2026

AP® Biology

Scoring Guidelines

Question 1: Interpreting and Evaluating Experimental Results — 9 points

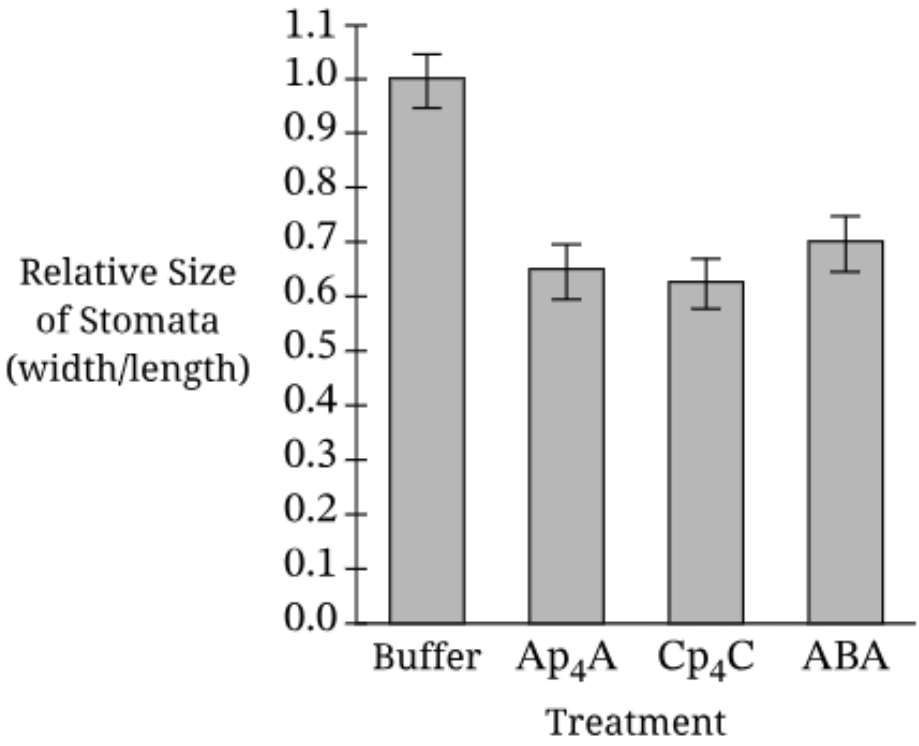
Molecules known as dinucleoside polyphosphates, a type of nucleotide, are signaling molecules that accumulate in plant cells during dry or stressful conditions.

Stomata are pores on the surface of leaves that open when exposed to light and regulate the flow of carbon dioxide, oxygen, and water vapor in and out of a plant. In response to dry environmental conditions, many plants close their stomata, which reduces water loss.

Scientists hypothesized that the dinucleoside polyphosphates $\mathrm{Ap_4A}$ and $\mathrm{Cp_4C}$ bind to DORN1 receptors on the plasma membrane of plant cells and initiate signaling cascades that cause stomata to close. The scientists exposed plants to light to open the stomata and then placed samples of the leaves in buffer alone or in buffer containing one of three different compounds: $\mathrm{Ap_4A}$, $\mathrm{Cp_4C}$, or abscisic acid (ABA), a molecule that causes stomata to close.

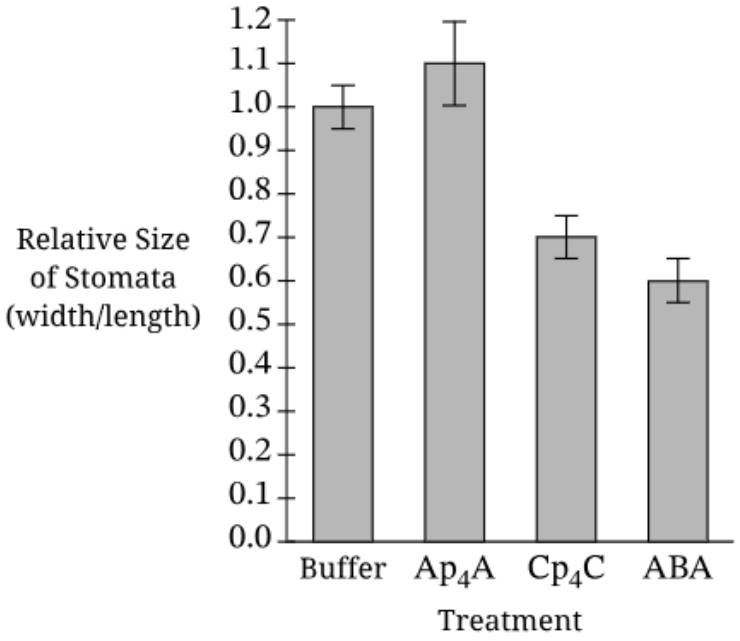
The scientists measured the size of the stomata in each sample and calculated their sizes relative to the size of the stomata in the sample kept in buffer alone, as shown in Figure 1.

Figure 1. Effect of Ap_4A, Cp_4C, and ABA on Relative Stomatal Size (Error Bars Represent $\pm SE_{\bar{x}}$)



In a second experiment, the scientists used plants that were identical to those in the first experiment except that the gene encoding the DORN1 receptor was mutated. The scientists repeated the procedure of the first experiment. Their results are shown in Figure 2.

Figure 2. Effect of Ap_4A, Cp_4C, and ABA on Relative Stomatal Size in DORN1 Mutants (Error Bars Represent $\pm SE_{\bar{x}}$)



A	**Describe** the three structural components of a nucleotide. • (The three structural components of a nucleotide) are a sugar/ribose/deoxyribose, a phosphate (group), and a (nitrogenous) base.	**Point A1**
B	**Identify** the dependent variable in the scientists' first experiment. • (Relative) size of stomata.	**Point B1**
	Based on Figure 1, **describe** the relative size of the stomata in the Cp_4C treatment group as compared with the size of the stomata in the group treated with buffer alone. • (The stomata in the Cp_4C treatment) are smaller (than the relative size of stomata in the presence of buffer alone).	**Point B2**
	Justify the use of buffer alone as a control in the scientists' experiments. Examples of acceptable responses may include the following: • (Using buffer alone) serves as a baseline for comparison in order to isolate the effects of the compounds. • (Using buffer alone) allows distinguishing between the effects of the test compounds and the effects of the buffer alone on the (closing of) stomata.	**Point B3**

C	**Justify** the scientists treating one sample of leaves with ABA in the experiments. Examples of acceptable responses may include the following: • (Treatment with ABA) serves as a baseline for comparison with the other compounds' ability to close the stomata. • ABA is a (positive) control for stomata closing.	**Point C1**
	Based on Figure 2, **describe** the difference between the effects of $\mathrm{Ap_4A}$ and $\mathrm{Cp_4C}$ treatments on the size of stomata in plants with mutated DORN1 receptors. Examples of acceptable responses may include the following: • The stomata treated with $\mathrm{Cp_4C}$ are smaller than stomata treated with $\mathrm{Ap_4A}$. • The stomata treated with $\mathrm{Ap_4A}$ are larger than stomata treated with $\mathrm{Cp_4C}$. • (Compared to stomata treated with buffer alone) the stomata treated with $\mathrm{Ap_4A}$ are the same size, while the stomata treated with $\mathrm{Cp_4C}$ are smaller.	**Point C2**
	Activation of DORN1 receptors induces plant cells to produce certain molecules that cause the stomata to close. Based on the data in Figures 1 and 2 for cells treated with $\mathrm{Ap_4A}$, **predict** the relative production of the molecules by DORN1-mutated cells in comparison to the production by nonmutated cells. • Fewer of the molecules will be produced (by DORN1-mutated cells).	**Point C3**
D	The DORN1 receptor transmits signals that result in an increase in the transcription of genes involved in plant defenses. The scientists then developed DORN1-mutant plants in which the DORN1 receptor lacked most of its intracellular domain. In cells homozygous for this mutation, **predict** the effect of $\mathrm{Ap_4A}$ treatment on transcription of the genes involved in plant defenses relative to the effect of $\mathrm{Ap_4A}$ on nonmutated cells. • There will be <u>less</u>/<u>no</u> (transcription in cells of the mutant plants as compared with nonmutated cells).	**Point D1**
	Justify your prediction. • The receptor (lacking its intracellular domain) will be unable to transmit intracellular signals (that induce transcription).	**Point D2**

Question 2: Interpreting and Evaluating Experimental Results with Graphing — 9 points

Eukaryotic cells use small interfering RNA (siRNA) molecules that regulate the expression of certain genes by binding to complementary sequences in target mRNAs. This binding causes the protein AGO2 to cleave the target mRNAs. As a result of the cleavage, the mRNAs are not translated.

To investigate the role of AGO2 in the cleavage of mRNA transcribed from two genes, Gene *G* and Gene *H*, scientists determined the amount of Gene *G* and Gene *H* mRNA produced in cells with three different *AGO2* genotypes:

- Homozygous for the wild-type AGO2 protein ($AGO2^{+/+}$)
- Heterozygous for the allele encoding a nonfunctional AGO2 protein ($AGO2^{+/-}$)
- Homozygous for the allele encoding a nonfunctional AGO2 protein ($AGO2^{-/-}$)

The scientists then calculated the amount of Gene *G* and Gene *H* mRNA produced from cells of each genotype relative to that in $AGO2^{+/+}$ cells. These results are shown in the table.

Relative Average Amounts of Gene *G* and Gene *H* mRNA in Cells with Different *AGO2* Genotypes

	mRNA in $AGO2^{+/+}$ Cells $\pm \mathrm{SE}_{\overline{x}}$	mRNA in $AGO2^{+/-}$ Cells $\pm \mathrm{SE}_{\overline{x}}$	mRNA in $AGO2^{-/-}$ Cells $\pm \mathrm{SE}_{\overline{x}}$
Gene *G*	1.0 ± 0.1	0.9 ± 0.4	1.5 ± 0.5
Gene *H*	1.0 ± 0.1	2.0 ± 0.1	3.0 ± 0.4

A **Describe** one location where ribosomes are found in eukaryotic cells. **Point A1**

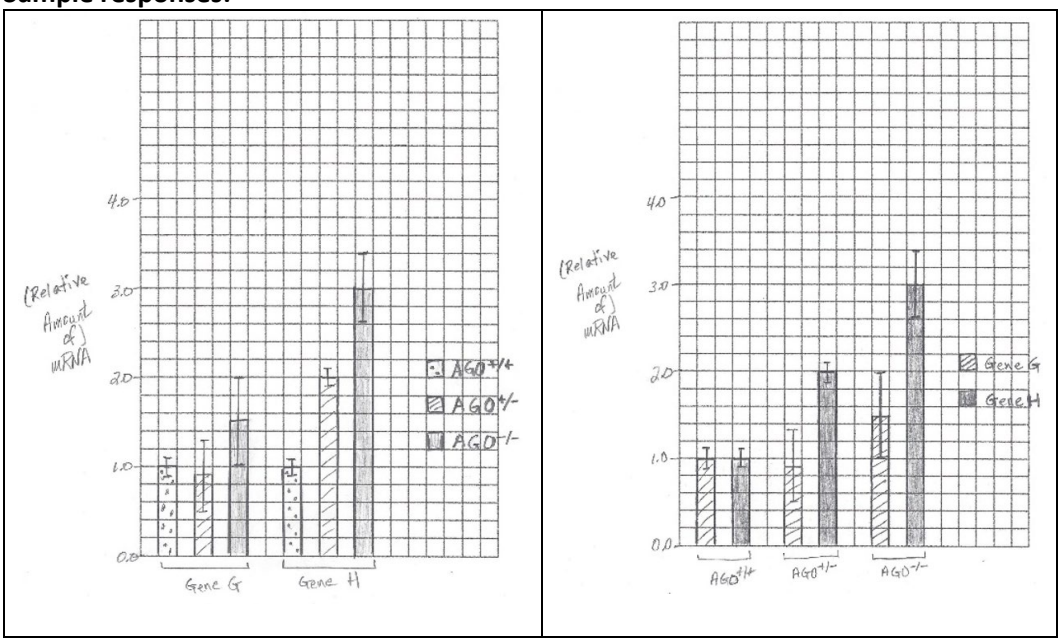
Examples of acceptable responses may include the following:

- (Ribosomes in eukaryotes are found) in the cytosol/cytoplasm.
- (Ribosomes in eukaryotes are found) on (the cytosolic surface of) the (rough) endoplasmic reticulum/ER.
- (Ribosomes in eukaryotes are found) on the cytosolic surface of the nuclear envelope.
- (Ribosomes in eukaryotes are found) in mitochondria/chloroplasts.

B Using the template in the space provided for your response, **construct** a bar graph that represents the data in the table. Your graph should be appropriately plotted and labeled. **Point B1**

Construction:

Sample responses:



- Data are represented in a bar graph.

Using the template in the space provided for your response, **construct** a bar graph that represents the data in the table. Your graph should be appropriately plotted and labeled. **Point B2**

- Data and error bars are accurately plotted.

Using the template in the space provided for your response, **construct** a bar graph that represents the data in the table. Your graph should be appropriately plotted and labeled. **Point B3**

- Graph includes correctly labeled axes and legend.

Based on the table, **determine** all the cells in which the amount of Gene *G* mRNA produced is statistically the same as the amount in the cells with the *AGO2*$^{+/+}$genotype. **Point B4**

- (The cells that have the genotypes) *AGO2*$^{+/-}$ and *AGO2*$^{-/-}$

C Based on the table, **describe** the relationship between the number of wild-type copies of the *AGO2* gene and the amount of Gene *H* mRNA in the cells. **Point C1**

Examples of acceptable responses may include the following:

- There is an indirect/a negative correlation.
- There is an inverse relationship.
- As the number of wild-type copies of the *AGO2* gene increases, (the amount of Gene *H* mRNA) decreases.

Based on the data in the table for Gene *H*, **calculate** the percent by which the average amount of mRNA in $AGO2^{-/-}$ cells increases compared with that in $AGO2^{+/-}$ cells. **Point C2**

- 50(%) [100×[(2.0 – 3.0)/2.0)] = 100×(1.0/2.0) = 100×0.50 = 50%]

D	The scientists claim that siRNA binding and AGO2 cleavage of mRNAs play a greater role in the regulation of Gene *H* expression than in the regulation of Gene *G* expression. Based on the table, **support** the scientists' claim. Examples of acceptable responses may include the following: • The amount of mRNA increases as the number of *AGO2*$^{+}$ alleles/amount of functional protein decreases for Gene *H* (and not for Gene *G*). • The amount of Gene *G* mRNA is the same in all groups (of cells), whereas the amount of Gene *H* mRNA changes (as the number of *AGO2*$^{+}$ alleles changes).	**Point D1**
	Anaphase I of meiosis is blocked in mice with the *AGO*$2^{-/-}$ genotype. Scientists hypothesize that the block in meiosis occurs because the continued presence of a spindle-fiber stabilizing protein prevents the chromosomes from separating. Based on the table, **explain** how the $AGO2^{-/-}$ genotype could cause this effect on the dividing cells. Examples of acceptable responses may include the following: • Because AGO2 (protein) is not as functional/nonfunctional, cleavage of the mRNA encoding the (spindle-fiber stabilizing) protein is prevented/limited. • Because AGO2 (protein) is not as functional/nonfunctional, mRNA is still translated (and the spindle-fiber stabilizing protein is still present).	**Point D2**

Question 3: Scientific Investigation — 4 points

Cyanide is a chemical that affects the enzyme cytochrome *c* oxidase (CCO), a key enzyme in the mitochondrial electron transport chain. At high cyanide concentrations, CCO activity is much lower than when no cyanide is present. At low concentrations of cyanide, CCO activity is slightly higher than when no cyanide is present, as shown in Table 1.

Table 1. Effects of Cyanide on CCO Activity

No Cyanide	Low Cyanide	High Cyanide
Normal CCO activity	Increases CCO activity slightly	Decreases CCO activity greatly

Some strains of bacteria produce cyanide, which they then release into their environment. Other strains of bacteria do not produce cyanide. Researchers grew both types of bacteria in high-concentration nutrient medium and then isolated the medium from the bacteria. One-half of each medium sample was left at a high concentration, while the concentration of the other half was lowered.

To study the effects of cyanide on mammalian cells, researchers then added the four samples of media to the cells growing in culture dishes, as shown in Table 2. They measured ATP and lactic acid production by the mammalian cells in each of the four treatment groups.

Table 2. Experimental Design to Test the Effect of Cyanide on Mammalian Cells

Mammalian Cell Treatment Group	Cyanide in Nutrient Medium?	Concentration of Medium
1	Yes	High
2	Yes	Low
3	No	High
4	No	Low

A **Describe** the advantage to cells of producing ATP from one molecule of glucose by aerobic cellular respiration rather than by glycolysis alone. — **1 point**

Examples of acceptable responses may include the following:

- (Aerobic cellular respiration) produces more (ATP per molecule of glucose).
- Glycolysis produces less (ATP per molecule of glucose).
- 32 ATPs (produced) from aerobic respiration (acceptable range 30–38), compared to two/four ATPs (produced from glycolysis)

B **Identify** the two treatment groups that served as controls in the researchers' experiment. — **1 point**

Examples of acceptable responses may include the following:

- (Treatment Groups) 3 and 4
- (Mammalian cells) treated with medium lacking cyanide

C Based on the information provided in both tables, **predict** the treatment group that is likely to have the highest ATP production of all four treatment groups. — **1 point**

Examples of acceptable responses may include the following:

- (Treatment Group) 2
- Cells treated with low-concentration growth media from the cyanide-producing (strain of bacteria)

D	The researchers claim that cells in which CCO activity is inhibited will show an increase in lactic acid production. **Support** the researchers' claim. • (Cells in which CCO activity is inhibited) will switch to fermentation/anaerobic respiration (which produces lactic acid).	**1 point**

Question 4: Conceptual Analysis — 4 points

The process of meiosis enables animals that reproduce sexually to produce gametes.

A — **1 point**

Describe one characteristic of chromosome movement during Meiosis I.

Examples of acceptable responses may include the following:

- (Homologous) chromosomes pair/cross over.
- (Homologous) chromosomes separate (to daughter cells).
- Chromosomes align/separate (at the metaphase plate)

B — **1 point**

Explain why chromosomes are more visible when viewed under a microscope during mitosis or meiosis than at any other time in the cell cycle.

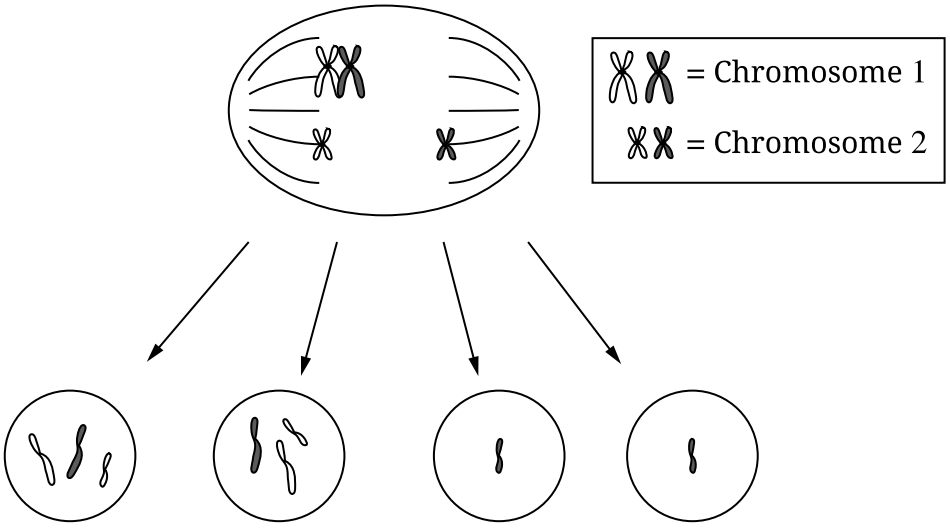
Examples of acceptable responses may include the following:

- (Chromosomes are more visible during mitosis or meiosis) because they are tightly packed/condensed (during prophase, metaphase, and anaphase).
- During most of the cell cycle, DNA exists as a loosely packed chromatin, so it is not/less visible under the microscope.

C — **1 point**

An animal cell with two pairs of homologous chromosomes (a diploid number of four) has undergone meiosis to produce four gametes, and an error occurred at one step, as shown in the figure. One set of chromosomes is represented in white, and the other set is represented in gray.

An Animal Cell Undergoing Meiosis



Assume that each gamete produced by the cell shown in the figure is fertilized by a gamete with a complete haploid set of chromosomes. Also assume gene regulation on Chromosome 1 is not affected by the number of copies of Chromosome 1 in the four resulting viable zygotes. **Predict** the difference in mRNA production from genes on Chromosome 1 among the four possible zygotes.

Examples of acceptable responses may include the following:

- (The zygotes) with more/too many chromosomes will produce more mRNA.
- (The zygotes) with less/fewer chromosomes will produce less mRNA.

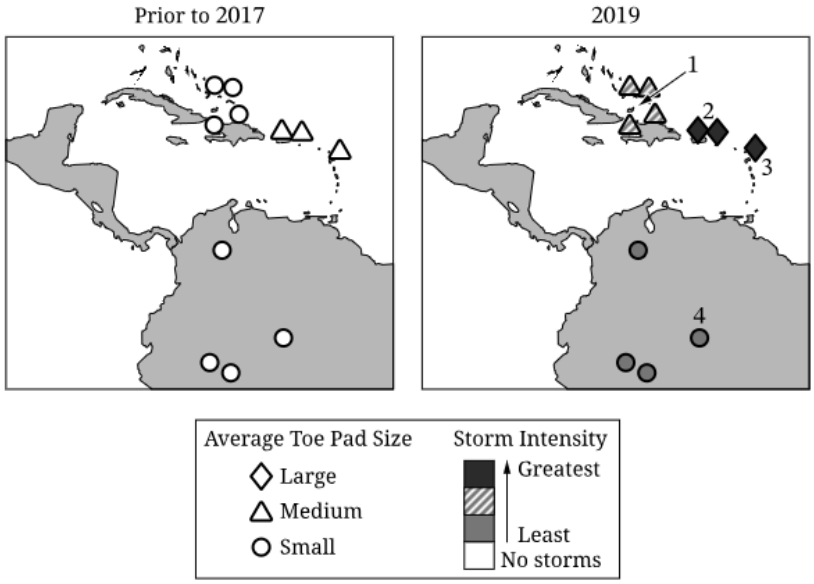
D	Triploidy describes a condition in which an organism has three complete sets of chromosomes in each cell. Provide reasoning to **justify** the claim that most organisms with triploidy cannot produce gametes with the chromosome number typical of the species. Examples of acceptable responses may include the following: • (Homologous) chromosomes cannot pair during meiosis/align correctly. • The chromosomes will not segregate equally (during anaphase, creating gametes with extra or missing chromosomes). • One of the three copies of each chromosome will not have a homologous chromosome with which to pair (during prophase, creating gametes with extra or missing chromosomes).	**1 point**

Question 5: Analyze Model or Visual Representation of a Biological Concept or Process — 4 points

Anole lizards throughout the Caribbean islands and Central and South America have pads of varying sizes on the bottom surfaces of their toes. The sizes of the toe pads are genetically determined and not the result of phenotypic plasticity. During storms with high winds, anoles cling to trees with the help of their toe pads. In recent years, an increase in both the number and intensity of storms has occurred across the range of anole habitats.

In 2017, two very intense storms occurred in the Caribbean islands within a month. In 2019, scientists investigated the relationship between the intense storms and the average toe pad size of the offspring of lizards that survived the storms. The scientists determined the average toe pad size of the surviving offspring and grouped their measurements into three categories: small, medium, and large toe pads. The scientists then compared the 2019 toe pad measurements with measurements recorded prior to 2017. Their data are represented in the figure.

A Map Representing Toe Pad Size Distributions Prior to 2017 and in 2019



A	**Describe** the role that changes in abiotic factors have in natural selection. Examples of acceptable responses may include the following: • (Changes in abiotic factors) act as selective pressures (on the phenotypes of individuals). • (Changes in abiotic factors) can affect the (reproductive) fitness of individuals.	**1 point**

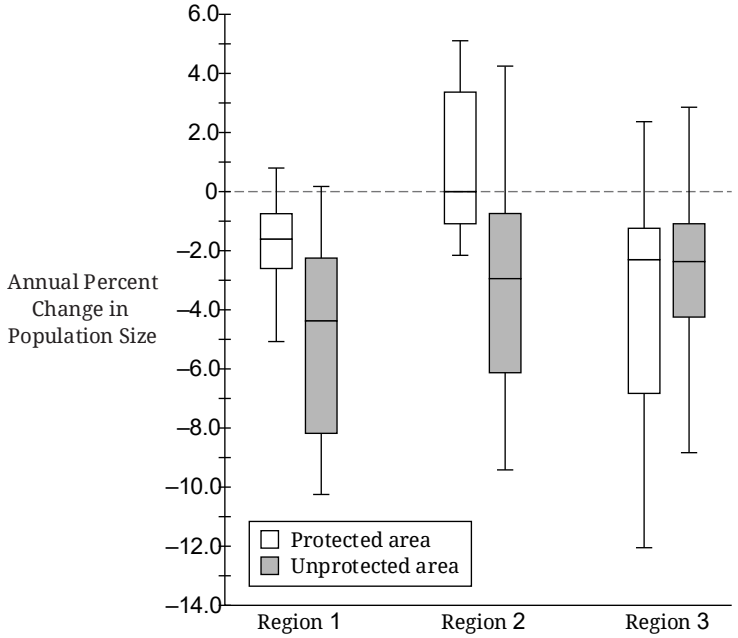
B	Based on the figure, **explain** the relationship between storm intensity and average toe pad size. Examples of acceptable responses may include the following: • (As storm intensity) increases, the average toe pad size increases. • (As storm intensity) decreases, the average toe pad size decreases/remains the same**.** • Individuals with smaller toes pads were less likely to survive in areas with more intense storms (than those with larger toe pads).	**1 point**
C	**Identify** the region on the 2019 map, by indicating the number, that experienced the least storm intensity. • 4/South America	**1 point**
D	Based on the information provided, **explain** how continued differences in storm intensity can apply different selective pressures on anole populations living on the Caribbean islands, eventually leading to speciation. Examples of acceptable responses may include the following: • Anoles with larger toepads have access to different food/habitats/mates higher in the trees, (eventually) leading to reproductive isolation. • (Differences in storm intensity) could lead to differences in phenotypes/toe pad size, which could lead to reproductive isolation. • Anoles on islands that experience more intense storms will have larger toe pads and will become reproductively isolated (from those on islands with less intense storms). • Anoles on islands that experience fewer intense storms will have smaller toe pads and will become reproductively isolated (from those on islands with more intense storms).	**1 point**

Question 6: Analyze Data — 4 points

Many raptors (GLOSSED: type of bird) in Africa are top predators and keystone species in their ecosystems. Raptor population sizes have been declining in recent years.

Scientists studied the relationship between the conversion of the raptors' natural habitat into farmland and the population sizes of raptors in those regions. They compiled raptor population size data from three different regions of Africa: Region 1, Region 2, and Region 3. In each of the regions, the scientists compared the annual percent change in the raptor population size in areas that were protected from farming (protected) with the annual percent change in areas where farming occurred (unprotected). Their results are shown in the box and whisker plot.

Median Annual Percent Change in the Population Size of Raptors in Protected and Unprotected Areas



A	Based on the box and whisker plot, **identify** the median annual percent change in population size in the unprotected area of Region 2. • 3(%) decline/-3(%) (acceptable range -2.8% to -3.2%)	**1 point**
B	Based on the box and whisker plot, **identify** the region and area that experienced the greatest median annual percent change in population size. • Region 1, unprotected area	**1 point**

C	Researchers hypothesize that if farming is eliminated in region 2, there will no longer be a decline in the raptor population size. Based on the data in the box and whisker plot, **evaluate** the researchers' hypothesis. Examples of acceptable responses may include the following: • (Their hypothesis) is supported because there is an increase in the population size in the protected area compared to the unprotected area (of Region 2). • (Their hypothesis) is supported because the (annual percent change in) population in the protected area (of Region 2) is zero. • (Their hypothesis) is not supported because (if farming was eliminated) there is no difference between the (annual percent) change in the populations in protected and unprotected areas (of Region 2). • (Their hypothesis) is not supported because (if farming was eliminated) there is still a decline within the (annual percent change in) population (size) in the protected area (of Region 2).	**1 point**
D	Based on the information provided, **explain** why the ecosystem resilience in unprotected areas may decline over time. Examples of acceptable responses may include the following: • A decrease in raptors/top predators/keystone species will result in a decrease in biodiversity (leading to a decrease in ecosystem resilience). • A decrease in raptors/top predators/keystone species will result in a trophic cascade (leading to a decrease in ecosystem resilience).	**1 point**