1. Read the article below and answer the questions that follow.

Fremont Examiner

Microalgae for Fuel Production: Can Green Goo Solve Our Energy and Climate Problems?

Scientists and investors are promoting the potential of some of the smallest, oiliest critters on Earth as a solution to our energy problems. Although the humble organisms look like green goo, some species of microalgae are over 50 percent oil. Scientists say microalgae are the most efficient organisms at converting sunlight to energy. In fact, they beat other oil crops for production per acre, hands down.

<table>
<thead>
<tr>
<th>Gallons of Oil per Acre per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
</tr>
<tr>
<td>Soybeans</td>
</tr>
<tr>
<td>Safflower</td>
</tr>
<tr>
<td>Sunflower</td>
</tr>
<tr>
<td>Rapeseed</td>
</tr>
<tr>
<td>Oil palm</td>
</tr>
<tr>
<td>Microalgae</td>
</tr>
</tbody>
</table>

Seventy percent of this oil can be recovered by pressing the algae; over 90 percent can be recovered by solvent extraction. The resulting oil can be used for heating, for electricity generation, or for making other fuels, like biodiesel. After the oil is removed, the remaining material can be used as animal feed or soil amendment. The Germans are even looking into using it for construction material. “In this way, we sequester that carbon indefinitely,” said Dr. Klaus Mueller. Some scientists are bubbling emissions from coal-burning power plants through algae-filled tanks to remove CO₂.

Proponents claim that microalgae can be used to capture nutrients from animal feedlot waste lagoons and sewage treatment plants. Because they grow only in the top inch of water, the algae might even be grown in rooftop pools someday. But are microalgae really all they’re cracked up to be? Like other monoculture crops, they may be susceptible to widespread damage from disease.
(a) Calculate the number of acres required to produce 1,000 gallons of oil in one year from
   (i) microalgae
   (ii) soybeans

(b) Describe TWO environmental advantages that biodiesel production from microalgae offers over biodiesel production from the other crops listed in the table.

(c) Explain why burning biodiesel fuel has a different impact on atmospheric CO₂ concentrations than does burning fossil fuels.

(d) Discuss TWO benefits, other than those related to atmospheric impacts, of increased reliance on biodiesel fuels over the next 50 years.

(e) Describe TWO economic or societal problems associated with producing fuel from corn.
Question 1

(a) Calculate the number of acres required to produce 1,000 gallons of oil in one year from

(i) microalgae

(One point is earned for the correct answer.)

\[
\frac{10,000 \text{ gal}}{1 \text{ acre}} = \frac{1,000 \text{ gal}}{x \text{ acres}} \Rightarrow x = 0.1 \text{ acre}
\]

OR

\[
1 \text{ acre} = 10,000 \text{ gal} ; \quad 1,000 \text{ gal} \times \frac{1 \text{ acre}}{10,000 \text{ gal}} = 0.1 \text{ acre}
\]

(ii) soybeans

(One point is earned for the correct answer.)

\[
\frac{50 \text{ gal}}{1 \text{ acre}} = \frac{1,000 \text{ gal}}{x \text{ acres}} \Rightarrow x = 20 \text{ acres}
\]

OR

\[
1 \text{ acre} = 50 \text{ gal} ; \quad 1,000 \text{ gal} \times \frac{1 \text{ acre}}{50 \text{ gal}} = 20 \text{ acres}
\]

(A third point is earned in part (a) for a correct setup of both the microalgae and soybean calculations.)
(b) Describe TWO environmental advantages that biodiesel production from microalgae offers over biodiesel production from the other crops listed in the table.

(One point is earned for each correct advantage; accept only the first two advantages given. Each advantage listed must include a corresponding description.)

<table>
<thead>
<tr>
<th>Advantage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less land use</td>
<td>• Less habitat destruction and/or less loss of biodiversity</td>
</tr>
<tr>
<td></td>
<td>• Protection of watersheds from agricultural runoff</td>
</tr>
<tr>
<td>Decreased tilling of soil</td>
<td>• Less soil erosion</td>
</tr>
<tr>
<td>Decreased pesticide and/or fertilizer use</td>
<td>• Less runoff of pesticides and/or fertilizers</td>
</tr>
<tr>
<td>Decreased fossil fuel consumption for tilling soil, harvesting crops, and/or manufacturing and applying fertilizers and pesticides</td>
<td>• Less mining and drilling for fossil fuels, resulting in less habitat destruction and less loss of biodiversity</td>
</tr>
<tr>
<td></td>
<td>• Less air pollution (e.g., NO\textsubscript{x}, O\textsubscript{3})</td>
</tr>
<tr>
<td>Decreased energy consumption for extracting oils from microalgae</td>
<td>• Less mining and drilling for fossil fuels, resulting in less habitat destruction and less loss of biodiversity</td>
</tr>
<tr>
<td></td>
<td>• Less air pollution (e.g., NO\textsubscript{x}, O\textsubscript{3})</td>
</tr>
<tr>
<td>Decreased irrigation of land</td>
<td>• Less soil salinization and/or less desertification</td>
</tr>
<tr>
<td></td>
<td>• Less aquifer depletion</td>
</tr>
<tr>
<td>Less nutrient depletion of soil</td>
<td>• Less land under cultivation</td>
</tr>
<tr>
<td>Microalgae may be grown in wastewater</td>
<td>• Less runoff and less infiltration of wastewater</td>
</tr>
</tbody>
</table>
(c) Explain why burning biodiesel fuel has a different impact on atmospheric CO₂ concentrations than does burning fossil fuels.

(One point is earned for a correct explanation.)

Biodiesel contains carbon that was recently present in the atmosphere rather than fossil-fuel carbon that was in the atmosphere long ago and has been sequestered beneath Earth’s surface. Hence the burning of biodiesel does not contribute to a net increase in the amount of carbon dioxide currently circulating in the atmosphere, whereas the burning of fossil fuel does contribute to a net increase in the concentration of carbon dioxide in the atmosphere.

(d) Discuss TWO benefits, other than those related to atmospheric impacts, of increased reliance on biodiesel fuels over the next 50 years.

(A total of 3 points can be earned according to the following guidelines.)

- No point is earned for one correct benefit with no appropriate discussion.
- One point is earned for one correct benefit with an appropriate discussion.
- Two points are earned for two correct benefits with one appropriate discussion.
- Three points are earned for two correct benefits with two appropriate discussions.
- Only the first two benefits mentioned in the response can earn points.
- Benefits based on speculation about future energy prices do not earn points.
### Question 1 (continued)

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Sample Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biofuels are renewable resources</td>
<td>• Fossil fuels are nonrenewable</td>
</tr>
<tr>
<td></td>
<td>• Renewable resources are less likely to be exhausted</td>
</tr>
<tr>
<td>Increased jobs</td>
<td>• More labor needed in the agricultural sector</td>
</tr>
<tr>
<td>Increased profits for companies</td>
<td>• Industries in the agricultural sector will increase sales</td>
</tr>
<tr>
<td>Decreased reliance on imported fossil fuels</td>
<td>• Decreases political instability</td>
</tr>
<tr>
<td></td>
<td>• Results in a self-sufficient supply of energy</td>
</tr>
<tr>
<td>Increased global political stability</td>
<td>• Reliance on imported fossil fuels decreases</td>
</tr>
<tr>
<td></td>
<td>• Disputes over oil are frequently the cause of disagreements among nations</td>
</tr>
<tr>
<td>Reduced transportation costs</td>
<td>• Fewer oil spills during transport</td>
</tr>
<tr>
<td></td>
<td>• Fossil fuels must be transported over greater distances</td>
</tr>
<tr>
<td>Reduced land disturbance</td>
<td>• Result of less fossil fuel extraction</td>
</tr>
<tr>
<td>Preservation of petroleum</td>
<td>• For nonenergy uses (e.g., plastics, petrochemicals, medical purposes)</td>
</tr>
<tr>
<td>Reduced insecurity as fossil fuel reserves decrease</td>
<td>• Enhances a shift to alternate energy sources</td>
</tr>
<tr>
<td>Reduced petroleum use</td>
<td>• Petroleum reserves will dwindle over the next 50 years</td>
</tr>
<tr>
<td>Increased nutrient capture from wastewater</td>
<td>• Less escapes into the environment</td>
</tr>
<tr>
<td></td>
<td>• Reduced eutrophication of waterways</td>
</tr>
<tr>
<td>Increased availability of waste products</td>
<td>• Increased availability for use as animal feed or soil amendment</td>
</tr>
<tr>
<td>Decreased disposal of used cooking oil</td>
<td>• Results in less waste disposal</td>
</tr>
</tbody>
</table>
(e) Describe TWO economic or societal problems associated with producing fuel from corn.

(One point is earned for each correct response that includes a corresponding description; only the first two responses can earn points.)

<table>
<thead>
<tr>
<th>Problem</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase (or decrease) in corn prices</td>
<td>• As corn is used for energy production, the demand for corn will become greater</td>
</tr>
<tr>
<td></td>
<td>• Increased corn growing may flood market</td>
</tr>
<tr>
<td>Increased prices for food (e.g., beef, chicken, anything made with corn syrup)</td>
<td>• Result of increased corn prices</td>
</tr>
<tr>
<td></td>
<td>• Increased demand for corn</td>
</tr>
<tr>
<td>Increased prices for commodities other than corn</td>
<td>• Increased corn production reduces land area for other crops, reducing supply of commodities</td>
</tr>
<tr>
<td>Shortages of food for human consumption</td>
<td>• Decreased supply of corn</td>
</tr>
<tr>
<td></td>
<td>• Decreased availability of crops displaced by corn production</td>
</tr>
<tr>
<td>Cultural extinction</td>
<td>• Rainforest destruction for the production of crops displaced by corn production displaces indigenous cultures</td>
</tr>
<tr>
<td>Decreased aesthetic value of land</td>
<td>• Natural areas converted to farmland have less aesthetic value</td>
</tr>
<tr>
<td>Loss of jobs</td>
<td>• Lower demand for energy production jobs not associated with corn (e.g., coal mining, petroleum engineering)</td>
</tr>
<tr>
<td>Energy shortages</td>
<td>• Poor crop yields resulting from drought, pestilence, etc., result in less corn to produce energy</td>
</tr>
<tr>
<td>Increased land costs</td>
<td>• Due to increased demand for agricultural lands</td>
</tr>
<tr>
<td>Decreased availability of land for nonagricultural use leading to less land for cities</td>
<td>• Due to increased demand for agricultural lands</td>
</tr>
<tr>
<td>Problem</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Decreased availability of land for nonagricultural use leading to public opposition</td>
<td>• Due to increased demand for agricultural lands</td>
</tr>
<tr>
<td>Reduced water supply for cities</td>
<td>• Due to increased agricultural water consumption</td>
</tr>
<tr>
<td>Increased societal risks associated with exposure to agricultural chemicals</td>
<td>• Increased pesticide and fertilizer use</td>
</tr>
<tr>
<td>Higher costs to cultivate and maintain agricultural land</td>
<td>• Increased use of marginal lands to grow more corn</td>
</tr>
<tr>
<td>Overuse of agricultural land</td>
<td>• Loss of productive land</td>
</tr>
<tr>
<td>Increased taxes or unavailable public money</td>
<td>• Subsidies that divert public money to pay for corn production.</td>
</tr>
<tr>
<td>The need to convert combustion engines to burn ethanol or biodiesel</td>
<td>• Using corn for fuel will result in fuel that is not compatible with current engines</td>
</tr>
<tr>
<td>More expensive than alternatives</td>
<td>• Higher cost for resources (e.g., fertilizer, pesticides, land, water) needed to produce fuel from corn as compared with producing other fuels</td>
</tr>
</tbody>
</table>
(c) Explain why burning biodiesel fuel has a different impact on atmospheric CO₂ concentrations than does burning fossil fuels.

(d) Discuss TWO benefits, other than those related to atmospheric impacts, of increased reliance on biodiesel fuels over the next 50 years.

(e) Describe TWO economic or societal problems associated with producing fuel from corn.

\[
\text{a) microalgae: } \frac{10,000 \text{ gal}}{\text{acre}} \times \frac{1 \text{ acre}}{10,000 \text{ gal}} = 1 \text{ acre}
\]

\[
\frac{1 \text{ acre}}{10,000 \text{ gal}} \times \frac{10,000 \text{ gal}}{1 \text{ acre}} = 1 \text{ gal}
\]

\[
\text{b) Microalgae biodiesel production uses far less land than other crops. Therefore less wilderness and forest areas need to be destroyed and replaced with farmland. Also microalgae does not need as many fertilizers and pesticides to ensure substantial growth. Less chemicals and nutrients will run off into water ecosystem, poison plants and animals and not as much cultural eutrophication will occur.}
\]

\[
\text{c) Biodiesel fuel still creates CO₂ when burned just as fossil fuels do. However, biodiesel fuels only release as much CO₂ as extracted from the atmosphere during photosynthesis. Fossil fuels on the other hand release CO₂ that has been stored underground for millions of years. Biodiesel does not lead to a net increase in CO₂ levels and these levels remain constant in the atmosphere unlike when burning fossil fuels.}
\]
d) Increased benefits from biodiesel include less reliance on foreign countries providing essential fuel and using a renewable resource. In the current world, oil is extremely expensive and oil money supports instability in foreign countries such as Iraq and Nigeria. Increased use of biofuels would result in less dependence on these countries. Also biofuels are renewable and society does not have to fear they will run out. There is no depletion of biofuels and an impending crisis.

e) Using biofuels can raise the prices of food due to increased demand. The poor in the world may not be able to afford the increased food prices and may resort to violence and rioting. Also biofuels can displace jobs related to fossil fuel extraction and retirement causing unemployment and economic downturn in areas such as Texas or the Middle East.
Question 1

Overview

This was the document-based question. After reading a newspaper article, students were asked a series of questions related to the subject of the article, biodiesel fuel. The questions required students to demonstrate knowledge of alternative energy sources, the carbon cycle, and the issues surrounding the use of food products to produce energy.

Sample: I-1A
Score: 10

Part (a): 3 points were earned. The student earned 1 point in part (a)(i) and 1 point in part (a)(ii) for correctly answering that 1 acre and 20 acres of land would be required to produce 1,000 gallons of oil in one year from microalgae and soybeans, respectively. The student earned 1 point for correctly showing how to arrive at the answers to both parts (a)(i) and (a)(ii).

Part (b): 2 points were earned. The student describes two environmental advantages of using microalgae over the other crops listed in the document. The first correct description is “uses far less land,” resulting in “less wilderness and forest areas . . . destroyed.” The second correct description is that using “microalgae does not need as many fertilizers,” resulting in less “runoff.”

Part (c): The student earned 1 point for correctly explaining that biodiesel fuel releases the CO$_2$ that it "extracted . . . during photosynthesis,” while fossil fuels “release CO$_2$ that has been stored underground for millions of years.”

Part (d): 2 points were earned. The student earned 1 point for discussing one nonatmospheric benefit of increased use of biodiesel fuels over the next 50 years: “less reliance on foreign countries” for fuel, linked with “instability in foreign countries.” The second correct benefit the student identifies but does not discuss is that “biofuels are renewable.”

Part (e): 2 points were earned. The student describes two economic or social problems associated with producing fuel from corn. The first correct description is that “increased demand” can “raise the prices of food.” The second correct description is that using “biofuels can displace jobs related to fossil fuel extraction and refinement.”

Sample: I-1B
Score: 5

Part (a): 3 points were earned. The student earned 1 point in part (a)(i) and 1 point in part (a)(ii) for correctly answering that 1/10 acre and 20 acres of land would be required to produce 1,000 gallons of oil in one year from microalgae and soybeans, respectively. The student earned 1 point for correctly showing how to arrive at the answers to both parts (a)(i) and (a)(ii).

Part (b): No points were earned. The student does not describe an environmental advantage of using microalgae over the other crops listed in the document. The description of the first advantage, less land use, is too vague as “the least amount of land disruption” may not be an environmental advantage. The second advantage, removal of “CO$_2$ from coal-burning power plants,” is not described.
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2008 SCORING COMMENTARY

Question 1 (continued)

Part (c): The student earned 1 point for the correct explanation that “the plant grown to make” biodiesel fuel “absorbed” the CO$_2$ that is released when it is burned, while CO$_2$ released by fossil fuels is not “recapture[d].”

Part (d): No points were earned. The student does not discuss a nonatmospheric benefit of increased use of biodiesel fuels over the next 50 years. The first of the two proposed benefits is not adequate, and the second benefit is not discussed.

Part (e): The student earned 1 point for the correct description of one economic or social problem associated with producing fuel from corn: “an increase in corn crops, decreasing other crops,” leads to “a price increase on foods other than corn and in cotton.”

Sample: I-1C
Score: 2

Part (a): 2 points were earned. The student earned 1 point in part (a)(i) for correctly answering that .1 acre of land would be required to produce 1,000 gallons of oil in one year from microalgae. The student did not earn any points in part (a)(ii) because the answer—that 200 acres of land would be required to produce 1,000 gallons of oil in one year from soybeans—is incorrect. The student earned 1 point in part (a) for showing how to correctly arrive at the answers to both parts (a)(i) and (a)(ii).

Part (b): No points were earned.
Part (c): No points were earned.
Part (d): No points were earned.
Part (e): No points were earned. The student mentions that “[p]roducing fuel from corn provides less corn . . . to eat” but does not describe an associated societal problem (such as hunger, malnutrition, or social unrest).
Student Performance Q&A:
2008 AP® Environmental Science Free-Response Questions

The following comments on the 2008 free-response questions for AP® Environmental Science were written by the Chief Reader, Art Samel of Bowling Green State University in Bowling Green, Ohio. 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 was the document-based question. After reading a newspaper article, students were asked a series of questions related to the subject of the article, biodiesel fuel. The questions required students to demonstrate knowledge of alternative energy sources, the carbon cycle, and the issues surrounding the use of food products to produce energy.

How well did students perform on this question?
Students performed fairly well on this question. The mean score was 4.1 out of a possible 10 points. Most students attempted to answer part (a) and calculated the correct areas. In parts (b) and (e) many students provided descriptions that were not sufficiently thorough, and in part (d) many students did not include two complete discussions. Few students earned the point in part (c).

What were common student errors or omissions?
Students had difficulty with part (c). Only a few indicated an understanding of the difference between the impact of biodiesel fuel and fossil fuels on atmospheric CO₂ concentrations. Students commonly wrote that biodiesel fuel releases no CO₂ when burned or that biodiesel fuel reduces the atmospheric CO₂ concentration. Students also confused photosynthesis and respiration in their explanations.

In part (e) many students did not demonstrate an understanding of the problems of using a food commodity (corn) as fuel.
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?

- Remind students that when calculations are required on the exam, they must clearly show how they arrived at their answers.
- Encourage students to provide complete descriptions and discussions.
- Remind students to answer the questions that have been asked. For example, when asked to describe an environmental advantage, students did not earn points for descriptions of nonenvironmental advantages.
- Provide students opportunities to extemporaneously write explanations of environmental concepts—when answering this question, they were largely unable to explain the difference between old and new carbon.
- Give students the opportunity to discuss and write explanations of environmental issues currently in the news. Exam questions occasionally cover subject matter that is similar to recent world events.
2. The city of Fremont operates a municipal solid-waste landfill. As represented in the diagram above, the annual precipitation in Fremont is 200 mm/year: 50 percent of this water infiltrates through the landfill cover soil into the waste, and 50 percent drains off the landfill. A drainage system withdraws 90 percent of the leachate generated within the landfill for treatment. The rest of the leachate travels through the bottom liner of the landfill into the surrounding soil. Most of the cadmium disposed of in the landfill remains in the landfill; the leachate withdrawn from the landfill by the drainage system has an average cadmium concentration of 2.0 g/m³. Pumped to a treatment station, the leachate is treated at a cost of $10/m³.

(a) Calculate the volume, in m³, of each of the following:

(i) The water infiltrated through the landfill per year

(ii) The leachate that is treated per year

(b) Given that the cadmium concentration in the water draining from the landfill is 2.0 g/m³, calculate the mass, in kg, of cadmium that is released into the surrounding soil per year.

(c) What is the annual cost of treating the leachate from the drainage system?

(d) Discuss TWO viable methods for reducing the amount of cadmium entering the municipal waste input.

(e) Explain a shortcoming of ONE of the methods that you identified in part (d).
(a) Calculate the volume, in m³, of each of the following:

(Two points can be earned in each of parts (a)(i) and (a)(ii): 1 point for a correct setup, and 1 point for the correct answer.)

(i) The water infiltrated through the landfill per year

\[
200 \text{ mm rain } \times \frac{1 \text{ m}}{1,000 \text{ mm}} = 0.2 \text{ m rain}
\]

\[
\frac{10,000 \text{ m}^2 \times 0.2 \text{ m}}{10,000 \text{ m}^2} = 1,000 \text{ m}^3
\]

(ii) The leachate that is treated per year

\[
1,000 \text{ m}^3 \times 0.9 (90\%) = 900 \text{ m}^3
\]

Note: If the answer to (a)(i) is incorrect, then 0.9 times that answer still earns full credit in (a)(ii).

(b) Given that the cadmium concentration in the water draining from the landfill is 2.0 g/m³, calculate the mass, in kg, of cadmium that is released into the surrounding soil per year.

(Two points can be earned: 1 point for the correct setup, and 1 point for the correct answer.)

Note: The student can either begin with the difference between the answers for (a)(i) and (a)(ii) or take 10 percent of the answer from (a)(i). Metric conversions do not necessarily have to be shown.

\[
\frac{100 \text{ m}^3 \text{ drainage water}}{1 \text{ year}} \times \frac{0.2 \text{ g Cd}}{1 \text{ m}^3} \times \frac{1 \text{ kg}}{1,000 \text{ g}} = \frac{0.2 \text{ kg Cd/year}}{}
\]

(c) What is the annual cost of treating the leachate from the drainage system?

(Two points can be earned: 1 point for the correct setup, and 1 point for the correct answer.)

Note: The student must use the answer from (a)(ii).

\[
\frac{900 \text{ m}^3 \text{ treatable leachate}}{1 \text{ m}^3 \text{ leachate}} \times \frac{$10}{1 \text{ m}^3 \text{ leachate}} = $9,000 \text{ year}
\]
(d) Discuss TWO viable methods for reducing the amount of cadmium entering the municipal waste input.

(Two points can be earned: 1 point for a discussion of each viable method. Only the first two methods are scored.)

<table>
<thead>
<tr>
<th>Category of Reduction</th>
<th>Method or Action</th>
</tr>
</thead>
</table>
| **Disposal options**  | • Sort waste stream for cadmium-containing products (batteries, e-waste, paints and pigments, stabilizers, pesticides) headed to landfills  
  • Deposit these materials at a dropoff site or recycling facility, or return to manufacturer |
| **New/substitute technology or alternate materials** | Avoid use of cadmium-containing products by:  
  • using rechargeable batteries (e.g., lithium rechargeable)  
  • applying new technology and/or alternate materials that do not use cadmium |
| **Incentives and/or disincentives** | • Place restrictions on disposal of materials that contain cadmium (batteries, e-waste, paints and pigments, stabilizers, pesticides)  
  • Pass cradle-to-grave (RCRA) legislation  
  • Provide rebate incentives for using cadmium-free products  
  • Provide incentives for manufacturing cadmium-free products (e.g., research grants)  
  • Place a deposit (payable on return) or surcharge on cadmium-containing products |
| **Education** | Make the public aware of (any one of the following):  
  • concerns (health, environmental) associated with cadmium  
  • methods of cadmium-containing product/battery reduction/recycling  
  • availability of new/substitute technology |
(e) Explain a shortcoming of ONE of the methods that you identified in part (d).

(One point is earned for an explanation that is linked to an accepted method described in part (d).)

Difficulty and/or expense identified with:

- educating the public about benefits of recycling waste that contains cadmium
- providing efficient systems for cadmium waste pickup (recycling/reuse)
- sorting
- achieving 100 percent cadmium removal from waste or 100 percent replacement
- safe disposal, new technology, and substitute material development
- enforcement/regulations/compliance
- recycling (e.g., energy requirements)
- determining if a product contains cadmium
(a) i) \[ 100 \text{mm/yr.} = 50\% \text{ of } 300 \text{mm/yr.} \]
\[
\frac{1.0 \times 10^2 \text{mm}}{1 \text{m}} = \frac{1.0 \times 10^{-1} \text{m}}{1.0 \times 10^3 \text{mm}}
\]
\[
(1.0 \times 10^4 \text{m}^2)(1.0 \times 10^{-1} \text{m}) = 1.0 \times 10^3 \text{ m}^3 \text{ H}_2\text{O/yr.}
\]

ii) \[
(1.0 \times 10^{-3} \text{cm}^3) \frac{9}{(1.0 \times 10^3 \text{m}^3)(9.0 \times 10^{-1})} = \left[ 9.0 \times 10^2 \text{ m}^3 \text{ leachate/yr.} \right]
\]

b) \[
(1.0 \times 10^3 \text{m}^3)(1.0 \times 10^{-1}) = 1.0 \times 10^2 \text{ m}^3 \text{ leachate in soil}
\]
\[
\frac{1.0 \times 10^2 \text{m}^3}{2.0 \text{ g}} = \frac{1 \text{kg}}{1.0 \times 10^3 \text{g}} = 2.0 \times 10^{-1} \text{ kg cadmium/1}
\]

c) \[
9.0 \times 10^{-2} \text{ m}^3 \frac{6.0 \times 10^8}{\text{m}^3} = 5.4 \times 10^3
\]

d) The city of Fremont municipal solid waste landfill could enforce regulations that limited the amount of cadmium permitted in the landfill. For example, some items containing cadmium would be prohibited at the landfill or disposed of in another way or recycled. Another method includes the incineration of cadmium-containing waste.

e) The incineration of cadmium-containing waste would release toxic environmental particulate pollutants into the air, damaging the lungs and nerve tissue of those who breathe them.
Overview

The question assessed students’ abilities to analyze environmental information from a schematic diagram as well as text. The outcome of these analyses should have been a correct computation of landfill values for infiltrated water, cadmium-containing leachate, cadmium released into surrounding soil, and the annual costs associated with treating the leachate. The question also measured students’ abilities to recognize viable methods of waste-stream reduction for cadmium and the inherent shortcomings associated with the implementation of these methods.

Sample: I-2A
Score: 9

Part (a)(i): 2 points were earned—1 for the correct setup and 1 for the correct answer.

Part (a)(ii): 2 points were earned—1 for the correct setup and 1 for the correct answer.

Part (b): 2 points were earned—1 for the correct setup and 1 for the correct answer.

Part (c): 2 points were earned—1 for the correct setup and 1 for the correct answer.

Part (d): 1 point was earned for stating that the city “could enforce regulations,” which leads to alternate disposal. Incineration is not a viable method.

Part (e): No points were earned. Since incineration is not viable, the shortcoming did not earn a point.

Sample: I-2B
Score: 5

Part (a)(i): 2 points were earned for the correct setup and the correct answer.

Part (a)(ii): 1 point was earned. The student makes computational errors that limit the score.

Part (b): No points were earned. The setup is nearly correct, but the computation of 10 m$^3$ of infiltration into the surrounding soil should equal 100 m$^3$. This incorrect volume leads to an incorrect calculation and final value.

Part (c): 2 points were earned. In this case, the student is not penalized a second time for the incorrect computation in part (a)(ii). The student earned 1 point for a correct setup (bringing down the answer from part (a)(ii) and multiplying by $10/m^3$). As a result, the answer also earned a point.

Part (d): No points were earned because “an alternative use for the cadmium” is not the same thing as an alternative to cadmium. The second method refers to cadmium already in the landfill.

Part (e): No points were earned because the shortcoming is linked to a nonviable method.

Sample: I-2C
Score: 3

Part (a)(i): 1 point was earned for the correct value.
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Question 2 (continued)

Part (a)(ii): 2 points were earned for the correct setup and the correct answer.

Part (b): No points were earned.

Part (c): No points were earned. The student incorrectly applies the kg value from part (b).

Parts (d) and (e): No points were earned in part (d) because the first method is too vague and the second refers to cadmium already in the landfill. Part (e) does not link to a viable method in part (d).
Q&A

**Question 2**

_What was the intent of this question?_

The question assessed students’ abilities to analyze environmental information from a schematic diagram as well as from text. The outcome of these analyses should have been a correct computation of landfill values for infiltrated water, cadmium containing leachate, cadmium released into surrounding soil, and the annual costs associated with treating the leachate. The question also measured students’ abilities to recognize viable methods of waste stream reduction for cadmium and the inherent shortcomings associated with the implementation of these methods.

_How well did students perform on this question?_

Students performed fairly well on this question. The mean score was 2.26 out of a possible 10 points.

_What were common student errors or omissions?_

Many students chose not to answer this question. Integrating the prompts with the schematic and descriptive text appeared difficult for those students who attempted to answer.

In parts (a), (b), and (c) students often omitted calculations or had difficulty with the calculations. Students struggled with setting up the equations that were based on the schematic and text; showing correct dimensional analysis; and carrying correct units through the problem(s). They also had difficulty with metric units and the final computation. When students elected to answer the computational parts of the question (parts [a], [b], and [c]) with prose, the prose did not indicate a clear understanding of the setup.
In part (d) many students confused reducing municipal waste input with treating cadmium-bearing leachate already in the waste stream, and they inappropriately suggested filtering as a method. Many students were vague in their descriptions of methods (e.g., screening waste).

*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?*

- Encourage students to understand what the question is asking before they start writing answers.
- Encourage students to show all computational work. Work with students to organize computational problems that use dimensional analysis.
- Encourage students to complete all computational sets, so that they can earn points where possible.
- Encourage development of analytical skills: work with students on data analysis and the application of quantitative analysis to environmental problems.
- Encourage students to review their answers to determine whether the computations produce realistic results, with the right order of magnitude. If a computation produces an unrealistic result, then it is likely incorrect.
3. For decades, forest fires in the United States have been suppressed. In 2003 legislation was passed under the Healthy Forests Initiative (HFI) in response to the record-breaking wildfires that had occurred in the early 2000s. Some environmental and conservation groups fear that negative impacts could result if timber companies are encouraged to harvest medium- and large-size trees in federally owned forests while clearing away the smaller trees and underbrush.

(a) Identify TWO characteristics of forests that develop when fires are suppressed, and explain why the practice of fire suppression does not reduce, but actually increases, the risk of intense and extensive forest fires.

(b) The effects of the HFI are expected to extend beyond fire reduction. Excluding fire reduction, describe ONE positive and ONE negative effect likely to result from the implementation of the provisions of the HFI.

(c) Describe TWO ecosystem services provided for humans by forests. Explain how clear-cutting would affect each ecosystem service you describe.

(d) Identify a specific type of plant community or biome (other than a forest) that is naturally maintained by fire. Explain how the fire maintains the community or biome.
(a) Identify TWO characteristics of forests that develop when fires are suppressed, and explain why the practice of fire suppression does not reduce, but actually increases, the risk of intense and extensive forest fires.

(Three points can be earned: 1 point for each correct characteristic, and 1 point for a correct explanation. Only the first two characteristics given are scored.)

### Characteristics of Forests

- Accumulation of combustible materials (layer of leaf litter and debris on forest floor, dead trees, etc.)
- Increase in understory growth (grasses, shrubs, brush, ladder trees)
- Larger trees develop
- Even-aged stands develop
- Tree density increases
- Fire-intolerant species increase in number in the understory
- Fire-tolerant species that need fire to germinate seeds decrease in population
- Increased canopy coverage eliminates understory growth
- Increase or decrease in the rate of nutrient cycling (e.g., release of nutrients of litter, lack of nutrient-rich ash)
- No loss of nutrients to burning in intense fires
- Increased susceptibility to disease/parasites

### Explanations for Increased Fire Risk

**Adds to fuel load [intensity]**
- Increased leaf litter
- Increased density of large trees
- Increased size of trees
- Increase in brush and small trees
- Species composition change

**Adds to spreading of fire [extent]**
- Increased density of trees
- Increased density of understory growth
- Ladder trees leading to crown fires
(b) The effects of the HFI are expected to extend beyond fire reduction. Excluding fire reduction, describe ONE positive and ONE negative effect likely to result from the implementation of the provisions of the HFI.

(Two points can be earned: 1 point for a correct positive effect and description; 1 point for a correct negative effect and description.)

<table>
<thead>
<tr>
<th>Positive Effect and Description</th>
<th>Negative Effect and Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased removal of medium and large trees/small tree brush removal will:</td>
<td>The removal of medium and large trees/small tree brush removal will:</td>
</tr>
<tr>
<td>• lead to economic growth in the lumber industry</td>
<td>• reduce available habitat for other organisms in the forest biome</td>
</tr>
<tr>
<td>Increased removal of medium and large trees will:</td>
<td>• allow timber companies to cut in areas remote from forest communities not threatened by forest fires</td>
</tr>
<tr>
<td>• allow understory to develop into larger trees, potentially enhancing forest habitat</td>
<td>• cause a reduction in biodiversity (must include a specific example: reduction in nest sites, decrease in seed trees, etc.)</td>
</tr>
<tr>
<td>• make additional timber available to use (must indicate usage)</td>
<td>• increase soil erosion</td>
</tr>
<tr>
<td>• result in thinned trees resistant to pests and disease/impede spread of diseases and pests</td>
<td>• increase logging practices (e.g., roads providing access to new areas)</td>
</tr>
<tr>
<td>• enhance economic value of the surrounding areas (housing, lower insurance)</td>
<td>• reduce public input</td>
</tr>
<tr>
<td>• lower the cost of timber</td>
<td>• result in a change in aesthetics (with explanation)</td>
</tr>
<tr>
<td>• result in a change of aesthetics (with explanation)</td>
<td></td>
</tr>
</tbody>
</table>
Question 3 (continued)

(c) Describe TWO ecosystem services provided for humans by forests. Explain how clear-cutting would affect each ecosystem service you describe.

(Four points can be earned: 1 point for each correct ecosystem service, and 1 point for each correct link that describes the impact of clear-cutting. Only the first two characteristics given are scored.)

<table>
<thead>
<tr>
<th>Ecosystem Service</th>
<th>Impact of Clear-Cutting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon that is removed from the atmosphere by trees helps to limit the magnitude of the atmospheric greenhouse effect.</td>
<td>• Some carbon will be released to the atmosphere or will not be removed</td>
</tr>
<tr>
<td>Forests provide oxygen (via photosynthesis).</td>
<td>• Some loss of oxygen, without which we cannot live</td>
</tr>
<tr>
<td>Forests provide food products for human consumption (deer, nuts, fungi).</td>
<td>• Can change available browsing places and sighting of animals due to species composition change, increasing their availability for humans (e.g., deer)</td>
</tr>
<tr>
<td>Forests provide habitat for many species, some of which provide food and goods for humans, some of which cause harm.</td>
<td>• Loss of habitat (biodiversity)</td>
</tr>
<tr>
<td>Forests provide wood (e.g., construction material, paper)</td>
<td>• Increase in the short-term availability of wood, but potential long-term loss of availability</td>
</tr>
<tr>
<td>Forests provide wood for fuel.</td>
<td>• Increase in the short-term availability of wood, but potential long-term loss of availability</td>
</tr>
<tr>
<td>Many products, such as glue, rubber, and medicines, are produced with forest products.</td>
<td>• Increase in the short-term availability of these products, but potential long-term loss of availability</td>
</tr>
<tr>
<td>Forests influence the local microclimate affecting humans (change in temperature, shade, UV, wind breaks).</td>
<td>• Change in the microclimate</td>
</tr>
<tr>
<td>Forests have aesthetic value (hiking, camping, photography, tourism, etc.).</td>
<td>• Decreases in natural beauty</td>
</tr>
<tr>
<td>Forests improve the quality of soil and water used by humans. (Soil and water must be linked to a specific human use.)</td>
<td>• Increases in erosion and runoff and decreases in groundwater recharge, changing water quality</td>
</tr>
</tbody>
</table>
### Question 3 (continued)

<table>
<thead>
<tr>
<th>Ecosystem Service</th>
<th>Impact of Clear-Cutting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forests maintain watershed integrity (e.g., flood control with specific human application).</td>
<td>• Decreases in watershed integrity</td>
</tr>
</tbody>
</table>

(d) **Identify a specific type of plant community or biome (other than a forest) that is naturally maintained by fire. Explain how the fire maintains the community or biome.**

(Two points can be earned; 1 point for identification of biome; 1 point for correct explanation of how fire maintains biome.)

Grasslands (savannah, steppe, veldt, pampas, prairie, marquis, garrigue—regional descriptions should include mention of grasslands):

- Fire destroys invasive plant species (e.g., other grasses and trees) that compete for resources with native grasses.
- Fire removes cover and allows sunlight penetration.
- Fire helps the seeds of native grasses to germinate.
- Fires enhance cycling of nutrients back into the soil.

Chaparral (Mediterranean scrubland, Mediterranean shrubland—regional descriptions should include mention of location):

- Fire removes brush, reducing competition for resources.
- Fire helps plants that require fire or lack of brush cover to germinate.
- Species that vigorously stump sprout quickly regenerate themselves.
- Fires enhance cycling of nutrients back into the soil.

Note: Any forest biome earns no credit.
3. For decades, forest fires in the United States have been suppressed. In 2003 legislation was passed under the Healthy Forests Initiative (HFI) in response to the record-breaking wildfires that had occurred in the early 2000s. Some environmental and conservation groups fear that negative impacts could result if timber companies are encouraged to harvest medium- and large-size trees in federally owned forests while clearing away the smaller trees and underbrush.

(a) Identify TWO characteristics of forests that develop when fires are suppressed, and explain why the practice of fire suppression does not reduce, but actually increases, the risk of intense and extensive forest fires.

(b) The effects of the HFI are expected to extend beyond fire reduction. Excluding fire reduction, describe ONE positive and ONE negative effect likely to result from the implementation of the provisions of the HFI.

(c) Describe TWO ecosystem services provided for humans by forests. Explain how clear-cutting would affect each ecosystem service you describe.

(d) Identify a specific type of plant community or biome (other than a forest) that is naturally maintained by fire. Explain how the fire maintains the community or biome.

b) 1. When fire is suppressed, there is an increase of brush development on the floor of forest. This could include dead trees and bushes which are very flammable once they catch fire. It's just more fuel for the future fires which can burn very intensely.

2. When a fire is suppressed, some forest species cannot reproduce or live due to a lack of sunlight or heat necessary for them to disperse their seeds. This can lead to our very forest with many dead trees which can increase the risk of a major fire with all of the dead dry trees lying around.

b) One positive effect: With the removal of medium and large sized trees, there will be a steady input of wood to create products such as paper and building materials. HFI would help keep the prices of these things low.

Negative: There will be a major loss to biodiversity in the forest because certain species depend on certain plants and trees as a source of food and shelter. With those removed, the species will either need to move or die.
C.1) 1. Forests help keep the soil intact and help reduce soil erosion. If a forest was clear-cut, there would be an increase in soil erosion and land disturbance to property and agricultural areas.

2. Forests help remove large amounts of CO₂ from the air and put out O₂ which humans need to breath. If forests were clear-cut, we would just increase global warming with the increased CO₂ and reduce the amount of O₂ we have available to breath.

d. Grassland - Fires help maintain the biome by replenishing nutrients vital to plant growth back into the soil when the plants are burned. This helps ensure that future generations of plants will be able to grow in the fertile soil.
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Question 3

Overview

The intent of this question was to determine the level of students’ understanding of fire-suppressed forests, the impact of the Healthy Forest Initiative upon forests, ecosystem services provided by forests, and the effect of clear-cutting upon those services. In addition, students were asked to identify another plant community or biome maintained by fire, other than forests.

Sample: I-3A
Score: 10

Part (a): 3 points were earned. The student earned 1 point for identifying the characteristic that “there is an increase of brush development on the floor of [the] forest,” 1 point for explaining that “dead trees and bushes . . . are . . . fuel for the future fires, which can burn very intensley [sic],” and 1 point for the characteristic that some species need the heat of a fire “to disperse their seeds” for reproduction.

Part (b): 2 points were earned. The student earned 1 point for describing a positive effect of the Healthy Forest Initiative by stating that “[w]ith the removal of medium and large sized trees, there will be a steady input of wood,” resulting in low prices of wood products, and 1 point for a negative effect of the Healthy Forest Initiative for stating that “[t]here will be a major loss to biodiversity” due to a removal of “plants and trees as a source of food” for some species.

Part (c): 4 points were earned. The student earned 1 point for describing how forests “reduce soil erosion,” 1 point for explaining that a “clear-cut” forest causes “an increase in soil erosion and land disturbance to property and agricultural areas” (this shows the forest service to humans), 1 point for stating that “[f]orests help remove large amounts of CO₂ from the air,” and 1 point for explaining that clear-cut forests “increase global warming with the increased CO₂.”

Part (d): 2 points were earned. The student earned 1 point for identifying grasslands and 1 point for explaining that “[f]ires help maintain the biome by replenishing nutrients vital to plant growth, back into the soil.”

The student earned all 11 points available and received the maximum score of 10 points.

Sample: I-3B
Score: 6

Part (a): 3 points were earned. The student earned 1 point for identifying the characteristic of “many lowlying bushes and brush on the forest floor,” 1 point for identifying the characteristic of “alot [sic] of dead weeds and large amounts of wood that can easily catch fire,” and 1 point for an explanation of “increased risk of intense and extensive forest fires because there is . . . more to burn.”

Part (b): 1 point was earned for describing a negative effect of “taking away many habitats for many different species.” The student’s description of one positive effect of HFI—“that there will be less fires”—did not earn a point, as the question specifically states to exclude fire reduction.

Part (c): 2 points were earned. The student earned 1 point for stating that “[t]rees produce oxygen, [and] humans cannot live without oxygen,” and 1 point for explaining that “cutting down forest [limits] the amount of oxygen on earth.”

Part (d): No points were earned. The student incorrectly identifies a biome maintained by fire.
Sample: I-3C
Score: 3

Part (a): 3 points were earned. The student earned 1 point for identifying the characteristic of “excessive underbrush develops,” 1 point for identifying the characteristic of “dead trees cover the floor and there is often a lot of duff,” and 1 point for explaining that “when a wildfire occurs it feeds off of this brush and becomes intense and huge.”

Part (b): No points were earned. The response incorrectly includes fire reduction.

Part (c): No points were earned. The response fails to describe an ecosystem service to humans and link it to clear-cutting.

Part (d): No points were earned. The student incorrectly identifies a plant community maintained by fire.
Q&A

Question 3

What was the intent of this question?
The intent of this question was to determine the level of students’ understanding of fire-suppressed forests, the impact of the Healthy Forests Initiative upon forests, ecosystem services provided by forests, and the effect of clear-cutting upon those services. In addition, students were asked to identify another plant community or biome maintained by fire, other than forests.

How well did students perform on this question?
Students performed well on this question. The mean score was of 4.6 out of a possible 10 points. Almost all students attempted to answer the question.

What were common student errors or omissions?
In part (a) many students indicated “dry” as a condition of suppressed forests. Fire-suppressed forests are not dry but have an accumulation of combustible materials, an increase in understory growth, stored turpines in older trees, and other conditions that cause the fire risk to increase. Dryness is due to local climate, not forest conditions. Other students thought fire suppression followed a forest fire or the act of putting out a forest fire.

In part (b) students did not earn points for responding with fire-reduction methods.
Students who did not receive full credit in part (c) failed to identify an ecosystem service benefiting humans. A number of students who indicated clear-cutting the forest did not link it to an ecosystem service. Students also had difficulty explaining the carbon/oxygen cycle and omitted the human service of carbon dioxide reduction reducing climate change impacts. Many students incorrectly stated that oxygen is released from carbon dioxide during photosynthesis.

In part (d) some students did not know a specific plant community, other than forests, that is maintained by fire.

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?

- Students should read questions carefully and note where linkages and exclusions are specified within the questions (e.g., “excluding fire reduction” in part [b]). When students miss this subtlety, they may earn no points on one or more parts of a question.

- Students should be familiar with the ecological services provided by ecosystems and the impact of humans on ecosystems.

- Students should take sample exams in class and focus on providing responses that answer the specific questions that have been asked.
4. Answer the following regarding world human population.

(a) Create a graph of the data from table 1 below on the axes provided.

(b) Identify and discuss TWO of the causes for the trend in the worldwide TFR that you graphed in part (a).

<table>
<thead>
<tr>
<th>Year</th>
<th>TFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>5.0</td>
</tr>
<tr>
<td>1960</td>
<td>4.9</td>
</tr>
<tr>
<td>1970</td>
<td>4.7</td>
</tr>
<tr>
<td>1980</td>
<td>3.7</td>
</tr>
<tr>
<td>1990</td>
<td>3.4</td>
</tr>
<tr>
<td>2000</td>
<td>3.0</td>
</tr>
</tbody>
</table>
Table 2: Population Data for Selected Nations (2005)

<table>
<thead>
<tr>
<th>Country</th>
<th>TFR</th>
<th>Crude Birth Rate*</th>
<th>Crude Death Rate*</th>
<th>Infant Mortality Rate*</th>
<th>Per Capita Income (U.S. dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>1.6</td>
<td>12</td>
<td>7</td>
<td>27</td>
<td>6,500</td>
</tr>
<tr>
<td>Japan</td>
<td>1.3</td>
<td>9</td>
<td>8</td>
<td>2.8</td>
<td>31,400</td>
</tr>
<tr>
<td>Kenya</td>
<td>5.9</td>
<td>43</td>
<td>19</td>
<td>100</td>
<td>1,000</td>
</tr>
<tr>
<td>United States</td>
<td>2.0</td>
<td>14</td>
<td>8</td>
<td>6.7</td>
<td>42,000</td>
</tr>
</tbody>
</table>

* rates are per thousand per year

(c) Consider the data in table 2 above. Identify and discuss TWO economic or societal factors that account for the difference between the TFR of Kenya and that of the United States.

(d) Describe TWO human activities related to the rapidly growing world population that are having an impact on Earth’s biodiversity.
(a) Create a graph of the data from table 1 below on the axes provided.

(Two points can be earned: 1 point for correctly plotting the data [no more than one data point may be misaligned], and 1 point for correctly setting up BOTH axes with a consistent scale interval.)

Notes: Bar graphs are acceptable. Students need not connect the data points. Award no credit for flipped axes.

(b) Identify and discuss TWO of the causes for the trend in the worldwide TFR that you graphed in part (a).

(Three points can be earned: 1 point for each valid cause, and 1 point for discussion of a valid cause—cause and discussion MUST BE LINKED. Two points maximum may be earned for causes; 1 point maximum for discussion. A single discussion point may be earned by itself.)

<table>
<thead>
<tr>
<th>Cause</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased/improved family planning</td>
<td>• Fewer pregnancies/control of fertility/choice in number of children born</td>
</tr>
<tr>
<td>Increased education for women (stay in school longer)/improved social status of women</td>
<td>• Delay having children/choosing to have fewer children</td>
</tr>
<tr>
<td>More women enter the workforce</td>
<td>• Delay having children</td>
</tr>
<tr>
<td>Reduced need for children in workforce/on farm</td>
<td>• More industrialization/less agriculture/increased urbanization</td>
</tr>
<tr>
<td>More industrialization/less agriculture/increased urbanization</td>
<td>• Reduced need for children in workforce/on farm</td>
</tr>
</tbody>
</table>
(c) **Consider the data in table 2 above. Identify and discuss TWO economic or societal factors that account for the difference between the TFR of Kenya and that of the United States.**

(Four points can be earned: 1 point for each correct factor, and 1 point for each correct discussion of the factor. Discussion points may be earned without an identified factor. However, if factors are given, discussion and factors MUST BE LINKED.)

<table>
<thead>
<tr>
<th>Factors (Societal or Economic)</th>
<th>Discussion</th>
</tr>
</thead>
</table>
| Kenya has a much higher infant mortality rate. | • There is a shortage of prenatal and pediatric care due to poverty in Kenya.  
• Kenyans have more children to ensure that some survive. |
| Kenya is more agricultural (second stage of demographic transition). | • In Kenya more children are needed to help farm. |
| Kenya is a less-developed country (lower per-capita income)/poorer/nonindustrialized. | • Children provide income to the family.  
• Contraceptives are not affordable. |
**Factors (Societal or Economic)**

<table>
<thead>
<tr>
<th></th>
<th>Discussion</th>
</tr>
</thead>
</table>
| Women in Kenya lack education and job opportunities. | • Women in Kenya have fewer career/work choices so they have children at an earlier age than women in the United States do.  
• Women in Kenya do not delay childbearing, in contrast with women in the United States who often delay starting a family due to the high cost of childcare. |
| There is no pension system to support people as they age in Kenya. | • More children are needed to support parents in old age. |
| There is less education about family planning in Kenya. | • There is less ability to control fertility. |
| Cultural values favor larger families in Kenya. | • More children mean greater social status. |
| Women in Kenya have a low social status/marry at an earlier age. | • Women have little or no choice/control of their fertility; they have more years of childbearing. |
| There is a preference for male children in Kenya. | • People have more children to get as many sons as possible, because sons will continue to support the family. |
| The cost of raising a child in the United States is much higher than in Kenya. | • People in the United States choose to have smaller families. |
| Abortion is illegal in Kenya. | • Results in more births. |
| Religious values in Kenya prohibit contraception/abortion. | • Results in more births. |
(d) Describe TWO human activities related to the rapidly growing world population that are having an impact on Earth’s biodiversity.

(Two points can be earned: 1 point for each accurate description. The student must link a specific activity to a specific impact on biodiversity.)

- Deforestation for the following purpose destroys habitats and reduces biodiversity (may use two activities for 1 point each):
  - farming (i.e., creation of monocultures);
  - housing/development (i.e., urbanization);
  - fuel (wood);
  - fossil-fuel recovery (mining and drilling).
- Fossil-fuel burning releases carbon dioxide resulting in climate change, altering global/regional/local temperature and precipitation patterns leading to reduction of biodiversity within ecosystems where organisms have very specific climatic requirements for survival.
- Pollution (student must identify specific contaminants linked to human activity that have a negative impact on species and biodiversity).
- Intensive fish farming spreads parasites and disease to native species, reducing biodiversity.
- Diversion of freshwater for agricultural, municipal, and industrial use reduces water supply for biodiverse freshwater ecosystems.
- Damming of rivers makes it difficult for species that breed/spawn upstream (e.g., salmon) to reproduce, reducing biodiversity.
- Overfishing leads to small, unsustainable populations of fish species, reducing biodiversity.
- Building landfills for increased amounts of trash destroys habitat, reducing biodiversity.
- Poaching of wild animals (e.g., bush meat) due to increased human population and demand for food leads to dwindling populations that may not be sustainable.
- Using genetically modified crops to increase yield of food crops can negatively impact other species (e.g., monarch butterfly larvae can be killed when they ingest toxin-containing genetically modified corn pollen that has settled on milkweed leaves near genetically modified corn fields).
4. Answer the following regarding world human population.

(a) Create a graph of the data from table 1 below on the axes provided.

<table>
<thead>
<tr>
<th>Year</th>
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</tr>
<tr>
<td>2000</td>
<td>3.0</td>
</tr>
</tbody>
</table>

(b) Identify and discuss TWO of the causes for the trend in the worldwide TFR that you graphed in part (a).

(c) Consider the data in table 2 above. Identify and discuss TWO economic or societal factors that account for the difference between the TFR of Kenya and that of the United States.

(d) Describe TWO human activities related to the rapidly growing world population that are having an impact on Earth’s biodiversity.
B) One cause for the decline in the worldwide TFR is increasing education and rights for women. More education for women and increasing rights for women has been shown to decrease the number of children a woman has. As her education increases, her fertility decreases. Also, the increasing widespread use and knowledge of contraceptives decreases the amount of babies a couple will have. As more people are also aware informed on the subject of contraception, they will have less babies and the fertility rate, or the amount of children born per woman will decline.

C) The TFR of Kenya is higher than the United States' because the per capita income is lower in Kenya. People who make less money usually have more children to help the family's economic situation. More kids means more work that can be done. Also, the infant mortality rate is very high in Kenya so couples have more babies in order to account for the high rate of people in Kenya who die and thus they compensate by having more children. Also, religious or societal pressures may dictate that a couple have more babies.
D) Humans are clearing more and more land for both agriculture and livestock to feed a growing population. This destroys forests and thus habitats, decreasing biodiversity. Also as the population grows rapidly, urbanization and urban sprawl destroys both habitats and food sources, which decreases biodiversity. The increasing use of oil and gasoline, natural gas, and coal (and biomass for energy sources) release pollutants that can cause acid rain and global warming both contributing to species and habitat loss, and inescapably, biodiversity will decrease.
Overview

The aim of this question was to assess students’ knowledge of contemporary issues related to human population growth and its impact on the environment. Students were required to graph and analyze Total Fertility Rate (TFR) data, which should have shown a decreasing trend, and then to give two causes for this decrease over the past fifty years. Students were then asked to compare the TFR for a developed country (the United States) and a less-developed country (Kenya) and to discuss two factors that would account for the difference. Lastly, students were required to relate two effects of rapid human population growth on the biodiversity of the Earth.

Sample: I-4A
Score: 10

Part (a): 1 point was earned for correctly setting up both axes, but the second and third data points are misaligned.

Part (b): 3 points were earned. The student earned 1 point for identifying “increasing education and rights for women” and 1 discussion point for stating a decrease in “the number of children” per woman. Another point was earned for identifying “increasing widespread use and knowledge of contraceptives.” The linked discussion did not earn a point since the maximum score is 3 points.

Part (c): 4 points were earned. The student earned 1 point for correctly comparing the per capita income of the United States and Kenya and 1 discussion point for the link to needing children “to help the family’s economic situation.” One point was earned for correctly comparing infant mortality rates in the United States and Kenya, and 1 linked discussion point was earned for needing to “have more babies” to ensure that some survive. The identification of “religious or societal pressures” did not earn a point since it is the third factor, and the maximum number of points was already earned.

Part (d): 2 points were earned. The student earned 1 point for describing the activity of “clearing more and more land for both agriculture and livestock” linked to the destruction of “forests and thus habitats,” and 1 point for describing the activity of “urbanization and urban sprawl” linked to destroying habitats. A third activity did not earn additional points because the maximum number of points was already earned.

Sample: I-4B
Score: 7

Part (a): 1 point was earned for correctly setting up both axes, but the data points are not plotted clearly or correctly.

Part (b): 2 points were earned. The student earned 1 point for identifying the cause of “everything is a lot more expensive now . . . so people cannot afford as many children,” and 1 point for identifying a second cause of China “forbidding people to have more than one child.”

Part (c): 4 points were earned. The student earned 1 point for correctly comparing the infant mortality rates in Kenya and the United States and 1 linked discussion point for stating that “people there have more babies so some will survive.” Another point was earned for comparing per capita income in Kenya and the United States, and 1 linked discussion point was earned for stating that “the people in Kenya probably can’t afford birth controls.”
Question 4 (continued)

Part (d): No points were earned. The student gives a list of two activities (“medicine” and “education”) that do not correctly address the question. At the end the student correctly refers to “green house gas emissions” and links them to “specialist species,” but because this is the third human activity the student lists, it did not earn a point.

Sample: I-4C
Score: 2

Part (a): 1 point was earned. The student correctly sets up both axes but does not correctly plot the data points 1970, 1980, 1990, or 2000, which causes the graph to show a straight line. Additionally, the student extrapolates beyond the data given.

Part (b): No points were earned. The student’s identification of “per capita income of the world is not high enough” is not a correct cause, and the statement that “population is getting too crowded” does not specify any region or country.

Part (c): 1 point was earned. The student identifies the factor “that the U.S. is much more developed than Kenya.” The second factor—“the U.S. has a much larger per capita income than Kenya”—is too similar to the first factor to earn a point.

Part (d): No points were earned. The student does not describe a human activity that impacts biodiversity.
Question 4

What was the intent of this question?

The aim of this question was to assess students’ knowledge of contemporary issues related to human population growth and its impact on the environment. Students were required to graph and analyze Total Fertility Rate (TFR) data, which should have shown a decreasing trend, and then to give two causes for this decrease over the past fifty years. Students were then asked to compare the TFR for a developed country (the United States) and a less-developed country (Kenya) and to discuss two factors that would account for the difference. Lastly, students were required to relate two effects of rapid human population growth on the biodiversity of the Earth.

How well did students perform on this question?

Students performed fairly well on this question. The mean score was 5.81 out of a possible 10 points.

What were common student errors or omissions?

In part (b) students often did not specify the role played by increased educational opportunities for women in reducing the TFR. Instead, they simply gave “increased education” as a cause. Another common error was to link the end of the baby boom with the end of wars in Korea, Vietnam, and Iraq to explain decreased worldwide TFR after 1950.

In part (c) students sometimes did not qualify their statements by stating which country they were describing and therefore did not earn points.
In part (d) students had difficulty identifying how human population growth impacts biodiversity. Many students gave answers that related to human health and human biodiversity, rather than to the biodiversity of nonhuman species. Many students erroneously mentioned marriage between people of two different races as a factor that would increase biodiversity, or they used answers that would have been appropriate for parts (b) or (c).

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?

- Encourage students to fully discuss or describe their ideas, even when it may seem that the discussion point is an obvious outcome of the cause or factor being discussed. A list is not the same thing as a discussion or a description.

- Work with students to accurately plot data on a graph. Be sure that they know how to plot points and bars and how to draw pie charts. Stress attention to detail. It is also important to focus on the interpretation of drawn graphs.