



AP®

AP® Biology

Practice Exam #3 and Notes

For the
Spring 2020
Exam

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Practice Exam

Exam Content and Format

The AP Biology Exam is approximately 3 hours in length. There are two sections.

- Section I is 1 hour, 30 minutes and consists of 60 multiple-choice questions, accounting for 50 percent of the final score.
- Section II is 1 hour, 30 minutes and consists of 2 long free-response questions and 4 short free-response questions, accounting for 50 percent of the final score.

Administering the Practice Exam

This section contains instructions for administering the AP Biology Practice Exam. You may wish to use these instructions to create an exam situation that resembles an actual administration. If so, read the indented, boldface directions to the students; all other instructions are for administering the exam and need not be read aloud. Before beginning testing, have all exam materials ready for distribution. These include test booklets and answer sheets. (Reminder: Final instructions for every AP Exam are published in the AP Exam Instructions book.)

SECTION I: Multiple Choice

When you are ready to begin Section I, say:

Section I is the multiple-choice portion of the exam. Mark all of your responses on your answer sheet, one response per question. If you need to erase, do so carefully and completely. Your score on the multiple-choice section will be based solely on the number of questions answered correctly. You may use a four-function (with square root), scientific, or graphing calculator. Are there any questions?

You have 1 hour and 30 minutes for this section. Open your Section I booklet and begin.

Note Start Time here _____. Note Stop Time here _____. After 1 hour and 20 minutes, say:

There are 10 minutes remaining.

After 10 minutes, say:

Stop working. I will now collect your Section I booklet and multiple-choice answer sheet.

There is a 10-minute break between Sections I and II.

SECTION II: Free Response

After the break, say:

Section II is the free-response portion of the exam.

You have 1 hour and 30 minutes to answer the questions. You are responsible for pacing yourself, and may proceed freely from one question to the next. Write your answers on the lined pages provided for each question. If you need more paper during the exam, raise your hand. At the top of each extra piece of paper you use, be sure to write your name and the number of the question you are working on. Are there any questions? Open your Section II booklet and begin.

Note Start Time here _____. Note Stop Time here _____. After 1 hour and 20 minutes, say:

There are 10 minutes remaining.

After 10 minutes, say:

Stop working and close your exam booklet. Put your exam booklet on your desk, face up. Remain in your seat, without talking, while the exam materials are collected.

If any students used extra paper for the free-response section, have those students staple the extra sheet/s to the first page corresponding to that question in their exam booklets. Collect a Section II booklet from each student and check that each student wrote answers on the lined pages corresponding to each question. Then say:

The exam is over. You are now dismissed.

Name: _____

**AP® Biology
Answer Sheet
for Multiple-Choice Section**

No.	Answer
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AP[®] Biology Exam

SECTION I: Multiple Choice

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

At a Glance

Total Time	1 hour and 30 minutes
Number of Questions	60
Percent of Total Score	50%
Writing Instrument	Pencil required
Electronic Device	Calculator allowed

Instructions

Section I of this exam contains 60 multiple-choice questions. Indicate all of your answers to the Section I questions on the answer sheet. No credit will be given for anything written in this exam booklet, but you may use the booklet for notes or scratch work.

Use your time effectively, working as quickly as you can without losing accuracy. Do not spend too much time on any one question. Go on to other questions and come back to the ones you have not answered if you have time. It is not expected that everyone will know the answers to all of the multiple-choice questions.

Your total score on Section I is based only on the number of questions answered correctly. Points are not deducted for incorrect answers or unanswered questions.

AP® BIOLOGY EQUATIONS AND FORMULAS

Statistical Analysis and Probability

Mean

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

Standard Deviation

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

Standard Error of the Mean

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

Chi-Square

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

Chi-Square Table

p value	Degrees of Freedom							
	1	2	3	4	5	6	7	8
0.05	3.84	5.99	7.81	9.49	11.07	12.59	14.07	15.51
0.01	6.63	9.21	11.34	13.28	15.09	16.81	18.48	20.09

Laws of Probability

If A and B are mutually exclusive, then:

$$P(A \text{ or } B) = P(A) + P(B)$$

If A and B are independent, then:

$$P(A \text{ and } B) = P(A) \times P(B)$$

Hardy-Weinberg Equations

$$p^2 + 2pq + q^2 = 1 \quad p = \text{frequency of allele 1 in a population}$$

$$p + q = 1 \quad q = \text{frequency of allele 2 in a population}$$

Standard Deviation

\bar{x} = sample mean

n = sample size

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

o = observed results

e = expected results

Σ = sum of all

Degrees of freedom are equal to the number of distinct possible outcomes minus one.

Metric Prefixes

<u>Factor</u>	<u>Prefix</u>	<u>Symbol</u>
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-1}	deci	d
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)

<p>Rate and Growth</p> <p>Rate</p> $\frac{dY}{dt}$ <p>Population Growth</p> $\frac{dN}{dt} = B - D$ <p>Exponential Growth</p> $\frac{dN}{dt} = r_{\max} N$ <p>Logistic Growth</p> $\frac{dN}{dt} = r_{\max} N \left(\frac{K - N}{K} \right)$	<p>dY = amount of change</p> <p>dt = change in time</p> <p>B = birth rate</p> <p>D = death rate</p> <p>N = population size</p> <p>K = carrying capacity</p> <p>r_{\max} = maximum per capita growth rate of population</p>	<p>Water Potential (Ψ)</p> <p>$\Psi = \Psi_P + \Psi_S$</p> <p>Ψ_P = pressure potential</p> <p>Ψ_S = solute potential</p> <p>The water potential will be equal to the solute potential of a solution in an open container because the pressure potential of the solution in an open container is zero.</p>																								
<p>Simpson's Diversity Index</p> <p>Diversity Index = $1 - \sum \left(\frac{n}{N} \right)^2$</p> <p>$n$ = total number of organisms of a particular species</p> <p>N = total number of organisms of all species</p>																										
<p>Surface Area and Volume</p>																										
<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 33%;">Surface Area of a Sphere</td> <td style="width: 33%;">Volume of a Sphere</td> <td style="width: 33%;">r = radius</td> </tr> <tr> <td>$SA = 4\pi r^2$</td> <td>$V = \frac{4}{3}\pi r^3$</td> <td>l = length</td> </tr> <tr> <td>Surface Area of a Rectangular Solid</td> <td>Volume of a Rectangular Solid</td> <td>h = height</td> </tr> <tr> <td>$SA = 2lh + 2lw + 2wh$</td> <td>$V = lwh$</td> <td>w = width</td> </tr> <tr> <td>Surface Area of a Cylinder</td> <td>Volume of a Cylinder</td> <td>s = length of one side of a cube</td> </tr> <tr> <td>$SA = 2\pi rh + 2\pi r^2$</td> <td>$V = \pi r^2 h$</td> <td>SA = surface area</td> </tr> <tr> <td>Surface Area of a Cube</td> <td>Volume of a Cube</td> <td>V = volume</td> </tr> <tr> <td>$SA = 6s^2$</td> <td>$V = s^3$</td> <td></td> </tr> </table>			Surface Area of a Sphere	Volume of a Sphere	r = radius	$SA = 4\pi r^2$	$V = \frac{4}{3}\pi r^3$	l = length	Surface Area of a Rectangular Solid	Volume of a Rectangular Solid	h = height	$SA = 2lh + 2lw + 2wh$	$V = lwh$	w = width	Surface Area of a Cylinder	Volume of a Cylinder	s = length of one side of a cube	$SA = 2\pi rh + 2\pi r^2$	$V = \pi r^2 h$	SA = surface area	Surface Area of a Cube	Volume of a Cube	V = volume	$SA = 6s^2$	$V = s^3$	
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BIOLOGY

SECTION I

Time—1 hour and 30 minutes

60 Questions

Directions: Each of the questions or incomplete statements below is followed by four suggested answers or completions. Select the one that is best in each case and then enter the letter in the corresponding space on the answer sheet.

1. Many species of corals are threatened by the increasing temperatures and decreasing pH of ocean waters. One species, *Stylophora pistillata*, has been found to thrive in water that is warmer and has a lower pH than the water that corals typically thrive in. Additionally, researchers have found that the tolerance for the new water conditions is heritable.

Which of the following statements best explains the changes seen in *S. pistillata* in response to the changing water conditions?

- (A) The corals' adaptation is an example of natural selection because the tolerance is in response to a changing environment and has a genetic basis.
- (B) The corals' adaptation is an example of the founder effect because the majority of corals do not have a tolerance for warmer water.
- (C) The corals' adaptation is an example of genetic drift because the change was a chance event and not the result of selection in response to environmental change.
- (D) The corals' adaptation is an example of adaptive radiation because it has resulted in a wide range of species adapting to the new ocean conditions.

2. A researcher measured the temperature at which two different samples of double-stranded DNA denature (separate into single strands). Sample 1 denatured at a significantly lower temperature than sample 2 did. Based on the data, the researcher claims that the DNA in sample 2 is composed of a higher percentage of guanine and cytosine than the DNA in sample 1 is.

Which of the following best supports the researcher's claim?

- (A) The bonds between guanine and cytosine are covalent bonds, which require more energy to disrupt than those between adenine and thymine.
- (B) Guanine-cytosine pairs denature at a higher temperature because they have more hydrogen bonds between them than adenine-thymine pairs do.
- (C) Adenine-thymine pairs require less energy to separate because adenine and thymine are both single-ring bases.
- (D) Guanine-cytosine pairs require more energy to separate because one is a purine and one is a pyrimidine.

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3. Researchers studying the bacterium *Escherichia coli* split a population of the bacteria into two samples.

Sample 1 was transformed with a plasmid containing a gene that makes the bacteria resistant to the antibiotic kanamycin. Sample 2 was transformed with a plasmid lacking the antibiotic resistance gene. A portion of each sample was then added to growth plates containing just nutrients or growth plates containing nutrients and kanamycin.

After being allowed to grow for 24 hours at 37°C, the number of colonies on each growth plate was counted (Table 1).

TABLE 1. BACTERIAL GROWTH FOLLOWING TRANSFORMATION WITH OR WITHOUT THE KANAMYCIN RESISTANCE GENE

Plate #	Transforming Plasmid Contains Kanamycin Resistance Gene	Growth Media	Results
1	No	Nutrient only	Too many colonies to count (lawn)
2	Yes	Nutrient only	Too many colonies to count (lawn)
3	No	Nutrient with antibiotic	No colonies observed
4	Yes	Nutrient with antibiotic	7 colonies observed

Which of the following claims is best supported by the data in Table 1?

- (A) The transformation procedure killed all the bacteria that were added to plate 3.
- (B) More bacteria on plates 1 and 2 were successfully transformed than on any other plate.
- (C) None of the bacteria on plate 2 were successfully transformed with the kanamycin resistance gene.
- (D) Only the bacteria that were successfully transformed with the kanamycin resistance gene grew on plate 4.

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4. The fertilization of ovules from plant Q by pollen from plant R results in the production of seeds. What percent of the genes in each offspring's chloroplasts will have been inherited from plant R ?

- (A) 0%
- (B) 25%
- (C) 50%
- (D) 100%

GO ON TO THE NEXT PAGE.

Questions 5 - 8

High levels of certain plant nutrients in runoff can lead to rapid growth of algae (an algal bloom) in aquatic ecosystems. These algal blooms are generally followed by algal death and decomposition, which consumes large amounts of dissolved oxygen in the water and results in oxygen levels insufficient to support aerobic respiration. This process is known as eutrophication. The amount of algae present in a body of water can be estimated from the amount of chlorophyll *a* in a sample of the water. A researcher studying eutrophication collected samples at different times of the year in a freshwater ecosystem. The samples were analyzed for total nitrogen and chlorophyll *a* concentration (Figure 1) as well as total phosphorus and chlorophyll *a* concentration (Figure 2).

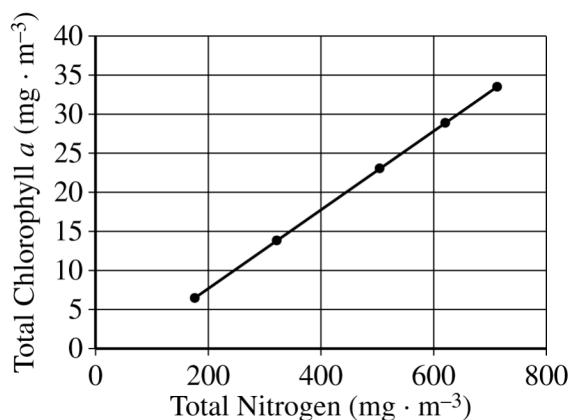


Figure 1. Amount of chlorophyll *a* in relation to the amount of total nitrogen

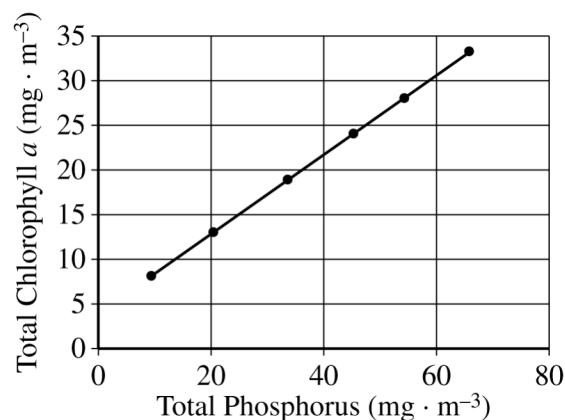


Figure 2. Amount of chlorophyll *a* in relation to the amount of total phosphorous

5. Which of the following best explains how higher concentrations of nitrogen and phosphorus contribute to eutrophication?
- (A) An increase in the population of algae results in more nitrogen and phosphorus in the water, causing severe eutrophication.
 - (B) Both bacteria and algae require nitrogen and phosphorus, so the algae must grow faster to compete with bacteria.
 - (C) Nitrogen and phosphorus stimulate oxidative phosphorylation, which consumes the available oxygen in the water.
 - (D) Algae require nitrogen and phosphorus to build macromolecules, so higher concentrations of these nutrients can result in algal blooms.

6. Which of the following was the dependent variable in the researcher's study?
- (A) The concentration of chlorophyll *a*
 - (B) The concentration of total nitrogen and phosphorus
 - (C) The slope of the trend line showing the rate of change
 - (D) The variance of the data points from the trend line

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7. Which of the following describes the relationship between the amount of chlorophyll *a* in a water sample and the concentration of nitrogen in that sample?
- (A) As the concentration of chlorophyll *a* increases, the concentration of nitrogen decreases.
- (B) The concentrations of nitrogen and chlorophyll *a* are directly correlated.
- (C) The concentrations of chlorophyll *a* and nitrogen increase throughout the year.
- (D) There is no relationship between the concentrations of chlorophyll *a* and nitrogen.
8. Which of the following investigations would enable researchers to test the claim that an increased concentration of algae has a negative effect on the number of aquatic invertebrates in the ecosystem?
- (A) Examining the contents of the digestive tracts of aquatic invertebrates and looking for the presence of algae
- (B) Examining the growth rate of algae in the absence of aquatic invertebrates
- (C) Counting the number of aquatic invertebrates at different concentrations of chlorophyll *a* in the water
- (D) Counting the number of aquatic invertebrates at different concentrations of nitrogen and phosphorus in the water

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9. Amylase is an enzyme that converts carbohydrate polymers into monomers. Glycogen synthase is one of the enzymes involved in converting carbohydrate monomers into polymers.

Which of the following best explains the reactions of these enzymes?

- (A) Amylase aids in the removal of a water molecule to break covalent bonds whereas glycogen synthase aids in the addition of a water molecule to form covalent bonds.
- (B) Amylase aids in the addition of a water molecule to break covalent bonds whereas glycogen synthase aids in the removal of a water molecule to form covalent bonds.
- (C) Amylase aids in the addition of a water molecule to form covalent bonds whereas glycogen synthase aids in the removal of a water molecule to break covalent bonds.
- (D) Amylase aids in the removal of a water molecule to form covalent bonds whereas glycogen synthase aids in the addition of a water molecule to break covalent bonds.

11. Lactase is the enzyme needed to digest lactose, the sugar found in milk. Most mammals produce lactase when they are young but stop once nursing ends. In humans however, many people continue to produce lactase into adulthood and are referred to as lactase-persistent.

Which of the following mutations is most likely to cause lactase persistence in humans?

- (A) A nucleotide substitution in the coding region of the lactase gene that interferes with the interaction between lactase and lactose
- (B) A mutation that turns off the expression of transcription factors that activate the expression of lactase
- (C) A mutation that increases the binding of transcription factors to the promoter of the lactase gene
- (D) The insertion of a single nucleotide into the lactase gene that results in the formation of a stop codon

10. Which of the following describes the most likely location of cholesterol in an animal cell?

- (A) Embedded in the plasma membrane
- (B) Dissolved in the cytosol
- (C) Suspended in the stroma of the chloroplast
- (D) Bound to free ribosomes

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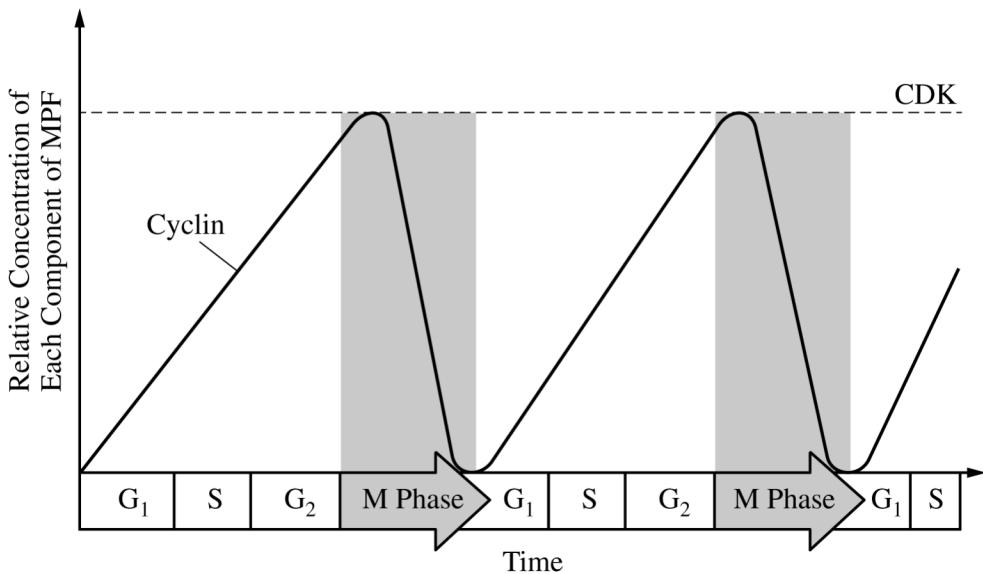


Figure 1. The relative concentrations of both the cyclin and CDK components of MPF

12. Maturation promoting factor, MPF, is a cyclin-CDK complex that catalyzes the phosphorylation of other proteins to start mitosis. The activity level of MPF is dependent on the relative concentrations of the cyclin and CDK components of MPF (Figure 1).

Based on Figure 1, which of the following describes the role of cyclin in the regulation of the cell cycle?

- (A) During G₁ phase, the cyclin level decreases to signal the start of the resting phase of the cell cycle.
- (B) During M phase, the cyclin level peaks, resulting in an increased binding frequency with CDK.
- (C) During S phase, the cyclin level remains the same because DNA replication is occurring.
- (D) During G₂ phase, the cyclin level remains low, causing MPF activity to decrease, which leads cells to initiate mitosis.

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13. Modern bananas originated from a cross between a tetraploid banana species and a diploid banana species. The product of this cross was the triploid Cavendish banana strain, a sterile hybrid that is only grown asexually. Recently, the Panama fungus has been observed more frequently parasitizing the Cavendish banana, and scientists claim that this type of banana is on the brink of extinction.

Which of the following provides the best explanation of the scientists' claim regarding the threat to the Cavendish banana?

- (A) The triploid genome of the Cavendish banana makes it susceptible to the negative impact of recessive alleles.
- (B) Having three of each chromosome interferes with normal function of the cells and increases the likelihood of contracting a disease.
- (C) The lack of genetic diversity of the Cavendish banana decreases the chance that a variation exists in the population that is immune to the fungus.
- (D) Asexual reproduction increases the mutation rate during replication, resulting in a greater chance that the offspring have a dysfunctional immune system.

14. Belding's ground squirrels (*Spermophilus beldingi*) live in closely related groups. When they feed in the open, certain individuals (guard squirrels) watch for predators instead of feeding. The guard squirrels give an alarm call when a predator is sighted, allowing the rest of the group to run to safety. Researchers have noted that, because the alarm call draws attention to the guard, the guard is more likely to be caught by the predator and therefore has a lower survival rate in comparison with the other squirrels.

Which of the following best explains the behavior of the guard squirrels?

- (A) The behavior of the guard squirrels increases the survival of close relatives that share the genes of the guard squirrels.
- (B) The guard squirrels confuse the predator, lowering the predator's success rate because the predator cannot tell which squirrel is producing the sound.
- (C) Guard squirrels typically have recessive alleles, and by sacrificing themselves, they lessen the chance that recessive alleles will get passed on.
- (D) Guard squirrels are typically females who have already reproduced, so they are no longer needed by the group.

15. If 30% of the nucleotides in a single-stranded RNA molecule are adenine, then what percent are expected to be thymine?

- (A) 0%
- (B) 20%
- (C) 30%
- (D) 70%

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Questions 16 - 19

Melanocytes are skin cells that can become cancerous and develop into a cancer known as melanoma. Some cancerous melanocytes have developed resistance to the drugs currently used to treat melanoma. As a result, researchers are investigating the effects of a new compound (drug X) on four different melanoma cell lines. Researchers analyzed cell survival in two cell lines (Figure 1) and oxygen consumption in the presence of drug X in all four cell lines (Figure 2). Figure 3 shows the proposed mechanism by which drug X affects cells.

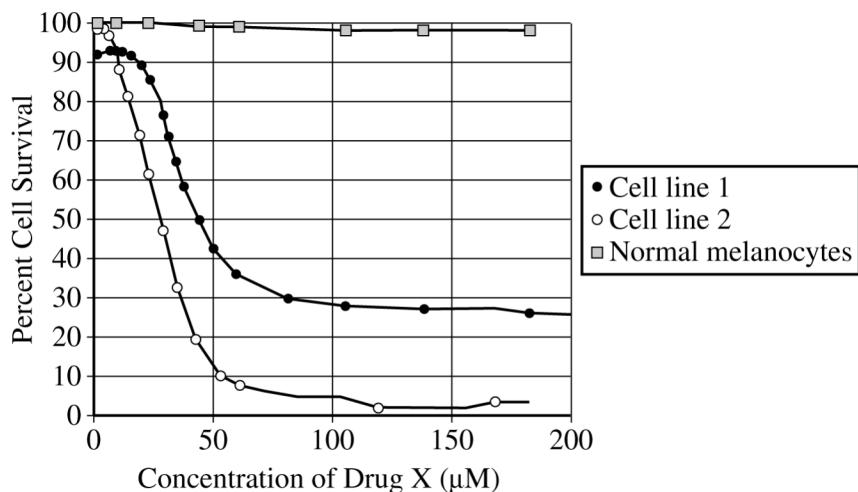


Figure 1. Percent survival of normal melanocytes and cancerous melanocyte (melanoma) lines 1 and 2 after treatment with different concentrations of drug X

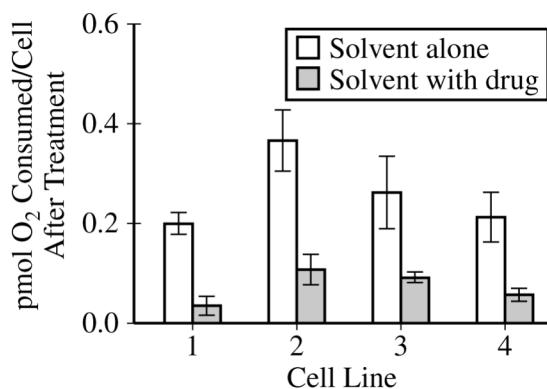


Figure 2. Oxygen consumption per cell in four melanoma lines after treatment with either solvent alone or solvent containing drug X. Error bars represent $\pm 2\text{SE}_x$.

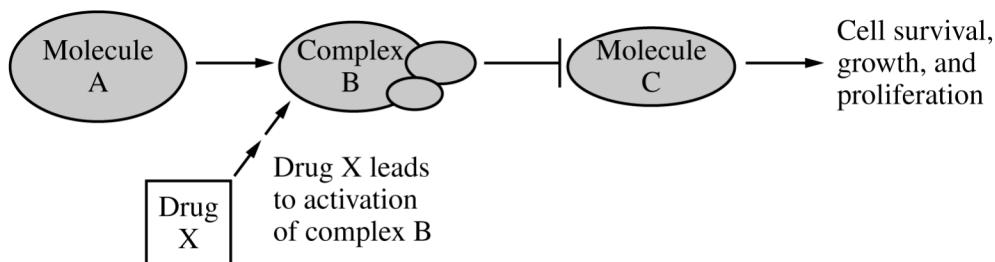


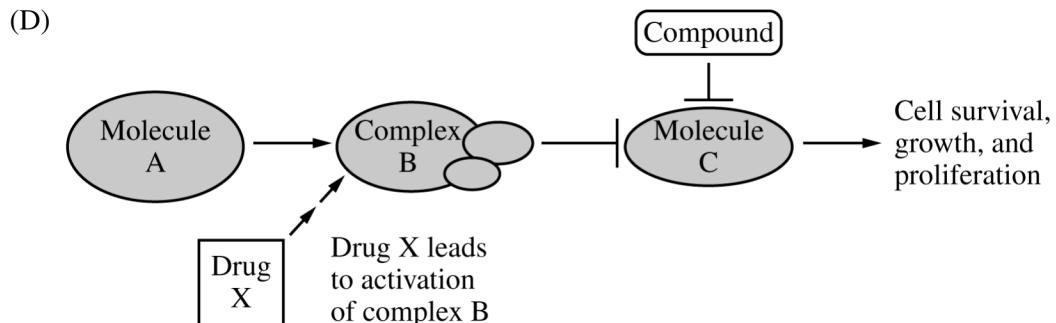
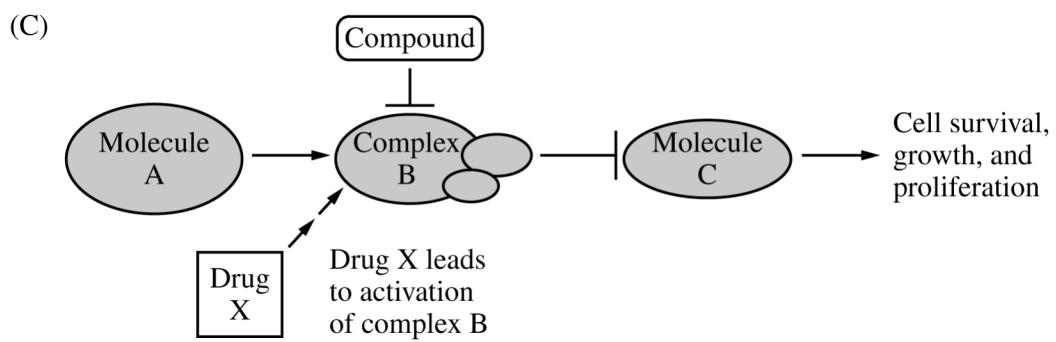
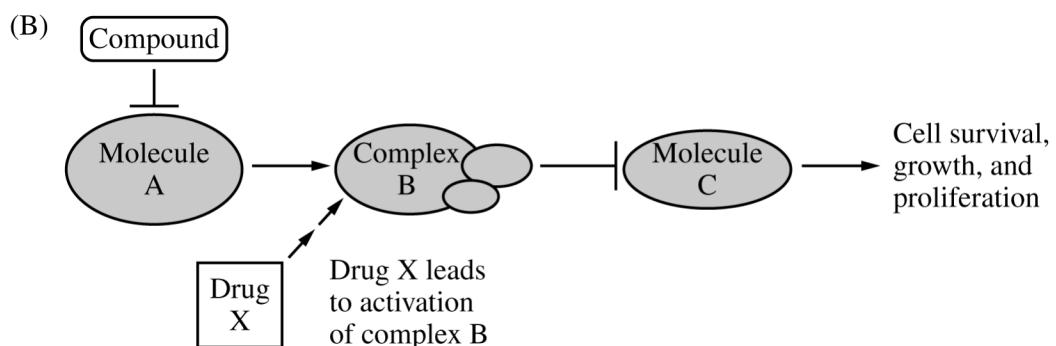
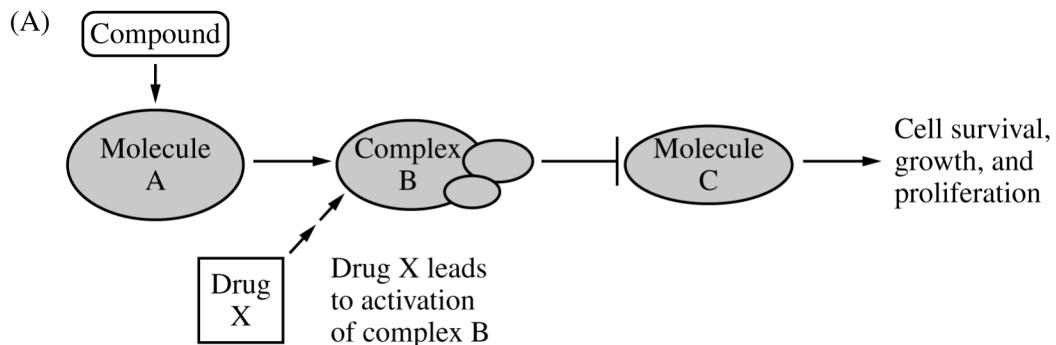
Figure 3. Pathway leading to cell survival, growth, and proliferation and the likely effect of drug X

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16. Which of the following best describes the data in Figure 1 ?
- (A) As the concentration of drug X increases, there is an increase in melanoma cell survival.
(B) At a concentration above $10\text{ }\mu\text{M}$, drug X reduces melanoma cell survival.
(C) At a concentration below $25\text{ }\mu\text{M}$, drug X increases survival in all melanoma cell lines.
(D) At a concentration of $25\text{ }\mu\text{M}$, drug X has a greater effect on melanoma line 1 than on melanoma line 2.
17. Based on Figure 2, which of the following best supports the claim that drug X inhibits oxygen consumption?
- (A) In the absence of drug X, melanoma lines 1 and 4 consume similar amounts of oxygen.
(B) In the presence of drug X, melanoma line 2 consumes statistically more oxygen per cell than does melanoma line 3.
(C) Melanoma line 3 consumes statistically less oxygen per cell in the presence of drug X than it does in the presence of the solvent alone.
(D) Melanoma line 2 in the presence of drug X consumes statistically less oxygen than does melanoma line 4 in the absence of drug X.
18. Based on the information presented, which of the following best explains why the researchers measured oxygen consumption as an indicator of the effectiveness of drug X ?
- (A) Oxygen provides the source of electrons for cellular respiration and is necessary for energy production.
(B) Oxygen consumption increases the mutation rate and causes cells to become cancerous.
(C) Oxygen activates apoptosis, which results in the death of melanoma cells.
(D) Oxygen accepts electrons in oxidative phosphorylation, a process necessary for melanoma cell survival.

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19. A researcher has identified a compound that reverses the effect of drug X. Based on Figure 3, which of the following best explains how the compound acts in the pathway to reverse the effects of drug X?



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20. Which of the following best explains how molecules such as O₂ and CO₂ can move across the membrane of a cell?
- (A) The majority of the cell membrane contains protein channels that allow this type of molecule into the cell.
 - (B) The majority of the cell membrane is nonpolar, which allows small, nonpolar molecules to freely cross.
 - (C) The phospholipids of the membrane are tightly packed, so only small molecules and ions can fit between phospholipids.
 - (D) ATP is hydrolyzed to provide energy to help O₂ and CO₂ move against their concentration gradient and across the membrane.

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21. Scientists investigated the effect of oxygen levels on the net rate of carbon fixation in two types of plants. The plants were grown in either well-watered soil (control) or dry soil and then exposed to either 21% or 1% O₂. The net rate of CO₂ fixation for both types of plants was measured. Data are shown in Figure 1 and Figure 2.

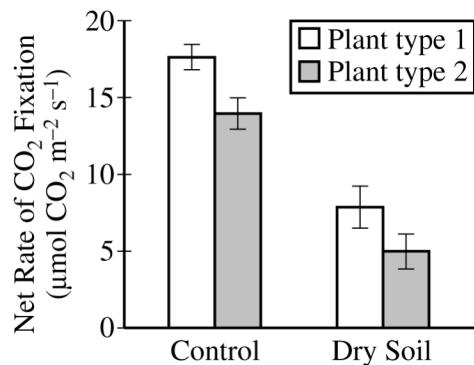


Figure 1. Net rate of CO₂ fixation in two types of plants grown in wet (control) or dry soil at 21% O₂

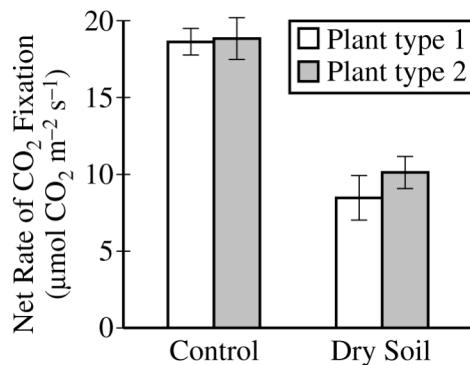


Figure 2. Net rate of CO₂ fixation in two types of plants grown in wet (control) or dry soil at 1% O₂

Which of the following statements about the rate of CO₂ fixation in the two types of plants is supported by the data shown in the figures?

- (A) At 21% O₂, plant type 2 has a lower rate of CO₂ fixation than plant type 1 does in both types of soil.
- (B) At 1% O₂, plant type 2 has a higher rate of CO₂ fixation than plant type 1 does in the dry soil but not in the control soil.
- (C) Plant types 1 and 2 have a statistically different rate of CO₂ fixation in both soil types at both oxygen levels.
- (D) The rate of CO₂ fixation is the same in both types of plants in the control soil at both oxygen levels.

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22. A researcher is conducting an experiment in which cells in different phases of the cell cycle are fused together. The researcher then records what happens to the nuclei of the resulting cell (Table 1).

TABLE 1. COMBINATIONS OF CELLS THAT WERE FUSED AND THE PHASE OF NUCLEI IN THE RESULTING CELL

Phase of Cell 1	Phase of Cell 2	Phase of Nuclei in Resulting Cell
S phase	G ₁ phase	Two S-phase nuclei
S phase	G ₂ phase	One S-phase nucleus and one G ₂ -phase nucleus
G ₁ phase	G ₂ phase	One G ₁ -phase nucleus and one G ₂ -phase nucleus
Interphase	M phase	Two M-phase nuclei

Which of the following research questions is best addressed by the experiment?

- (A) How do chemical messengers affect a cell's transition between the phases of the cell cycle?
- (B) How does the number of chromosomes affect when a cell transitions to the next phase of the cell cycle?
- (C) How does the amount of genetic information change throughout the cell cycle?
- (D) How does the checkpoint at G₂ serve to prevent the transmission of mutations?

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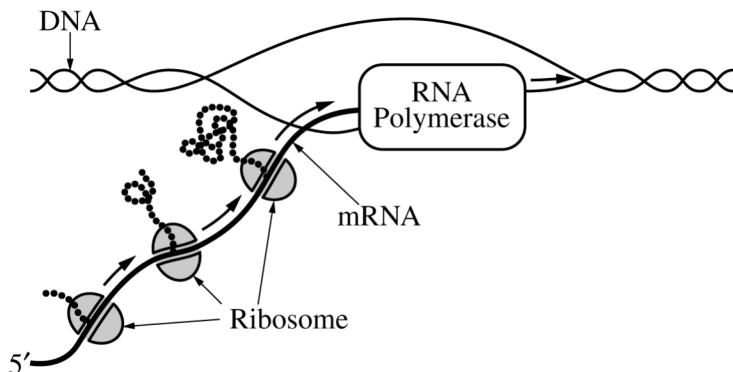


Figure 1. Protein synthesis in a prokaryotic cell

23. Which of the following best describes a characteristic of the process shown in Figure 1 that is unique to prokaryotes?
- The mRNA is synthesized in a 5' to 3' direction.
 - A single strand of the DNA is being used as a template for the transcription of the mRNA.
 - The translation of the mRNA is occurring while the mRNA is still being transcribed.
 - The enzyme that is transcribing the mRNA is RNA polymerase.
24. A scientist is investigating the possibility that two traits in a particular plant are determined by genes that are on the same chromosome. The scientist crossed a plant that is homozygous dominant for both traits with a plant that is homozygous recessive for both traits. The heterozygous offspring in the F₁ generation were then crossed with a plant that is homozygous recessive for both traits. The results expected if the genes independently assort and the observed results are presented in the table.

Phenotype	Expected Number in F ₂	Observed Number in F ₂
Long stems, white flowers	25	17
Short stems, red flowers	25	19
Long stems, red flowers	25	31
Short stems, white flowers	25	33
Total number of plants	100	100

Which of the following critical values should the scientist use for the chi-square analysis of the data?

- 3.00
- 3.84
- 7.81
- 8.00

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25. Sugar gliders and Northern flying squirrels are mammals that have many morphological similarities despite being genetically different. Both are nocturnal and have large eyes to help them see in the dark. Both live in trees and have flaps of skin connecting their front and back legs, and when their front and back legs are extended, the flaps allow the animals to glide from one tree branch to another. Sugar gliders are native to Australia, and Northern flying squirrels are native to North America.

Which of the following best explains the morphological similarities between these two species?

- (A) The similarities in traits indicate the species are the result of divergent evolution from a common ancestor that had the same traits that these two species share.
- (B) The traits evolved through sympatric speciation, which often results in species being highly similar because they evolve in the same area.
- (C) The two species evolved as the result of two separate bottleneck events that reduced the existing populations to a few individuals who happened to have the same traits.
- (D) The similarities between the species evolved independently as a result of similar selective pressures in each species' environment.

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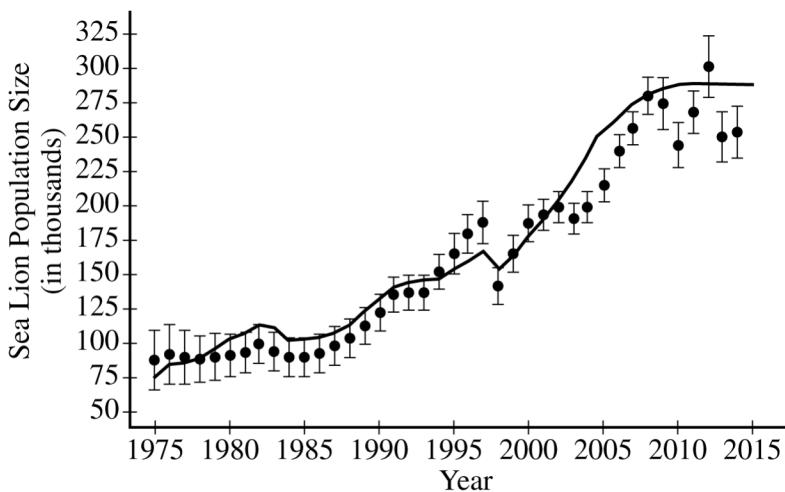
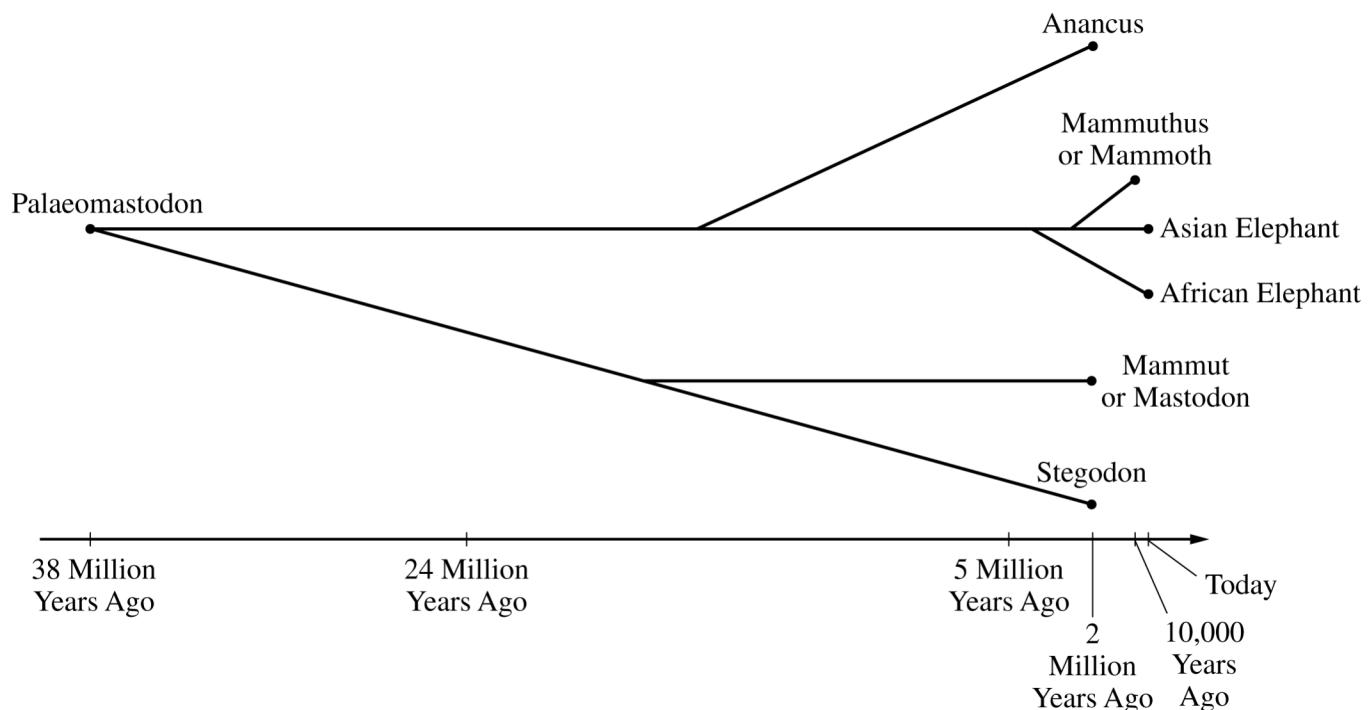


Figure 1. Change in the population size of sea lions over time. Error bars represent $\pm 2\text{SE}_x$.

26. Which of the following best estimates the population size of the sea lions in 2000 based on the data shown in Figure 1 ?

- (A) 100,000
- (B) 125,000
- (C) 175,000
- (D) 285,000

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27. The figure shows a phylogenetic tree of various members of the order Proboscidea, which includes modern elephants. Which of the following claims is best supported by the information in the figure?

- (A) The Asian and African elephants are the most closely related species shown on the tree.
- (B) The mammoth diverged from its most recent common ancestor with African elephants before the mastodon diverged from its most recent common ancestor with Stegodons.
- (C) The mastodon and the Stegodon diverged from their common ancestor 2 million years ago.
- (D) The common ancestor of the African elephant and the mastodon is the Palaeomastodon.

28. Which of the following describes the most direct effect of a mutation in the DNA that encodes a cell's rRNA?

- (A) The cell's ability to transport the amino acids needed for translation will be reduced.
- (B) The cell's ability to transcribe RNA transcripts that will be translated will be reduced.
- (C) The cell's ability to properly assemble ribosomes and initiate translation will be reduced.
- (D) The cell's ability to modify proteins after they have been assembled will be reduced.

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Questions 29 - 32

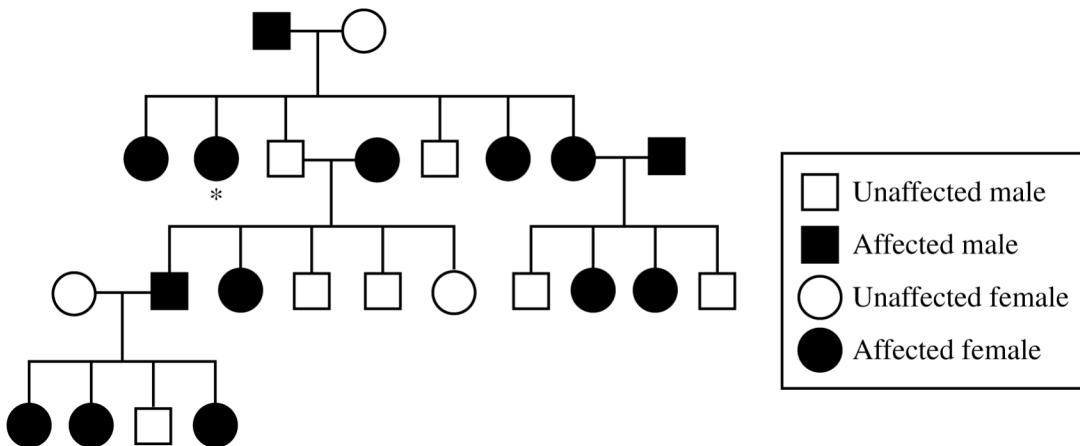


Figure 1. Incidence of protoporphyrria in a particular family

Protoporphyrria is a genetic disorder characterized by an extreme sensitivity to sunlight. One form of protoporphyrria is caused by a mutation in the *ALAS2* gene that results in the accumulation of protoporphyrin, an organic compound, in the blood, liver, and skin. The pedigree in Figure 1 shows the incidence of protoporphyrria in a particular family.

29. Which of the following best describes the genotype of the individual identified with an asterisk in the pedigree in Figure 1 ?
- Two dominant *ALAS2* alleles
 - Two recessive *ALAS2* alleles
 - One dominant *ALAS2* allele and one recessive *ALAS2* allele
 - One recessive *ALAS2* allele and no second allele for the *ALAS2* gene
30. Which of the following best describes the inheritance pattern illustrated in Figure 1 ?
- Protoporphyrria has an autosomal recessive inheritance pattern.
 - Protoporphyrria has an X-linked dominant inheritance pattern.
 - Protoporphyrria has an X-linked recessive inheritance pattern.
 - Protoporphyrria has a mitochondrial inheritance pattern.

31. One mutation in *ALAS2* that is associated with protoporphyrria is a four-nucleotide deletion. The protein expressed from the mutant allele is 20 amino acids shorter than the wild-type protein.

Which of the following best explains why a shortened protein is produced?

- The mutation disrupts the start codon, preventing the ribosome from beginning translation.
- The mutation introduces a premature stop codon, causing translation to end early.
- The mutation changes the gene's regulatory region, causing unregulated gene expression.
- The mutation affects posttranscriptional modifications by preventing the removal of introns.

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32. A researcher claims that an individual has protoporphyrin, based on a physical exam. Which of the following techniques would most likely confirm the researcher's claim?
- (A) Transforming bacteria with the mutant variation of *ALAS2* to measure gene expression
(B) Culturing cells from the individual in the lab and measuring the cells' growth rate
(C) Using light microscopy to examine the individual's chromosomes during metaphase
(D) Determining the nucleotide sequence of the individual's *ALAS2* alleles
-
33. Which of the following is evidence that eukaryotes and prokaryotes share a common ancestor?
- (A) All eukaryotes and prokaryotes contain linear DNA.
(B) All eukaryotes and prokaryotes contain ribosomes.
(C) All eukaryotes and prokaryotes use organic molecules as an energy source.
(D) All eukaryotes and prokaryotes are capable of mitosis.
34. Wolves, once native to Yellowstone National Park, were hunted to the point of complete extinction in the park. As a result, the elk population in the park flourished, putting extra demands on the carrying capacity of the park. Many other species, such as certain trees and beavers, were negatively affected by the increase in elk.
- Years later, wolves were reintroduced into the park. While the elk population decreased after the wolves returned, the beaver and songbird populations began to increase as did the populations of various plant species.
- Which of the following best explains how wolves are a keystone species in this ecosystem?
- (A) Wolves help balance the population sizes of other species, allowing more species to thrive in the wolves' presence than in their absence.
(B) Wolves prey on certain species, increasing competition among other species, which results in a decrease in biodiversity in the ecosystem.
(C) Wolves are not affected by factors that typically limit the population size; therefore their population can grow exponentially, increasing the demand on the parks' resources.
(D) Wolves prey on other species without having any natural predators themselves; therefore their presence significantly decreases many populations within the community.

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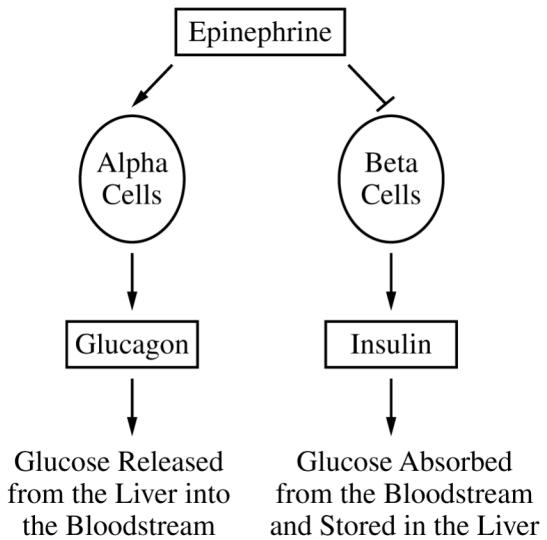


Figure 1. A model of epinephrine signaling

35. Two types of cells, alpha and beta cells, produce signaling molecules that affect blood sugar levels in opposite ways (Figure 1). Epinephrine is a chemical, often released during periods of exercise, that ultimately causes an increase in blood sugar levels in the body.

Based on Figure 1, which of the following best explains how exercise causes blood glucose levels to rise?

- (A) Epinephrine inhibits alpha cells, causing the release of glucagon, and activates beta cells, blocking the release of insulin.
- (B) Epinephrine activates alpha cells, blocking the release of glucagon, and inhibits beta cells, causing the release of insulin.
- (C) Epinephrine activates alpha cells, causing the release of glucagon, and inhibits beta cells, blocking the release of insulin.
- (D) Epinephrine inhibits alpha cells, blocking the release of glucagon, and activates beta cells, causing the release of insulin.

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36. Pesticides are chemicals that are often sprayed on crops to kill plant-eating insects, preventing damage to the crops. While pesticides are effective initially, many researchers claim that any single pesticide will see reduced effectiveness in as little as ten to fifteen years.

Which of the following best supports the claim by scientists that the pesticides will eventually lose their effectiveness?

- (A) Insects will evolve to avoid any plant sprayed with pesticides to increase their chances of survival.
- (B) Insects that are naturally resistant to the pesticide will survive and reproduce more than the insects that are sensitive to the pesticide.
- (C) The insects will build up a tolerance to the pesticides, and eventually the pesticide will not affect them.
- (D) The pesticides will increase the mutation rate in the insects, resulting in higher genetic diversity and higher survival rate.

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37. Newborn babies and hibernating animals contain a large amount of brown adipose (fat) tissue (BAT). Certain proteins in the BAT cells increase the permeability of the inner mitochondrial membrane to protons, disrupting the proton gradient.

Which of the following best predicts the effect of disrupting the proton gradient in BAT?

- (A) The pH of the matrix will increase, allowing the production of more ATP per gram of substrate.
- (B) The pH of the intermembrane space will decrease, allowing a steeper proton gradient to form.
- (C) Electron transport and oxidative phosphorylation will be decoupled, generating more heat but less ATP.
- (D) The number of protons available to pass through ATP synthase will increase, resulting in more ATP.

38. In pea plants, flower color and the length of the flower's pollen grains are genetically determined. Researchers studying pea plants crossed homozygous dominant pea plants with homozygous recessive pea plants. The F₁ plants were then crossed, and the number of offspring with each phenotype was recorded. The researchers' observed data, however, differed from the expected data. The researchers did a chi-square analysis and calculated the chi-square value to be 5.5.

Based on their calculation, the researchers would most likely conclude which of the following?

- (A) The genes that determine these two traits are likely on the same chromosome.
- (B) The differences between observed data and expected data are due to chance.
- (C) The genes mutated since the researchers began the experiment and now have a different inheritance pattern.
- (D) The allele frequencies of the offspring have changed, suggesting the population is evolving.

39. A massive increase in the growth of a specific species of algae resulted in record-breaking levels of a potentially dangerous toxin being released into the water. A researcher hypothesizes that the unusual growth of this algal species was caused by an increase in water temperature. The researcher designs an experiment to test the hypothesis.

Which of the following is the dependent variable in the researcher's experiment?

- (A) The growth of the algae
- (B) The temperature of the water
- (C) The concentration of toxin in the water
- (D) The different species of algae growing in the water

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40. Which of the following is the most likely effect of a mutation in the gene coding for a DNA repair enzyme?

- (A) The cell containing the mutation will divide more frequently because the cell cycle checkpoints will not function properly.
- (B) Mutations will accumulate more quickly because the cell will not be able to fix errors in replication.
- (C) The mutated gene will not be transcribed because RNA polymerase cannot transcribe mutated DNA.
- (D) The cell will immediately undergo apoptosis so that mutated DNA is not replicated in future rounds of cell division.

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Questions 41 - 45

Certain chemicals, including sodium fluoride (NaF), are capable of inhibiting specific steps of glycolysis. Figure 1 shows the steps of the glycolysis pathway, indicating where various macromolecules enter the pathway as well as the specific reaction inhibited by NaF.

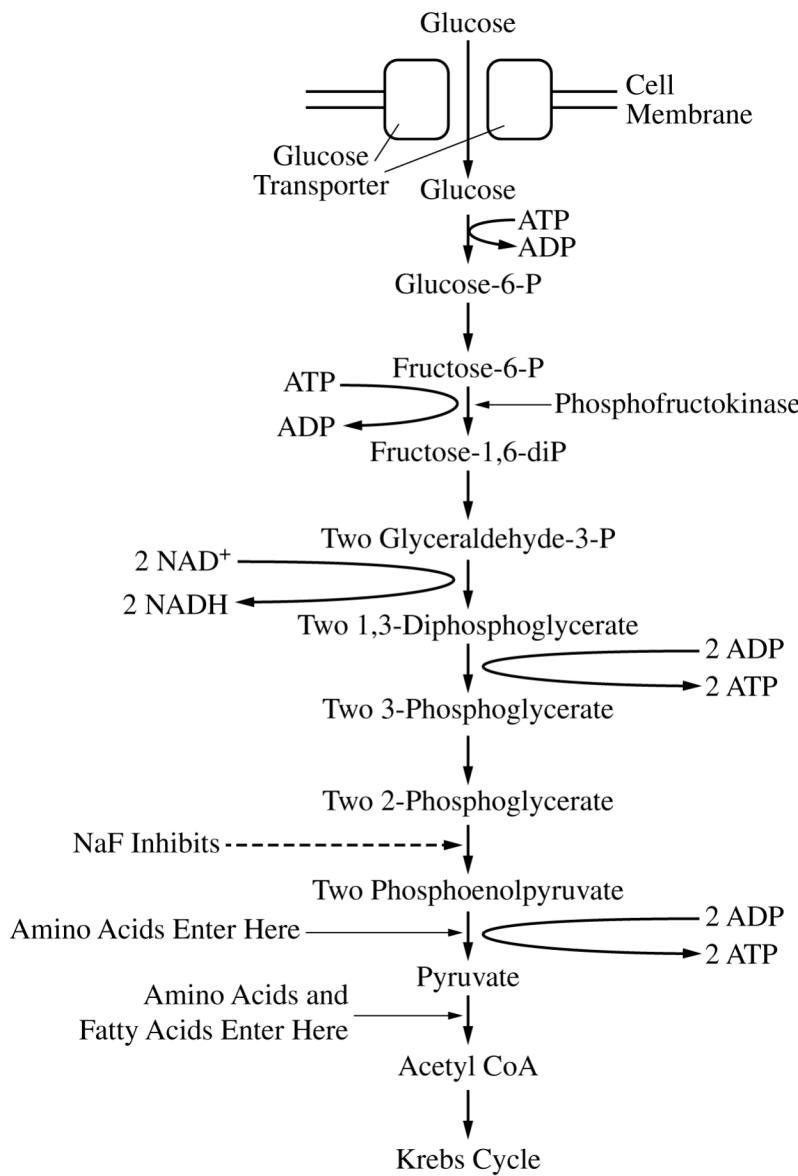


Figure 1. Key steps in the metabolic pathway of glucose

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41. If NaF is added to cells undergoing cellular respiration, which of the following will most likely accumulate in the cells?
- (A) Glucose Transporter
(B) Pyruvate
(C) Phosphoenolpyruvate (PEP)
(D) 2-phosphoglycerate
42. Based on Figure 1, the net number of ATP molecules produced during glycolysis from the metabolism of a single glucose molecule is closest to which of the following?
- (A) 0
(B) 2
(C) 4
(D) 8
43. An increase in the concentration of protons in the cytosol will most likely have which of the following effects on glycolysis?
- (A) Glycolytic enzymes will denature as a result of the increased H⁺ concentration.
(B) Reaction rate will increase as a result of the increased H⁺ concentration.
(C) H⁺ will replace phosphorous and inhibit ATP formation from ADP.
(D) The water potential will increase, resulting in a decrease in the rate of glycolysis.
44. Which of the following describes why a glucose transporter is needed to move glucose into the cell?
- (A) Glucose is nonpolar and requires ATP to move across the membrane.
(B) Glucose molecules are polar and need to move from low concentration to high concentration.
(C) Glucose molecules are charged, and charged molecules are only ever actively transported.
(D) Glucose is large and polar and cannot pass through the phospholipid bilayer.
45. Tarui disease is an inherited disorder that is caused by mutations in *PFKM*, the gene that encodes a subunit of phosphofructokinase, an enzyme in the glycolysis pathway. Individuals with Tarui disease produce little or no functional phosphofructokinase in skeletal muscle cells. Based on Figure 1, which of the following best explains why a low carbohydrate diet is recommended for those with Tarui disease?
- (A) Carbohydrates are capable of undergoing lactic acid fermentation, and amino acids and fatty acids are not.
(B) Carbohydrate metabolism requires all the reactions of glycolysis, and amino acids and fatty acids do not.
(C) Carbohydrates cannot be used to synthesize important metabolic enzymes like amino acids and fatty acids can be.
(D) Carbohydrates cannot be stored, while amino acids and fatty acids can be.

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46. A mutation in the upland cotton plant causes the development of chloroplasts with a single outer membrane and no internal membranes. Which of the following would most likely be observed in chloroplasts of cotton plants with this mutation?
- (A) They would be unable to remove waste products, because internal transport proteins would not be present.
- (B) They would be unable to generate the ATP and NADPH needed to make sugars, because these processes occur on membranes within the chloroplast.
- (C) They would be unable to take up carbon dioxide, because CO_2 is transported into the chloroplast in membrane-bound vesicles.
- (D) They would be unable to move within the cell, because only organelles with double membranes are mobile.
47. A researcher is crossing two organisms that are heterozygous for three Mendelian, unlinked traits ($XxYyZz$). Which of the following is the fraction of offspring that are predicted to have the genotype $xxyyzz$?
- (A) $1/64$
- (B) $1/32$
- (C) $1/16$
- (D) $1/8$
48. Mosquitoes are frequently a target of insect control strategies because of their ability to spread disease. One strategy is to introduce guppies, a type of freshwater fish, into areas where mosquitoes are a problem. Guppies can consume large numbers of mosquito larvae, which cuts down on the number of mosquitoes living to adulthood.
- Researchers assessing the effectiveness of the guppy solution are concerned that the introduction of guppies might cause more problems than it is fixing. Guppies are hardy, tolerant of a wide range of environmental conditions, and fast-reproducing.
- Which of the following predicts the most likely ecological problem that would occur if guppies are introduced into new areas to control the mosquito population?
- (A) The guppies might have no natural predators, which will result in a dramatic increase in the guppy population and an increase in competition for other native species.
- (B) The guppy population will likely evolve to consume another food source instead of the mosquito larvae.
- (C) The larvae will evolve a mechanism that will enable them to avoid predation from the guppies.
- (D) Predators in the area will consume the guppies, requiring the addition of more guppies on a regular basis.

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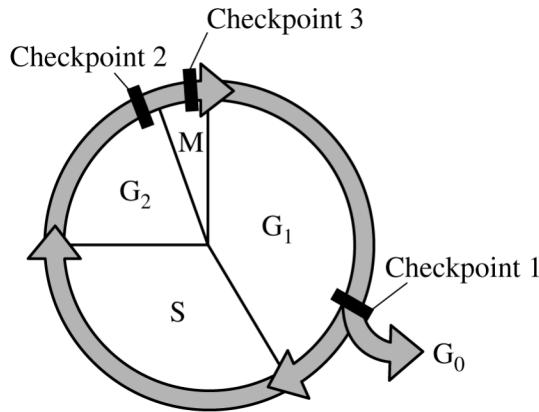


Figure 1. Diagram of the cell cycle with key checkpoints

49. Which of the following describes a mutation that would lead to an increase in the frequency of nondisjunction?
- (A) A mutation affecting checkpoint 1 proteins that forces cells to enter G₀
 - (B) A mutation affecting checkpoint 2 proteins that allows cells to divide with DNA damage
 - (C) A mutation affecting checkpoint 3 proteins that prevents attachment of spindle fibers
 - (D) A mutation affecting checkpoint 2 proteins that prevents duplication of the chromosomes
50. Scientists studying a wild population of mantled howler monkeys found the average birth rate to be 0.22 and the average death rate to be 0.12. At the start of the study, the population consisted of 13 monkeys.
- Assuming no immigration or emigration, which of the following best describes the change in population size that will occur over the next year?
- (A) The population size will decrease because a population of 13 is too small to sustain itself.
 - (B) The population will decrease because more monkeys are dying each year than are being born.
 - (C) The population will increase exponentially because it is so small that there are likely few competitors and abundant resources.
 - (D) The population will increase because more monkeys are being born each year than are dying.
51. Which of the following best explains how the prokaryotic expression of a metabolic protein can be regulated when the protein is already present at a high concentration?
- (A) Repressor proteins can be activated and bind to regulatory sequences to block transcription.
 - (B) Transcription factors can bind to regulatory sequences to increase RNA polymerase binding.
 - (C) Regulatory proteins can be inactivated to increase gene expression.
 - (D) Histone modification can prevent transcription of the gene.

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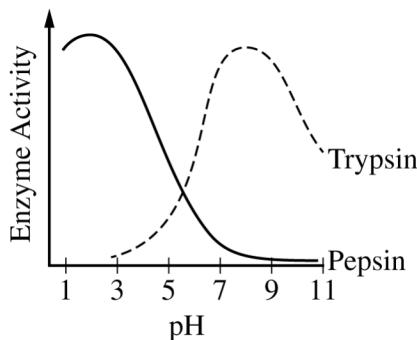


Figure 1. Activity levels of two digestive enzymes over a range of pH

52. Trypsin and pepsin are enzymes that function in different areas of the digestive tract. One functions in the stomach, where the pH is between 1.5 and 3.5, while the other functions in the small intestines, where the pH is between 6 and 8.

Based on Figure 1, which of the following best describes where each enzyme functions?

- (A) Pepsin works in the intestines because the optimal pH for pepsin is basic.
- (B) Trypsin works in the stomach because the optimal pH for trypsin is basic.
- (C) Pepsin works in the stomach because the optimal pH for pepsin is acidic.
- (D) Trypsin works in the stomach because the optimal pH for trypsin is acidic.

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Questions 53 - 57

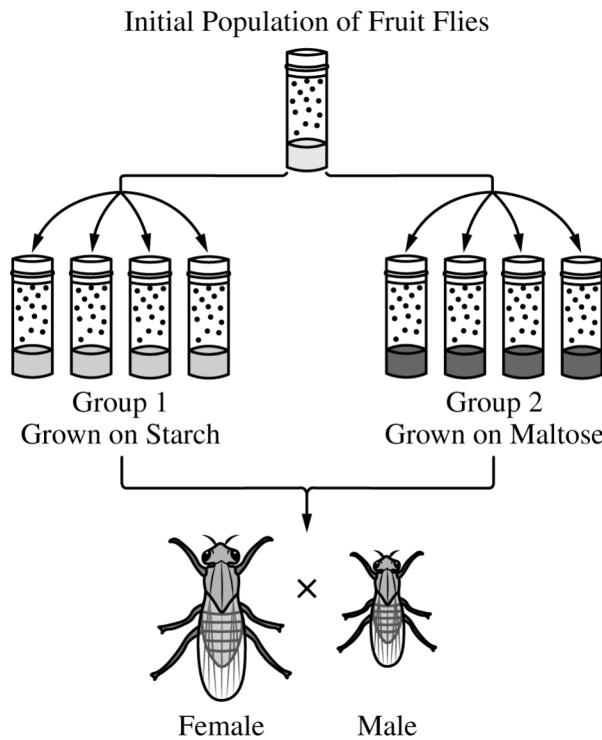


Figure 1. Experimental steps taken to determine whether the nutrient source in a growth chamber affects mating preference

A population of fruit flies (*Drosophila pseudoobscura*) grown on a typical nutrient source was separated into several growth chambers. Each of the new chambers was assigned a different source of carbohydrates for nutrition, either starch or maltose, and maintained for many generations (Figure 1).

After a year, male and female flies were paired up in different combinations. The instances of mating between the males and females grown on the same nutrient source and males and females grown on different nutrient sources were recorded (Table 1).

TABLE 1. MATING INSTANCES BETWEEN MALES AND FEMALES GROWN ON THE SAME OR DIFFERENT NUTRIENT SOURCES

	Females Grown on Starch	Females Grown on Maltose
Males Grown on Starch	22	9
Males Grown on Maltose	8	20

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To test whether the mating preferences were simply the result of being isolated in separate growth chambers, the researchers tested the mating preferences of flies that were both grown on starch, but in either the same or different chambers (Table 2).

TABLE 2. MATING INSTANCES BETWEEN MALES AND FEMALES GROWN ON THE SAME NUTRIENT SOURCE IN THE SAME OR DIFFERENT CHAMBERS

	Females Grown on Starch in Chamber 1	Females Grown on Starch in Chamber 2
Males Grown on Starch in Chamber 1	18	15
Males Grown on Starch in Chamber 2	12	15

53. Which of the following best represents the null hypothesis for the experiment detailed in Figure 1?

- (A) The mating preferences of flies are not dependent on the nutrient source on which they are grown.
- (B) Prolonged exposure to a different diet can change behavior in fruit flies.
- (C) When crossed, flies grown on the same medium will not produce viable offspring.
- (D) Growing flies in a confined chamber will not create a barrier to mating in fruit flies.

54. For a population to be in Hardy-Weinberg equilibrium, certain conditions must be met. Which of the following best explains a characteristic of the fly populations that meets a condition of Hardy-Weinberg equilibrium?

- (A) The population size of the flies was very small, which increases the likelihood of random mutations having a greater impact.
- (B) Since the flies were confined in chambers, they did not experience any migration, so no new alleles were introduced through migration.
- (C) Flies have a relatively short generation time and therefore are more likely to pass mutations to the next generation.
- (D) The different food sources may have exerted selective pressure on the fly populations, giving an advantage to certain flies.

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55. Which of the following claims is best supported by the data in Tables 1 and 2 ?
- (A) The population of flies has undergone sympatric speciation.
(B) The flies have developed a form of behavioral preference that could lead to divergence.
(C) A postzygotic barrier has evolved between the populations of flies that prevents the birth of viable offspring.
(D) The flies have undergone allopatric speciation, since only flies from the same chamber mated.
56. Starch is a complex carbohydrate that is digested by the enzyme amylase. A mutation in the gene that encodes amylase prevents the digestion of starch. The inability to digest starch is an autosomal recessive trait. In a population of 1,000 flies, 410 were unable to break down starch.
- Which of the following is closest to the number of flies expected to be heterozygous for the amylase mutation assuming all conditions of Hardy-Weinberg equilibrium are met?
- (A) 0.13
(B) 0.36
(C) 0.46
(D) 0.64
57. Which of the following combinations of flies showed the highest number of mating instances?
- (A) Males grown on maltose paired with females grown on starch
(B) Males grown on starch paired with females grown on starch
(C) Males grown on maltose paired with females grown on maltose
(D) Males grown on starch paired with females grown on maltose
-
58. The primary function of the kidney is to exchange molecules across a membrane between the blood and the urine. One type of kidney cell has a basic rectangular shape, except for a single surface, which is lined with tiny, finger-like projections that extend into the surrounding extracellular space.
- Which of the following best explains the advantage these projections provide the cell?
- (A) The projections increase the volume of the cell without affecting the surface area, which increases the metabolic needs of the cell.
(B) The projections increase the surface area-to-volume ratio of the cell, which allows for more efficient nutrient exchange with the environment.
(C) The projections increase the speed at which an individual molecule can move, resulting in faster nutrient exchange with the environment.
(D) The projections increase the selectivity of the membrane because the small size of the projections limits the number of transport proteins that can be embedded in the membrane.

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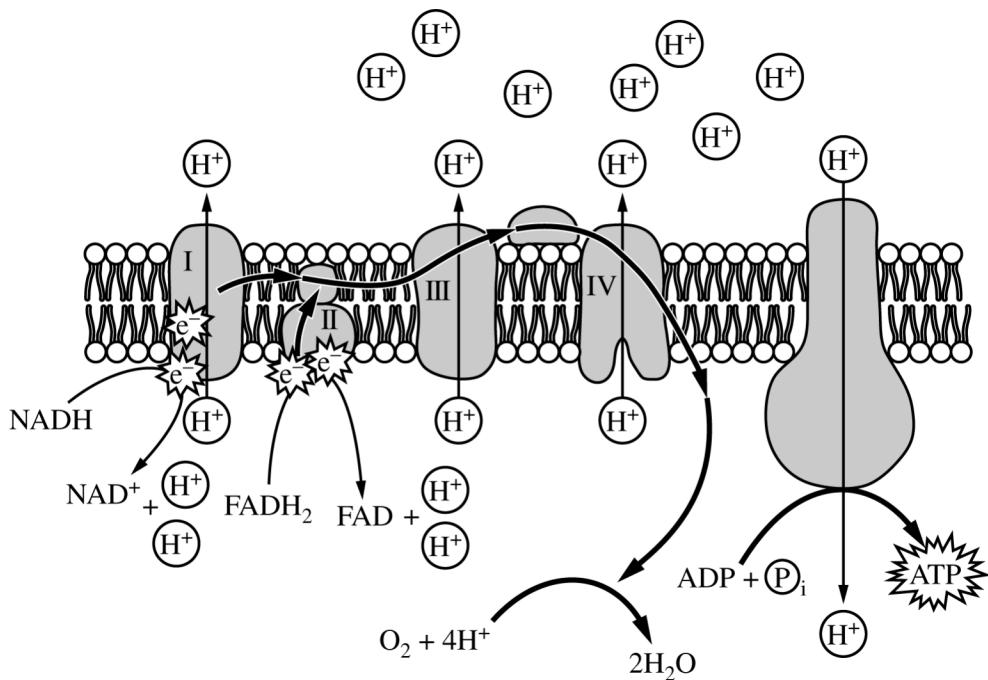


Figure 1. Diagram of the electron transport chain and ATP synthase in the membrane of mitochondria

59. On average, more ATP can be produced from an NADH molecule than can be produced from a molecule of FADH₂. Based on Figure 1, which of the following best explains the difference in ATP production between these two molecules?

- (A) NADH contributes more electrons to the electron transport chain than FADH₂ does and therefore provides more energy to pump protons.
- (B) The electrons of FADH₂ are transferred through three complexes of the electron transport chain whereas those of NADH are transferred through all four complexes.
- (C) FADH₂ contributes more protons to the mitochondrial matrix, which decreases the proton gradient.
- (D) The protons contributed by FADH₂ are combined with O₂ to make water and are not pumped across the membrane.

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60. Which of the following best explains why ligase is required for DNA replication?

- (A) The lagging strand cannot be replicated continuously, and ligase is needed to join the fragments.
- (B) Ligase forms the hydrogen bonds between complementary bases in the two strands of DNA.
- (C) Ligase facilitates the binding of RNA polymerase to the promoter region.
- (D) Ligase enables the newly synthesized DNA to twist into a double helix.

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END OF SECTION I

**IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY
CHECK YOUR WORK ON THIS SECTION.**

DO NOT GO ON TO SECTION II UNTIL YOU ARE TOLD TO DO SO.

MAKE SURE YOU HAVE DONE THE FOLLOWING:

- PLACED YOUR AP ID LABEL ON YOUR ANSWER SHEET
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AP® Biology Exam

SECTION II: Free Response

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Total Time
1 hour and 30 minutes

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6

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50%

Writing Instrument

Pen with black or dark blue ink

Electronic Device
Calculator allowed

Suggested Time
Approximately
25 minutes per long question, and 10 minutes per short question.

Weight
Approximate weights:
Questions 1 and 2:
26% each
Questions 3–6:
12% each

Instructions

The questions for Section II are printed in this booklet. You may use the unlined pages to organize your answers and for scratch work, but you must write your answers on the labeled pages provided for each question.

Each answer should be written in paragraph form; an outline or bulleted list alone is not acceptable. Do not spend time restating the questions or providing more than the number of examples called for. For instance, if a question calls for two examples, you can earn credit only for the first two examples that you provide. Labeled diagrams may be used to supplement discussion, but unless specifically called for by the question, a diagram alone will not receive credit. Write clearly and legibly. Begin each answer on a new page. Do not skip lines. Cross out any errors you make; crossed-out work will not be scored.

Manage your time carefully. You may proceed freely from one question to the next. You may review your responses if you finish before the end of the exam is announced.

AP® BIOLOGY EQUATIONS AND FORMULAS

Statistical Analysis and Probability

Mean

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

Standard Deviation

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

Standard Error of the Mean

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

Chi-Square

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

Chi-Square Table

p value	Degrees of Freedom							
	1	2	3	4	5	6	7	8
0.05	3.84	5.99	7.81	9.49	11.07	12.59	14.07	15.51
0.01	6.63	9.21	11.34	13.28	15.09	16.81	18.48	20.09

Laws of Probability

If A and B are mutually exclusive, then:

$$P(A \text{ or } B) = P(A) + P(B)$$

If A and B are independent, then:

$$P(A \text{ and } B) = P(A) \times P(B)$$

Hardy-Weinberg Equations

$$p^2 + 2pq + q^2 = 1 \quad p = \text{frequency of allele 1 in a population}$$

$$p + q = 1 \quad q = \text{frequency of allele 2 in a population}$$

Standard Deviation

\bar{x} = sample mean

n = sample size

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

o = observed results

e = expected results

Σ = sum of all

Degrees of freedom are equal to the number of distinct possible outcomes minus one.

Metric Prefixes

<u>Factor</u>	<u>Prefix</u>	<u>Symbol</u>
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-1}	deci	d
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)

<p>Rate and Growth</p> <p>Rate</p> $\frac{dY}{dt}$ <p>Population Growth</p> $\frac{dN}{dt} = B - D$ <p>Exponential Growth</p> $\frac{dN}{dt} = r_{\max} N$ <p>Logistic Growth</p> $\frac{dN}{dt} = r_{\max} N \left(\frac{K - N}{K} \right)$	dY = amount of change dt = change in time B = birth rate D = death rate N = population size K = carrying capacity r_{\max} = maximum per capita growth rate of population	<p>Water Potential (Ψ)</p> $\Psi = \Psi_P + \Psi_S$ <p>Ψ_P = pressure potential</p> <p>Ψ_S = solute potential</p> <p>The water potential will be equal to the solute potential of a solution in an open container because the pressure potential of the solution in an open container is zero.</p>
<p>Simpson's Diversity Index</p> <p>Diversity Index = $1 - \sum \left(\frac{n}{N} \right)^2$</p> <p>$n$ = total number of organisms of a particular species</p> <p>N = total number of organisms of all species</p>		$\Psi_S = -iCRT$ i = ionization constant (1.0 for sucrose because sucrose does not ionize in water) C = molar concentration R = pressure constant ($R = 0.0831$ liter bars/mole K) T = temperature in Kelvin ($^{\circ}\text{C} + 273$) pH = $-\log[\text{H}^+]$
<p>Surface Area and Volume</p>		
<p>Surface Area of a Sphere</p> $SA = 4\pi r^2$ <p>Surface Area of a Rectangular Solid</p> $SA = 2lh + 2lw + 2wh$ <p>Surface Area of a Cylinder</p> $SA = 2\pi rh + 2\pi r^2$ <p>Surface Area of a Cube</p> $SA = 6s^2$	<p>Volume of a Sphere</p> $V = \frac{4}{3}\pi r^3$ <p>Volume of a Rectangular Solid</p> $V = lwh$ <p>Volume of a Cylinder</p> $V = \pi r^2 h$ <p>Volume of a Cube</p> $V = s^3$	r = radius l = length h = height w = width s = length of one side of a cube SA = surface area V = volume

BIOLOGY
SECTION II
Time—1 hour and 30 minutes
6 Questions

Directions: Questions 1 and 2 are long free-response questions that require about 25 minutes each to answer. Questions 3 through 6 are short free-response questions that require about 10 minutes each to answer.

Read each question carefully and completely. Write your response in the space provided for each question. Only material written in the space provided will be scored. Answers must be written out in paragraph form. Outlines, bulleted lists, or diagrams alone are not acceptable.

Question 1 is on the following page.

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1. *Cryptosporidium parvum* (*C. parvum*) is a single-celled, eukaryotic parasite that infects human cells in the digestive system and causes illness.

Although it is a eukaryote, *C. parvum* does not have functional mitochondria and generates ATP only through glycolysis. *C. parvum* uses the enzyme lactate dehydrogenase to perform fermentation after glycolysis.

Two chemicals, gossypol and FX11, are noncompetitive inhibitors of lactate dehydrogenase. Researchers investigated the effectiveness of gossypol and FX11 as drugs to kill *C. parvum*. In the experiment, human cells were treated with different concentrations of either gossypol or FX11 after infection with *C. parvum*, and the relative growth of *C. parvum* compared with that of control cells was measured (Figures 1 and 2).

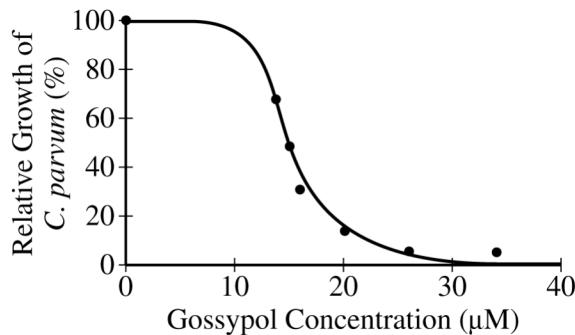


Figure 1. Effect of different concentrations of gossypol on *C. parvum* growth

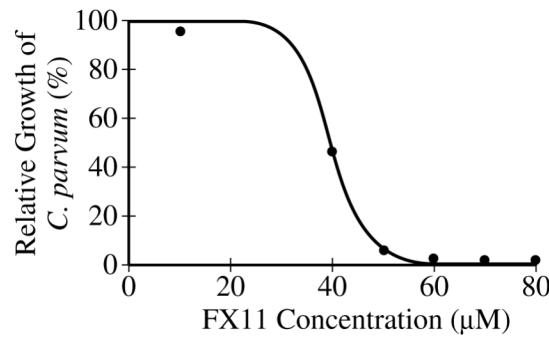


Figure 2. Effect of different concentrations of FX11 on *C. parvum* growth

- (a) **Describe** how *C. parvum* obtains the glucose it needs for glycolysis after it has infected another cell. **Explain** the role of lactate dehydrogenase in enabling *C. parvum* to continue producing ATP by glycolysis.
- (b) **Identify** the independent variable used in the experiment. **Identify** the difference between the control cells and the experimental cells used in the experiment. **Justify** the researchers using a different range of concentrations for FX11 than was used for gossypol.
- (c) Based on the data in Figure 1, **identify** the concentration of gossypol that reduced *C. parvum* growth to 50% of that in control cells.
- (d) Researchers discovered a strain of *C. parvum* that expresses a functional variation of the lactate dehydrogenase gene. A DNA sequence comparison showed that the variant differs from the normal sequence in the region that codes for the enzyme's allosteric site. **Predict** the effect of FX11 treatment on *C. parvum* cells that express this variant of lactate dehydrogenase. **Provide reasoning** to support your prediction. **Explain** how gossypol and FX11 might be used as drugs to treat *C. parvum* infections in humans without negatively affecting human cells.

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**THIS PAGE MAY BE USED FOR TAKING NOTES AND PLANNING YOUR
ANSWERS. NOTES WRITTEN ON THIS PAGE WILL NOT BE SCORED.
WRITE ALL YOUR RESPONSES ON THE LINED PAGES.**

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PAGE FOR ANSWERING QUESTION 1

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ADDITIONAL PAGE FOR ANSWERING QUESTION 1

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ADDITIONAL PAGE FOR ANSWERING QUESTION 1

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ADDITIONAL PAGE FOR ANSWERING QUESTION 1

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2. Many types of cancer are treated with a combination of therapies. In lung cancer, some tumors respond well to the drug paclitaxel followed by radiation treatment. Paclitaxel is a chemical that disrupts mitosis. Instead of spindle fibers originating from the two sides (poles) of the cell, paclitaxel-treated cells develop three poles and then divide into three cells (tripolar division). Radiation therapy is more effective on tumor cells that have undergone tripolar division than on cells that have undergone normal mitosis.

Researchers treated cancer cells in the lab with different concentrations of paclitaxel for 15 hours. The researchers then determined the average percent of mitotic cells that were tripolar. The results are shown in Table 1.

TABLE 1. EFFECT OF PACLITAXEL CONCENTRATION ON PERCENT OF MITOTIC CELLS THAT WERE TRIPOLAR

Concentration of Paclitaxel (nM)	Average Percent of Mitotic Cells that were Tripolar ($\pm 2SE_{\bar{x}}$)
0	0.0 \pm 0.0
2	17.0 \pm 3.0
4	48.0 \pm 3.5
6	65.0 \pm 5.0
8	70.0 \pm 4.0
10	50.0 \pm 2.0

The *AURKA* gene encodes an enzyme that helps assemble the spindle fibers, which signals the cells to continue through mitosis. When researchers analyzed the levels of *AURKA* protein in different types of cancer cells, they found that cancer cells expressing high levels of *AURKA* protein had more tripolar divisions when treated with paclitaxel, than did cancer cells expressing low levels of *AURKA* protein.

- (a) **Describe** the situations in which a normal human cell would enter the cell cycle and undergo mitotic cell division. **Explain** how spindle fibers help ensure the products of mitosis are two identical cells with a full set of chromosomes.
- (b) Using the template in the space provided for your response, **construct** an appropriately labeled graph that represents the data shown in Table 1. Based on the data, **determine** the concentration(s) of paclitaxel that is (are) most effective in causing tripolar cell division.
- (c) Based on the data, **identify** the lowest level of paclitaxel that will allow for at least 50% of the cells to be tripolar. From the start codon through the stop codon, the length of the fully processed *AURKA* mRNA is 1,212 nucleotides. **Calculate** the number of amino acids in the polypeptide chain coded for by the mRNA.
- (d) **Predict** the effect of a mutation that prevents the expression of *AURKA* on a normal (noncancerous) cell.

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THIS PAGE MAY BE USED FOR TAKING NOTES AND PLANNING YOUR ANSWERS.

NOTES WRITTEN ON THIS PAGE WILL NOT BE SCORED.

WRITE ALL YOUR RESPONSES ON THE LINED PAGES.

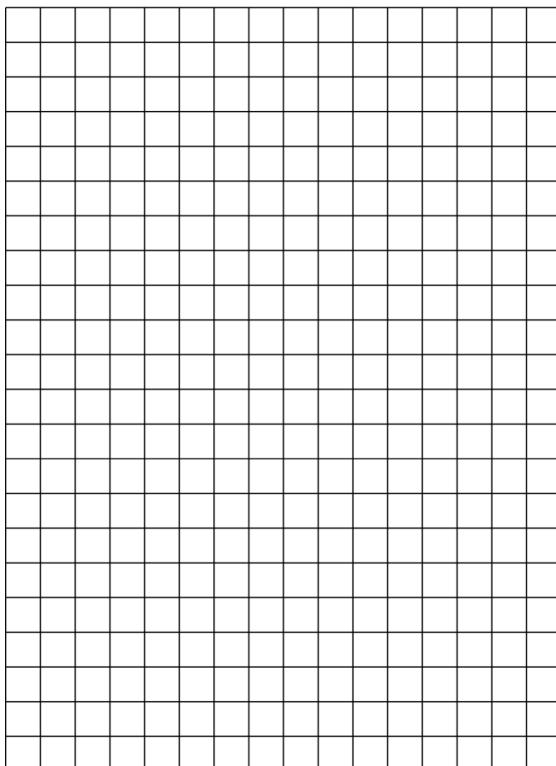
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PAGE FOR ANSWERING QUESTION 2

(data table reprinted for reference)

TABLE 1. EFFECT OF PACLITAXEL CONCENTRATION ON PERCENT OF MITOTIC CELLS THAT WERE TRIPOLAR

Concentration of Paclitaxel (nM)	Average Percent of Mitotic Cells that were Tripolar ($\pm 2SE_{\bar{x}}$)
0	0.0 \pm 0.0
2	17.0 \pm 3.0
4	48.0 \pm 3.5
6	65.0 \pm 5.0
8	70.0 \pm 4.0
10	50.0 \pm 2.0



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ADDITIONAL PAGE FOR ANSWERING QUESTION 2

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ADDITIONAL PAGE FOR ANSWERING QUESTION 2

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3. In mice, fur color is a genetically determined trait. To observe the effects of natural selection on fur color in mice, scientists set up six enclosures with either light- or dark-colored sand on the ground. The enclosures were isolated from all ground predators and wild mice but accessible to predatory birds. The scientists placed equal numbers of light- and dark-colored mice into each enclosure. A total of 500 mice were used in the experiment. After several generations, the scientists sampled the mice and found that populations in the light sand enclosures were, on average, lighter in color than the original population, while those in the dark sand enclosures were, on average, darker in color than the mice in the original population.

- (a) **Describe** the way the scientists will determine the evolutionary fitness of the mice in the experiment.
- (b) **Identify** the independent variable in the scientists' experiment.
- (c) **State** the null hypothesis of this experiment.
- (d) The scientists claim that the changes in the frequency of fur color were the result of natural selection.
Justify the researchers' claim.

PAGE FOR ANSWERING QUESTION 3

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ADDITIONAL PAGE FOR ANSWERING QUESTION 3

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4. The pinewood nematode is a eukaryote that infects certain species of pine trees, feeds on the cells surrounding the trees' transport system, and ultimately kills the trees. Trees are infected when nematode-carrying beetles feed off the trees and inject the nematode into the trees when they bite through the bark. Once infected, pine trees increase the production of chemicals that serve as a defense mechanism for the trees by negatively affecting the nematodes.

Researchers have found that pinewood nematodes contain symbiotic bacteria that can degrade the pine trees' defensive chemicals. To investigate the role these bacteria play in nematode survival in the presence of these defensive chemicals, researchers pretreated nematodes with antibiotics and then exposed them to α -pinene, one of the defensive chemicals produced by the pine trees.

- (a) **Describe** the relationship between a parasite and its host.
- (b) **Explain** how producing the enzymes that digest α -pinene is beneficial to the bacterial species living within the nematodes.
- (c) **Predict** the effect of the antibiotic treatments on the mortality rate of the nematodes when exposed to α -pinene.
- (d) Provide reasoning to **justify** your prediction in part (c).

PAGE FOR ANSWERING QUESTION 4

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ADDITIONAL PAGE FOR ANSWERING QUESTION 4

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5. A cross section of a chloroplast showing membranes and the spaces between membranes is shown in Figure 1.

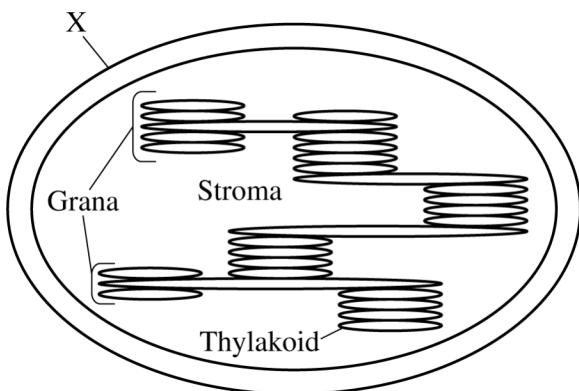


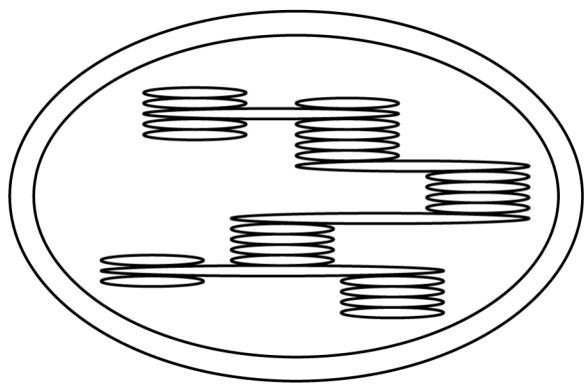
Figure 1. A diagram of the cross section of a chloroplast

- (a) **Describe** the major process that takes place in this eukaryotic organelle.
- (b) **Explain** the function of the structure labeled with an X in Figure 1.
- (c) On the template in the space provided for your response, **represent** the location where carbon fixation takes place by writing " CF " and the location of the electron transport proteins by writing " ETP ".
- (d) **Explain** how the shape and stacking of the thylakoids contributes to the rate of carbon fixation by the chloroplast.

GO ON TO THE NEXT PAGE TO BEGIN YOUR ANSWER TO QUESTION 5.

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PAGE FOR ANSWERING QUESTION 5



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ADDITIONAL PAGE FOR ANSWERING QUESTION 5

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6. *Drosophila melanogaster* (*D. melanogaster*) is a species of fruit fly frequently used by researchers in genetic studies. Members of this species have two of each of four different chromosomes: the sex chromosome (flies have X and Y) and three autosomes (chromosomes 2, 3, and 4). Researchers studying *D. melanogaster* conducted genetic crosses to investigate a particular X-linked recessive trait encoded by a single gene (Table 1). Affected flies have the trait.

TABLE 1. CROSSES PERFORMED AND THE PHENOTYPES OF THE RESULTING OFFSPRING

Cross Number	Phenotype of Females Used in the Cross	Phenotype of Males Used in the Cross	Percent of Total Population That Are Affected	Percent of Male Offspring That Are Affected	Percent of Female Offspring That Are Affected
1	Unaffected	Affected	0	0	0
2	Affected	Unaffected	50	100	0
3	Unaffected	Unaffected	25	50	0
4	Affected	Affected	100	100	100

- (a) **Identify** the genotypes of the male and female flies used in cross 2.
- (b) **Identify** the cross in which the female parent was most likely heterozygous.
- (c) The researchers hypothesize that crossing any unaffected female and an affected male will result in a 0% chance of producing an affected male offspring. **Evaluate** the validity of the hypothesis.
- (d) **Explain** how the results exclude the possibility that the trait is encoded by a mitochondrial gene.

PAGE FOR ANSWERING QUESTION 6

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ADDITIONAL PAGE FOR ANSWERING QUESTION 6

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STOP

END OF EXAM

**IF YOU FINISH BEFORE TIME IS CALLED,
YOU MAY CHECK YOUR WORK ON THIS SECTION.**

**THE FOLLOWING INSTRUCTIONS APPLY TO THE COVERS OF THE SECTION II BOOKLET.
MAKE SURE YOU HAVE DONE THE FOLLOWING:**

- COMPLETED THE IDENTIFICATION INFORMATION AS REQUESTED ON THE FRONT AND BACK COVERS OF THE SECTION II BOOKLET
- CHECKED THAT YOUR AP ID LABEL IS IN THE BOX ON THE FRONT COVER

Notes on the AP Biology Practice Exam

Multiple-Choice Section

Course Framework Alignment and Rationales

Question 1

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	EVO-1.E: Describe the importance of phenotypic variation in a population.	Natural Selection
(A)	Correct. The changes in the ocean water have put selective pressure on the corals. Those with tolerance for warm water had an advantage.	
(B)	Incorrect. The founder effect refers to the loss of genetic variation seen when a population is descended from only a few individuals. There is nothing to suggest the corals' adaptation is an example of the founder effect.	
(C)	Incorrect. Genetic drift results in changes due to chance events. The adaptation of the coral is in response to selective pressure, not chance.	
(D)	Incorrect. There is nothing to indicate that populations of this species have diverged and formed their own species.	

Question 2

Skill	Learning Objective	Topic
6.B: Support a claim with evidence from biological principles, concepts, processes, and/or data.	SYI-1.C: Explain how a change in the subunits of a polymer may lead to changes in structure or function of the macromolecule.	Structure and Function of Biological Macromolecules
(A)	Incorrect. While covalent bonds form between adjacent nucleotides in the sequence, only hydrogen bonds form between base pairs.	
(B)	Correct. Three hydrogen bonds form between guanine and cytosine, while only two hydrogen bonds form between adenine and thymine.	
(C)	Incorrect. All nucleotide pairs consist of one single-ring nitrogenous base and one double-ring nitrogenous base.	
(D)	Incorrect. While guanine-cytosine pairs do consist of one purine and one pyrimidine, this is true for all base pairs and does not explain the higher denaturing temperature.	

Question 3

Skill	Learning Objective	Topic
6.B: Support a claim with evidence from biological principles, concepts, processes, and/or data.	IST-1.P: Explain the use of genetic engineering techniques in analyzing or manipulating DNA.	Biotechnology
(A)	Incorrect. The same bacteria grew successfully in the absence of the antibiotic (plate 1), indicating that the antibiotic and not the transformation procedure killed the bacteria.	
(B)	Incorrect. There was no selective pressure (antibiotic) applied to these plates to determine the effectiveness of the transformation.	
(C)	Incorrect. There was no selective pressure (antibiotic) applied to plate 2 to determine whether any of the bacteria were successfully transformed.	
(D)	Correct. Plate 4 contains kanamycin, which will kill any bacteria that do not contain the kanamycin resistance gene. The bacteria that grew are expected to contain the gene.	

Question 4

Skill	Learning Objective	Topic
1.A: Describe biological concepts and/or processes.	IST-1.J: Explain deviations from Mendel's model of the inheritance of traits.	Non-Mendelian Genetics
(A)	Correct. Chloroplasts are transmitted in the ovule, not the pollen. Therefore chloroplast-determined traits would be 100% inherited from plant Q.	
(B)	Incorrect. Chloroplasts are transmitted in the ovule, not the pollen. Therefore chloroplast-determined traits would be 100% inherited from plant Q.	
(C)	Incorrect. Chloroplasts are transmitted in the ovule, not the pollen. Therefore chloroplast-determined traits would be 100% inherited from plant Q.	
(D)	Incorrect. Chloroplasts are transmitted in the ovule, not the pollen. Therefore chloroplast-determined traits would be 100% inherited from plant Q.	

Question 5

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	ENE-1.A: Describe the composition of macromolecules required by living organisms.	Elements of Life
(A)	Incorrect. Algal populations grow in the presence of nitrogen and phosphorus; they do not release nitrogen and phosphorus.	
(B)	Incorrect. Algal population growth is not driven by competition with bacteria.	
(C)	Incorrect. Oxidative phosphorylation is not stimulated by nitrogen or phosphorus.	
(D)	Correct. Algae use nitrogen and phosphorus in the synthesis of macromolecules, so the addition of these nutrients increases the growth of the algae.	

Question 6

Skill	Learning Objective	Topic
3.C: Identify experimental procedures that are aligned to the question, including- a. Identifying dependent and independent variables. b. Identifying appropriate controls. c. Justifying appropriate controls.	ENE-1.A: Describe the composition of macromolecules required by living organisms.	Elements of Life
(A)	Correct. The concentration of chlorophyll <i>a</i> is dependent on the concentrations of nitrogen and phosphorus.	
(B)	Incorrect. These are independent variables in the experiment.	
(C)	Incorrect. The slope of the trend line is a visual and mathematical descriptor of the data.	
(D)	Incorrect. The variance is a statistical descriptor of the collected data.	

Question 7

Skill	Learning Objective	Topic
4.B: Describe data from a table or graph, including- a. Identifying specific data points. b. Describing trends and/or patterns in the data. c. Describing relationships between variables.	ENE-1.A: Describe the composition of macromolecules required by living organisms.	Elements of Life
(A)	Incorrect. The data do not suggest that the concentration of chlorophyll <i>a</i> increases as the concentration of nitrogen decreases.	
(B)	Correct. The data indicate that as the amount of nitrogen increases, the amount of chlorophyll in the water sample increases.	
(C)	Incorrect. The data do not indicate that there was a steady increase in nitrogen throughout the year.	
(D)	Incorrect. The data indicate that there is a relationship between the concentrations of chlorophyll <i>a</i> and nitrogen.	

Question 8

Skill	Learning Objective	Topic
3.E: Propose a new/next investigation based on- a. An evaluation of the evidence from an experiment. b. An evaluation of the design/methods.	SYI-3.F: Describe the relationship between ecosystem diversity and its resilience to changes in the environment.	Biodiversity
(A)	Incorrect. Examining the contents of the digestive tracts of aquatic invertebrates would indicate whether they ate algae but not whether they were being negatively affected by algae.	
(B)	Incorrect. This would provide information on the effect of invertebrates on the growth of algae, not the effect of algae on invertebrates.	
(C)	Correct. If the number of aquatic invertebrates decreases as chlorophyll <i>a</i> increases, it suggests the increased concentration of algae has a negative effect on the invertebrates.	
(D)	Incorrect. Concentrations of nitrogen and phosphorus are not indicators of how the algae population affects invertebrates.	

Question 9

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	SYI-1.B: Describe the properties of the monomers and the type of bonds that connect the monomers in biological macromolecules.	Introduction to Biological Macromolecules
(A)	Incorrect. Amylase breaks bonds in polymers (hydrolysis) and water molecules are not removed to break bonds. Glycogen synthase forms bonds between monomers (dehydration synthesis) and water is not added to form bonds.	
(B)	Correct. Amylase breaks bonds in polymers (hydrolysis) and glycogen synthase forms bonds between monomers (dehydration synthesis). Water is added to break bonds and removed to form them.	
(C)	Incorrect. Amylase converts polymers into monomers which involves breaking covalent bonds, not forming them. Glycogen synthase converts monomers into polymers which would require forming covalent bonds, not breaking them.	
(D)	Incorrect. Amylase converts polymers into monomers which involves breaking covalent bonds, not forming them. Glycogen synthase converts monomers into polymers which would require forming covalent bonds, not breaking them.	

Question 10

Skill	Learning Objective	Topic
1.A: Describe biological concepts and/or processes.	ENE-2.B: Describe the Fluid Mosaic Model of cell membranes.	Plasma Membranes
(A)	Correct. Cholesterol is a nonpolar steroid that can be found embedded in the membrane between phospholipids.	
(B)	Incorrect. Cholesterol is nonpolar and would not likely be found in the cytosol, which is aqueous.	
(C)	Incorrect. Chloroplasts are not found in animal cells. Additionally, cholesterol is nonpolar and would not likely be found in the stroma of the chloroplast, which is an aqueous environment.	
(D)	Incorrect. Cholesterol is nonpolar and would not likely be found attached to free ribosomes located in the aqueous cytosol.	

Question 11

Skill	Learning Objective	Topic
6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on- a. Biological concepts or processes. b. A visual representation of a biological concept, process, or model. c. Data.	IST-2.C: Explain how the binding of transcription factors to promoter regions affects gene expression and/or the phenotype of the organism.	Gene Expression and Cell Specialization
(A)	Incorrect. Any mutation that interferes with the binding of an enzyme and its substrate is more likely to decrease enzyme activity than increase it.	
(B)	Incorrect. If the transcription factors that activate lactase expression are not produced, then the lactase enzyme will not be made. As a result, no lactose digestion will occur.	
(C)	Correct. A mutation that results in an increase in transcription-factor binding will result in a higher expression of the lactase gene.	
(D)	Incorrect. A mutation that creates a stop codon will likely result in the formation of a truncated enzyme that will likely be dysfunctional.	

Question 12

Skill	Learning Objective	Topic
2.A: Describe characteristics of a biological concept, process, or model represented visually.	IST-1.D: Describe the role of checkpoints in regulating the cell cycle.	Regulation of Cell Cycle
(A)	Incorrect. As seen in Figure 1, the cyclin level is increasing (not decreasing) in preparation for the next round of cell division (not resting phase).	
(B)	Correct. The cyclin and the CDK must bind for the MPF to be active and lead to the initiation of mitosis. The higher the concentration of cyclin, the more likely this binding will occur.	
(C)	Incorrect. While DNA replication does occur during S phase, the cyclin level is increasing. It is the CDK level that remains the same.	
(D)	Incorrect. According to the graph, cyclin levels are almost at their highest at G ₂ .	

Question 13

Skill	Learning Objective	Topic
6.D: Explain the relationship between experimental results and larger biological concepts, processes, or theories.	SYI-3.D: Explain how the genetic diversity of a species or population affects its ability to withstand environmental pressures.	Variations in Populations
(A)	Incorrect. Being triploid, the plant would need to acquire three recessive alleles to have the recessive phenotype.	
(B)	Incorrect. There is nothing to suggest that being triploid increases a plant's susceptibility to disease.	
(C)	Correct. Species and populations with little genetic diversity, like the asexually grown Cavendish hybrid, are at a greater risk when environmental changes occur.	
(D)	Incorrect. Asexual reproduction does not increase the mutation rate during replication.	

Question 14

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	IST-5.A: Explain how the behavioral responses of organisms affect their overall fitness and may contribute to the success of the population.	Responses to the Environment
(A)	Correct. Protecting those that are genetically similar contributes to the presence of many of the same genes in the next generation.	
(B)	Incorrect. The squirrel is actually calling attention to itself, resulting in an increased chance that the predator will catch it.	
(C)	Incorrect. There is nothing to suggest that it is only squirrels with recessive alleles serve this function.	
(D)	Incorrect. While it is true that these guards are more often females, there is nothing to suggest that females that have reproduced are no longer needed.	

Question 15

Skill	Learning Objective	Topic
1.A: Describe biological concepts and/or processes.	IST-1.A: Describe the structural similarities and differences between DNA and RNA.	Nucleic Acids
(A)	Correct. RNA does not contain the nitrogenous base thymine.	
(B)	Incorrect. Regardless of the percentage of adenine, RNA does not contain the nitrogenous base thymine.	
(C)	Incorrect. While this would be the percentage of thymine found in a double-stranded DNA molecule containing 30% adenine, RNA does not contain thymine.	
(D)	Incorrect. Regardless of the percentage of adenine, RNA does not contain the nitrogenous base thymine.	

Question 16

Skill	Learning Objective	Topic
4.B: Describe data from a table or graph, including- a. Identifying specific data points. b. Describing trends and/or patterns in the data. c. Describing relationships between variables.	IST-3.F: Describe the different types of cellular responses elicited by a signal transduction pathway.	Signal Transduction
(A)	Incorrect. There is a decrease in the number of surviving melanoma cells as the concentration of drug X increases.	
(B)	Correct. Fewer melanoma cells survive in the presence of 10 μ M drug X or more than when the drug is not present.	
(C)	Incorrect. There is a decrease in the number of surviving melanoma cells when the concentration of drug X is between 0 and 25 μ M.	
(D)	Incorrect. Drug X has a greater effect on melanoma line 2 than on melanoma line 1.	

Question 17

Skill	Learning Objective	Topic
5.B: Use confidence intervals and/or error bars (both determined using standard errors) to determine whether sample means are statistically different.	IST-1.E: Describe the effects of disruptions to the cell cycle on the cell or organism.	Regulation of Cell Cycle
(A)	Incorrect. While this is true because the error bars overlap, comparison of the two cell lines in the absence of the drug does not provide any information about the effect of the drug on oxygen consumption.	
(B)	Incorrect. The error bars overlap indicating that this is not true. Additionally, comparison of the two cell lines in the presence of the drug does not provide any information about the effect of the drug on oxygen consumption.	
(C)	Correct. To determine the effect of the drug on oxygen consumption, the oxygen consumption of cells in the presence of the drug would be compared to the oxygen consumption of cells from the same cell line in the absence of the drug to see if the data are statistically different (error bars do not overlap).	
(D)	Incorrect. While this is true (error bars do not overlap), a comparison of oxygen consumption in one cell line in the presence of the drug and another cell line in the absence of the drug does not provide information about the effect of the drug on oxygen consumption.	

Question 18

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	ENE-1.K: Describe the processes that allow organisms to use energy stored in biological macromolecules.	Cellular Respiration
(A)	Incorrect. Oxygen is the final electron acceptor in the electron transport chain, not the donor.	
(B)	Incorrect. The mutation rate of the cell is independent of the rate of oxygen consumption.	
(C)	Incorrect. Oxygen does not activate the apoptotic pathway.	
(D)	Correct. Melanoma cells require oxygen for normal metabolism, so oxygen consumption is a good indicator of metabolism.	

Question 19

Skill	Learning Objective	Topic
2.B: Explain relationships between different characteristics of biological concepts or processes represented visually- a. In theoretical contexts. b. In applied contexts.	IST-3.G: Explain how a change in the structure of any signaling molecule affects the activity of the signaling pathway.	Changes in Signal Transduction Pathways
(A)	Incorrect. Drug X stimulates the activity of complex B, so the activation of molecule A would not have an effect.	
(B)	Incorrect. Drug X stimulates the activity of complex B, so the inhibition of molecule A would not have an effect.	
(C)	Correct. Drug X activates complex B, which inhibits molecule C and thus cellular division. Reversing the effect of drug X requires the inhibition of complex B.	
(D)	Incorrect. Inhibition of molecule C would mimic the effect of drug X.	

Question 20

Skill	Learning Objective	Topic
1.B: Explain biological concepts and/or processes.	ENE-2.C: Explain how the structure of biological membranes influences selective permeability.	Membrane Permeability
(A)	Incorrect. While the membrane does contain channel proteins, they are specific to certain molecules and are unnecessary for the movement of O ₂ and CO ₂ .	
(B)	Correct. Small, nonpolar molecules can pass through the cell membrane by simple diffusion because the membrane is composed of phospholipids with nonpolar tails.	
(C)	Incorrect. Size alone does not determine whether a molecule can cross the membrane. Additionally, ions will not diffuse across the membrane because they are charged.	
(D)	Incorrect. ATP is hydrolyzed only during certain types of active transport when molecules are moved against the concentration gradient. O ₂ and CO ₂ do not require active transport because they move down the concentration gradient.	

Question 21

Skill	Learning Objective	Topic
5.B: Use confidence intervals and/or error bars (both determined using standard errors) to determine whether sample means are statistically different.	ENE-1.J: Explain how cells capture energy from light and transfer it to biological molecules for storage and use.	Photosynthesis
(A)	Correct. The standard error bars do not overlap for the two types of plants at 21% O ₂ in either soil type, indicating that there is a statistical difference between the rates of CO ₂ fixation.	
(B)	Incorrect. At 1% O ₂ the standard error bars overlap for both types of soil, indicating that there is not a statistical difference.	
(C)	Incorrect. While the error bars do not overlap for either soil type at 21% O ₂ , there is an overlap for both soil types at 1% O ₂ .	
(D)	Incorrect. While the error bars overlap for the wet soil at 1% O ₂ , they do not overlap for the wet soil at 21% O ₂ , suggesting there is a statistical difference.	

Question 22

Skill	Learning Objective	Topic
3.A: Identify or pose a testable question based on an observation, data, or a model.	IST-1.D: Describe the role of checkpoints in regulating the cell cycle.	Regulation of Cell Cycle
(A)	Correct. By fusing these cells, the researcher was able to determine which phases had chemical messengers and how those messengers could influence cells in other phases.	
(B)	Incorrect. The researchers did not focus on the number of chromosomes in the cell. Additionally the number of chromosomes does affect a cell's movement through the cell cycle.	
(C)	Incorrect. The researchers did not measure the amount of genetic information in each cell in this experiment.	
(D)	Incorrect. While the G ₂ check point does prevent a cell with damaged DNA from entering mitosis, it is not what is being tested in this experiment.	

Question 23

Skill	Learning Objective	Topic
2.A: Describe characteristics of a biological concept, process, or model represented visually.	IST-1.O: Describe how the phenotype of an organism is determined by its genotype.	Translation
(A)	Incorrect. The mRNA is synthesized in a 5' to 3' direction in all cells.	
(B)	Incorrect. A single strand of DNA is used as a template for transcription in all cells.	
(C)	Correct. In eukaryotes, RNA transcripts need to be modified before they can be translated, but prokaryotes can translate the beginning of an mRNA molecule while the end is still being transcribed.	
(D)	Incorrect. The enzyme RNA polymerase is used for transcription in all cells.	

Question 24

Skill	Learning Objective	Topic
5.C: Perform chi-square hypothesis testing.	IST-1.J: Explain deviations from Mendel's model of the inheritance of traits.	Non-Mendelian Genetics
(A)	Incorrect. This represents the number of degrees of freedom for this analysis.	
(B)	Incorrect. This represents the critical value for an analysis with only one degree of freedom.	
(C)	Correct. This is the critical value for an analysis with three degrees of freedom.	
(D)	Incorrect. This is the calculated chi-square value for the data given.	

Question 25

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	EVO-1.G: Explain the relationship between changes in the environment and evolutionary changes in the population.	Artificial Selection
(A)	Incorrect. Species that share a recent common ancestor typically have many molecular similarities inherited from that ancestor. In this case, the genetic makeup of the two species is different.	
(B)	Incorrect. The two species are located on separate continents, but in sympatric speciation, the new and ancestral species occupy the same location.	
(C)	Incorrect. This explanation suggests the similarities were already present in the two species and does not explain how the similarities evolved.	
(D)	Correct. The lack of genetic similarity between the two species suggests that the similarities arose independently in the two species and that the similarities are the result of convergent evolution.	

Question 26

Skill	Learning Objective	Topic
4.B: Describe data from a table or graph, including- a. Identifying specific data points. b. Describing trends and/or patterns in the data. c. Describing relationships between variables.	SYI-1.H: Explain how the density of a population affects and is determined by resource availability in the environment.	Effect of Density of Populations
(A)	Incorrect. This is closer to what the population size was between 1980 and 1985.	
(B)	Incorrect. This was the population size in 1990.	
(C)	Correct. The data indicate that the population in 2000 was almost 175,000.	
(D)	Incorrect. The population doesn't reach this size until almost 2010.	

Question 27

Skill	Learning Objective	Topic
6.A: Make a scientific claim	EVO-3.B: Describe the types of evidence that can be used to infer an evolutionary relationship.	Phylogeny
(A)	Incorrect. The Asian elephant is more closely related to the mammoth than it is to the African elephant.	
(B)	Incorrect. The mammoth diverged from its ancestor around 3 million years ago, whereas the mastodon diverged from its ancestor over 5 million years ago.	
(C)	Incorrect. While both species existed until about 2 million years ago, they diverged from their common ancestor over 5 million years ago.	
(D)	Correct. If the lineages of the African elephant and the mastodon are traced back until they intersect, the species at the point of intersection is the Palaeomastodon.	

Question 28

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	IST-1.O: Describe how the phenotype of an organism is determined by its genotype.	Translation
(A)	Incorrect. It is the tRNA molecules that are responsible for transporting the amino acids to the ribosomes for translation.	
(B)	Incorrect. rRNA molecules do not play a role in the formation of the mRNA transcripts that are then translated.	
(C)	Correct. rRNA molecules, along with proteins, make up the structure of the ribosome. Translation is initiated when the rRNA interacts with the start codon in the mRNA.	
(D)	Incorrect. Modification of proteins happens after translation and does not involve rRNA molecules.	

Question 29

Skill	Learning Objective	Topic
2.A: Describe characteristics of a biological concept, process, or model represented visually.	IST-1.J: Explain deviations from Mendel's model of the inheritance of traits.	Non-Mendelian Genetics
(A)	Incorrect. The individual must have inherited at least one recessive allele because the individual's mother is unaffected.	
(B)	Incorrect. The individual must have inherited at least one dominant allele because the individual is affected.	
(C)	Correct. The individual must have one copy of the dominant allele because the individual is affected and one recessive allele because the individual's mother is unaffected.	
(D)	Incorrect. The individual must have at least one dominant allele to be affected. Additionally, the individual should have two alleles for the <i>ALAS2</i> gene.	

Question 30

Skill	Learning Objective	Topic
2.B: Explain relationships between different characteristics of biological concepts or processes represented visually- a. In theoretical contexts. b. In applied contexts.	IST-1.J: Explain deviations from Mendel's model of the inheritance of traits.	Non-Mendelian Genetics
(A)	Incorrect. It cannot be an autosomal recessive inheritance pattern because there are unaffected offspring of two affected parents.	
(B)	Correct. There are unaffected offspring of two affected parents, indicating both had a recessive allele to pass on to those offspring. Additionally, affected males pass only to female offspring, whereas affected females pass to either male or female offspring.	
(C)	Incorrect. It cannot be an X-linked recessive inheritance pattern because there are unaffected offspring with two affected parents.	
(D)	Incorrect. It cannot be a mitochondrial inheritance pattern because there are unaffected mothers with affected children.	

Question 31

Skill	Learning Objective	Topic
6.A: Make a scientific claim	IST-1.O: Describe how the phenotype of an organism is determined by its genotype.	Translation
(A)	Incorrect. Disruption of a start codon will prevent any of the protein from being produced.	
(B)	Correct. The introduction of a stop codon will result in the production of a shortened protein.	
(C)	Incorrect. A mutation in the regulatory region will affect the amount of protein produced, but not the length of an individual protein.	
(D)	Incorrect. Preventing the removal of introns will result in a protein that is longer than normal.	

Question 32

Skill	Learning Objective	Topic
3.E: Propose a new/next investigation based on- a. An evaluation of the evidence from an experiment. b. An evaluation of the design/methods.	IST-1.P: Explain the use of genetic engineering techniques in analyzing or manipulating DNA.	Biotechnology
(A)	Incorrect. This experiment will not provide any confirmation about the individual's genotype.	
(B)	Incorrect. The growth rate of the cells will likely not be affected by the presence of a mutant allele.	
(C)	Incorrect. Chromosomes carrying a mutant <i>ALAS2</i> allele will appear identical to those carrying a wild-type <i>ALAS2</i> allele.	
(D)	Correct. Sequencing the individual's DNA will allow a researcher to confirm that the individual carries a mutant <i>ALAS2</i> allele.	

Question 33

Skill	Learning Objective	Topic
1.A: Describe biological concepts and/or processes.	SYI-1.D: Describe the structure and/or function of subcellular components and organelles.	Cell Structure - Subcellular Components
(A)	Incorrect. While eukaryotes have linear chromosomes, prokaryotic chromosomes are circular.	
(B)	Correct. Although the ribosomes of eukaryotes and prokaryotes have a slightly different structure, both contain ribosomes that perform the same function, suggesting that the trait came from a common ancestor.	
(C)	Incorrect. Not all prokaryotes use organic molecules as an energy source. Chemoautotrophs derive their energy from inorganic compounds.	
(D)	Incorrect. While prokaryotes and eukaryotes both undergo some form of cell division, mitosis is specifically the division of the nucleus, a structure not found in prokaryotes.	

Question 34

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	SYI-3.F: Describe the relationship between ecosystem diversity and its resilience to changes in the environment.	Biodiversity
(A)	Correct. By decreasing the elk population to a size that is sustainable in the ecosystem, the wolves increased the amount of resources available to other species.	
(B)	Incorrect. While the presence of the wolves did result in a decrease in the elk population, it resulted in an increase in biodiversity as a whole.	
(C)	Incorrect. Despite having a significant impact on an ecosystem, keystone species still experience the effect of limiting factors on their population growth.	
(D)	Incorrect. This is a characteristic of an invasive species rather than a keystone species. The presence of the wolves had a positive impact on many species.	

Question 35

Skill	Learning Objective	Topic
2.B: Explain relationships between different characteristics of biological concepts or processes represented visually- a. In theoretical contexts. b. In applied contexts.	IST-3.E: Describe the role of the environment in eliciting a cellular response.	Signal Transduction
(A)	Incorrect. Epinephrine activates alpha cells and inhibits beta cells.	
(B)	Incorrect. While epinephrine does activate alpha cells, this activation would increase secretion of glucagon.	
(C)	Correct. Epinephrine activates alpha cells, thus activating glucagon release, and inhibits beta cells, which inhibits insulin release.	
(D)	Incorrect. Epinephrine activates alpha cells and inhibits beta cells.	

Question 36

Skill	Learning Objective	Topic
6.C: Provide reasoning to justify a claim by connecting evidence to biological theories.	EVO-1.E: Describe the importance of phenotypic variation in a population.	Natural Selection
(A)	Incorrect. Evolution is based on chance mutations. It is unlikely that this specific mutation would occur simply because it would be beneficial.	
(B)	Correct. An already-existing variation that makes an insect resistant would increase the insect's fitness, resulting in an increase in the frequency of resistance genes in future generations.	
(C)	Incorrect. It is unlikely that an insect would build up a tolerance to a poisonous chemical when it is applied at concentrations strong enough to kill them.	
(D)	Incorrect. While the chemical might induce mutations in the insect, these mutations would have to be in the reproductive cells to be passed on. Also, most mutations are detrimental or neutral and would be unlikely to increase survival.	

Question 37

Skill	Learning Objective	Topic
6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on- a. Biological concepts or processes. b. A visual representation of a biological concept, process, or model. c. Data.	ENE-1.K: Describe the processes that allow organisms to use energy stored in biological macromolecules.	Cellular Respiration
(A)	Incorrect. If protons can diffuse across the membrane, a proton gradient will not be established and ATP will not be produced.	
(B)	Incorrect. If protons could diffuse passively across the membrane, they will move down the concentration gradient, which will not make the gradient steeper.	
(C)	Correct. The protons pumped into the matrix because of electron transport will diffuse back into the intermembrane space and will not be available for oxidative phosphorylation. As a result, more energy will be converted to heat and less will be available for ATP production.	
(D)	Incorrect. If protons can diffuse through the membrane, there will be fewer protons to pass through ATP synthase and less ATP will be produced.	

Question 38

Skill	Learning Objective	Topic
5.C: Perform chi-square hypothesis testing.	IST-1.I: Explain the inheritance of genes and traits as described by Mendel's laws.	Mendelian Genetics
(A)	Incorrect. The calculated chi-square value is less than the critical value for three degrees of freedom (four possible phenotype combinations - 1), indicating the researchers will fail to reject the null hypothesis.	
(B)	Correct. The calculated chi-square value is less than the critical value for three degrees of freedom (four possible phenotype combinations - 1), indicating the researchers will fail to reject the null hypothesis.	
(C)	Incorrect. The calculated chi-square value is less than the critical value for three degrees of freedom (four possible phenotype combinations - 1), indicating the researchers will fail to reject the null hypothesis.	
(D)	Incorrect. The calculated chi-square value is less than the critical value for three degrees of freedom (four possible phenotype combinations - 1), indicating the researchers will fail to reject the null hypothesis.	

Question 39

Skill	Learning Objective	Topic
3.C: Identify experimental procedures that are aligned to the question, including- <ul style="list-style-type: none"> a. Identifying dependent and independent variables. b. Identifying appropriate controls. c. Justifying appropriate controls. 	SYI-2.C: Explain how geological and meteorological activity leads to changes in ecosystem structure and/or dynamics.	Disruptions to Ecosystems
(A)	Correct. The researcher hypothesizes that an increase in water temperature will affect the growth of the algae, making algae growth the dependent variable.	
(B)	Incorrect. The temperature of the water would be the experimental/independent variable.	
(C)	Incorrect. The chemical levels are a result of the algae growth. The researcher is testing the effect of water temperature on algae growth.	
(D)	Incorrect. The researcher is studying a single species of algae.	

Question 40

Skill	Learning Objective	Topic
6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on- <ul style="list-style-type: none"> a. Biological concepts or processes. b. A visual representation of a biological concept, process, or model. c. Data. 	IST-4.A: Explain how changes in genotype may result in changes in phenotype.	Mutations
(A)	Incorrect. The inability to correct errors in replication will not, on its own, increase the rate of cell division.	
(B)	Correct. DNA repair enzymes detect and correct errors that occur during replication. If the cell cannot do so, mutations will be passed on during future rounds of division.	
(C)	Incorrect. As long as the transcription start site is functional, RNA polymerase is capable of transcribing DNA, even if it contains mutations.	
(D)	Incorrect. Not all mutations trigger apoptosis. Many mutations are replicated in future rounds of cell division.	

Question 41

Skill	Learning Objective	Topic
2.A: Describe characteristics of a biological concept, process, or model represented visually.	ENE-1.H: Describe the role of energy in living organisms.	Cellular Energy
(A)	Incorrect. The glucose transporter is a membrane protein that will be unaffected by the presence of NaF.	
(B)	Incorrect. Pyruvate will not accumulate because there will be little phosphoenolpyruvate if NaF is present.	
(C)	Incorrect. Phosphoenolpyruvate will not accumulate because NaF will prevent it from being synthesized from 2-phosphoglycerate.	
(D)	Correct. 2-Phosphoglycerate will accumulate because it is the last chemical in the pathway prior to the NaF inhibition.	

Question 42

Skill	Learning Objective	Topic
2.A: Describe characteristics of a biological concept, process, or model represented visually.	ENE-1.L: Explain how cells obtain energy from biological macromolecules in order to power cellular functions.	Cellular Respiration
(A)	Incorrect. During glycolysis 4 ATP are generated, but 2 are converted to ADP in the process.	
(B)	Correct. During glycolysis 4 ATP are generated, but 2 are converted to ADP in the process.	
(C)	Incorrect. During glycolysis 4 ATP are generated, but 2 are converted to ADP in the process.	
(D)	Incorrect. During glycolysis 4 ATP are generated, but 2 are converted to ADP in the process.	

Question 43

Skill	Learning Objective	Topic
6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on- a. Biological concepts or processes. b. A visual representation of a biological concept, process, or model. c. Data.	ENE-1.G: Explain how the cellular environment affects enzyme activity.	Environmental Impacts on Enzyme Function
(A)	Correct. A decrease in the pH could cause enzymes in the glycolysis pathway to become denatured.	
(B)	Incorrect. An increased H^+ concentration will not positively affect the reaction rate.	
(C)	Incorrect. Protons cannot replace phosphorus atoms in ATP.	
(D)	Incorrect. A change in the water potential will most likely not have an effect on the rate of reactions in glycolysis.	

Question 44

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	ENE-2.C: Explain how the structure of biological membranes influences selective permeability.	Membrane Permeability
(A)	Incorrect. Nonpolar molecules can diffuse across the membrane by simple diffusion.	
(B)	Incorrect. Glucose does not move from low concentration to high concentration.	
(C)	Incorrect. Glucose molecules are not charged. Additionally, not all charged molecules need to be actively transported.	
(D)	Correct. Glucose is a relatively large and polar molecule and requires a transport protein to cross the membrane.	

Question 45

Skill	Learning Objective	Topic
2.C: Explain how biological concepts or processes represented visually relate to larger biological principles, concepts, processes or theories.	ENE-1.K: Describe the processes that allow organisms to use energy stored in biological macromolecules.	Cellular Respiration
(A)	Incorrect. Lactic acid fermentation still requires glucose to be metabolized via the glycolysis pathway.	
(B)	Correct. Noncarbohydrates can provide energy to a cell through other metabolic pathways.	
(C)	Incorrect. Carbohydrates are used to provide energy for the synthesis of enzymes.	
(D)	Incorrect. Carbohydrates can be stored within cells.	

Question 46

Skill	Learning Objective	Topic
6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on- a. Biological concepts or processes. b. A visual representation of a biological concept, process, or model. c. Data.	SYI-1.F: Describe the structural features of a cell that allow organisms to capture, store, and use energy.	Cell Structure and Function
(A)	Incorrect. The removal of waste products from the cell would still be able to occur through transport proteins located in the plasma membrane of the cell.	
(B)	Correct. Many of the molecules needed to perform the light reactions of photosynthesis are embedded in the membranes of the thylakoids.	
(C)	Incorrect. CO_2 is transported into the chloroplast through simple diffusion. Additionally, delivery to the chloroplast is unaffected, because the outer membrane of the chloroplast remains intact.	
(D)	Incorrect. Movement of an organelle within a cell is not dependent on the number of membranes the organelle has.	

Question 47

Skill	Learning Objective	Topic
5.A: Perform mathematical calculations, including- <ul style="list-style-type: none"> a. Mathematical equations in the curriculum. b. Means. c. Rates. d. Ratios. e. Percentages. 	IST-1.I: Explain the inheritance of genes and traits as described by Mendel's laws.	Mendelian Genetics
(A)	Correct. One out of four offspring are expected to be homozygous recessive for each of the three genes. To determine the fraction expected to be homozygous recessive for all three genes one would calculate: $\frac{1}{4} \times \frac{1}{4} \times \frac{1}{4} = \frac{1}{64}$	
(B)	Incorrect. This would be the fraction of offspring expected to be homozygous for two of the three genes and heterozygous for the third. $\left(\frac{1}{4} \times \frac{1}{4} \times \frac{1}{2} = \frac{1}{32} \right)$	
(C)	Incorrect. This would be the fraction of offspring expected to be heterozygous for two of the three genes and homozygous for the third. $\left(\frac{1}{2} \times \frac{1}{2} \times \frac{1}{4} = \frac{1}{16} \right)$	
(D)	Incorrect. This would be the fraction of offspring expected to be heterozygous for all three genes. $\left(\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{8} \right)$	

Question 48

Skill	Learning Objective	Topic
6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on- <ul style="list-style-type: none"> a. Biological concepts or processes. b. A visual representation of a biological concept, process, or model. c. Data. 	SYI-2.A: Explain how invasive species affect ecosystem dynamics.	Disruptions to Ecosystems
(A)	Correct. Guppies are strong and fertile. If they have ample resources and few predators, their population could grow unchecked and create problems for native species.	
(B)	Incorrect. There is nothing to suggest that there are any selective pressures that will drive guppies to change to another food source.	
(C)	Incorrect. Although it is possible that the larvae could evolve a mechanism to avoid predation from guppies, this adaptation is unlikely to cause an ecological problem because guppies are not native to this ecosystem.	
(D)	Incorrect. There are unlikely to be many natural predators of the guppies because guppies are not native to the areas to which they are introduced.	

Question 49

Skill	Learning Objective	Topic
2.A: Describe characteristics of a biological concept, process, or model represented visually.	IST-1.D: Describe the role of checkpoints in regulating the cell cycle.	Regulation of Cell Cycle
(A)	Incorrect. Forcing cells into the resting phase of the cell cycle would not result in an increase in nondisjunction.	
(B)	Incorrect. This might lead to an increase in mutations but not an immediate increase in nondisjunction.	
(C)	Correct. If the cells move into anaphase without the spindle fibers properly attached to the chromosomes, the chances of nondisjunction occurring will increase.	
(D)	Incorrect. Preventing the duplication of chromosomes will not result in an increase in nondisjunction.	

Question 50

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	SYI-1.G: Describe factors that influence growth dynamics of populations.	Population Ecology
(A)	Incorrect. Populations can sustain themselves even when small.	
(B)	Incorrect. According to the data provided, the death rate is less than the birth rate.	
(C)	Incorrect. It is entirely possible that the ecosystem can support only a small population of this particular species. In this type of a population, the growth rate during a single year does not provide evidence of a sustained, positive growth rate representative of exponential growth.	
(D)	Correct. The birth rate exceeds the death rate. Therefore, the population is expected to grow.	

Question 51

Skill	Learning Objective	Topic
1.B: Explain biological concepts and/or processes.	IST-2.B: Explain how the location of regulatory sequences relates to their function.	Regulation of Gene Expression
(A)	Correct. High levels of protein product can result in a negative feedback mechanism in which a repressor protein is activated, binds to the regulatory sequence, and blocks transcription.	
(B)	Incorrect. Increasing the binding of RNA polymerase would result in more product. High concentrations of product usually initiate a mechanism to shut down production.	
(C)	Incorrect. High concentrations of product usually initiate a mechanism to shut down expression of the product not increase it.	
(D)	Incorrect. The concentration of the product does not affect histone modification. Additionally, prokaryotes do not have histones.	

Question 52

Skill	Learning Objective	Topic
4.B: Describe data from a table or graph, including- a. Identifying specific data points. b. Describing trends and/or patterns in the data. c. Describing relationships between variables.	ENE-1.G: Explain how the cellular environment affects enzyme activity.	Environmental Impacts on Enzyme Function
(A)	Incorrect. The optimal pH for pepsin is around 2, which is acidic, not basic.	
(B)	Incorrect. While the optimal pH for trypsin is basic, the stomach is highly acidic, and it is unlikely that trypsin would function in an acidic environment.	
(C)	Correct. The optimal pH for pepsin is around 2, and the pH of the stomach is between 1.5 and 3.5, making the stomach an ideal environment for pepsin.	
(D)	Incorrect. The optimal pH for trypsin is almost 9, which is basic, not acidic.	

Question 53

Skill	Learning Objective	Topic
3.B: State the null and alternative hypotheses or predict the results of an experiment.	EVO-1.H: Explain how random occurrences affect the genetic makeup of a population.	Population Genetics
(A)	Correct. The null hypothesis is one that states that the variable tested does not affect the variable measured. In this case the null hypothesis is that growth on different nutrient sources does not affect mate selection.	
(B)	Incorrect. This is the alternate hypothesis that the experimenters were testing.	
(C)	Incorrect. The researchers did not investigate the effect of the different media on the viability of offspring.	
(D)	Incorrect. The researchers were studying the effect of different nutrient sources, not confinement.	

Question 54

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	EVO-1.K: Describe the conditions under which allele and genotype frequencies will change in populations.	Hardy-Weinberg Equilibrium
(A)	Incorrect. A large population size is one of the conditions of Hardy-Weinberg equilibrium, because genetic drift is less likely to have a large impact on large populations than on small populations.	
(B)	Correct. No migration is a condition of Hardy-Weinberg equilibrium, so the fact that the flies were contained met this condition.	
(C)	Incorrect. The length of generations does not affect Hardy-Weinberg equilibrium. Additionally, a short generation time does not increase the chances of mutations being passed to the next generation.	
(D)	Incorrect. An absence of selection is a condition of Hardy-Weinberg equilibrium, so if there were selective pressures exerted on the flies, this condition would not have been met.	

Question 55

Skill	Learning Objective	Topic
6.A: Make a scientific claim	EVO-3.F: Explain the processes and mechanisms that drive speciation.	Speciation
(A)	Incorrect. In sympatric speciation, a new species forms while occupying the same habitat as the ancestral species. These populations of flies were grown in separate chambers.	
(B)	Correct. Divergence might now occur because flies demonstrate differential mate selection based on the food source on which they were grown.	
(C)	Incorrect. In the experiment, it was observed that the flies do not mate, which means there is a prezygotic barrier. Additionally, there are no data to support that the offspring are less viable when mating does occur.	
(D)	Incorrect. Table 2 shows that there was no mating preference between flies grown in separate chambers as long as they were grown on the same growth medium.	

Question 56

Skill	Learning Objective	Topic
5.A: Perform mathematical calculations, including- <ul style="list-style-type: none"> a. Mathematical equations in the curriculum. b. Means. c. Rates. d. Ratios. e. Percentages. 	EVO-1.K: Describe the conditions under which allele and genotype frequencies will change in populations.	Hardy-Weinberg Equilibrium
(A)	Incorrect. This is the frequency expected to be homozygous dominant, p^2 , in the population.	
(B)	Incorrect. This is the frequency of the dominant allele, p, in the population.	
(C)	Correct. The frequency expected to be heterozygous is $2pq$, where $q = 0.64$ (calculation: $\sqrt{(410 / 1000)}$) and $p = 0.36$ (calculation: $1 - q$).	
(D)	This is the frequency of the recessive allele, q, in the population.	

Question 57

Skill	Learning Objective	Topic
4.B: Describe data from a table or graph, including- a. Identifying specific data points. b. Describing trends and/or patterns in the data. c. Describing relationships between variables.	EVO-1.F: Explain how humans can affect diversity within a population.	Artificial Selection
(A)	Incorrect. There were only 8 instances of mating between these types of flies.	
(B)	Correct. There were 22 instances of mating between these types of flies.	
(C)	Incorrect. While there were 20 instances of mating between these types of flies, that number was not the highest.	
(D)	Incorrect. There were only 9 instances of mating between these types of flies.	

Question 58

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	ENE-1.B: Explain the effect of surface area-to-volume ratios on the exchange of materials between cells or organisms and the environment.	Cell Size
(A)	Incorrect. While the projections do add to the volume of the cell, the surface area increases more dramatically. The metabolic needs would likely not increase substantially.	
(B)	Correct. These projections add significantly more membrane than they do cellular volume. That results in a greater surface area-to-volume ratio and more efficient nutrient exchange.	
(C)	Incorrect. The speed at which an individual molecule can move is not affected by the amount of membrane a cell has.	
(D)	Incorrect. The increased surface area will increase the number of transport proteins that can fit in the membrane, not decrease it.	

Question 59

Skill	Learning Objective	Topic
2.B: Explain relationships between different characteristics of biological concepts or processes represented visually- a. In theoretical contexts. b. In applied contexts.	ENE-1.K: Describe the processes that allow organisms to use energy stored in biological macromolecules.	Cellular Respiration
(A)	Incorrect. Both NADH and FADH ₂ contribute two electrons to the electron transport chain.	
(B)	Correct. The electrons from FADH ₂ are contributed to complex II rather than complex I and therefore are transferred through fewer complexes and have a lesser effect on the proton gradient than the electrons from NADH do.	
(C)	Incorrect. FADH ₂ and NADH contribute the same number of protons to the mitochondrial matrix.	
(D)	Incorrect. While protons in the matrix do combine with electrons and O ₂ to make water, the protons are not specifically from FADH ₂ .	

Question 60

Skill	Learning Objective	Topic
1.B: Explain biological concepts and/or processes.	IST-1.M: Describe the mechanisms by which genetic information is copied for transmission between generations.	Replication
(A)	Correct. Since DNA is synthesized in the 5' to 3' direction, one strand of DNA is synthesized discontinuously, forming fragments that are joined by ligase.	
(B)	Incorrect. Hydrogen bonds form between complementary bases when DNA polymerase places the correct nucleotide in the chain.	
(C)	Incorrect. RNA polymerase binds to the promoter region during transcription, not replication.	
(D)	Incorrect. Ligase is not involved in the completed DNA molecule twisting into a double helix.	

Answer Key and Question Alignment to Course Framework

Multiple-Choice Question	Answer	Skill	Learning Objective	Topic
1	A	1.C	EVO-1.E	Natural Selection
2	B	6.B	SYI-1.C	Structure and Function of Biological Macromolecules
3	D	6.B	IST-1.P	Biotechnology
4	A	1.A	IST-1.J	Non-Mendelian Genetics
5	D	1.C	ENE-1.A	Elements of Life
6	A	3.C	ENE-1.A	Elements of Life
7	B	4.B	ENE-1.A	Elements of Life
8	C	3.E	SYI-3.F	Biodiversity
9	B	1.C	SYI-1.B	Introduction to Biological Macromolecules
10	A	1.A	ENE-2.B	Plasma Membranes
11	C	6.E	IST-2.C	Gene Expression and Cell Specialization
12	B	2.A	IST-1.D	Regulation of Cell Cycle
13	C	6.D	SYI-3.D	Variations in Populations
14	A	1.C	IST-5.A	Responses to the Environment
15	A	1.A	IST-1.A	Nucleic Acids
16	B	4.B	IST-3.F	Signal Transduction
17	C	5.B	IST-1.E	Regulation of Cell Cycle
18	D	1.C	ENE-1.K	Cellular Respiration
19	C	2.B	IST-3.G	Changes in Signal Transduction Pathways
20	B	1.B	ENE-2.C	Membrane Permeability
21	A	5.B	ENE-1.J	Photosynthesis
22	A	3.A	IST-1.D	Regulation of Cell Cycle
23	C	2.A	IST-1.O	Translation
24	C	5.C	IST-1.J	Non-Mendelian Genetics
25	D	1.C	EVO-1.G	Artificial Selection
26	C	4.B	SYI-1.H	Effect of Density of Populations
27	D	6.A	EVO-3.B	Phylogeny
28	C	1.C	IST-1.O	Translation
29	C	2.A	IST-1.J	Non-Mendelian Genetics
30	B	2.B	IST-1.J	Non-Mendelian Genetics

Multiple-Choice Question	Answer	Skill	Learning Objective	Topic
31	B	6.A	IST-1.O	Translation
32	D	3.E	IST-1.P	Biotechnology
33	B	1.A	SYI-1.D	Cell Structure - Subcellular Components
34	A	1.C	SYI-3.F	Biodiversity
35	C	2.B	IST-3.E	Signal Transduction
36	B	6.C	EVO-1.E	Natural Selection
37	C	6.E	ENE-1.K	Cellular Respiration
38	B	5.C	IST-1.I	Mendelian Genetics
39	A	3.C	SYI-2.C	Disruptions to Ecosystems
40	B	6.E	IST-4.A	Mutations
41	D	2.A	ENE-1.H	Cellular Energy
42	B	2.A	ENE-1.L	Cellular Respiration
43	A	6.E	ENE-1.G	Environmental Impacts on Enzyme Function
44	D	1.C	ENE-2.C	Membrane Permeability
45	B	2.C	ENE-1.K	Cellular Respiration
46	B	6.E	SYI-1.F	Cell Structure and Function
47	A	5.A	IST-1.I	Mendelian Genetics
48	A	6.E	SYI-2.A	Disruptions to Ecosystems
49	C	2.A	IST-1.D	Regulation of Cell Cycle
50	D	1.C	SYI-1.G	Population Ecology
51	A	1.B	IST-2.B	Regulation of Gene Expression
52	C	4.B	ENE-1.G	Environmental Impacts on Enzyme Function
53	A	3.B	EVO-1.H	Population Genetics
54	B	1.C	EVO-1.K	Hardy-Weinberg Equilibrium
55	B	6.A	EVO-3.F	Speciation
56	C	5.A	EVO-1.K	Hardy-Weinberg Equilibrium
57	B	4.B	EVO-1.F	Artificial Selection
58	B	1.C	ENE-1.B	Cell Size
59	B	2.B	ENE-1.K	Cellular Respiration
60	A	1.B	IST-1.M	Replication

Free-Response Section

Scoring Guidelines

Question 1: Interpreting and Evaluating Experimental Results 9 points

Learning Objectives: ENE-1.A ENE-1.G ENE-1.L

- (A) Describe how *C. parvum* obtains the glucose it needs for glycolysis after it has infected another cell. 1 point
1.A

- *C. parvum* absorbs glucose from its environment, which, in this case, takes glucose away from its host.

- Explain the role of lactate dehydrogenase in enabling *C. parvum* to continue producing ATP by glycolysis. 1 point
1.C

- Lactate dehydrogenase allows fermentation to convert NADH to NAD⁺, which is needed for glycolysis to continue making ATP.

Total for part (A) 2 points

- (B) Identify the independent variable used in the experiment 1 point
3.C

- The concentration of the chemical

- Identify the difference between the control cells and the experimental cells used in the experiment. 1 point
3.C

- The control cells were the same type of cells, infected with the parasite, but not treated with any chemicals, as were the experimental cells.

- Justify the researchers using a different range of concentrations for FX11 than was used for gossypol. 1 point
3.C

- FX11 had minimal impact on the growth of *C. parvum* until it reached a concentration of greater than 30μM, which was the maximum concentration of gossypol that was tested.

Total for part (B) 3 points

- (C) Based on the data in Figure 1, identify the concentration of gossypol that reduced *C. parvum* growth to 50% of that in control cells. 1 point
4.B

- 15μM

Total for part (C) 1 point

(D)	<p>Researchers discovered a strain of <i>C. parvum</i> that expresses a functional variation of the lactate dehydrogenase gene. A DNA sequence comparison showed that the variant differs from the normal sequence in the region that codes for the enzyme's allosteric site. Predict the effect of FX11 treatment on <i>C. parvum</i> cells that express this variant of lactase dehydrogenase.</p> <ul style="list-style-type: none">FX11 will have little to no effect.	1 point 3.B
	<p>Provide reasoning to support your prediction.</p> <ul style="list-style-type: none">The allosteric site is the region of the enzyme where a non-competitive inhibitor like FX11 would bind. It is likely that changing the sequence of this region would decrease inhibitor binding.	1 point 6.C
	<p>Explain how gossypol and FX11 might be used as drugs to treat <i>C. parvum</i> infections in humans without negatively affecting human cells.</p> <ul style="list-style-type: none">The drugs will prevent <i>C. parvum</i> from generating the ATP it needs to survive by inhibiting a key enzyme in fermentation. Since human cells have mitochondria and do not rely on fermentation to produce ATP, they are not likely to be harmed.	1 point 6.D

Total for part (D) 3 points

Total for question 1 9 points

Question 2: Interpreting and Evaluating Experimental Results with Graphing

9 points

Learning Objectives: IST-1.C IST-1.O IST-2.E

- (A) Describe the situations in which a normal human cell would enter the cell cycle and undergo mitotic cell division. **1 point**
1.A

- Cells divide by mitosis when the organism is growing or repairing tissues.

- Explain how spindle fibers help ensure the products of mitosis are two identical cells with a full set of chromosomes. **1 point**
1.C

- Spindle fibers attach to the center of each duplicated chromosome and assist in pulling one chromatid to each pole of the cell so that, when the cell divides, each daughter cell contains a copy of each chromosome.

Total for part (A) **2 points**

- (B) Using the template in the space provided for your response, construct an appropriately labeled graph that represents the data shown in Table 1. **3 points**
4.A

One point for each of the following:

- Correct axes and labeling
- Correctly plotted points and scaling
- Correctly plotted error bars

- Based on the data, determine the concentration(s) of paclitaxel that is (are) most effective in causing tripolar cell division. **1 point**
5.B

- A concentration of 6-8 nM

Total for part (B) **4 points**

- (C) Based on the data, identify the lowest level of paclitaxel that will allow for at least 50% of the cells to be tripolar. **1 point**
4.B

- 4 nM

- From the start codon through the stop codon, the length of the fully processed AURKA mRNA is 1,212 nucleotides. Calculate the number of amino acids in the polypeptide chain coded for by the mRNA. **1 point**
5.A

- 1,212 nucleotides minus 3 nucleotides (for the stop codon) equals 1,209. 1,209 divided by 3 nucleotides per amino acid equals 403 amino acids.

Total for part (C) **2 points**

-
- (D) Predict the effect of a mutation that prevents the expression of AURKA on a normal (noncancerous) cell. **1 point**
6.E
- The cell will be unable to undergo mitosis.

Total for part (D) **1 point**

Total for question 2 **9 points**

Question 3: Scientific Investigation

4 points

Learning Objectives: EVO-1.E EVO-1.D

-
- (A) Describe the way the scientists will determine the evolutionary fitness of the mice in the experiment. **1 point**
• By determining whether the mice survive to successfully reproduce. **1.A**
- (B) Identify the independent variable in the scientists' experiment. **1 point**
• The color of the ground in each of the enclosures **3.C**
- (C) State the null hypothesis of this experiment. **1 point**
• The color of the enclosure ground will not affect the frequency of light and dark mice in the population. **3.B**
- (D) The scientists claim that the changes in the frequency of fur color were the result of natural selection. Justify the researchers' claim. **1 point**
• Mice with a fur color that helped them blend into the environment were able to avoid predation and reproduce, increasing the frequency of their genes in the population. **6.C**
-

Total for question 3 4 points

Question 4: Conceptual Analysis

4 points

Learning Objectives: ENE-4.B ENE-4.C

- (A) Describe the relationship between a parasite and its host. **1 point**
• The parasite will benefit while the host will be harmed. **1.A**
- (B) Explain how producing the enzymes that digest α -pinene is beneficial to the bacterial species living within the nematodes. **1 point**
• By producing the enzymes that digest α -pinene, the bacteria increase the survival rate of the nematodes. This ensures that the nematodes continue provide a protected habitat and resources for the bacteria. **1.B**
- (C) Predict the effect of the antibiotic treatments on the mortality rate of the nematodes when exposed to α -pinene. **1 point**
• The mortality rate of the nematodes will increase after the nematodes are treated with antibiotics. **1.C**
- (D) Provide reasoning to justify your prediction in part (c). **1 point**
• Antibiotics will reduce the bacterial population thereby preventing the degradation of α -pinene. As a result, there will be more α -pinene to negatively affect the nematodes and more nematodes will die. **1.D**
-

Total for question 4 4 points

**Question 5: Analyze Model
or Visual Representation of a Biological Concept or Process**

4 points

Learning Objectives: SYI-1.F SYI-1.D

- (A) Describe the major process that takes place in this eukaryotic organelle. **1 point**
• Light provides the energy to fix carbon into organic molecules **1.A**
- (B) Explain the function of the structure labeled with an X in Figure 1. **1 point**
• Specific metabolic functions are more efficiently carried out because the outer membrane enables the compartmentalization of chemical reactions. **2.B**
- (C) On the template in the space provided for your response, represent the location where carbon fixation takes place by writing “CF” and the location of the electron transport proteins by writing “ETP.” **1 point**
• “CF” must be marked in the stroma and “ETP” must be marked on a thylakoid membrane. **2.D**
- (D) Explain how the shape and stacking of the thylakoids contributes to the rate of carbon fixation by the chloroplast. **1 point**
• The thin and stacked nature of the thylakoids increases the surface area of the thylakoid membrane, allowing for a greater number of chlorophyll molecules and electron transport proteins. **2.C**
-

Total for question 5 4 points

Question 6: Analyze Data

4 points

Learning Objectives: IST-1.J

- (A) Identify the genotypes of the male and female flies used in cross 2. **1 point**
• X^rX^r and X^RY **4.B**
- (B) Identify the cross in which the female parent was most likely heterozygous. **1 point**
• Cross 3 **4.B**
- (C) The researchers hypothesize that crossing any unaffected female and an affected male will result in a 0% chance of producing an affected male offspring. Evaluate the validity of the hypothesis. **1 point**
• This hypothesis is not supported. If the unaffected mother is heterozygous, she can pass on the recessive allele and the male offspring will be affected. **5.D**
- (D) Explain how the results exclude the possibility that the trait is encoded by a mitochondrial gene. **1 point**
• Traits encoded by mitochondrial genes are inherited from the female parent only, resulting in offspring that all have the same genotype as their mother. **6.D**
-

Total for question 6 4 points

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