1. Read the following article from the *Fremont Examiner*.

FREMONT EXAMINER

**Worm Invasion**

A researcher studying the ecology of the deciduous forest outside of Fremont has made an alarming discovery. While taking an inventory of the species present on the forest floor, Professor Peter Tate discovered many earthworms of an Asian species not previously known to live in this area. The Asian worms, unlike native worms, have voracious appetites. The forest floor is home to a myriad of species that live in the leaf litter, which is composed of several years’ accumulation of slowly decomposing leaves. Dr. Tate explained that “the leaf litter is critical to the survival of local species of forest plants.” Dr. Tate has found the Asian worms, unlike their indigenous cousins, consume the entire layer of leaf litter in a single season. He said, “This sets the stage for the takeover by invasive exotics such as Japanese stilt grass.” Dr. Tate and other scientists are exploring strategies for the control of the Asian worms.

(a) Support Dr. Tate’s assertion that “the leaf litter is critical to the survival of local species of forest plants.” Include in your discussion the roles of leaf litter in a deciduous forest ecosystem.

(b) Describe THREE abiotic changes that would be likely to result if the exotic worms consumed all the leaf litter in a single year.

(c) For one of the changes you identified in part (b), explain how the change could set the stage for the takeover of Japanese stilt grass or other exotic species.

(d) Design a controlled experiment to determine whether the worms, in fact, do change the forest ecosystem. Identify the environmental factor you will measure, and include the specific hypothesis you will test and the data you will collect.
Question 1

(a) Support Dr. Tate’s assertion that “the leaf litter is critical to the survival of local species of forest plants.”
Include in your discussion the roles of leaf litter in a deciduous forest ecosystem.

(2 points total)

(1 pt.) Student must make one statement that pertains to plants
- Student may use the description taken directly from the article: “…This* sets the stage for the takeover by invasive exotics such as Japanese stilt grass.” (*refers to the consumption of the entire layer of leaf litter in a single season)

OR
- Student provides another supporting role of leaf litter in a deciduous forest ecosystem that is tied to plants.

(1 pt.) Student provides another supporting role of leaf litter in a deciduous forest ecosystem (does not need to be tied to plants):
- Serves as ground cover
- Serves as habitat area: e.g., soil microorganisms/nitrogen-fixing bacteria/fungi, serves as a “home to a myriad of species” (statement is in the document; similar statement accepted)
- Provides shelter
- Reservoir for many nutrients: absorbs and releases
- Allows germination of seedlings
- Rooting area: especially important for shallow root perennials
- Helps maintain moisture/water retention
- Assists in the infiltration and percolation of water (by absorbing it/reducing water runoff)
- Contributes to humus production
- Growth/over-wintering area for bulbs, corms, etc.
- Provides shelter for seedlings
- Helps reduce erosion
- Serves as food source: e.g., for detritus feeders ⇒ increased surface area ⇒ decomposition

(b) Describe THREE abiotic changes that would be likely to result if the exotic worms consumed all the leaf litter in a single year.  

(3 points total)

Student must describe, not just list; 1 pt. for each described; score only the first three
- Nutrient levels in soil would change/soil fertility reduced
- Erosion of soil would increase
- Fluctuations in soil temperature/change in soil temperature
- Forest soil pH changes
- Soil would be more compacted/aeration would decrease
- Soil surface light levels would increase
- Decreased moisture above and below ground /drier soil/desiccated soil
- Increased evaporation
- Loss of soil cover/less topsoil
Question 1 (cont’d.)

- Increased water runoff/formation of rivulets, rills, gullies
- Increased sedimentation in local waterways ⇒ increased turbidity in local waterways from runoff
- Leaching of topsoil layers (short term; due to absence of leaf litter/humus)
- Shelter area reduced
- Ground cover reduced
- Rate of movement of pollutants into the soil would increase (would not be absorbed by leaf litter)
- Altered soil texture/changes in soil porosity/changes in soil permeability
- Decreased nutrient-holding capacity of soil/decreased ion-exchange capacity
- Decreased chemical weathering of parent material and bedrock
- Mineralization may occur (loss of humus, subsequent collapse of topsoil fertility; soil becomes gritty due to high mineral content in absence of humus)
- Decreased illuviation (long term) (deposition of material into lower soil layers from higher soil layers via leaching.)
- Reduced habitat area
- Decreased intensity/severity of forest fires

(c) For one of the changes you identified in part (b), explain how the change could set the stage for the takeover of Japanese stilt grass or other exotic species. (1 point total)

The answer in part (c) must be based on an abiotic change in part (b). If part (b) is left blank or is incorrect, no point can be earned in part (c). Many acceptable responses are based on tolerance/range of tolerance and may include major characteristics of successful invader/exotic species, such as: generalists, “early successional species”, high dispersal rate, the release of growth-inhibiting hormones into the soil, r-selected species, etc. Examples include: “the exotic species are often more tolerant than native species of drier soils, and therefore out-compete native species”, “a lack of nutrients may decrease native plant growth, but not exotics.”, and “exotic species can tolerate higher light levels (more intense ultraviolet light) than native species, and therefore the exotic species are at a distinct advantage in thriving in such conditions”.
(d) Design a controlled experiment to determine whether the worms, in fact, do change the forest ecosystem. Identify the environmental factor you will measure, and include the specific hypothesis you will test and the data you will collect. (4 pts. total)

1 pt.) Hypothesis: student states a specific, testable explanation. Hypothesis must include the environmental factor measured and be tied to worms changing the forest ecosystem. Environmental factors NOT accepted (too general): nutrients, food, habitat

2 pts.) Student outlines valid/reasonable procedure for a controlled experiment:

1 point for outlining experimental procedures by including the following (three components are required to earn this point):
- control group required
- experimental group required
- one other from the following list required: specific time, specific area, specific materials, specific sample size

1 point for description of one of the following as part of the procedure (the design point above must be earned in order to earn this point):
- Repeated experiments
- Correlation to other experiments
- How other variables are controlled or tested
- How the experiment could be expanded or modified

1 pt.) Data collected: student describes quantifiable data related to the dependent variable.

Note: An “Observational Experiment” is acceptable: must meet the same criteria as for a more traditional type of experiment where a variable is manipulated by the researcher in the experimental site.
(a) Leaf litter has several important roles in a deciduous forest ecosystem. It prevents soil erosion, and in turn, it helps the soil retain valuable nutrients such as nitrates and phosphates. The leaf litter itself is being decomposed by detritivores (bacteria) which creates a nutrient-rich black soil full of humus. Leaf litter prevents other shrubbery from competing with the trees. By locking in moisture, leaf litter is also home to several types of animals and insects, notably: worms, snakes, small rodents, and sometimes amphibians.

(b) One abiotic change would definitively be a lack of moisture in the soil if the exotic worms consumed all the leaf litter. Other abiotic changes include increased susceptibility to erosion and a lack of nutrient-rich humus which makes the soil so perfect for deciduous trees. In the winter, it is possible that the soil could freeze (very bad for plants) without a protective insulating layer of leaf litter.

(c) Without the nutrient rich layer of humus that comes with leaf litter, the stage is set for other plant species, such as the Japanese stilt grass, to move in. Other exotic plants could follow, ones that don’t need moisture and nutrient-rich soil to survive. Once any exotic species can get settled, it puts the native species in jeopardy of being out-competed.

(d) A controlled experiment to determine the effects of the invasive new worm would involve setting up several plots of deciduous forest land for investigation. Each plot should have finite boundaries so it may be easiest for the experimenter...
to set up artificial ecosystems in the lab. Next, there should be three key groups, one without any worms, one with only the native worms, and one with both the native and exotic worm species. The same conditions should be applied to each individual plot, in essence, same precipitation, # of trees, and — most importantly — the same amount of initial leaf litter. At the end of the experiment’s time-span, the mass of the leaf litter should be taken and compared to the original mass. It is expected for the plot with the exotic worms to have the least amount of remaining leaf litter. The hypothesis reads: If an exotic worm species is introduced into a deciduous forest ecosystem, then the amount of leaf litter remaining at the end of a season will be significantly less than the amount remaining from a plot with only the native worm species. Multiple trials of this experiment should be conducted to ensure accurate results.
Question 1

Sample 1A (10 points)

In part (a), one point is earned for stating that leaf litter reduces soil erosion, and one point is earned for stating that leaf litter helps prevent “other shrubbery” from competing with the trees, thereby allowing the native vegetation to remain. In part (b), one point each is earned for a description of the following abiotic changes: a lack of moisture in the soil, increased susceptibility to erosion, and a lack of nutrient-rich humus in the soil. In part (c), one point is earned for explaining how exotic species, such as Japanese stilt grass, might not require as much moisture as native species, and therefore would be at an advantage. In part (d), one point is earned for providing a control group, an experimental group, and a specific area component in the design of the experiment. One point is earned for stating what data would be collected (mass of leaf litter), and one point is earned for proposing a specific and testable hypothesis. One additional point is earned for noting that multiple trials of this experiment would be conducted to ensure accurate results.

Sample 1B (Score 8)

In part (a), one point is earned for stating that leaf litter serves as a food source for bacteria and other decomposers, and one point is earned for stating that decomposed leaf litter will produce the nutrients to help plants grow. In part (b), one point each is earned for describing a decline in soil nutrients, increased erosion/loss of soil depth, and an increase in sedimentation in waterways as a result of the increase in eroded soil. In part (c), one point is earned for explaining how an exotic species, such as Japanese stilt grass, might be able to thrive in soils that have experienced a reduction in nutrients. In part (d), one point is earned for a specific and testable hypothesis, and one point is earned for describing the data that would be collected. Neither of the two points related to the experimental design or protocol were earned.

Sample 1C (Score 6)

In part (a), one point is earned for describing leaf litter decomposing and providing nutrients in the soil for plant growth. One point is also earned for stating that leaf litter serves as habitat for insects and microorganisms. In part (b), one point is earned for each of the following: a decline in soil nutrients, and decreased habitat area that was previously provided by leaf litter. In part (c), no points are earned because the student did not explain how one of the abiotic changes identified in part (b) might set the stage for the takeover by an exotic species. In part (d), one point is earned for providing a control group, an experimental group, and an area component in the design of the controlled experiment. One point is earned for stating a specific and testable hypothesis. The data collection point could have been earned by providing a more specific response; the data mentioned for collection is too general in nature. Also, the response could have earned one additional point if it had provided one other specific experimental design component.
Student Performance Q&A:

2003 AP® Environmental Science Free-Response Questions

The following comments on the 2003 free-response questions for AP® Environmental Science were written by the Chief Reader, Thomas Mowbray of Salem College in Winston-Salem, North Carolina. They give an overview of each free-response question and of how students performed on the question, including typical student errors. General comments regarding the skills and content that students frequently have the most problems with are included. Some suggestions for improving student performance in these areas are also provided. Teachers are encouraged to attend a College Board workshop, to learn strategies for improving student performance in specific areas.

Question 1

What was the intent of this question?

This question was based on an article about the discovery of an invasive species (an Asian worm) in a deciduous forest. The question was intended to test students’ knowledge of several fundamental ecological processes as well as students’ ability to apply that knowledge in the context of the ecological problem described in the article. The question also tested students’ skills in designing a controlled experiment to determine how the worms might be changing the forest ecosystem.

How well did students perform on this question?

Students were generally able to earn at least one of the points in Part (a) and, if they recognized the question was asking for an abiotic change, another point in Part (b). Many students were unable to take one of the abiotic changes they described in Part (b) and explain how that specific change could set the stage for the takeover of the Japanese stilt grass or other exotic species. Part (d) proved challenging to the majority of students, with many unable to earn any points. The mean score for this question was 3.33 out of a possible 10 points.

What were common student errors or omissions?

In Part (a) the most common error was not including at least one role of leaf litter that is tied to plants and/or giving only one role. In Part (b) the most common error was to describe biotic changes rather than abiotic changes that would be likely to result if the exotic worms consumed all the leaf litter in a single year. It was very common for students to describe changes in biodiversity, such as loss of particular plants and animals.
The most common error in Part (c) was linked with Part (b) in assuming that all the native plants would die and, as a result, there would be more open space. Many students stated that open space alone was the reason for the invasion of an exotic species. From student responses, it was clear that many were unable to distinguish the reason an exotic rather than an indigenous species would be able to colonize an area.

In Part (d) the most common error was the lack of organization and specificity in the design of an experiment. Many student responses lacked a specific and testable hypothesis; for example, “test for nutrients” did not earn a point. Students often did not narrow down the hypothesis or the data collection to realistic targets, such as measuring soil nitrogen levels. Frequently, they did not identify the source of the data. Although students sometimes knew that more than one area or “plot of land” would be necessary, they often did not provide sufficient specificity to earn the protocol point that could be earned for the inclusion of control group(s), experimental group(s), and either a specific time or a specific area, or specific materials, or a specific sample size. It seems clear that many students did have some familiarity with a hypothesis statement, a control group, and an experimental group, but most showed poor understanding of what a specific testable hypothesis is and how to properly connect that functional hypothesis with an experiment that could actually be carried out.

**Based on your experience of student responses at the AP Reading, what message would you like to send to teachers that might help them to improve the performance of their students on the exam?**

Teachers are encouraged to provide as many experimental design activities as possible for their students throughout the academic year. These activities should include hypothesis development, designing experimental protocol, observation, and analysis.

Teachers are also encouraged to continue emphasizing the need for specificity, detail, and completeness in their students’ answers. Specificity and detail should not be confused with regurgitation of “factoid”-like information; rather, it should be treated as an essential part of the comprehensive understanding of concepts and processes expected in a college-level course. Teachers should constantly remind their students that responses that are too vague and general in nature do not earn points on the exam.