

# Supplemental Material

*CBE—Life Sciences Education*

Jensen *et al.*

## Appendix A.

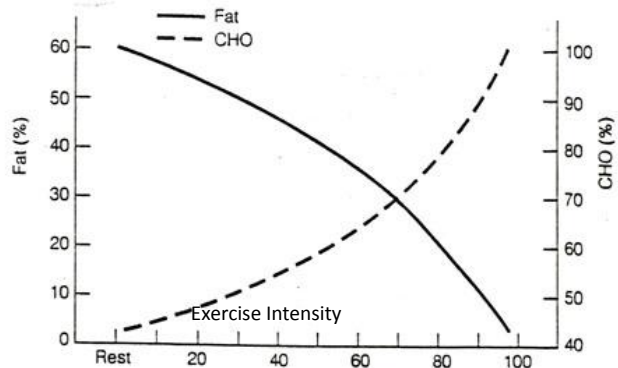
### Curriculum

<b>Tested Content: Items taught during class activities AND appearing on an exam</b>	<b>Untested Content: Items taught during class activities that DID NOT appear on an exam</b>
Nature of Science	Stabilizing Selection
Types of Evidence	Diversifying Selection
Hypothesis and Experiments	Lamarckian Theory
Dependent and Independent Variable	Biological Species Concept
Basic Evolutionary Theory	Gene Pool
Fossil Record	Speciation
Vestigial Traits	Genetic Mechanisms
Common Descent	Disease Treatment and Prevention
Homology and Analogy	Vaccines
Convergence	Gametogenesis
Congruence	Menstrual Cycle And Hormones
Interpreting a Phylogenetic Tree	Reproductive physiology
Exponential Population Growth	DNA Replication
Logistic Population Growth	Cell Cycle Control
Hardy Weinberg Equation	Benign And Malignant Tumors
Natural Selection	Risk Factors To Cancer
Directional Selection	Telomerase
Allele Frequencies	Membrane Transport
Gene Flow	Cellular Organelles
Genetic Drift	Macromolecule Type and Structure
Random Mutation	Micronutrients
Virus versus Bacteria	Dehydration
Structure Of Pathogens	Transcriptional Enzymes
Chromosome structure	Mechanisms of Translation
Mitosis	Gene Regulation
Meiosis	Cellular Respiration (Structural)
Mechanisms of Cancer	Photosynthesis (Structural)
Mendelian Genetics	Atomic Structure
Homozygous versus Heterozygous	Climate
Genotype	Biogeography
Phenotype	Conservation Mechanisms
Heritability of Traits	Ecological Relationships
Incomplete Dominance	Functional Plant Types
Codominance	
ABO Blood System	
Rh Factor	
Sex Chromosomes	
Sex Linked Genes	

Pedigrees	
Enzymes	
Rates of Reactions	
Types of Reactions	
Exergonic versus Endergonic	
Calories	
Transcription	
Translation	
Mutations	
PCR	
Cloning	
Cell Respiration Inputs/Outputs	
Photosynthesis Inputs/Outputs	
Water	
Chemical Bonds (ionic and covalent)	

**Tested High-Level Items (Bloom’s levels are listed in parentheses)**

The percent of carbohydrate (CHO) and fat used as fuel during exercise is illustrated in the following figure. During low to moderate intensity exercise, CHO and fat both play important roles as fuels in energy production. From the figure below, answer the following questions.



1. (Apply) What is/are the independent variable(s)?
  - a. Time
  - b. Exercise Intensity
  - c. CHO and Fat
  - d. CHO, Fat, and Time
2. (Analyze) What is the best statement to summarize the overall conclusion communicated in the figure above?
  - a. The greater the intensity of exercise, the higher the percent fat used as fuel in energy production.
  - b. At high intensities of exercise, CHO becomes the predominant fuel compared to fat.
  - c. At low intensity exercise, Fat is the predominant fuel compared to CHO.
  - d. There is a shift from fat to CHO fueled energy as exercise intensity increases.
3. (Evaluate) If a population of 100 is growing in an area with a carrying capacity of 400, and 200 individuals of a new species is introduced that competes for the same resources as the original population, what do you predict will happen to the growth rate of the original population?
  - a. It will stay the same
  - b. It will decrease by one fourth
  - c. It will decrease by two thirds
  - d. It will drop to zero
  - e. It will increase by one half

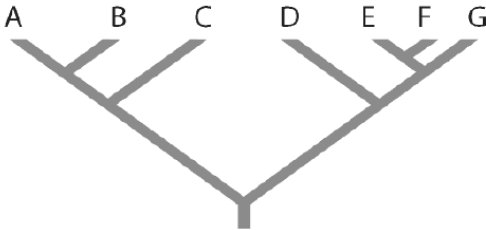
The table below records the percent of people with various blood types in a modern group of 228 members of the closed, conservative religious sect called Dunkers. This community was founded around 1720 in eastern Pennsylvania by 50 families who emigrated from the Rhineland region of Germany. Comparisons with contemporary German and U.S. populations are included.

Group	# People Tested	Type O	Type A	Type B	Type AB
Dunkers	228	35.5%	59.3%	3.1%	2.2%
Rhineland Germans	3,036	40.7%	44.6%	10.0%	4.7%
United States	30,000	45.2%	39.5%	11.2%	4.2%
Pennsylvania	5,100	42.1%	44.2%	10.6%	3.1%

4. (Evaluate) What is the most likely explanation for these data?
  - a. There is an environmental condition in eastern Pennsylvania that selects against persons of the B phenotype.
  - b. The Dunker population is not evolving because marriage with outsiders is prohibited.
  - c. The distribution of blood types in Rhineland Germans differs from that of Americans due to dietary and exercise habits in the U.S.
  - d. The Dunker population is exhibiting genetic drift.
  - e. Persons with the A blood group are more resistant to disease
5. (Apply) Which of the following violations to Hardy-Weinberg assumptions would be most likely to change the allele frequency of a small population of pigmy monkeys living on an island?
  - a. Mutation
  - b. Changing environment
  - c. Genetic drift
  - d. Gene flow
  - e. Selection
  - f. Non-random mating
  - g. All of the above have an equal chance of moving the population out of Hardy Weinberg equilibrium.
6. (Analyze) You are studying a population. You have examined several genetic variants, measuring individual genotypes from individuals in the population over several generations. In the first sampling of this population, the marker you examined has genotype frequencies as follows: AA=0.64; Aa=0.32; aa=0.04. What are the frequencies of "A" and "a" in this population?
  - a. A=0.08; a=0.02
  - b. A=8; a=2
  - c. A=0.6; a=0.4
  - d. A=0.8; a=0.2
  - e. A=6; a=4
7. (Analyze) After graduation, you and 19 friends build a raft, sail off and are shipwrecked on a deserted island, starting a new population, totally isolated from the world (one of your friends is a Bishop and can perform civil marriages). Two of your friends carry (that is, are heterozygous for) the recessive *cf* allele, which in homozygotes causes cystic fibrosis. Assuming that the frequency of this allele does not change as the population grows (i.e., Hardy Weinberg Equilibrium), what will be the incidence of cystic fibrosis on your island?
  - a. 0.05%
  - b. 0.0026%
  - c. 0.25%
  - d. 0.5%
8. (Apply) You are studying size differences in a population of zebrafish in your lab. In the first sampling of the population you find the following genotype frequencies where the recessive allele corresponds to smaller fish size: RR=.3025; Rr=.495; rr=.2025. You introduce a selective force into your tanks that reduces the fitness of one of the

genotypes. 10 generations later, you find that your genotype frequencies are now:  $RR=.49$ ;  $Rr=.42$ ;  $rr=.09$ . What type of selection is occurring?

- Directional
- Stabilizing
- Repressive
- Disruptive

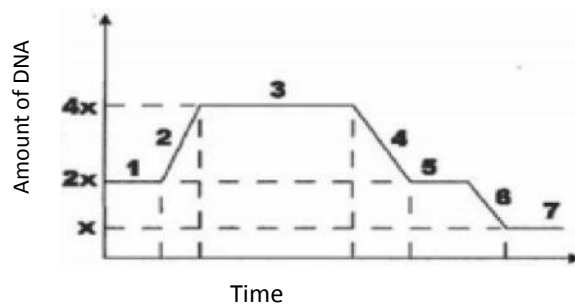


- (Analyze) Referring to the figure above, who is the closest living relative to species C?
  - Species D
  - Species B
  - Species A
  - Species A or B
  - Species A, B, or D, it is impossible to tell
- (Analyze) Red/green colorblindness is an X-linked recessive disorder. A colorblind man, whose father was *not* colorblind, married a woman who has normal color vision, but whose father *was* colorblind. If their first child is male, what is the probability that he will be colorblind?
  - 0%
  - 25%
  - 50%
  - 75%
  - It is impossible to tell without knowing the genotype of the woman
- (Analyze) Jane is not colorblind, but she is a carrier of the red/green colorblind gene. If Jane marries a man who is NOT colorblind, what possible children could she have?
  - Normal males and color-blind females only
  - Normal males, color-blind males, and normal females only
  - Color-blind males and normal females only
  - Normal males, color-blind males, normal females, and color-blind females
- (Analyze) The first child of a young couple (parents both have normal phenotypes) has cystic fibrosis, an autosomal recessive trait. What is the probability that their next two children will also have the disease?
  - 1/16 (6.25%)
  - 1/8 (12.5%)
  - 1/4 (25%)
  - 1/2 (50%)
  - 3/4 (75%)
  - 1 (100%)
- (Analyze) In horses, the allele for the trotting gait (T) is dominant over the allele for the pacing gait (t) in gene "T", and the bay color allele (B) is dominant over the black color allele (b) of gene "B". These two genes are not linked. A prize bay trotter stallion was

crossed to two mares. Mare #1, a black trotter, produced a black trotter colt. Mare #2, a bay trotter, produced a bay pacer colt. What was the genotype of the stallion?

- BBTT
- BBTt
- BBtt
- BbTT
- BbTt
- Bbtt
- bbTT
- bbTt
- bbtt

14. (Analyze) The following figure shows changes in DNA throughout the life cycle of a cell (X = an arbitrary unit of DNA). This graph shows which of the following?



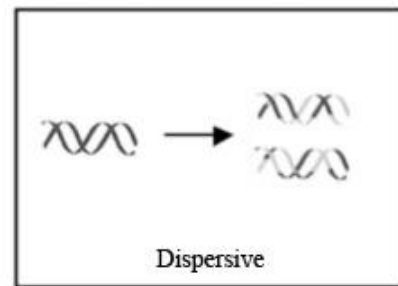
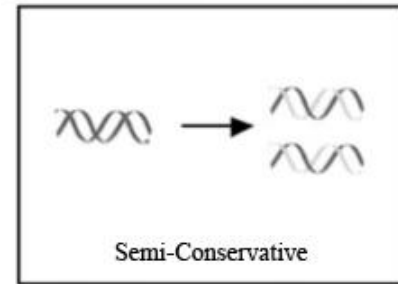
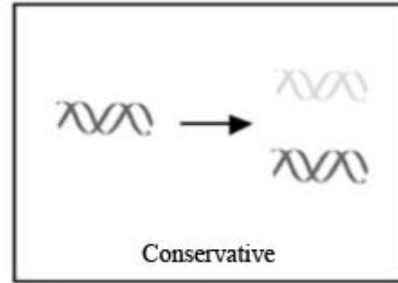
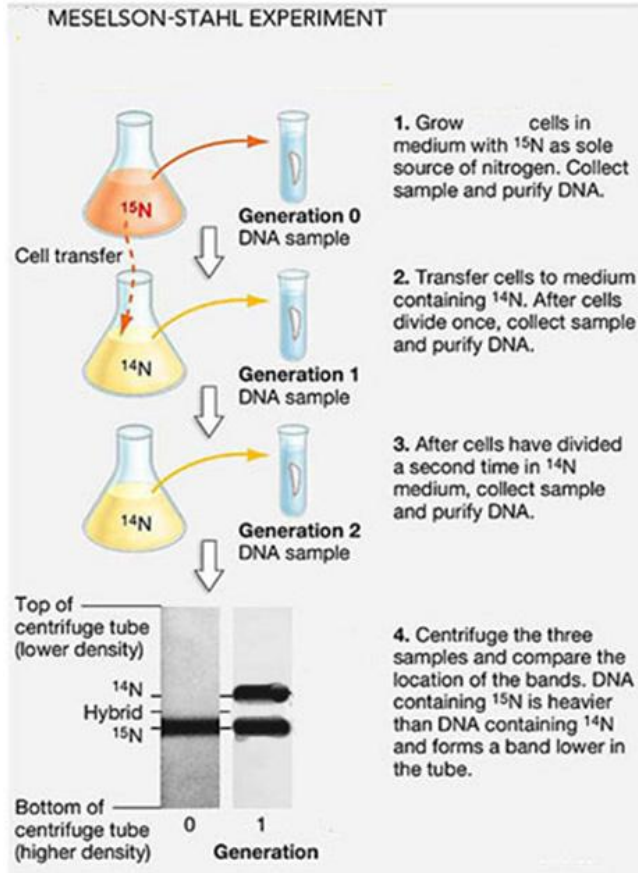
- Stages 1, 2 and 3 represent the G1, S and G2 periods, respectively. Stages 4-7 represent a cell in  $G_0$ .
  - Stages 1, 2 and 3 represent interphase and stages 4 – 7 represent the cell going through mitosis.
  - Stages 1 through 5 illustrate meiosis I, and stages 6 and 7 illustrate meiosis II.
  - Stages 1, 2 and 3 represent the G1, S and G2 periods, respectively. Stages 4 – 7 represent meiosis I and II.
  - Stages 1, 5, and 7 represent G1. Stage 2 represents S phase. Stages 4 and 6 represent mitosis.
15. (Evaluate) The human hexokinase enzyme has the same function as the bacterial hexokinase enzyme but is somewhat different in its amino acid sequence. You have obtained a mutant bacterial strain in which the gene for hexokinase and its promoter are missing. If you introduce into your mutant strain a DNA plasmid engineered to contain the coding sequence of the human hexokinase gene, driven by the normal bacterial promoter, the resulting bacteria will now produce:
- The bacterial form of hexokinase.
  - The human form of hexokinase.
  - A hybrid enzyme that is partly human, partly bacterial.
  - Both forms of the enzyme.
16. (Evaluate) If green algae cells in a buffer solution containing only inorganic salts are placed in a sealed container at room temperature with excess carbon dioxide gas and exposed to light, the cells will
- Live for many hours and multiply.

- b. Live for several hours, but fail to multiply because there is no source of carbon in the buffer solution.
- c. Live for several hours, but fail to multiply because no oxygen is present.
- d. Die rapidly, because no oxygen is present.

**Untested High-Level Items (Bloom's levels are listed in parentheses)**

1. (Evaluate) A certain species of ant lives on the small thorns of the Acacia tree in Africa living off the sweet sap produced by the trees. In turn, the ants bite and pester large animals trying to graze on the tree. Scientists, in an attempt to confirm that this is a mutualistic relationship, fenced in several acacia trees to prevent wild animals from grazing on the trees. What evidence would suggest that this is a mutualistic relationship?
  - a. Fenced in trees have lower hanging branches than unfenced trees.
  - b. Fenced in trees produce less sap and have less ants than unfenced trees.
  - c. Fenced in trees have greener foliage than unfenced trees.
  - d. Fenced in trees have more damage from the ants than unfenced trees.
2. (Evaluate) The passage of a cell through the checkpoints of the cell cycle is tightly controlled by the manufacture of a protein called cyclin. As cyclin concentrations build up, they bind to an ever-present enzyme, cyclin-dependent kinase (cdk) that activates the cell cycle. To turn the cell cycle off, cdk is destroyed. Cancer would most likely be caused by
  - a. An inactivation of the cyclin gene
  - b. An inactivation of the cdk gene
  - c. An over-activation of the cyclin gene
  - d. An over-activation of the cdk gene
  - e. Both *a* and *b* would cause cancer
  - f. Both *c* and *d* would cause cancer





3. (Evaluate) The experimental protocol outlined above on the left was followed using cells of a previously unknown strain of microorganism discovered on a meteorite. The three hypothesized modes of DNA replication are pictured on the right. After interpreting the data, which statement below is correct about the conclusion from this experiment regarding DNA replication in this new organism?
  - a. This protocol can't distinguish conservative, semi-conservative or dispersive replication.
  - b. The results are too ambiguous to tell.
  - c. Replication in this organism is semiconservative.
  - d. Replication in this organism is conservative.
  - e. Replication in this organism is dispersive.
4. (Analyze) A certain protein consisting of a single polypeptide chain has a molecular weight of approximately 31,000 g/mol. What is the best estimate for the molecular weight of the exons of the coding strand, which programs the synthesis of this protein? The molecular weight of an average amino acid is 120 g/mol, and the average nucleotide molecular weight is 310 g/mol.
  - a. 72,000
  - b. 96,000
  - c. 124,000
  - d. 188,000
  - e. 240,000
  - f. 393,000

- g. 480,000
  - h. 558,000
  - i. 603,000
5. (Analyze) In a certain mutant strain of bacteria, the enzyme leucyl-tRNA synthetase mistakenly attaches isoleucine to leucyl-tRNA 10% of the time instead of attaching leucine. These bacteria will synthesize:
- a. Proteins in which leucine is inserted at some positions normally occupied by isoleucine.
  - b. Proteins in which isoleucine is inserted at some positions normally occupied by leucine.
  - c. No abnormal proteins, because the ribosomal translation machinery will recognize the inappropriately activated tNRAs and exclude them from the translation process.
  - d. No proteins, because the inappropriately activated tRNAs will block translation.

The hydrogen car runs off the power of hydrogen created from splitting water using electricity. The first reaction is as follows:



6. (Evaluate) In order to create hydrogen gas ( $\text{H}_2$ ), what must now occur?
- a. Each  $\text{H}^+$  ion must receive an electron, then share that pair in a covalent bond.
  - b. Each  $\text{H}^+$  ion must receive two electrons, then share both pairs in a double covalent bond.
  - c. Each  $\text{H}^+$  ion must donate an electron to the  $\text{O}_2$  before covalently bonding to each other.
  - d. Each  $\text{H}^+$  ion must share its valence shell with a neighboring  $\text{H}^+$  ion to form a covalent bond.
7. (Apply) Which kind of metabolic poison would most directly interfere with glycolysis?
- a. an agent that reacts with oxygen and depletes its concentration in the cell
  - b. an agent that binds to pyruvate and inactivates it
  - c. an agent that closely mimics the structure of glucose but is not metabolized
  - d. an agent that reacts with NADH and oxidizes it to  $\text{NAD}^+$
  - e. an agent that blocks the passage of electrons between proteins with different electronegativities
8. (Evaluate) You are a scientist in a pharmaceutical company interested in developing drugs for weight loss. You have discovered a drug that you have named compound 7609. After running a number of tests, you find that the compound blocks the  $\text{H}^+$ /pyruvate symporter that transports pyruvate into the mitochondria. Which of the following outcomes and reasoning would you expect from this drug?
- a. It causes weigh gain because it inhibits the citric acid cycle
  - b. It causes weight loss because it inhibits the citric acid cycle
  - c. It causes weight gain because it inhibits acetyl CoA production
  - d. It causes weight loss because it inhibits acetyl CoA production
  - e. It causes weight loss because it inhibits the citric acid cycle *and* acetyl CoA production
9. (Apply) Very low concentrations of detergent make membranes leaky to small molecules and ions without damaging proteins. In isolated mitochondria exposed to detergent, the molecules of the electron transport chain and of ATP synthase remain intact. Do you

expect ATP synthesis to continue in the presence of low concentrations of detergent?

- Yes, because all enzymes and electron carriers are functional.
- No, because with a leaky membrane, an H<sup>+</sup> gradient cannot be maintained.
- No, because leaky membranes do not allow NADH's to donate their electrons to the electron transport chain.
- No, because leaky membranes inhibit glycolysis.

10. (Analyze) An industrial pollutant is suspected of being responsible for a local 'fish kill' in a stream. It is hypothesized that the substance impairs an organism's ability to perform cellular respiration. Studies were conducted to determine the effect of the substance on muscle cells under high oxygen concentrations. Below are the results of the study, showing the products of each metabolic pathway per glucose molecule metabolized:

<b>Glycolysis</b>	<b>Pyruvate Oxidation (addition of CoA)</b>	<b>Citric Acid Cycle</b>	<b>Oxidative Phosphorylation (ETC)</b>
2 ATP (Net)	0 ATP	2 ATP	12 ATP
2 NADH	2 NADH	6 NADH	3 NAD
2 pyruvate	2 CO <sub>2</sub>	2 FADH <sub>2</sub>	1 FAD
		4 CO <sub>2</sub>	

Which pathway seems to be directly impacted by the substance?

- glycolysis
  - pyruvate metabolism
  - citric acid cycle/Krebs cycle
  - oxidative phosphorylation
  - catabolism
11. (Apply) Some drugs known as uncouplers facilitate diffusion of protons across the mitochondrial inner membrane. When such a drug is added, what will happen to ATP synthesis and oxygen consumption?
- Both ATP synthesis and oxygen consumption will decrease.
  - ATP synthesis will decrease; oxygen consumption will increase.
  - ATP synthesis will increase; oxygen consumption will decrease.
  - Both ATP synthesis and oxygen consumption will increase.
  - ATP synthesis will decrease; oxygen consumption will stay the same
12. (Evaluate) According to the Census Bureau, the highest population growth rates are in underdeveloped countries. A possible explanation for this is
- Lower death rates
  - Shorter generation times
  - Decreased biotic potential
  - Less limiting factors