# Biology

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http://denisemeeks.com/science/notebooks/notebook_biology.pdf

## Biology: Hypothesis for the Origin of Life

stage 1, abiotic synthesis of organic monomers: non-living synthesis of small organic molecules, including amino acid and nucleotide monomers

stage 2, abiotic synthesis of polymers: the joining of these small molecules into macromolecules

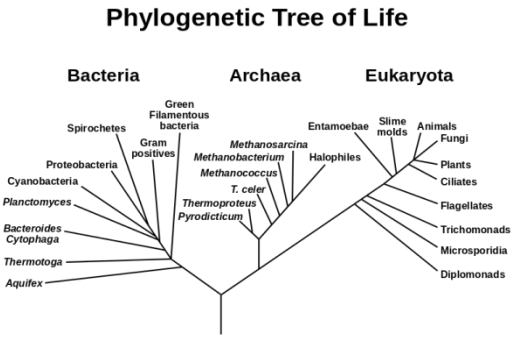
stage 3, formation of pre-cells: packaging of all these molecules into pre-cells, with membranes that maintained and internal chemistry different than the surroundings

stage 4, origin of self-replicating molecules: made inheritance possible

(Source: Essential Biology, Campbell, 4th ed., 2013)

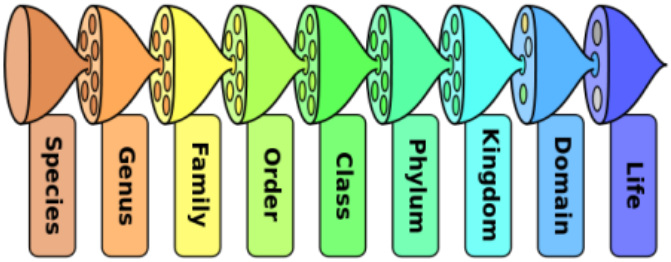
## Biology: Tree of Life

life: has order; is regulated by its internal and external environment; grows and develops based on DNA; takes in energy and uses it to perform all of life's activities; responds to environmental stimuli




(Image source: https://en.wikipedia.org/wiki/File:Phylogenetic_tree.svg, NASA Astrobiology Institute, public domain)

## Biology: Classification of Organisms




(Image source: https://en.wikipedia.org/wiki/File:Biological_classification_L_Pengo_vflip.svg, Pengo, public domain)

## Biology: Taxonomy Basics

binomial: two-part species name consisting of a geus to which a species belongsand a unique name for that species within a genus

convergent evolution: species from different evolutionary branches may share structures that are superficially similar

analogy: similarity due to convergence

cladistics: organisms are grouped by common ancestry

clade: an ancestral species and all its evolutionary descendants

three-domain system: recognizes two groups of prokaryotes, bacteria and archaea, and one domain of eukaryotes

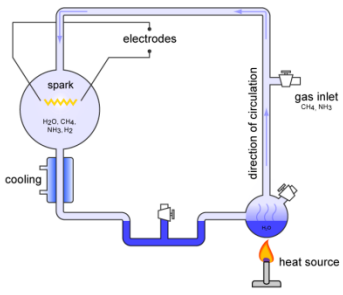
(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Miller-Urey Experiment (1)

- simulated conditions thought to be present on early Earth
- used water, methane, ammonia, and hydrogen, sealed inside a sterile 5-liter glass flask connected to a 500 ml flask half-full of liquid water
- liquid water in the smaller flask was heated to induce evaporation, water vapor was allowed to enter the larger flask
- continuous electrical sparks were fired between the electrodes to simulate lightning in the water vapor and gaseous mixture
- simulated atmosphere cooled so the water condensed and trickled into a U-shaped trap at the bottom of the apparatus
- after a day, the solution collected at the trap had turned pink
- at the end of one week of operation, the boiling flask was removed, and mercuric chloride was added to prevent microbial contamination

## Biology: Miller-Urey Experiment (2)

- reaction was stopped by adding barium hydroxide and sulfuric acid, and evaporated to remove impurities
- Miller identified five amino acids present in the solution; glycine, α-alanine and β-alanine were positively identified, while aspartic acid and α-aminobutyric acid (AABA) were less certain, due to the spots being faint




(Image source: https://en.wikipedia.org/wiki/Miller%E2%80%93Urey_experiment#/media/File:MUexperiment.png, Carney, CC BY 2.5, source: https://en.wikipedia.org/wiki/Miller%E2%80%93Urey_experiment)

## Biology: Darwin's Theory of Evolution

natural selection: organisms with certain inherited traits are more likely to survive and reproduce
population: group of individuals of the same species living in the same place at the same time
evolutionary adaptation: population's increase in the frequency of traits suited to the environment
observation 1: overproduction and competition; any population can produce far more offspring than the environment can possibly support with available resources, leading to competition
observation 2: individual variation; individuals in a population vary in many inherited traits; no two are exactly alike
conclusion: unequal reporductive success; individuals with inherited traits best suited for the environmentare more likely to have the greatest reproductive success
(Source: Essential Biology, Campbell, 4th ed., 2013)

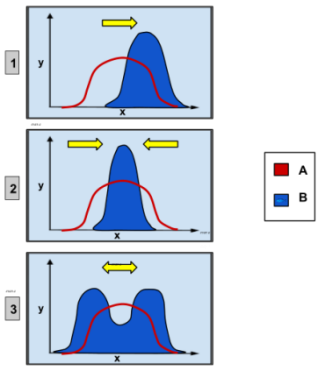
## Biology: Evidence of Evolution

fossil record: ordered sequence of fossils in rock layers
biogeography: geographic distribution of species
comparative anatomy: comparison of body structures in different species
homology: similarity in structure due to common ancestry
vestigal structures: remnants of features that served important functions in an organism's ancestors
comparative embryology: comparison of early stages of development reveals homologies not visible in adult organisms
molecular biology: examination of genes and nucleotide sequences
modern synthesis: fusion of genetics with evolutionary biology

(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: General Outcomes of Natural Selection

1. directional selection: shifts the overall makeup of the population by favoring variants at one extreme
2. stabilizing selection: removes extreme variants from the population
3. disruptive selection: favors variants at opposite extremes over intermediate individuals




(Image source: https://en.wikipedia.org/wiki/Directional_selection#/media/File:Genetic_Distribution.svg, Ealbert17, CC BY-SA 4.0)

## Biology: Origin of Species and Speciation

species: a group of populations whose members have the potential to interbreed with one another in nature to produce fertile offspring
reproductive barrier: anything that prevents individuals of closely related species from interbreeding
prezygotic barrier: prevents mating or fertilization between species
postzygotic barrier: results in hybrid zygotes if interspecies mating occurs
allopatric speciation: initial block to gene flow is a geographic barrier
sympatric speciation: origin of a new species without geographic isolation
punctuated equilibria: long periods of little apparent change interrupted by brief periods of rapid change
(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Hardy-Weinberg Equilibrium

Hardy-Weinberg equilibrium: allele and genotype frequencies in a population will remain constant from generation to generation in the absence of other evolutionary influences
Seven assumptions underlying Hardy–Weinberg equilibrium:

- organisms are diploid
- only sexual reproduction occurs
- generations are non overlapping
- mating is random
- population size is infinitely large
- allele frequencies are equal in the sexes
- there is no migration, mutation or selection

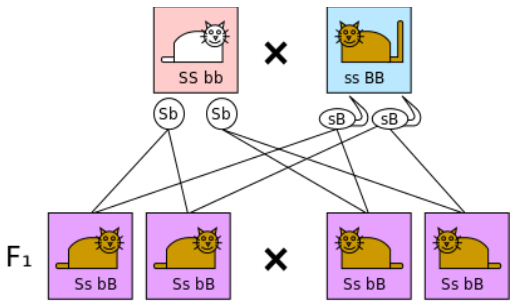
(Source: https://en.wikipedia.org/wiki/Hardy%E2%80%93Weinberg_principle)

## Biology: Mendelian Inheritance (1)

| | | | eggs R: p = a | eggs r: q = 1-a |
|---|---|---|---|---|
| sperm | R | p = a | $p^2 = a^2$ | pq = a(1-a) |
| | r | q = 1-a | pq = a(1-a) | $q^2 = (1-a)^2$ |

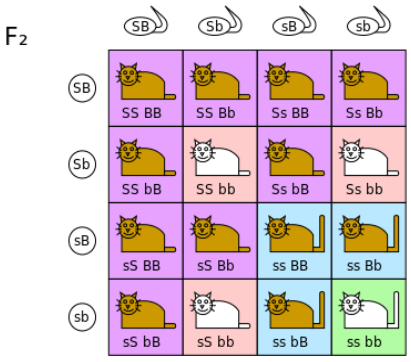
a = probability of allele R in the population, where R is dominant
1–a = probability of allele r in the population, where r is recessive

## Biology: Mendelian Inheritance (2)




Coat color is indicated by B (brown, dominant) or b (white, recessive), while tail length is indicated by S (short, dominant) or s (long, recessive). When parents are homozygous for each trait (SSbb and ssBB), their children in the F1 generation are heterozygous at both loci and only show the dominant phenotypes (SsbB).

## Biology: Mendelian Inheritance (3)




Tocharianne and White Timberwolf, public domain)

If the children mate with each other, in the F2 generation all combinations of coat color and tail length occur: 9 are brown/short (purple boxes), 3 are white/short (pink boxes), 3 are brown/long (blue boxes) and 1 is white/long (green box).
(Image and information source: https://en.wikipedia.org/wiki/Mendelian_inheritance#/media/File:Dihybrid_cross.svg,

## Biology: Mendel's Law of Segregation

1. there are alternative versions of genes that account for variations in inherited characters
2. for each inherited character, an organism inherits two alleles, one from each parent
3. if the two alleles of an inherited pair differ, then the dominant one determines the organism's appearance
4. a sperm or egg carries only one allele for each inherited characterbecause two two alleles for a character separate from each other during the production of gametes

(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Mendel's Laws of Independent Assortment and Dominance

law of independent assortment: each pair of alleles segregates independently of other pairs of alleles during gamete formation
testcross: mating between an idividual of dominant phenotype but unknown genotype

law of dominance: recessive alleles will always be masked by dominant alleles; a cross between a homozygous dominant and a homozygous recessive will always express the dominant phenotype, while still having a heterozygous genotype

(Source: https://en.wikipedia.org/wiki/Mendelian_inheritance)

## Biology: Bayesian Statistics

## Biology: Mechanisms of Evolution and Diversity

genetic drift: change in the gene pool of a population due to chance
bottleneck effect: genetic drift due to a drastic reduction in population size
founder effect: genetic drift resulting from the establishment of a small, new population whose gene pool differs from that of the parent poplulation
gene flow: when a population gains or loses alleles when fertile individuals move into or out of the population or when gametes are transferred between populations
sexual selection: for of natural selection in which individuals with certain traits are more likely than others to obtain mates
sexual dimorphism: manifested in size difference or adornment
(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Macroevolution

macroevolution: evolutionary change above the species level
evo-devo: evolutionary developmental biology
paedomorphosis: retention into adulthood of features that were juvenile in an ancestral species
geologic time scale: divides Earth's history into a sequence of geologic eras, periods, and epochs
radiometric dating: used to determine the age of rocks based on the decay of radioactive isotopes
plate tectonics: movement of Earth's crustal plates

## Biology: Big 5 Extinction Events

| event | description |
|---|---|
| Cretaceous–Paleogene | 66 Ma; formerly called the Cretaceous-Tertiary or K–T extinction; about 17% all families, 50% all genera, 75% all species became extinct |
| Triassic-Jurassic | 201.3 Ma; about 23% all families, 48% all genera (20% of marine families, 55% of marine genera), 70%-75% all species became extinct |
| Permian-Triassic | 252 Ma; killed 57% all families, 83% all genera; 90%-96% all species (53% of marine families, 84% of marine genera, about 96% all marine species and an estimated 70% of land species, including insects) |
| Late Devonian | 375–360 Ma; prolonged series of extinctions eliminated about 19% of all families, 50% of all genera and at least 70% of all species; may have lasted 20 million years |
| Ordovician-Silurian | 450–440 Ma; two events occurred that killed off 27% of all families, 57% of all genera and 60% to 70% of all species |

(Source: https://en.wikipedia.org/wiki/Extinction_event#List_of_extinction_events)

## Biology: Subdivisions of Biological Organisms

| domain | cell structure | properties | kingdom |
|---|---|---|---|
| eukaryotes | eurkariotic | multicellular, extensive differentiation of cells and tissues unicellular, coenocytic or mycellal, little or no tissue differentiation | • plants<br>• animals<br>• protists<br>• fungi |
| eubacteria | prokaryotic | cell chemistry similar to eucaryotes | eubacteria |
| archaebacteria | prokaryotic | distinctive cell chemistry | archaea |

## Biology: Prokariotic Cell Structure (1)

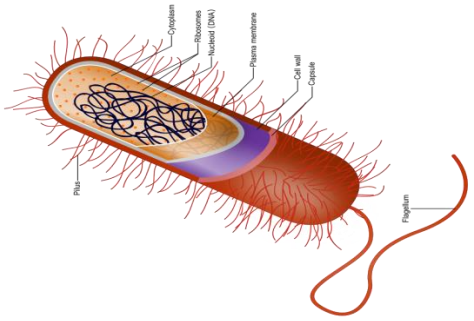



Image source: https://commons.wikimedia.org/wiki/File:Prokaryote_cell.svg, Ali Zifan, CC BY-SA 4.0)

## Biology: Prokaryotic Cell Structure (2)

cocci: spherical prokaryotic cells
bacilli: rod-shaped prokaryotic cells
spirochaetes: sspiral-shaped prokaryotic cells
binary fission: repeatedly dividing in half
endospore: thick-coated protective cell produced within the produced within a prokaryotic cell when exposed to unfavorable conditions
capsule: slimy outer coating of the cell wall. It is composed of the polypeptide. The main function of the capsule is to protect the cell from getting dry and also helps in protecting cells from external pressures
cell wall: protects the plasma membrane, plays a vital role in supporting and protecting the cells, thick outer layer made of cellulose
cell membrane: double layered, thin barrier, surrounds the cell to control the entry and exit of certain substances

## Biology: Prokaryotic Cell Structure (3)

nucleiod: cytoplasm region containing genetic material, DNA of a prokaryotic organism in one big loop or circular, located inside nucleoid, plays vital role in cell division
ribosome: plays a vital role in protein synthesis
plasmids: smallest cell membrane of with double stranded DNA, rarely present in prokaryotic organisms, main role of plasmids is it helps in DNA exchanging between the bacterial cells
pilli: thinnest membrane of prokaryotic cell, composed of protein complex called pilin; mainly involved in sticking to objects especially during sexual reproduction
flagella: helical shaped membrane; sizes range from 19-20nm diameter; plays vital role in organism motility from place to place; helps in swimming, gliding, spinning and rotating both in clockwise and counterclockwise directions
(Sources: Essential Biology, Campbell, 4th ed., 2013, https://en.wikipedia.org/wiki/Prokaryote)

## Biology: Archaea

- similar in size and shape to bacteria
- possess genes and metabolic pathways closely related to eukaryotes, including enzymes involved in transcription and translation
- rely on ether lipids in their cell membranes, including aerosols
- use more energy sources than eukaryotes, including organic compounds, metal ions, hydrogen gas, carbon-fixing
- reproduce asexually by binary fission, fragmentation or budding
- no known species forms spores
- numerous in oceans
- play roles in carbon and nitrogen cycles
- can be mutualists or commensuals

(Source: https://en.wikipedia.org/wiki/Archaea)

## Biology: Bacteria

- typically a few micrometers in length
- in a large variety of shapes
- among the first forms of life on Earth
- inhabit many environments, including soil, water, acidic hot springs, radioactive waste, and deep in Earth's crust
- live in symbiotic and parsitic relationships with plants and animals
- typically 40 million bacterial cells in a gram of soil and a million bacterial cells in a millimeter of fresh water
- about 5 x $10^{30}$ bacteria on Earth, exceeding the biomass of all plants and animals
- vital to the nutrient cycle
- several species are pathogenic, producing exotoxins or endotoxins

(Source: https://en.wikipedia.org/wiki/Bacteria)

## Biology: Protists

- informal term for any eukaryotic organism that is not an animal, plant or fungus
- often grouped together for convenience, like algae or invertebrates.
- In some biological classification systems protists make up a kingdom called Protista, composed of "organisms which are unicellular or unicellular-colonial and which form no tissues
- now considered to mean similar-appearing but diverse taxa that are not related through an exclusive common ancestor
- have different life cycles, trophic levels, modes of locomotion, and cellular structures

(Source: https://en.wikipedia.org/wiki/Protist)

## Biology: Protozoans and Slime Molds

protozoan: protist that lives primarily by ingesting food
flagellate: protozoan that moves by means of one or more flagella
amoeba: have great flexibility in body shape and absence of permanent organelles for locomotion
pseudopodia: amoeba that can assume virtually any shape while creeping over rocks, sticks, or mud at the bottom of ponds or oceans
foram: pseudopodia with a shell
apicomplexan: parasitic, has structure for penetrating host cells
ciliate: protozoan names for hair-like structures called cilia
plasmodial slime mold: amoeboid mass that can measure several centimeters across
cellular slime mold: swarm together to form a colony
(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Unicellular and Colonial Algae

plankton: communities of microscopic organisms that drift or swim near the surfaces of large bodies of water
dinoflagellate: a type of marine plankton with flagella
diatom: has glassy cell walls containing silica
green algae: named for grass-green chloroplasts; live in fresh water and aquariums
seaweed: has slimy and rubbery cell walls; can be very large and grow in large colonies

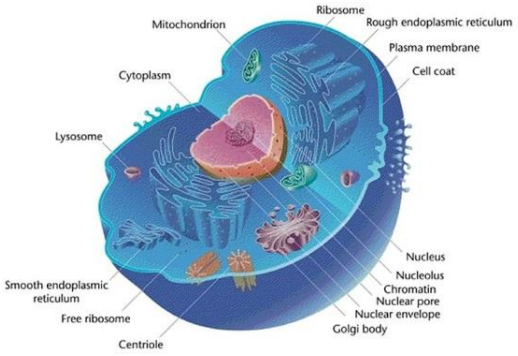
(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Multicellular Life

- has evolved independently at least 46 times including in some prokaryotes, cyanobacteria, myxobacteria, actinomycetes, and others
- complex multicellular organisms evolved only in six eukaryotic groups: animals, fungi, brown algae, red algae, green algae, and land plants
- evolved repeatedly for green algae and land plants, at least once for animals, once for brown algae, three times in fungi and several times for slime molds and red algae
- first evidence of multicellularity is from cyanobacteria-like organisms that lived 3–3.5 billion years ago
- to reproduce, true multicellular organisms must regenerate a whole organism from sperm and egg cells
- animals have evolved a diversity of cell types in a multicellular body (100–150 different cell types), compared with 10–20 in plants and fungi

(Source: https://en.wikipedia.org/wiki/Multicellular_organism)

## Biology: Eukariotic Cell Structure (1)




(Image source: https://commons.wikimedia.org/wiki/File:Eukaryotic_Cell_(animal).jpg, Mediran, CC BY-SA 3.0)

## Biology: Eukariotic Cell Structure (2)

plasma membrane: semi-permeable membrane, acts as boundary of a cell, protects and separates the cell from the external environment
nucleus: membrane bound organelles, found in all eukaryotic cells, important organelle, controls the complete activity and plays a vital role in reproduction
nuclear membrane: bilayer membrane, acts as a barrier between cell nucleus and other organs of a cell
nucleolus: important membrane found inside the nucleus, plays a vital role in the production of cell's ribosome
mitochondria: double membrane, filamentous organelles, which play vital role in generating and transforming the energy and in various functions of the cell metabolisms including oxidative phosphorylation

(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Eukariotic Cell Structure (3)

endoplasmic reticulum: helps in the movement of materials around the cell, contains an enzyme that helps in building molecules and in manufacturing of proteins, main function is storage and secretion
ribosome: plays a vital role in protein synthesis
golgi bodies: help in the movement of materials within the cell
lysosomes: help in cell renewal and break down of old cell parts
cytoplasm: membrane which protects the cell by keeping organelles separate, helps keep cell stable, where many vital biochemical reactions take place
enzyme: biological catalyst
chromosomes: made up of DNA and stored in the nucleus, which contains the instructions for traits and characteristics

(Source: https://en.wikipedia.org/wiki/Eukaryote)

## Biology: Modes of Nutrition

| | | energy source | |
|---|---|---|---|
| | | **light** | **chemical** |
| **carbon source** | **$CO_2$** | **photoautotrophs use light to drive synthesis of organic compounds from $CO_2$** | **chemoautotrophs extract energy from inorganic substances such as ammonia; all chemoautotrophs are prokaryotes** |
| | **organic compounds** | **photoheterotrophs harness energy from light but must obtain carbon in organic form; all photoheterotrophs are prokaryotes** | **chemoheterotrophs consume organic molecules for both energy and carbon, include some prokaryotes, and protists, and and all fungi and animals** |

(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Oxidation and Reduction

redox reaction: chemical reactions that transfer electrons from one substance to another
oxidation: loss of electrons during a redox reaction
reduction: acceptance of electrons during a redox reaction

## Biology: Cellular Respiration (1)

stage 1, glycolysis: (a) a six-carbon glucose molecule is broken in half, forming two three-carbon molecules; split requires an energy investment of two ATP molecules per glucose; (b) the three-carbon molecules donate high-energy electrons to NAD (nicotinamide adenine dinucleotide) to form NADH (NAD + hydrogen); (c) also makes four ATP molecules when enzymes transfer phosphate groups from fuel molecules to ADP; net of two molecules of ATP produced; two molecules of pyruvic acid remain

## Biology: Cellular Respiration (2)

stage 2, citric acid cycle: (a) each pyruvic acid loses carbon as $CO_2$; remaining fuel molecules, each with two carbons left, are acetic acid (vinegar); (b) oxidation of the fuel generates NAHD; (c) each acidic acid is attached to coenzyme A (CoA) , derived from B vitamin pantothenic acid, forms acetyl CoA, which escorts acetic acid into first citric acid cycle reaction; (d) acetic acid joins four-carbon acceptor molecule to form a six-carbon citric acid; (e) for every acetic acid molecule that enters the cycle as fuel, two $CO_2$ molecules exist as waste; citric acid cycle harvests energy from the fuel; (f) some energy is used to produce ATP directly; (g) the cycle captures more energy in the form of NADH and (h) a second, closely related electron carrier $FADH_2$; (i) all carbon atoms that entered the cycle as fuel are accounted for as $CO_2$ exhaust, and the four-carbon acceptor molecule is recycled

## Biology: Cellular Respiration (3)

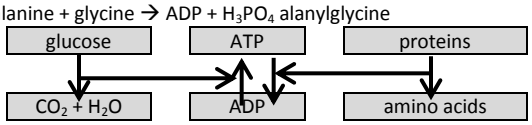
stage 3, electron transport: (a) NADH and (b) $FADH_2$ transfer electrons to an electron transport chain; (c) the electron transport chain uses this energy supply to pump $H^+$ across the inner mitochondrial membrane; (d) oxygen pulls electrons down the transport chain; (e) the $H^+$ concentrated on one side of the membrane rushes back "downhill" through an ATP synthase; this action spins a component of the ATP synthase; (f) the rotation activates parts of the synthase molecule that attach phosphate groups to ADP molecules to generate ATP

(Source: Essential Biology,Campbell, 4th ed., 2013)

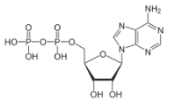
## Biology: Cellular Respiration (4)

$ADP + H_3PO_4 \rightarrow ATP + H_2O$ alanine + glycine → alanylgycine

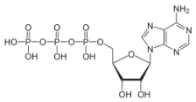
$ATP + H_2O$ + alanine + glycine → $ADP + H_3PO_4$ alanylglycine




ADP molecule



ATP molecule



(Image sources: https://en.wikipedia.org/wiki/Adenosine_diphosphate#/media/File:Adenosindiphosphat_protoniert.svg, https://en.wikipedia.org/wiki/Adenosine_triphosphate#/media/File:Adenosintriphosphat_protoniert.svg, NEUROtiker, public domain)

## Biology: Cellular Respiration (5)

aerobic respiration:

glucose + oxygen → carbon dioxide + water + energy

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + 2900 kJ/mol

anaerobic respiration in animals:

glucose → lactic acid + energy

$C_6H_{12}O_6 \rightarrow 2C_3H_6O_3$ + 120 kJ/mol

anaerobic respiration in plants:

glucose → ethanol + carbon dioxide + energy

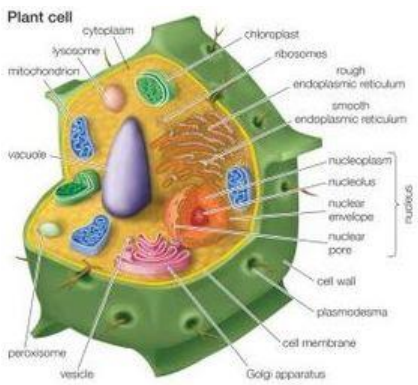
$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ + Energy

## Biology: Plants

| name(s) | scope | description |
|---|---|---|
| **land plants, also known as Embryophyta** | **Plantae *sensu strictissimo*** | **plants in a strictest sense, includes liverworts, hornworts, mosses, and vascular plants, fossil plants similar to these surviving groups** |
| **green plants, also known as Viridiplantae, Viridiphyta or Chlorobionta** | **Plantae *sensu stricto*** | **plants in a strict sense, includes green algae, and land plants that emerged within them, stoneworts** |
| **Archaeplastida, also known as Plastida or Primoplantae** | **Plantae *sensu lato*** | **plants in a broad sense, green plants plus Rhodophyta, Glaucophyta, includes organisms that eons ago acquired chloroplasts by engulfing cyanobacteria** |
| **Old definitions of plant (obsolete)** | **Plantae *sensu amplo*** | **plants in an ample sense, old classifications, now obsolete** |

(Source: https://en.wikipedia.org/wiki/Plant)

## Biology: Plant Cell Structure (1)




(Image source: https://www.britannica.com/science/plant-cell, Encyclopedia Britannica)

## Biology: Plant Cell Structure (2)

mitochondrion: containing genetic material and many enzymes important for cell metabolism, including those responsible for the conversion of food to usable energy

lysosome: an organelle in the cytoplasm of eukaryotic cells containing degradative enzymes enclosed in a membrane

cytoplasm: material or protoplasm within a living cell, excluding the nucleus

chloroplasts: light-absorbing organelles

stroma: thick fluid surrounded by chloroplast inner membrane

thylakoids: interconnected membraneous sacs in stroma

grana: concentrated stacks of thylakoids

ribosome: minute particle consisting of RNA and associated proteins, found in large numbers in the cytoplasm of living cells; bind messenger RNA and transfer RNA to synthesize polypeptides and proteins

## Biology: Plant Cell Structure (3)

rough endoplasmic reticulum: network of tubular membranes within the cytoplasm of the cell, with a rough surface

smooth endoplasmic reticulum: network of tubular membranes within the cytoplasm of the cell, with a smooth surface

nucleoplasm: substance of a cell nucleus, especially that not forming part of a nucleolus

nucleolus: small dense spherical structure in the nucleus of a cell during interphase

nuclear envelope: double membrane structure that surrounds the nucleus in eukaryotic cells and provides this compartmentalization

nuclear pore: protein-lined channel in the nuclear envelope that regulates the transportation of molecules between the nucleus and the cytoplasm

cell wall: rigid layer of polysaccharides lying outside the plasma membrane of the cells of plants, fungi, and bacteria

## Biology: Plant Cell Structure (4)

plasmodesma: narrow thread of cytoplasm that passes through the cell walls of adjacent plant cells and allows communication between them

cell membrane: semipermeable membrane surrounding the cytoplasm of a cell

Golgi apparatus: complex of vesicles and folded membranes within the cytoplasm of most eukaryotic cells, involved in secretion and intracellular transport

vesicle: small fluid-filled bladder

peroxisome: small organelle that is present in the cytoplasm of many cells and that contains the reducing enzyme catalase and usually some oxidases

vacuole: space or vesicle within the cytoplasm of a cell, enclosed by a membrane and typically containing fluid

(Source: Essential Biology, Campbell, 4th ed., 2013)

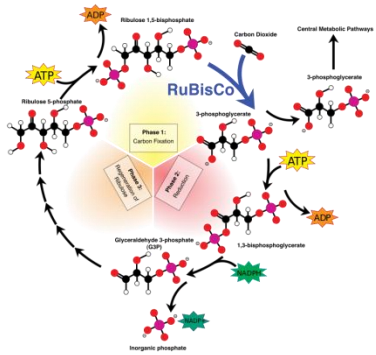
## Biology: Photosynthesis

photosynthesis: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

light reactions: generate ATP and NADHP: (a) photons excite electrons in chlorophyll of water-splitting photosystem; photons are then trapped by the primary electron acceptor; watter-splitting photosystem replaces its light-excited electrons by extracting electrons from water, which releases $O_2$; (b) energized electrons from water-splitting photosystem pass down an electron transport chain to NADPH-producing photosystem; choloroplast uses the energy released to make ATP; (c) the NADPH-producing photosystem transfers it light-excited electrons to NADP, reducing it to NADPH
(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Calvin Cycle

Calvin cycle: uses products of light reactions to power production of sugar from carbon dioxide; enzymes driving the cycle are dissolved in the stroma; ATP generated by light reactions provides energy for sugar synthesis; NADPH produced by light reactions provide high energy electrons for reduction of carbon dioxide to glucose




(Image source: https://en.wikipedia.org/wiki/Light-independent_reactions#/media/File:Calvin-cycle4.svg, Mike Jones, CC BY-SA 3.0)

## Biology: Plant Anatomy

symbiosis: mutually beneficial interaction between two different organisms living in close physical association
plant: multicellular eukaryote that makes organic molecules through photosynthesis
shoots: leaf-bearing plant organs
roots: subterranean plant organs
mycorrhizae: root-fungus combinations
stomata: microscopic pores found on leaf surfaces
cuticle: waxy layerthat coats the leaves of plants
lignin: chemical that hardens plant cell walls
vascular tissue: system of tube-shaped cells branching throughout a plant
xylem: dead cells with tubular cavities for water transport and minerals
phloem: living cells that distribute sugars for leave to roots
gametangium: protective cells surrounding moist gamete chamber
(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Plant Evolution (1)

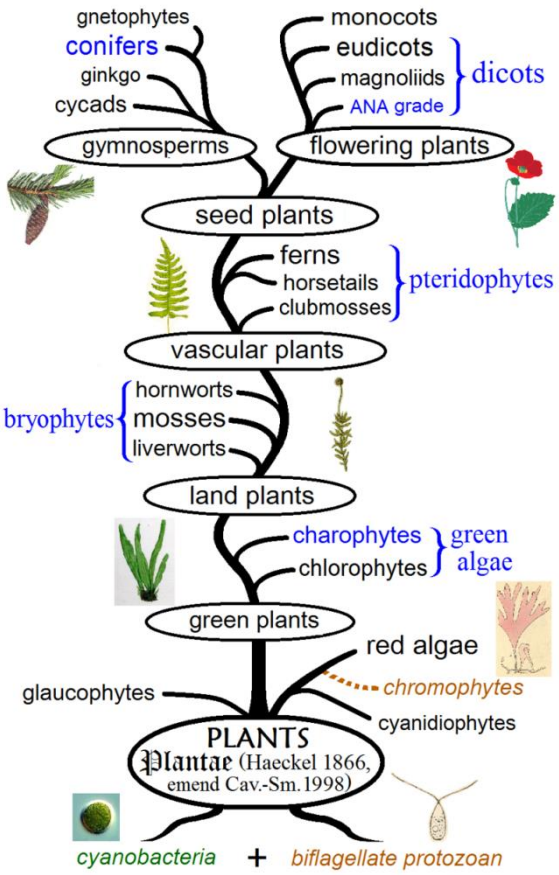
bryophyte: a small flowerless green plant of the division *Bryophyta*, which comprises the mosses and liverworts
moss: matted bryophyte
gametophyte: green, spnge-like part of moss
sporophyte: stalk-like part of moss
fern: flowerless plant that has feathery or leafy fronds and reproduces by spores released from the undersides of the fronds; has a vascular system for the transport of water and nutrients
gymnosperm: plant that has seeds unprotected by an ovary or fruit; include the conifers, cycads, and ginkgo
pollen grain: plant male gamete
conifer: tree that bears cones and evergreen needlelike or scalelike leaves

## Biology: Plant Evolution (2)

angiosperm: plant that has flowers and produces seeds enclosed within a carpel. The angiosperms are a large group and include herbaceous plants, shrubs, grasses, and most trees
flower: complex reproductive structure that bears seeds
sepal: outer layer of a flower base
petal: usually colorful parts of a flower
stamen: male reproductive structure
anther: sac at the top of each stamen
ovary: protective chamber containing one or more ovules
stigma: stickly part of the carpel which traps pollen

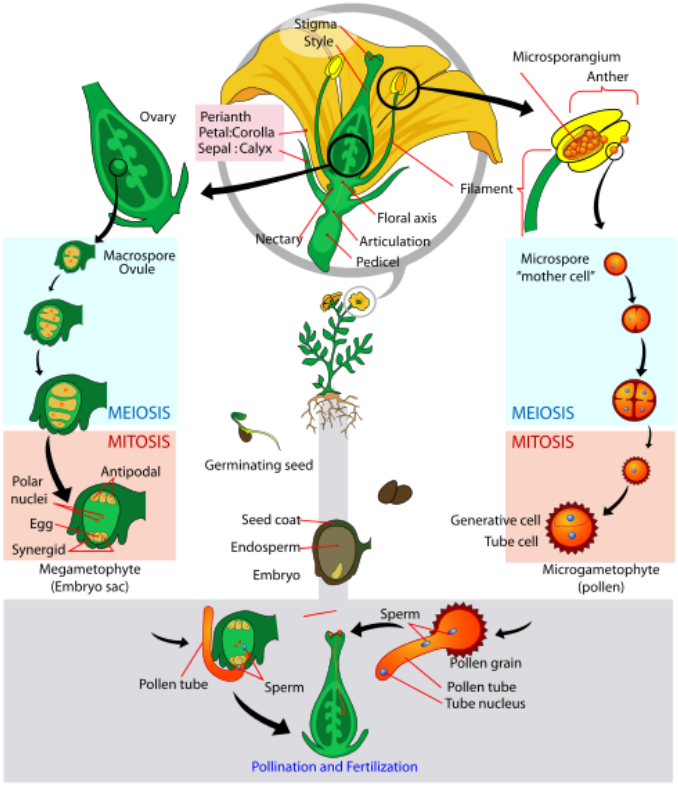
(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Plant Evolution (3)




(Image source: https://en.wikipedia.org/wiki/Evolutionary_history_of_plants#/media/File:Plant_phylogeny.png, Maulucioni, CC BY-SA 4.0)

## Biology: Angiosperm Life Cycle




(Image source: https://en.wikipedia.org/wiki/File:Angiosperm_life_cycle_diagram-en.svg, Mariana Ruiz, public domain)

## Biology: Fungi

fungus: any of a group of unicellular, multicellular, or syncytial spore-producing organisms feeding on organic matter, including molds, yeast, mushrooms, and toadstools
absorption: small organic molecules are absorbed from the sourrounding environment
hyphae: thread-like filaments that make up fungi
mycelium: feeding structure of fungus

(Source: Essential Biology, Campbell, 4th ed., 2013)

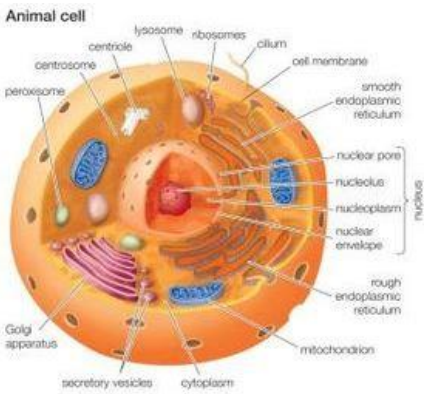
## Biology: Animals

animal: eukaryotic, multicellular, heterotrophic organism that obtains nutrients by eating

1. male and female adult animals make haploid gametes through meiosis
2. egg and sperm fuse together
3. zygote divides by mitosis
4. forms early embryonic stage called a blastula, a hollow ball of cells
5. one side of the blastula folds inward, forming a gastrula
6. gastrula develops into a sac-like embryo, which may become an adult or,
7. develop into a larva
8. which undergoes metamorphosis to become an adult

(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Animal Cell Structure (1)




(Image source: https://www.britannica.com/science/lysosome, Encyclopedia Britannica)

## Biology: Animal Cell Structure (2)

peroxisome: small organelle that is present in the cytoplasm of many cells and that contains the reducing enzyme catalase and usually some oxidases
centrosome: organelle near the nucleus of a cell that contains the centrioles (in animal cells) and from which the spindle fibers develop in cell division
centriole: minute cylindrical organelle near the nucleus in animal cells, occurring in pairs and involved in the development of spindle fibers in cell division
lysosome: organelle in the cytoplasm of eukaryotic cells containing degradative enzymes enclosed in a membrane
ribosome: minute particle consisting of RNA and associated proteins, found in large numbers in the cytoplasm of living cells; bind messenger RNA and transfer RNA to synthesize polypeptides and proteins

## Biology: Animal Cell Structure (3)

cilium: short, microscopic, hairlike vibrating structure
cell membrane: semipermeable membrane surrounding the cytoplasm of a cell
smooth endoplasmic reticulum: network of tubular membranes within the cytoplasm of the cell, with a smooth surface
nuclear pore: protein-lined channel in the nuclear envelope that regulates the transportation of molecules between the nucleus and the cytoplasm
nucleolus: small dense spherical structure in the nucleus of a cell during interphase
nucleoplasm: substance of a cell nucleus, especially that not forming part of a nucleolus
nuclear envelope: double membrane structure that surrounds the nucleus in eukaryotic cells

## Biology: Animal Cell Structure (4)

rough endoplasmic reticulum: network of tubular membranes within the cytoplasm of the cell, with a rough surface
mitochondrian: containing genetic material and many enzymes important for cell metabolism, including those responsible for the conversion of food to usable energy
cytoplasm: material or protoplasm within a living cell, excluding the nucleus
secretory vesicles:
Golgi apparatus: complex of vesicles and folded membranes within the cytoplasm of most eukaryotic cells, involved in secretion and intracellular transport

(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Animal and Plant Cell Differences (1)

1. size: animal cells are generally smaller; animal cells range from 10 to 30 micrometers in length, while plant cells range from 10 and 100 micrometers in length
2. shape: animal cells come in various sizes and tend to have round or irregular shapes; plant cells are more similar in size and are typically rectangular or cube shaped
3. energy storage: animals cells store energy in the form of the complex carbohydrate glycogen; plant cells store energy as starch
4. proteins: of the 20 amino acids needed to produce proteins, only 10 can be produced naturally in animal cells; . The other essential amino acids must be acquired through diet; plants are capable of synthesizing all 20 amino acids
5. differentiation: in animal cells, only stem cells are capable of converting to other cell types; most plant cell types are capable of differentiation

## Biology: Animal and Plant Cell Differences (2)

6. growth: animal cells increase in size by increasing in cell numbers; plant cells mainly increase cell size by becoming larger and grow by absorbing more water into the central vacuole
7. cell wall: animal cells do not have a cell wall but have a cell membrane; plant cells have a cell wall composed of cellulose as well as a cell membrane
8. centrioles: animal cells contain these cylindrical structures that organize the assembly of microtubules during cell division; plant cells do not typically contain centrioles
9. cilia: found in animal cells but not usually in plant cells;
10. cytokinesis: division of the cytoplasm during cell division, occurs in animal cells when a cleavage furrow forms that pinches the cell membrane in half; in plant cell cytokinesis, a cell plate is constructed that divides cell

(Source: http://biology.about.com/od/cellbiology/ss/Animal-Cells-vs-Plant-Cells.htm)

## Biology: Animal and Plant Cell Differences (3)

11. glyoxysomes: not found in animal cells, but present in plant cells; help to degrade lipids, particularly in germinating seeds, for production of sugar
12. lysosomes: animal cells possess lysosomes which contain enzymes that digest cellular macromolecules; plant cells rarely contain lysosomes as the plant vacuole handles molecule degradation
13. plastids: animal cells do not have plastids; plant cells contain plastids such as chloroplasts, which are needed for photosynthesis
14. plasmodesmata: animal cells do not have plasmodesmata; plant cells have plasmodesmata, which are pores between plant cell walls that allow molecules and communication signals to pass between individual plant cells
15. vacuole: animal cells may have many small vacuoles; plant cells have a large central vacuole that can occupy up to 90% of the cell's volume

(Source: http://biology.about.com/od/cellbiology/ss/Animal-Cells-vs-Plant-Cells.htm, About Education)

## Biology: Animal Phylogeny

body cavity: fluid-filled space separating the digestive tract from the outer body wall
mesoderm: middle layer of tissue
edoderm: inner layer of the gastrula embryo
ectoderm: outer layer of the gastrula embyro
pseudocoelom: if the body cavity is not completely lined by mesoderm tissue
coelum: body cavity completely lined by tissue derived from mesoderm

(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Major Invertebrate Phyla (1)

sponges: stationary, mainly marine animals that appear immobile
cnidarians: have body tissues, radial symmetry, and tentacles with stinging cells
gastrovascular activity: sac with central digestive compartment
polyp: adheres to larger objects and extends tentacles
medusa: flattened, mouth-down version of a polyp
molluscs: snails, slugs, oysters, and clams
radula: file-like organ used by molluscs for feeding
mantle: drapes over the visceral mass and secretes the shell
gastropods: molluscs protected by a single, spiraled shell into which an animal can retreat; include snails and sea slugs
bivalves: molluscs; shells divided into two halves hinged together; include clams, oysters, mussels, and scallops

## Biology: Major Invertebrate Phyla (2)

cephalopods: molluscs; have small, internal shells; fast and agile; include octopus and nautilus
flatworms: simplest animals with bilateral symmetry
annelids: worms with body segmentation
complete digestive tract: digestive tube with a mouth and an anus
earthworms: annelids; segmented internally and externally
polychaetes: annelids; marine, crawling or burrowing segmented worms
leeches: annelids; free-living carnivores that eat small invertebrates
roundworms: also called nematodes; found in marine habitats, and as parasites

(Source: Essential Biology, Campbell, 4th ed., 2013)

**Biology: Major Invertebrate Phyla (3)**

arthropods: jointed appendages; include crabs, lobsters, spiders, scorpions, grasshoppers, moths; have specialized body parts
arachnids: arthropods; scorpions, spiders, ticks, and mites; usually have four pairs of walking legs and specialized feeding appendages
crustaceans: arthropods; crabs, lobsters, crayfish, shrimps, barnacles, and pill bugs; have multiple pairs of specialized appendages
millipeds and centipedes: arthropods; resemble annelids, but have jointed legs, making them arthropods
insects: arthropods; three part body consisting of head, thorax, and abdomen; most can fly
echinoderms: spiny surfaces; sea stars, sea urchins, sea cucumbers, sand dollars

(Source: Essential Biology, Campbell, 4th ed., 2013)

**Biology: Chordate Characteristics**

characteristics:

1. dorsal, hollow nerve cord
2. notochord: flexible, longitudinal rod located between digestive tract and nerve cord
3. pharyngeal slits: groove in the pharynx, region of digestive tube behind the mouth
4. post-anal tail: tail to the rear of the anus
5. body segmentation in backbones

invertebrate chordates:

(Source: Essential Biology, Campbell, 4th ed., 2013)

**Biology: Inertebrate Chordates**

tunicates: marine invertebrates including sea squirts, salps; have rubbery or hard outer coat, two siphons to draw water in and out
lancelets: small elongated marine invertebrates; resemble fish; lack jaws and obvious sense organs

(Source: Essential Biology, Campbell, 4th ed., 2013)

**Biology: Fishes**

hagfishes: primitive and jawless;related to lampreys; slimy eellike body, slitlike mouth surrounded by barbels, rasping tongue used for feeding on dead or dying fish
lampreys: eel-like, aquatic, and jawless; have a sucker mouth, horny teeth, rasping tongue; adult often parasitic
cartilaginous fishes: sharks and rays; have flexible skeleton made of cartilage
lateral line system: row of sensory organs running along the side of the body
bony fishes: reinforced by calcium
operculum: covers a chamber containing gills
swim bladder: gas-filled sac
ray-finned fishes: fins supported by skeletal rays; tuna, trout, goldfish
lobe-finned fishes: muscular fins supported by stout bones homologous to amphibian limb bones

(Source: Essential Biology, Campbell, 4th ed., 2013)

**Biology: Amphibians**

amphibians: cold-blooded vertebrate animals including frogs, toads, newts, and salamanders; distinguished by aquatic gill-breathing larval stage followed by terrestrial lung-breathing adult stage
tetrapods: include amphibians, reptiles, and mammals

**Biology: Reptiles**

amniotes: animals whose embryo develops in an amnion and chorion and has an allantois; a mammal, bird, or reptile
amniotic egg: fluid-filled egg with waterproof shell that encloses a developing embryo
reptiles: snakes, lizards, turtles, crocodiles, alligators, birds, dinosaurs
ectotherms: animals dependent on external sources of body heat
birds: warm-blooded egg-laying vertebrates distinguished by the possession of feathers, wings, and a beak and typically able to fly
endotherm: animal dependent on or capable of the internal generation of heat; a warm-blooded animal

**Biology: Mammals**

mammals: warm-blooded vertebrate animals distinguished by possession of hair or fur, secretion of milk by females, and typically birth of live young
monotremes: egg-laying mammals; dick-billed platypus and echidna
placenta: consists of embryonic and maternal tissues; joins the embryo to the mother
marsupials: pouched mammals; kangaroos, koalas, opossums
eutherians: placental mammals

## Biology: Primate Evolution (1)

primates: any of an orderof mammals that are characterized especially by advanced development of binocular vision resulting in stereoscopic depth perception, specialization of the hands and feet for grasping, and enlargement of the cerebral hemispheres and that include humans, apes, monkeys, and related forms such as lemurs and tarsiers

anthropoids: includes monkeys and apes

hominins: primates of a taxonomic tribe, which comprises those species regarded as human, directly ancestral to humans, or very closely related to humans

*Australopithecus*: fossil bipedal primate with both apelike and human characteristics, found in Pliocene and lower Pleistocene deposits (*c* 4 million to 1 million years old) in Africa

## Biology: Primate Evolution (2)

*Homo habilus*: extinct hominid known from sub-Saharan fossil remains associated with crude stone tools; estimated to have flourished 1.6 to 2 million years ago; believed to be predecessor of *Homo erectus*

*Homo erectus*: extinct species of human lineage; formerly known as *Pithecanthropus erectus*; upright stature, well-evolved postcranial skeleton, but with a smallish brain, low forehead, and protruding face

*Homo neanderthalensis*: lived between 28,000 and 300,000 years ago; specimens found across Europe and Middle East; had bigger brain size (i.e. approx. 1500 cc), shorter, brawnier stature, marked mid-face forward projection, larger and rounder eye sockets, broad nose, larger teeth, and jaw lacking a projecting bony chin

*Homo sapiens*: binomial nomenclature for only extant human species; *Homo* is the human genus, which also includes *Neanderthals* and many other extinct species of hominid; *H.sapiens* is the only surviving species of the genus *Homo*

## Biology: Mitosis (1)

cell division: reproduction of cells

chromosome: structures that contain cell DNA

mitosis: cell division resulting in two daughter cells each having the same number and kind of chromosomes as parent nucleus

asexual reproduction: reproduction not involving fertilization of an egg by sperm

chromatin: fibers composed of roughly equal amounts of DNA and protein molecules

histone: small proteins found only in eukaryotes

nucleosome: DNA wound around histone molecules

sister chromatids: DNA copies

centromere: narrow "waist" of a chromosome

cytokinesis: process where cytoplasm divides in two

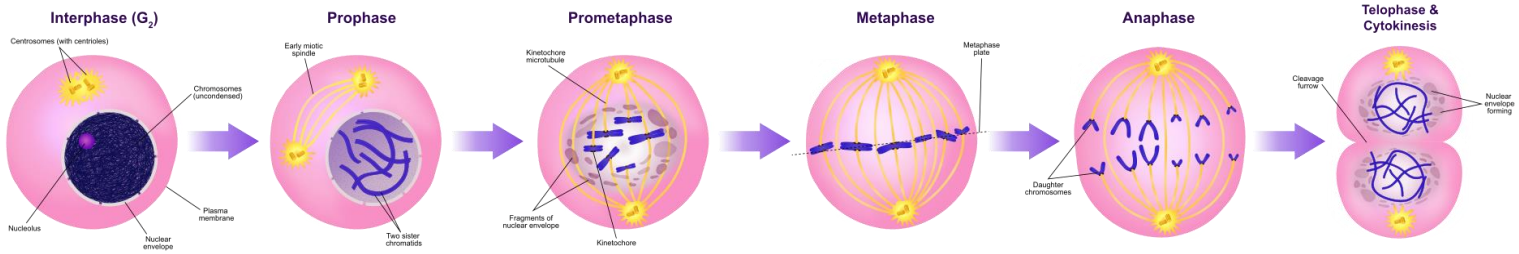
(Source: Essential Biology,Campbell, 4th ed., 2013)

## Biology: Mitosis (2)

| phase | description |
|---|---|
| interphase | period of cell growth when cell makes new molecules and organelles; cytoplasm contains two centrosomes; chromosomes are duplicated but cannot be distinguished individually |
| prophase | changes occur in nucleus and cytoplasm; chromosomes can be seen with a light microscope; each chromosome exists with identical sister joined at centromere "waist" |
| prometaphase | last minute DNA repair, and DNA winding;chromosomes two to three times longer than metaphase chromosomes |
| metaphase | mitotic spindle fully formed; chromosome centromeres line up; microtubules of mitotic spindle attach to two sister chromatids |
| anaphase | sister chromatids separate; chromosomes move toward opposite poles of cell |
| telophase & cytokinesis | two groups of chromosomes have reached opposite ends of the cell; reverse of prophase; cytokinesis usually occurs with telophase |

(Source: Essential Biology,Campbell, 4th ed., 2013)

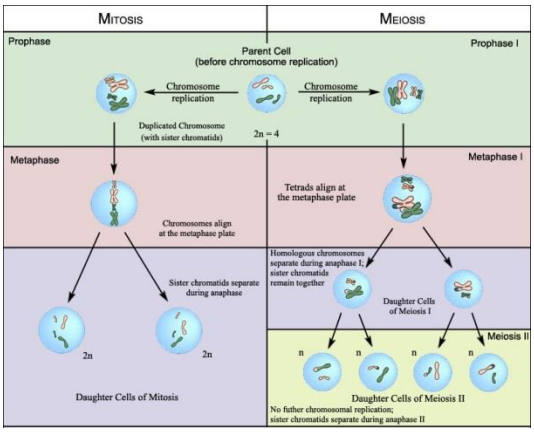
## Biology: Mitosis (3)




(Image source: https://en.wikipedia.org/wiki/Cell_cycle#/media/File:Mitosis_Stages.svg, Ali Zifan, CC BY-SA 4.0)

pp. 126-127 if specifics on graphic above needed

## Biology: Meiosis v. Mitosis




(Image source: https://mrborden.files.wordpress.com/2014/01/mitosis-meiosis.jpg)

## Biology: Meiosis

sexual reproduction: reproduction involving fertilization of an egg by sperm

gametes: eggs and sperm

meiosis: cell division reducing number of chromosomes in parent cell by half; produces four gamete cells; required to produce egg and sperm cells

somatic cell: has 46 chromosomes

karyotype: arrangement of ordered chromosomes in matching pairs

homologous chromosomes: members of a matching pair

sex chromosomes: determine an organism's sex

autosomes: non-sex chromosomes

life cycle: sequence of stages leading from the adults of one generation to adults of the next

diploid organism: organisms with pairs of matching chromosomes

haploid cell: has only one member of each pair of homologous chromosomes

nondisjunction: members of a chromosome pair fail to separate anaphase

(Source: Essential Biology,Campbell, 4th ed., 2013)

## Biology: Meiosis I

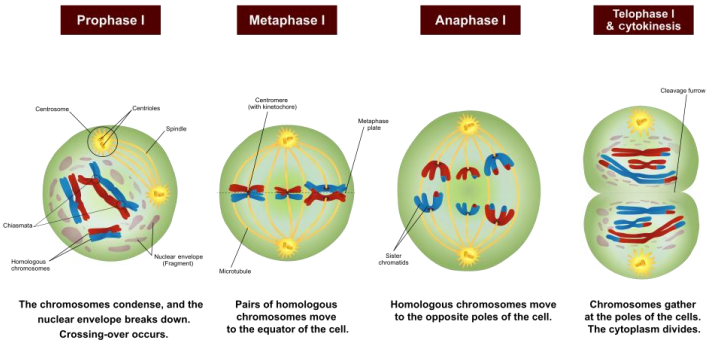
| homologous cell separation | |
|---|---|
| phase | description |
| interphase | chromosomes duplicate |
| prophase I | homologous chromosomes stick together; resulting structure has four chromatids which exchange corresponding segments |
| metaphase I | homologous pairs align; are anchored to spindle microtubules |
| anaphase I | attachment between homologous chromosomes breaks; sister chromosomes migrate as a pair |
| telophase I & cytokinesis | chromosomes arrive at cell poles; each pole has haploid set |

## Biology: Meiosis II

| sister chromatids separate | |
|---|---|
| phase | description |
| prophase II | chromosomes can be seen with a light microscope; each chromosome exists with identical sister joined at centromere |
| metaphase II | mitotic spindle fully formed; chromosome centromeres line up; microtubules of mitotic spindle attach to two sister chromatids |
| anaphase II | sister chromatids separate; chromosomes move toward opposite poles of cell |
| telophase II & cytokinesis | two groups of chromosomes have reached opposite ends of the cell; reverse of prophase; cytokinesis usually occurs with telophase |

(Source: Essential Biology,Campbell, 4th ed., 2013)

## Biology: Meiosis (3)




(Image source: https://en.wikipedia.org/wiki/Meiosis#/media/File:Meiosis_Stages.svg, Ali Zifan, CC BY-SA 4.0) pp 132-33

## Biology: Common Chromosomal Structural Abnormalities

deletions: a portion of the chromosome is missing or deleted
duplications: a portion of the chromosome is duplicated
translocations: a portion of one chromosome is transferred to another chromosome:
reciprocal translocation: segments from two different chromosomes exchanged
Robertsonian translocation: entire chromosome attached to another at centromere; in humans occurs only with chromosomes 13, 14, 15, 21, 22
inversions: portion of a chromosome has broken off, turned upside down, and reattached
insertions: portion of one chromosome has been deleted from its normal place and inserted into another chromosome
rings: chromosome portion has broken off and formed a circle or ring; can happen with or without loss of genetic material
isochromosome: formed by the mirror image copy of a chromosome segment

## Biology: Aneuploidy (1)

aneuploidy: presence of an abnormal number of chromosomes
euploidy: state of a cell or organism having one or more than one set of the same set of chromosomes, possibly excluding the sex-determining chromosomes

| number of chromosomes | name | description |
|---|---|---|
| 1 | monosomy | refers to lack of one chromosome of the normal complement |
| 2 | disomy | presence of two copies of a chromosome; normal condition |
| 3 | trisomy | presence of three copies |
| 4/5 | tetrasomy/ pentasomy | presence of four or five chromosome copies sec chromosome tetrasomy and pentasomy have been reported in humans |

## Biology: Aneuploidy (2)

trisomy 21: Down's syndrome, most common chromosome number abnormality and most common serious birth defect in the U.S.; intellectual disability, heart defects, hearing and vision problems
trisomy 18: Edward's syndrome; babies are often born small and have heart defects; other features include a small head, small jaw, clenched fists with overlapping fingers, and severe intellectual disability
trisomy 13: Patau syndrome; most common characteristics of this syndrome are problems such as late development, mental disability, multiple malformations, cardiopathy, and kidney abnormalities

## Biology: Sex Chromosome Abnormalities (1)

47, XXX: often taller than average; usually no other physical differences; normal fertility; occasionally learning difficulties, decreased muscle tone, seizures, or kidney problems; frequently undiagnosed

48, XXXX: distinctive facial features, epicanthal folds, flat nasal bridges, upslanting palpebral fissures, midface hypoplasia, small mouths, cleft palates, delayed or absent teeth, enamel defects; since 1961 approximately 100 cases reported worldwide

49, XXXXY: numerous skeletal abnormalities; occurs in approximately 1 out of 85,000 to 100,000 males

Klinefelter syndrome XXY: may include weaker muscles, greater height, poor coordination, less body hair, smaller genitals, breast growth; occurs in 1:500 to 1:1000 live male births

## Biology: Sex Chromosome Abnormalities (2)

XX gonadal dysgenesis: a type of female hypogonadism in which no functional ovaries are present to induce puberty in an otherwise normal girl whose karyotype is found to be 46, XX

de la Chapelle syndrome XX male syndrome: rare sex chromosomal disorder usually caused by unequal crossing over between X and Y chromosomes during meiosis in the father, results in X chromosome containing the normally-male SRY gene; when this X combines with a normal X from the mother during fertilization, the result is an XX male; occurs in approximately four or five in 100,000 individuals

47, XYY syndrome: above average height, may have learning disabilities; Around 1 in 1,000 boys are born with a 47,XYY karyotype

## Biology: Sex Chromosome Abnormalities (3)

48, XXYY syndrome: estimated it affects one in every 18,000–40,000 male births; developmental delays in early childhood, learning or intellectual disability, adaptive functioning difficulties, neurodevelopmental disorders such as ADHD or autism spectrum disorders, anxiety, depression, mood dysregulation

Turner syndrome 45, X: often have short, webbed neck, low-set ears, low hairline at the back of the neck, short stature; typically only develop menstrual periods and breasts with hormone treatment; unable to have children without reproductive technology; heart defects, diabetes; normal intelligence

(Source: https://en.wikipedia.org/wiki/Sex_chromosome_disorders)

## Biology: Common Genetic Diseases and Disorders

cystic fibrosis: most common lethal genetic disease in the U.S.

inbreeding: mating between close relatives

achodroplasia: form of dwarfism in wich the head and torso develop normally, but arms and legs are short

Huntington's disease: degeneration of the nervous system that usually does not begin until middle age

hypercholesterolemia: disease marked by dangerously high levels of cholesterol in the blood

sickle-cell disease: red blood cells produce abnormal hemoglobin proteins

red-green colorblindness: caused by malfunction of light-sensitive eye cells

hemophilia: disease marked by excessive bleeding

## Biology: Genetic Inheritance (1)

character: heritable feature that varies among individuals

trait: variant of a character

monohybrid cross: when parents differ in only one character

alleles: alternative versions of genes

homozygous: organism that has two identical alleles for a gene

heterozygous: organism that has two different alleles for a gene

dominant allele: the allele that determines an organism's appearance

recessive allele: the allele that has no noticeable effect on an organism's appearance

Punnett square: pictoral representation of four possible combinations of gametes and resulting offspring

phenotype: physical appearance

genotype: genetic makeup

## Biology: Genetic Inheritance (2)

locus: specific location of a gene along the chromosome

dihybrid cross: mating of parental varieties differing in two characters

wild-type trait: those seen most often in nature

pedigree: family tree that includes genetic information

carriers: those with a recessive allele for a disorder who are not affected by that disorder

incomplete dominance: hybrids that fall between the phenotypes of parents

codominance: both alleles are expressed in heterozygous individuals

## Biology: Genetic Inheritance (3)

pleiotropy: when one gene influences several characters

polygenic inheritance: additive effects of two or more genes on a single phenotype character

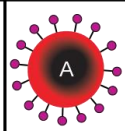
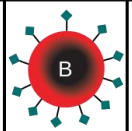
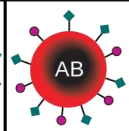
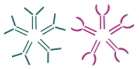
chromosomal theory of inheritance: genes are located at specific loci on chromosomes and the behavior of chromosomes during meiosis and fertilization accounts for inheritance patterns

linked genes: tend to be inherited as a set

linkage map: diagram of relative gene locations

sex-linked gene: gene located on a sex chromosome

## Biology: Blood Types

| | Group A | Group B | Group AB | Group O |
|---|---|---|---|---|
| Red blood cell type |   |   |   |   |
| Antibodies in Plasma |  Anti-B |  Anti-A | None |  Anti-A and Anti-B |
| Antigens in Red Blood Cell |  A antigen |  B antigen |  A and B antigens | None |

(Image source: https://en.wikipedia.org/wiki/Blood_type#/media/File:ABO_blood_type.svg, InvictaHOG, public domain)

## Biology: DNA Structure and Replication (1)

molecular biology: study of heredity at the molecular level
nucleotide: long chain of chemical units
polynucleotide: nucleotide polymer
sugar-phosphate backbone: repeating pattern of sugar-phosphate-sugra-phosphate
DNA: deoxyribonucleic acid; nuclei refers to location in the nuclei of eukaryotic cells
thymine: single ring structure
cytosine: single ring structure
adenine: larger, double-ring structure
guanine: larger, double-ring structure
DNA polymerases: enzymes that make covalent bonds between the nucleotides of a new DNA strand

## Biology: DNA Structure and Replication (2)

transcription: transfer of genetic information from DNA to RNA
translation: transfer of information from RNA to a protein
genetic code: set of rules that convert a nucleotide sequence in RNA to an amino acid
RNA polymerase: enzyme that links RNA nucleotides
mutagen: physical and chemical agents of mutation

## Biology: DNA Replication Proteins (1)

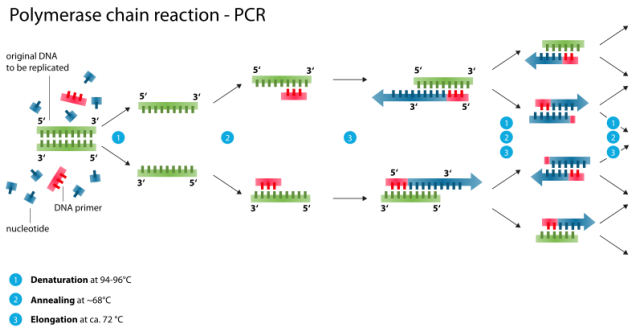
| enzyme | function in DNA replication |
|---|---|
| DNA helicase | separates the two strands of DNA at the replication fork behind the topoisomerase |
| DNA polymerase | catalyzes addition of nucleotide substrates to DNA in the 5' to 3' direction during DNA replication; performs proof-reading and error correction |
| DNA clamp | protein which prevents elongating DNA polymerases from dissociating from the DNA parent strand |
| single-strand binding (SSB) proteins | bind to ssDNA; prevent DNA double helix from re-annealing after DNA helicase unwinds; maintains strand separation; facilitates synthesis of nascent strand |
| topo-isomerase | relaxes the DNA from its super-coiled nature |

## Biology: DNA Replication Proteins (2)

| enzyme | function in DNA replication |
|---|---|
| DNA gyrase | Relieves strain of unwinding by DNA helicase; this is a specific type of topoisomerase |
| DNA ligase | Re-anneals the semi-conservative strands and joins Okazaki Fragments of the lagging strand |
| primase | provides starting point of RNA (or DNA) for DNA polymerase to begin synthesis of the new DNA strand |
| telomerase | lengthens telomeric DNA by adding repetitive nucleotide sequences to the ends of eukaryotic chromosomes; allows germ cells and stem cells to avoid Hayflick limit on cell division |

(Source: https://en.wikipedia.org/wiki/DNA_replication)

## Biology: Polymerase Chain Reaction




(Image source: https://en.wikipedia.org/wiki/Polymerase_chain_reaction#/media/File:Polymerase_chain_reaction.svg, Enzoklop, CC BY-SA 3.0)

## Biology: Hormonal Effects on DNA Replication

## Biology: Transcription from DNA to RNA

1. initiation of transcription: attachment of RNA polymerase to the promoter; start of RNA synthesis; promoter dictates which DNA strand is transcribed
2. RNA elongation: RNA elongates, RNA strand peels away from its DNA template, two separated DNA strands come back together
3. transcription termination: RNA polymerase reaches the DNA terminator; polymerase molecule detaches from the RNA molecule and the gene; DNA strands rejoin

(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Translation

1. an mRNA molecule binds to a small ribosomal subunit; special initiator tRNA binds to the start dodon, where translation begins on mRNA; initiator tRNA carries the amino acid methionine ; its anticodon UAC binds to the start codon AUG
2. a large ribosomal subunit binds to the small one, creating a functional ribosome; tRNA fits into the P site on the ribosome

(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Elongation

1. codon recognition: anticodon of an incoming tRNA molecule pairs with the mRNA codon in the A site of the ribosome
2. peptide bond formation: the polypeptide leaves the tRNA in the P site, attaching to the amino acid on the tRNA in the A site
3. translocation: the P site of the tRNA leaves the ribosome, which moves the remaining tRNA carrying the growing peptide to the P site; the mRNA and tRNA move as a unit
4. termination: elongation continues until a stop codon reaches the ribosome's A site; stop codons UAA, UAG, and UGA, tell translation to stop

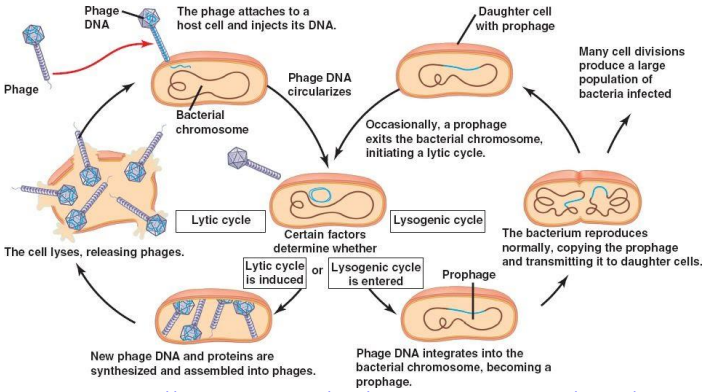
(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Viruses and Infectious Agents

bacteriophage: viruses that attack bacteria
plant virus: infect plant celss, stunt growth; use RNA instead of DNA
animal virus: most have an outer envelope made of phospholipid membrane, with projecting spikes of protein

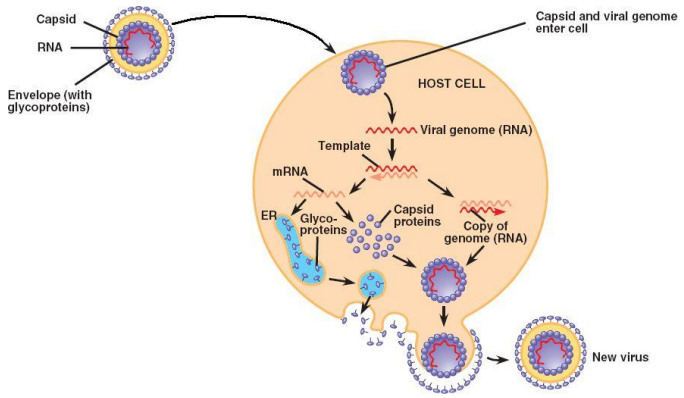
(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Lytic and Lysogenic Cycles




(Image source: https://sites.google.com/site/cundiffbiologyportfolio/home/science-as-a-process/viral-life-cycles, Cundiff Biology Portfolio)

## Biology: Virus Reproductive Cycle




(Image source: http://bio1151.nicerweb.com/Locked/media/ch19/RNA-virus.html)

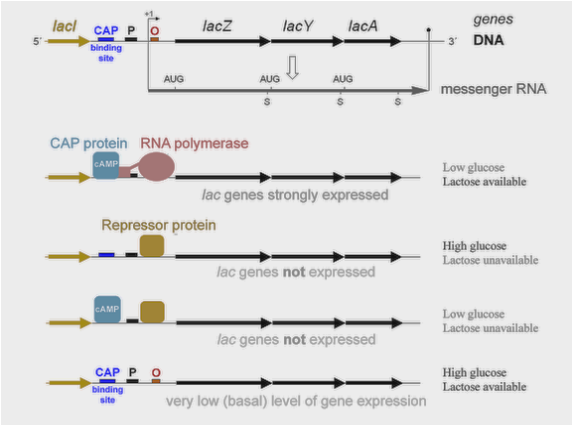
## Biology: Gene Regulation

cellular differentiation: cells become specialized in structure and function
gene regulation: turning on and off of genes
gene expression: the overall process by which genetic information flows from genes to proteins
operon: cluster of genes with related functions, along with DNA control sequences
promoter: site where the enzyme RNA polymerase attaches and initiates transcription
operator: acts as a switch, turning on and off, depending on where a specific protein is bound
X-chromosome inactivation: when one of two X chromosomes in each cell is inactivatedat random

## Biology: Gene Regulation

transcription factors: proteins that bind to DNA sequences called enhancers
silencers: inhibit the start of transcription
activators: proteins that turn on genes by binding to DNA
alternative RNA splicing: allows an organism to produce more than one polypeptide from a single gene
DNA microarray: glass slide with thousands of different kinds of single-stranded DNA fragments

## Biology: Lac Operon and Its Control Elements




(Image source: https://upload.wikimedia.org/wikipedia/commons/thumb/d/d2/Lac_operon-2010-21-01.png/576px-Lac_operon-2010-21-01.png, Tereseik, CC BY 2.0)

## Biology: Cell Signaling (1)

- intracrine signals: produced by the target cell that stay within the target cell
- autocrine signals: produced by target cell, secreted, and affect target cell itself via receptors; sometimes autocrine cells can target cells close by if they are the same type of cell as the emitting cell; example: immune cells
- juxtacrine signals: target adjacent cells; signals transmitted along cell membranes via protein or lipid components integral to the membrane; and capable of affecting either the emitting cell or cells immediately adjacent
- paracrine signals: target cells in the vicinity of the emitting cell; example:neurotransmitters
- endocrine signals: target distant cells; endocrine cells produce hormones that travel through the blood to reach all parts of the body

(Source: https://en.wikipedia.org/wiki/Cell_signaling)

## Biology: Cancer Cells

cancer: disease of the cell cyclemarked by excessive division
tumor: abnormal growing mass of body cells
benign tumor: abnormal cells which remain at the original site
malignant tumor: tumor that has spread into neighboring tissues and other body parts
radiation therapy: body parts are exposed to high energy to kill caner cells
chemotherapy: druges are used to interrupt cell division
oncogene: gene that causes cancer
proto-oncogene: a normal gene with the potential to become and oncogene
growth factors: proteins that stimulate cell division

## Biology: Six Hallmarks of Cancer

- cell growth and division absent the proper signals
- continuous growth and division even given contrary signals
- avoidance of programmed cell death
- limitless number of cell divisions
- promoting blood vessel construction
- invasion of tissue and formation of metastases

(Source: https://en.wikipedia.org/wiki/Cancer)

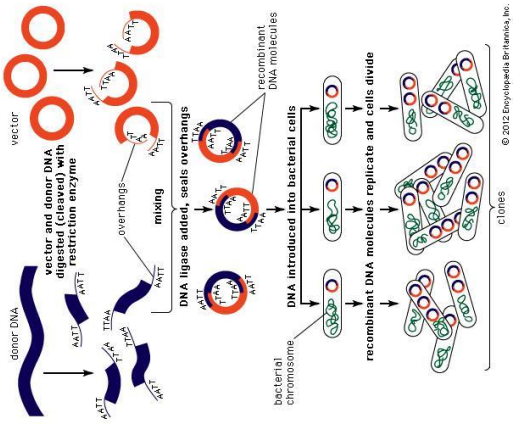
## Biology: Recombitant DNA Technology (1)

DNA technology: modern lab techniques for studying and manipulating genetic material
recombitant DNA: constructed when scientists combine pieces of DNA from two different sources, often from different species to form a single DNA molecule
genetic engineering: direct manipulation of genes for practical purposes
vaccine: harmless variant or derivative of a disease-causing microbe
genetically modified organisms: organisms that have acquired one or more genes by artificial means
transgenic organism: if a newly acquired gene is from another organism, typically of another species

## Biology: Recombitant DNA Technology (2)

plasmid: small, circular DNA molecule that replicates separately from larger, bacterial chromosomes
gene cloning: production of multiple, identical copies of a gene-carrying piece of DNA
genomic library: collection of cloned DNA fragments that include an organism's entire genome

## Biology: Recombitant DNA Technology (3)




(Image source: https://www.britannica.com/science/recombinant-DNA-technology, Anthony J.F. Griffiths, Encyclopedia Britannica, 2009)

## Biology: DNA Profiling (1)

restriction fragment length polymorphism (RFLP): technique exploits variations in homologous DNA sequences; refers to difference between samples of homologous DNA molecules from differing locations of restriction enzyme sites, and related laboratory technique by which these segments can be illustrated; DNA sample is broken into pieces and digested by restriction enzymes; resulting restriction fragments separated according to lengths by gel electrophoresis; now largely obsolete
polymerase chain reaction (PCR): technique used to amplify single copy or a few copies of a piece of DNA across several orders of magnitude; generates thousands to millions of copies of particular DNA sequence; easy and cheap tool to amplify a focused segment of DNA, useful for such purposes as the diagnosis and monitoring of genetic diseases, identification of criminals and studying the function of a targeted segment of DNA

## Biology: DNA Profiling (2)

Y-chromosome analysis: allows resolution of mixed DNA sample from a male and female or cases in which a differential extraction is not possible; helps in identification of paternally related males; yields weaker results than autosomal chromosome analysis; leads to a less precise analysis than if autosomal chromosomes were tested, because of the random matching that occurs between pairs of chromosomes as zygotes are being made
mitochondrial analysis: sometimes typed due to there being many copies of mtDNA in a cell, while there may only be 1-2 copies of nuclear DNA; forensic scientists amplify HV1 and HV2 regions of the mtDNA, then sequence each region and compare single-nucleotide differences to a reference; mtDNA is maternally inherited, directly linked maternal relatives can be used as match references, such as one's maternal grandmother's daughter's son

(Source: https://en.wikipedia.org/wiki/DNA_profiling)

## Biology: Human Genome Project

This project was publicly funded and initiated in 1990 with the objective of determining the DNA sequence of the entire euchromatic human genome within 15 years. The $3-billion project was formally founded by the U.S. Department of Energy and the National Institutes of Health. The international consortium comprised geneticists in the U.S., United Kingdom, France, Australia, China and others. The project was not able to sequence all DNA found in human cells, sequencing only “euchromatic"regions of the genome, which make up more than 95% of the genome. The other regions, called "heterochromatic,"are found in centromeres and telomeres, and were not sequenced. The project was declared complete in April 2003. Although this was reported to cover 99% of the euchromatic human genome with 99.99% accuracy, a major quality assessment of the human genome sequence was published on May 27, 2004 indicating over 92% of sampling exceeded 99.99% accuracy which was within the intended goal.
(Source: https://en.wikipedia.org/wiki/Human_Genome_Project)

## Biology: Human Gene Therapy

1. a gene from a normal individual is cloned , converted to an RNA version, and inserted into the RNA genome of a harmless virus
2. bone marrow cells are taken from the patient and infected with the recombitant virus
3. the virus inserts a DNA copy of it genome, including the normal human gene, into the DNA of the patient’s cells
4. the engineered cells are then injected back into the patient
5. the normal gene is transcribed and translated within the patient’s body, producing the desired protein

## Biology: Membrane Function (1)

transport proteins: membrane proteins that help move substances across cell membranes
diffusion: movement of molecules to fill available space
osmosis: selective passage of solvent molecules through a porous membrane from a dliute solution to a more concentrated one
semipermeable membrane: allows the passage of solvent molecules but blocks the passage of solute molecules
hypertonic: solution with a higher concentration of solute
hypotonic: solution with a lower concentration of solute
isotonic: solutions with equal concentration of solute
osmoregulation: control of water balance

## Biology: Membrane Fuction (2)

osmotic pressure: pressure required to stop osmosis $\pi = MRT$
$M$ = molarity $R$ = gas constant $T$ = absolute temperature
exocytosis: secretory proteins exit cells from transport vesicles that fuse with the plasma membrane, spilling contents outside the cell
endocytosis: a cell takes material in via vesicles that bud inward
phagocytosis: a cell engulfs a particle and packages it within a food vacuole

(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Carbohydrates

carbohydrates: molecules that include sugars and sugar polymers; primary source of dietary energy and raw materials for manufacturing other kinds of organic compounds; in plants serve as building material for much of the plant body; hydrophilic
monosaccharides: monomers of carbohdrates; cannot be broken down into smaller sugars; include glucose and fructose; main fuel molecules for cellular work
disaccharides: double sugar; constructed from two monosaccharides by a dehydration reaction; common include sucrose, lactose, maltose
polysaccharides: complex carbohydrates; long chains of sugars; include starch, glycogen, cellulose

(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Lipids

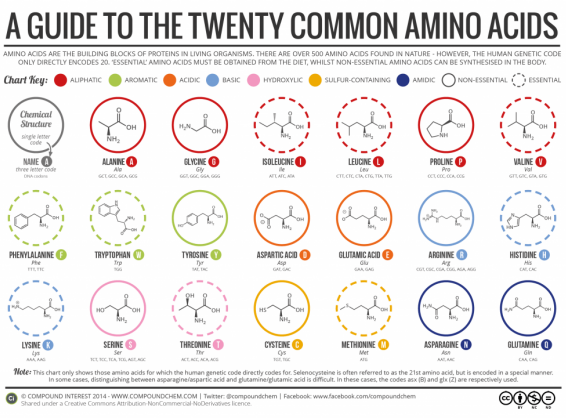
lipids: hydrophobic; neither macromolecules nor polymers
triglycerides: consist of a glycerol molecule joined with three fatty acid molcules via dehydrationreactions
unsaturated fats: have fewer than the maximum number of hdrogens at the double bond
saturated fats: contain the maximum number of hydrogen atoms, making them straight
hydrogenation: process that converts unsaturated fats to saturated fats
steroids: hydrophobic; have a carbon skeleton with four fused rings, include cholesterol, anabolic steroids

(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Proteins (1)

proteins: polymers of amino acid monomers; most elaborate and diverse of life’s molecules; account for more than 50% of cell dry weight
amino acids: consist of central carbon atom bonded to four covalent partners; three of those common to all 20 amino acids; include caboxyl group –COOH, amino acid group –$NH_2$, and hydrogen atom; variable is radical, R, group
peptide bonds: bonds between adjacent amino acids
polypeptides: long chains of amino acids
primary structures: specific amino acid sequences
secondary structures: stretches of polypeptides with local patterns
tertiary structures: overall three-dimensional shapes of polypeptides
quarternary structures: proteins with two or more polypeptide chains have these, result from bonds between the chains
denaturation: unravelling and loosening of a protein due to unfavorable changes in temperature, pH, or other environmental factor
(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Proteins (2)




(Image source: http://www.compoundchem.com/2014/09/16/aminoacids/, www.compoundchem.com, Creative Commons Attribution Noncommercial Nonderivatve License)

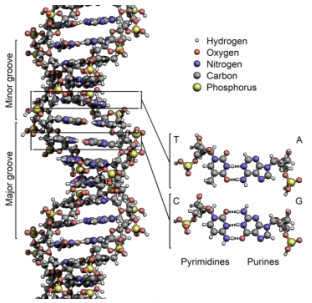
## Biology: Nucleic Acids (1)

nucleic acids: high molar mass polymers that play an essential role in protein synthesis

deoxyribonucleic acid (DNA): among the largest molecules known, can have molar masses of up to tens of billions of grams; has two strands

nucleotides: consist of a base, a deoxyribose, and a phosphate group linked together

ribonucleic acid (RNA): molecules vary greatly in size, some having a molar mass of about 25,000 grams




(Image source: https://en.wikipedia.org/wiki/DNA#/media/File:DNA_Structure%2BKey%2BLabelled.pn_NoBB.png, Zephyris, CC BY-SA 3.0)

## Biology: Nucleic Acids (2)

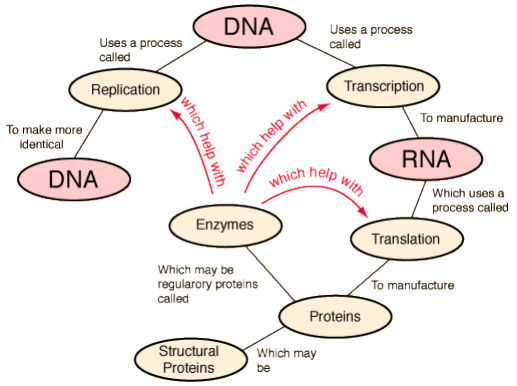
genes: regions of DNA made up of nucleotides; molecular units of heredity; programs amino acid sequences of polypeptides

nucleotides: monomers that form polymer nucleic acids

sugar-phosphate backbone: repeating pattern of sugar-phosphate-sugar-phosphate with bases A, T, C, or G, hanging off the backbone like appendages

double helix: two polynucleotide strands wrapped around each other

## Biology: DNA Protein Production




(Image source: http://hyperphysics.phy-astr.gsu.edu/hbase/Organic/dna.html, R. Nave, used with permission)

## Biology: Chargaff's Rules

Chargaff's rules:

1. the amount of adenine (a purine) is equal to that of thymine (a pyrimidine), A = T
2. the amount of cytosine (a pyrimidine) is equal to that of guanine (a purine), C = G
3. the total number of purine bases is equal to the total number of pyrimidine bases, A + G = C + T

(Source: https://en.wikipedia.org/wiki/Chargaff%27s_rules)

## Biology: Classification of Marine Organisms (1)

| kingdom | phylum | class | organism |
|---|---|---|---|
| monera | cyanophytra | | blue-green algae |
| | schizophyta | | bacteria |
| protista | chrysophyta | | diatoms, coccolithophores |
| | protozoa | | foraminifera, radiolaria, flagellates |
| | pyrrophyta | | dinoflagellates, zooxanthellae |
| | ciliophora | | cilates |
| fungi | mycophyta | | fungi, lichens |
| plantae | rhodophyta | | red algae |
| | phaeophyta | | brown algae |
| | chlorophyta | | green algae |
| | tracheophyta | | salt-marsh grasses, eel grasses, mangroves |

(Source: Oceanography, Paul R. Pinet, 1992)

## Biology: Classification of Marine Organisms (2)

| kingdom | phylum | class | organism |
|---|---|---|---|
| animalia | ctenophora | | comb jellies |
| | cnidaria | hydrazoa | hydras |
| | | schyphozoa | jellyfishes |
| | | anthozoa | corals, sea anemones |
| | porifera | | sponges |
| | bryzoa | | moss animals |
| | platyhelminthes | | flatworms |
| | chaetognatha | | arrow worms |
| | annelida | | polychaete worms |
| | brachyiopoda | | lamp shells |

## Biology: Classification of Marine Organisms (3)

| kingdom | phylum | class | organisms |
|---|---|---|---|
| animalia | mollusca | amphineura | chitons |
| | | gastropoda | snails, limpets |
| | | bivalvia | clams, oysters, mussels, scallops |
| | | scaphopoda | |
| | | cephalopoda | |
| | arthropoda | merostomata | horseshoe crabs |
| | | arachnida | marine mites |
| | | pycnogonida | sea spiders |
| | | crustacea | copepods, barnacles, krill, shrimp, crabs, lobsters, isopods, amphipods |

## Biology: Classification of Marine Organisms (4)

| kingdom | phylum | class | organisms |
|---|---|---|---|
| animalia | echinodermata | asteroidea | starfish |
| | | echinoidea | sea urchins, sand dollars |
| | | holothuroidea | sea cucumbers |
| | | ophiuroidea | brittle stars |
| | | crinoidea | sea lillies |
| | protochordata | | pterobranches, acorn worms |
| | chordata | urochordata | tunicates, salps |
| | | cephalochordata | lancelets |
| | | pisces | cartilaginous, bony, jawless fish |
| | | reptilia | sea turtles, sea snakes |
| | | aves | sea birds |
| | | mammalia | seals, sea otters, manatees, whales, porpoises, dolphins, walruses |

## Biology: Light Penetration in the Ocean

| color | depth in m |
|---|---|
| ultraviolet | 50 |
| red | 100 |
| yellow | 200 |
| green | 300 |
| blue | 450 |

## Biology: Chemical Abundance in Humans

| Symbol | Element | Percent |
|---|---|---|
| O | oxygen | 65 |
| C | carbon | 18 |
| H | hydrogen | 10 |
| N | nitrogen | 3 |
| Ca | calcium | 1.5 |
| P | phosphorus | 1 |
| K | potassium | 0.35 |
| S | sulfur | 0.25 |
| Na | sodium | 0.15 |
| Mg | magnesium | 0.05 |

## Biology: Body Systems (1)

- circulatory: pumping and channeling blood to and from the body and lungs with heart, blood and blood vessels
- integumentary: skin, hair, fat, and nails
- skeletal: structural support and protection with bones, cartilage, ligaments and tendons
- reproductive: sex organs, such as ovaries, fallopian tubes, uterus, vagina, mammary glands, testes, vas deferens, seminal vesicles and prostate
- digestive: digestion and processing food with salivary glands, oesophagus, stomach, liver, gallbladder, pancreas, intestines, rectum and anus
- urinary: kidneys, ureters, bladder and urethra involved in fluid balance, electrolyte balance and excretion of urine
- respiratory: organs used for breathing, the pharynx, larynx, bronchi, lungs and diaphragm

## Biology: Body Systems (2)

- endocrine: communication within the body using hormones made by endocrine glands such as the hypothalamus, pituitary gland, pineal gland, thyroid, parathyroid and adrenal glands
- immune: protects the organism from foreign bodies
  - lymphatic: structures involved in the transfer of lymph between tissues and the blood stream; includes the lymph and the nodes and vessels; the lymphatic system includes functions including immune responses and development of antibodies
- muscular: allows for manipulation of the environment, provides locomotion, maintains posture, and produces heat. Include skeletal muscles, smooth muscles and cardiac muscle
- nervous: collecting, transferring and processing information with brain, spinal cord and peripheral nervous system.

(Source: https://en.wikipedia.org/wiki/Biological_system)

## Biology: Organism Relationships

ecology: branch of biology that deals with the relations of organisms to one another and to their physical surroundings
parasite: organism with sustained contact with another organism to host's detriment
host: an organism that harbors a parasitic, a mutual, or a commensal symbiont, typically providing nourishment and shelter
niche: describes how an organism or population responds to the distribution of resources and competitors
predator: an organism that is hunting and feeds on prey
prey: the organism that is attacked
consumer: heterotrophic organism feeding on other organisms in food chain
producer: autotrophic organism that serves as a source of food for other organisms in a food chain
decomposer: an organism, especially a soil bacterium, fungus, or invertebrate, that decomposes organic material

## Biology: Climate Change

climate change: change in statistical distribution of weather patterns over an extended period of time ; may refer to a change in average weather conditions, or in the time variation of weather around longer-term average conditions; caused by factors such as biotic processes, variations in solar radiation, plate tectonics, and volcanic eruption
climate system: includes atmosphere, cryosphere, hydrosphere, and lithosphere
climate change causes: ocean-atmosphere variability, life, orbital variation, solar output, volcanism, plate tectonics, human influences
global warming: increase in Earth's average temperature
anthropogenic global warming: increase in Earth's average temperature related to human activities
carbon footprint: amount of carbon dioxide and other carbon compounds emitted due to consumption of fossil fuels by particular person, group, etc.

(Source: https://en.wikipedia.org/wiki/Climate_change)

## Biology: Levels of Organization (1)

- biosphere: all life on Earth or all life plus the physical environment
- terrestrial biome: continental scale, climatically and geographically contiguous areas with similar climatic conditions, grouping of ecosystems
- ecosystem: groups of organisms from all biological domains in conjunction with the physical environment
- habitat: specific environment in which a species lives
- community: interspecific groups of interacting populations
- population: groups of interacting individuals of a species
- organism: individual living thing that may be made up of one or more organ systems

(Source: https://en.wikipedia.org/wiki/Biological_organisation)

## Biology: Levels of Organization (2)

- organ system: group of organs that work together to perform a certain function, examples of organ systems in a human include the skeletal, nervous, and reproductive systems
- organ: structure composed of one or more types of tissues, the tissues of an organ work together to perfume a specific function, human organs include the brain, stomach, kidney, and liver, plant organs include roots, stems, and leaves
- tissues: each organ consists of several different tissues
- cell: smallest unit that can display all the characteristics of life
- organelle: fuctional component of a cell
- molecule: combination of one or more atoms
- atom: basic unit of a chemical element

## Biology: Population Ecology

population ecology: concerned with changes in population size and factors that regulate populations over time
population density: number of individuals of a species per unit area or volume
age structure: distribution of individuals of different age groups
life tables: track survivorship to a particular age
survivorship curve: plot of number of individuals still alive at each age in the maximum life span
life history: set of traits that affect and organism's schedule of reproduction and survival
opportunistic life history: life history that enables a plant or animal to take immediate advantage of favorable conditions
equilibrial life history: pattern of developing and reaching sexual maturity slowly and producing few, well-cared-for offspring

(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Population Growth Models

exponential population growth: expansion of a population in an ideal, unlimited environment
limiting factors: environmental factors that restrict population growth
logistic population growth: growth rate decreases as population size approaches carrying capacity
density-dependent factors: limiting factors whose intensity is related to population density
intraspecific competition: competition between individuals of the same species for limited resources
density independent factors: limiting factors whose intensity is unrelated to population density

(Source: Essential Biology, Campbell, 4th ed., 2013)

## Biology: Applications of Population Ecology

endangered species: one that is in danger of extinction throughout all of a significant portion of its range
threatened species: those that are likely to become endangered in the foreseeable future
invasive species: non-native species that has spread far beyond original point of introduction, causing environmental and/or economic damage
biological control: intentional release of a natural enemy to attack a pest population

## Biology: Human Population Growth

population momentum: population expansion resulting from increased proportion of women of childbearing age
ecological footprint: impact of a person or community on the environment, expressed as the amount of land required to sustain their use of natural resources

logistic equation $\frac{dP(t)}{dt} = kP(t)\left(1-\frac{P(t)}{K}\right)$ → $P(t) = \frac{K}{1+\left(\frac{K-P_0}{P_0}\right)e^{-kt}}$

$P_0$ = population at time 0 $P(t)$ = population after time $t$
$t$ = time a population grows
$k$ = relative growth rate coefficient $K$ = population carrying capacity

## Biology: Whittaker Biome Classification System (1)

1. Tropical rainforest
2. Tropical seasonal rainforest
   deciduous
   semideciduous
3. Temperate giant rainforest
4. Montane rainforest
5. Temperate deciduous forest
6. Temperate evergreen forest
   needleleaf
   sclerophyll
7. Subarctic-subalpin needle-leaved forests (taiga)
8. Elfin woodland
9. Thorn forests and woodlands

## Biology: Whittaker Biome Classification System (2)

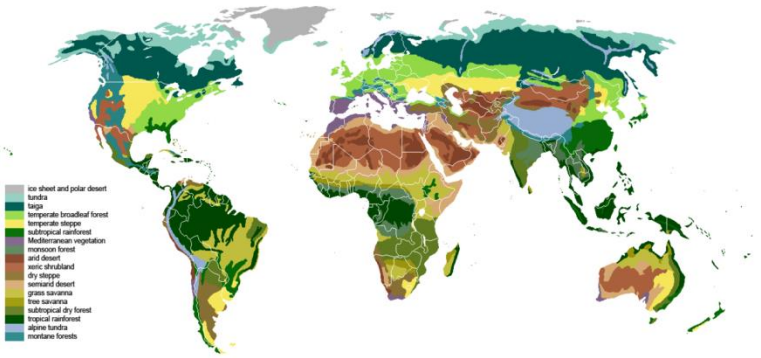
10. Thorn scrub
11. Temperate woodland
12. Temperate shrublands
    deciduous
    heath
    sclerophyll
    subalpine-needleleaf
    subalpine-broadleaf
13. Savanna
14. Temperate grassland
15. Alpine grassland
16. Tundra
17. Tropical desert

## Biology: Whittaker Biome Classification System (3)

18. Warm-temperate desert
19. Cool temperate desert scrub
20. Arctic-alpine desert
21. Bog
22. Tropical fresh-water swamp forest
23. Temperate fresh-water swamp forest
24. Mangrove swamp
25. Salt marsh
26. Wetland

(Source: https://en.wikipedia.org/wiki/Biome#Whittaker_.281962.2C_1970.2C_1975.29_biome-types)

## Biology: Terrestrial Biomes




(Image source: https://en.wikipedia.org/wiki/Biome#/media/File:Vegetation.png, Ville Koistinen, CC BY-SA 3.0)

## Biology: Walter Aquatic Ecosystems (1)

A. Inland Aquatic Ecosystems
   - River and Stream Ecosystems
   - Lakes and Reservoirs

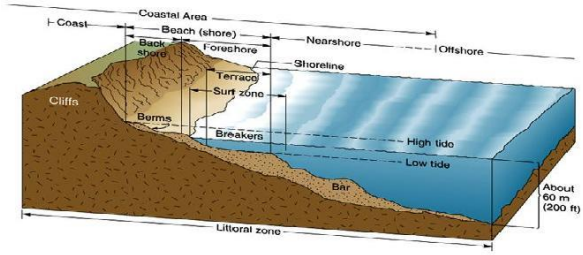
B. Marine Ecosystems
   - Intertidal and Littoral Ecosystems
   - Coral Reefs
   - Estuaries and Enclosed Seas
   - Ecosystems of the Continental Shelves
   - Ecosystems of the Deep Ocean

C. Managed Aquatic Ecosystems
   - Managed Aquatic Ecosystems

(Source: https://en.wikipedia.org/wiki/Biome#Whittaker_.281962.2C_1970.2C_1975.29_biome-types)

## Biology: Marine Habitats (1)

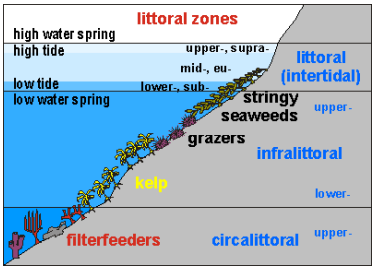
littoral zone: part of a sea, lake or river that is close to the shore; extends from the high water mark to shoreline areas that are permanently submerged; always includes the intertidal zone and is often used to mean the same as the intertidal zone, but can extend. beyond the intertidal zone




(Image source: https://en.wikipedia.org/wiki/Littoral_zone#/media/File:Littoral_Zones.jpg, public domain)

## Biology: Marine Habitats (2)

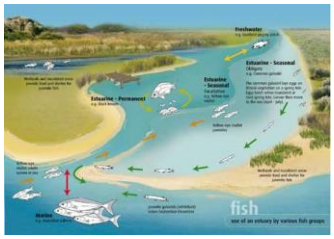
intertidal zone: also known as the seashore; sometimes referred to as the littoral zone,; area that is above water at low tide and under water at high tide;. can many habitats, with starfish, sea urchins, and coral; includes steep rocky cliffs, sandy beaches, wetlands, mudflats




(Image source: https://sites.google.com/site/islandecology2011/intertidal-zone, Island Ecology 2011)

## Biology: Marine Habitats (3)

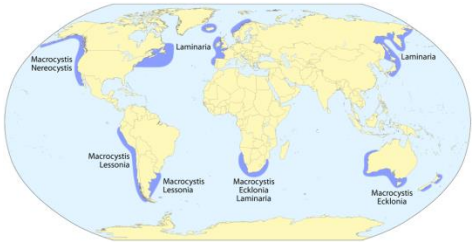
estuaries: partially enclosed coastal body of brackish water with one or more rivers or streams flowing into it, and a free connection to the open sea; form a transition zone between river environments and maritime environments;. subject to marine influences, such as tides, waves, and influx of saline water, and riverine influences, such as fresh water flows and sediment; among the most productive natural habitats in the world




(Image source: http://www.estuarywatch.org.au/cb_pages/victorias_estuaries.php, Victoria State Government)

## Biology: Marine Habitats (4)

kelp forests: underwater areas with a high density of kelp; recognized as one of the most productive and dynamic ecosystems on Earth; smaller areas of anchored kelp are called kelp beds; physically formed by brown macroalgae, the order Laminariales, kelp forests provide a unique, three-dimensional habitat for marine organisms and are a source for understanding many ecological processes



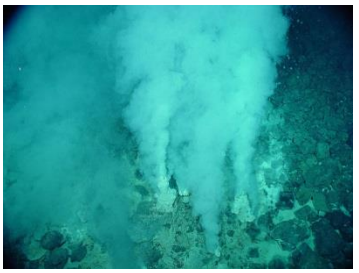

(Image source: https://en.wikipedia.org/wiki/Kelp_forest#/media/File:Kelp_forest_distribution_map.png, Maximilian Dörrbecker, CC BY-SA 2.0)

## Biology: Marine Habitats (5)

coral reefs: diverse underwater ecosystems held together by calcium carbonate structures secreted by corals; built by colonies of tiny animals found in marine waters that contain few nutrients; built from stony corals, which in consist of polyps that cluster in groups; polyps belong to a group of animals known as Cnidaria, which includes sea anemones and jellyfish; .corals secrete hard carbonate exoskeletons which support and protect the coral polyps; most reefs grow best in warm, shallow, clear, sunny and agitated waters
(Image source: https://en.wikipedia.org/wiki/Coral_reef#/media/File:Blue_Linckia_Starfish.JPG, Richard Ling, CC BY-SA 3.0)

## Biology: Marine Habitats (6)

hydrothermal vents: fissures in a planet's surface from which geothermally heated water spews; commonly found near volcanically active locations, areas where tectonic plates are moving apart, ocean basins, and hotspots; common land types include hot springs, fumaroles and geysers; may form features called black smokers; areas around submarine hydrothermal vents are biologically productive, hosting complex communities fueled by the chemicals dissolved in the vent fluids



(Image source: https://en.wikipedia.org/wiki/Hydrothermal_vent#/media/File:Champagne_vent_white_smokers.jpg, NOAA, public domain)

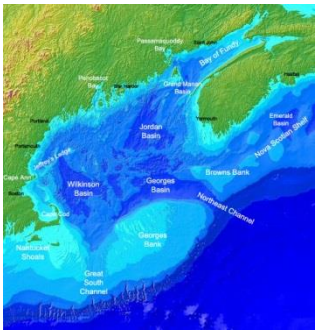
## Biology: Marine Habitats (7)

cold seeps: areas of the ocean floor where hydrogen sulfide, methane and other hydrocarbon-rich fluid seepage occurs, often in the form of a brine pool; the temperature of the seepage is often slightly higher than the surrounding ocean; constitute a biome supporting several endemic species; develop unique topography over time, where reactions between methane and seawater create carbonate rock formations and reefs

(Image source: https://en.wikipedia.org/wiki/Cold_seep#/media/File:Lamellibrachia_luymesi1.png, Charles Fisher, CC BY 2.5)

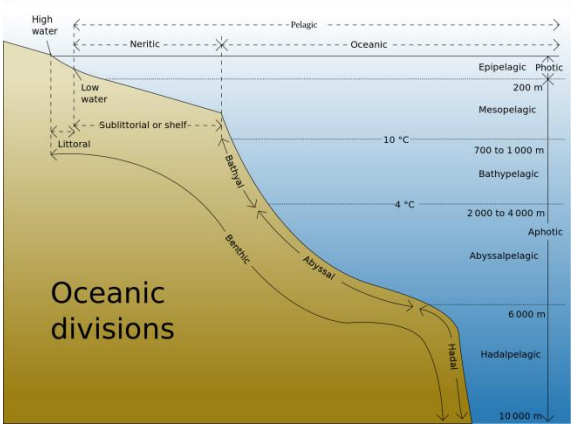
## Biology: Marine Habitats (8)

ocean banks: part of the sea which is shallow compared to its surrounding area, such as a shoal or the top of an underwater hill; similar to .continental slopes, ocean banks slopes can upwell as tidal and other flows intercept them, resulting sometimes in nutrient rich currents; rich fishing sites




(Image source: https://en.wikipedia.org/wiki/Ocean_bank#/media/File:GulfofMaine.jpg, NOAA, public domain)
(Source: https://en.wikipedia.org/wiki/Marine_habitats)

## Biology: Ocean Zones (1)




(Image source: https://en.wikipedia.org/wiki/Oceanic_zone#/media/File:Oceanic_divisions.svg, K. Aainsqatsi , public domain)

## Biology: Ocean Zones (2)

neritic zone: water above the continental shelf; relatively shallow part of the ocean above the drop-off of the continental shelf, approximately 200 meters deep; forms a relatively stable and well-illuminated environment for marine life, from plankton up to large fish and corals; where the oceanic system interacts with the coast; permanently covered with generally well-oxygenated water; receives a lot of sunlight and has low water pressure; relatively stable temperature, pressure, light and salinity levels; suitable for photosynthetic life
demersal zone: part of the ocean or deep lake comprising the water column near to and affected by the seabed and benthos; just above the benthic zone, it forms a layer of the larger profundal zone; is variable in depth and can be part of the photic zone where light can penetrate and photosynthetic organisms grow, or the aphotic zone, which begins between depths of roughly 200 and 1,000 m and extends to the ocean depths, where no light penetrates
(Source: https://en.wikipedia.org/wiki/Oceanic_zone)

## Biology: Pelagic Zone (1)

pelagic zone: any water in a sea or lake that is neither close to the bottom nor near the shore; can be thought of as an imaginary cylinder or water column extending from the sea surface almost to the bottom; pressure increases with depth, temperature drops and less light penetrates; depending on the depth, water column, may be divided into different layer


(Image source: https://commons.wikimedia.org/wiki/File:Pelagiczone.svg, omCatX, public domain)

## Biology: Pelagic Zone (2)

| layer | depth (m) | volume (%) | description |
|---|---|---|---|
| epipelagic | 0-200 | 3 | sunlit zone, supports photosynthesis; temperatures range from 40 to −3°C |
| mesopelagic | 200-1,000 | 28 | small amounts of light penetrate; referred to as Twilight Zone; temperatures from 5 to 4°C; pressure up to 10,100,000 Pa and increases with depth |
| bathypelagic | 1,000-2,000 | 15 | no light penetrates; also called the midnight zone; high water pressures and the temperatures near freezing, range 0 to 6°C |
| abyssopelagic | 2,000-6,000 | 54 | remains in perpetual darkness |
| hadalpelagic | >6,000 | <1 | deepest trenches in the ocean |

(Source: Oceanography, Paul R. Pinet, 1992, p. 291)

## Biology: Benthic Zone (1)

benthic zone: ecological region at the lowest level of a body of water such as an ocean or a lake, including the sediment surface and some sub-surface layers; organisms living in this zone are called benthos, and include crustaceans and polychaetes; organisms generally live in close relationship with the substrate bottom and many are permanently attached to the bottom; the superficial layer of the soil lining the given body of water, the benthic boundary layer, is an integral part of the benthic zone greatly influences biological activity; contact soil layers include sand bottoms, rocky outcrops, coral, and bay mud.

## Biology: Benthic Zone (2)

| layer | depth (m) | area (%) | description |
|---|---|---|---|
| littoral | intertidal | | close to the shore; extends from high water mark, which is rarely inundated, to shoreline areas permanently submerged |
| sublittoral | 0-200 | 8 | red and brown algae characteristic; typical animals include sea anemones and corals on rocky shores, shrimps, crabs, and flounders on sandy shores; also called subtidal zone |
| bathyl | 200-2,000 | 16 | seaward of shallower neritic zone, landward of deeper abyssal zone; upper limit marked by the edge of continental shelf; may include trenches and submarine canyons |
| abyssal | 2,000-6,000 | 75 | no light, high pressure |
| hadal | >6,000 | 1 | no light, high pressure |

(Source: Oceanography, Paul R. Pinet, 1992, http://encyclopedia.com)

## Biology: Natural Selection (1)

natural selection: differential survival and reproduction of individuals due to differences in phenotype
variation: exists due to random mutations in the genome of an individual organism that can be inherited by offspring
species: the basic unit of biological classification and a taxonomic rank; often defined as the largest group of organisms in which two individuals can produce fertile offspring
biological diversity: refers to the variety and variability of life on Earth

## Biology: Natural Selection (2)

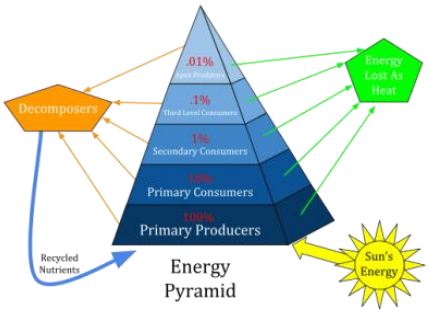
phenotype: composite of an organism's observable characteristics or traits, including morphology, development, biochemical or physiological properties, behavior, products of behavior; results from expression of an organism's genetic code, genotype, and as the influence of environmental factors and their interactions
genotype: the part (DNA sequence) of the genetic makeup of a cell, and an organism or individual, which determines a specific phenotype of that cell/organism/individual
polymorphism: occurrence of two or more different forms, referred to as alternative phenotypes, in the population of a species;morphs must occupy the same habitat at the same time and belong to a panmictic population
panmictic population: a population without mating restrictions

## Biology: Food Web Categories

- source - one or more node(s), all of their predators, all the food these predators eat, etc.
- sink - one or more node(s), all of their prey, all the food that these prey eat, etc.
- community (or connectedness) - a group of nodes and all the connections of who eats whom
- energy flow - quantified fluxes of energy between nodes along links between a resource and a consumer
- paleoecological - reconstructs ecosystems from the fossil record
- functional - emphasizes the functional significance of certain connections having strong interaction strength and greater bearing on community organization, more so than energy flow pathways, has compartments, which are sub-groups in the larger network where there are different densities and strengths of interaction

## Biology: Ecological/Energy Pyramid

producers: bring energy from non-living sources into the community
primary consumers: eat producers, making them herbivores
secondary consumers: eat the primary consumers, making them carnivores
tertiary consumers: eat the secondary consumers




(Image source: https://commons.wikimedia.org/wiki/File:Ecological_Pyramid.svg, Swiggity.Swag.YOLO.Bro, CC BY-SA 4.0)

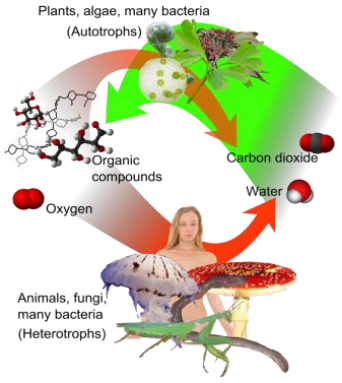
## Biology: Food Chain (1)

food chain: linear network of links in a food web starting from producer organisms, ending at apex predator species, detritivores, or decomposers; shows how organisms are related with each other by the food they eat; each level represents a different trophic level; differs from a food web, because the complex network of different animals' feeding relations are aggregated and the chain only follows a direct, linear pathway of one animal at a time

food chain length: the length of a chain is the number of links between a trophic consumer and the base of the web and the
mean chain length of an entire web: the arithmetic average of the lengths of all chains in a food web

## Biology: Food Chain (2)

detrivore: heterotrophs that obtain nutrients by consuming detritus
detritus: decomposing plant and animal parts and feces
trophic level: position an organism occupies in a food chain




(Image source: https://en.wikipedia.org/wiki/Heterotroph#/media/File:Auto-and_heterotrophs.png, Mikael Häggström, CC BY-SA 3.0)

## Biology: Autotroph (1)

autotroph: organism producing complex organic compounds, such as carbohydrates, fats, and proteins, from simple substances present in its surroundings, generally using energy from light (photosynthesis) or inorganic chemical reactions (chemosynthesis)

- chemoautotroph: synthesize organic compounds from carbon dioxide, use inorganic energy sources, such as hydrogen sulfide, elemental sulfur, ferrous iron, and molecular hydrogen, and ammonia; most are bacteria or archaea in hostile environments

## Biology: Autotroph (2)

- lithotroph: diverse group of organisms using inorganic substrate (usually of mineral origin) to obtain reducing equivalents for use in biosynthesis (e.g., carbon dioxide fixation) or energy conservation (i.e., ATP production) via aerobic or anaerobic respiration
- photoautotroph: synthesizes food from inorganic substances using light as an energy source; includes green plants and photosynthetic bacteria are photoautotrophs; capable of using carbon dioxide as their principal carbon source

(Source: https://en.wikipedia.org/wiki/Autotroph)

## Biology: Heterotroph (1)

- heterotroph: an organism that cannot fix carbon from inorganic sources (such as carbon dioxide) but uses organic carbon for growth
- chemoheterotroph: unable to fix carbon to form their own organic compounds, can be chemolithoheterotrophs, utilizing inorganic energy sources such as sulfur or chemoorgano-heterotrophs, utilizing organic energy sources such as carbohydrates, lipids, and proteins
- lithotroph: diverse group of organisms using inorganic substrate (usually of mineral origin) to obtain reducing equivalents for use in biosynthesis (e.g., carbon dioxide fixation) or energy conservation (i.e., ATP production) via aerobic or anaerobic respiration

## Biology: Heterotroph (2)

- photoheterotroph: organisms that use light for energy, but cannot use carbon dioxide as their sole carbon source; they use organic compounds from the environment to satisfy carbon requirements, including carbohydrates, fatty acids, and alcohols; examples include purple non-sulfur bacteria, green non-sulfur bacteria, and heliobacteria
- organotroph: organism that obtains hydrogen or electrons from organic substrates, describes organisms based on how they obtain electrons for their respiration processes; some are also heterotrophs; can be either anaerobic or aerobic

(Source: https://en.wikipedia.org/wiki/Heterotroph)

## Biology: Abiotic Factors

abiotic factors: non-living chemical and physical parts of the environment that affect living organisms and the functioning of ecosystems; include physical conditions and non-living resources that affect living organisms in terms of growth, maintenance, and reproduction; resources are distinguished as substances or objects in the environment required by one organism and consumed or otherwise made unavailable for use by other organisms; include water, light, radiation, temperature, humidity, atmosphere, and soil; pressure and sound waves in marine or sub-terrestrial environments

## Biology: Biotic Factors

biotic factors: any living component that affects the population of another organism, or environment, including animals that consume the organism, and living food that the organism consumes; also include human influence, pathogens and disease outbreaks.
acclimation: gradual, but reversible, physiological adjustment that occurs in response to environmental changes
anatomical changes: can be reversible or irreversible over the life of an individual
behavioral response: includes migration, changes in exposure to climate and weather

## Biology: Extremophiles (1)

acidophile: organism with optimal growth at pH levels of 3 or below
alkaliphile: organism with optimal growth at pH levels of 9 or above
anaerobe: organism that does not require oxygen for growth; two sub-types exist: facultative anaerobe and obligate anaerobe: a facultative anaerobe can tolerate anaerobic and aerobic conditions; an obligate anaerobe would die in the presence of even trace levels of oxygen
cryptoendolith: organism that lives in microscopic spaces within rocks, such as pores between aggregate grains and in fissures, aquifers, and faults filled with groundwater in the deep subsurface
halophile: organism requiring at least 0.2M concentrations of salt for growth
hyperthermophile: organism that can thrive at temperatures above 80 °C, such as those found in hydrothermal systems
hypolith: organism that lives underneath rocks in cold deserts

## Biology: Extremophiles (2)

lithoautotroph: organism whose sole source of carbon is carbon dioxide; capable of deriving energy from reduced mineral compounds; active in geochemical cycling and weathering of bedrock to form soil
metallotolerant: capable of tolerating high levels of dissolved heavy metals in solution, such as copper, cadmium, arsenic, and zinc
oligotroph: organism capable of growth in nutritionally limited environments
osmophile: organism capable of growth in environments with a high sugar concentration
piezophile: organism that lives optimally at high pressures such as those deep in the ocean or underground; common in the deep terrestrial subsurface, as well as in oceanic trenches

**Biology: Extremophiles (3)**

polyextremophile: organism that qualifies under more than one category
psychrophile/cryophile: organism capable of survival, growth or reproduction at temperatures of -15°C or lower for extended periods; common in cold soils, permafrost, polar ice, cold ocean water, and in or under alpine snowpack
radioresistant: organisms resistant to high levels of ionizing radiation, most commonly ultraviolet radiation, but also including organisms capable of resisting nuclear radiation
thermophile: organism that can thrive at temperatures between 45–122°C
thermoacidophile: combination of thermophile and acidophile; prefer temperatures of 70–80°C and pH between 2 and 3
xerophile: organism that can grow in extremely dry, desiccating conditions; exemplified by the soil microbes of the Atacama Desert
(Source: https://en.wikipedia.org/wiki/Extremophile)