AP Biology Exam Review Information

The AP Biology Exam puts your knowledge and understanding of modern biology to the test -- and gives you the chance to earn college credit before you're done with high school.

The AP Biology Exam consists of two sections: multiple choice and free response. Both sections include questions that assess students' understanding of the big ideas, enduring understandings, and essential knowledge and the ways in which this understanding can be applied through the science practices. These may include questions on the following:

- the use of modeling to explain biological principles;
- the use of mathematical processes to explain concepts;
- the making of predictions and the justification of phenomena;
- the implementation of experimental design; and
- the manipulation and interpretation of data.

The exam is 3 hours long and includes both a 90-minute multiple choice section and a 90-minute free-response section that begins with a mandatory 10-minute reading period. The multiple-choice section accounts for half of the student's exam grade, and the free-response section accounts for the other half.

THE FOUR BIG IDEAS OF AP BIOLOGY:

The key concepts and related content that define the AP Biology Exam are organized around a few underlying principles called the big ideas, which encompass the core scientific principles, theories and processes governing living organisms and biological systems.

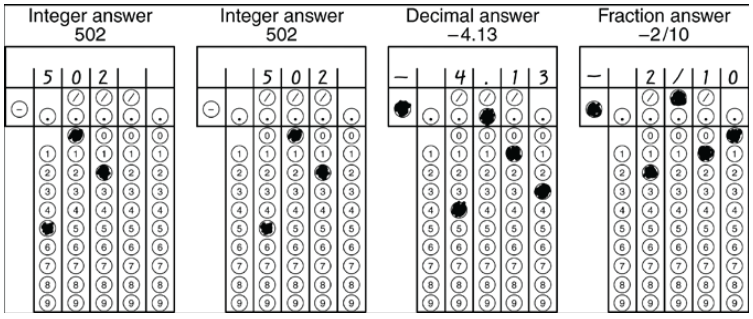
BIG IDEA 1: The process of evolution drives the diversity and unity of life. Evolution occupies a central position in the discipline of biology.

BIG IDEA 2: Biological systems utilize free energy and molecular building blocks to grow, to reproduce and to maintain dynamic homeostasis. Different organisms employ various strategies to capture, use, and store free energy and exchange matter with the environment.

BIG IDEA 3: Living systems store, retrieve, transmit and respond to information essential to life processes. Genetic information provides for continuity of life, and this information is passed from parent to offspring. Random changes in information allow for evolution, with natural selection acting upon phenotypes.

BIG IDEA 4: Biological systems interact, and these systems and their interactions possess complex properties. All biological systems are composed of parts that interact with one another and the environment, and these interactions result in characteristics not found in the individual parts alone.

Section I, Part A, consists of 63 multiple-choice questions that represent the knowledge and science practices outlined in the AP Biology Curriculum Framework that students should understand and be able to apply. Part B includes 6 grid-in questions that require the integration of science and mathematical skills. For the grid-in responses, students will need to calculate the correct answer for each question and enter it in a grid in the grid-in section on their answer sheet, as shown below.



In Section II, students should use the mandatory 10 minute reading period to read and review the questions and begin planning their responses. This section contains two types of free-response questions (short and long), and the student will have a total of 80 minutes to complete all of the questions.

Due to the increased emphasis on quantitative skills and application of mathematical methods in the questions on both sections, students will be allowed to use simple four-function calculators (with square root) on the entire exam. Students will also be supplied with a formula list as part of their testing materials.

A student's total score on the multiple-choice section is based on the number of questions answered correctly. Points are not deducted for incorrect answers or unanswered questions.

Exam Review Sessions

Review sessions for the AP Biology Exam will occur in room 301 on Tuesdays after school beginning on March 25th. During the week prior to the exam, we will have morning review sessions on Monday, Tuesday, Wednesday, and Friday. Although these review sessions are not required, it is highly recommended that you attend as many as possible.

During these sessions, students will be given the opportunity to ask questions concerning the material that is covered in the AP Biology Exam Review Packet, as well as the material covered this semester. We will also be discussing the format of the exam and reviewing some videos about the science practices that students will be expected to be able to demonstrate on the exam.

Review Session Schedule	
Tuesday, March 25th	3:15 pm – 4:15 pm
Tuesday, April 1st	3:15 pm – 4:15 pm
Tuesday, April 8th	3:15 pm – 4:15 pm
Tuesday, April 15th	3:15 pm – 4:15 pm
Tuesday, April 22nd	3:15 pm – 4:15 pm
Tuesday, April 29th	3:15 pm – 4:15 pm
Monday, May 5th	7:00 am – 7:30 am
Tuesday, May 6th	7:00 am – 7:30 am
Tuesday, May 6th	3:15 pm – 4:15 pm
Wednesday, May 7th	7:00 am – 7:30 am
Friday, May 9th	7:00 am – 7:30 am

AP Biology Exam Review Packet
AP Biology
Free Response Writing Tips

General Tips:

- One or more of the questions will likely be AP Lab-based. (See **"Tips for AP Lab Questions"** below.)
- You must write in paragraph form! There is room on the test for you to create an outline to guide your answer, but outlines are not graded. That being said, perfect essay writing is not expected. There are no deductions for grammar or spelling mishaps (provided the spelling is close enough to determine the word you are trying to write).
- Diagrams are helpful. However, if you draw a diagram, be sure to refer to it in your answer. You will not earn points for diagrams that stand by themselves.
- Points are not deducted from your score if you give an incorrect statement. You just do not receive points for incorrect statements. However, you must be careful not to contradict yourself. If you state something correctly but then later state the opposite, you will not earn the point.

Tips for AP Lab Questions:

- AP Lab Questions will often present an experiment setup very similar to one of the AP Labs you performed. Review each of the labs thoroughly before the exam.
- Remember to always reference an experimental control. Using an experimental control in an experiment involves setting up control groups that have not been affected by the experimental (independent) variable.
    - Controls are used so that an experimenter can compare the group that has changed to the group that stayed the same. In other words, control groups are not exposed to a chemical or treatment being investigated so that it can be compared with experimental groups that are exposed to the chemical or treatment
    - Control groups are useful to derive baseline measures or observations used for evaluating the effects of an experimental (independent) variable.
- In EVERY AP Lab Question, you should discuss the following information, even if the question does not specifically ask for it: (remember, you are never deducted for too much information, but keep it relevant):
    - State the testable hypothesis and identify it as such.
    - State the control group.
    - State the independent (experimental) and dependent (measured) variable(s). (*Example: If you decide to measure the product of an enzymatic reaction at different times, then time is the independent variable and product concentration is the dependent variable.*)
    - Identify other variables being held constant. (*Example: amount of time, stirring, temperature, etc.*)
    - State how and when data will be collected or observations made. (*Example: measure mass after 3 minutes*)
    - State what calculation will be used. (*Example: average 3 values for mass, write out formulas used*)
    - State how you will be confident in your results. (*Example: repeat trials, using a large sample size, etc.*)
    - State how you will share your results. (*Example: tables, graphs, drawings, etc.)*
    - State what you expect to happen and why.
- We will do practice AP Test Lab questions so that all of this will seem a breeze! Nevertheless, it is a good idea to practice on your own with an AP Biology Exam practice book to prepare.

Students who pass with an 80% or better on the multiple choice section of the test and earn 50% or better of the points on their free responses, usually earn 5s on the exam. An overall score of 50% combined (multiple choice and free response) usually earns a score of 3 or above.

DOS and DON'TS on Exam Day

DO THIS on Exam Day:

- **DO** use your ten minute reading time advantageously. Carefully read all of free response questions and map out your answers. These maps will NOT be graded, but you can use them to write your responses.
    - Read the prompt thoroughly, then read the prompt again, then read the prompt, then read the prompt again, then read the prompt, then…
    - Jot down the big ideas. Make sure you clearly understand what you are being asked to do.
    - Use this time to create a mindmap or bullet points of the main terms you want to elaborate on.
    - Outline your answer to organize your thoughts.
    - Remain focused and on task.
- **DO <u>underline</u> the important terms** in the question such as "OR" and "CHOOSE 2"and the power verbs such as "DESCRIBE," "IDENTIFY," "LABEL," "CONSTRUCT," "DESIGN," or "EXPLAIN."
- **DO** use the **80 minutes** to write thorough responses to all of the free response questions.
- **DO** stay focused on what the prompt is requiring you to do—it is all in the format of the question and how it is worded. Pay particular attention to words like these:
    - **Discuss:** give reasoning pro and con; analyze carefully
    - **Analyze:** summarize in detail with a selected focus
    - **Explain:** clarify and interpret; give reasons for differences, analyze causes
    - **Compare/contrast:** emphasize similarities and differences
    - **Relate:** show how ideas or concepts are connected to each other
- **DO** use the outline, mindmap or bullet points that you developed during the 10 minute reading time.
- **DO** write as legibly as possible, using **black** ink. If the person scoring your answers cannot read what you have written, then you will not earn any points.
- **DO** answer in the format of the question so that you do not slow the reader down.
    - Use the format of the free response to write your answer so that the reader has an easy time finding your responses to each section of each question.
    - Organize the free response questions using the format of the question—write '1a' then respond to 1a; write '1b' then respond to 1b, etc…
    - It is best not to skip around when responding to sub-questions in one question.
- **DO** apply the language of science, show depth, elaboration, and give examples.
    - Pull, tie, link and loop together your ideas—show how ideas connect.
    - Use a scientific term and then explain what it means.
    - Write for clarity, accuracy, thoroughness, and breadth (not just factual regurgitation).
- **DO** use graphs or diagrams when it will enhance your response. However, unless the prompt specifically asks for drawings/graphs, every thought you convey should also be put in writing.
- **DO** clearly mark your answer sheet with the free response question you are answering. The free response questions do not have to be answered in any particular order, as long as they are clearly marked. Write freely on the response sheet—use several sheets as needed. Usually the longer the answer to the question the more points you will earn! Write! Write! Write!
- **DO** answer ALL subunits of a question thoroughly—to ensure you will gain maximum points for your response.
- **DO** label all graphs correctly.
    - Include a graph title.
    - Include a key identifying lines and data points.
    - Label axes (including units).
- **DO** use the time at the end to re-read responses—underlining key concepts, checking for clarity, accuracy and thoroughness.

DON'T DO THIS on Exam Day:

- **DON'T** leave any free responses questions blank.
    - Even if the question seems odd or you draw a temporary blank, find the "core biological topic" being addressed and elaborate on it.
    - Remember that all students in the nation will be in the same boat with a difficult or unclear question.
- **DON'T** obsess over correct grammar. There are no deductions for grammatical imperfections.
- **DON'T** write introductory or closing paragraphs. No points are earned for thesis statements or topic sentences.
- **DON'T** ramble. Get to the point. Do not waste time describing your feelings about how glad you are that the AP College Board asked you about photosynthesis. If anything, this will annoy the reader.
- **DON'T** write only in outline format. Your answers must be in paragraph form.
- **DON'T** over-answer the sub-questions of a free response question.
    - Remember that for any given question requiring sub-question responses, each response is allotted a maximum number of points. Writing more than is necessary will not earn you more points.

AP Biology Equations and Formulas

Statistical Analysis and Probability

Standard Error

$$SE_{\bar{x}} = \frac{s}{\sqrt{n}}$$

Mean

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Standard Deviation

$$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$$

Chi-Square

$$\chi^2 = \sum \frac{(o-e)^2}{e}$$

s = sample standard deviation (i.e., the sample based estimate of the standard deviation of the population)

$\bar{x}$ = mean

n = size of the sample

o = observed individuals with observed genotype

e = expected individuals with observed genotype

Degrees of freedom equals the number of distinct possible outcomes minus one.

Chi-Square Table

	Degrees of Freedom							
p	1	2	3	4	5	6	7	8
0.05	3.84	5.99	7.82	9.49	11.07	12.59	14.07	15.51
0.01	6.64	9.32	11.34	13.28	15.09	16.81	18.48	20.09

Laws of Probability

If A and B are mutually exclusive, then P (A or B) = P(A) + P(B)

If A and B are independent, then P (A and B) = P(A) x P(B)

Hardy-Weinberg Equations

$p^2 + 2pq + q^2 = 1$

$p + q = 1$

p = frequency of the dominant allele in a population

q = frequency of the recessive allele in a population

Metric Prefixes

Factor	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Mode = value that occurs most frequently in a data set

Median = middle value that separates the greater and lesser halves of a data set

Mean = sum of all data points divided by number of data points

Range = value obtained by subtracting the smallest observation (sample minimum) from the greatest (sample maximum)

AP Biology Equations and Formulas

Rate and Growth

Rate

$\frac{dY}{dt}$

Population Growth

$\frac{dN}{dt} = B - D$

Exponential Growth

$\frac{dN}{dt} = r_{max} N$

Logistic Growth

$\frac{dN}{dt} = r_{max} N \left(\frac{K - N}{K}\right)$

dY= amount of change

t = time

B = birth rate

D = death rate

N = population size

K = carrying capacity

r_{max} = maximum per capita growth rate of population

Water Potential (Ψ)

$\Psi = \Psi_p + \Psi_s$

Ψ_p = pressure potential

Ψ_s = solute potential

The water potential will be equal to the solute potential of a solution in an open container, since the pressure potential of the solution in an open container is zero.

The Solute Potential of the Solution

$\Psi_s = -iCRT$

i = ionization constant (For sucrose this is 1.0 because sucrose does not ionize in water)

C= molar concentration

R= pressure constant (R = 0.0831 liter bars/mole K)

T = temperature in Kelvin (273 + °C)

Temperature Coefficient Q_{10}

$Q_{10} = \left(\frac{k_2}{k_1}\right)^{\frac{10}{t_2 - t_1}}$

Primary Productivity Calculation

mg O_2/L x 0.698 = mL O_2/L

mL O_2/L x 0.536 = mg carbon fixed/L

t_2 = higher temperature

t_1 = lower temperature

k_2 = metabolic rate at t_2

k_1 = metabolic rate at t_1

Q_{10} = the *factor* by which the reaction rate increases when the temperature is raised by ten degrees

Surface Area and Volume

Volume of Sphere

$V = 4/3\ \pi r^3$

Volume of a cube (or square column)

$V = l\ w\ h$

Volume of a column

$V = \pi r^2 h$

Surface area of a sphere

$A = 4\ \pi r^2$

Surface area of a cube

$A = 6\ a$

Surface area of a rectangular solid

$A = \Sigma$ (surface area of each side)

r = radius

l = length

h = height

w = width

A = surface area

V = volume

Σ=Sum of all

a = surface area of one side of the cube

Dilution - used to create a dilute solution from a concentrated stock solution

$C_i V_i = C_f V_f$

i=initial (starting) C = concentration of solute

f=final (desired) V = volume of solution

Gibbs Free Energy

$\Delta G = \Delta H - T\Delta S$

ΔG = change in Gibbs free energy

ΔS = change in entropy

ΔH = change in enthalpy

T = absolute temperature (in Kelvin)

pH $= -\log [H^+]$

AP Biology - AP Exam Review

Chapter 1 - Exploring Life

Biology – the scientific study of life

Characteristics of Living Organisms (life is impossible to define)
1. Highly ordered structure
2. Evolutionary adaptation
3. Response to the environment (irritability)
4. Regulation (homeostasis, constant body temperature for warm-blooded organisms)
5. Energy processing
6. Reproduction
7. Growth and development (DNA goes along with this)

Levels of Biological Organization (either direction – simplest to complex or vice versa)
1. **Biosphere** – the area around the earth where living organisms are found)
2. **Ecosystems** – consists of all the living thins in a particular area, along with all the nonliving components with which living organisms interact
3. **Communities** – the entire array of organisms inhabiting a particular ecosystem
4. **Population** – all the individuals of a species living within the bounds of a specified area
5. **Organisms** – individual living things are called organisms
6. **Organs and Organ Systems** – an organ is a body part consisting of 2 or more tissues; an organ system is a team of organs that cooperate in a specific function
7. **Tissues** – a tissue is a group of similar cells
8. **Cells** – the basic unit of structure and function of all living things
9. **Organelles** – the functional components that make up cells
10. **Molecules** – a molecule is a chemical structure consisting of two or more small chemical units called atoms

Ecosystem Dynamics – Two Major Processes
1. Cycling of nutrients
2. Flow of energy from sunlight to producers (plants and other photosynthetic organisms that convert light energy to chemical energy) to consumers (feed on producers and other consumers)

Systems Biology - seeks to create models of the dynamic behavior of whole biological systems. With such models, scientists are able to predict how a change in one part of the system will affect the rest of the system

Feedback Regulation
1. In negative feedback, accumulation of an end product slows the process that produces the product
2. In positive feedback, the end products speeds up its production

Discovery Science - describes natural structures and processes as accurately as possible through observation and data analysis

Inquiry – a search for information often focusing on a specific question

Inductive Reasoning – generalizations based on a large number of specific observations

Deductive Reasoning – start with generalizations and move to specifics (If….then)

Scientific Method

Independent Variable – tested - x-axis
Dependent Variable – measured – y-axis

Themes That Unify Biology

1. The cell
2. Heritable information
3. Emergence of biological systems
4. Regulation
5. Interaction with the environment
6. Energy and life
7. Unity and diversity
8. Evolution
9. Structure and function
10. Scientific inquiry
11. Science, technology, and society

Chapter 2 - The Chemical Context of Life ("simple chemistry")

Matter – anything that takes up space and has mass

Element – a substance that cannot be broken down to other substances by chemical reactions – 92 naturally occurring elements

Compound – two or more different elements combined in a fixed ratio

Essential Elements (O, C, H, N, Ca, P, K, S, Na, Cl, and Mg)

Trace Elements – required in small quantities

Atom – smallest unit of matter that still retains the properties of an element, composed of protons, neutrons, & electrons

Atomic Number = number of protons
Atomic Mass = protons + neutrons

Isotope – same element with different number of neutrons

Valence Electrons – involved in bonding – outermost "s" and "p"

Electron Orbital – where an electron has a strong chance of being located

Chemical Bond – holds atoms together

Covalent Bond – sharing of pairs of valence electrons (single, double, and triple bonds)

Polar vs Nonpolar Bonds – due to unequal sharing of electrons

Ionic Bond – electrostatic attraction between a positive and negative ion

Hydrogen Bond - relatively weak attraction between H in one molecule (or part of a molecule) with F, O, or N in another molecule (or part of a molecule)

Van der Waals Forces - dispersion forces, IMF's

The structure of a molecule determines the function of the molecule.

Chemical Reaction – the making and breaking of chemical bonds, leading to changes in the composition of matter. The transformation of reactants into products

Chapter 3 - Water and the Fitness of the Environment
Structure of water – the polarity of the molecule leads to the unique characteristics of water

Why is water so important to living organisms?
1. Cohesive
2. Adhesive
3. Evaporative coolant
4. Less dense as a solid than as a liquid
5. Good solvent
6. High specific heat

$H_2O \rightarrow H^+ + OH^-$ (Dissociation of a water molecule - this is the basis of acids and bases)

Acid – increases the H^+ concentration of a solution
Base – reduces the H^+ concentration of a solution

pH scale - based on the $[H^+]$
- log scale (pH of 14 = 10^{-14} – pH of 1 = 10^{-1})
- pH of 7 is considered neutral, 1-7 is acidic, and 8–14 is alkaline or basic
- going down the scale (from base to acid), the $[H^+]$ concentration increases 10x
- the pOH scale would be based on the concentration of the OH^- ion
- A buffer keeps the pH constant by shuffling H^+ (release of these ions makes things more acidic, pick up of these ions makes the solution more basic)

Chapter 4 - Carbon and the Molecular Diversity of Life
Organic chemistry is carbon-based because carbon can bond with up to 4 other atoms. Carbon skeleton or carbon backbone leads to a variety of structures – carbon can form single bonds, double bonds, triple bonds, straight chain molecules, branching molecules, and rings.

Hydrocarbons - molecule that consists only of carbon and hydrogen (major components of fossil fuels, fats and phospholipids have hydrocarbon tails)

Isomers - molecules that have the same structural formula but different arrangement of molecules

Functional Groups (See Figure 4.10 on pp. 64-65): Know the structure and functional properties of the following: Hydroxyl, Carbonyl, Carboxyl, Amino, Sulfhydryl, Phosphate

Chapter 5 - The Structure and Function of Macromolecules

Monomer - building block unit

Polymer - many monomers joined together

Dehydration Synthesis or Condensation Reactions – a building process – monomers are joined together – a molecule of water is removed in the process

Hydrolysis Reactions – a break-down process – polymers are broken into monomers through the addition of a molecule of water

Carbohydrates – sugars and polymers of sugars. Characterized by the presence of multiple hydroxyl groups and a carbonyl group.
- If the carbonyl group is at an end, the sugar is an aldose sugar because of the presence of an aldehyde.
- If the carbonyl group is in the middle, the sugar is a ketose sugar because of the presence of a ketone.

Monosaccharide – simple sugar – generally has a formula that is a multiple of the unit CH_2O
A simple sugar typically has 3 – 7 carbons in its carbon skeleton
Glucose ($C_6H_{12}O_6$) is the most common monosaccharide

Disaccharide – combination of two monsaccharides held together with a glycosidic linkage - covalent bond between two monosaccharides formed by dehydration synthesis.

Polysaccharide – many monosaccharides bonded together
- **Starch** – plant energy storage
- **Glycogen** – animal energy storage
- **Cellulose** – structural carbohydrate, major component of a cell wall
- **Chitin** – structural carbohydrate, major component of arthropod exoskeletons, also found in the cell walls of fungi

Lipids - no affinity for water – mostly hydrocarbons – important storage molecule for cells

Fats – made up of glycerol and fatty acids

Fatty Acids – saturated or unsaturated
- **Saturated Fatty Acids** - contain maximum number of hydrogen atoms, are typically from animals, and are solids at room temperature.
- **Unsaturated Fatty Acids** - have some double and triple bonds, are typically from plants, and are liquids at room temperature.

Phospholipid – one of the fatty acids of a triglyceride is replaced by a phosphate group – major component of cell membranes

Steroid – carbon skeleton made up of 4 fused rings

Cholesterol – component of animal cell membrane – precursor of many other hormones

Proteins – made of 20 different amino acids joined by peptide bonds (also called "polypeptides")

Functions of Proteins
1. Structural components
2. Enzymes
3. Hormones
4. Storage
5. Transport (through membranes)
6. Defense proteins
7. Receptor proteins

Levels of Protein Structure
- **Primary** – chain of amino acids (as the protein is formed on the ribosome)

- **Secondary** – result of hydrogen bonding between the components of the polypeptide backbone (Alpha helix & Beta pleated sheet)

- **Tertiary Structure** – result of interactions between the components of the "R" chain (van der Waals forces, hydrophobic interactions, etc.)

- **Quarternary Structure** – results from the aggregation of polypeptide subunits

Denaturation - proteins are denatured (broken down) by heat, acids, and high ion concentrations

Chapter 6 - A Tour of the Cell

Cell Theory
1. The cell is the basic unit of structure and function of all living organisms.
2. Everything is made up of cells.
3. Cells come from other cells as the result of cell division.

Microscopy
- Magnification – ratio of the objects image to its real size
- Resolution – measure of the clarity of the image

Light Microscope – visible light is passed through the specimen and through glass lenses which bend the light rays in such a way that the image is magnified as it is projected onto the eye.
Light microscopes are limited to around 1000X magnification - limited by the shortest wavelength used to illuminate the specimen.

Electron Microscope – focuses a beam of light through or on the surface of the specimen
- SEM – scanning electron microscope – study details of the surface of the specimen
- TEM – transmission electron microscope – study the internal ultrastructure of a specimen

Cell Fractionation – uses an ultracentrifuge to take cells apart and separate the major organelles

Eukaryotic vs. Prokaryotic Cells (study this – it is often on the test in some form)

All cells have a plasma membrane, cytosol (cytoplasm), chromosomes, and ribosomes	
Prokaryotic Cells	**Eukaryotic Cells**
Lack a nucleus	Chromosomes in a membrane-bound nucleus
Lack membrane-bound organelles	Membrane-bound organelles
Single, circular chromosome	Linear chromosomes
Both have a cell wall, cilia, and flagella, but the structures are different	

Surface-to-volume ratio - cells are limited in size by the fact that the internal volume increases more rapidly that the surface area of the cell membrane

Cell Structures/Organelles:

- **Nucleus** – control center of the cell – contains the chromosomes/DNA

- **Nuclear Membrane or Envelope** – separates the nucleus from the cytoplasm – selective

- **Nucleolus** – dark-staining body in the nucleus where ribosomes are formed

- **Ribosomes** – site of protein synthesis

- **Endomembrane System (also called Cytomembrane System)** – synthesis of proteins and their transport in and out of the cell – metabolism and movement of lipids – detoxification of poisons
    - **Endoplasmic Reticulum** – extension of the membranes throughout the cytoplasm – a network of membranes and sacs called cisternae
        A. **Rough** – ribosomes found in the folds
        B. **Smooth** – lacks the ribosomes

    - **Golgi apparatus** – modifies, stores, and ships proteins

    - **Vessicles** – membrane-bound – transport materials throughout cytoplasm

- **Lysosomes** – digest and destroy

- **Vacuoles** – fluid-filled container – carries out hydrolysis – food vacuoles (formed by phagocytosis), contractile vacuoles (pump out excess water), large central vacuole (plant cell – membrane around it is called the tonoplast)

- **Mitochondria** – site of cellular respiration

- **Chloroplast** – site of photosynthesis

- **Peroxisomes** – contain enzymes that transfer hydrogen from various substrates to oxygen, producing hydrogen peroxide as a by-product

- **Cytoskeleton** – gives a cell shape, mechanical support and allows for movement
    - **Microtubles** – made up of tubulin subunits – maintains cell shape, cell motility (cilia and flagella, chromosome movement during mitosis and meiosis, organelle movement

    - **Microfilaments** – made up of actin subunits – maintains cell shape, changes in cell shape, muscle contractions, cytoplasmic streaming, cell movement (pseudopods), and cell division

    - **Intermediate Filaments** – fibrous proteins supercoiled into thicker cables – maintains cell shape, anchors the nucleus and certain other organelles

- **Centrosome** – microtubules grow from this – pair of centrioles

- **Cilium** – short structures projecting from a cell and containing bundles of microtubules that move a cell through its surroundings or move fluid over the cell's surface

- **Flagellum** - long, thin, whip-like structures, with the same core of microtubules as cilia

- Both cilia and flagella are composed of a special arrangement of microtubules – 9 + 2 arrangement (nine pairs of microtubules arranged around a central pair). The surrounding microtubules are linked to the neighboring pairs by dynein arms – the cilia "beats." When the dynein arm "walks" up the neighboring microtubule, causing it to bend.

- **Plant Cell Wall** – protects, maintains shape, and prevents excess water intake – although the structure varies, it is primarily composed of cellulose

- **Plasmodesmata** – openings between adjacent plant cells that allows materials to pass back and forth

- **Extracellular matrix (animal cells)**
    - **Glycoproteins** - collagen is the most abundant

    - **Fibronectin** -bind to cell surface receptors

    - **Integrins** - span the cell membrane and bind to microfilaments of the cytoskeleton)

- **Tight Junction** – the membranes of neighboring cells are very tightly pressed against each other, bound together by specific proteins

- **Desmosomes** – anchoring junctions that fasten cells together in strong sheets

- **Gap junction** – communicating junctions that provide cytoplasmic channels from one cell to the adjacent cell

Chapter 7 - Membrane Structure and Function

Phospholipid bilayer - double layer – hydrophobic tails and hydrophilic heads (referred to as an "amphipathic" molecule)

Fluid Mosiac Model of the Cell Membrane

1. **Fluid** – phospholipids in the membrane are is motion, changing places, switching sides – unsaturated "tails" in the hydrophobic area increase fluidity by preventing the molecules from packing together – cholesterol in the membrane decreases fluidity

2. **Mosaic** – there are many proteins embedded in the membrane
- **Integral Proteins** – penetrate the membrane
- **Peripheral Proteins** – not embedded, but loosely bound to the membrane surface
- **Transport Proteins** – span the membrane – serve as a channel for the movement of certain materials through the membrane
- **Enzyme Activity Proteins** – proteins built into the membrane may be enzymes with the active site available for a reaction to take place
- **Signal Transduction Proteins** – binding site for a chemical messenger
- **Cell-cell Recognition Proteins** – identification tags
- **Intercellular Joining Proteins** – hook cells together - adhesion
- **Attachment Proteins** – connect the cytoskeleton to the extracellular matrix

3. **Membrane Carbohydrates**
- Glycolipids and glycoproteins help in cell recognition

Passes easily through a cell membrane: carbon dioxide, oxygen, nonpolar molecules that would dissolve the hydrophobic (fat) layer

Does not pass easily through a cell membrane: polar molecules, ions, complex molecules, transport molecules have to move these through

Diffusion – movement of a substance from an area of high concentration to an area of low concentration – down a concentration gradient

Osmosis – diffusion of water through a semipermeable membrane

Tonicity – the ability of a solution to cause a cell to gain or lose water
The following terms are relative to each other:

- **Isotonic** – interior and exterior of cell have the same concentration – equal exchange of water molecules

- **Hypertonic** – high concentration of solute, low water – tends to gain water

- **Hypotonic** – low concentration of solute, high water – tends to lose water

Osmoregulation – the control of water balance

In a **hypotonic** environment, an animal cell would gain water. Enough water could cause the cell to burst (contractile vacuoles are adaptations to remove this excess water). Because of the cell wall, and a plant cell stiffens (turgor pressure) too much excess water simply flows back out because of the cell wall.

In a **hypertonic** environment, both plant and animal cells would shrink (plasmolysis)

Facilitated Diffusion – certain substances enter and leave the cell because of the assistance of transport proteins (energy is not required in either case)

- **Channel Proteins** simply serve as a pathway through which these molecules travel
- **Carrier Proteins** shuttle molecules through the membrane because of a change in the shape of the protein

Active Transport – requires energy and is typically through a membrane protein – often from a lower concentration to a higher concentration

Sodium-Potassium Pump – requires ATP, which bonds (one of the phosphate groups) to the channel protein and changes its shape – 3 sodium ions are pumped to the outside and are released – the phosphate group is released, allowing two potassium ions to enter the channel and move into the cell

Proton Pump – the movement of hydrogen ions through the membrane against the concentration gradient

Coupled Transport – The movement of hydrogen ions gives the energy for other molecules to move back into the cell

Endocytosis – the movement of large molecules through a cell membrane – engulfed

Exocytosis – the release of large molecules by a cell

Chapter 8 - An Introduction to Metabolism

Metabolism – all of the chemical reactions in an organism

Metabolic Pathways – a sequence of events, each controlled by an enzyme, that converts a specific molecule to a product – through these pathways the cell transforms and creates organic molecules that provide the energy and material needed for life

Catabolic Pathways – release energy stored in complex molecules through the breaking down these molecules into simpler compounds

Anabolic pathways (biosynthetic pathways) – require energy to combine simpler molecules into more complex molecules – fueled by the energy that is released in catabolic pathways

Bioenergetics – study of how organisms transform energy

Energy – capacity to cause change (some types of energy can do work)

- **Kinetic Energy** – energy of motion
- **Heat or Thermal Energy** – the kinetic energy of randomly moving molecules
- **Potential Energy** – the capacity of matter to cause change as a consequence of its location or arrangement
- **Chemical Energy** – a form of potential energy stored in the arrangement of atoms in molecules and available for release in chemical reactions

Thermodynamics – the study of energy transformations

- **First Law of Thermodynamics** – energy cannot by created or destroyed, it can only change form – the total energy in the universe remains constant
- **Second Law of Thermodynamics** – every energy transformation or transfer results in increasing disorder in the universe (entropy is the measure of disorder)

In every energy transfer or transformation, some of the energy is converted to heat, the lowest form of energy. For a process to occur spontaneously (without the input of external energy) it must result in an increase in entropy. A nonspontaneous process will occur only if energy is added to a system.

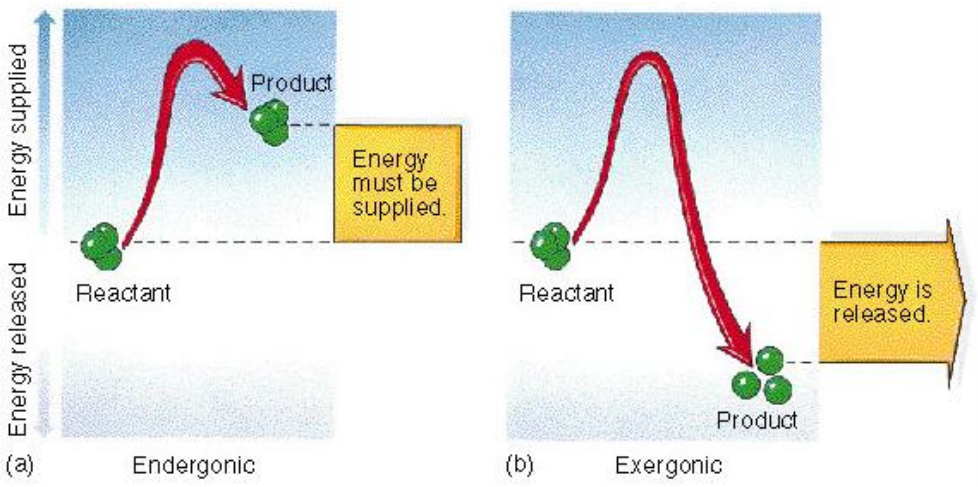
An organism may become more ordered as it develops, but it does so with an increase in the entropy in its surroundings. An organism takes in and uses highly ordered organic molecules as a source of energy. It returns heat and the simple molecules of carbon dioxide and water to the environment.

Free Energy – the portion of a system's energy available to perform work when the system's temperature and pressure are constant.

- When ΔG is negative, the final state has less free energy than the initial state; thus the final state is less likely to change and is more stable. A system rich in free energy has a tendency to change spontaneously to a more stable state.

Exergonic Reaction – same as exothermic (-ΔG) proceeds with a net release of free energy and is spontaneous

Endergonic Reaction – same as endothermic (+ΔG) are nonspontaneous – they must absorb free energy from the environment

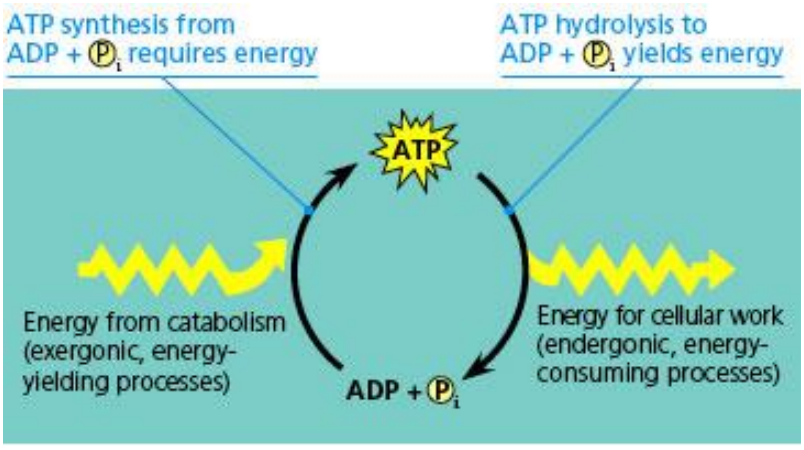


Energy Coupling – using exergonic processes to power endergonic processes

ATP (adenosine triphosphate) – consists of the nitrogenous base adenine connected to the a ribose sugar and a chain of 3 phosphate groups

In a cell, the free energy released from the hydrolysis of ATP is used to transfer the phosphate to another molecule, producing a phosphorylated molecule that is more reactive. The phosphorylation of molecules by ATP forms the basis for almost all cellular work.

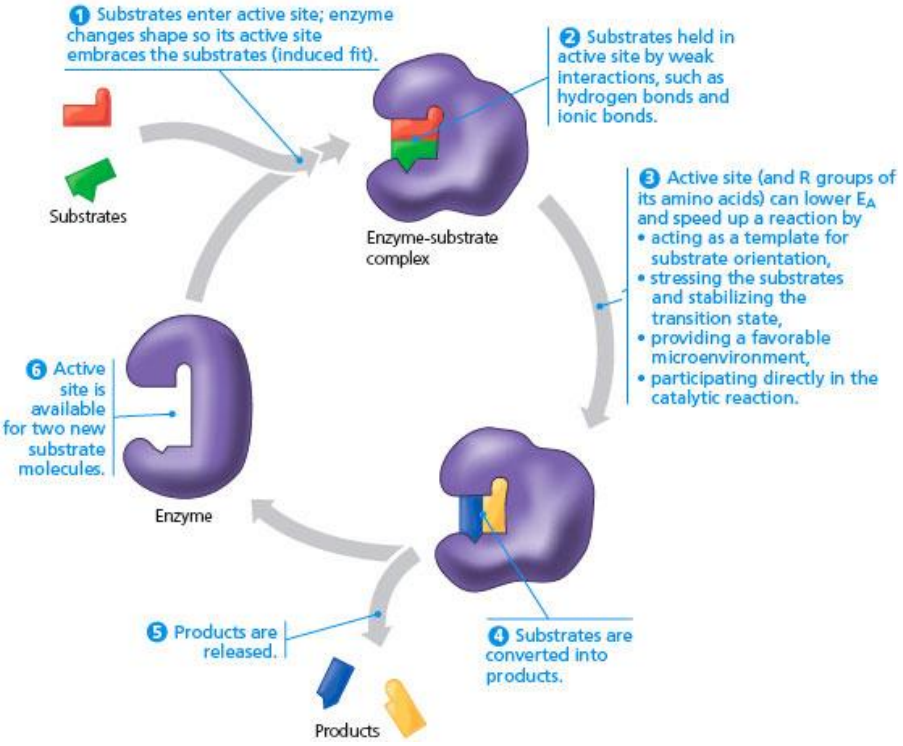
ATP → ADP Cycle



Enzymes – biological catalysts that speed the rate of a reaction but are unchanged by the reaction

Activation Energy (Free Energy of Activation) – the energy required to start the reaction

Enzyme-Substrate Model



Cofactors – small molecules that bind with enzymes are necessary for the enzyme to function

Coenzymes – organic molecules that are cofactors

Inhibitors – disrupt the action of the enzyme
- **Competitive Inhibitors** – compete with the substrate for the active site of the enzyme
- **Noncompetitive Inhibitors** – bind to an part of the enzyme away from the active site and change the formation of the enzyme, thus slowing or stopping the action of the enzyme

Allosteric Regulation – molecules inhibit or activate by binding to a site other than the active site

Chapter 9 - Cellular Respiration: Harvesting Chemical Energy

Fermentation – occurs without oxygen and is the partial breakdown (degradation) of sugars and release of energy

Cellular Respiration - uses oxygen in the breakdown of sugars, producing energy, heat, carbon dioxide, and water

Write the Equation for Cellular Respiration (you should have this memorized!):

Oxidation-Reduction Reactions (Redox Reactions) - involve the partial or complete transfer of one or more electrons from one reactant to another

- **Oxidation** - the loss of electrons
- **Reduction** - the addition of electrons
- The substance that loses electrons becomes oxidized and acts as a reducing agent (electron donor) to the substance that gains electrons. By gaining electrons, a substance acts as an oxidizing agent (electron acceptor) and becomes reduced.
- Oxygen strongly attracts electrons and is a powerful oxidizing agent. As electrons shift toward a more electronegative atom, they give up potential energy. Chemical energy is released in a redox reaction that shuffles electrons closer to oxygen. Organic molecules that contain many hydrogen atoms are rich in "hilltop" electrons that release their potential energy when they "fall" closer to the oxygen.
- At certain stages in the oxidation of glucose, 2 hydrogen atoms are removed by enzymes called dehydrogenases – 2 electrons and a proton are picked up by the coenzyme **NAD^+** (nicotinamide adenine dinucleotide) – it is reduced to **NADH**.

Cellular Respiration Takes Place in 3 Stages:

1. **Glycolysis** - occurs in the cytoplasm (outside the mitochondria) - Glycolysis is common to fermentation and respiration. It probably evolved in ancient prokaryotes before oxygen was present.

2. **Krebs or Citric Acid Cycle** - occurs in the matrix of the mitochondria

3. **Electron Transport Chain and Chemiosmosis (Oxidative Phosphorylation)** - occurs in the inner membranes of the mitochondria

Glycolysis – Glucose is broken down into 2 molecules of pyruvate. An energy input of 2 molecules of ATP is required to start the process – 4 molecules of ATP are produced, for a net gain of molecules of ATP. The ATP is produced by substrate level phosphorylation, in which an enzyme transfers a phosphate group from the substrate to ADP. In addition, 2 NADH are produced.

Input: glucose, 2 ATP, 2 ADP, and 2 NAD^+

Output: 2 pyruvate (pyruvate is a 3C molecule), 4 ATP, and 2 NADH

Acetyl-CoA Formation: A carboxyl group is removed from each pyruvate molecule and is released as carbon dioxide. The remaining acetate molecule is picked up by coenzyme A, forming **acetyl-CoA.** NAD^+ picks up electrons and a hydrogen ion to form NADH.

Input: 2 pyruvate, 2 NAD^+, 2 CoA

Output: 2 acetyl-CoA, 2 NADH, and 2 CO_2

Citric Acid Cycle or Krebs Cycle: One molecule of acetyl CoA enters the citric acid cycle. The 2-carbon fragment of acetyl CoA attaches to the 4-carbon molecule oxaloacetate in the first reaction of the cycle. This forms citrate. In a series of steps, bonds break and reform. Two carbon atoms are released, one at a time, in molecules of carbon dioxide. Electrons are carried off by molecules of NADH and FADH2. One step produces an ATP molecule by substrate-level phosphorylation. A 4-carbon oxaloacetate molecule is regenerated. Since two acetyl CoA molecules are produced for each glucose molecule broken down, a second acetyl CoA enters the citric acid cycle. The same series of reactions occurs, releasing carbon dioxide and producing more NADH, FADH2, and ATP. The cell has gained two ATPs that can be used directly. However, most of the energy originally contained in the bonds of glucose is now carried by the NADH and FADH2 molecules.

Input: 2 acetyl-CoA, 2 ADP, 4 NAD^+, and 2 FAD (flavin adenine dinucleotide)

Output: 4 CO_2, 2 ATP, 4 NADH, and 2 $FADH_2$

Oxidative Phosphorylation – Occurs in Two Parts

Part 1 - Electron Transport Chain: Electron transport chains are embedded in the cristae (infolding of the inner mitochondrial membrane). Most of the chain consists of proteins with tightly bonded nonprotein prosthetic groups. The electron carriers shift between reduced and oxidized states as they accept and donate electrons. The electrons are donated from NADH and $FADH_2$. At the end, the electrons are passed to oxygen which also picks up H ions. These combine and are released as water. One of the groups of carrier molecules in the membrane is called "cytochrome."

Part 2 - Chemiosmosis: A protein complex embedded in the inner membrane accepts the hydrogen ions from NADH and $FADH_2$. The H ions are "pumped" through the membrane. These build up in a high concentration (a proton gradient that can be referred to as the proton-motive force). The hydrogen ions move through a protein channel with ATP synthase, forming ATP.

Input: 8 NADH, 2 $FADH_2$, O_2

Output: 34 ATP, 8 NAD^+, 2 FAD, H_2O

Fermentation – anaerobic respiration – generates ATP by substrate level phosphorylation of glucose, resulting in the formation of 2 ATP and the regeneration of NAD^+, the oxidizing agent for glycolysis

Alcoholic Fermentation – pyruvate (the product of glycolysis) is converted into acetaldehyde and then ethanol. CO_2 is released (the 2 ATP of glycolysis are produced)

Lactic Acid Fermentation – pyruvate is broken down to form lactic acid (ATP from glycolysis). Muscle cells make ATP by this process when energy demand is high and the oxygen supply is low.

Fats, Proteins, and Carbohydrates Can All be Used by Cellular Respiration

- Proteins – broken to amino acids – amine group removed – can enter respiration in several locations
- Fats – broken into glycerol, which is converted into an intermediary in glycolysis, and fatty acids, which enter the citric acid cycle as acetyl-CoA
- The carbon skeletons of food molecules are used in biosynthesis

Chapter 10 - Photosynthesis

Autotrophs – "self-feeders" – make their own organic molecules from inorganic raw materials

Heterotrophs – consumers

Write the Equation for Photosynthesis (you should have this memorized!):

In the leaf of a plant, **chlorophyll** is found predominantly in the mesophyll cells. **Carbon dioxide** enters the leaf and **oxygen** exits through an opening called the **stomata**. **Wate**r is delivered to the leaves through veins (specifically, the xylem) and the **products of photosynthesis** are distributed through these veins (specifically, the phloem).

The chloroplast consists of a membrane system called the **thylakoid membrane system**. Part of the process of photosynthesis takes place in the inner membrane space. Thylakoid sacs stacked on top of each other are referred to as the **grana**. The fluid surrounding the thylakoid is the **stroma**.

It was determined experimentally (by C.B. van Neil) that water is the source of hydrogen ions and electrons and that the water provides the oxygen that is released in photosynthesis.
Sunlight - Electromagnetic energy (radiation) travels as rhythmic wave disturbances of electrical and magnetic fields. The distance between the crests (or troughs) of waves is the wavelength.

The **electromagnetic spectrum** consists of short gamma rays to long radio waves. Visible light is from 380 to 750 nm. Light behaves as if it consists of discrete particles called photons, which have a fixed quantity of energy. The amount of energy in a photon is inversely related to its wavelength.

A **spectrophotometer** measures the amount of light absorbed by a pigment. Chlorophyll a is the main pigment in photosynthesis – it absorbs violet-blue and red light the best. Chlorophyll b and other accessory pigments, such as carotenoids, absorb different light waves to increase the range of photosynthesis. Some carotenoids protect plants by absorbing excessive light energy that might damage chlorophyll or interact with oxygen to form reactive molecules (they act as antioxidants).

When a pigment molecule absorbs photons of light energy, the electrons in the molecule "jump" to a higher energy level. This excited state is unstable and energy is released as heat as the electron returns to its ground state. Sometimes this energy is given off as light or fluorescence.

Photosystems are located in the thylakoid membrane and contain light harvesting complexes and reaction centers, a protein complex with chlorophyll a and b as well as a primary electron acceptor. When sunlight hits the light harvesting complex, the energy is passed from pigment to pigment until it reaches the reaction center and becomes excited. In a redox (oxidation-reduction reaction), the excited electron is accepted by the primary electron acceptor before it returns to its ground state. There are two photosystems, photosystem II or P680 and photosystem I or P700 (these are named after the wavelength of light that is best absorbed).

Light-Dependent Reactions (First Phase of Photosynthesis)

In these reactions, hydrogen ions are pumped through the thylakoid membrane and ATP is formed through chemiosmosis.

Noncyclic Electron Flow:

- Water serves as the source of hydrogen ions and electrons.
- The process through which the water is broken down is called "photolysis."
- The hydrogen ions and electrons are used in the noncyclic flow.
- Oxygen is given off as a waste product.
- Electrons continuously pass from water to $NADP^+$ - an excited electron of P680 in photosystem II is trapped by the primary electron acceptor.
- The primary electron acceptor passes the excited electron to an electron transport chain made up of plastoquinone (Pq), a cytochrome complex, and plastocyanin (Pc).
- The energy released as the electron "falls" to its ground state is used to form ATP.
- At the bottom of the electron transport chain, the electrons are passed to photosystem I.
- The electrons are passed down a second electron transport chain through ferredoxin (Fd).
- The electrons are eventually passed to $NADP^+$, forming NADPH.

Cyclic Electron Flow:

- Electrons excited in photosystem II pass from Fd to the cytochrome complex and then back to photosystem II.
- Oxygen and NADPH are not formed.
- Additional ATP needed for the Calvin cycle may come from this process in addition to the noncyclic flow.

Light Independent Reactions (Second Phase of Photosynthesis)

The Calvin or Calvin-Benson Cycle uses ATP and NADPH to convert CO_2 to sugar.

Calvin Cycle: The Calvin cycle turns 3 times to fix 3 molecules of CO_2 and produce a 3 carbon sugar called glyceraldehyde-3-phosphate (G3P). Nine molecules of ATP and 6 molecules of NADPH are required to synthesize one G3P.

3 Stages of the Calvin Cycle:

1. **Carbon Fixation:** CO_2 is added to a five carbon sugar, ribulose bisphosphate (RuBP) in a reaction catalyzed by the enzyme RuBP carboxylase (rubisco). The unstable 6-carbon molecule immediately splits into 2 molecules of 3-phosphoglycerate (PGA), each with 3 carbon atoms. Because the first stable molecule has 3 carbons, this can be referred to as C3 photosynthesis.

2. **Reduction:** Each molecule of PGA is then phosphorylated by ATP. Two electrons from NADPH reduce this compound to form G3P. It takes 3 turns of the cycle to form 1 G3P.

3. **Regeneration of RuBP:** The rearrangement of 5 molecules of G3P into 3 molecules of RuBP.

Photorespiration: When C3 plants close the stomata on a hot, dry day to limit water loss, the CO_2 concentration in the leaf rises, slowing the Calvin cycle. As more oxygen accumulates, rubisco adds O_2 instead of CO_2 to RuBP. The product of this process is a 2-carbon sugar that is broken down to release CO_2 – a wasteful process.

C4 Plants: CO_2 is first added to a 3-carbon compound PEP that has a high affinity to CO_2. The resulting 4-carbon compound (oxaloacetate) is transported to bundle-sheath cells that are tightly packed around the veins of the leaf. The compound is broken down to release CO_2, creating concentrations high enough for rubisco to accept CO_2 rather than O_2. These plants fix CO_2 twice.

CAM Plants (Crassulacean Acid Metabolism): Many succulent plants close their stomata during the day to prevent water loss. At night, they open their stomata to pick up CO_2 and incorporate it into a variety of organic acids.

Chapter 11 - Cell Communication

Signal Transduction Pathway – the series of steps involved in the conversion of a cell surface signal to a cellular response - similarities among the pathways in bacteria, yeast, plants, and animals suggest an early evolution of cell-signaling mechanisms

Paracrine Signaling - in animals, a signaling cell releases messenger molecules into the extracellular matrix fluid and these local regulators influence nearby cells.

Synaptic signaling - a nerve cell releases neurotransmitter molecules into the synapse separating it from its target cell.

Hormones - are chemical signals that travel to more distant parts of an organism.

Stages in Cell Signaling:
1. **Reception** – a chemical signal binds to a receptor protein on the surface of the cell or inside

2. **Transduction** – chemical pathway

3. **Response** – activation of cellular processes

Chemical signals may be communicated between cells through direct cytoplasmic connections (gap junctions, plasmodesmata) or through contact of surface molecules.

Reception

Ligand – binds to a receptor protein and usually induces a change in the receptor's shape

Intracellular Receptors – hydrophobic chemical messengers may cross a cell's plasma membrane and bind to receptors in the cytoplasm or nucleus of target cells.

Steroid Hormones - activate receptors in target cells that function as transcription factors to regulate gene function

Receptors in the Plasma Membrane – there are 3 major types membrane receptors that bind with water-soluble signal molecules and transmit information into the cell

1. **G-Protein Linked Receptors** – the various receptors that work with the aid of a G-protein
    - A GTP-binding protein that relays signals from a plasma membrane signal receptor, known as a G-protein-linked receptor, to other signal transduction proteins inside the cell. When such a receptor is activated, it in turn activates the G protein, causing it to bind a molecule of GTP in place of GDP. Hydrolysis of the bound GTP to GDP inactivates the G protein.
    - Are structurally similar, with 7 helices spanning the plasma membrane.
    - Binding of the appropriate G extracellular signal to a G-protein-linked receptor activates the receptor, which binds to and activates a specific G protein located on the cytoplasmic side of the plasma membrane.
    - Occurs when a GTP nucleotide replaces the GDP bound to the G protein.
    - The G-protein then activates a membrane-bound enzyme, after which it hydrolyzes its GTP and becomes inactive again.
    - The activated enzyme triggers the next step in the pathway to the cell's response

2. **Receptor Tyrosine Kinases** – receptor proteins with enzymatic activity that can trigger several pathways at once
    - Part of the receptor protein is tyrosine kinase, an enzyme that transfers phosphate groups from ATP to the amino acid tyrosine on a protein.

3. **The Binding of a Chemical Signal to a Ligand** – gated ion channel opens or closes the protein pore, thus allowing or blocking the flow of specific ions through the membrane
    - The resulting change in ion concentration inside the cell triggers a cellular response
    - Neurotransmitters often bind to ligand-gated ion channels in the transmission of nervous signals

Transduction – a cascade reaction.

Multistep Signal Pathways - allow a small number of extracellular signal molecules to be amplified to produce a large cellular response.

Signal Transduction Pathways – the relay molecules in a signal transduction pathway are usually proteins, which interact as they pass the message from the extracellular signal to the protein that produces the cellular response.

Protein Phosphorylation and Dephosphorylation – protein kinases are enzymes that transfer phosphate groups from ATP to proteins, often to the amino acid serine or threonine
- relay molecules in transduction are often protein kinases, which are sequentially phosphorylated, producing a structural change that activates each enzyme
- protein phosphatases are enzymes that remove phosphate groups from proteins – they shut down signaling pathways when the extracellular signal is no longer present

Second Messengers - Small molecules and ions often function as second messengers, which rapidly relay the signal from the membrane receptor into the cell's interior

Response

- Signal transduction pathways may lead to the activation of cytoplasmic enzymes or other proteins or may lead to the synthesis of such proteins by affecting gene expression.
- A signal transduction pathway can amplify a signal in an enzyme cascade, as each successive enzyme in the pathway can process multiple molecules that then activate the next step.
- As a result of a particular set of receptor proteins, relay proteins, and effector proteins, different cells can respond to different signals or can exhibit different responses to the same molecular signal.
- Scaffolding proteins are large relay proteins to which other relay proteins attach, increasing the efficiency of signal transduction in a pathway.

Chapter 12 - The Cell Cycle

A cell's complete complement of DNA is called its "genome." Diploid organisms have a characteristic number of chromosomes in each somatic cell while each gamete has half that number of chromosomes. Each chromosome is a very long DNA molecule with associated proteins (histones) – this DNA-protein complex is called "chromatin."

Before cell division, a cell copies its DNA and each chromosome densely coils and shortens. Each replicated chromosome consists of two identical sister chromatids attached in their condensed form at regions called centromeres.

Phases of the Cell Cycle

G1 Phase: "gap phase" - growth phase before DNA duplicated – normal cell activities

G0 Phase: a permanent G1 phase for cells that do not divide

S Phase: chromosomes are duplicated through DNA replication

G2 Phase: growth phase after the DNA is duplicated – normal cell activities

M Phase: "mitotic phase"
- **Mitosis** (division of the chromosomes)
- **Cytokinesis** (division of the cytoplasm)

Mitotic Spindle - consists of fibers made of microtubules and associated proteins – begins in the centrosome.

Phases of Mitosis:

- **Prophase:** the nucleoli disappear and the chromatin fibers coil and fold into visible chromosomes – nuclear membrane disappears
- **Prometaphase:** Spindle microtubules attach to each chromosomes' kinetochore – chromosomes begin moving to the equator of the cell
- **Metaphase:** Chromosomes line up at the equator of the cell
- **Anaphase:** Sister chromatids separate and begin migrating to the poles of the cell
- **Telophase:** Sets of chromosomes reach the poles of the cell, nuclear membrane reappears, nucleoli reappear, chromosomes lengthen and disappear, cytokinesis begins

Cytokinesis – division of cytoplasm
- Plant Cells: cell plate forms to separate two plant cells
- Animal Cells: cleavage furrow separates two animal cells

Control of the Cell Cycle

A cell cycle control system, consisting of a set of molecules that function cyclically. Important internal and external signals are monitored to determine whether the cell cycle will proceed past the 3 main checkpoints in the G1, G2, and M phases.

Cancer - Loss of Control of the Cell Cycle:

Cancer cells escape from the body's normal control mechanisms. When grown in tissue culture, cancer cells do not show density-dependent inhibition and may continue to divide indefinitely.

When a normal cell is transformed or converted to a cancer cell, the body's immune system normally destroys it. If it proliferates, a mass of abnormal cells develops.

Benign Tumors - remain at their original site and can be removed by surgery.

Malignant Tumors - cause cancer as they invade and disrupt functions of one or more organs. Malignant tumors may have abnormal metabolism and/or unusual chromosome numbers. These cells may metastasize, moving from the original location to other organs, often through the blood and lymphatic system.

Chapter 13 - Meiosis and Sexual Life Cycles

Genes – discrete units of information coded in segments of DNA

Gene Locus - specific location of a gene on a chromosome

Asexual Reproduction – a single parent passes copies of all its genes on to its offspring

Clone – group of genetically identical offspring of an asexually reproducing individual

Sexual Reproduction – an individual receives a unique combination of genes inherited from 2 parents

Diploid - double set of chromosomes - one from each parent = 2n

Haploid - single set of chromosomes = 1n

Somatic Cells - diploid cells containing 2 chromosomes of each type

Gametes – haploid cells containing 1 chromosome of each type

Homologous Chromosome – one of a matching pair of chromosomes, one inherited from each parent, also known as "homologues." A gene controlling a particular trait is found at the same locus on each chromosomes of a homologous pair

Karyotype - an ordered display of an individual's chromosomes

Sex Chromosomes - determine the sex of a person. In humans, females have 2 homologous X chromosomes and males have an X and a Y.

Autosomes - chromosomes other that the sex chromosomes

Fertilization - the fusion of egg and sperm cells – produces a zygote

Meiosis – a special type of cell division that reduces the number of chromosomes by one half

Phases of Meiosis

- **Interphase I** – each chromosomes replicates, producing 2 genetically identical sister chromatids that are attached at the centromere
- **Meiosis I** – Reduces the number of chromosomes (2n → 1n)
    - **Prophase I** – homologous chromosomes synapse, forming tetrads, **crossing over** may occur
    - **Metaphase I** – chromosomes pairs (tetrads) line up at the equator of the cell
    - **Anaphase I** – homologous pairs separate and begin moving to the poles of the cell
    - **Telophase I** – chromosomes (still duplicated) reach the poles of the cell
    - **Cytokinesis** occurs, but no replication of chromosomes (sometimes called interkinesis)
- **Meiosis II** – just like mitosis, except that the cells that begin the process are haploid

Mitosis	Meiosis
Genetically identical daughter cells	Genetically different daughter cells
2n → 2n	2n → 1n
2 daughter cells	4 daughter cells
1 division	2 divisions

Chapter 14 – Mendel and the Gene Idea

An analysis of genetic crosses depends upon an understanding of Mendel's two laws:

The Principle of Segregation (First Law): The two members of a gene pair (alleles) segregate (separate) from each other in the formation of gametes. Half the gametes carry one allele, and the other half carry the other allele.

The Principle of Independent Assortment (Second Law): Genes for different traits assort independently of one another in the formation of gametes.

In practice, the manifestation of Mendel's laws is seen by characteristic ratios of phenotypic classes, such as 3:1 and 9:3:3:1. Further, the Mendelian principles just stated include the simple assumption that one allele is dominant to the other allele. In the time since Mendel's original experiments, we have come to learn that there are extensions to Mendelian principles, including the fact that some alleles are incompletely dominant, that some genes are sex-linked, and that some pairs of genes do not assort independently because they are physically linked on a chromosome.

Important Genetic Terminology:

- **Allele** - one of a number of different forms of the same gene for a specific trait
- **Phenotype** - the physical characteristics of an organism
- **Genotype** - the genetic makeup of an organism
- **Homozygous** - a word describing an organism that has two identical alleles for a particular trait
- **Heterozygous** - a word describing an organism that has two different alleles for a particular trait
- **Dominant** – an allele that is expressed even if present with a contrasting recessive allele
- **Recessive** – an allele that is only expressed when two copies are present
- **Testcross** – breeding of an organism of unknown genotype with a homozygous recessive individual to determine the unknown genotype. The ratio of phenotypes in the offspring determines the unknown genotype.

Patterns of Inheritance

- **Incomplete Dominance** - one allele of a pair is not fully dominant over its counterpart (also called "intermediate inheritance")
- **Intermediate Inheritance** - in this inheritance pattern, heterozygotes have a phenotype intermediate between the phenotypes of the two homozygotes (also called "incomplete dominance")
- **Codominance** - both alleles are expressed fully
- **Multiple Alleles** - more than two alleles for a gene are found within a population
- **Epistasis** - one gene alters the effect of another gene
- **Polygenic Inheritance** - many genes contribute to a phenotype
- **Gene Linkage** - genes on the same chromosome are linked and thus will not be sorted out independently of each other
- **Sex Linkage** - if a male gets a recessive (or dominant) allele on the X chromosome from his mother, he will express that trait

Chapter 15 – The Chromosomal Basis of Inheritance

Chromosome Theory of Inheritance: In the early 1900s, several researchers proposed that genes are located on chromosomes and that the behavior of chromosomes during meiosis accounts for Mendel's laws of segregation and independent assortment.

Genetic Recombination and Linkage: Each chromosome has hundreds or thousands of genes. Genes on the same chromosome whose alleles are so close together that they do not assort independently are said to be "linked." The alleles of unlinked genes are either on separate chromosome or so far apart on the same chromosome that they assort independently. Recombinant offspring exhibit new combinations of traits inherited from two parents. Because of the independent assortment of chromosomes and random fertilization, unlinked genes exhibit a 50% frequency of recombination. Even with crossing over between nonsister chromatids during the first meiotic division, linked genes exhibit recombination frequencies less than 50%.

Alterations of Chromosome Number or Structure Cause Some Genetic Disorders

- **Nondisjunction** – an error in meiosis or mitosis, in which both members of a pair of homologous chromosomes or both sister chromatids fail to move apart properly (Downs Syndrome)
- **Monosomic** – referring to a cell that has only one copy of a particular chromosome, instead of the normal two
- **Trisomic** – referring to a cell that has three copies of a particular chromosome, instead of the normal two
- **Polyploidy** –a chromosomal alteration in which the organism possesses more than two complete chromosome sets

Chapter 16 – The Molecular Basis of Inheritance

History of DNA Research

Frederick Griffith: In 1928, a scientist named Frederick Griffith completed a project that opened a door to the molecular world of inheritance. Griffith's experiment involved mice and two types of pneumonia, a pathogenic and a non-pathogenic strain. He injected the pathogenic pneumonia into a mouse, and the mouse died. Next, he injected the nonpathogenic pneumonia into a mouse, and the mouse lived. After this, he heated the pathogenic bacteria to kill it and injected it into a mouse. This mouse lived. Last, he mixed nonpathogenic pneumonia and pathogenic pneumonia that had been heated and killed and injected this mixture into a mouse. This mouse died. Why? Griffith thought that the dead pathogenic bacteria had passed on a characteristic to the non-pathogenic bacteria to make it pathogenic. He thought that this characteristic was in the inheritance molecule. He called the process he had observed "transformation."

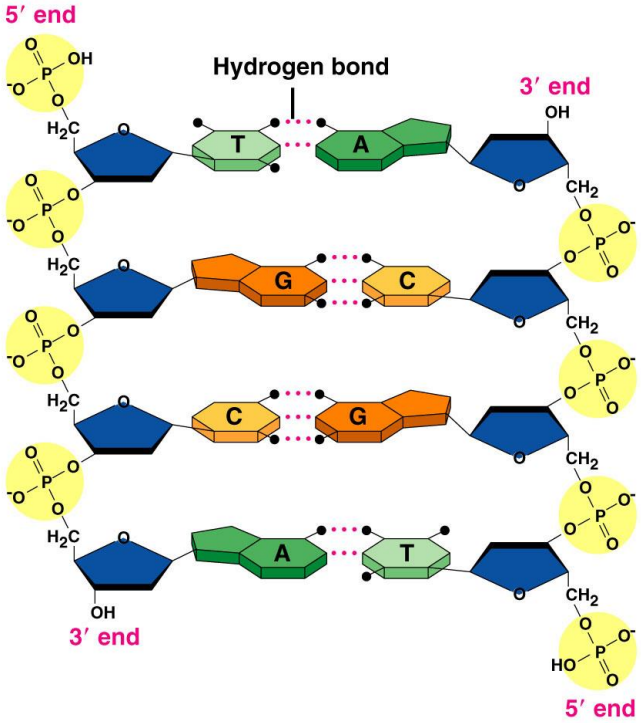
Oswald Avery: In 1944, a scientist named Oswald Avery continued with Griffith's experiment to see what the inheritance molecule was. He purified various types of molecules from the heat-killed pathogenic bacteria and then tried to transform live nonpathogenic bacteria with each type. Only DNA caused transformation to occur. Avery had found that the inheritance molecule was DNA.

Erwin Chargaff: In 1947, another scientist named Erwin Chargaff noticed a pattern in the amounts of the four bases: adenine, guanine, cytosine, and thymine. He took samples of DNA of different cells and found that the amount of adenine was almost equal to the amount of thymine, and that the amount of guanine was almost equal to the amount of cytosine. Thus you could say: A=T, and G=C. This discovery later became Chargaff's Rule.

Alfred Hershey and Martha Chase: In their famous 1952 experiment, they used radioactive sulfur and phosphorus to trace the fates of the protein and DNA, respectively, of T2 phages that infected bacterial cells. They found radioactivity in the bacteria that had been infected with the T2 phage containing radioactively labeled DNA. From this, they concluded that nucleic acids are the hereditary material.

Rosalind Franklin and Maurice Wilkins: In the early 1950s, these two scientists used X-ray diffraction to understand the physical structure of the DNA molecule.

James Watson and Francis Crick: In 1953, this pair of scientists used the images produced by Franklin to deduce that DNA is a double-helix. The beauty of the model they presented was that the structure of DNA suggested the basic mechanism of it replication.



DNA Structure: The DNA molecule has two complementary strands. Each nucleotide base is paired by hydrogen bonding with its specific partner, A with T and G with C.

← Review building blocks and their arrangement

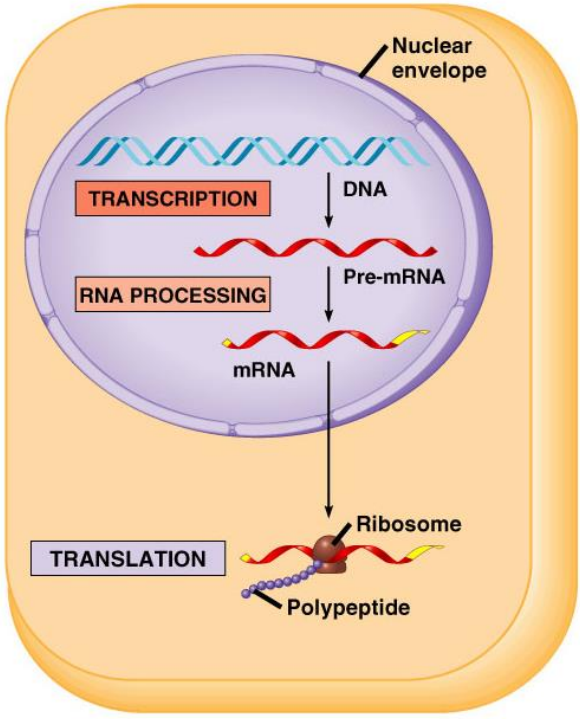
DNA Replication

1. The first step in replication is separation of the two DNA strands.
2. Each parental strand now serves as a template that determines the order of nucleotides along a new, complementary strand.
3. The nucleotides are connected to form the sugar-phosphate backbones of the new strands. Each "daughter" DNA molecule consists of one parental strand and one new strand (this is known as "semiconservative replication".)

Chapter 17 – From Gene to Protein

The central dogma of molecular biology describes the two-step process, transcription and translation, by which the information in genes flows into proteins: DNA →RNA → protein.

The Genetic Code: Genetic information is encoded as a sequence of non-overlapping base triplets, or codons. A codon in messenger RNA (mRNA) either is translated in an amino acid (61 codons) or serves as a translational stop signal (3 codons). Codons must be read in the correct reading frame for the specified polypeptide to be produced.



(b) Eukaryotic cell

Transcription: Involves the synthesis of an RNA copy of a segment of DNA. RNA is synthesized by the enzyme RNA polymerase in the nucleus of the cell.

RNA Processing (eukaryotes only): The gene transcript is processed to remove extra sequences (introns) before it leaves the nucleus. The pre-mRNA is processed to remove the introns and splice the exons together into a translatable mRNA.

Translation: The ribosome binds to the mRNA at the start codon (AUG) that is recognized only by the initiator tRNA. During the elongation phase, complexes composed of an amino acid linked to tRNA sequentially bind to the appropriate codon in mRNA by forming complementary base pairs with the tRNA anticodon. The ribosome moves from codon to codon along the mRNA. Amino acids are added one by one, translated into polypeptidic sequences dictated by DNA and represented by mRNA. At the end, a release factor binds to the stop codon, terminating translation and releasing the complete polypeptide from the ribosome.

The Control of Gene Expression

- The expression of genes can be turned off and on at any point along the pathway from gene to functional protein.
- Genes in **heterochromatin** (which is highly packed) usually are not transcribed – this is one form of gene control.
- **DNA methylation** (the adding of methyl groups) is one way in which the transcription of genes is controlled. Apparently methylation of DNA is responsible for the long-term inactivation of genes.
- In **histone acetylation**, acetyl groups are added to amino acids of histone proteins – this makes the chromatin less tightly packed and encourages transcription.
- Transcription initiation is another important control point in gene expression. At this stage, DNA control elements that bind **transcription factors** (needed to initiate transcription) are involved in regulation.
- Gene control also occurs after transcription and during RNA processing, in **alternative RNA splicing**.
- The control of gene expression also occurs both prior to translation and just after translation, when proteins are processed.

Mutations

- A point mutation is a change in one DNA base pair, which may lead to production of a nonfunctional protein or no protein at all. Base-pair substitutions can cause missense or nonsense mutations. Base-pair insertions or deletions may produce frameshift mutations.
- Spontaneous mutations can occur during DNA replication, recombination, or repair. Chemical and physical mutagens can also alter genes.