STUDY CARD for *CAMPBELL BIOLOGY*, Ninth Edition

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Themes in the Study of Life (Ch. 1)

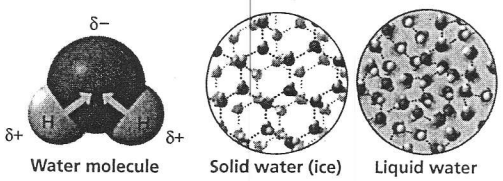
1. Evolution accounts for life's unity and diversity.
2. New properties emerge at each level of the biological hierarchy, from atoms to the biosphere.
3. Organisms interact with their environments.
4. Life requires energy transfer.
5. Structure and function are correlated.
6. The cell is the basic unit of an organism.
7. DNA transmits heritable information.
8. Feedback mechanisms regulate biological systems.

The Chemical Context of Life (Ch. 2)

1. Matter consists of chemical elements in pure form and in combinations called compounds.
2. An element's properties depend upon the structure of its atoms.
   a. The number of protons (+) determines the element.
   b. Electrons (−) occupy electron shells.
3. Chemical bonds form when atoms interact and complete their outer (valence) shells.
   a. Single or double covalent bonds form when pairs of electrons are shared between atoms.
   b. Electron transfer forms ions. An ionic bond is the attraction between oppositely charged ions.
   c. Weak bonds include hydrogen bonds and van der Waals interactions.
4. Chemical reactions make and break chemical bonds as reactants are converted to products.

Water and Life (Ch. 3)

1. Water molecules are polar. Hydrogen bonding between water molecules gives water unique properties that allow life to exist on Earth.
   a. Cohesion due to hydrogen bonding contributes to the transport of water against gravity in plants.
   b. Water's high specific heat and high heat of vaporization moderate temperatures on Earth.
   c. Ice floats because hydrogen bonds lock water into a crystalline lattice that reduces its density.



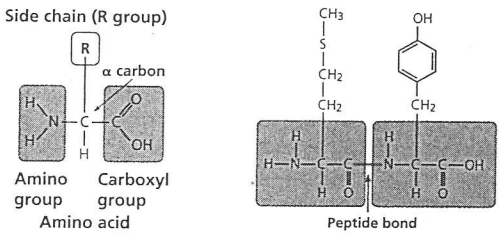
   d. Water is a versatile solvent.
   e. Hydrophilic substances have an affinity for water, whereas hydrophobic substances repel water.
2. Acidic and basic conditions affect organisms.
   a. Acidic solutions have a pH < 7.
   b. Basic solutions have a pH > 7.
   c. Buffers minimize changes in pH.

Carbon and Molecular Diversity (Ch. 4)

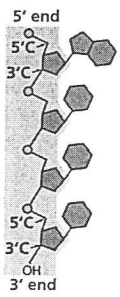
1. Organic chemistry is the study of carbon compounds.
2. Carbon atoms can form diverse molecules by bonding with up to four other atoms.
   a. Carbon chains form the skeletons of most organic molecules.
   b. Hydrocarbons consist of only C and H.
   c. Isomers have the same molecular formula but different structures and properties.
3. Functional groups are the parts of molecules involved in chemical reactions.
4. ATP is an important source of energy for cellular processes: ATP → ADP + $\mathcal{P}_i$ + Energy

Large Biological Molecules (Ch. 5)

1. Macromolecules are polymers synthesized from monomers by dehydration reactions.
   a. Polymers are disassembled to monomers by the addition of a water molecule (hydrolysis).
   b. Variation in the linear sequence of monomers results in the diversity of polymers.
   c. Four major classes of large biological molecules are found in cells.
2. Carbohydrates include sugars (mono- and disaccharides) and polymers of sugars (polysaccharides).
   a. Most monosaccharides are multiples of CH_2O.
   b. Starch (in plants) and glycogen (in animals) are polysaccharides that store energy.
   c. Cellulose (in plants) and chitin (in animals) are polysaccharides that provide structural support.
3. Lipids are hydrophobic.
   a. Fats (glycerol linked to three fatty acid chains) can be saturated or unsaturated; they store energy.
   b. Phospholipids (glycerol, two fatty acids, and phosphate) have hydrophobic and hydrophilic regions; they form a bilayer in water.
   c. Steroids (a carbon skeleton with four fused rings) include cholesterol and sex hormones.
4. Proteins have diverse structures and functions.
   a. A protein consists of one or more polypeptides, each a polymer of amino acids (from a set of 20).
   b. A peptide bond joins the carboxyl group of one amino acid with the amino group of the next.

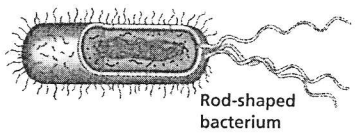


   c. Four levels of protein structure lead to the unique shape and function of each protein.
5. Nucleic acids store, transmit, and help express hereditary information.
   a. DNA and RNA are polymers of nucleotides.
   b. A nucleotide has a nitrogenous base, a five-carbon sugar, and one or more phosphate groups.
   c. DNA has deoxyribose as its sugar. RNA has ribose.
   d. DNA has A, G, C, and T as bases. RNA has A, G, C, and U.
   e. DNA is a double helix. RNA varies in shape.
   f. A gene (hereditary unit) is a stretch of DNA that dictates the synthesis of RNA, which then directs the amino acid sequence of a polypeptide.

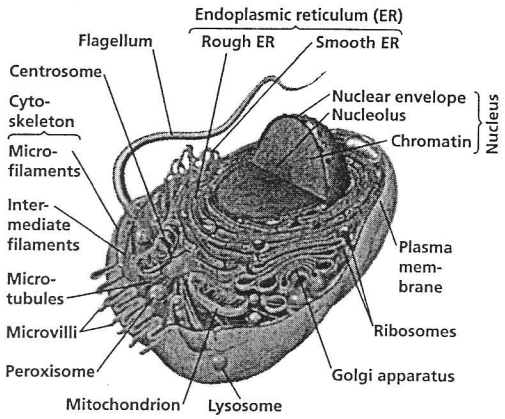


A Tour of the Cell (Ch. 6)

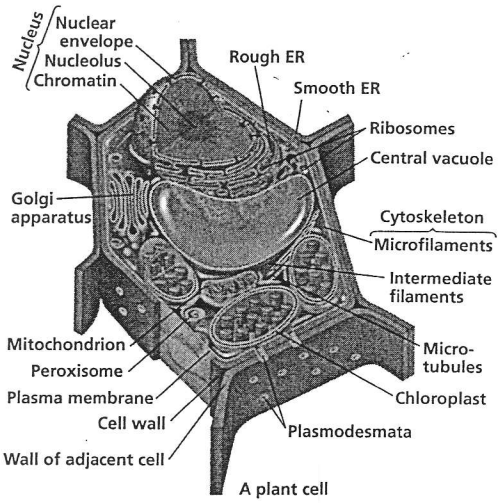
1. All organisms are composed of one or more cells.
2. All cells are bounded by a plasma membrane and contain cytosol, one or more chromosomes, and ribosomes.
3. Prokaryotic cells usually have a cell wall but lack a nucleus and membrane-bounded organelles.



4. Eukaryotic cells are generally larger than prokaryotic cells and have a nucleus and organelles.



An animal cell



A plant cell

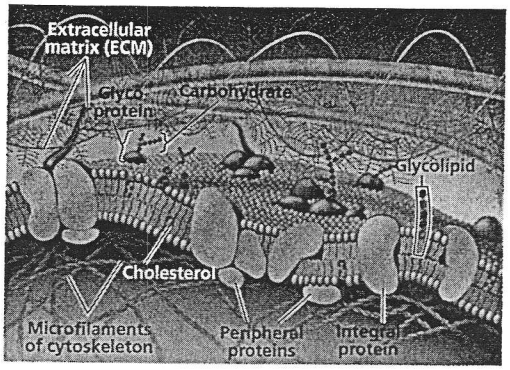
5. Within the nucleus, chromosomes made up of chromatin (DNA and proteins) carry the genetic instructions for making polypeptides.
6. Ribosomes are the cellular complexes that carry out protein synthesis.
7. The endomembrane system is a network of membranes, including the endoplasmic reticulum (ER).
   a. Smooth ER functions in lipid synthesis, carbohydrate metabolism, and detoxification.
   b. Rough ER has ribosomes that synthesize secretory proteins, which enter the ER lumen. Rough ER also synthesizes membrane proteins and phospholipids.
   c. The Golgi apparatus refines ER products and packages them in vesicles.
   d. Lysosomes, sacs containing hydrolytic enzymes, digest macromolecules and recycle organelles.
   e. Vacuoles function in digestion, storage, waste disposal, water balance, and cell growth.
8. Mitochondria and chloroplasts change energy from one form to another.
   a. Mitochondria, the sites of cellular respiration, extract energy from food and make ATP.

b. Chloroplasts, found in plants and algae, convert solar energy to chemical energy.

9. The cytoskeleton is a network of fibers that organizes structures and activities in the cell.
10. Extracellular components and connections between cells help coordinate cellular activities.
    a. Plant cells have cell walls and plasmodesmata.
    b. Animal cells have an extracellular matrix and tight junctions, desmosomes, and gap junctions.

Membrane Structure and Function (Ch. 7)

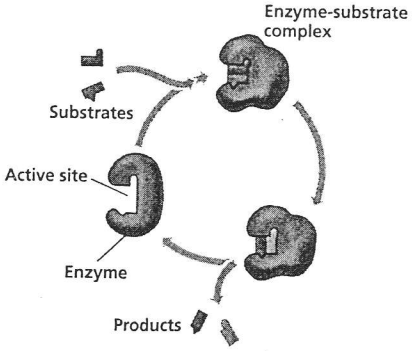
1. A cell membrane is a fluid mosaic of proteins embedded in a phospholipid bilayer:



2. Functions of membrane proteins include transport, enzymatic activity, signal transduction, cell-cell recognition, intercellular joining, and attachment.
3. Membrane structure results in selective permeability.
4. A substance diffuses down its concentration gradient. Diffusion across a biological membrane with no energy investment is passive transport.
5. Osmosis is the diffusion of water across a selectively permeable membrane.
6. Facilitated diffusion is passive transport aided by proteins.
7. Active transport moves substances against their gradients, using membrane proteins and energy from ATP. Active transport is sometimes indirect (as in cotransport).
8. Bulk transport across the plasma membrane occurs by exocytosis and endocytosis.

An Introduction to Metabolism (Ch. 8)

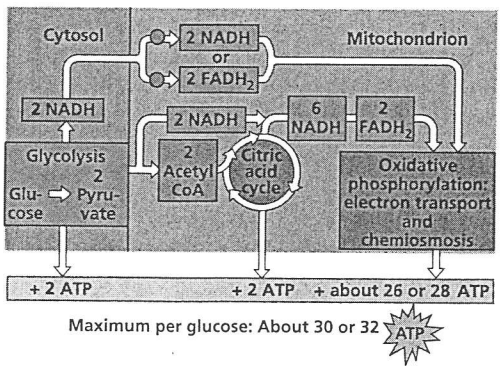
1. Metabolism is the collection of chemical reactions that occur in an organism.
    a. Anabolic pathways build molecules, using energy.
    b. Catabolic pathways break down molecules, releasing energy.
2. Energy is the capacity to cause change.
    a. Kinetic energy is possessed by moving objects.
    b. Potential energy is possessed by matter due to its location or structure.
3. Two laws of thermodynamics govern energy transformations.
    a. First law: Energy can be transferred and transformed, but it cannot be created or destroyed.
    b. Second law: Every energy transfer or transformation increases the entropy of the universe.
4. The free-energy change (ΔG) of a reaction tells us whether or not the reaction occurs spontaneously.
    a. Exergonic reactions have a net release of free energy.
    b. Endergonic reactions absorb free energy from their surroundings.
    c. Metabolism as a whole is never at equilibrium.
5. ATP powers cellular work by coupling exergonic reactions to endergonic reactions, often by transferring a phosphate group.
    a. Hydrolysis of ATP releases energy.
    b. Cells require energy to regenerate ATP.
6. An enzyme speeds up a chemical reaction by lowering the activation energy barrier. The enzyme is not consumed in the reaction.



7. Enzymes are affected by temperature, pH, and inhibitors. Regulation of enzyme activity, including allosteric regulation, helps control metabolism.

Cellular Respiration (Ch. 9)

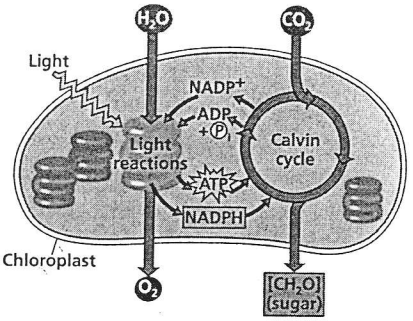
1. Cellular respiration has three stages.
    a. Glycolysis: In the cytosol, a glucose molecule is split into two pyruvate molecules, yielding two ATP and two NADH molecules.
    b. Pyruvate oxidation and the citric acid cycle: In the mitochondrion, pyruvate is oxidized to acetyl CoA, which enters the citric acid cycle and is broken down to CO_2. Electron transfer yields NADH and $FADH_2$.
    c. Oxidative phosphorylation: In the inner mitochondrial membrane, electrons move along the electron transport chain and H^+ is pumped into the intermembrane space. The electrons combine with oxygen and H^+, forming water. H^+ diffuses back through ATP synthase, yielding ATP (chemiosmosis).



2. Fermentation occurs in the absence of oxygen. Pyruvate is converted to ethanol or lactate and NAD^+ is regenerated, allowing glycolysis to continue and generate some ATP.
3. Glycolysis and the citric acid cycle connect to many other metabolic pathways.

Photosynthesis (Ch. 10)

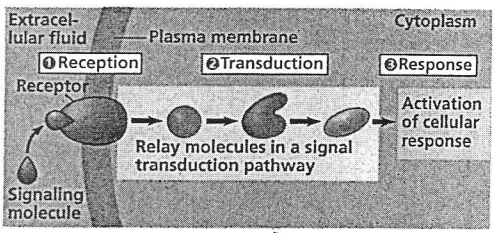
1. Autotrophs produce their own organic compounds. Heterotrophs obtain their organic compounds from autotrophs.
2. Photosynthesis is a redox process in which H_2O is oxidized and CO_2 is reduced:
   $6\ CO_2 + 6\ H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$
3. Photosynthesis in eukaryotes has two stages.
    a. Light reactions: Light energy excites electrons in pigments in the reaction centers of two photosystems within the thylakoid membranes, producing O_2, ATP, and NADPH.
    b. Calvin cycle: A cyclic series of chemical reactions in the stroma makes the energy-rich sugar G3P from CO_2, using ATP and NADPH.



4. Adaptations of C_4 and CAM plants reduce water loss by allowing sugar production to continue when stomata are partially or fully closed.
5. Plants use sugars to make other molecules, and they break sugars down in cellular respiration for energy.

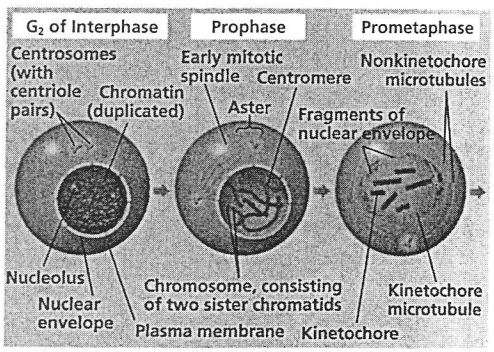
Cell Communication (Ch. 11)

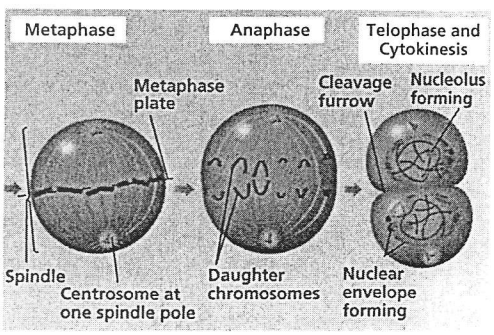
1. During cell signaling, external signals are converted to cellular responses in three stages:



The Cell Cycle (Ch. 12)

1. Cell division results in genetically identical daughter cells.
2. In the eukaryotic cell cycle, the mitotic phase (mitosis and cytokinesis) alternates with interphase, which has three parts: G_1 (growth), S (DNA synthesis), and G_2 (further growth).
3. Mitosis has five stages:





Mitosis in an animal cell

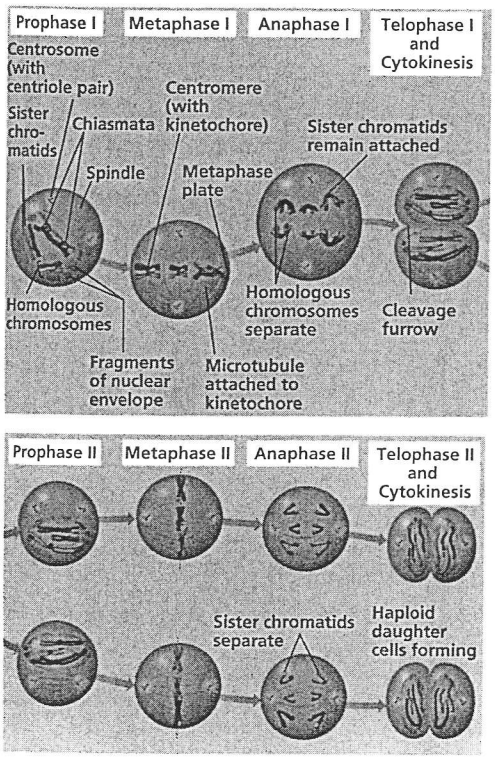
    a. Prophase: Chromosomes condense, nucleoli disappear, and the mitotic spindle begins to form.

b. Prometaphase: The nuclear envelope fragments, and microtubules extend from each pole; some attach to one kinetochore on each chromosome.
c. Metaphase: Chromosomes convene at the metaphase plate.
d. Anaphase: Sister chromatids separate and move to opposite ends of the cell; the cell elongates.
e. Telophase: Daughter nuclei form, nucleoli reappear, and chromosomes become less condensed.

4. Cytokinesis: In animals, a cleavage furrow forms; in plants, a cell plate forms and becomes a cell wall.
5. A prokaryotic cell divides by binary fission.
6. The cell cycle is regulated by a control system. Loss of cell cycle controls may result in cancer.

Meiosis and Sexual Life Cycles (Ch. 13)

1. Offspring acquire genes from parents by inheriting one set of chromosomes from each parent.
2. Fertilization and meiosis alternate in sexual life cycles.
   a. Diploid cells ($2n$) have two sets of chromosomes; haploid cells (n) have one set.
   b. Diploid cells have pairs of homologous chromosomes, one from each set.
   c. Humans have 22 pairs of autosomes and 1 pair of sex chromosomes (X and Y).
   d. In humans, meiosis forms haploid gametes (egg and sperm), which unite at fertilization and form a diploid zygote.
   e. Two other types of sexual life cycles vary in the timing of meiosis and fertilization.
3. In meiosis, a single chromosomal duplication is followed by two divisions: meiosis I and meiosis II. Meiosis I has four stages:

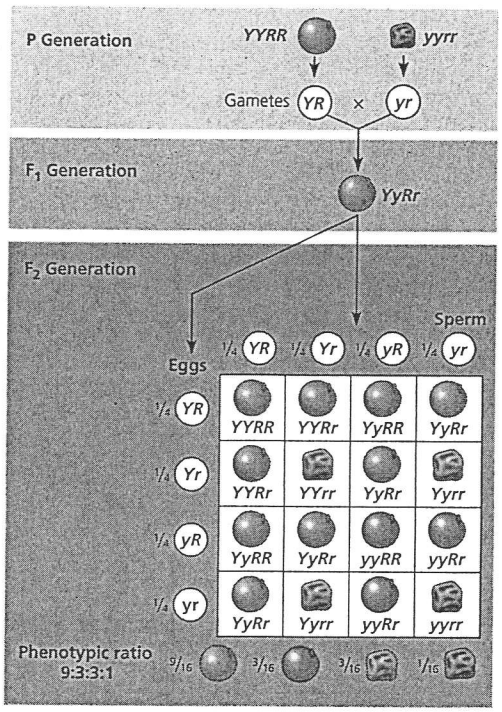


Meiosis in an animal cell

   a. Prophase I: Homologous chromosomes undergo synapsis and crossing over, exchanging segments. Chiasmata appear at crossovers.
   b. Metaphase I: Pairs of homologous chromosomes line up on the metaphase plate.
   c. Anaphase I: Homologous chromosomes separate and migrate to opposite poles of the cell.
   d. Telophase I and cytokinesis: Two daughter cells may form, each with one member of each homologous pair of chromosomes. Each chromosome still consists of two sister chromatids.
4. Meiosis II also has four stages, which resemble those of mitosis. Sister chromatids separate in anaphase II.
5. Genetic diversity results from three mechanisms:
   a. Independent assortment of homologous chromosomes into daughter cells.
   b. Crossing over between homologous chromosomes.
   c. Random fertilization of any egg by any sperm.

Mendel and the Gene Idea (Ch. 14)

1. Mendel's experiments on garden peas revealed the mechanisms of inheritance.
   a. Alternative versions of genes (different alleles) account for variation in inherited characters.
   b. For each character, an organism inherits two alleles, one from each parent.
   c. If the two alleles differ, the dominant allele is expressed and the recessive allele is masked.
2. The law of segregation states that the two alleles of a gene separate during gamete formation.
3. A homozygous individual has two identical alleles of a gene. A heterozygous individual has two different alleles.
4. An individual's genotype is its genetic makeup. Its phenotype is its observable traits.
5. The law of independent assortment states that alleles of each gene segregate into gametes independently of alleles of other genes, as shown by a dihybrid cross:



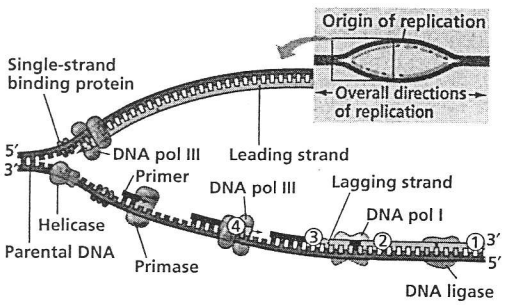
6. A testcross (crossing with a homozygous recessive individual) can reveal the genotype of an individual with a dominant phenotype.
7. The laws of probability govern inheritance.
8. Inheritance patterns are often more complex than predicted by simple Mendelian genetics.
   a. Incomplete dominance: The phenotype is between those of the homozygotes.
   b. Codominance: Both alleles affect the phenotype in separate, distinguishable ways.
   c. Multiple alleles can exist for a single gene, although each individual has only two alleles.
   d. Pleiotropy: A gene can have multiple effects.
   e. Epistasis: The phenotypic expression of a gene at one locus alters that of a gene at a second locus.
   f. Polygenic inheritance: Multiple genes affect the same character.
   g. Environmental factors can influence a phenotype.
9. The inheritance of many human traits follows Mendel's principles, so geneticists can use family pedigrees to determine genotypes. Many inherited disorders are controlled by a single gene.

Chromosomes and Inheritance (Ch. 15)

1. Mendelian inheritance has its physical basis in the behavior of chromosomes.
2. Sex has a chromosomal basis.
   a. Human females are XX; males are XY.
   b. Most genes on the X chromosome do not have corresponding loci on the Y chromosome.
   c. X-linked genes have a different pattern of inheritance: Recessive disorders appear more often in males because they have only one allele.
   d. In females, one X chromosome is inactivated (the Barr body).
3. Linked genes tend to be inherited together because they are located near each other on the same chromosome.
   a. Crossing over can separate specific alleles of linked genes and produce recombinant chromosomes.
   b. Geneticists can use recombination data to map the relative positions of genes on a chromosome.
4. Alterations of chromosome number or structure cause genetic disorders, such as Down syndrome.

The Molecular Basis of Inheritance (Ch. 16)

1. Experiments by Griffith and by Hershey and Chase showed that DNA is the genetic material.
2. Using Franklin's X-ray diffraction data and other considerations, Watson and Crick proposed that DNA is a double-stranded helix.
   a. Each strand has a sugar-phosphate backbone.
   b. The two strands are held together by hydrogen bonds between adenine (A) and thymine (T) and between guanine (G) and cytosine (C).
   c. Each strand has a 5′ end and a 3′ end and thus is directional; the two strands are antiparallel (run in opposite directions).
3. During DNA replication, the two strands separate, and each acts as a template for formation of a new complementary strand.



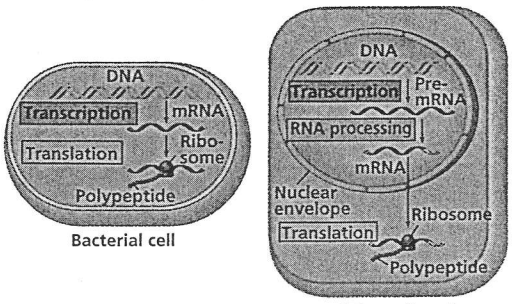
   a. Replication is semiconservative. Each new DNA molecule has one parental strand and one newly synthesized strand.
   b. The strands separate at origins of replication, forming a replication bubble with two forks. At each fork, helicase untwists the double helix.
   c. Primase makes a short RNA primer.
   d. Nucleotides line up along the existing strand by complementary base pairing. DNA polymerase joins them together one by one, adding to the 3′ end of the new polynucleotide chain (beginning with the primer).

e. The leading strand is synthesized continuously toward the replication fork. The lagging strand is made away from each fork as short (Okazaki) fragments, joined later by DNA ligase.
f. RNA primers are degraded and replaced with DNA nucleotides before fragments are joined.

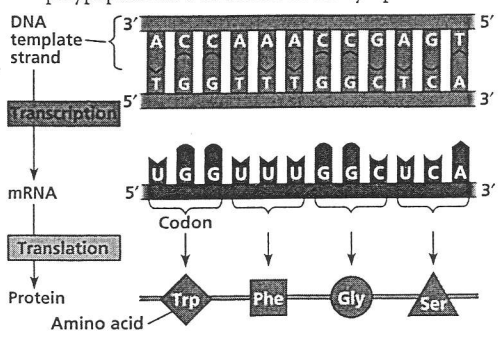
4. Chromatin structure is based on DNA packing.
   a. The nucleosome is the basic structural unit.
   b. Heterochromatin is condensed during interphase and usually not transcribed. Genes in euchromatin are less condensed during interphase and thus are available for transcription.

From Gene to Protein (Ch. 17)

1. A gene (DNA) is transcribed into RNA, which is translated into a polypeptide. The process is more complex in eukaryotes.



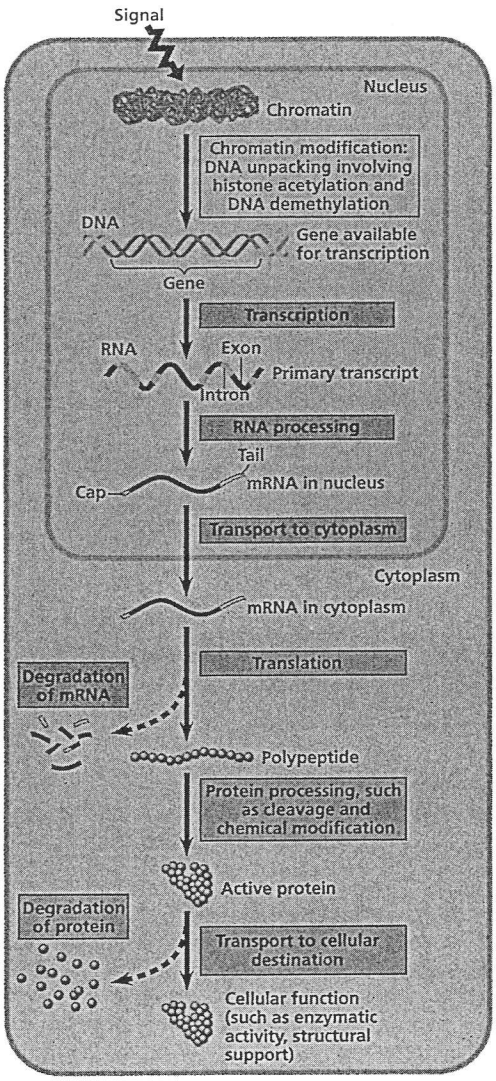
2. Research by Garrod, Beadle, Tatum, and others pointed to a link between genes and proteins.
3. Transcription occurs in three stages.
   a. Initiation: RNA polymerase binds to the promoter and unwinds the DNA. RNA synthesis begins, with one DNA strand as a template.
   b. Elongation: RNA polymerase moves down the DNA template strand, elongating the RNA transcript by adding nucleotides to the 3′ end.
   c. Termination: After passing a certain DNA sequence, the RNA transcript is released, and RNA polymerase detaches from the DNA.
4. Eukaryotic cells modify the primary transcript (pre-mRNA) in the nucleus.
   a. A modified G is added to the 5′ end (5′ cap).
   b. A poly-A tail is added to the 3′ end.
   c. Introns (noncoding segments) are spliced out, and exons are joined together.
5. Translation is the mRNA-directed synthesis of a polypeptide on a ribosome in the cytoplasm.



   a. Of the 64 triplets of mRNA bases (codons), 61 code for amino acids (including AUG, which signals *start* as well as Met); three codons (UAA, UAG, and UGA) signal *stop*.
   b. Each transfer RNA (tRNA) is bound to the appropriate amino acid; its anticodon is complementary to the appropriate mRNA codon.
   c. Ribosomes have a large and a small subunit.
   d. Translation occurs in three stages.
      1. Initiation: mRNA, tRNA with the first amino acid (Met), and the two ribosomal subunits associate.
      2. Elongation: The next amino acid is joined to the end of the growing polypeptide. GTP is used for energy.
      3. Termination: When a stop codon is reached, the polypeptide is released, and the mRNA and ribosomal subunits dissociate.
   e. Many ribosomes may translate the same mRNA simultaneously, forming a polyribosome.
   f. The polypeptide folds as it is being made; it may be further modified or targeted to a specific site.
6. Changes in the DNA (mutations) can affect protein structure and function.
7. In bacteria, transcription and translation are coupled (occur simultaneously for the same mRNA).

Regulation of Gene Expression (Ch. 18)

1. Operons enable bacteria to regulate gene expression in response to environmental conditions.
   a. An operon consists of a promoter, an operator, and a coordinately regulated cluster of genes.
   b. A repressor protein binds to the operator under certain conditions, turning off gene expression.
2. Eukaryotic gene expression is regulated at many stages:



   a. Transcription factors can bind to the enhancer of a gene, causing transcription to begin.
   b. Genes that have similar sequences in their enhancers are coordinately regulated. Specific transcription factors that bind to them are present only in certain cell types.
3. Noncoding RNAs (miRNAs and siRNAs) can promote heterochromatin formation and block the translation of specific mRNAs.
4. Different cell types result from differential gene expression in cells with the same DNA.
   a. Differential gene expression results from transcriptional regulation of gene expression during development.
   b. Initial differences in a developing embryo are established by cytoplasmic determinants and cell-cell signaling (induction).
   c. In animal embryos, pattern formation begins when molecular cues tell a cell its location relative to the body axes and to other cells.
5. Cancer results from changes in proto-oncogenes or tumor-suppressor genes that affect cell cycle control.

Viruses (Ch. 19)

1. A virus has a genome surrounded by a protein coat; some viruses also have a membranous envelope.
2. A virus can replicate only within a host cell.
   a. The viral genome enters the host cell and reprograms the cell to make more viruses.
   b. The replicative cycles of bacteriophages can be lytic or lysogenic.
   c. Animal viruses can have single- or double-stranded DNA or RNA and often have an envelope. Their replicative cycles vary.

Biotechnology (Ch. 20)

1. DNA cloning permits the production of multiple copies of specific genes or other DNA segments.
2. Restriction fragment analysis detects DNA differences that affect restriction sites.
3. Cloning demonstrates the genomic equivalence of all cells in an organism.
4. DNA technology has medical, forensic, environmental, agricultural, and ethical applications.

Genomes and Their Evolution (Ch. 21)

1. Using the tools of bioinformatics, scientists can compare genomes and study sets of genes and proteins as whole systems (genomics and proteomics).
2. Eukaryotic genomes generally are larger and contain more genes than prokaryotic genomes.
3. Eukaryotic genomes can have a large amount of noncoding DNA, including transposable elements, simple sequence DNA, and other repetitive DNA.
4. Eukaryotic genes can exist in multigene families.
5. Duplications, rearrangements, and mutations of DNA contribute to genome evolution. Rearrangements may be due to exon duplication, exon shuffling, or movement by transposable elements.
6. Comparative studies help explain how the evolution of development leads to morphological diversity.
   a. Developmental genes are widely conserved among animals.
   b. In both plants and animals, development relies on a cascade of gene activation and inactivation by transcriptional regulators.

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Darwin's Theory of Evolution (Ch. 22)

1. Evolution is both a pattern and a process.
   a. Evolution explains three key observations about life: fit of organisms to their environments, shared characteristics (unity), and diversity.
   b. New species arise from ancestral species by descent with modification (adaptation).
2. Darwin's theory of natural selection connected several observations and ideas.
   a. Individuals vary in their heritable traits.
   b. Organisms overreproduce, leading to a struggle for limited resources.
   c. Individuals with traits that are better suited to the environment tend to leave more offspring than others, causing favorable traits (adaptations) to accumulate in a population over time.
3. Vast evidence supports Darwin's theory, including the spread of drug resistance, the fossil record, and structural and molecular similarities in organisms.

The Evolution of Populations (Ch. 23)

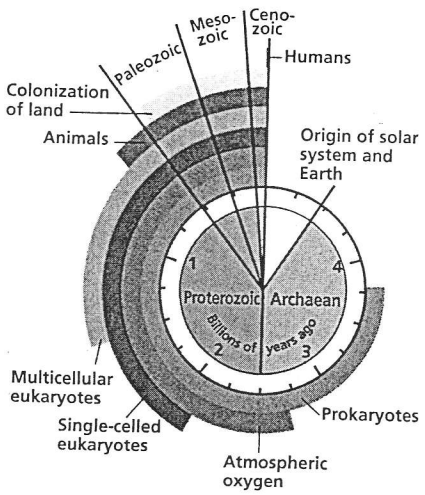
1. Mutation, gene duplication, and sexual reproduction produce genetic variation. A population's gene pool consists of all the alleles of its members.
2. According to the Hardy-Weinberg principle, allele frequencies in a gene pool remain constant if:
   a. There are no mutations.
   b. Mating is random.
   c. Individuals have equal reproductive success.
   d. The population size is extremely large.
   e. No gene flow occurs.
3. Deviations usually result in evolution.
   a. Mutation alters alleles or genes are disrupted.
   b. Individuals mate preferentially within a subset of the population.
   c. Natural selection favors certain genotypes.
   d. Finite populations may be affected by genetic drift.
   e. Gene flow transfers alleles between populations.

The Origin of Species (Ch. 24)

1. Isolation of divergent gene pools forms species.
   a. Allopatric speciation occurs when a population is split into geographically isolated groups.
   b. Sympatric speciation occurs in geographically overlapping populations by polyploidy, habitat differentiation, or sexual selection.
2. In a hybrid zone, gene flow occurs between species. Over time, a new species of hybrids may form; alternatively, the two species may stop mating, may fuse, or may continue to produce hybrids.
3. In punctuated equilibria, species change most when they appear and then change little.

The History of Life on Earth (Ch. 25)

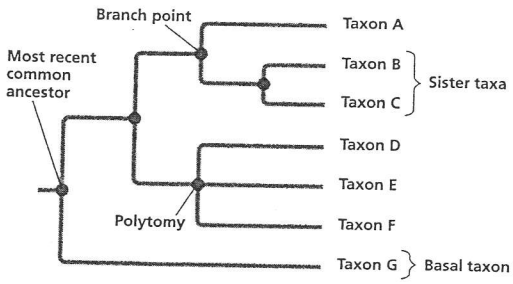
1. Lightning and UV radiation on early Earth may have provided energy for the synthesis of organic compounds from inorganic molecules.
2. Simple cells likely arose from monomer synthesis, polymerization, membrane formation, and synthesis of self-replicating nucleic acids.
3. The earliest organisms on Earth were prokaryotes.
4. Eukaryotic cells evolved from prokaryotic cells. Mitochondria and plastids likely evolved from prokaryotes within host cells (endosymbiosis).
5. Multicellularity evolved several times, leading to algal, fungal, plant, and animal lineages. Animals diversified about 535–525 mya, during the "Cambrian explosion."
6. Continental drift separated landmasses into evolutionary arenas.



7. The fossil record shows that life's history includes mass extinctions and adaptive radiations.
8. "Evo-devo" studies how changes in the sequence or regulation of genes that control development may result in major morphological changes in organisms, producing novel forms.
9. Evolution is not goal-oriented—it can only modify existing variations. Structures can become co-opted for new functions in changing environments.

Phylogeny and the Tree of Life (Ch. 26)

1. A phylogeny shows evolutionary history and can be represented in a phylogenetic tree:



   a. Shared ancestry leads to morphological and molecular similarities (homologies).
   b. Homologies must be distinguished from analogies (products of convergent evolution).
   c. A clade includes an ancestral species and all of its descendants.
2. Molecular clocks are based on the rate of change in the sequence of certain genes.
3. The tree of life includes three domains (Bacteria, Archaea, and Eukarya) based on rRNA genes. Horizontal gene transfer has likely played a key role in the history of life.

Prokaryotes (Ch. 27)

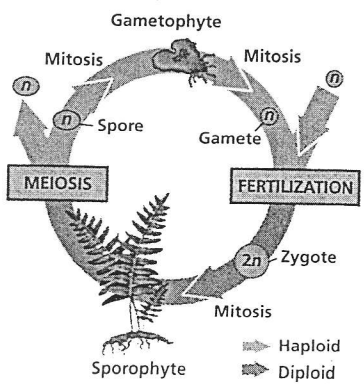
1. Prokaryotes are unicellular and include the domains Bacteria and Archaea.
   a. Most bacterial cell walls contain peptidoglycan; archaeal cell walls lack peptidoglycan.
   b. Flagella enable some prokaryotes to move.
   c. Internal membranes may carry out various functions but do not form compartments.
   d. The prokaryotic genome usually consists of a single ring of DNA plus separate plasmids.
2. Prokaryotes reproduce by binary fission. Some can form resistant cells called endospores.
3. Rapid division, mutation, and genetic recombination contribute to genetic diversity in prokaryotes. Recombination can occur by several mechanisms.
   a. Transformation: A cell takes up foreign DNA from its surroundings.
   b. Transduction: A bacteriophage (virus) carries bacterial genes from one cell to another.
   c. Conjugation: Genetic material is transferred between two cells that are temporarily joined.
4. Prokaryotes are metabolically diverse.
   a. Nutritional modes include photoautotrophy, chemoautotrophy, photoheterotrophy, and chemoheterotrophy.
   b. Prokaryotes include aerobes and anaerobes.
   c. Some prokaryotes can convert atmospheric nitrogen to ammonia (nitrogen fixation).
5. Some prokaryotes are pathogens, but many others serve as chemical recyclers, symbiotic partners, and industrial producers.

Protists (Ch. 28)

1. Protists are a polyphyletic assortment of autotrophic, heterotrophic, and mixotrophic eukaryotes.
   a. Most protists are aquatic; some are terrestrial.
   b. Protists reproduce asexually, sexually, or both.
   c. Secondary endosymbiosis occurred in some algal lineages.
2. One current phylogenetic hypothesis organizes eukaryotes into five "supergroups."
   a. The excavates include diplomonads and parabasalids, which have modified mitochondria, and euglenozoans, which have a unique rod inside their flagella.
   b. The chromalveolates include alveolates (dinoflagellates, apicomplexans, and ciliates) and stramenopiles (diatoms, golden algae, brown algae, and oomycetes).
   c. The rhizarians include radiolarians, forams, and cercozoans.
   d. The archaeplastida include red algae and green algae, the closest relatives of land plants.
   e. The unikonts include protists that are closely related to fungi and animals: amoebozoans, nucleariids, and choanoflagellates.
3. Many protists are ecologically important as symbiotic partners and as producers.

Plant Origins, Seedless Plants (Ch. 29)

1. Plants evolved from green algae with similar cellulose synthesis, peroxisomes, flagellated sperm, cell division, and sporopollenin.
2. Derived traits of plants include alternation of generations and multicellular, dependent embryos; walled spores; multicellular gametangia; and apical meristems.
3. Nonvascular plants ("bryophytes") include liverworts, mosses, and hornworts.
   a. Bryophytes have dominant gametophytes and dependent sporophytes.
   b. Bryophytes are low-growing plants that require a moist environment for fertilization.
4. Seedless vascular plants have dominant sporophytes and small gametophytes.



a. The sporophytes have leaves, stems, and roots.
b. Transport occurs in vascular tissues (xylem and phloem).
c. Sporophylls are modified leaves that bear sporangia.
d. The two groups are lycophytes (club mosses and relatives) and pterophytes (ferns and relatives).

Seed Plants (Ch. 30)

1. Seed plants have vascular tissue, a dominant sporophyte, a reduced gametophyte, and seeds.
   a. Pollen grains contain male gametophytes, which produce sperm.
   b. Each egg is produced by a female gametophyte within an ovule.
   c. After fertilization, an ovule becomes a seed, consisting of three parts: an embryo, a food supply, and a seed coat.
2. Gymnosperms have exposed seeds on modified leaves (cones). They include cycads, *Ginkgo biloba*, gnetophytes, and conifers.
3. Angiosperms have flowers, which contain ovules inside an ovary, and fruits.
   a. A flower has up to four rings of modified leaves: sepals (enclose flower), petals (attract pollinators), stamens (make pollen), and carpels (make ovules).
   b. A fruit is a mature ovary containing seeds.
4. Humans depend greatly on seed plants for food, lumber, fuel, and medicine.

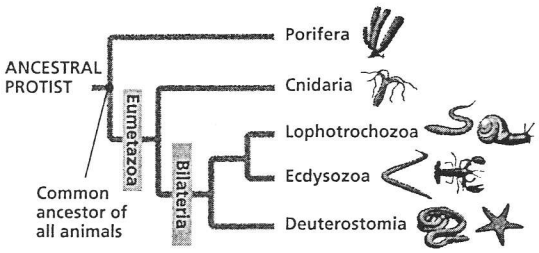
Fungi (Ch. 31)

1. Fungi are heterotrophs that absorb nutrients from their surroundings, often by excreting enzymes.
2. Fungal cell walls contain chitin.
3. Most fungi are multicellular, with bodies consisting of filaments (hyphae) woven into a mass (mycelium). Some fungi are unicellular (yeasts).
4. Fungal groups include chytrids, zygomycetes, glomeromycetes (arbuscular mycorrhizal fungi), ascomycetes (sac fungi), and basidiomycetes (club fungi).
5. Fungi have a dominant haploid phase.
   a. Mycelia of different mating types fuse (plasmogamy), leading to a heterokaryotic stage.
   b. Nuclei fuse (karyogamy), forming a diploid zygote, which undergoes meiosis, forming haploid spores.
6. Fungi include decomposers, parasites, and mutualists (including species that form mycorrhizae with plants).

Introduction to Animal Diversity (Ch. 32)

1. Animals are multicellular, heterotrophic eukaryotes that develop from embryonic tissue layers.
   a. Food is ingested and then digested internally.
   b. Animal cells lack cell walls and contain collagen.
   c. The zygote undergoes cleavage, forming a blastula, a gastrula, and germ and tissue layers.
2. Animals have various "body plans."
   a. Most have bilateral or radial symmetry.
   b. Most animals have two (diploblastic) or three (triploblastic) germ layers.
   c. Some triploblastic animals have a body cavity (coelom).
   d. In protostome development, the blastopore forms the mouth; cleavage is spiral and determinate.
   e. In deuterostome development, the blastopore forms the anus; cleavage is radial and indeterminate.
3. Molecular data have stimulated new ideas about animal phylogeny.

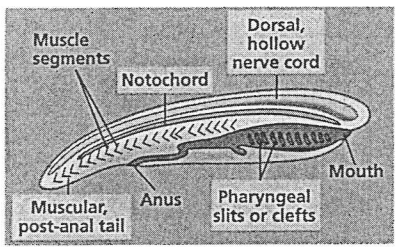
Introduction to Invertebrates (Ch. 33)



1. Sponges are sessile suspension feeders that lack true tissues.
2. Cnidarians are radially symmetrical, sessile (polyps) or floating (medusae) carnivores with tentacles and cnidocytes.
3. Lophotrochozoans include flatworms, which have no coelom; rotifers; lophophorates; molluscs, which have a foot, visceral mass, and mantle; and annelids, which are segmented worms.
4. Ecdyzoans include nematodes (roundworms) and arthropods, segmented coelomates with an exoskeleton and jointed appendages (such as crustaceans and insects).
5. Echinoderms have a water vascular system, tube feet, and a calcareous endoskeleton.

Evolution of Vertebrates (Ch. 34)

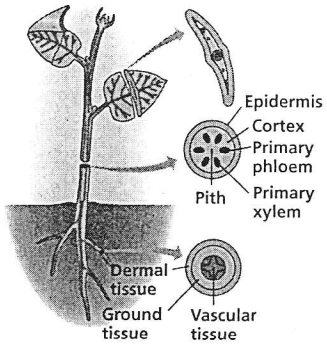
1. All chordates have four key derived characters:



2. Two groups of invertebrate chordates are the lancelets and the tunicates.
3. Craniates are chordates that have a head.
   a. The neural crest gives rise to many structures.
   b. A skull, eyes, and a brain allow for an active, predatory lifestyle, such as in hagfishes.
   c. Other features include a muscular digestive tract, a heart with two or more chambers, red blood cells, and kidneys.
4. Vertebrates are craniates that have a backbone. Lampreys are jawless parasites that have an endoskeleton made of cartilage.
5. Gnathostomes are jawed vertebrates that have a mineralized endoskeleton. They include chondrichthyans (such as sharks and rays), ray-finned fishes, and lobe-fins.
6. Tetrapods are lobe-fins that have limbs and feet.
   a. Most amphibians (such as frogs and salamanders) have aquatic larvae and terrestrial adults.
   b. Reptiles (such as lizards, snakes, and birds) are amniotes that have a terrestrially adapted egg. Birds also have feathers and other flight adaptations.
   c. Mammals are amniotes that have hair and produce milk. All mammals are endotherms.
   d. Humans are primate mammals that have a large brain and bipedal locomotion.

Plant Structure and Growth (Ch. 35)

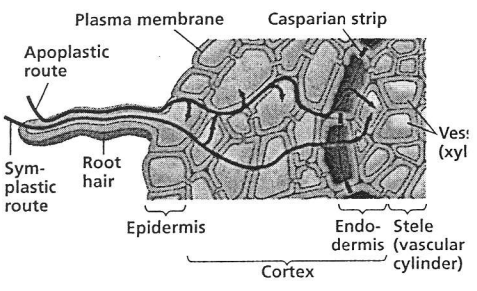
1. Plant bodies have three basic organs.
   a. Roots anchor the plant and absorb water and minerals through root hairs.
   b. Stems bear leaves and (in angiosperms) flowe
   c. Leaves are the main photosynthetic organs.



2. Plants have three tissue systems.
   a. Dermal tissue is the outer covering.
   b. Vascular tissues are xylem and phloem.
   c. Ground tissue is tissue that is neither dermal nor vascular.
3. Common cells are parenchyma, collenchyma, sclerenchyma, tracheids, vessel elements, sieve-tube elements, and companion cells.
4. Apical meristems produce primary growth (grow in length) of roots and shoots.
5. Lateral meristems produce secondary growth (growth in diameter) of woody roots and stems.
   a. The vascular cambium adds secondary xylem (wood) and secondary phloem.
   b. The cork cambium produces periderm.
6. A typical root has a central vascular cylinder.
7. Stems have vascular bundles arranged in a ring (gymnosperms and most eudicots) or scattered throughout the ground tissue (most monocots).
8. Leaves are composed of epidermis, mesophyll, an vascular bundles that form veins.

Transport in Vascular Plants (Ch. 36)

1. Leaf size and arrangement, branching, and stem thickness help shoots acquire CO_2 and light.
2. Root branching and mycorrhizae enhance acquisition of water and minerals.
3. The membrane potential and H^+ gradient generated by proton pumps drive solute transpor
4. Water flows down a gradient of water potential.
   a. Solutes decrease water potential.
   b. Positive pressure increases water potential.
5. Roots absorb water and minerals.
   a. Root hairs, mycorrhizae, and cortical cells increase the surface area for absorption.
   b. The Casparian strip blocks the apoplast, ensuring that minerals cannot enter the vascu cylinder without crossing a plasma membrane



6. Water and minerals ascend from roots to shoots bulk flow through vessels of the xylem.
   a. Transpiration lowers water potential in the leaves by producing tension in the apoplast.
   b. Cohesion and adhesion of water transmit the te sion produced by transpirational pull to the roo
7. Stomata regulate the rate of transpiration by opening when turgid and closing when flaccid.

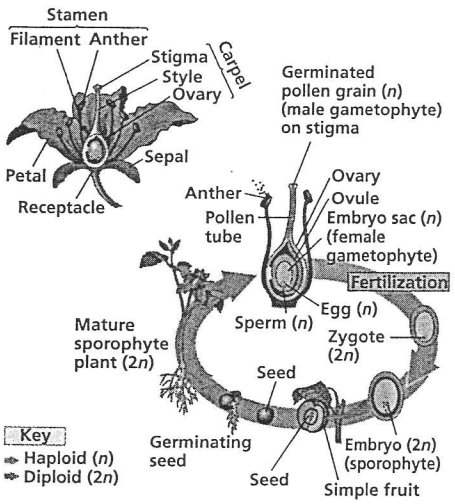
8. Sugar (sucrose) moves from sources to sinks through phloem sieve-tube elements by bulk flow.
   a. Leaves and roots are sources that load sucrose into the phloem by active cotransport.
   b. Roots, buds, stems, and fruits are sinks that unload sucrose by facilitated transport.
   c. Bulk flow occurs in response to the pressure gradient between source and sink.
9. The symplast can also transport macromolecules and conduct electrical signals.

Plant Nutrition (Ch. 37)

1. Soil texture (particle sizes) and components (inorganic and organic) affect nutrient absorption.
2. Macronutrients are required in large amounts; micronutrients are required in small amounts.
3. Mutualistic relationships with soil bacteria and fungi make nutrients more available to plants.

Angiosperm Reproduction (Ch. 38)

1. In a flower's anthers, microspores develop into pollen grains (containing male gametophytes).
2. In each ovule, a megaspore develops into an embryo sac (female gametophyte) containing one egg cell, two synergids, three antipodal cells, and one large central cell with two polar nuclei.



3. After pollination brings pollen to the stigma of a carpel, the pollen germinates.
   a. The pollen tube grows through the style and into the micropyle of the ovule.
   b. The generative cell divides into two sperm.
4. In double fertilization, one sperm fertilizes the egg, forming a zygote, and the other sperm combines with the two polar nuclei, forming a cell that gives rise to the endosperm, which contains nutrients.
5. After fertilization, the ovule develops into a seed that protects the embryo. The seed is contained within a fruit, which is the mature ovary.

Plant Responses to Signals (Ch. 39)

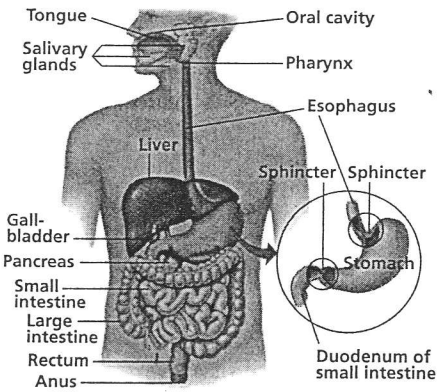
1. Plant hormones affect seed germination and the growth of roots, stems, leaves, and fruit.
2. Plant detection of light affects processes such as seed germination, stomatal opening, and flowering.
3. Plant growth is also influenced by responses to gravity, mechanical stimuli, and stresses such as drought and heat.
4. Plants chemically defend against herbivory and disease.

Animal Form and Function (Ch. 40)

1. Animals exhibit hierarchical levels of organization.
   a. Tissues are groups of cells with a similar appearance and common function. The main tissue types are epithelial, connective, muscle, and nervous.
   b. Organs are composed of different types of tissues.
   c. Organ systems consist of several organs.
2. Thermoregulation enables animals to maintain a body temperature within a tolerable range.
   a. Ectotherms gain most of their heat from the environment. Endotherms can regulate their body temperature by using metabolic heat.
   b. Conduction, convection, radiation, and evaporation account for heat gain or loss.

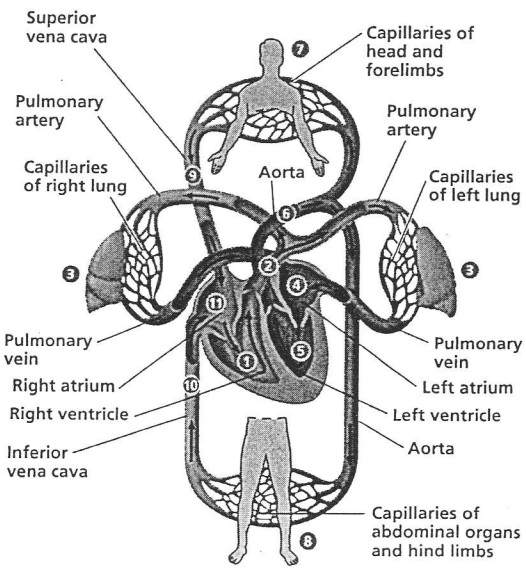
Animal Nutrition (Ch. 41)

1. An animal's diet must supply carbon skeletons and some amino acids, fatty acids, vitamins, and minerals.
2. In cnidarians and flatworms, digestion occurs in a gastrovascular cavity. In most other animals, digestion occurs in an alimentary canal with two openings (mouth, anus).
3. The mammalian digestive system consists of the alimentary canal and various accessory glands:



Circulation and Gas Exchange (Ch. 42)

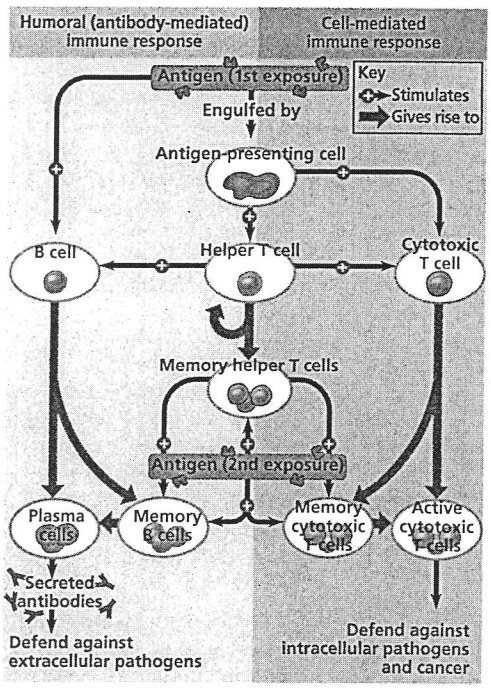
1. Circulatory systems transport fluid containing gases, nutrients, hormones, and wastes.
   a. In an open circulatory system, there is no distinction between blood and interstitial fluid.
   b. In a closed circulatory system, blood is confined to vessels.
   c. Mammals and birds have a four-chambered heart that pumps blood via pulmonary and systemic circuits:



   d. Blood consists of cellular elements (erythrocytes, leukocytes, platelets) in liquid (plasma).
2. Animals that are small, thin, or flat can exchange O_2 and CO_2 across their body surface. Most other animals have respiratory organs: gills, tracheae (in insects), or lungs.
3. Respiratory pigments bind O_2, greatly increasing O_2 transport by hemolymph or blood.

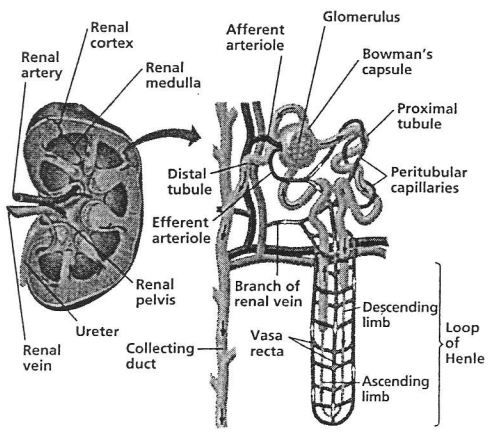
The Immune System (Ch. 43)

1. Innate immunity is mediated by barrier defenses (skin, mucous membranes, secretions) and internal defenses (phagocytic and natural killer cells, proteins, inflammatory response).
2. Adaptive immunity involves antigen recognition by lymphocytes and consists of humoral and cell-mediated responses:



Osmoregulation and Excretion (Ch. 44)

1. Osmoregulators control the osmolarity of their body fluids, adjusting for water uptake or loss.
2. Animals excrete nitrogenous waste in the form of ammonia, urea, or uric acid.
3. In mammals, the kidneys are the principal organs of osmoregulation and excretion:



Hormones and Endocrine System (Ch. 45)

1. Hormones are transported throughout the body by the circulatory system and bind to receptors on or

in target cells. Negative feedback often regulates hormone levels.
2. In vertebrates, the hypothalamus and anterior pituitary control many other endocrine glands in maintaining homeostasis.

Animal Reproduction (Ch. 46)

1. Asexual reproduction can occur by fission, budding, regeneration, or parthenogenesis.
2. Fertilization (the union of sperm and egg) can be internal or external in sexual reproduction.
3. Human females produce eggs in ovaries and release them in a hormone-regulated cycle.
4. Human males produce vast numbers of sperm in testes and release them during ejaculation.
5. Placental mammalian embryos (eutherians) develop in a uterus.

Animal Development (Ch. 47)

1. Embryonic development occurs in three phases: cleavage, gastrulation, and organogenesis.
2. The extracellular matrix and cell adhesion molecules anchor and guide moving cells.
3. As embryonic development proceeds, the potential of cells becomes progressively more limited.
4. Cells in an embryo receive inductive signals that vary with location.

Neurons, Synapses, and Signaling (Ch. 48)

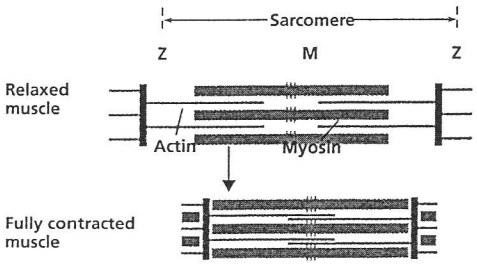
1. Information is transmitted through the nervous system by action potentials, strong membrane depolarizations that travel along an axon.
2. Neurons communicate with other cells at synapses, usually by releasing neurotransmitters.

Nervous Systems (Ch. 49)

1. The vertebrate nervous system consists of the peripheral nervous system (motor system and autonomic nervous system) and the central nervous system (spinal cord and brain).
2. The vertebrate brain is regionally specialized. The cerebral cortex controls cognitive functions.
3. Memory, learning, and nervous system disorders depend on molecular and structural changes.

Sensory and Motor Mechanisms (Ch. 50)

1. Sensory receptors convert the energy in environmental stimuli into a change in membrane potential.
2. Each receptor detects a type of stimulus, such as pressure, touch, sound, chemicals, light, or heat.
3. A muscle fiber contracts when thick filaments slide past thin filaments:

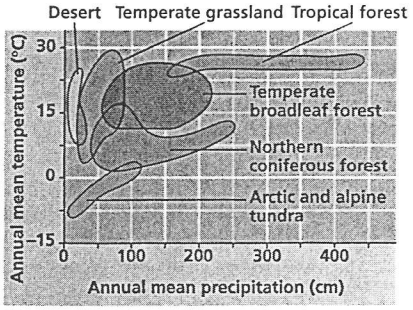


Animal Behavior (Ch. 51)

1. Behavior includes muscular and nonmuscular activity.
2. Both genes and the environment affect behavior.
3. Proximate causation is how a behavior occurs or is modified. Ultimate causation is why a behavior occurs in the context of natural selection.
4. Animal communication requires the transmission of, reception of, and response to signals, which may be visual, auditory, chemical, or tactile.
5. Learning is the modification of behavior based on specific experiences.
6. Both genetic and environmental factors can influence the development of behavior.
7. Natural selection favors behaviors that increase survival and reproductive success.
8. Altruism may increase the odds of contributing genes.
9. Social learning occurs when information is transferred in a population by observation and teaching of others.

Ecology and the Biosphere (Ch. 52)

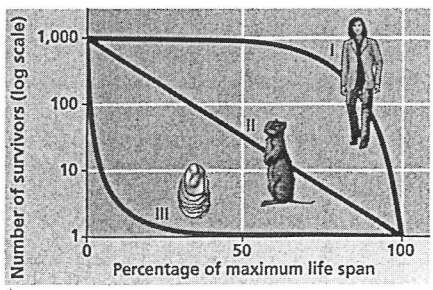
1. Ecology is the study of interactions between organisms and the environment.
2. Terrestrial biomes are characterized by climate and predominant vegetation:



3. Aquatic biomes are stratified in light penetration, temperature, and distance from shore.
4. The distribution of species is affected by habitat selection behavior and by biotic and abiotic factors.

Population Ecology (Ch. 53)

1. Population dispersion is the spacing of individuals. Dispersion may be clumped, uniform, or random.
2. Survivorship curves represent data in life tables:



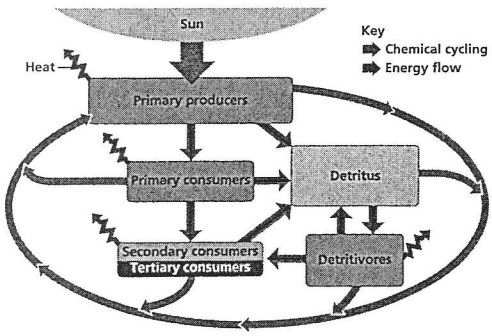
3. A population's growth rate (r) is the difference between its birth rate and death rate.
4. Exponential growth is expressed by $dN/dt = r_{max}N$, where dN/dt is the change in population size over time, r_{max} is the maximum rate of increase, and N is the number of organisms in the population.
   a. Population growth accelerates as N increases, resulting in a J-shaped growth curve.
   b. Exponential growth is characteristic of r-selection (density-independent selection).
5. Logistic growth is given by the equation $dN/dt = r_{max}N\,[(K - N)/K]$, where K is the carrying capacity of the environment.
   a. Population growth slows as N approaches K, resulting in a sigmoid (S-shaped) growth curve.
   b. Logistic growth is characteristic of K-selection (density-dependent selection).
6. Life histories may be characterized by semelparity or iteroparity.
7. Age structure predicts future population growth trends.

Community Ecology (Ch. 54)

1. A community is an assemblage of different species that have the potential to interact.
2. Interspecific interactions include competition, predation, herbivory, parasitism, mutualism, commensalism, and facilitation.
3. Community structure depends on the number and variety of species.
   a. Species diversity has two components: the number of species (species richness) and the relative abundance of the different species.
   b. Trophic structure is the feeding relationships of species as energy moves through food webs.
   c. Keystone species maintain species diversity by reducing populations of competing species.
   d. Ecosystem engineers affect community structure by changing the physical environment.
   e. Community control can be bottom-up (determined by nutrients and abiotic factors) or top-down (determined by predation effects).
4. Intermediate levels of disturbance can increase species diversity.
5. Ecological succession results from disturbance.
   a. Primary succession occurs where soil has not yet formed (for example, on a new volcanic island).
   b. Secondary succession occurs where soil is intact after a disturbance, such as a fire.
6. Biogeographic factors affect species diversity.
   a. Species richness decreases with latitude.
   b. On an island, species richness decreases with distance from the mainland and increases with the size of the island.
   c. Species richness is a balance between immigration and extinction.
7. Pathogens can alter community structure in terrestrial and aquatic ecosystems.

Ecosystems and Restoration Ecology (Ch. 55)

1. Energy and nutrients pass through trophic levels.
2. Primary production refers to autotrophic biomass.
3. Secondary production refers to animal biomass.
4. Energy transfer between trophic levels is typically only 10% efficient.



5. Restoration ecologists help return degraded ecosystems to a more natural state.

Conservation Biology and Global Change (Ch. 56)

1. Landscape and regional conservation help sustain biodiversity.
2. Earth is changing rapidly as a result of human actions.