

AP Biology Review Part 2: Energy Conversions & Enzymes and Cell Cycle and Cell Communication

2A1: All living system require constant input of free energy.

2A2: Organisms capture free energy and store free energy for use in biological processes.

3A2: In eukaryotes, heritable information is passed to the next generation via processes that include the cell cycle and mitosis or meiosis plus fertilization.

3B2: A variety of intercellular and intracellular signal transmissions mediate gene expression.

3D1: Cell communication processes share common features that reflect a shared evolutionary history.

3D2: Cells communicate with each other through direct contact with other cells or from a distance via chemical signaling.

3D3: Signal transduction pathways link signal reception with cellular response.

3D4: Changes in signal transduction pathways can alter cellular response.

4B1: Interactions between molecules affect their structure and function

1. Energy

- a. Organisms use free energy for organization, growth and reproduction. Loss of order or free energy flow results in death.
- b. More free energy (ex. Food) than needed will be stored for growth (roots, glycogen, fat, etc.).
- c. Matter and energy are not created but change form (1st law of thermo; ex. Sun energy to bond energy in glucose) and entropy is increasing in disorganization of energy (i.e. heat released by cell respiration). More organized or built up compounds have more free energy and less entropy (i.e. glucose) and less organized have less free energy and more entropy (i.e. carbon dioxide).
- d. Reactions can be coupled to maintain a system, ex. Photosynthesis and cell respiration

2. Enzymes

- a. Biological catalysts (made of protein) that speed up rate of chemical reactions by lowering activation energy required for reaction to occur
- b. Enzyme has active site (exposed R groups) where reaction occurs
- c. Enzymes can break down substance (catabolic reaction) or build up substances (anabolic)
- d. Enzyme/substrate complex is formed
- e. Substrate is what enzyme acts on
- f. Rate is determined by collisions between substrate and enzyme
- g. Ends in -ase, named after substrate often
- h. Enzyme is specific to substrate; the substrate must be complementary to the surface properties (shape and charge) of the active site (which is made up of R groups with specific chemistry, i.e. hydrophobic).
- i. Enzyme rate is affected by:
 - **pH** (optimal for each enzyme),
 - **temperature** (optimal for each enzyme but in general increased temp means increased collisions so rate goes up initially; too much heat can denature enzyme), enzyme concentration (more enzyme faster rate or vice versa)
 - **substrate concentration** (more substrate faster rate; v_{max} is fastest enzyme can work when saturated)
- j. Inhibition-competitive inhibition (something competes for active site; can be overcome with more substrate)
- k. Non-competitive inhibition- attaches at allosteric site and changes shape of enzyme so it is not functional; can not be overcome with more substrate
- l. Coenzymes (organic; NAD and vitamin B etc.) and cofactors (inorganic; zinc, magnesium etc.) interact with enzymes to put them into the right structure to do work.

3. Energy Transformations

ATP- adenosine triphosphate- energy molecule for cells (recyclable)

A. Photosynthesis $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$

Photosynthetic organisms capture free energy present in sunlight and use water and carbon dioxide to make carbon products and free oxygen.

Light-dependent reactions- photophosphorylation

- (1) Photosystems I and II (chlorophyll and proteins) are embedded in the internal membranes of chloroplasts (thylakoids of the grana). They pass electrons through an electron transport chain (ETC). When electrons are passed they allow hydrogen ions (protons) across the thylakoid membrane. The formation of the proton gradient powers the process of ATP synthesis to add a phosphate ADP to ATP (chemiosmosis).
- (2) Electrons are passed to NADP⁺ to make NADPH (electron carrier)
- (3) H₂O is used and O₂ released as by-product
- (4) Red and blue light works best (green is reflected typically)
- (5) Pigments= chlorophyll a and b; accessory pigments
- (6) Energy converted from sun into chemical energy of ATP and NADPH to be used in building of sugar (Calvin Cycle)

Light-independent reactions- Calvin Cycle

- (1) carbon fixation occurs
- (2) occurs in stroma of chloroplasts
- (3) ATP and NADPH are used; rubisco is enzyme that fixes carbon (not picky and will fix O₂ too- photorespiration; "the ho")

Evolution of Photosynthesis

- (1) Photosynthesis first evolved in prokaryotic organisms; (bacterial) photosynthesis was responsible for the production of an oxygenated atmosphere
- (2) C₄ photosynthesis- crabgrass, corn, drought resistance, uses new enzyme- PEP carboxylase which is specific for just CO₂ and CAM- Crassulacean Acid metabolism used in dry climates, ex. Cacti stomates are closed during day and open at night

B. Cellular respiration $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$

Makes ATP for cell use; uses glucose and oxygen makes waste products of carbon dioxide and water; occurs in mitochondria; NADH is electron carrier used

Glycolysis

- (1) occurs in cytoplasm; anaerobic
- (2) rearranges the bonds in glucose molecules, releasing free energy to form ATP from ADP resulting in the production of pyruvate.

Kreb's cycle

- (1) occurs in mitochondrial matrix
- (2) also called the citric acid cycle
- (3) occurs twice (one for each acetyl co-a)
- (4) Pyruvate is oxidized further and carbon dioxide is released ; ATP is synthesized from ADP and inorganic phosphate via substrate level phosphorylation and electrons are captured by coenzymes (NAD⁺ and FAD).

NADH and FADH₂ carry them to the electron transport chain.

- (5) The electron transport chain captures in a process similar to light dependent reactions to make ATP.
- (6) At end 38 ATP made per glucose molecule- could be 36 if it cost ATP to get in mitochondria; some of the energy in bonds is lost as heat (not completely efficient but since it occurs in several reactions with enzymes it is more efficient than one combustion)

Anaerobic Fermentation

- (1) No oxygen; cell only goes through glycolysis followed by fermentation
- (2) Fermentation recycles NAD needed to restart glycolysis
- (3) alcohol fermentation ex. yeast cells- glucose → ethyl alcohol + CO₂ + NAD
- (4) lactic acid fermentation ex. muscle cells- glucose → lactic acid + NAD
- (5) Fermentation does not make ATP but glycolysis does- 2ATP; very inefficient; sufficient for microorganisms

4. Cell cycle

- a. Reason for division- as cells increase in volume, the surface area decreases and demand for material resources increases which limits cell size
- b. Smaller cells have a more favorable surface area-to-volume ratio for exchange of materials with the environment (diffusion, etc.). High SA:V ratio is favorable. Ex. 6:1 is better than 6:5
- c. Cell cycle switches between interphase and cell division.
- d. Interphase has three phases: growth (G₁), synthesis of DNA (S) and preparation for mitosis (G₂).
- e. During mitosis duplicated chromosomes line up in center with spindle fibers attached to help pull them apart. Duplicated chromosomes are pulled apart by spindle fibers.
- f. Cytokinesis-division of cytoplasm and reformation of cell membrane. Animal cell- pinches in (cleavage) using microfilaments; plant cell- form cell plate reforms cell wall (golgi deposits material).
- g. The cell cycle is directed by internal controls or checkpoints. Internal (enzymes and promoting factors) and external signals (growth factors) provide stop and- go signs at the checkpoints. Ex. Mitosis-promoting factor (MPF); Platelet-derived growth factor (PDGF); p53 gene products
- h. Cancer results from disruptions in cell cycle control (too much division, defective tumor suppressor genes, overactive genes) which are a result of DNA damage to proto-oncogenes (regulatory genes) which make products like cyclins and cyclin-dependent kinases.
- i. Cells spend different amounts of time in interphase or division. Nondividing cells may exit the cell cycle; or hold at a particular stage in the cell cycle.
- j. Mitosis is used for growth and repair in animals; plants use mitosis to make gametes and for growth or repair.
- k. Mitosis usually begins with 1 cell, makes 2 identical cells or clones; maintains chromosome number; 1n → 1n or 2n → 2n.
- l. Meiosis (occurs after interphase) takes diploid cells and reduces the chromosome number to haploid. 2n → 1n.
- m. During meiosis, homologous chromosomes are paired (one from mom and one from dad) and line up in the center of the cell randomly. The homologues are pulled apart and separated in meiosis I. A second division occurs in which the duplicated chromosomes are pulled apart.
- o. Variation occurs in gametes during “crossing over,” and fertilization because of all possible combinations.

5. Cell to Cell Communication

- a. Cells receive or send inhibitory or stimulatory signals from other cells, organisms or the environment.
- b. In single-celled organisms it is response to its environment. Ex. quorum sensing,

- d. In multicellular organisms, signal transduction pathways coordinate the activities within individual cells. Ex. Epinephrine stimulation of glycogen breakdown in mammals
- e. Cells communicate by cell-to-cell contact. Ex Immune cells interact by cell-cell contact, antigen-presenting cells (APCs), helper T-cells and killer T cells or plasmodesmata between plant cells that allow material to be transported from cell to cell.
- f. Cells communicate over short distances by using local regulators that target cells in the vicinity of the emitting cell. Ex. Neurotransmitters, plant immune response
- g. Signals released by one cell type can travel long distances to target cells of another cell type. Ex. Hormones.
- h. A receptor protein recognizes signal molecules, causing the receptor protein's shape to change, which initiates transduction of the signal. Ex. G-protein linked receptors, ligand-gated ion channels, tyrosine kinase receptors.
- i. Signal transduction is the process by which a signal is converted to a cellular response. Signaling cascades relay signals from receptors to cell targets, often amplifying the incoming signals, with the result of appropriate responses by the cell.
- j. Second messengers are often essential to the function of the cascade. Ex. cyclic AMP calcium ions (Ca²⁺), and inositol triphosphate (IP₃)
- k. Many signal transduction pathways include: Protein modifications or phosphorylation cascades in which a series of protein kinases add a phosphate group to the next protein in the cascade sequence.

AP Lab Investigation 5 Photosynthesis

Overview: Spinach cut out disks were placed in two different syringes (bicarbonate and without) and those photosynthetic rate was calculated by measuring the number that floated over time. Students then designed their own experiment to see what factors affected photosynthesis.

IV: presence of bicarbonate

DV: number of disks floating

Equations: ET_{50} = the point at which 50% of the leaf disks are floating (the median or ET_{50} , the Estimated Time it takes 50% of the disks to float), inverse relationship between rate and ET_{50} so we graphed $1/ET_{50}$ in this lab.

AP Lab Investigation 6 Cell Respiration

Overview: Germinating and non-germinating seeds (peas) were placed in different temperature water baths and cell respiration rate was determined based on oxygen consumption. Design your own experiment to determine what other factors affect cell respiration (type of seed, age of seed, etc.)

IV: germinating or non-germinating and temperature

DV: O₂ consumption

*volume was controlled with glass beads, CO₂ gas was controlled with KOH, temperature was controlled with water bath

Equations: dY/dt or product formed (dY) over time interval (dt)

AP Lab Investigation 7 Cell Cycle

Part I: Mitosis

Overview: Two treatment groups of plant root tips were compared, one group was treated with lectin (increases cell division) and the other was a control group that had not been treated with lectin (we used cards for these). Chi-square analysis was used to determine if there was a significant difference between the two groups.

IV: Lectin

DV: Rate of Division

$$\chi^2 = \sum (o-e)^2/e$$

Equations: χ^2 value is compared to chart under .05 probability and correct degrees of freedom (number of groups -1). Numbers at critical value or above reject null hypothesis.

Part II: Meiosis

Overview: Spores of a fungus were evaluated for crossing over and cross over rates were calculated. Also karyotypes were evaluated for cancer and genetic diseases as a result of cross over mistakes.

Equations: # of crossover/total number of spores = % cross over, % cross over /2 = map units

AP Lab Investigation 13 Enzymes

Overview: Rate of decomposition (breakdown) of hydrogen peroxide by the enzyme peroxidase was measured by measuring the amount of O₂ gas produced in the reaction. An indicator called guaiacol was used to detect oxygen by changing a darker color which was measured by a colorimeter (measures transmittance of light through a sample). Designing your own experiment to determine what other factors affect enzyme reaction (light, temperature, pH or concentrations).

IV: Time

DV: color change (indicates oxygen production)

Equations: rate dY/dt (change in transmittance of light over change in time)

Cell Division:

anaphase
cancer
cell cycle
cellular differentiation
cell division
centrioles
chromosome
crossing over
crossover frequency
cyclin-dependent kinase
cytokinesis
differentiation

diploid (2N)
DNA replication
fertilization
gamete
haploid (1N)
homologous chromosomes
independent assortment
interphase
maternal chromosome
meiosis
metaphase
mitosis

nuclear division
p53
paternal chromosome
potency
prophase
recombination
sex chromosome
somatic cell
specialized cell
synapsis
telophase

Communication

communication
cyclic AMP (cAMP)
G-protein linked receptor
phosphorylation cascade

protein kinase
quorum sensing
receptor
second messenger

signal cascade
signal transduction
signal transduction pathway

Cell Energy

absorption spectrum
accessory pigment
acetyl coA
action spectrum
activation energy
active site
anabolism
anaerobic metabolism
allosteric regulation
ATP
autotroph
Calvin cycle
catabolism
catalyst
cellular respiration
chemiosmosis
chemoautotroph
chlorophyll

chloroplast
citric acid cycle
coenzyme
cofactor
compartmentalization
consumer
cyclic electron flow
denaturation
electron transport chain
entropy
endergonic reaction
enzyme
exergonic reaction
feedback inhibition
fermentation
glycolysis
heterotroph
induced fit model

light dependent reactions
light independent reactions
metabolic pathway
mitochondrion
NAD
NADP
negative feedback
non-cyclic electron flow
oxidative phosphorylation
photolysis
photosynthesis
positive feedback
ribulose biphosphate
substrate-level phosphorylation
thylakoid membrane

Questions and Practice

1. How do the laws of thermodynamics relate to the biochemical processes that provide energy to living systems?
2. How do enzymes regulate the rate of chemical reactions?
3. How does the specificity of an enzyme depend on its structure?
4. How is the activity of an enzyme regulated?
5. How does the cell cycle assure genetic continuity?
6. How does mitosis allow for the even distribution of genetic information to new cells?
7. What are the mechanisms of cytokinesis?

8. How is the cell cycle regulated?
9. How can aberrations in the cell cycle lead to tumor formation?
10. Why is meiosis important in heredity?
11. How is meiosis related to gametogenesis?
12. What are the similarities and differences between gametogenesis in animals and plants?
13. What is the role of ATP in coupling the cell's anabolic and catabolic processes?
14. How does chemiosmosis function in bioenergetics?
15. How are organic molecules broken down by catabolic pathways?
16. What is the role of oxygen in energy-yielding pathways?
17. How do cells generate ATP in the absence of oxygen?
18. How does photosynthesis convert light energy into chemical energy?
19. How are the chemical products of the light-trapping reactions coupled to the synthesis of carbohydrates?
20. What kinds of photosynthetic adaptations have evolved in response to different environmental conditions?
21. What interactions exist between photosynthesis and cellular respiration?

22. How was photosynthetic rate measured in the photosynthesis lab?
23. What was the IV in the photosynthesis lab? DV? Control? Controlled variables?
24. How was respiration rate measured in respiration lab?
25. What was the IV in the lab? DV? Control? Controlled variables?
26. Make a concept map to relate the following terms: high free energy, low free energy, entropy, enzymes, photosynthesis, light dependent reaction, light independent reaction, cell respiration, glycolysis, krebs, etc, and fermentation.
27. Make a concept map to relate the following terms: cell cycle, interphase, growth, dna replication, mitosis, meiosis, homologous chromosomes, separation of chromosomes, cancer, checkpoints, regulatory proteins.
28. Make a concept map to relate the following terms: unicellular, multicellular, local regulators, long distance regulation, contact, receptor, signal transduction, enzyme cascade, response