AP® BIOLOGY
2014 SCORING GUIDELINES

Question 1

Trichomes are hairlike outgrowths of the epidermis of plants that are thought to provide protection against being eaten by herbivores (herbivory). In a certain plant species, stem trichome density is genetically determined.

To investigate variation in stem trichome density within the plant species, a student counted the number of trichomes on the stems of six plants in each of three different populations. The student used the data to calculate the mean trichome density (numbers of hairs per square centimeter) for each population. The results are provided in the table below.

TRICHOME DENSITY IN THREE PLANT POPULATIONS (number of trichomes/cm^2)

Population	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Sample Mean	Standard Error of the Mean (SEM)
I	8	11	9	10	8	6	9	1
II	12	6	15	9	13	8	11	1
III	13	17	9	14	12	16	14	1

(a) On the axes provided, **create** an appropriately labeled graph to illustrate the sample means of the three populations to within 95 percent confidence (i.e., sample mean ± 2 SEM). (**3 points maximum**; LO 1.1)
- Correctly labeled, scaled, with proper units
- Bar graph or modified bar graph with appropriately plotted means
- 2x standard error (SEM) above and below means

(b) Based on the sample means and standard errors of the means, **identify** the two populations that are most likely to have statistically significant differences in the mean stem trichome densities. **Justify** your response. (**2 points maximum**; LO 4.11, 4.19)

Identification (**1 point**)
- Populations I and III

Justification (**1 point**)
- The error bars/95 percent confidence intervals for populations I and III do not overlap
- (Sample mean + 2 SEM of population I) < (Sample mean − 2 SEM of population III)

(c) **Describe** the independent and dependent variables and a control treatment for an experiment to test the hypothesis that higher trichome density in plants is selected for in the presence of herbivores. Also **identify** an appropriate duration of the experiment to ensure that natural selection is measured and **predict** the experimental results that would support the hypothesis. (**5 points maximum**; LO 1.5, 1.11)

NOTE: Points are earned in a single row only.

Independent Variable (**1 point**)	Dependent Variable (**1 point**)	Control (**1 point**)	Duration (**1 point**)	Prediction (**1 point**)
Presence of herbivores	Trichome density	Absence of herbivores	More than one generation	Increased trichome density relative to control
Trichome density in the presence of herbivores	Reproductive success OR # of plants	Plants with lower trichome density	More than one generation	Size of the population with higher trichome density will be larger than control population

$\dfrac{Trichomes}{cm^2}$ vs. Plant Population 1A₁

$\dfrac{Trichomes}{cm^2}$
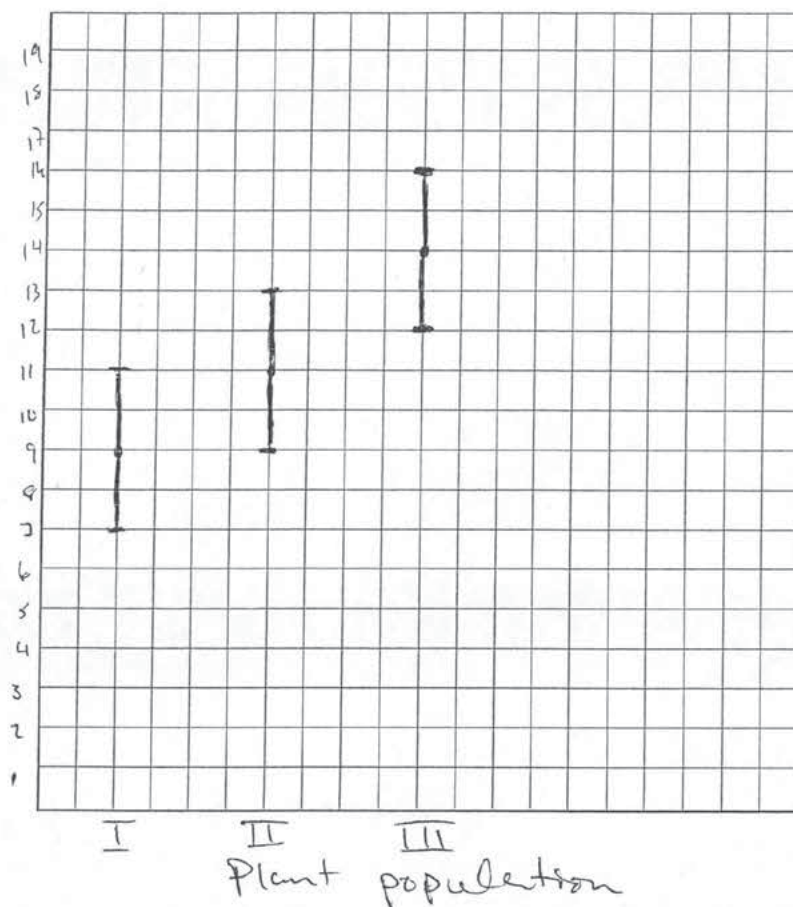
Plant population

b) Plant population I is most likely to have significantly differences in mean stem trichomes density to population III because the mean as well as the standard error of the mean do not overlap numerically. There is a difference of 1 between the highest limit of pop I (at 11) and the lowest of pop III (at 12). This means that data within those data sets can not equal each other* and remain acceptable as data in those sets.

*data in the other set

c) In an ~~bypass~~ experiment to test for whether 'high trichomes density is selected for with the presence of herbivores, the independent variable would be exposure to herbivores, the dependent variable would be the number trichomes $/cm^2$, and a control would be population of an plants that is not exposed to herbivores. An appropriate duration would be over several generations, let us say ~~10~~ 7 so that the offspring of the generations begin to show the phenotype that is being selected for in a measurable percentage that can be compared to the change of the control. This change will occur if natural selection changes the frequency of phenotypes.

I predict that the mean and SEM will be higher (higher Trichomes/cm^2) in the plant population that is exposed to herbivores than in the population without exposure to herbivores

1 B₁
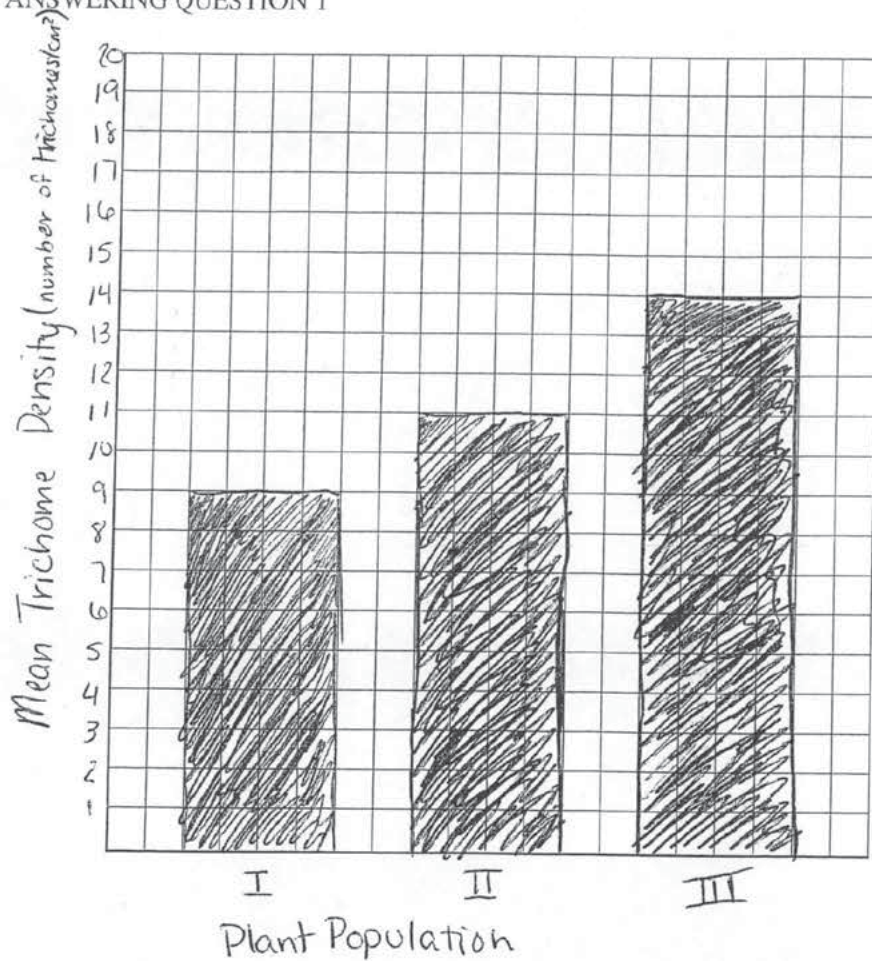
Based on the sample means and standard error of the means, plant population I and plant population III are most likely to have statistically significant differences in the mean stem trichome densities. On average population I ~~has~~ has 5 trichomes per ~~square~~ square centimeter fewer than the average plant in Population ~~III~~ III, ~~~~ Due to Natural Selection and evolution, the plants in population III ~~have been~~ are genetically favoring more hairs based on environmental factors such as

GO ON TO THE NEXT PAGE.

1 B₂

predation,

In an experiment designed to test the hypothesis that higher trichome density in plants is selected for in the presence of herbivores you need to observe many plants throughout many generations. Your control group would be 100 plants of the same species with similar trichome densities to start out with. The test group would ⊗⊗⊗⊗ consist of 100 plants of the same species used in the control with similar trichome densities as the control group to start out with. Your independent variable would be predators, in the control group there will be no predators and in the test group predators will be present. The dependent variable will be the trichome density. For the hypothesis to be true you would not observe change in trichome density in control group plants after many generations. You would observe higher trichome density among plants in the test group that were exposed to predation. As long as both groups were treated equally in every aspect except predation then these results would support this hypothesis.

1C₁

a)

Means of Three Plant Populations
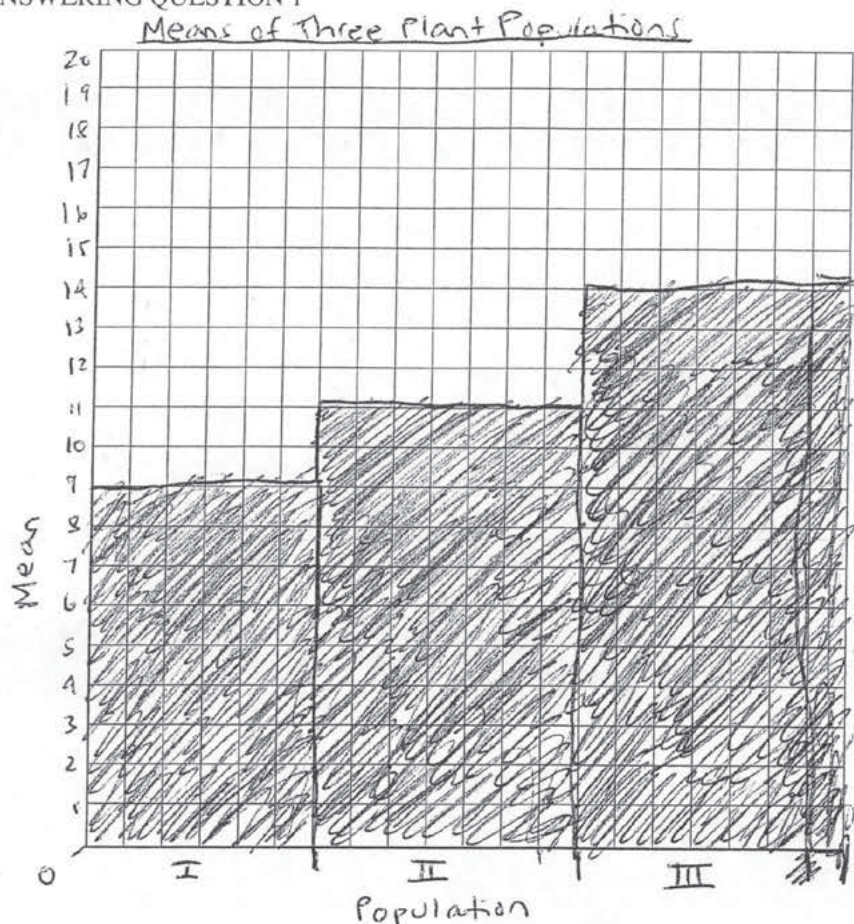
b) The two populations that are most likely to have statistically significant differences in the mean stem trichome densities are population ~~III~~ I and ~~popu~~ population III because they represent the smallest mean density and the largest mean density, respectively.

1C₂

c) The independent variable for this experiment would be trichone density.* The dependent variable would be the number of plants remaining after a period of time.⁺ The control would be a population of plants with ~~average~~ no trichomes. The approximate duration of the experiment should be ~~several~~ 2 years to ensure that natural selection is measured. I would predict the experimental results to show that there are more plants ~~surviving after 2 years~~ ~~which have high trichome density~~ that have a higher trichone density, and fewer that have a low trichone density.

* Trichome density for this experiment should vary from 1 trichome/cm² to 20 trichomes/cm²

⁺ After a period of time during which they are all exposed to the same number and kind of herbivores

° Still exposed to the same number and type of herbivores after the given time

AP® BIOLOGY
2014 SCORING COMMENTARY

Question 1

Question 1 was written to the following Learning Objectives in the AP Biology Curriculum Framework: 1.1, 1.5, 1.11, 4.11, 4.19

Overview

Question 1 is based on a laboratory investigation of the evolution of trichomes, a structural and functional feature of plants, when exposed to herbivores. Students were presented with the sample mean trichome densities and standard error of the means (SEM) of three populations of plants. Students were asked to appropriately graph the means, including the 95% confidence intervals ($\pm$ 2×SEM) for each of the three samples. Students were then asked to identify the two populations most likely to be significantly different, and to justify the difference based on an analysis of the sample means and standard errors of the mean. Students were then asked to design a plan to test the hypothesis that trichomes provide protection from herbivory and are a phenotype that is acted on by natural selection. For the experimental design, students were asked to describe an independent variable, a dependent variable, and an appropriate control treatment, as well as to identify the appropriate duration of the experiment to ensure that natural selection is measured. Finally, students were asked to select the kind of data necessary to predict a measurable experimental result supporting the original hypothesis.

Sample: 1A
Score: 10

The response in Sample 1A earned 1 point in part (a) for correctly scaling and labeling the axes with units. It also earned 1 point for correctly plotting the sample means of the three populations, and 1 point for including 2×SEM error bars above and below the means.

The response earned 1 point in part (b) for identifying that populations I and III are most likely to have significant differences in mean stem trichome density. The responses earned 1 point for the justification that "the standard error of the means do not overlap." The response continued with the justification that the upper limit of the estimated mean of population I (11) is 1 less than the lower limit of the estimated mean of population III (12), but the justification point had already been earned.

The response earned 1 point in part (c) for describing that the independent variable is the presence of herbivores. The response earned 1 point for describing that the dependent variable is the trichome density, ("number of trichomes/cm^2"). The response earned 1 point for describing that plants not exposed to herbivores serve as the control treatment. The response earned 1 point for describing that the duration of the experiment should be several generations. The response earned 1 point for predicting that the mean trichome density "will be higher…in the plant population that is exposed to herbivores than in the population without exposure to herbivores."

Sample: 1B
Score: 8

The response in Sample 1B earned 1 point in part (a) for correctly scaling and labeling the axes with units. The response also earned 1 point for correctly plotting the sample means of the three populations.

The response earned 1 point in part (b) for identifying that "plant population I and plant population III are most likely to have statistically significant differences in the mean stem trichome densities."

The response earned 1 point in part (c) for describing that the duration of the experiment should be many generations. The response earned 1 point for describing that the independent variable is the presence of herbivores ("predators"). The response earned 1 point for describing that plants without herbivores serve as the control treatment. The response earned 1 point for describing that the dependent variable is trichome density. The response earned 1 point for predicting that the mean trichome density will be higher in populations exposed to herbivores than in the control population.

Sample: 1C
Score: 6

The response in Sample 1C earned 1 point in part (a) for correctly plotting the sample means of the three populations.

The response earned 1 point in part (b) for identifying that "The two populations that are most likely to have statistically significant differences in the mean stem trichome densities are population I and population III."

The response earned 1 point in part (c) for describing that the independent variable is trichome density. The response earned 1 point for describing that the dependent variable is number of plants remaining. The response earned 1 point for describing that the control treatment is a population of plants with no trichomes. The response earned 1 point for predicting that the size of the population with a higher trichome density will be larger than the size of the population with a lower trichome density.