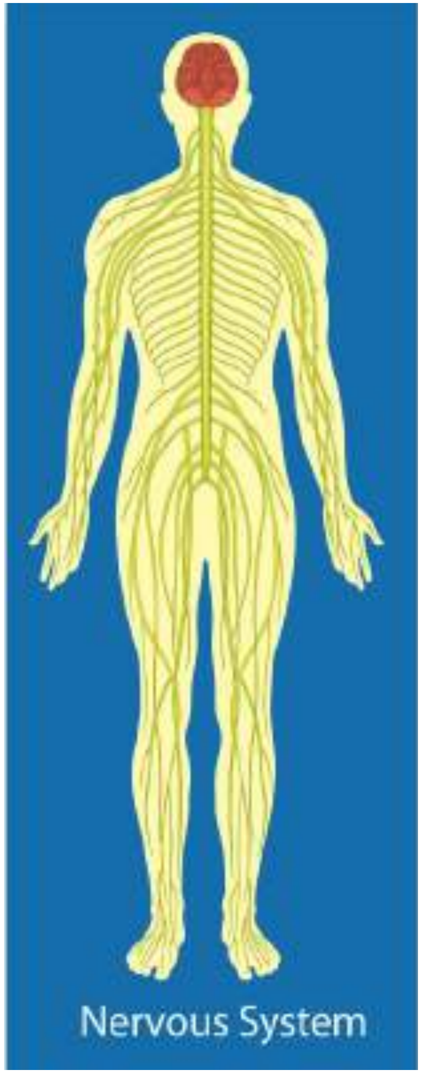
Musculoskeletal System

Muscles & skeleton work together to provide support, stability, movement



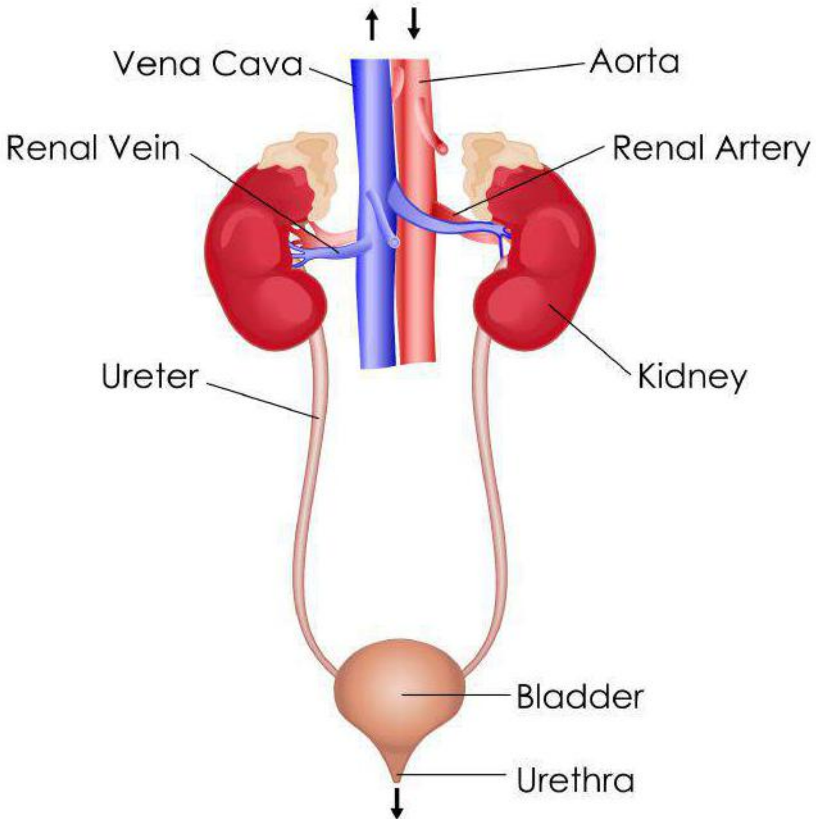
Nervous System

Passes messages between brain & body



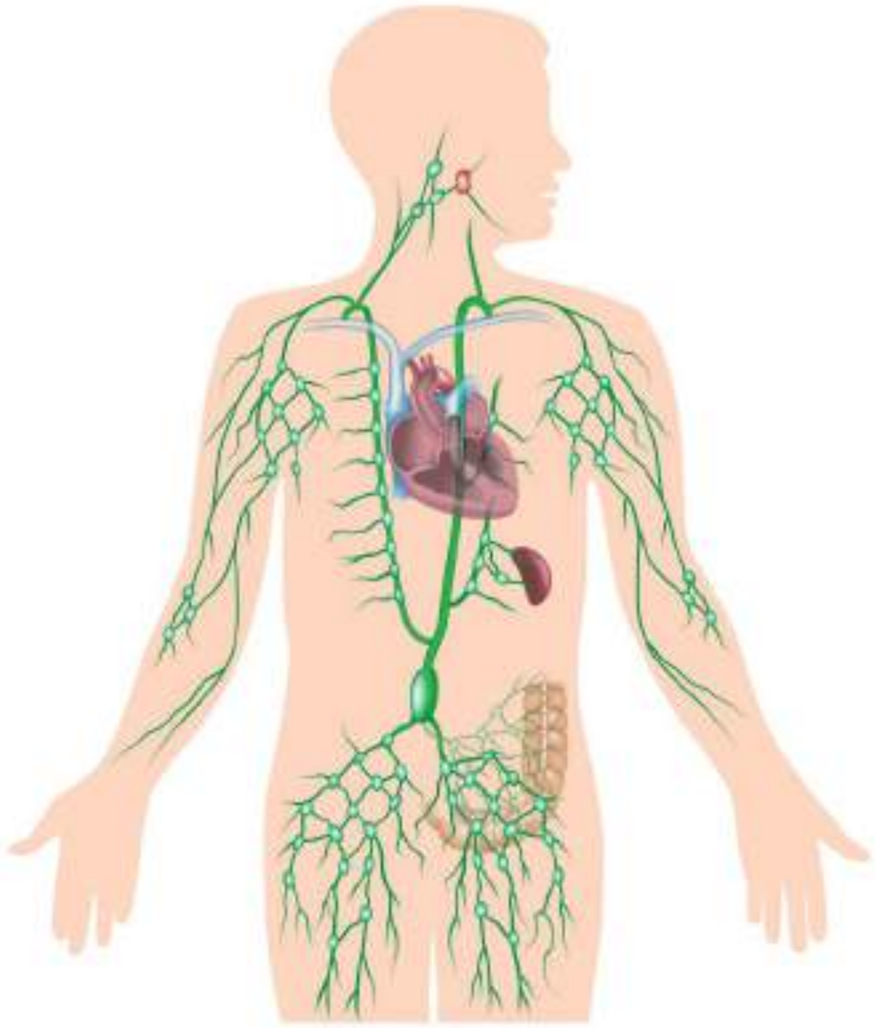
Excretory System

Filters wastes & excess water from blood, releases outside body



Immune/ Lymphatic System

Defense against invaders (bacteria, viruses, parasites...)



2.3.2 Homeostatic Mechanisms

Homeostasis

"Steady state," refers to maintenance of internal balance

Examples:

- temperature
- ion concentration
- blood oxygen
- blood glucose

Homeostasis

Set point: animal maintains a variable at or near a particular value

Stimulus: fluctuations in a variable

Sensor: detects stimuli & sends signal to control center

Control center: generates output that triggers a physiological response to stimulus

Hormones are chemicals used as signals, important for homeostasis

Homeostasis

Relies largely on negative feedback cycles, which reduce stimulus

“Negative” feedback because stimulus results in events that decrease it

Example:

1. human body temperature set point= 98.6°F
2. exercise produces heat that raises your body temperature (stimulus)
3. nervous system (sensor) sends message to control center (brain)
4. brain causes body to sweat (response)
5. Cooling from sweat decreases body temperature & sweating stops

Thermoregulation

Endothermy: internal temperature regulation through heat generated by metabolism; mammals, birds

Ectothermy: internal temperature regulated by external environment; amphibians, reptiles, most fish, most invertebrates

2.3.3 Hormones in Homeostasis & Reproduction

Endocrine System

Regulates body’s ‘set points’- temperature, heart rate, metabolism

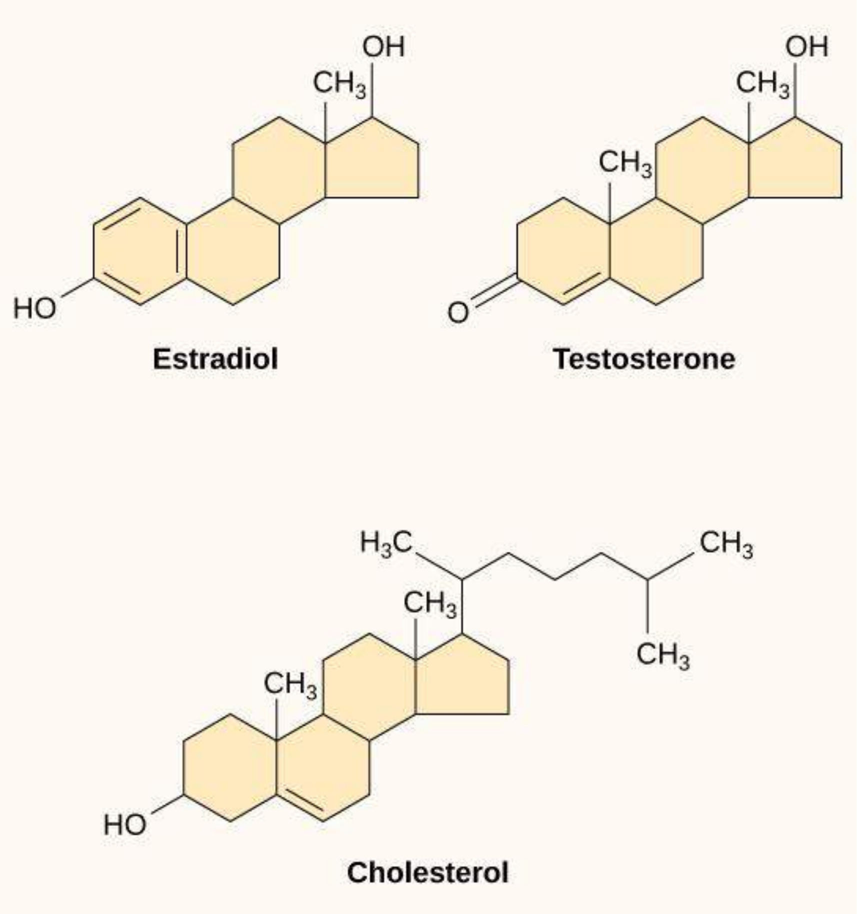
Triggers important physiological events- puberty, reproduction

Facilitates cell to cell communication- glucose uptake, antihistamine release

Hormone

A chemical secreted by an endocrine gland/organ into the blood for transport

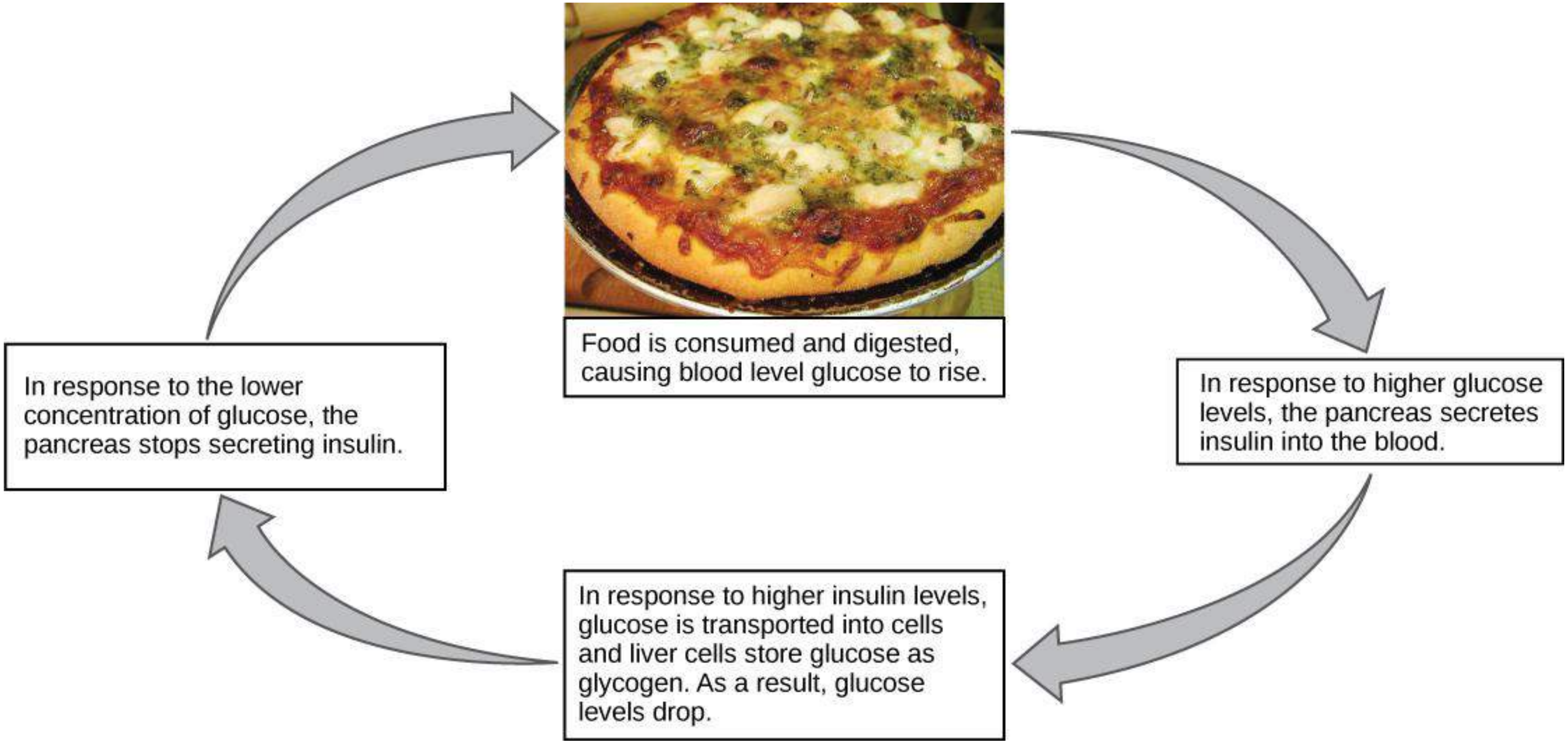
Affects growth, metabolism, development, homeostasis



Endocrine Gland

A ductless gland or single cell that secretes a hormone, which travels through blood

Hormone targets the cells or organs that have receptors for the hormone


Food is consumed and digested, causing blood level glucose to rise.
In response to higher glucose levels, the pancreas secretes insulin into the blood.
In response to higher insulin levels, glucose is transported into cells and liver cells store glucose as glycogen. As a result, glucose levels drop.
In response to the lower concentration of glucose, the pancreas stops secreting insulin.

Hormones as Signals

Once released by the control center (usually the brain), hormones work as signals in one of two ways:

1. diffuse into cells' cytoplasm and join w/ receptor protein, which causes a response
2. join w/ receptor protein in cell membranes, which causes a response

Hormones in Reproduction

Hormones responsible for sexual maturation & cycling:

- development of gonads, which also release hormones
- development of sperm & eggs
- release of eggs
- development of embryos after fertilization
- contractions during labor or egg-laying
- lactation and other maternal behavior

2.4 Animal Reproduction & Development

Animal Reproduction & Development

1- Gamete Formation & Fertilization

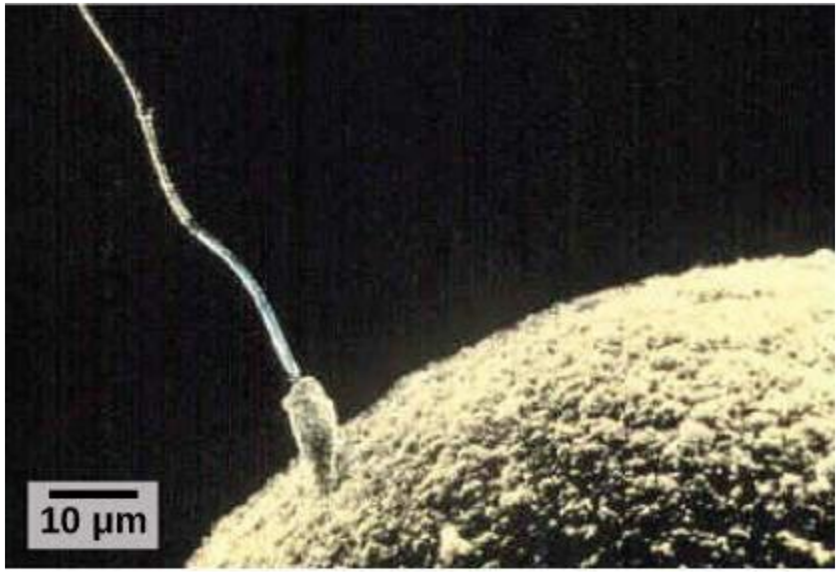
2- Cleavage, Gastrulation, Germ Layers, Organ System Differentiation

3- Experimental Analysis of Vertebrate Development

4- Extraembryonic Membranes

5- Formation & Function of Mammalian Placenta

6- Blood Circulation in Human Embryo

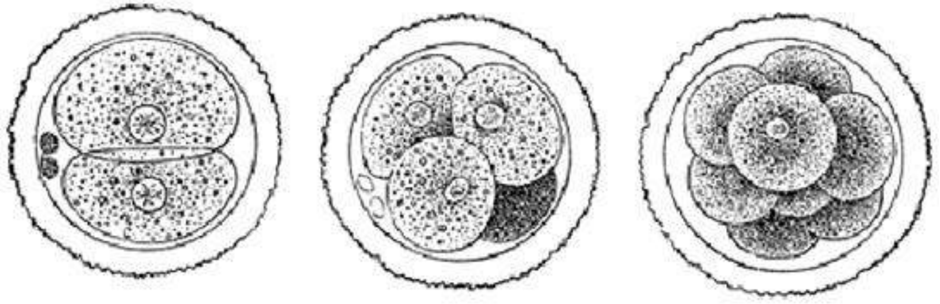


Gamete Formation & Fertilization

- reproduction
- gametogenesis
- spermatogenesis
- oogenesis
- fertilization

Cleavage, Gastrulation, Germ Layers, Organ System Differentiation

- the zygote
- cleavage
- developmental stages
- germ layers

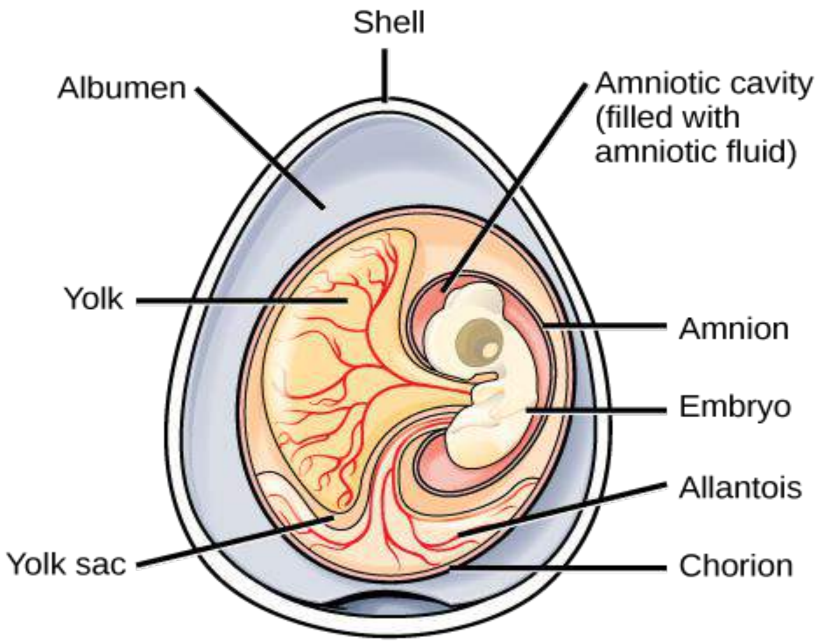


Experimental Analysis of Vertebrate Development

- Model Organisms
- Zebrafish
- Frogs
- Chicks
- Mice
- Fish in Space!

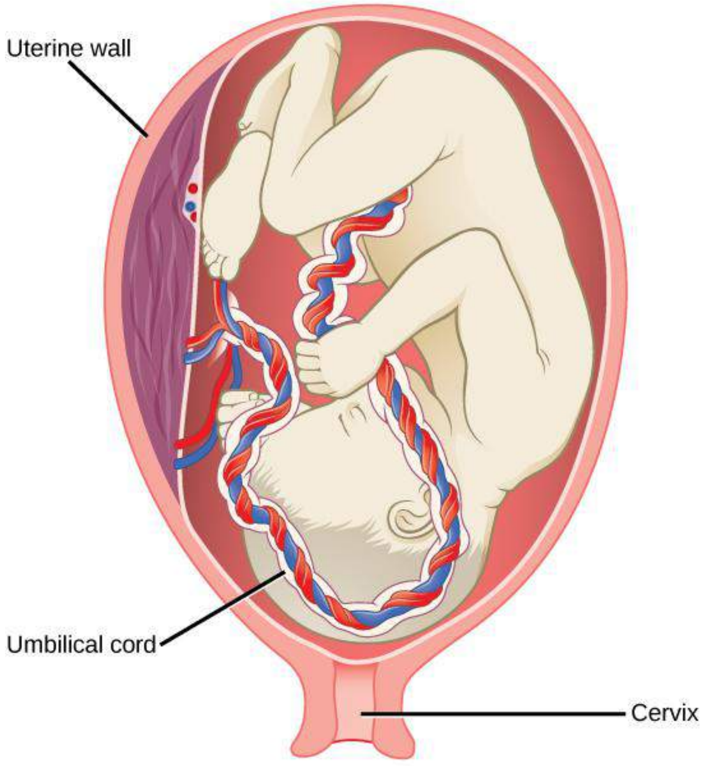
Extraembryonic Membranes

- extraembryonic membranes
- chorion
- amnion
- allantois
- yolk sac membrane



Formation & Function of Mammalian Placenta

- placental formation
- placental function



Blood Circulation in the Human Embryo

- embryonic blood vessels
- exchange with mother

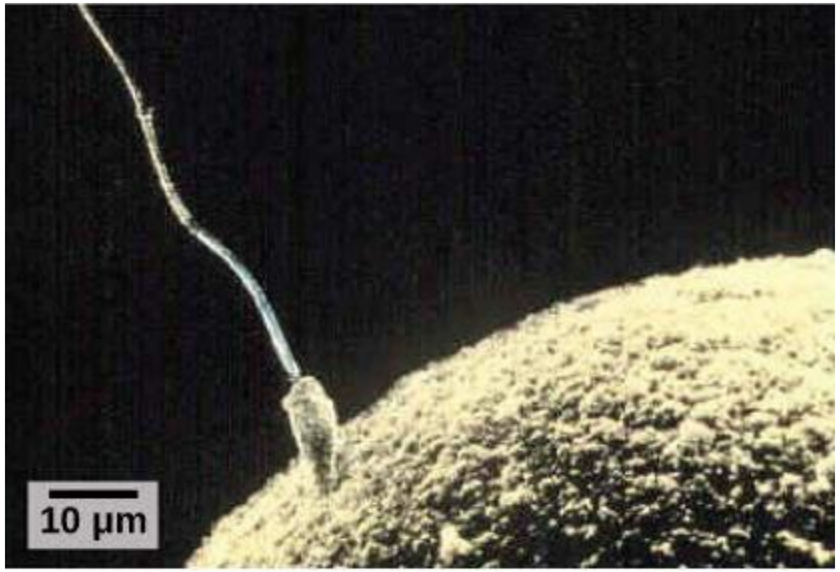
2.4.1 Gamete Formation & Fertilization

Reproduction

Reproduction is complicated for multicellular organisms

Two processes involved

1. **gametogenesis**
2. **fertilization**



Gametogenesis

"Making gametes"

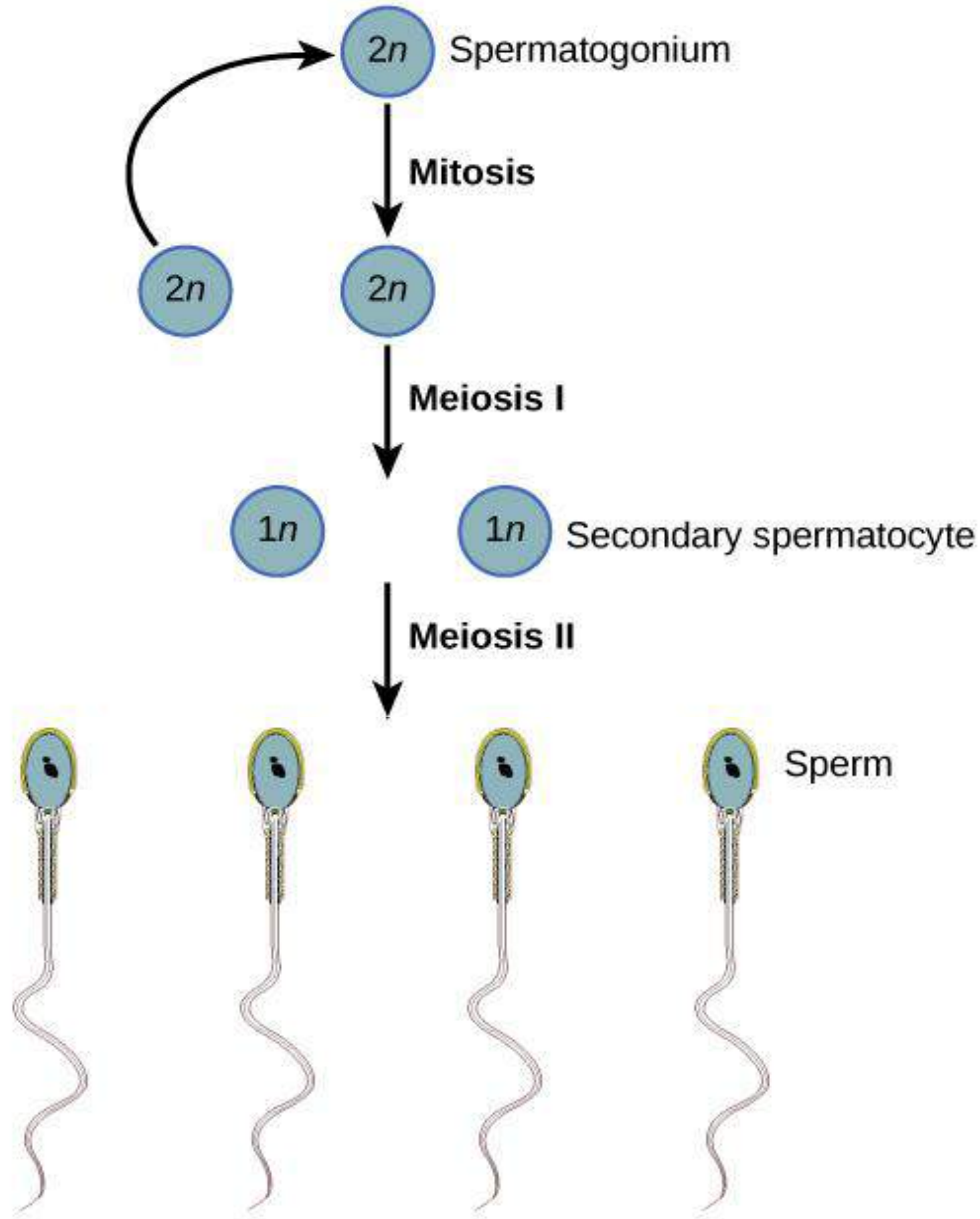
- sperm
- eggs

Spermatogenesis

Formation of sperm

Occurs in spermatogonia- cells in testes

1. Primary spermatocytes (2n) formed
2. Secondary spermatocytes (1n) formed from primary, via Meiosis 1
3. Sperm cells (1n) formed from secondary spermatocytes via Meiosis II

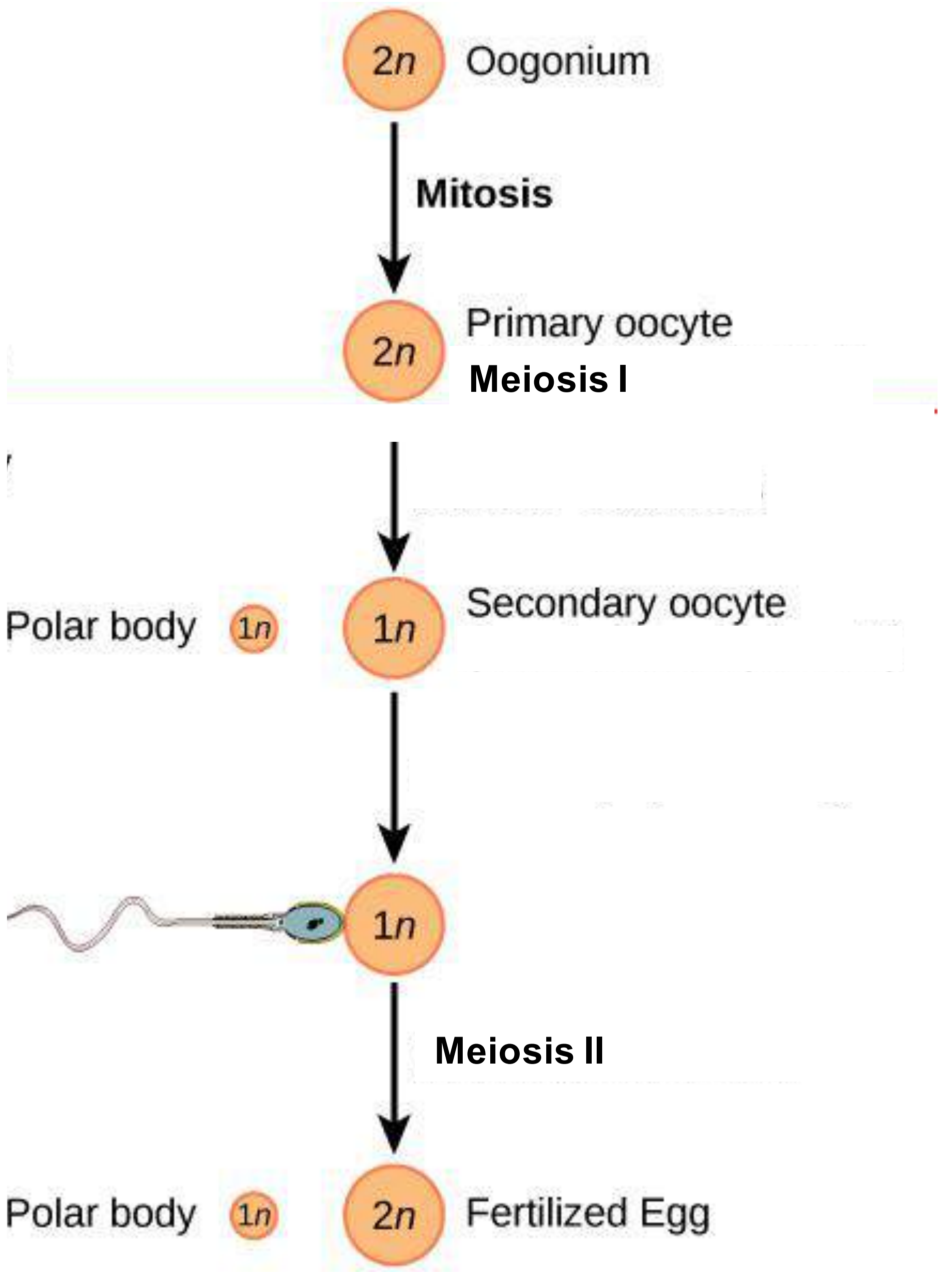

2n
Spermatogonium
Mitosis
2n
2n
Meiosis I
1n
1n
Secondary spermatocyte
Meiosis II
Sperm

Oogenesis

Formation of eggs

Occurs in oogonia- cells in ovaries

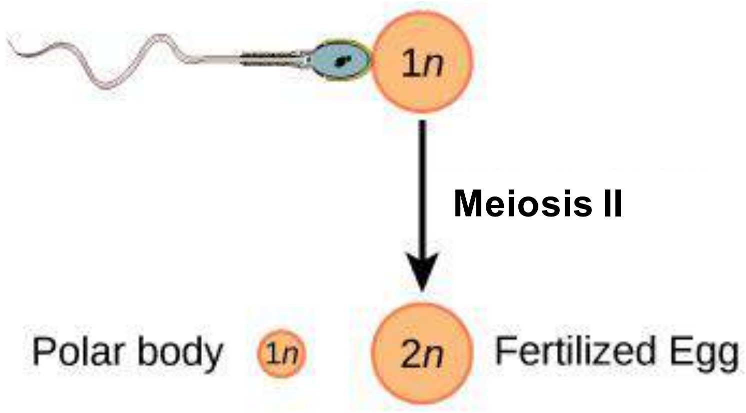
1. **Primary oocyte (2n) present in ovaries from birth**
2. **Secondary oocytes (1n) formed from primary, via Meiosis 1; polar body also formed**
3. **Egg cells and polar bodies (1n) formed from secondary oocytes via Meiosis II**
4. **Polar bodies recycled**



2n
Oogonium
Mitosis
2n
Primary oocyte
Meiosis I
Polar body
1n
1n
Secondary oocyte
1n
Meiosis II
Polar body
1n
2n
Fertilized Egg

Fertilization

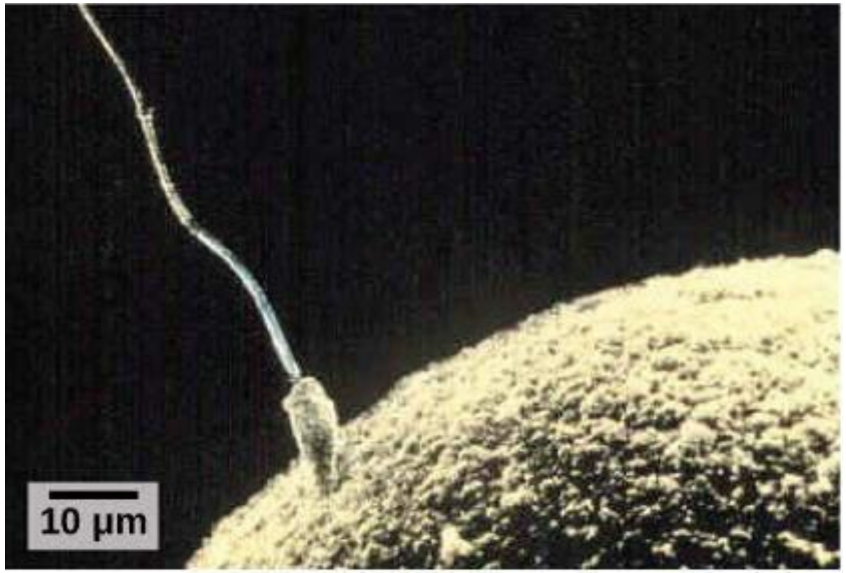
Sperm and egg join to form zygote



2.4.2 Cleavage, Gastrulation, Germ Layers, Organ System Differentiation

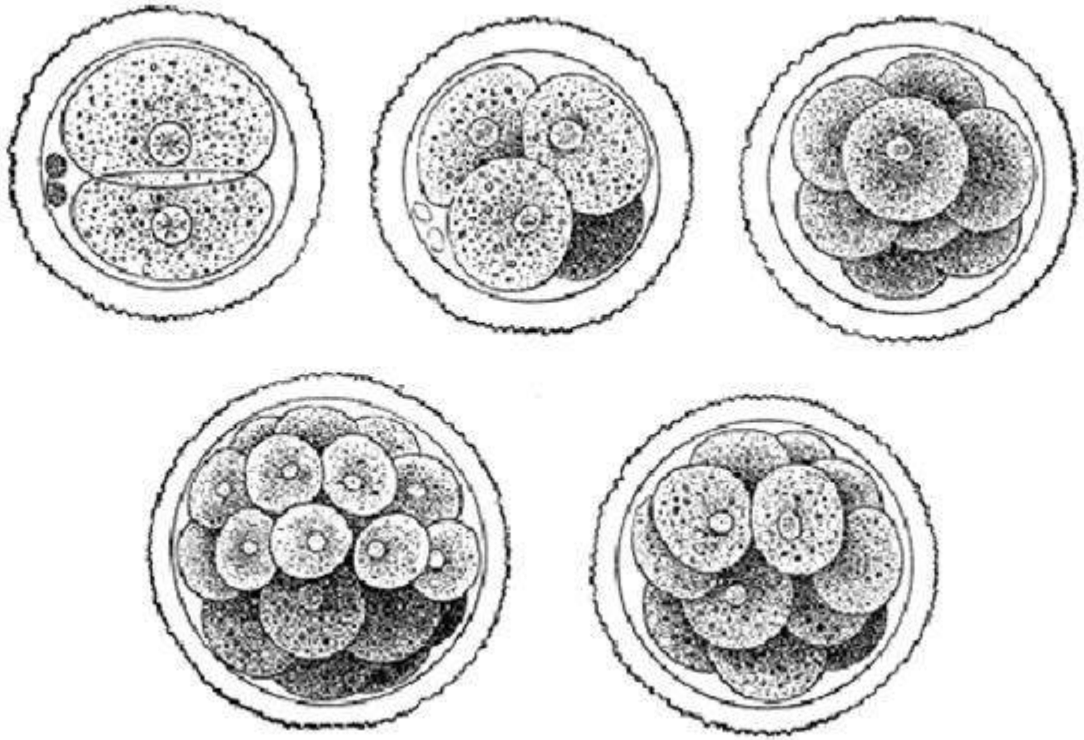
The Zygote

All sexually-reproducing multicellular organisms start life as a zygote (fertilized egg)



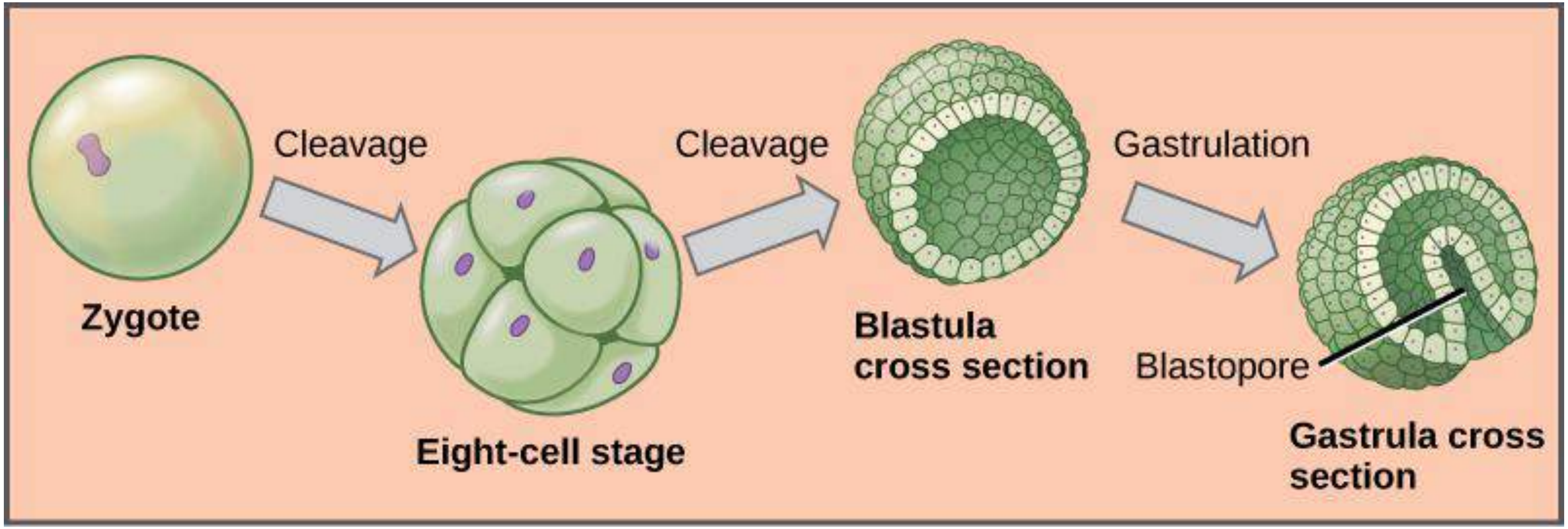
Cleavage

Zygote divides several times via mitosis, without changing size



Developmental Stages

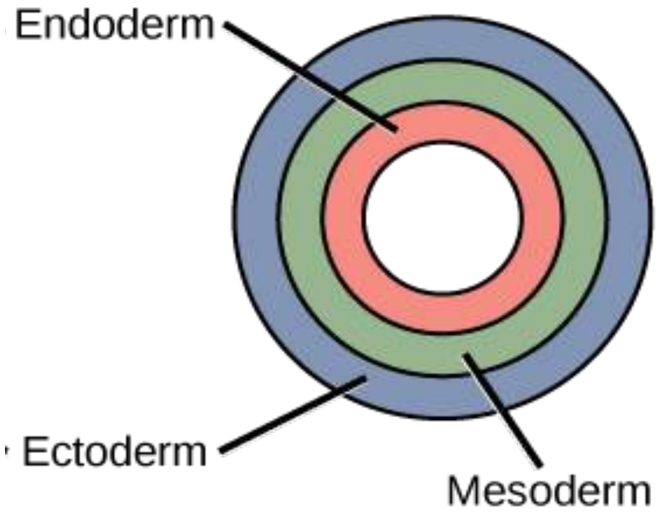
1. Morula- solid ball of cells
2. Blastula- hollow sphere of cells
3. Gastrula (gastrulation)- hollow sphere of cells w/ tube through center that forms digestive canal


Cleavage
Cleavage
Gastrulation
Zygote
Eight-cell stage
Blastula
cross section
Blastopore
Gastrula cross
section

Germ Layers

Layers of tissue in developing organism

1. Endoderm- inside, forms alimentary canal
2. Mesoderm- in middle, forms muscles, bones, circulatory system, reproductive system
3. Ectoderm- outside, forms skin, nervous system



2.4.3 Experimental Analysis of Vertebrate Development

Model Organisms

Model organisms are used to learn about generalities in vertebrate development

The majority of what we know about development has come from these models

Zebrafish

Zebrafish embryos have been used to explore:

- **effects of inhibitors**
- **effects of alcohol**
- **stages of development**

Frogs

Frog embryos have been used to investigate:

- blastula formation
- causes of two-headedness
- control of spinal formation

Chicks

Chicken embryos are used to learn about:

- formation of limbs
- signaling molecules

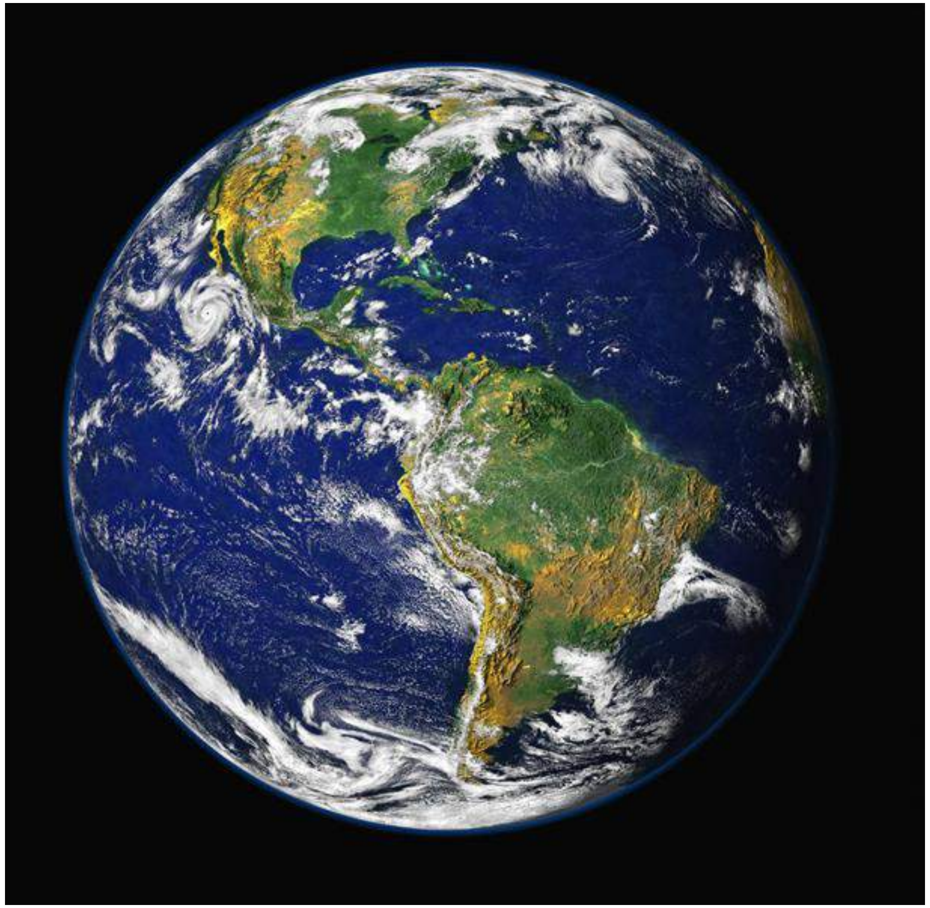
Mice

Study of mouse embryos have helped us understand:

- toe formation & separation
- cell fate determinants

Fish in Space!

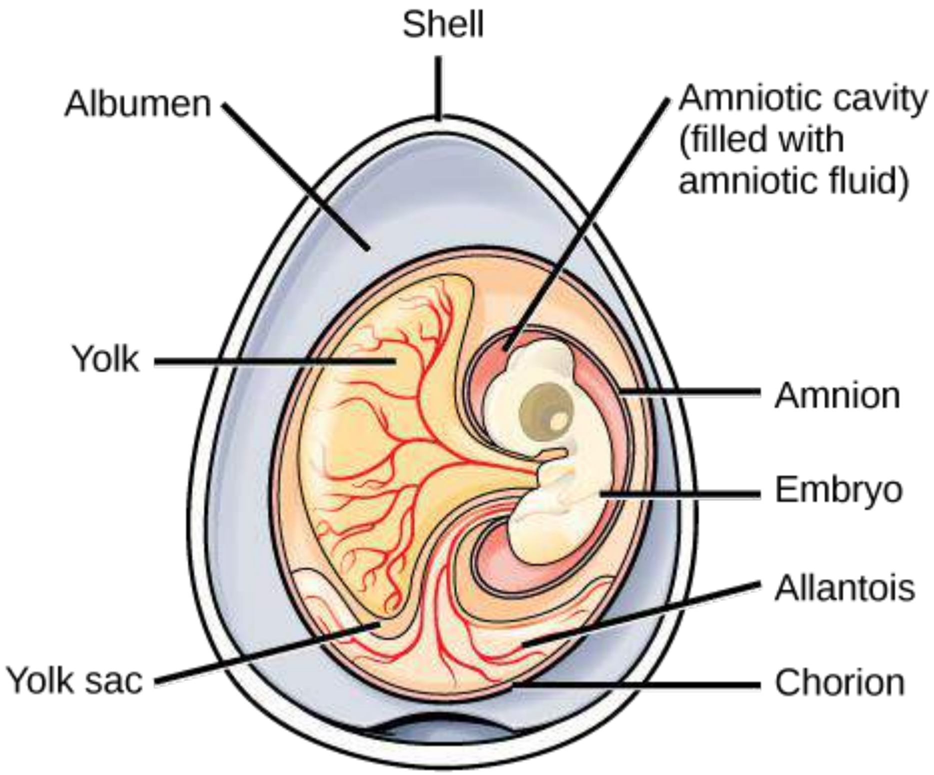
The medaka, and Asian relative of the zebrafish, is being used to study the effects of low gravity on vertebrate embryo development



2.4.4 Extraembryonic Membranes

Extraembryonic Membranes

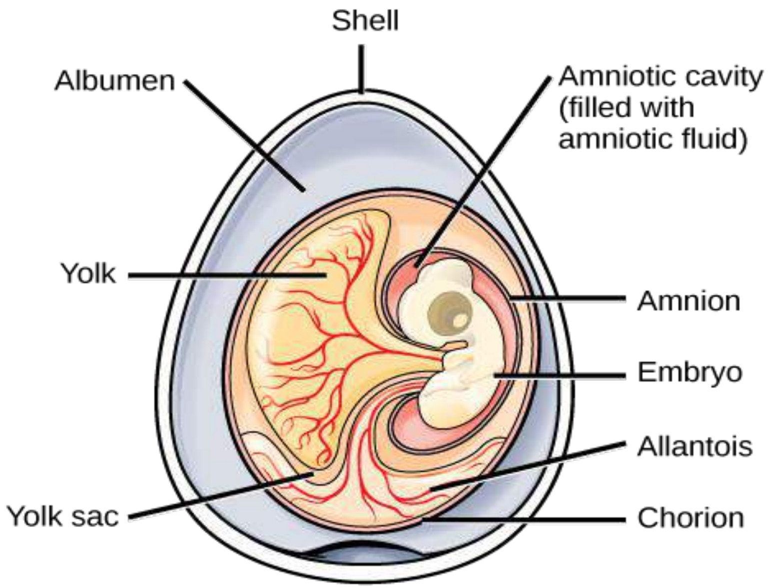
Membranes outside the embryo, surrounding embryo during development



Chorion

Regulates water, gases, nutrients, wastes

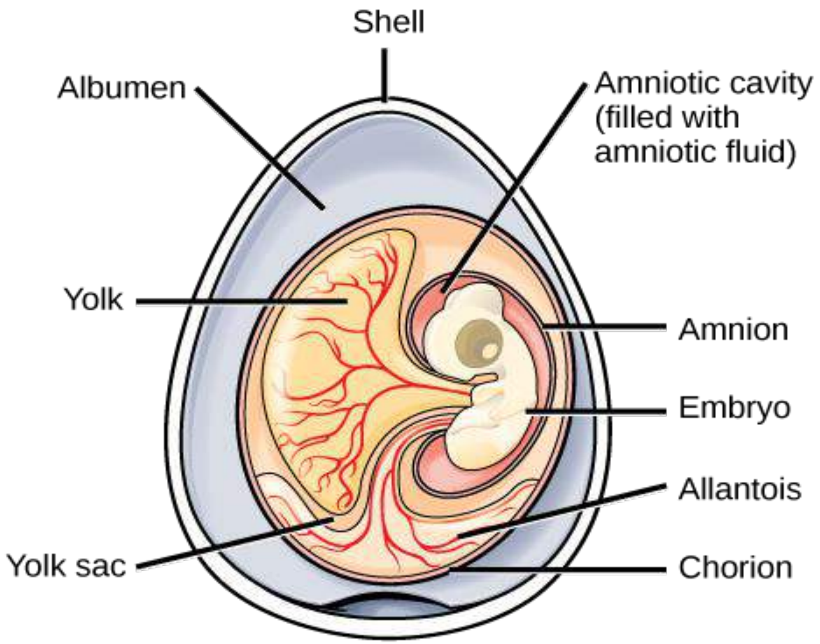
- In egg-layers, in contact with inner shell surface
- In others, in contact with uterus



Amnion

Fluid-filled sac around embryo

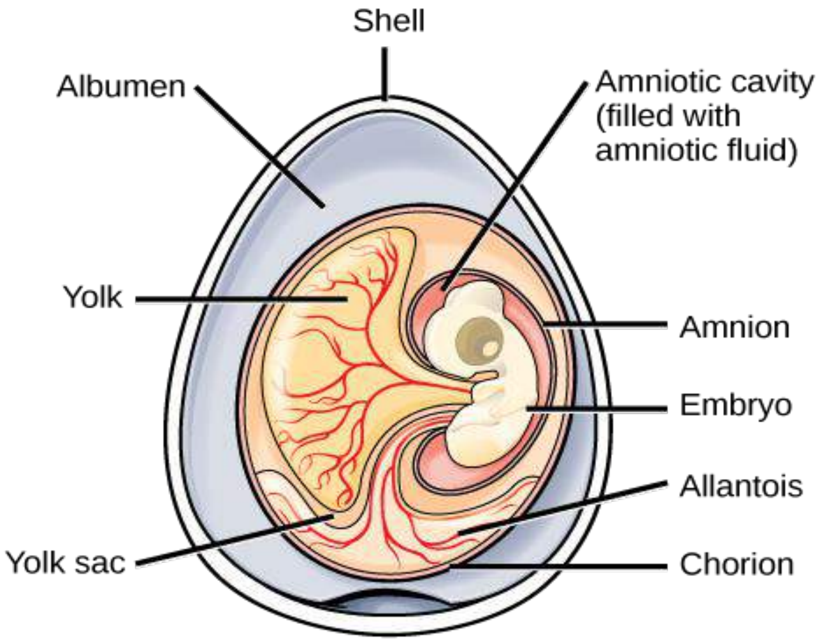
- **cushioning**
- **temperature regulation**



Allantois

Comes from developing digestive tract, gas & nutrient exchange

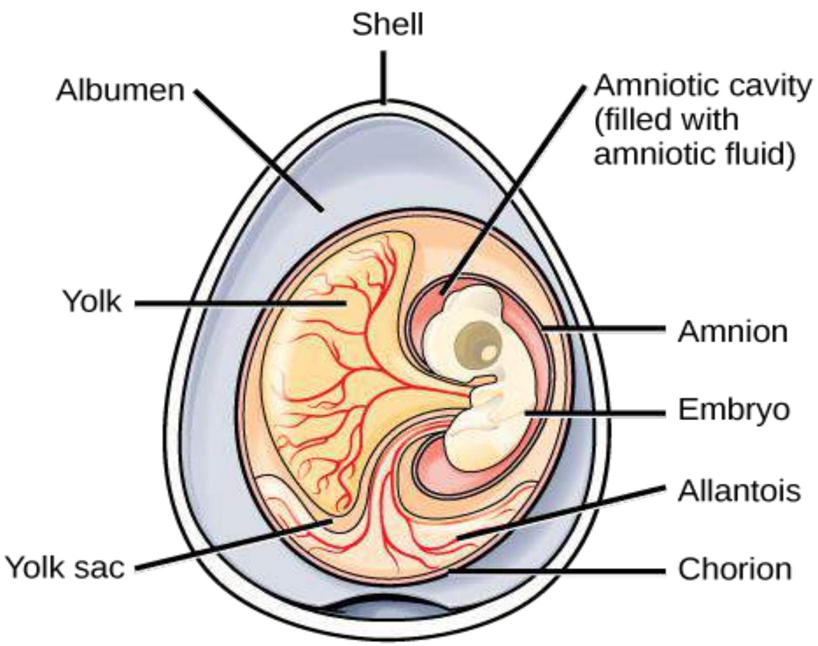
- becomes umbilical cord in non-egg layers
- waste storage in egg-layers



Yolk Sac Membrane

Comes from developing digestive tract, encloses yolk sac that stores nutrients

- **becomes part of umbilical cord in non-egg layers**
- **larger in non-egg layers**

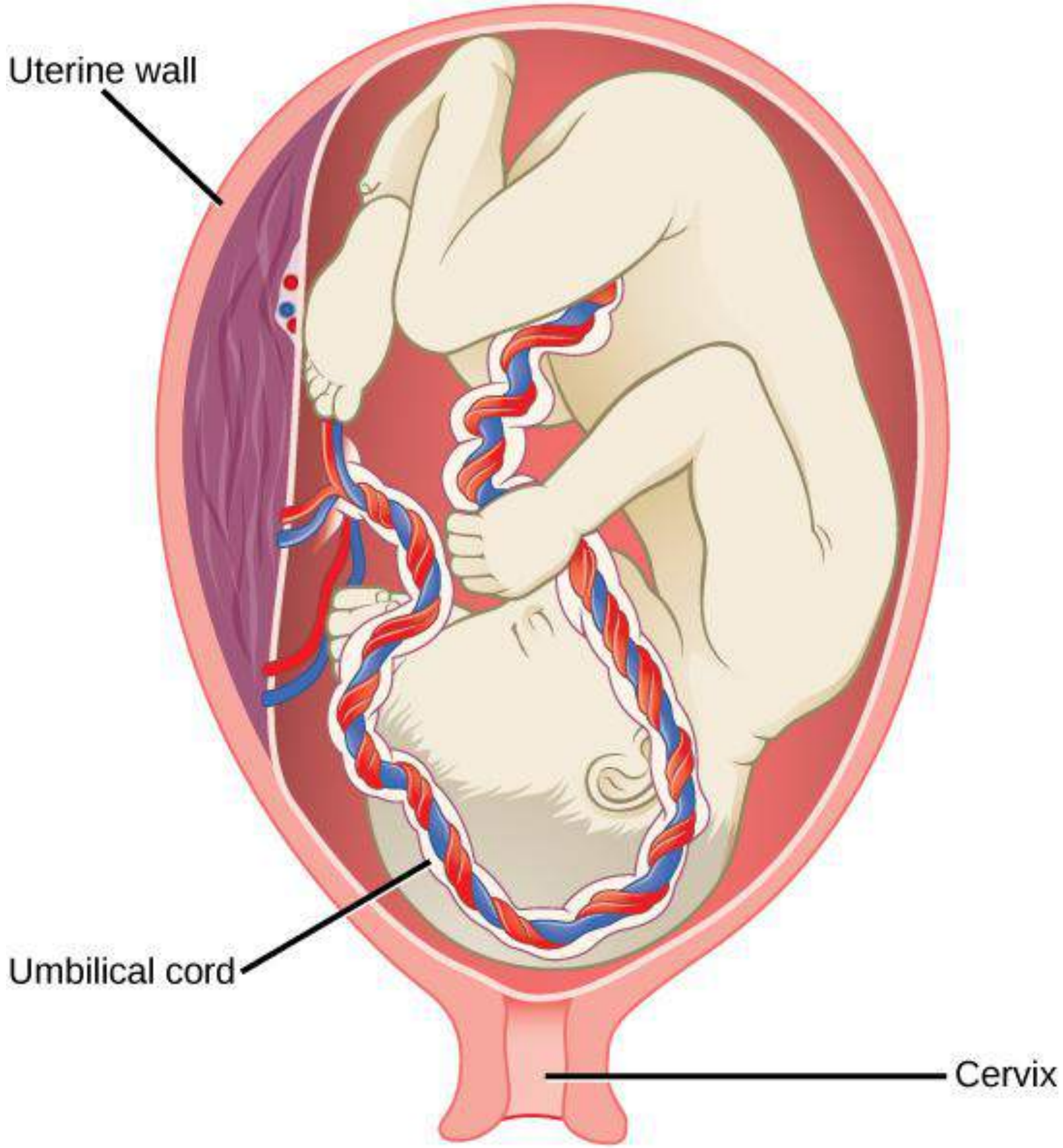


2.4.5 Formation & Function of Mammalian Placenta

Placental Formation

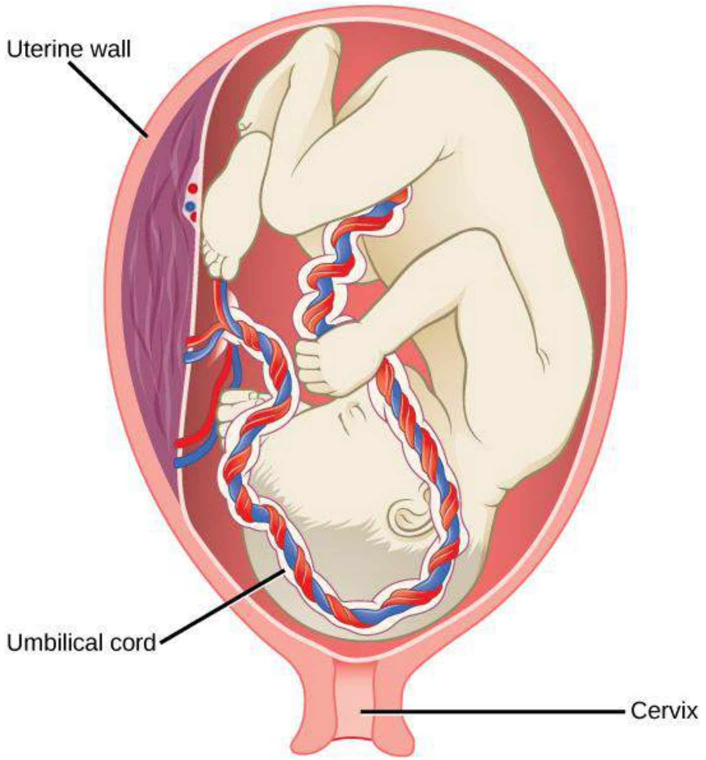
Formed from outer cells of embryo and inner cells of uterus

Connection between mother & embryo


Uterine wall
Umbilical cord
Cervix

Placental Function

Function: transfer nutrients, water, wastes between mother & embryo



2.4.6 Blood Circulation in Human Embryo

Human embryos develop their own blood vessels

Embryo’s blood vessels next to mothers, and molecules exchanged via diffusion:

- from mother to embryo- nutrients, water, oxygen
- from embryo to mother- carbon dioxide & waste

2.5 Principles of Heredity

Principles of Heredity

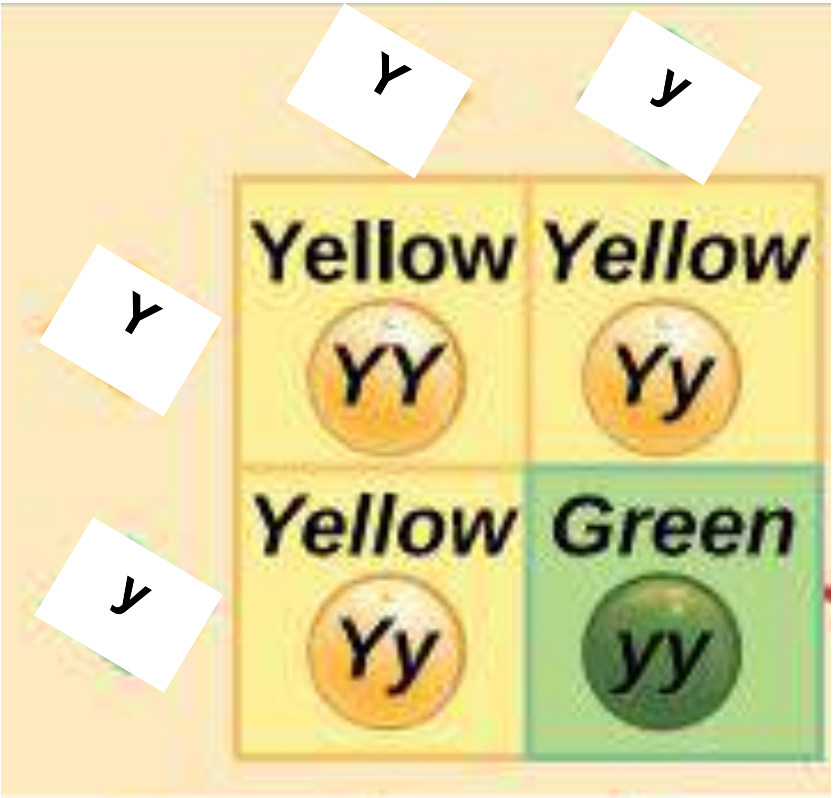
1- Mendelian Inheritance
2- Chromosomal Basis of Inheritance
3- Linkage
4- Polygenic Inheritance

Mendelian Inheritance

- Gregor Mendel
- terminology

Chromosomal Basis of Inheritance

- Mendel’s Laws
- probability
- Punnett square

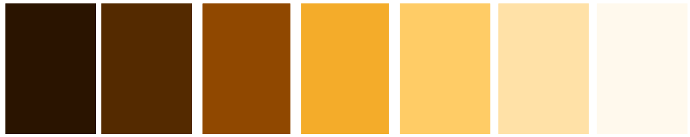


Linkage

- Non-Mendelian genetics
- sex linkage
- cat coat color
- other Linkage

Polygenic Inheritance

- multiple genes
- disease



2.5.1 Mendelian Inheritance

Gregor Mendel

Inheritance: characteristics passed from one generation to another, in form of genes

Mendel: Austrian monk who studied pea plant inheritance ~1865

First to quantify genetic tests

Terminology

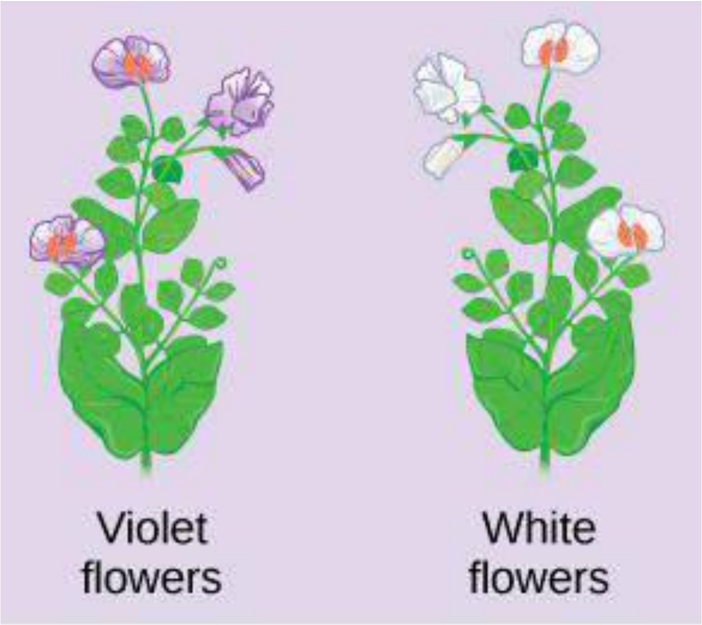
Mendel's ideas still accurate for simple systems

Mendel coined several terms still used:

1. Allele: alternate form of gene, everyone has 2 alleles for each gene, represented by a letter (R, r)
2. Homozygous: two copies of same allele (RR or rr)
3. Heterozygous: one copy of each allele (Rr)

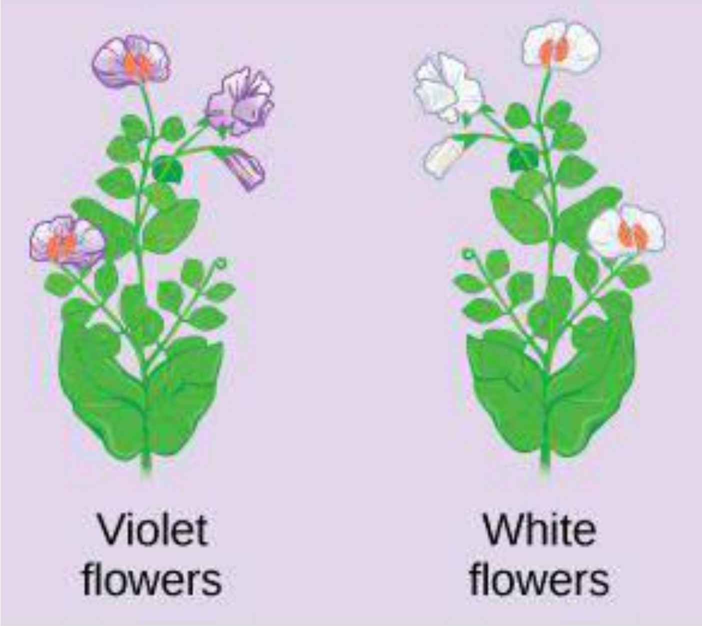
Terminology

4. **Dominant allele: always expressed when present, shown by capital letter (R, G, N)**
5. **Recessive allele: masked when dominant allele present, shown by lowercase letter (r, g, n)**



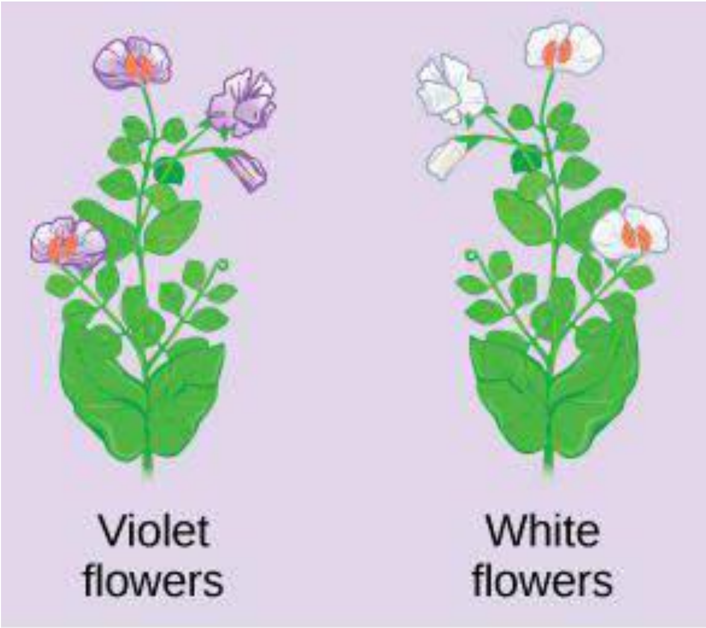
Terminology

6. Genotype: alleles carried by individual
7. Phenotype: appearance of individual
8. Cross: sexual reproduction between different individuals



Terminology

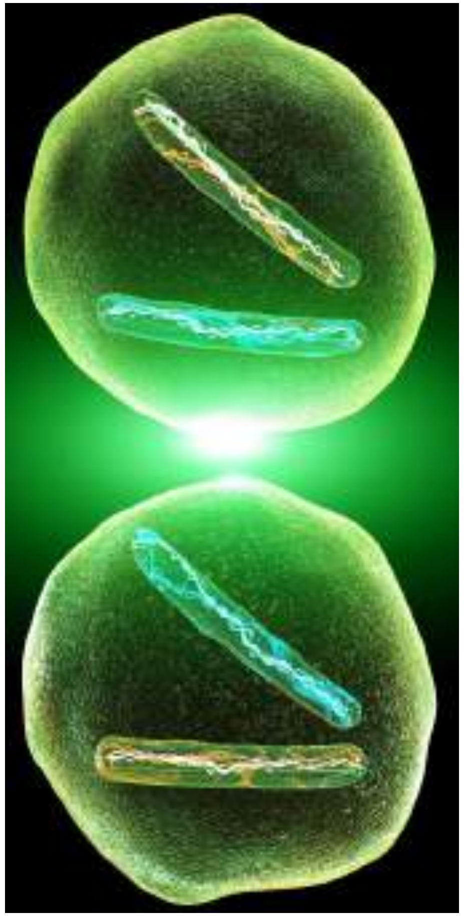
9. Character: a feature, like hair color or plant height
10. Trait: the genotype or phenotype of an individual for a given character (red hair or dwarf plants)

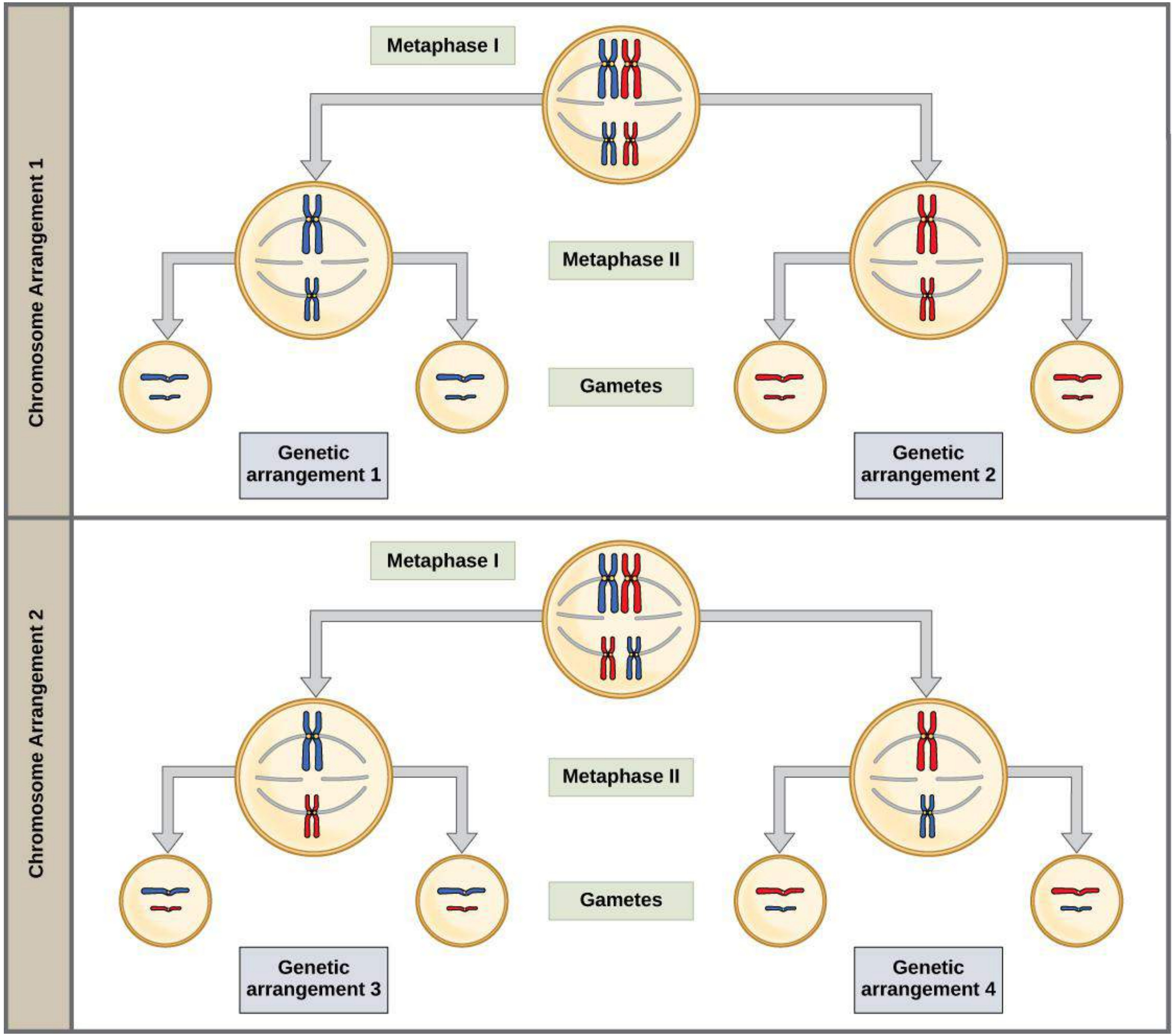


2.5.2 Chromosomal Basis of Inheritance

Mendel’s Laws

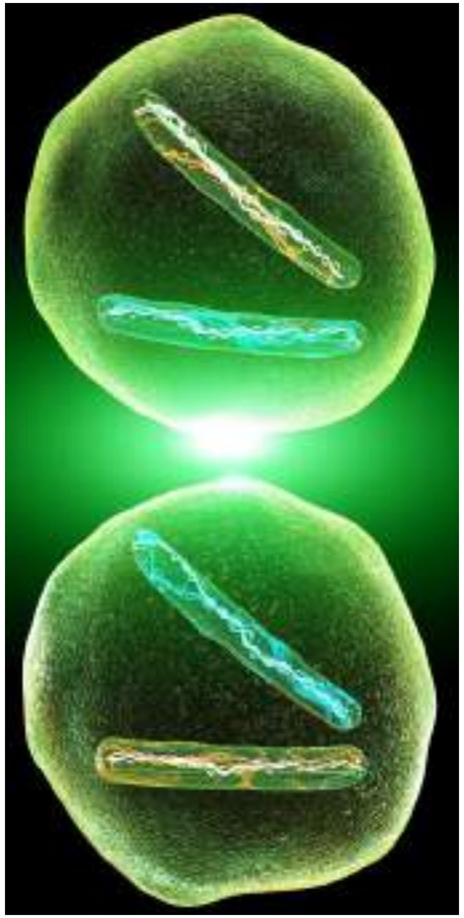
Law of Independent Assortment: Every possible combination of alleles is equally likely for each gamete




Chromosome Arrangement 1
Metaphase I
Metaphase II
Gametes
Genetic arrangement 1
Genetic arrangement 2
Chromosome Arrangement 2
Metaphase I
Metaphase II
Gametes
Genetic arrangement 3
Genetic arrangement 4

Mendel’s Laws

Law of Segregation: Paired genes separate and randomly recombine in gametes, so offspring have an equal likelihood of inheriting either



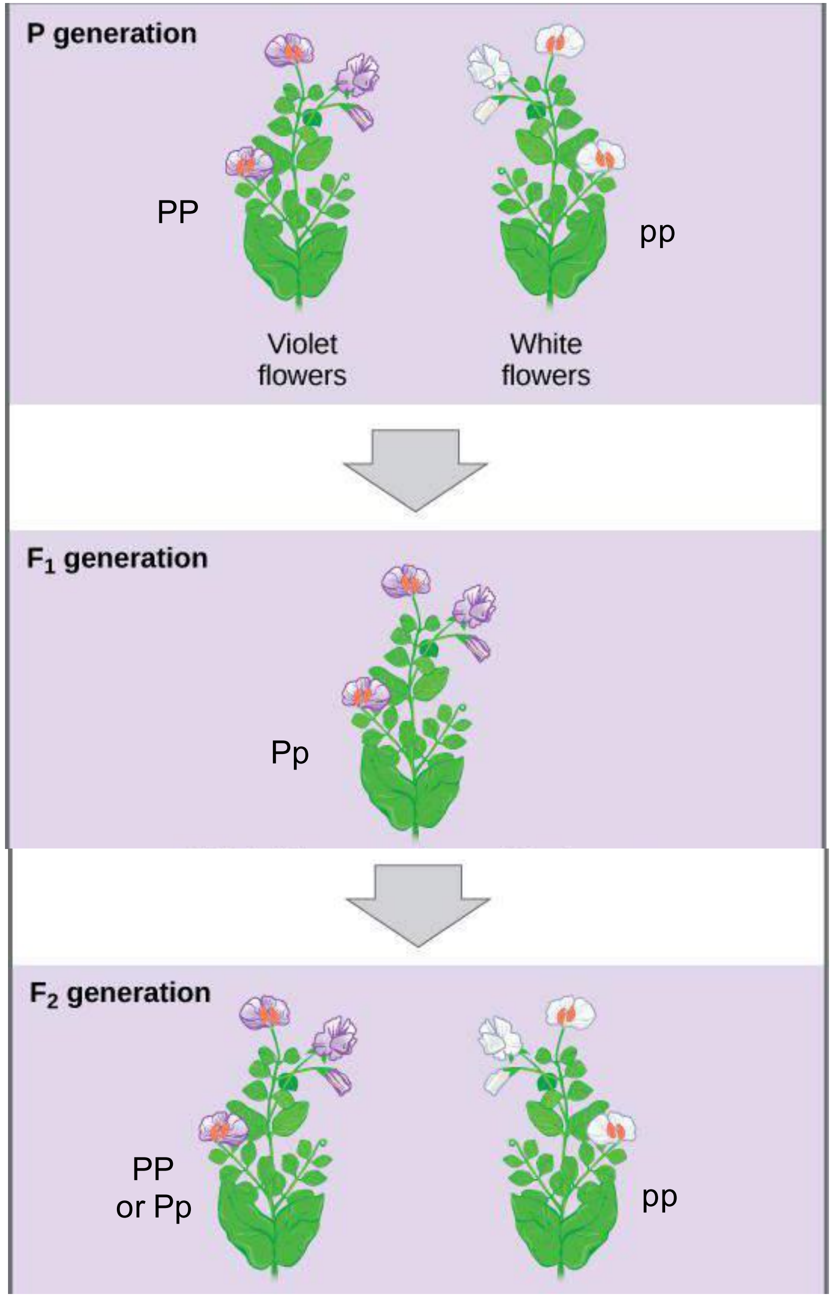
Probability

If independent assortment is occurring, laws of probability predict genotypes of offspring from crosses

Parental generation (P): the parents of a cross b/w two individuals

First Filial generation (F_1): offspring of P

Second Filial generation (F_2): offspring from cross b/w two F_1 individuals

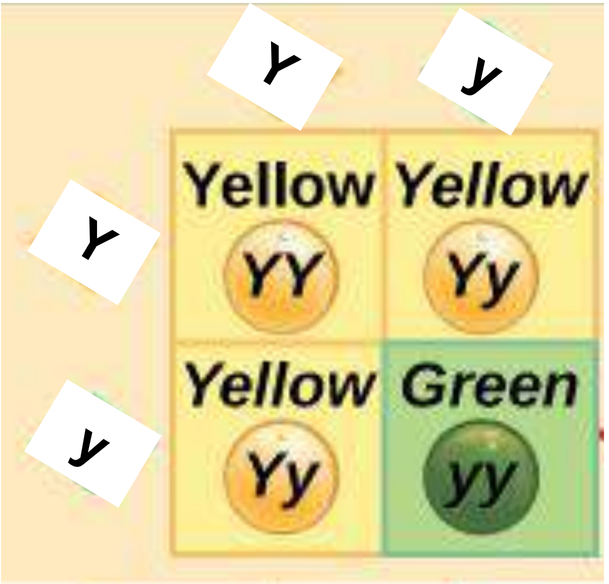

P generation
PP
pp
Violet flowers
White flowers
F1 generation
Pp
F2 generation
PP or Pp
pp

Punnett Square

Method of predicting offspring genotypes, using probability

Use gametes possible from each parent to see predicted offspring genotypes & phenotype ratios

P: Yy x Yy
F_1: ¼ YY, ½ Yy, ¼ yy



2.5.3 Linkage

Non-Mendelian Genetics

Since Mendel's time, we've discovered that his Law of Independent Assortment isn't always true.

- Some genes only on sex chromosomes
- Some genes always inherited together

Sex Linkage

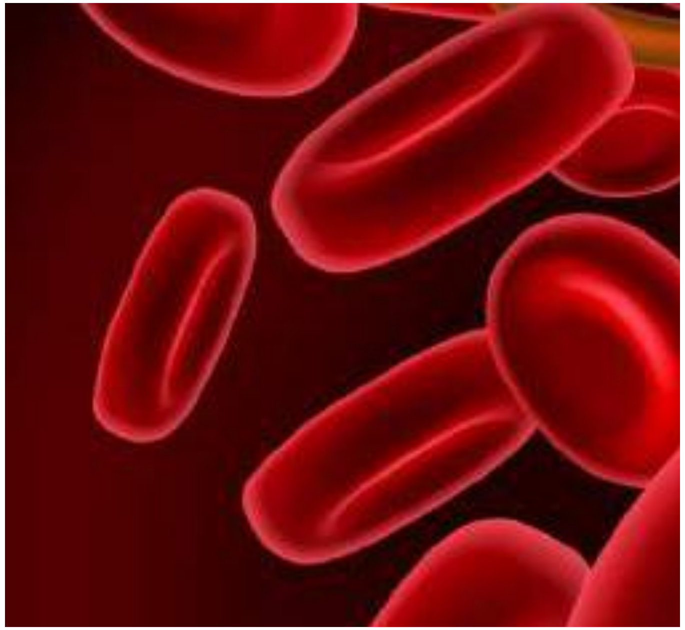
Sex-linked genes: those located on either sex chromosome

Y-linked genes usually harmless because so small

Sex Linkage

X-linked genes are responsible for several human genetic conditions

- color-blindness in men
- Duschene muscular dystrophy in men
- hemophilia



Cat Coat Color

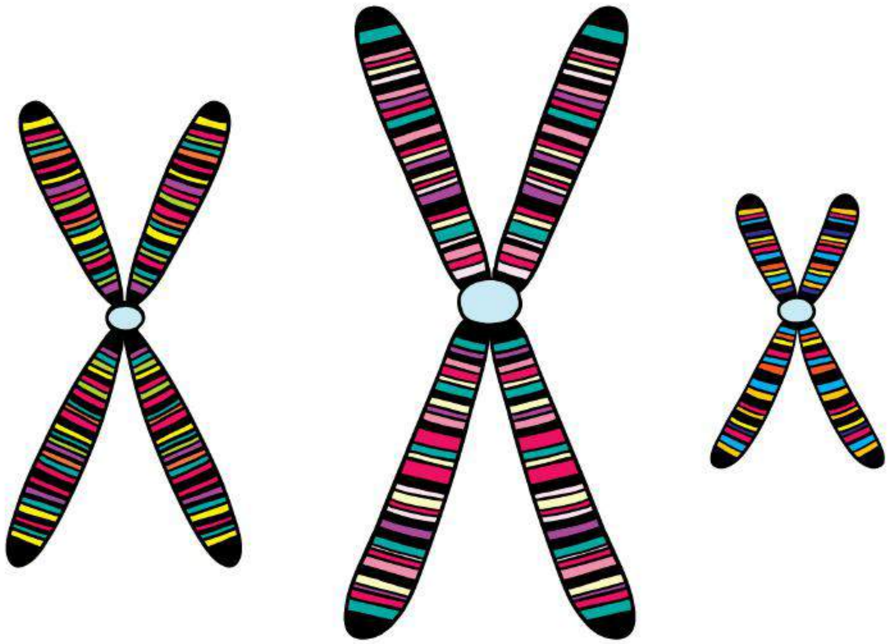
Tortoiseshell coat coloration the result of X-linked genes

- genes for orange and black coat color are both on the X chromosome
- males (Xy) express the color on their one X
- females (XX) express both colors, causing tortoise-shell patterning if black & orange
- only males with XXy genotype can be tortoiseshell or calico

Other Linkage

Linkage: autosomal genes inherited together during meiosis if close together

As distance between genes increases, likelihood of linkage decreases



2.5.4 Polygenic Inheritance

Multiple Genes

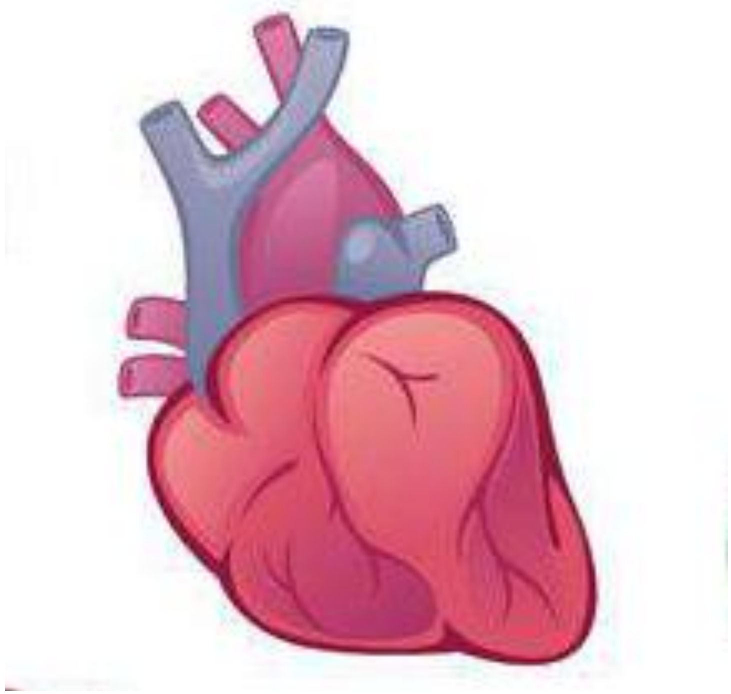
Polygenic inheritance: two or more genes affect the same phenotypic character

- Human height
- Human eye & skin color

Disease

Polygenic traits hard to predict, but can contribute to many illnesses

- **diabetes**
- **heart disease**
- **hypertension**



3. Population Biology

Principles of Ecology

1- Energy Flow & Productivity in Ecosystems
2- Biogeochemical Cycles
3- Population Growth & Regulation
4- Community Structure, Growth, Regulation
5- Habitat
6- Concept of Niche
7- Island Biogeography
8- Evolutionary Ecology

Principles of Evolution

1- History of Evolutionary Concepts
2- Concepts of Natural Selection
3- Adaptive Radiation
4- Major Features of Plant & Animal Evolution
5- Concepts of Homology & Analogy
6- Convergence, Extinction, Balanced Polymorphisms, Genetic Drift
7- Classification of Living Organisms
8- Evolutionary History of Humans

Principles of Behavior

1- Stereotyped, Learned Social Behavior
2- Societies

Social Biology

1- Human Population Growth
2- Human Intervention in Natural World
3- Biomedical Progress

3.1 Principles of Ecology

Principles of Ecology

1- Energy Flow & Productivity in Ecosystems
2- Biogeochemical Cycles
3- Population Growth & Regulation
4- Community Structure, Growth, Regulation
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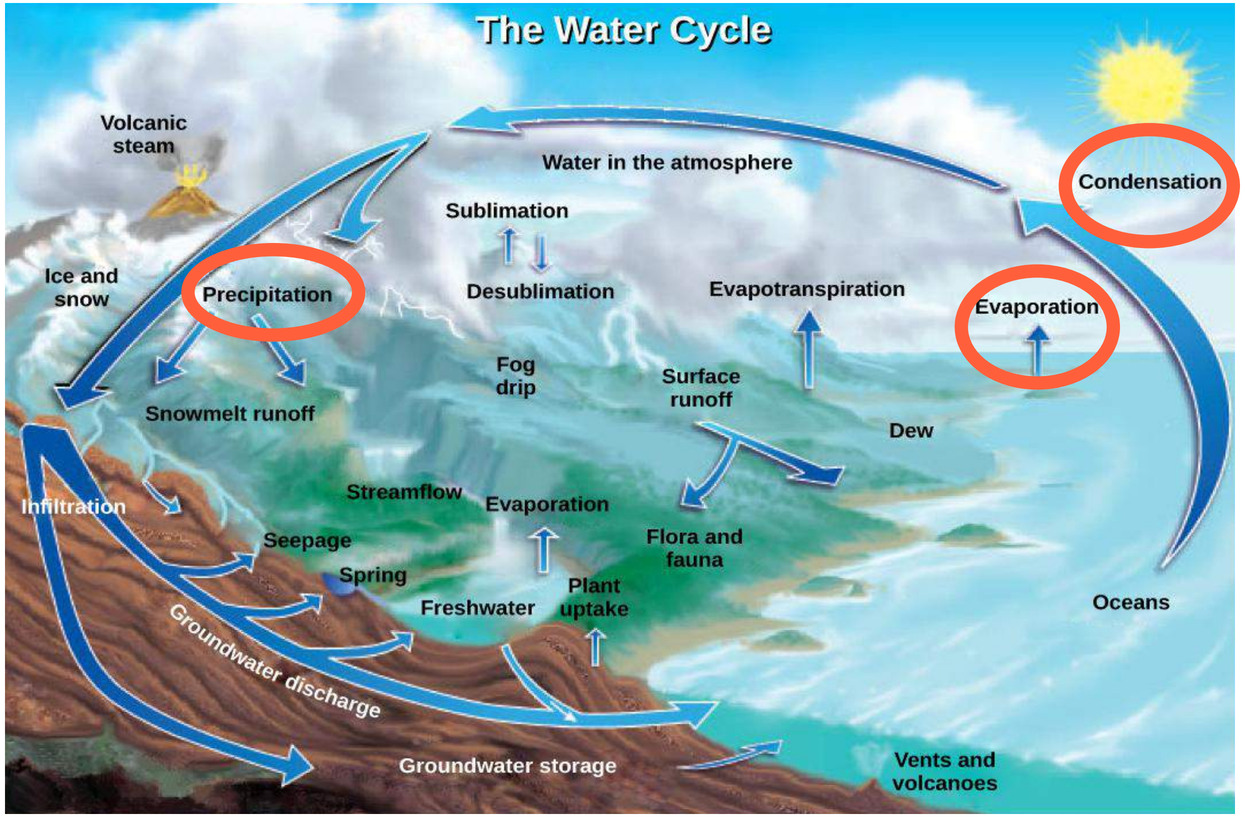
7- Island Biogeography
8- Evolutionary Ecology

Energy Flow & Productivity in Ecosystems

- Energy Flow
- Trophic Levels
- Trophic Categories
- Ecological Roles
- Transfer of Energy

Biogeochemical Cycles

- Introduction
- Water
- Carbon
- Nitrogen
- Phosphorous



Population Growth & Regulation

- Introduction
- Limiting Biotic Factors
- Limiting Abiotic Factors
- Density
- Demography & Growth

Community Structure, Growth, Regulation

- Introduction
- Competition
- Symbiosis
- Succession

Habitat

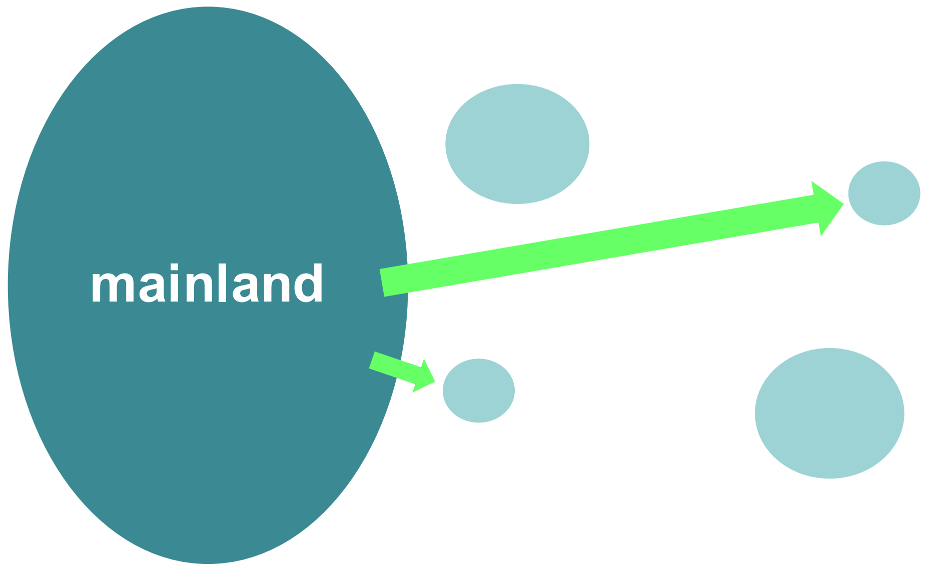
- Definition & examples

Concept of Niche

- Definition & examples

Island Biogeography

- Introduction
- Dispersal
- Species Diversity
- Immigration & Extinction
- Area Effects
- Distance Effects
- Age Effects



Evolutionary Ecology

- Introduction & Example
- Interactions
- One-way Interactions
- Reciprocal Interactions

3.1.1 Energy Flow & Productivity in Ecosystems

Energy Cycle

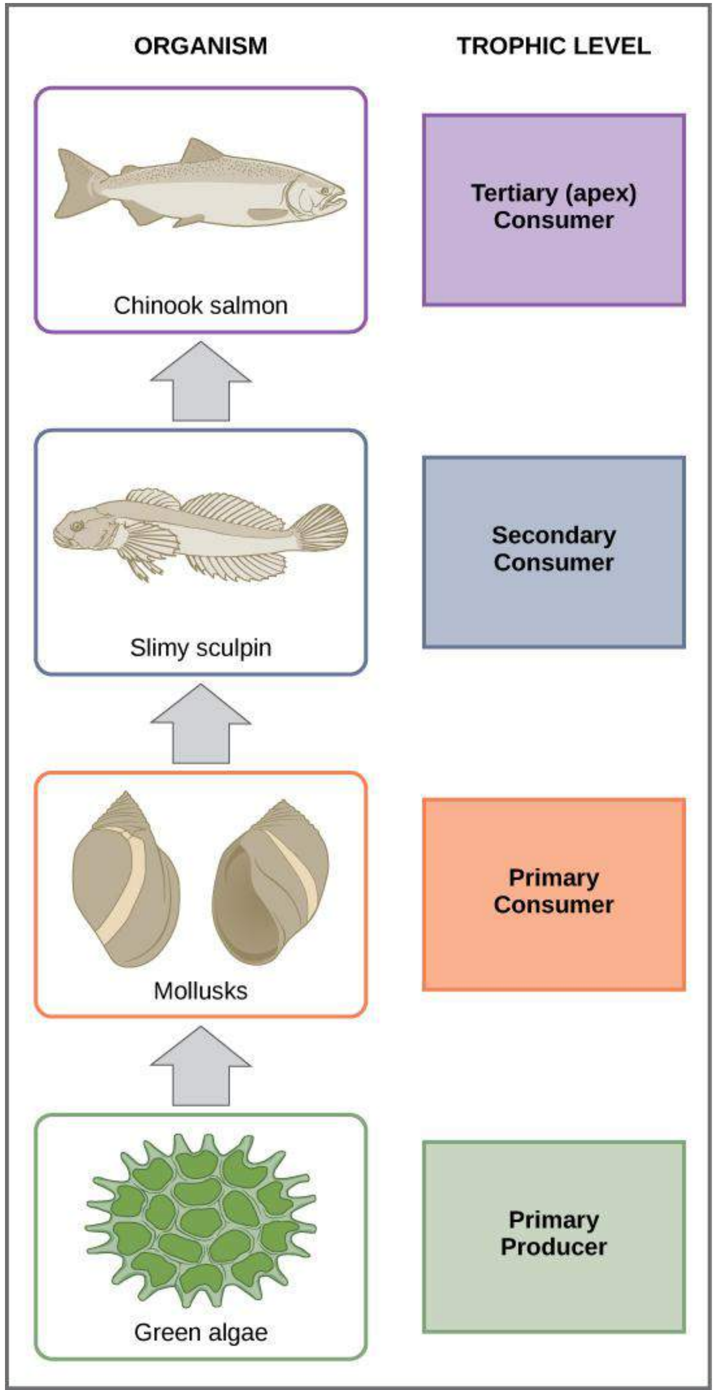
Also ‘Food Chain’ and ‘Food Web’

- represent flow of energy (matter)
- show how energy enters & leaves

Trophic Levels

Producers: make energy accessible to ecosystems via photosynthesis

Consumers: eat producers or other consumers


ORGANISM
TROPHIC LEVEL
Chinook salmon
Tertiary (apex) Consumer
Slimy sculpin
Secondary Consumer
Mollusks
Primary Consumer
Green algae
Primary Producer

Trophic Categories

Autotrophs: self-feeders, producers, make food molecules from sun

Heterotrophs: other-feeders, consumers, get food molecules from eating other

Ecological Roles

Herbivores: eat plants

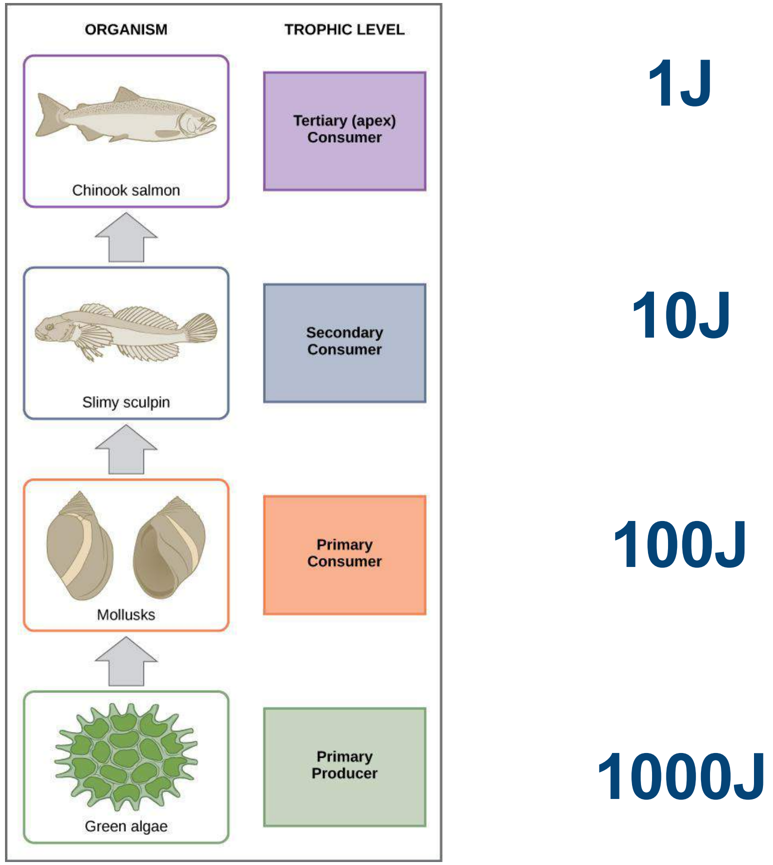
Carnivores: eat animals

Omnivores: eat plants & animals

Transfer of Energy

Very inefficient due to heat loss

Each higher level gets 10% of previous

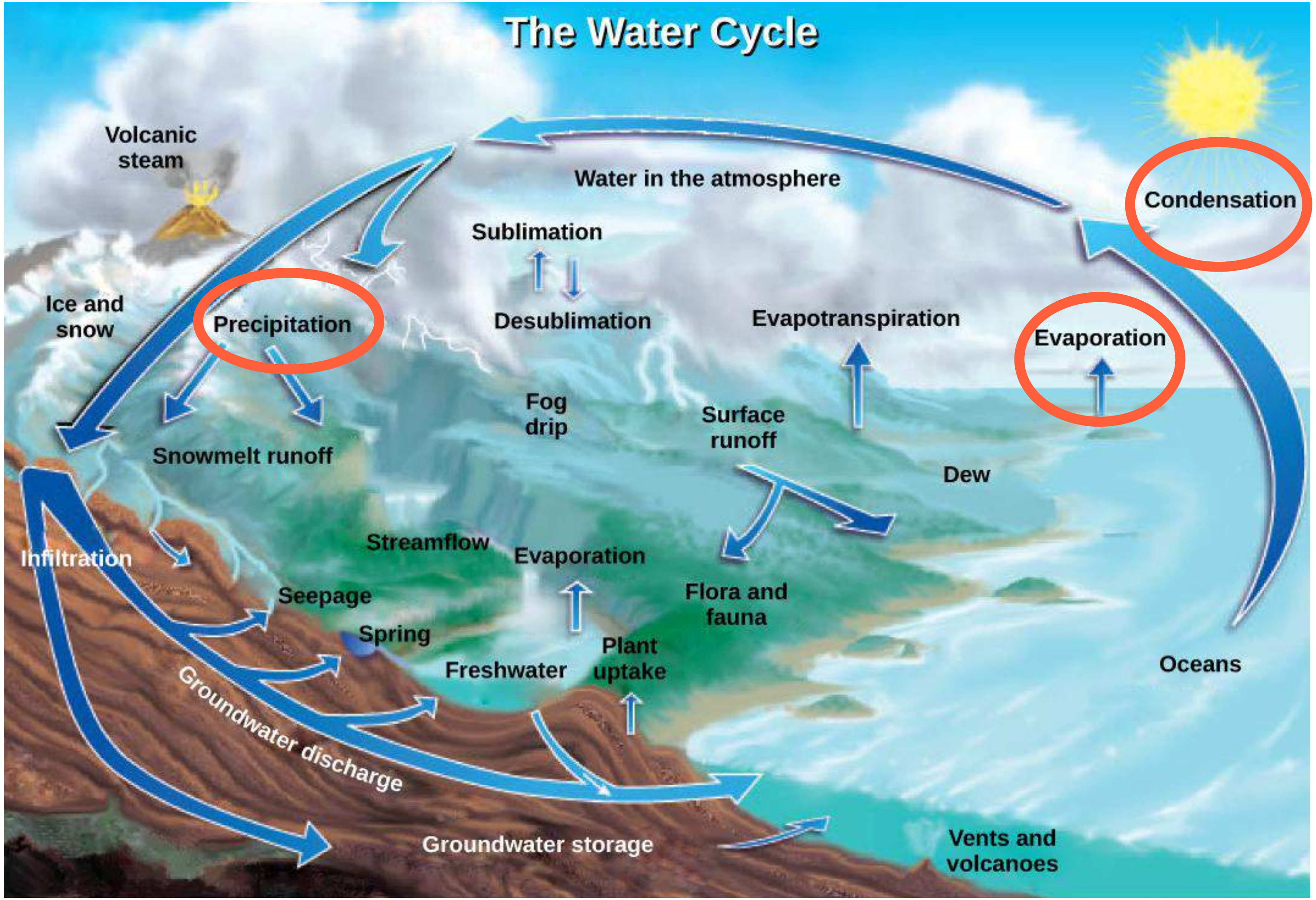


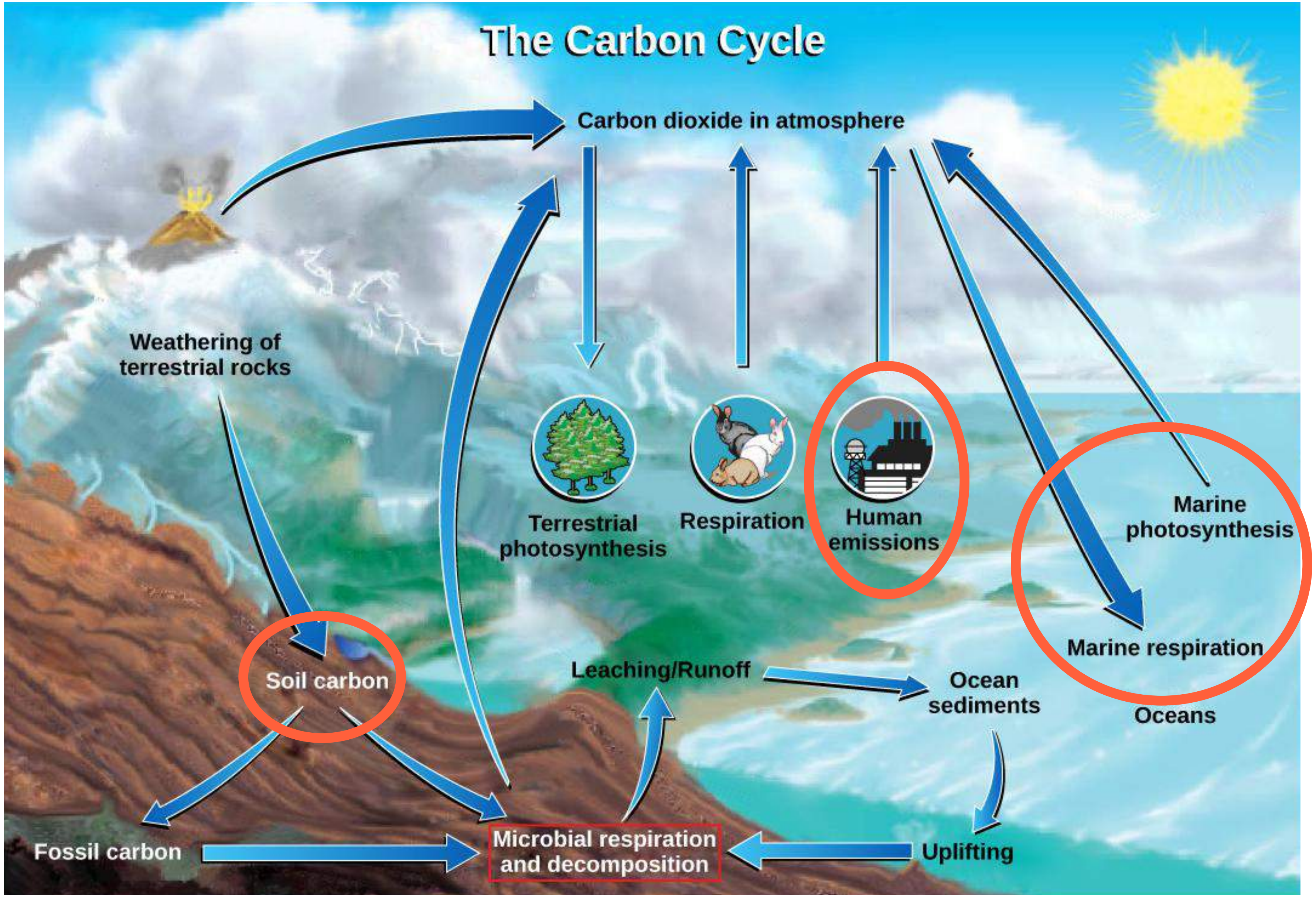
3.1.2 Biogeochemical Cycles

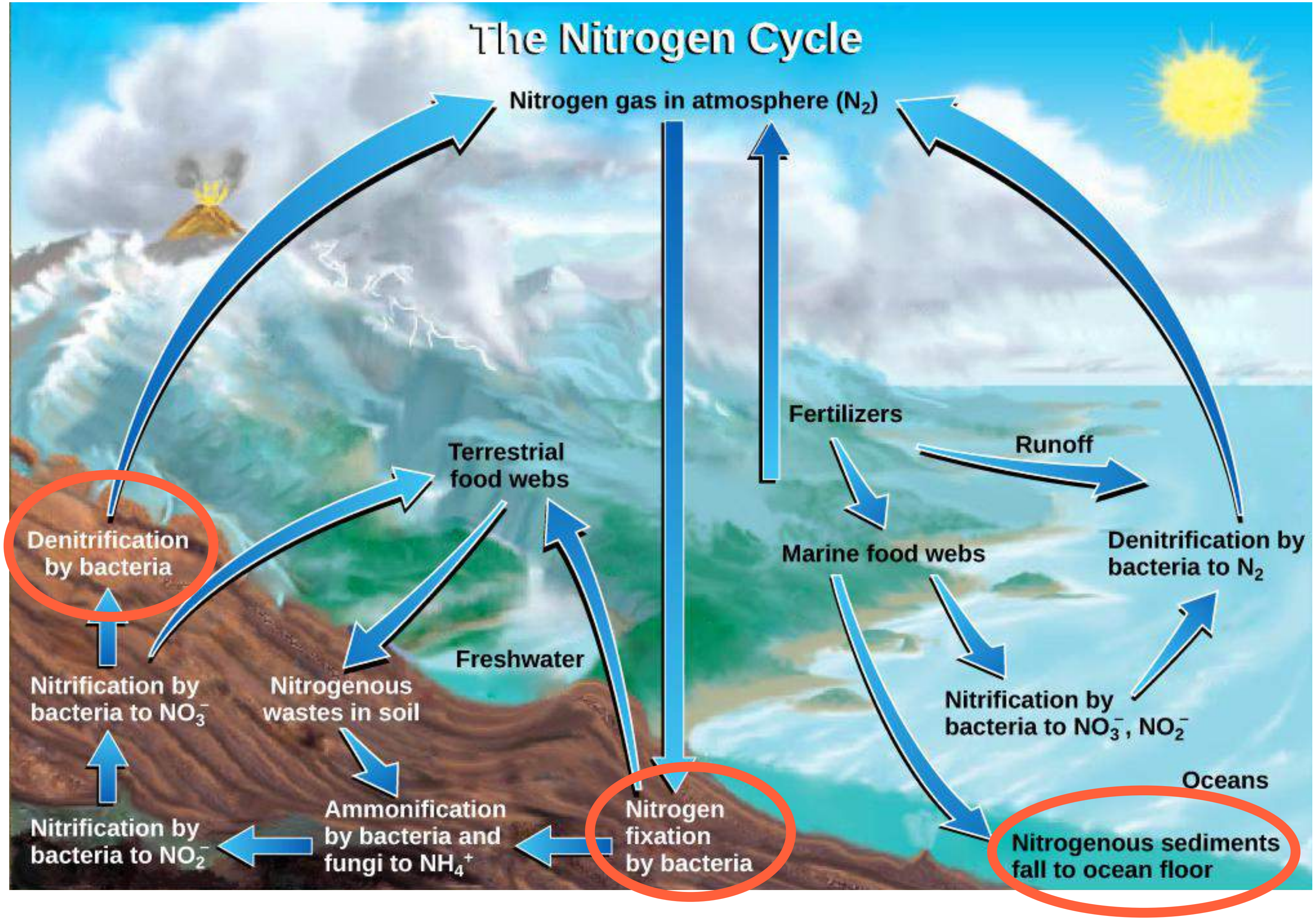
Biogeochemical Cycle?

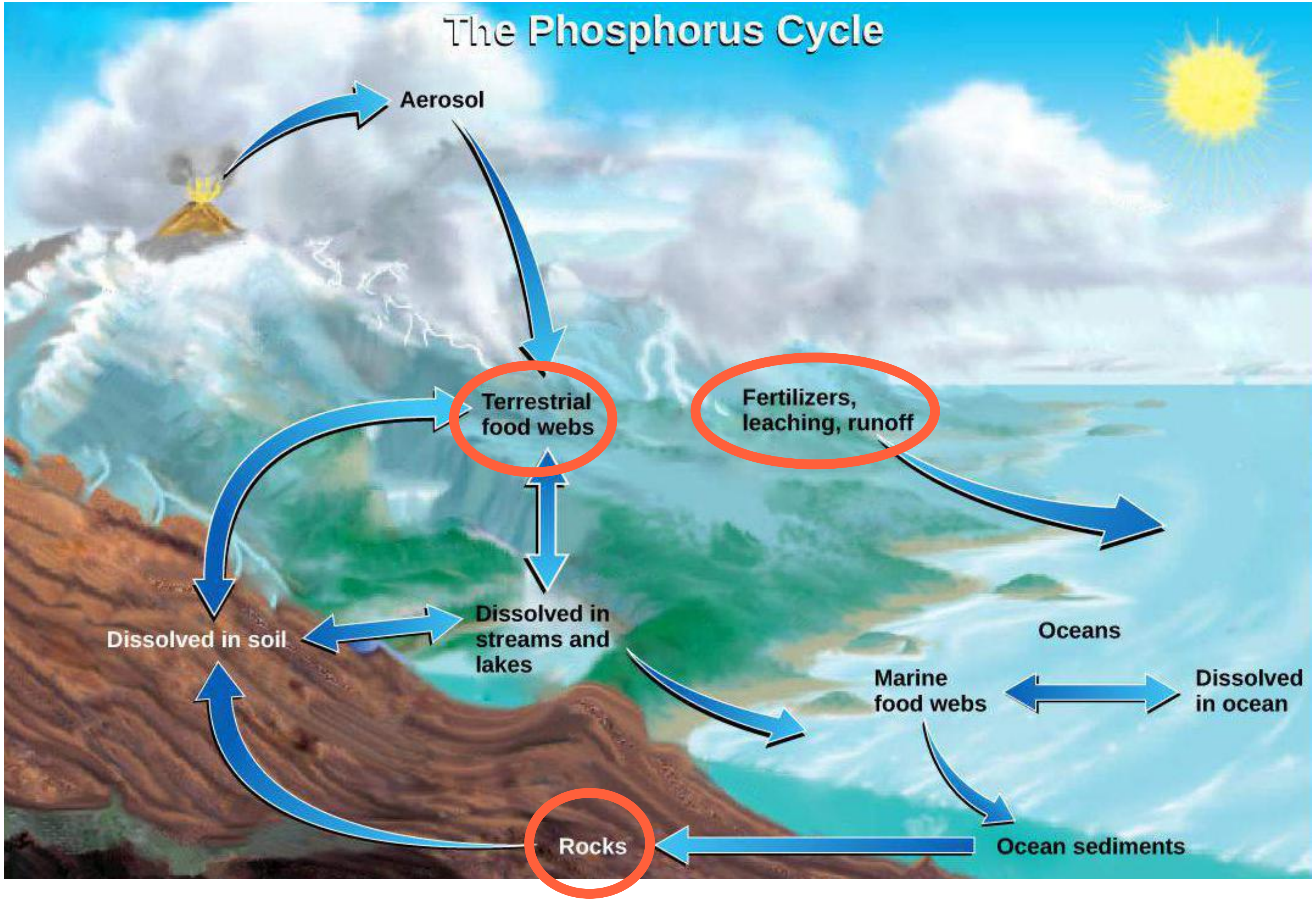
Bio: living things
Geo: sediments/ rocks
Chemical: molecules
Cycles: circular movement

Circular movement of molecules through an ecosystem’s living and non-living things


The Water Cycle
Volcanic steam
Water in the atmosphere
Condensation
Sublimation
Desublimation
Evapotranspiration
Evaporation
Ice and snow
Precipitation
Fog drip
Surface runoff
Snowmelt runoff
Dew
Streamflow
Evaporation
Infiltration
Flora and fauna
Seepage
Spring
Freshwater
Plant uptake
Oceans
Groundwater discharge
Groundwater storage
Vents and volcanoes


The Carbon Cycle
Carbon dioxide in atmosphere
Weathering of terrestrial rocks
Terrestrial photosynthesis
Respiration
Human emissions
Marine photosynthesis
Marine respiration
Oceans
Soil carbon
Leaching/Runoff
Ocean sediments
Fossil carbon
Microbial respiration and decomposition
Uplifting


The Nitrogen Cycle
Nitrogen gas in atmosphere (N_2)
Fertilizers
Runoff
Terrestrial food webs
Marine food webs
Denitrification by bacteria
Denitrification by bacteria to N_2
Freshwater
Nitrification by bacteria to NO_3^-
Nitrogenous wastes in soil
Nitrification by bacteria to NO_3^-, NO_2^-
Oceans
Ammonification by bacteria and fungi to NH_4^+
Nitrogen fixation by bacteria
Nitrification by bacteria to NO_2^-
Nitrogenous sediments fall to ocean floor


The Phosphorus Cycle
Aerosol
Terrestrial food webs
Fertilizers, leaching, runoff
Dissolved in soil
Dissolved in streams and lakes
Oceans
Marine food webs
Dissolved in ocean
Rocks
Ocean sediments

3.1.3 Population Growth & Regulation

What is it?

Study of groups of organisms of one species living together (population)

- **limiting factors**
- **birth rate**
- **death rate**
- **growth rate**

Limiting Biotic Factors

- Dispersal: movement away from center
- Competition
- Predators
- Lack of prey/ food
- Parasites

Limiting Abiotic Factors

- Climate
- Landscape
- Soil
- Water salinity
- Sunlight

Density

Density: # individuals per unit area

Density-dependent regulators:

- **competition**
- **predation**
- **disease**

Density

Density-independent regulators:

- climate
- disturbance (fire, flood, etc.)
- pollution

Demography & Growth

Demography: vital statistics like birth & death rate, age at maturity

Growth rate: how fast is population getting larger or smaller? Rate of growth (r) equals births (b) minus deaths (mortality, m)

$$r = b - m$$

3.1.4 Community Structure, Growth, Regulation

What is it?

Study of interactions among different species in the same area

- competition
- predation
- symbiosis
- succession

Competition

More than one species in community attempts to use the same limited resource

Competition

Competitive Exclusion Principle: no two species can occupy same niche indefinitely; one will be a better competitor, other will go extinct locally

Niche partitioning allows coexistence

Symbiosis

Close interaction b/w two species

1. Mutualism: both benefit
2. Commensalism: one benefits, other neutral
3. Parasitism: one benefits, other harmed

Succession

Process through which community recovers from disturbance

1. Primary: no soil
   (ex: lava flows, glacial moraine)
2. Secondary: soil present
   (ex: abandoned fields)

3.1.5 Habitat

Habitat

Species' physical location, including all biotic & abiotic factors it needs to survive

- **pond**
- **forest**
- **river**
- **grassland**

3.1.6 Concept of Niche

Ecological Niche

Species' role in community

- time of day/ year
- parts of habitat
- prey size
- temperature
- trophic level

3.1.7 Island Biogeography

Biogeography

Study of distribution of organisms in space, historically & currently

Island Biogeography

Biogeography specific to islands & their species

- dispersal
- species diversity
  - area effects
  - distance effects
  - age effects

Dispersal

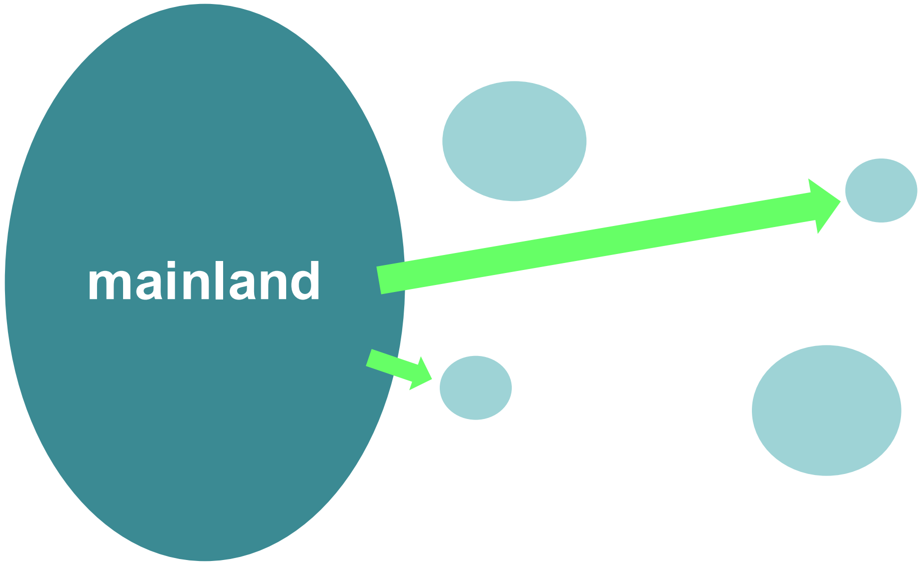
Species reach islands by dispersal methods

- flying
- blown by wind
- floating on water

Species Diversity

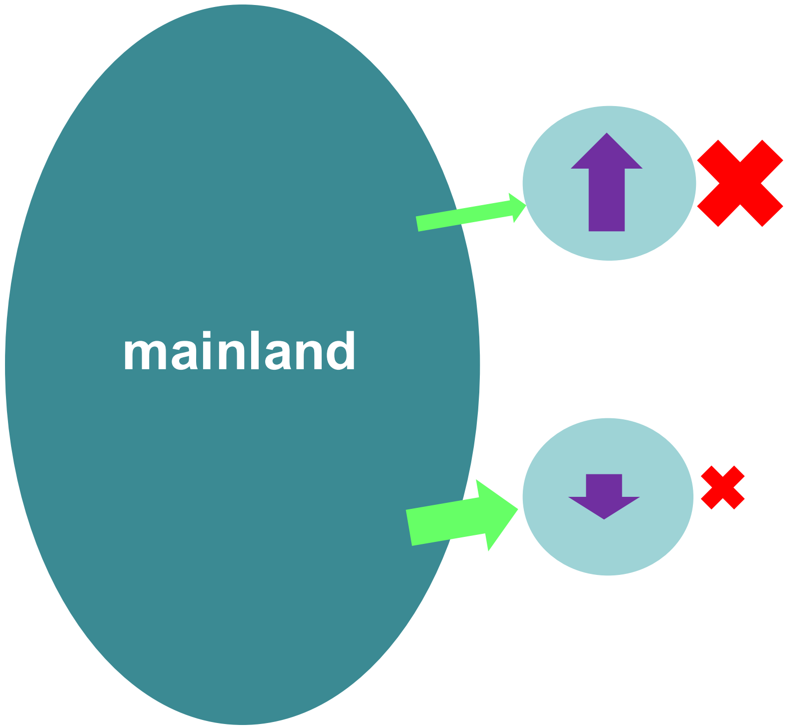
Number of species on island determined by:

- immigration & extinction rates
- size
- distance
- age



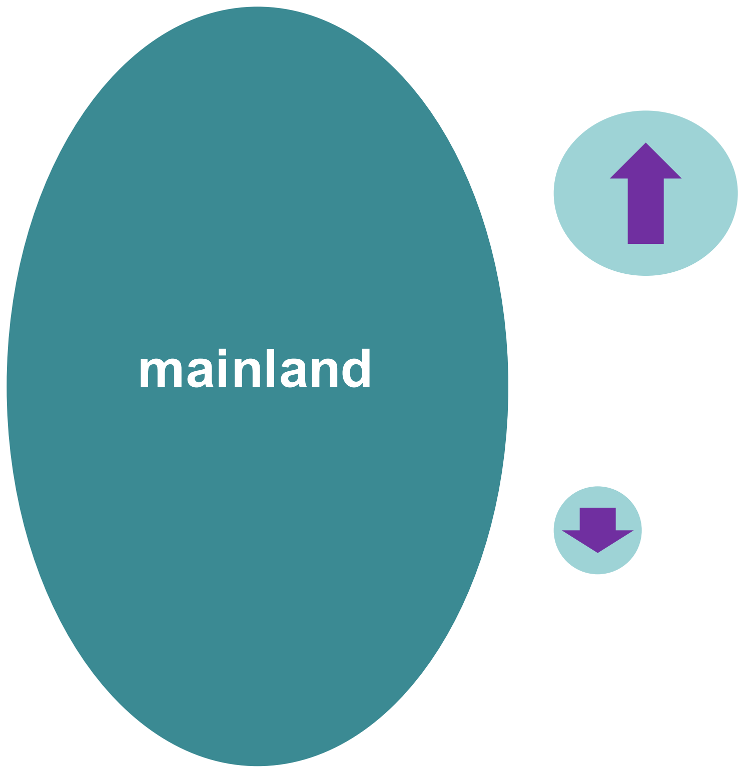
Immigration & Extinction

As diversity increases, immigration rate decreases and extinction rate increases



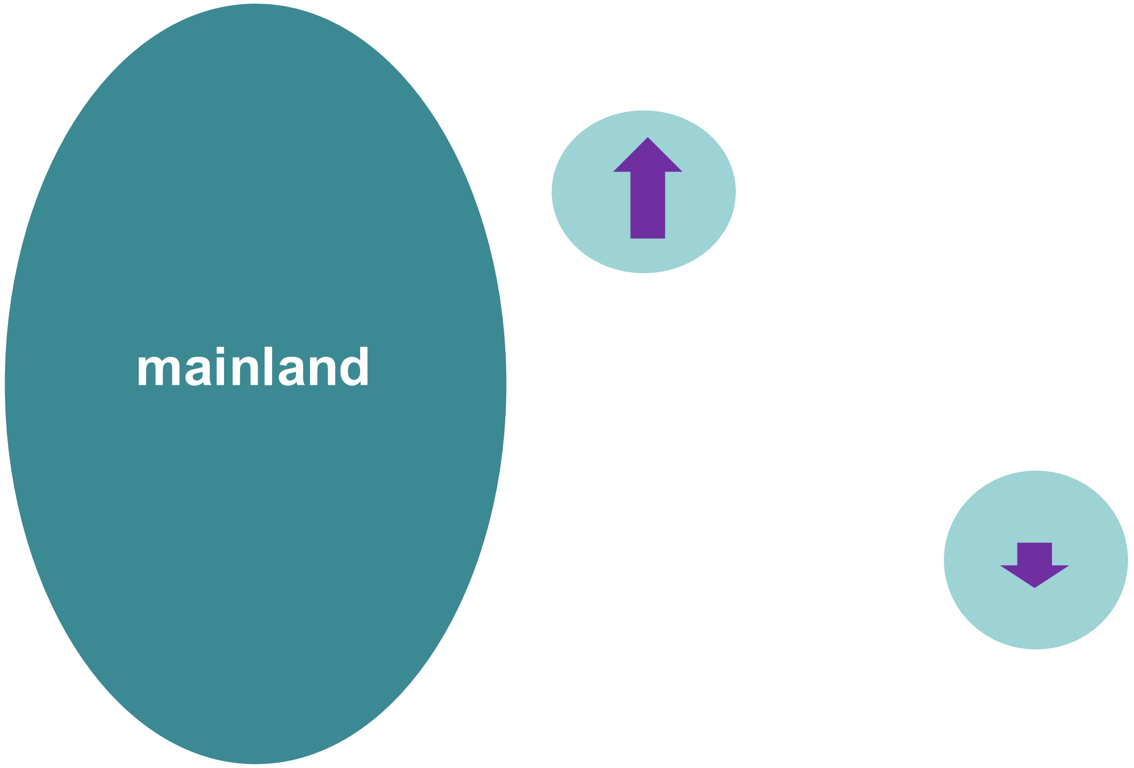
Area Effects

Diversity highest on larger islands



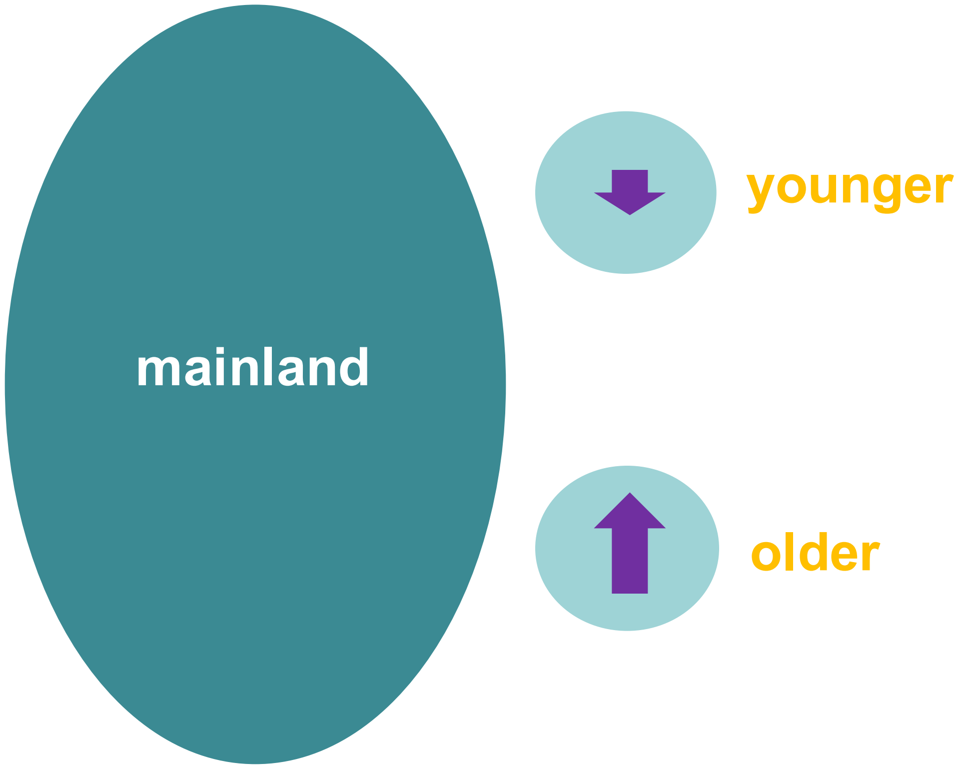
Distance Effects

Diversity highest on near islands



Age Effects

Diversity is highest on older islands



3.1.8 Evolutionary Ecology

What is it?

Study evolution of interactions between & among species and with their environment

- competitors
- mutualists
- predators
- prey
- pathogens

Example: Research on the origin of the mutualism b/w termites and protozoa

Interactions

Two types studied:

1. with physical environment
2. with other species
   a. one-way
   b. reciprocal

One-way Interactions

One species affects another, but not vice versa

- commensalism

Reciprocal Interactions

Two species affect each other

- predator-prey
- parasite-host
- competitors

3.2 Principles of Evolution

Principles of Evolution

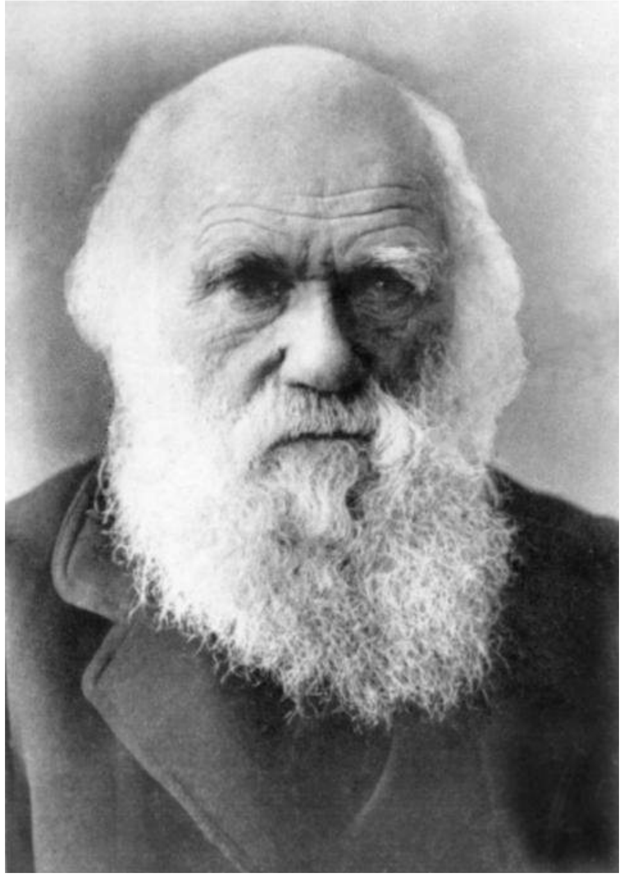
1- History of Evolutionary Concepts
2- Concepts of Natural Selection
3- Adaptive Radiation
4- Major Features of Plant & Animal Evolution
5- Concepts of Homology & Analogy
6- Convergence, Extinction, Balanced Polymorphisms, Genetic Drift
7- Classification of Living Organisms
8- Evolutionary History of Humans

History of Evolutionary Concepts

- Evolution
- Carolus Linnaeus
- Lamarck

Concepts of Natural Selection

- Darwinian Concept
- Modern Synthesis



Adaptive Radiation

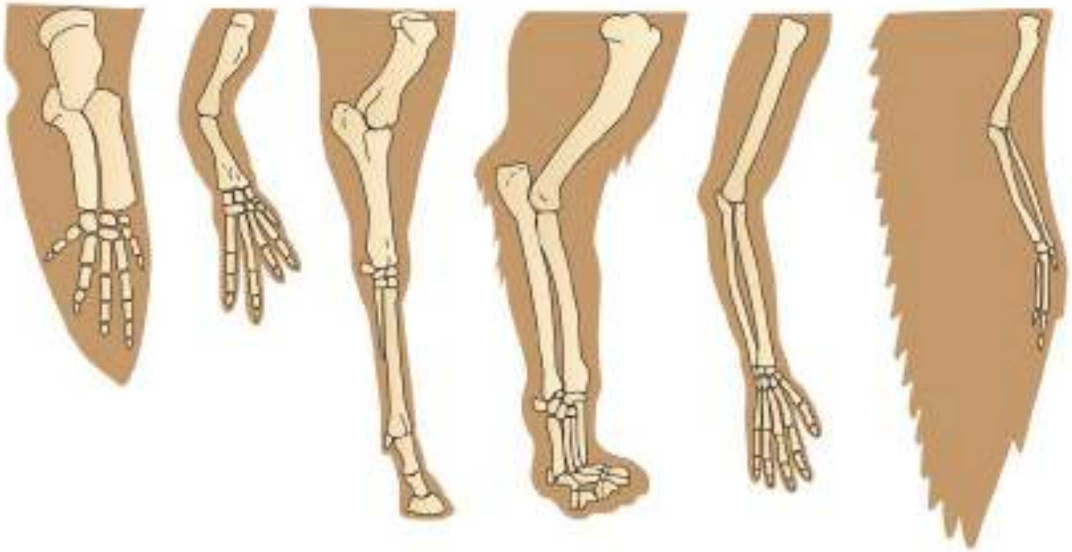
- Adaptations
- Species
- Resource Partitioning

Major Features of Plant & Animal Evolution

- Plant Evolution
- Animal Evolution
- Explosions

Concepts of Homology & Analogy

- Homology
- Analogy



Convergence, Extinction, Balanced Polymorphisms, Genetic Drift

- Convergence
- Extinction
- Balanced Polymorphisms
- Genetic Drift

Classification of Living Organisms

- Taxonomy
- Taxa
- The Domain
- Classification of Domestic Cat
- Eukaryote Kingdoms
- Animal Phyla

Evolutionary History of Humans

- Order Primates
- Great Apes
- Hominid Fossils
- Location

3.2.1 History of Evolutionary Concepts

Evolution

Genetic change in a population over time

Carolus Linnaeus

Invented binomial nomenclature

Wrote about origins & relationships b/w organisms (1700s)

Lamarck

Proposed that organisms acquire traits throughout lifespan & pass these on (proven false)

3.2.2 Concepts of Natural Selection

Darwinian Concept

Natural Selection is driving force behind evolution

- **more offspring produced than can survive**
- **variation in characteristics among individuals of population**
- **some individuals better competitors**
- **these have more offspring**
- **frequency of characteristic increases in population**
- **population smallest unit that can evolve**

Modern Synthesis

Darwin's theory still supported, but we know more details now:

- characteristics result from genes
- variations in characteristics result from alleles
- evolution can take thousands of years

3.2.3 Adaptive Radiation

Adaptations

Inherited characteristics that provide survival/ reproductive advantages

- speed
- camouflage
- armour
- hearing

Species

Population of interbreeding individuals, common gene pool, viable offspring, don’t interbreed w/ other populations

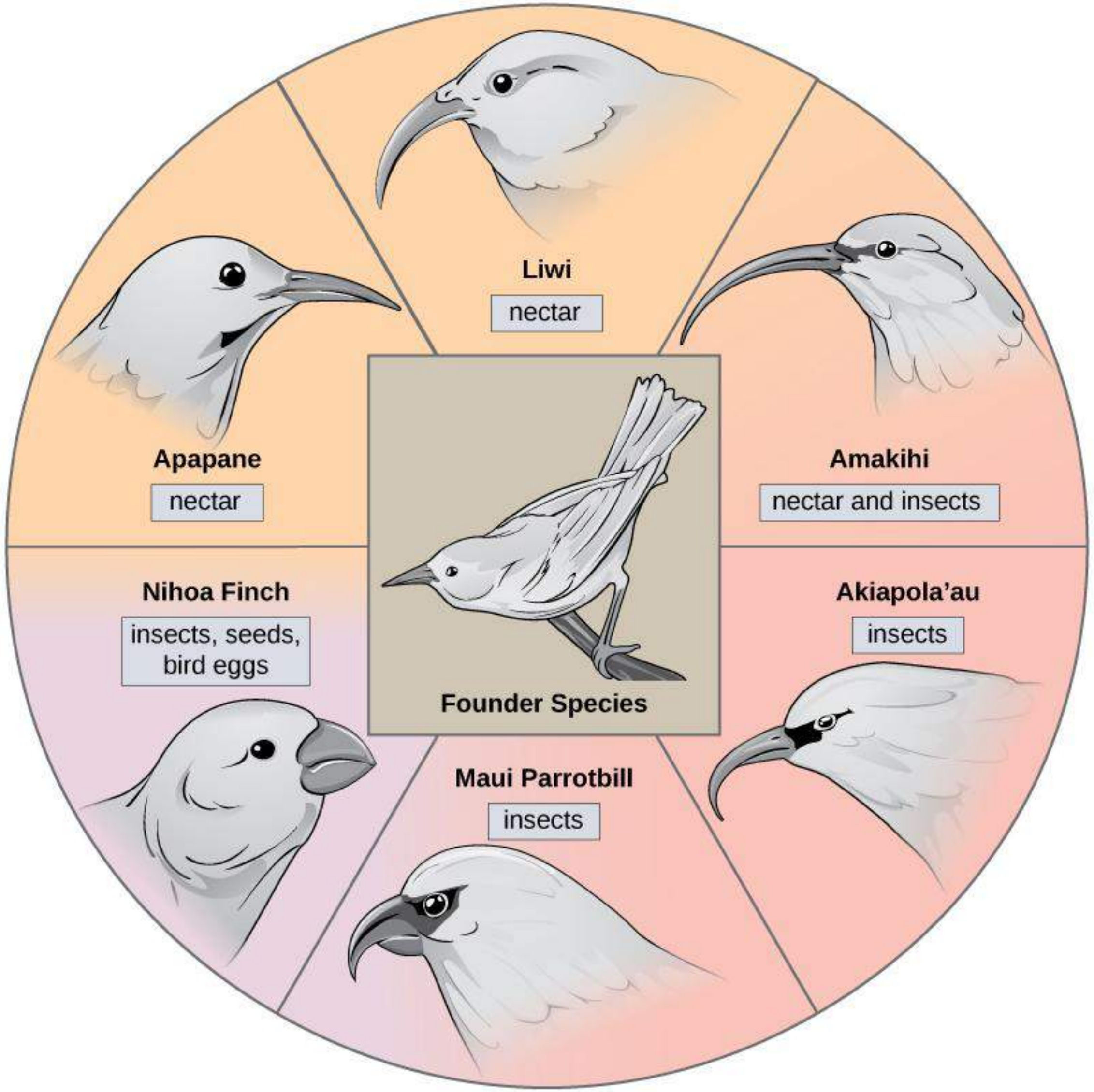
A new species forms when two populations no longer interbreed

Resource Partitioning

Decreases competition b/w species by utilizing more specialized niches

Adaptive radiation occurs as result of resource partitioning:

- alleles that allow individuals to use resources differently are adaptive
- over time, many new species evolve as result of benefits of using new niches



Liwi
nectar
Apapane
nectar
Amakihi
nectar and insects
Nihoa Finch
insects, seeds, bird eggs
Founder Species
Akiapola'au
insects
Maui Parrotbill
insects

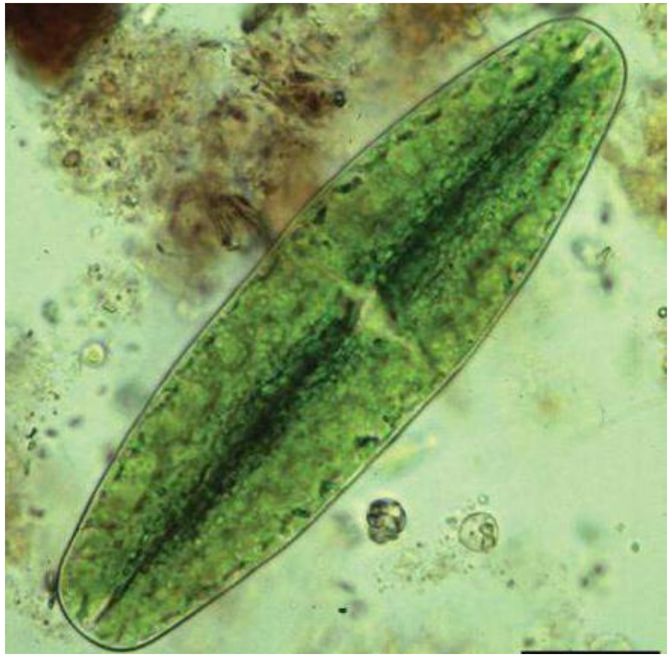
3.2.4 Major Features of Plant & Animal Evolution

Plant Evolution

Endosymbiont Theory explains evolution of autotrophs from heterotrophs

Early plants were aquatic, asexual

Movement to land accompanied by adaptations for water storage, increased gravitational pull



Plant Evolution

Separate sexes allowed for greater genetic diversity

First land plants didn't have seeds

Evolution of seeds allowed colonization of more habitats

Evolution of flowers allowed animal attraction for pollination & seed dispersal

Animal Evolution

First animals were aquatic, unicellular, soft-bodied

Multicellularity & hard structures appeared (spicules, exoskeletons)

Invertebrates first on land

Animal Evolution

Fish were first w/ backbones

Adaptations for conserving water & dealing with higher gravitational pull appeared with land colonization

Explosions

Cambrian explosion: rapid increase in multicellular organisms

- aquatic plants appeared
- most major animal phyla appeared
- new niches evident: active hunting, burrowing into sediment, making branching burrows

3.2.5 Concepts of Homology & Analogy

Homology

Similar structures resulting from common ancestry, could have different functions.

Analogy

Similar structures resulting from common function but not common ancestry

3.2.6 Convergence, Extinction, Balanced Polymorphism, Genetic Drift

Convergence

Convergent evolution: unrelated species evolve similar characteristics due to similar environments

Extinction

When a species disappears from planet forever

Permian extinction (250mya): 96% species lost

Balanced Polymorphism

Polymorphism: genetic diversity within a species for a particular trait

Balanced Polymorphism: natural selection tends to keep number of forms stable; when one is scarce, its fitness increases

Genetic Drift

Random change in allele frequency for a particular trait in a single population

Ex: Storm randomly causes death of most squirrels carrying alleles for light coat color

3.2.7 Classification of Living Organisms

Taxonomy

Organizes living things into groups based on appearance, genetics, evolutionary history

Carolus Linnaeus invented binomial nomenclature, using genus & species "Scientific name" *Borrelia burgdorferi*

Taxa

Taxon: level of classification of living things

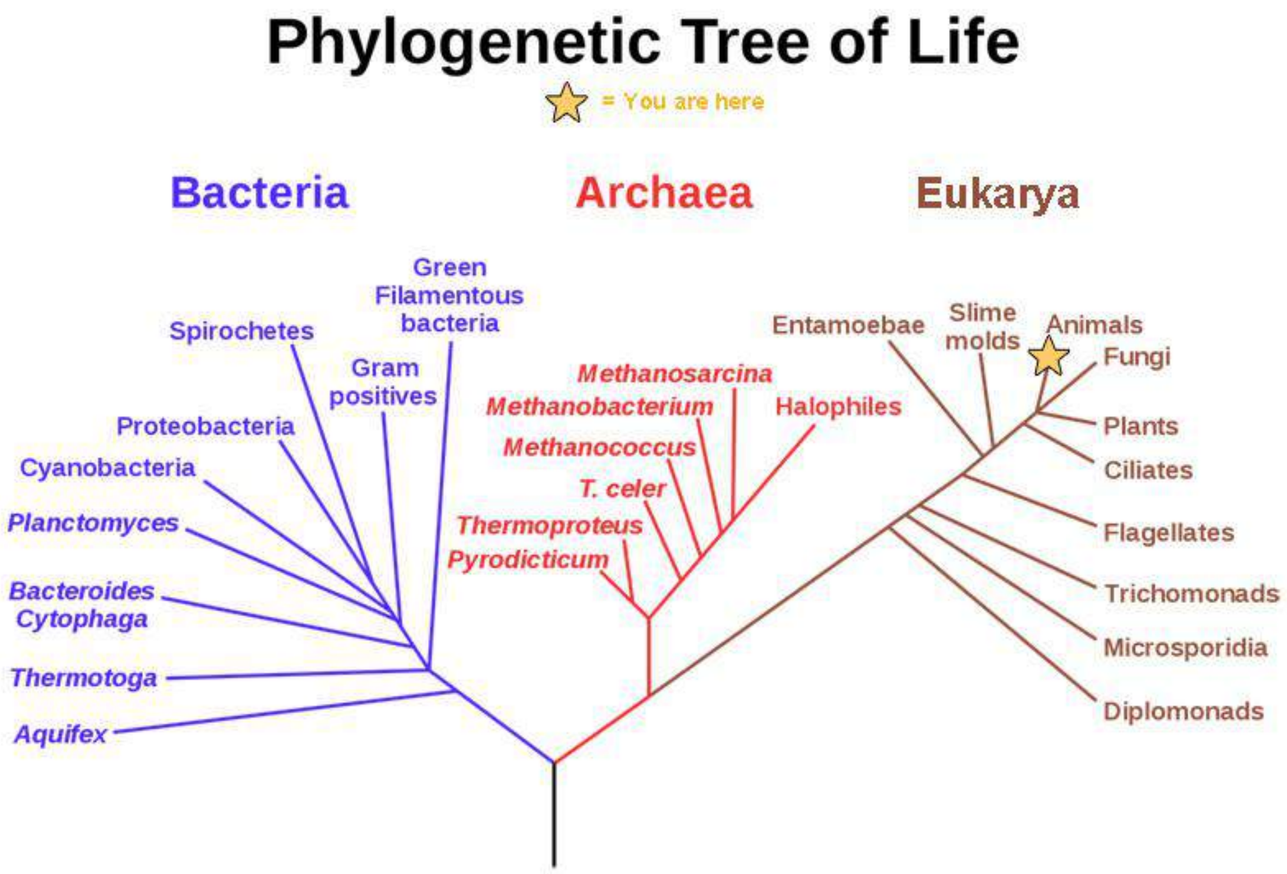
Kingdom
Phylum
Class
Order
Family
Genus
Species

The Domain

Recent addition to taxonomy

3 Domains, encompass all other taxa

- Archaea
- Eubacteria
- Eukaryota



Classification of Domestic Cat

Domain: Eukarya (eukaryotes)
Kingdom: Animalia (heterotrophs)
Phylum: Chordata (backbones)
Class: Mammalia (milk)
Order: Carnivora (meat)
Family: Felidae (hypercarnivore, claws)
Genus: *Felis* (small)
Species: *catus* (domesticated)

Scientific Name: *Felis catus*

Eukaryote Kingdoms

1. Animalia- animals
2. Plantae- plants
3. Monera- fungi
4. Protista- unicellular, animal-like or plant-like

Animal Phyla

1. Porifera- sponges
2. Cnidaria- jellies
3. Platyhelminthes- flatworms
4. Nematoda- roundworms
5. Mollusca- clams, snails, squid
6. Annelida- earthworms
7. Arthropoda- crabs, insects, spiders
8. Echinodermata- starfish, sea urchins
9. Chordata- fish, mammals, birds, reptiles, amphibians

3.2.8 Evolutionary History of Humans

Order Primates

Prosimians: lemurs, lorises

More recent:

- tarsiers
- new world monkeys
- old world monkeys
- apes- gorilla, chimpanzee, orangutan, human

Great Apes

Humans, gorillas, chimpanzees, bonobos, and orangutans have recent common ancestor

First true hominids 4.5mya, larger brains & bipedal locomotion

Hominid Fossils

1. *Australopithecus afarensis* (Lucy)- 4.5mya, head smaller, long arms
2. *Homo erectus*- first from same genus, 1.8mya, head larger, facial features
3. First *Homo sapiens* (Cro-Magnon Man)- 100,000 years ago, looked like us

Location

Oldest human fossils from Africa

Fossils suggest we evolved in Africa 100,000 years ago, migrated throughout Europe, Asia, the Americas

Crossed Bering Land Bridge into North America, then to Central & South America

3.3 Principles of Behavior

Principles of Behavior

1- Stereotyped, Learned Social Behavior
2- Societies

Stereotyped, Learned Social Behavior

- Stereotyped Behaviors
- Fixed Action Patterns
- Learned Behaviors
- Conditioning
- Habituation
- Imprinting

Societies

- Society
- Insect Societies
- Primate Societies

3.3.1 Stereotyped, Learned Social Behavior

Stereotyped Behaviors

Instinctive, performed the same way by all individuals of species, in response to a stimulus

1. taxis- directional
2. kinesis- speed change
3. reflex- automatic movement of body part
4. fixed action pattern- more complex series of behaviors

Fixed Action Pattern (FAP)

Behavior sequence continues, even when stimulus removed

- courtship behaviors
- feeding young
- circadian rhythms

Learned Behaviors

Not instinctive, must be seen & practiced, can be stopped mid-behavior, based on life experience

- conditioning
- habituation
- imprinting

Conditioning

Behavioral response to one stimulus is applied also to different stimulus

- **dogs drool when they smell food**
- **ring a bell when food presented**
- **dogs eventually drool BOTH when they smell food and hear bell**

Habituation

Response decreases with exposure to stimulus if no positive or negative result

- cat cries at night for attention
- you ignore cat, so nothing good or bad happens
- cat eventually stops crying at night

Imprinting

Attachment to another animal or object during critical period (usually shortly after birth/ hatching)

- **crane hatchlings see a person right after hatching, instead of another crane**
- **hatchlings imprint on person, following around to learn**

3.3.2 Societies

Society

Organization of individuals in population, tasks divided so group works together

Insect Societies

Bees, ants, some wasps

- only queen breeds
- workers are her daughters
- different jobs, depending on age
  - nursery
  - cleaner
  - queen care
  - guard
  - forager

Primate Societies

Built around concept of dominance

- more dominant individuals get best access to mates, resources
- individuals compete for status, often when sexual maturity reached by young
- altruistic behavior common when members related

3.4 Social Biology

Social Biology

1- Human Population Growth
2- Human Intervention in Natural World
3- Biomedical Progress

Human Population Growth

- Human Populations
- Life Span
- Growth Rate
- Demographic Transition

Human Intervention in Natural World

- Human Population Size
- Pollution
- Resource Management

Biomedical Progress

- Nutrition
- Medical Advances
- Treatments
- Other Advances

3.4.1 Human Population Growth

Human Populations

Grow by same means as other populations

births – deaths = growth

Complex, b/c we reason around resource limitations, technology, think about reproductive behavior

Life Span

Better nutrition & medicine have increased human life span

Infant mortality greatly decreased

Birth rate decreased due to contraception

Growth Rate

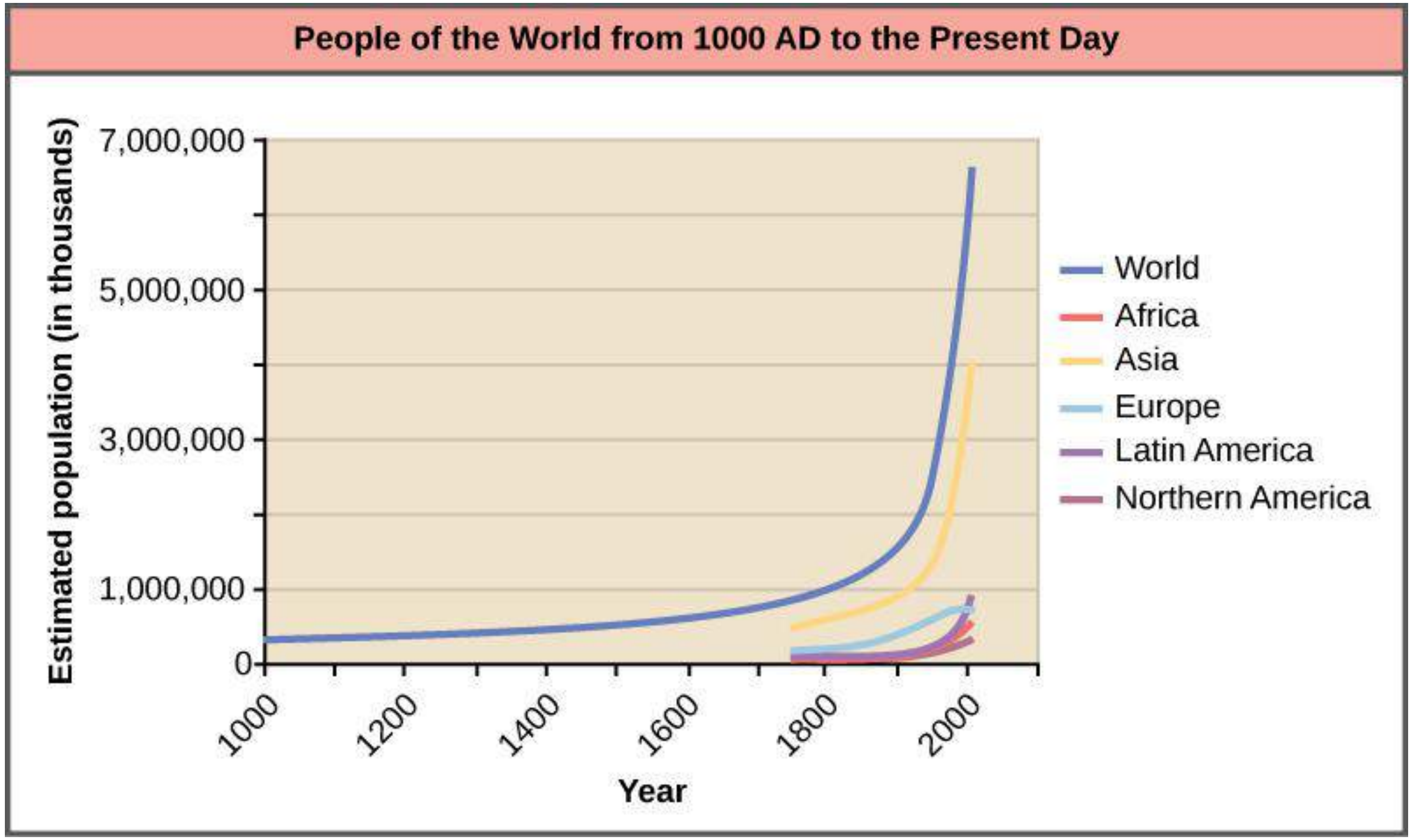
Over 7 billion people in 2016

Doubling time decreased

Technology increased food production, but starvation happens due to distribution

Demographic Transition

Theory proposes progressive demographic time periods of human population growth



Demographic Transition

1- At first, birth & death rates equal, population in equilibrium w/ environment

2- Societal developments of medicine & food production allow birth rate to overtake death rate, population increases rapidly

Demographic Transition

3- Agrarian lifestyles (many children for labor) become less common, children liability in urban society

4- medical advancement decreases infant mortality, urban populations increase rapidly

Demographic Transition

5- Industrialized countries lower birth rate using contraceptives

6- Increasing population strains environment, resources

3.4.2 Human Intervention in Natural World

Human Population Size

Profound effects on environment

- pollution
- habitat loss
- overharvesting
- introduced species
- climate change

1938 T. J. Hileman photo
Courtesy of GNP Archives

1981 Carl Key photo
USGS

1998 D. Fagre photo
USGS

2009 Lindsey Bengtson photo
USGS

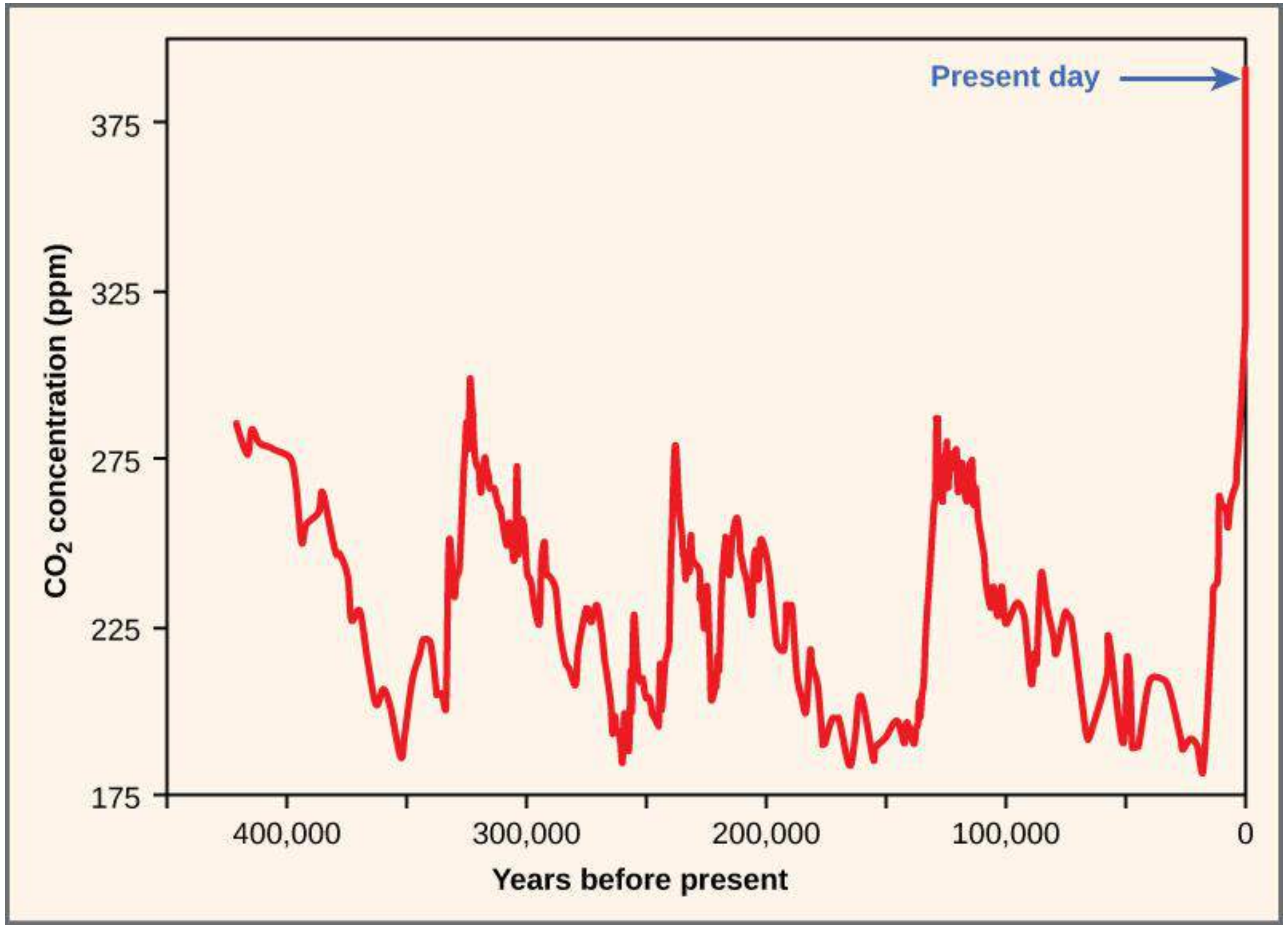
Pollution

Started as result of ignorance during Industrial Revolution

Addition of foreign substances to air, water, soil, etc.

- fertilizers, pesticides, herbicides
- industrial cleaners
- carbon emissions
- trash

Pollution



Present day
375
325
275
225
175
CO_2 concentration (ppm)
400,000
300,000
200,000
100,000
0
Years before present

Resource Management

We've had success repairing damaged ecosystems

We've learned ways to protect threatened species & ecosystems

"Reduce, reuse, recycle" works

3.4.3 Biomedical Progress

Nutrition

We’ve learned importance of essential nutrients, allowing healthier, longer lives

Decreases sickness due to malnutrition

- scurvy
- goiter
- anemia

Medical Advances

Development of antibiotics in 1920s decreased deaths from infection

Vaccines protect from previously lethal diseases (flu, smallpox, rabies, etc.)

Antiviral treatments decrease sickness after viral infection (AIDS)

Treatments

Improvements in managing illness, synthesizing molecules have allowed people to live longer & more comfortably

- **heart disease**
- **osteoporosis**
- **arthritis**
- **cancer**
- **diabetes**

Other Advances

Genetically Modified Organisms have increased agricultural output

Use bacteria to make:

- human insulin
- vaccines
- cancer treatments

Investigating stem cells for organ transplantation