

## ENVIRONMENTAL SCIENCE

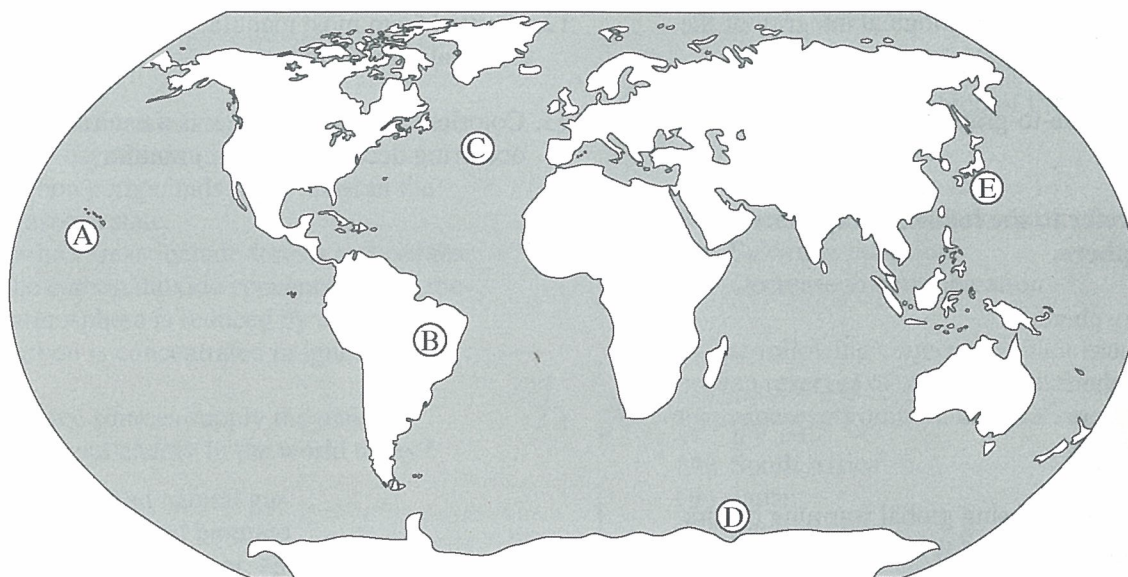
## Section I

Time—1 hour and 30 minutes

## Part A

Directions: Each set of lettered choices below refers to the numbered questions or statements immediately following it. Select the one lettered choice that best answers each question or best fits each statement and then fill in the corresponding oval on the answer sheet. A choice may be used once, more than once, or not at all in each set.

Questions 1-3 refer to the locations marked by letters on the world map below.



1. The location where new crust is being created at a divergent plate boundary
2. The location where one tectonic plate is being forced beneath another, creating a volcanic arc.
3. The intraplate location where hot-spot volcanism is occurring

1 - diver  
2 - conver  
3 - diver

## Section I

Questions 4-6 refer to the following.

- (A) Safe Drinking Water Act
- (B) Clean Water Act
- (C) Comprehensive Environmental Response Compensation and Liability Act (CERCLA)
- (D) Resource Conservation and Recovery Act
- (E) Toxic Substances Control Act

4. Requires minimum safety standards for community water supplies
5. Mandates the restoration and maintenance of the chemical, physical, and biological integrity of the nation's waters
6. Establishes cradle-to-grave tracking of hazardous waste

Questions 7-9 refer to the following regions of Earth's atmosphere.

- (A) Thermosphere
- (B) Exosphere
- (C) Troposphere
- (D) Mesosphere
- (E) Stratosphere

7. The phenomenon causing global warming occurs primarily in this region of the atmosphere.
8. The beneficial ozone layer is in this region of the atmosphere.
9. Most oxygen is found in this layer of the atmosphere.

Questions 10-13 refer to the substances listed.

- (A) Asbestos
- (B) Radon
- (C) Lead
- (D) Carbon monoxide
- (E) Formaldehyde

10. Found in old plumbing pipes and fixtures and some ceramic glazes
11. Composed of fibers known to cause lung disease
12. Emitted from most manufactured building materials and furniture
13. Colorless, odorless gas that is a naturally occurring decay product of uranium



## Part B

**Directions:** Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and then fill in the corresponding oval on the answer sheet.

14. The greatest amount of fresh water is found in which of the following?

(A) The atmosphere  
(B) Estuaries  
(C) Lakes  
(D) Rivers and streams  
(E) Polar ice caps and glaciers

15. Which of the following is true of carbon as it cycles in nature?

(A) Carbon dioxide is released during photosynthesis.  
(B) Carbon compounds rarely exist in the gaseous state.  
(C) Carbon sinks include forests and oceans.  
(D) The carbon dioxide concentration in the atmosphere is reduced by cutting trees.  
(E) Carbon is concentrated in igneous rocks.

16. Which three sources supply the majority of commercial energy in the world today?

(A) Coal, oil, and natural gas  
(B) Solar, wind, and biomass  
(C) Nuclear, hydropower, and photovoltaics  
(D) Wood, dung, and charcoal  
(E) Fuel cells, geothermal, and tidal power

17. By the year 2050, world population is expected to approach 10 billion. If the current population trends continue, which region of the world will most likely experience the majority of the growth?

(A) North and Central America  
(B) Central and South America  
(C) Eastern and Western Europe  
(D) Africa and Asia  
(E) Australia and New Zealand

18. Which of the following human activities is most closely associated with depletion of the stratospheric ozone layer?

(A) Mining of coal  
(B) Disposal of refrigerators and air conditioners  
(C) Heating of homes and factories  
(D) Generation of electricity  
(E) Agricultural irrigation

19. Overuse of groundwater in coastal areas would most likely result in which of the following?

(A) Rise in water table  
(B) Increase in stream flow  
(C) Bacterial contamination of surface water  
(D) Saltwater intrusion  
(E) Decrease in eutrophication

20. Of the following countries, which has the largest proven reserves of strategic metals such as manganese, chromium, and platinum?

(A) South Africa  
(B) Japan  
(C) Saudi Arabia  
(D) The United States  
(E) France

21. In 2007 in the United States there were approximately 480 cars for every 1,000 people. The total number of cars in the United States in 2007 was closest to

(A) 150,000  
(B) 30,000,000  
(C) 150,000,000  
(D) 300,000,000  
(E) 3,000,000,000

## Section I

22. Which of the following world regions contain the greatest area of rain forest?

- (A) Canada and the United States
- (B) Eastern and Western Europe
- (C) Russia and China
- (D) Australia and New Zealand
- (E) Brazil and Indonesia

23. Which of the following best exemplifies population momentum?

- (A) Continued growth of a population after fertility drops to replacement level
- (B) Continued growth of a population due to emigration
- (C) Decreased population due to increase in the death rate
- (D) Decreased population due to a reduced death rate and an increased fertility rate
- (E) Growth of a population after the fertility rate doubles

24. Of the following strategies to decrease the landfill volume of packaging material from food and other consumer products, the most energy efficient is

- (A) recovering plastic packaging material from the waste stream and recycling it
- (B) recovering metal packaging material from the waste stream and recycling it
- (C) limiting the size of individual beverage containers made from metal, glass, or plastic
- (D) using more packaging materials that are manufactured from raw materials that are renewable
- (E) promoting the use of reusable containers for consumer goods

25. An integrated pest-management approach to pest control emphasizes which of the following?

- (A) Eradication of the pest population
- (B) Reliance on spraying broad-spectrum pesticides
- (C) Reduction of crop damage to an economically tolerable level
- (D) Use of plant monocultures to simplify spraying
- (E) Elimination of the use of second-generation pesticides

26. Of the following, which is true of noise pollution?

- (A) Noise pollution is an insignificant occupational hazard.
- (B) Noise at 100 decibels has twice the energy of noise at 50 decibels.
- (C) Hearing damage occurs most quickly when the intensity level of the sound is low.
- (D) In urban areas, few individuals are exposed to noise pollution.
- (E) Sudden or persistent noise may lead to permanent hearing loss.

27. If a country has a crude birth rate of 24 per 1,000 and a crude death rate of 8 per 1,000, the natural annual percent increase of its population is

- (A) 0.6%
- (B) 1.6%
- (C) 3%
- (D) 16%
- (E) 32%

28. Which of the following shows the approximate concentration of  $\text{CO}_2$ ,  $\text{N}_2$ , and  $\text{O}_2$  in dry air?

| $\text{CO}_2$ | $\text{N}_2$ | $\text{O}_2$ |
|---------------|--------------|--------------|
| (A) 78%       | < 1%         | 21%          |
| (B) 43%       | < 1%         | 56%          |
| (C) 36%       | 8%           | 56%          |
| (D) 10%       | 70%          | 20%          |
| (E) < 1%      | 78%          | 21%          |

29. Which of the following best illustrates an abiotic component of the environment affecting a biotic component of the environment?

- (A) Composted manure is added to agricultural soil during spring tilling.
- (B) Coral reefs modify the direction of an ocean current.
- (C) Plants release  $\text{O}_2$  into the atmosphere during photosynthesis.
- (D) Low phosphorus content in soil limits the growth of vegetation.
- (E) A thick planting of ground cover reduces soil erosion on a hillside.



30. Of the following cities, which regularly experiences the worst levels of photochemical smog that is enhanced by thermal inversions?  
*definition*
- (A) New York City, New York
  - (B) Los Angeles, California
  - (C) Portland, Oregon
  - (D) Atlanta, Georgia
  - (E) Philadelphia, Pennsylvania
31. Which of the following best describes the first law of thermodynamics?  
*1. comparing*
- (A) Energy always changes from a more useful, more concentrated form to a less useful, less concentrated form.
  - (B) In a closed system of constant mass, the energy involved in any physical or chemical change is neither created nor destroyed, but merely changed from one form to another.
  - (C) Heat always flows from a hot body to a cold body.
  - (D) Entropy of a system increases as the state of disorganization in the system increases.
  - (E) In a reversible process, the entropy of the system is constant, whereas in an irreversible process, the entropy of the system increases.
32. What two main factors would best indicate the quality of life of a country's population?  
*1. comparing*
- (A) The total fertility rate and the death rate
  - (B) The crude birth rate and crude death rate
  - (C) The birth rate and the infant mortality rate
  - (D) The replacement-level fertility rate and the total fertility rate
  - (E) The life expectancy and the infant mortality rate
33. Rachel Carson's contributions to the environmental movement include which of the following?  
*definition*
- (A) Alerting the public to the hazardous waste problem at Love Canal
  - (B) Increasing public awareness of the risks of using pesticides
  - (C) Starting the first Earth Day in 1970
  - (D) Discovering the thinning of the ozone layer in polar regions
  - (E) Being the first female administrator of the EPA
34. In a typical forest ecosystem, dead trees and fallen trees are most important because of their role in which of the following?  
*1. cause*
- (A) Providing a valuable source of timber
  - (B) Providing habitats for wildlife
  - (C) Contributing to soil erosion
  - (D) Increasing water runoff
  - (E) Removing carbon dioxide from the air
35. Possible effects of a warmer atmosphere include which of the following?  
*1. multiple*
- I. Expanded ranges of tropical diseases
  - II. More intense hurricanes and typhoons
  - III. Increased crop damage from pests and diseases
- (A) I only
  - (B) II only
  - (C) I and III only
  - (D) II and III only
  - (E) I, II, and III
36. When a rain forest is slashed and burned, the local concentration of carbon dioxide in the atmosphere increases. This is primarily due to  
*1. cause*
- (A) changes in the local climate
  - (B) oxidation of carbon compounds
  - (C) cellular respiration of rain-forest plants
  - (D) erosion of exposed soil
  - (E) carbon dioxide being released by anaerobic organisms
37. Pollution is considered an external cost when  
*1. sequencing*
- (A) it has harmful effects borne only by the people who purchase the products that cause the pollution
  - (B) the cost to the environment is not reflected in the price of the products that produce the pollution
  - (C) it has a significant impact on the consumer's decision to buy a product that pollutes
  - (D) it is a hidden cost that would result in a greater demand for the product if the consumer were aware of the hidden cost
  - (E) it is produced in the external environment by a malfunction in the operation of the product

38. A sustainable society *low quality* would emphasize
- (A) maintaining the current rates of energy flow and resource use
  - (B) converting the world's high-quality energy resources to low-quality heat
  - (C) recycling both matter and high-quality energy
  - (D) using energy efficiently and reusing and recycling matter
  - (E) quickly expanding nuclear power, because it is a renewable resource
39. A large forested area is fragmented into small forest tracts separated by agricultural areas. This change will most likely lead to *sequencing*
- (A) an increase in the population of top carnivores
  - (B) an improvement in the dispersal mechanisms of forest species
  - (C) a more stable regional climate
  - (D) a decrease in the amount of edge habitat
  - (E) a decrease in the gene flow within species of the original forest
40. Which of the following is a greenhouse gas that is produced by domestic livestock? *T. definition*
- (A)  $\text{NO}_2$
  - (B)  $\text{CH}_4$
  - (C)  $\text{O}_3$
  - (D)  $\text{CO}$
  - (E)  $\text{SO}_2$

## Questions 41-42

In 1997 the World Resources Institute estimated the world's proven oil reserves to be 1,000 billion barrels and the ultimately recoverable reserves to be 2,000 billion barrels. The table below shows the world consumption of oil from 1986 to 1997.

| Year | Consumption (million barrels per day) |
|------|---------------------------------------|
| 1986 | 62                                    |
| 1987 | 63                                    |
| 1988 | 65                                    |
| 1989 | 66                                    |
| 1990 | 66                                    |
| 1991 | 67                                    |
| 1992 | 67                                    |
| 1993 | 67                                    |
| 1994 | 68                                    |
| 1995 | 70                                    |
| 1996 | 72                                    |
| 1997 | 74                                    |

41. At the 1997 rate of consumption, about how long will the estimated 2,000 billion barrels of oil last? *2. graph*
- (A) 25 years
  - (B) 50 years
  - (C) 75 years
  - (D) 200 years
  - (E) 500 years
42. What was the approximate percent increase in consumption from 1986 to 1997? *2. graph*
- (A) 10%
  - (B) 20%
  - (C) 30%
  - (D) 50%
  - (E) 80%



43. Which of the following is most typically associated with the transition from a rural to an urbanized society?

1. sequentially

- (A) Reduced birth rates
- (B) Reduced need for sewage-treatment facilities
- (C) Increased rates of population growth
- (D) Increased air quality in urban areas
- (E) Increased stabilization of microclimate in urban areas

44. Five islands, A, B, C, D, and E, differ only in distance from the mainland, area, and species diversity. Which island would be predicted to have the highest species diversity?

1. better localization

| Island | Distance<br>from Mainland<br>(kilometers) | Area<br>(hectares) |
|--------|-------------------------------------------|--------------------|
| (A) A  | 50                                        | $1 \times 10^2$    |
| (B) B  | 50                                        | $1 \times 10^6$    |
| (C) C  | 500                                       | $1 \times 10^2$    |
| (D) D  | 1,000                                     | $1 \times 10^2$    |
| (E) E  | 1,000                                     | $1 \times 10^6$    |

45. Which of the following best illustrates point-source pollution?

1. compare

- (A) Toxic sediments in the delta of a major river
- (B) Increase in  $\text{NO}_x$  in a traffic-clogged city
- (C) Dust blowing off unpaved roads
- (D) Smoke emitted from forest fires
- (E) Smokestack emissions from a large smelting company

46. The net annual primary productivity of a particular wetland ecosystem is found to be  $8,000 \text{ kcal/m}^2$  per year. If respiration by the aquatic producers is  $12,000 \text{ kcal/m}^2$  per year, what is the gross annual primary productivity for this ecosystem, in  $\text{kcal/m}^2$  per year?

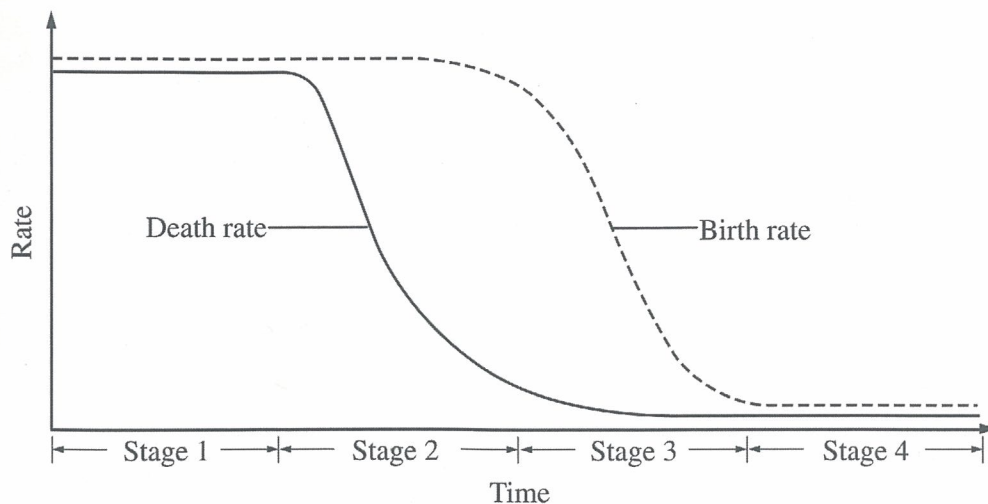
1. Sequence

- (A) 4,000
- (B) 8,000
- (C) 12,000
- (D) 20,000
- (E) 96,000

47. The three main anthropogenic sources of gaseous air pollutants in the United States are

1. Deforestation

- (A) soil erosion, volcanoes, and forest fires
- (B) soil erosion, volcanoes, and energy production
- (C) industry, construction, and agriculture
- (D) industry, transportation, and energy production
- (E) industry, transportation, and agriculture



48. During which stage of the demographic transition shown above does a population begin to experience an explosive increase in growth?

- (A) Stage 1  
(B) Stage 2  
(C) Stage 3  
(D) Stage 4  
(E) After stage 4

49. Most municipal solid waste in the United States is disposed of in

- (A) the oceans  
(B) sanitary landfills  
(C) deep wells  
(D) open dumps  
(E) abandoned mines

50. Which of the following would likely reduce the threats posed by exotic species to native species?

- I. Increasing inspections of goods coming into a country  
II. Mandating that bilgewater from vessels be emptied in ports instead of in the open ocean  
III. Enforcing legislation that restricts imported materials such as untreated wooden packing crates

- (A) I only  
(B) II only  
(C) III only  
(D) I and III only  
(E) I, II, and III

51. Which of the following is a measure of the amount of suspended material in water?

- (A) Salinity  
(B) Turbidity  
(C) Trace-metal concentration  
(D) Leachate concentration  
(E) pH

52. Acid deposition would most likely result in which of the following?

- (A) The release of aluminum ions from soil  
(B) An increase in populations of mollusks  
(C) The death of species tolerant of low pH levels  
(D) An increase in buffering of lake water by sulfates  
(E) An increase in the pH of unbuffered water

53. Which of the following are the three major sources of nutrients and calories for the global human population?

- (A) Potatoes, fish, and barley  
(B) Wheat, beef, and potatoes  
(C) Oats, soybeans, and poultry  
(D) Corn (maize), wheat, and rice  
(E) Rye, beef, and eggs

2. short q10  
54. If Earth had no atmosphere, the mean surface temperature would be approximately  $-15^{\circ}\text{C}$ . With our present atmosphere, Earth's mean surface temperature is approximately  $+15^{\circ}\text{C}$ . Which of the following is the best explanation for this difference?

- (A) Reflection of incident solar radiation by clouds
- (B) Scattering of visible radiation by aerosols
- (C) Absorption of ultraviolet radiation by the ozone layer
- (D) Absorption of infrared radiation by atmospheric gases
- (E) The breakdown of oxygen molecules in the thermosphere

55. Which of the following can be used to assess the biological diversity of an area? *comparing*

- (A) Population size of each species and area occupied by each population
- (B) Minimum population area and minimum viable population size
- (C) Ratio of  $r$ -strategists to  $K$ -strategists and life expectancy of  $K$ -strategists
- (D) Number of individuals under fifteen years old and number of individuals over sixty-five years old
- (E) Genetic variation within each species and number of species present

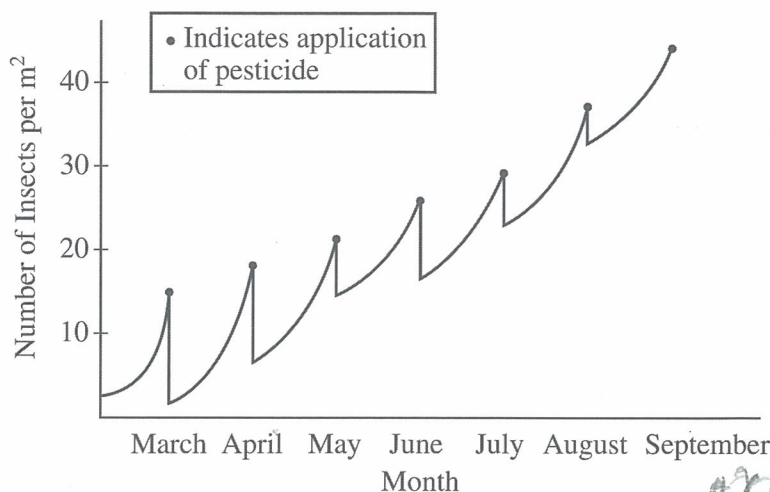
1. Hypo  
56. Which of the following is a way for the government to encourage efficient energy use?

- (A) Requiring higher fuel economy standards for new cars
- (B) Implementing government subsidies to keep gasoline prices low
- (C) Raising the speed limit from 55 to 70 miles per hour
- (D) Limiting the development of public transportation systems
- (E) Removing all taxes from gasoline at the fuel pump

57. Ground-level ozone in most major United States cities results primarily from

- (A) burning coal
  - (B) burning fuel for cooking
  - (C) producing electric power
  - (D) industrial emissions
  - (E) motor-vehicle exhaust
- 1. cause*





58. An insect population in an agricultural field is affected by monthly applications of a pesticide, as shown in the graph above. A likely cause of the overall increase in the insect population over time is

(A) an increase in the population of insect predators  
 (B) an increase in average temperature over the summer  
 (C) an increase in soil salinity  
 (D) a decrease in the moisture content of the soil  
 (E) the survival of increasing numbers of resistant insects

59. The process in the hydrologic cycle in which water vapor is released from leaves into the atmosphere is called

(A) infiltration  
 (B) transpiration  
 (C) sublimation  
 (D) reflection  
 (E) percolation

60. Which of the following terms applies to the economic approach of including external costs in the price of goods and services?

(A) Optimal-cost pricing  
 (B) Cost-benefit pricing  
 (C) Full-cost pricing  
 (D) Green pricing  
 (E) Subsidized pricing

61. Global warming is most likely to directly cause which of the following?

(A) Shifting of grain belts toward the equator  
 (B) Falling sea levels in the Southern Hemisphere  
 (C) Coastal flooding and submersion of low-lying areas  
 (D) A decrease in the amount of water vapor in the atmosphere  
 (E) An increase in the number and size of glaciers

62. Which of the following would encourage recycling?

(A) Decreasing government purchases of recycled materials  
 (B) Decreasing subsidies for recycling  
 (C) Decreasing taxes on resource-extracting industries  
 (D) Decreasing taxes on recycled material  
 (E) Decreasing fees for using landfills

1. compare  
63. Which of the following is a true statement about passive solar heating?

- (A) It is effective only during the summer months.
- (B) It is based in part on the principle of the greenhouse effect.
- (C) It is not used to heat commercial buildings.
- (D) It is not efficient because it cannot produce high-quality energy.
- (E) It produces more pollution than heating with an electric heat pump.

64. Which of the following is a common characteristic of lakes undergoing cultural eutrophication? 1. low

- (A) Decreased rates of sediment accumulation
- (B) Decreased amounts of green and blue-green algae
- (C) Increased levels of oxygen throughout the water column
- (D) Increased water clarity in the epilimnion
- (E) Increased levels of plant nutrients

65. An advantage of using natural gas, rather than oil, as a fuel is that natural gas is 1. large

- (A) less of a contributor to global warming because it does not release  $\text{CO}_2$  when it burns
- (B) less expensive because most reserves are in the United States
- (C) more abundant because it is a by-product of photosynthesis
- (D) cleaner because it burns more completely
- (E) safer to store because it is a gas

66. Which of the following best explains why the maximum sustainable yield for ocean fisheries has been exceeded? 1. large

- (A) Populations of fish-eating birds such as the albatross have increased.
- (B) Too many fish of reproductive age are harvested.
- (C) Too many marine fish farms have been created.
- (D) Everything trapped by large bottom trawl nets is used for food.
- (E) For every calorie of fish caught, a ship uses only about 0.5 calorie of fuel energy.

67. Although the fertility rate for women in the United States has declined in recent years to a value below replacement level, the United States population is still increasing because of

- (A) lower average age at first marriage
  - (B) lower infant death rates
  - (C) increased longevity
  - (D) improved health care
  - (E) immigration
2. short narrative

Item 68 was not scored.

69. Which of the following is an important contributor to both global warming and ozone depletion? 1. large

- (A) An increase in the concentration of carbon dioxide to higher-than-preindustrial levels
- (B) A buildup of methane in the stratosphere to higher-than-preindustrial levels
- (C) An increase in the levels of ultraviolet radiation reaching Earth's surface
- (D) An increase in the amount of infrared solar radiation absorbed in the troposphere
- (E) A release of chlorofluorocarbons to the atmosphere

70. The most populous countries in the world are China, India, and 1. generation

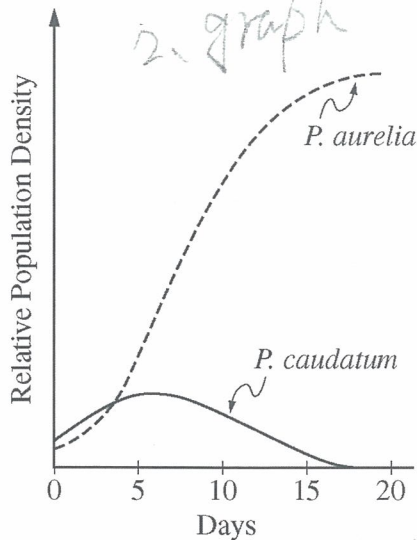
- (A) Indonesia
- (B) Russia
- (C) the United States
- (D) Japan
- (E) Mexico

## Section I

71. Lakes that are characterized by high water clarity and low concentrations of dissolved nutrients are classified as *1. defined*
- (A) buffered
  - (B) climax
  - (C) eutrophic
  - (D) oligotrophic
  - (E) stratified
72. Smoke from forest fires is most likely to affect air quality over larger areas for many days when *3. longer*
- (A) smog is produced due to chemical reactions in the atmosphere
  - (B) a persistent atmospheric inversion exists in the region
  - (C) oak trees are burned, releasing terpenes into the atmosphere
  - (D) primary, rather than secondary, forests are burned
  - (E) vegetation in the region is green and burns more slowly
73. In the majority of less developed countries, the major source of energy for domestic use is which of the following? *2. solution*
- (A) Oil
  - (B) Coal
  - (C) Biomass
  - (D) Nuclear
  - (E) Geothermal
74. When logging is carried out in a watershed, a likely effect on the local streams is *1. lower*
- (A) mitigation of anoxia
  - (B) decreased nutrient levels
  - (C) decreased input of sediments
  - (D) increased oligotrophic conditions
  - (E) increased water temperature
75. When scientists discover the existence of an emerging infectious disease such as SARS (severe acute respiratory syndrome), they must take immediate steps to determine the cause of the disease and the method of transmission. These initial steps would include which of the following? *2. short question*
- (A) Developing a vaccine to eliminate the disease
  - (B) Beginning a program to eradicate insect vectors for the disease
  - (C) Acquiring recent medical and travel histories of the disease victims
  - (D) Testing methods to block airborne transmission of the disease
  - (E) Estimating the cost of eradicating the disease
76. In a river ecosystem, dissolved oxygen concentrations drop quickly downstream from a point-source input of organic matter into the river. This effect is due to *1. cause*
- (A) increasing populations of mayfly and stonefly larvae
  - (B) increasing activity of trout and black bass
  - (C) increasing bacterial activity as organic matter decays
  - (D) decreasing bacterial activity as turbidity increases
  - (E) decreasing water temperature as surface evaporation increases
77. What is the population doubling time in years for a country with an annual growth rate of 3.5 percent? *1. 70 years*
- (A) 0.5
  - (B) 3.5
  - (C) 20
  - (D) 24.5
  - (E) 70



78. The graph below shows the results obtained when two species of *Paramecium* were grown together in the same medium.



The graph above best exemplifies

- (A) the demographic transition  
 (B) sustained logarithmic growth  
 (C) the edge effect  
 (D) competitive exclusion  
 (E) the normal distribution
79. In a cost-benefit analysis of the risks associated with an environmental hazard involving human health and safety, which of the following concerns is NOT typically taken into account?
- (A) Lower worker productivity resulting from health-related time lost on the job  
 (B) Higher production costs resulting from the installation of expensive pollution-control devices  
 (C) The long-term value and peace of mind to society resulting from a cleaner, healthier environment  
 (D) The initial capital investment required to purchase pollution-control devices  
 (E) The need to remove pollutants from factory effluents

80. Three common methods employed in the cleanup of oil spills are

- (A) aeration of water, skimmer boats, and genetically engineered bacteria  
 (B) aeration of water, phytoremediation, and genetically engineered bacteria  
 (C) skimmer boats, high temperature incineration, and phytoremediation  
 (D) large floating booms, high temperature incineration, and phytoremediation  
 (E) large floating booms, skimmer boats, and genetically engineered bacteria

81. Ticks are vectors for various diseases. The ticks acquire the disease-causing organisms from

- (A) polluted water  
 (B) feeding on host animals  
 (C) contact with other ticks  
 (D) trees and plants in a forest  
 (E) gene changes as they go through metamorphosis

82. Which of the following is most likely to increase both the nutrient levels and the bacterial content of lake water?

- (A) Runoff from a nearby hog farm  
 (B) Thermal pollution from a nearby power plant  
 (C) Increased aeration of the lake water  
 (D) Percolation of the water through soil to groundwater  
 (E) Acidification of the lake water by acid deposition

83. Which of the following is a major goal of the program begun in 1995 to reintroduce the gray wolf into Yellowstone National Park?

- (A) Decrease the number of grizzly bears, because they were becoming a nuisance  
 (B) Enable the removal of the gray wolf from the endangered species list  
 (C) Increase the dwindling numbers of tourists that visit the park each year  
 (D) Upset the natural predator-prey balance between coyotes and elk  
 (E) Decrease the number of sheep and cattle that wander into the park and overgraze the vegetation

## Section I

84. The half-life of radon gas is approximately four days. Four weeks after the introduction of radon into a sealed room, the fraction of the original amount remaining is closest to

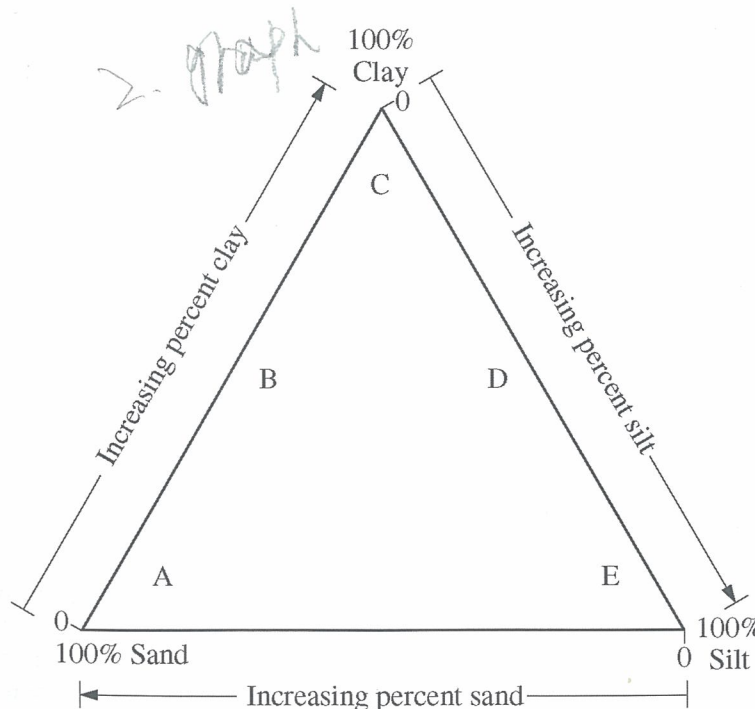
- (A)  $1/2$
- (B)  $1/8$
- (C)  $1/32$
- (D)  $1/64$
- (E)  $1/128$

85. The consumption of mosquitoes by bats and the control of flooding provided by tropical forests in mountainous areas of Central America are examples of

- (A) adaptive radiation
- (B) ecosystem services
- (C) evolution by natural selection
- (D) ecological equilibrium
- (E) positive feedback loops

86. Which of the following best explains why it is predicted that ozone depletion over the poles will be at its worst between 2010 and 2019?

- (A) Projected global warming from carbon dioxide emissions is expected to reach a peak during those years.
- (B) Ozone-depleting chemicals produced before their use was banned will take that long to reach peak concentrations in the stratosphere.
- (C) Deforestation in tropical regions is expected to reach a peak during the second decade of the twenty-first century.
- (D) Increased global population will lead to an increase in per capita  $\text{CO}_2$  production.
- (E) Acid deposition will continue to increase, reaching a peak in approximately 2015.



87. Which soil indicated on the soil triangle above would most likely have the highest water-holding capacity?

- (A) Soil A
- (B) Soil B
- (C) Soil C
- (D) Soil D
- (E) Soil E

88. Which of the following is a true statement concerning the production of electricity in conventional nuclear power plants using fission reactors?

- (A) New nuclear power plants will be built without containment structures, due to the increased insulation in the reactor core.  
 (B) Thermal energy is converted into mechanical energy and then to electrical energy, as in coal-burning power plants.  
 (C) Regularly scheduled releases of radioactive gases during production are well below the maximum contamination levels set by the EPA (Environmental Protection Agency).  
 (D) Nuclear production of electricity is much less expensive per kilowatt-hour than production of electricity at a coal-burning or natural-gas-fueled power plant.  
 (E) Storage of nuclear waste is no longer an issue, because power plants are now storing all wastes on-site in specialized containment units.

89. Alligators in a Florida lake polluted by high levels of dioxins (chlorinated hydrocarbons) had low testosterone levels and failed to reproduce. Scientists came to the conclusion that the dioxins were acting as which of the following?

- (A) Endocrine disruptors  
 (B) Growth hormones  
 (C) Carcinogens  
 (D) Immune-system suppressors  
 (E) Mutagens

90. Factors that affect the total fertility rate of a human population include which of the following?

- I. Cultural traditions  
 II. Government policies and economic incentives  
 III. Education level and economic opportunities for females

- (A) I only  
 (B) II only  
 (C) I and II only  
 (D) II and III only  
 (E) I, II, and III

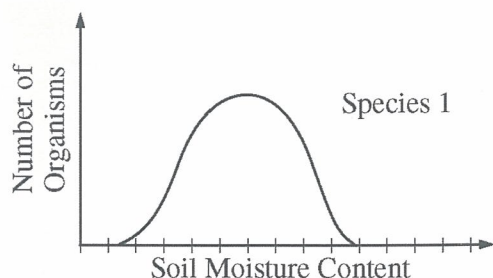
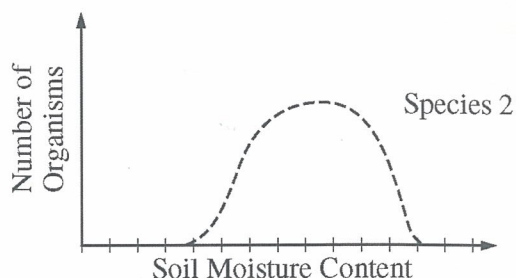
91. Sustainable use of forests in the United States would likely be encouraged by

- (A) cutting small groups of medium- and large-sized trees in uneven-aged forests  
 (B) clear-cutting old-growth forests to allow for secondary succession  
 (C) allowing road building in wilderness areas so that older, clear-cut forests have time to regenerate  
 (D) logging on steep slopes in designated wilderness areas  
 (E) enforcing all provisions of the Resource Conservation and Recovery Act (RCRA)

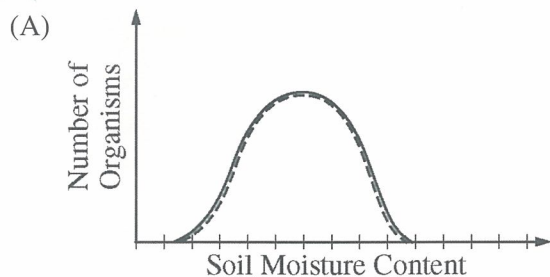
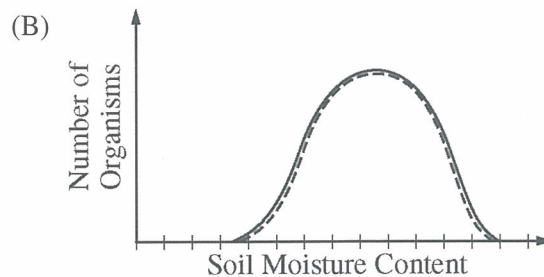
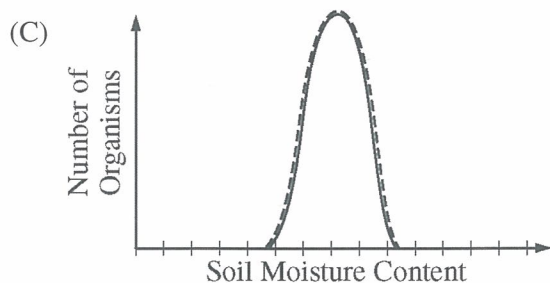
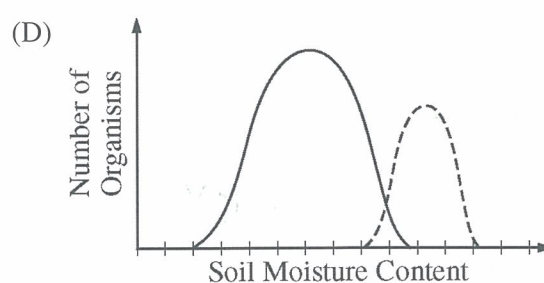
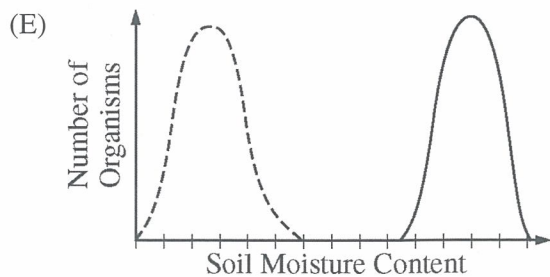
92. The use of which of the following to control agricultural insect pests is most likely to have a negative and persistent impact on an ecosystem?

- (A) *Bacillus thuringiensis*, a soil organism that kills insect larvae  
 (B) *Braconid sp.*, a parasitic wasp  
 (C) Insecticidal soap, a surfactant that kills through suffocation  
 (D) Lindane, a chlorinated hydrocarbon  
 (E) Rotenone, a toxic plant derivative





93. The diagrams above show the range of tolerance for soil moisture content for two different species of terrestrial invertebrate: Species 1 and Species 2. The ranges represented are for each species where it occurs alone. Soil moisture content is a limiting factor for both species. If populations of both species are placed together in a new location, which of the following diagrams represents the most likely actual (realized) ranges of the species' distribution of individuals with respect to soil moisture content after five generations?



94. Overgrazing of grasslands can lead to reduced range quality. Two of the major effects of overgrazing are

- (A) erosion and desertification
- (B) higher fire potential and increased productivity
- (C) eutrophication and increased methane production
- (D) higher primary productivity and ammonification
- (E) soil compaction and subsidence

95. Which of the following describes the heat-island effect?

- (A) Urban areas trap more heat than rural areas do.
- (B) Tropical islands reflect heat back into the atmosphere.
- (C) Warm water in the Pacific causes excessive evaporation into the atmosphere.
- (D) Lakes retain heat and provide warmth for landmasses nearby.
- (E) Rapid decomposition in swamps releases a large amount of heat.

96. Losses of usable energy between successive trophic levels in an ecosystem are best accounted for by which of the following?

- (A) The first law of thermodynamics
- (B) The second law of thermodynamics
- (C) The law of conservation of matter
- (D) The process of ecological succession
- (E) Limiting factors in the ecosystem

97. Which of the following actions would reduce global greenhouse emissions?

- (A) Increasing the use of automobiles
- (B) Decreasing the number of nuclear power plants
- (C) Replacing coal-burning power plants with wind farms
- (D) Converting tropical forests to rice paddies
- (E) Switching from hydroelectric power generation to power generation using natural gas as the primary fuel

98. A home uses ten 100-watt lightbulbs for five hours per day. Approximately how many kilowatt-hours of electrical energy are consumed in one year by using the lightbulbs?

- (A) 365
- (B) 1,825
- (C) 5,000
- (D) 10,500
- (E) 365,000

## Section I

1. generalization
99. During an El Niño–Southern Oscillation event, which of the following best describes conditions in the eastern part of the tropical Pacific Ocean (e.g., near Peru and Ecuador) ?

|     | Sea Surface<br>Temperature | Rainfall |
|-----|----------------------------|----------|
| (A) | Low                        | Low      |
| (B) | Low                        | High     |
| (C) | High                       | Low      |
| (D) | High                       | High     |
| (E) | High                       | Normal   |

2. multiple
100. True statements about ozone include which of the following?

- I. It is a pollutant in the troposphere.
- II. It filters out most of the UVC radiation in the stratosphere.
- III. Most of it is formed in the stratosphere by reaction between carbon dioxide and free oxygen atoms.

- (A) I only
- (B) II only
- (C) III only
- (D) I and II only
- (E) I, II, and III

**STOP**

**END OF SECTION I**



# AP<sup>®</sup> Environmental Science Exam

## SECTION II: Free-Response Questions

# 2008

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

### At a Glance

**Total Time**

1 hour, 30 minutes

**Number of Questions**

4

**Percent of Total Grade**

40%

**Writing Instrument**

Pen with black or dark blue ink

**Electronic Device**

None allowed

**Weight**

The questions are weighted equally, but the parts of a question are not necessarily given equal weight.

### IMPORTANT Identification Information

PLEASE PRINT WITH PEN:

1. First two letters of your last name

First letter of your first name

2. Date of birth

Month

Day

Year

3. Six-digit school code

4. Unless I check the box below, I grant the College Board the unlimited right to use, reproduce, and publish my free-response materials, both written and oral, for educational research and instructional purposes. My name and the name of my school will not be used in any way in connection with my free-response materials. I understand that I am free to mark "No" with no effect on my score or its reporting.

No, I do not grant the College Board these rights. ☐

### Instructions

The questions for Section II are printed in the green insert and in this pink booklet. You may use the insert to organize your answers and for scratch work, but you must write your answers in the pink Section II booklet. No credit will be given for any work written in the insert.

Each answer should be organized, comprehensive, and in prose form; outline form is not acceptable. Do not spend time restating the questions or providing more than the number of examples called for. Extra examples will not earn points. Diagrams may be used to supplement discussion, but diagrams alone will not suffice.

Write clearly and legibly. Cross out any errors you make; crossed-out work will not be graded.

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

## ENVIRONMENTAL SCIENCE

## SECTION II

Time—90 minutes

4 Questions

**Directions:** Answer all four questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers on the pages following the questions in the pink booklet. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples.

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.

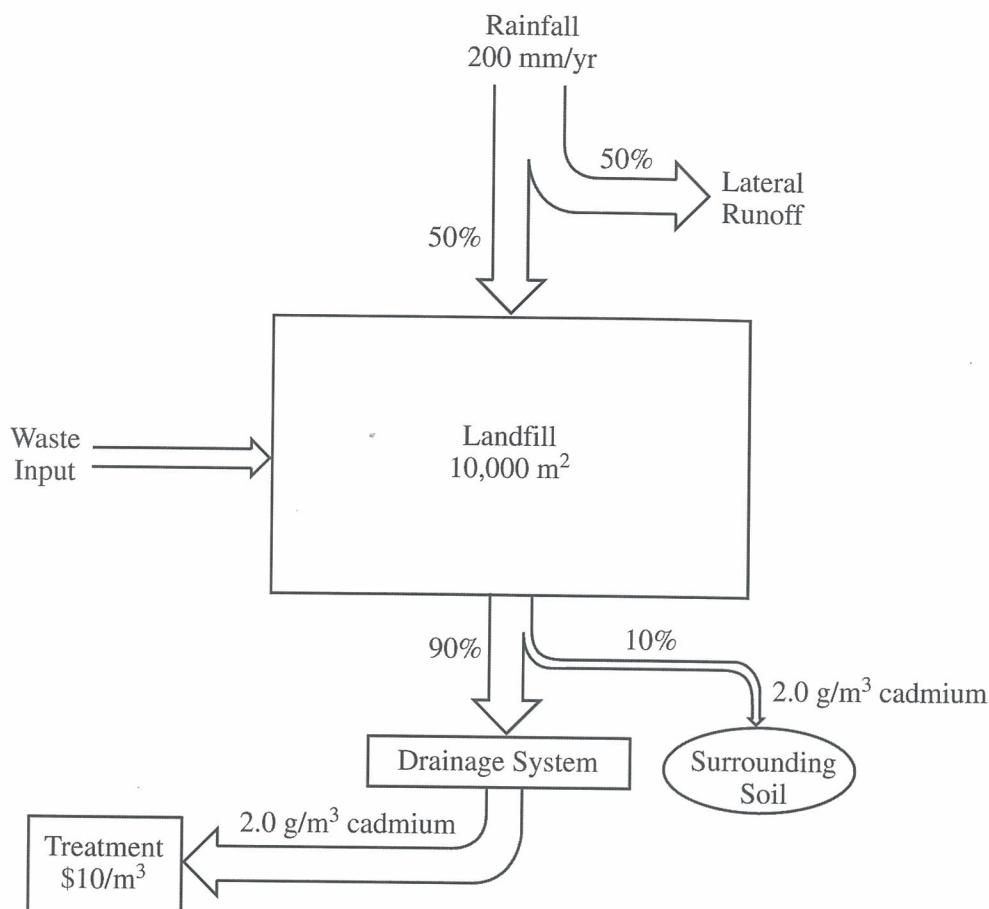
| Gallons of Oil per Acre per Year |        |
|----------------------------------|--------|
| Corn                             | 20     |
| Soybeans                         | 50     |
| Safflower                        | 83     |
| Sunflower                        | 102    |
| Rapeseed                         | 115    |
| Oil palm                         | 640    |
| Microalgae                       | 10,000 |

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 CO<sub>2</sub>.

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 CO<sub>2</sub> 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.





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/m<sup>3</sup>. Pumped to a treatment station, the leachate is treated at a cost of \$10/m<sup>3</sup>.

- Calculate the volume, in m<sup>3</sup>, of each of the following:
  - The water infiltrated through the landfill per year
  - The leachate that is treated per year
- Given that the cadmium concentration in the water draining from the landfill is 2.0 g/m<sup>3</sup>, calculate the mass, in kg, of cadmium that is released into the surrounding soil per year.
- What is the annual cost of treating the leachate from the drainage system?
- Discuss TWO viable methods for reducing the amount of cadmium entering the municipal waste input.
- Explain a shortcoming of ONE of the methods that you identified in part (d).

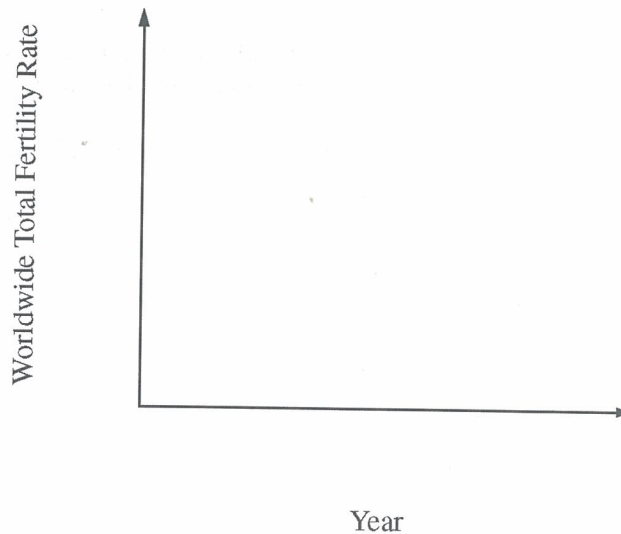
3. For decades, forest fires in the United States have been suppressed. In 2003 legislation was passed under the Healthy Forests Initiative (HFI) in response to the record-breaking wildfires that had occurred in the early 2000s. Some environmental and conservation groups fear that negative impacts could 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.

4. Answer the following regarding world human population.

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

Table 1:  
Worldwide  
Total Fertility  
Rate (TFR)

| Year | TFR |
|------|-----|
| 1950 | 5.0 |
| 1960 | 4.9 |
| 1970 | 4.7 |
| 1980 | 3.7 |
| 1990 | 3.4 |
| 2000 | 3.0 |



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

Table 2: Population Data for Selected Nations (2005)

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

\* 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.



**STOP**

**END OF EXAM**

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# **AP Environmental Science**

**2008**

## **APPENDIX - ANSWERS**

Matching multiple-choice answers and free-response scoring follow.

# Chapter III: Answers to the 2008 AP Environmental Science Exam

## ■ Section I: Multiple Choice

- Section I Answer Key and Percent Answering Correctly
- Analyzing Your Students' Performance on the Multiple-Choice Section
- Diagnostic Guide for the 2008 AP Environmental Science Exam

## ■ Section II: Free Response

- Comments from the Chief Reader
- Scoring Guidelines, Sample Student Responses, and Commentary
  - Question 1
  - Question 2
  - Question 3
  - Question 4

## Section I: Multiple Choice

Listed below are the correct answers to the multiple-choice questions, the percent of AP students who answered each question correctly by AP score, and the total percent answering correctly.

### Section I Answer Key and Percent Answering Correctly

| Item No. | Correct Answer | Percent Correct by Score |    |    |    |    | Total Percent Correct |
|----------|----------------|--------------------------|----|----|----|----|-----------------------|
|          |                | 5                        | 4  | 3  | 2  | 1  |                       |
| 1        | C              | 69                       | 51 | 42 | 35 | 27 | 42                    |
| 2        | E              | 59                       | 42 | 33 | 29 | 25 | 35                    |
| 3        | A              | 73                       | 62 | 57 | 53 | 45 | 56                    |
| 4        | A              | 89                       | 81 | 74 | 68 | 56 | 71                    |
| 5        | B              | 89                       | 79 | 71 | 63 | 48 | 67                    |
| 6        | D              | 35                       | 22 | 15 | 11 | 9  | 16                    |
| 7        | C              | 64                       | 54 | 46 | 39 | 31 | 44                    |
| 8        | E              | 96                       | 89 | 79 | 68 | 48 | 72                    |
| 9        | C              | 83                       | 71 | 61 | 53 | 40 | 58                    |
| 10       | C              | 93                       | 85 | 78 | 72 | 57 | 74                    |
| 11       | A              | 91                       | 77 | 65 | 55 | 37 | 61                    |
| 12       | E              | 73                       | 55 | 42 | 35 | 24 | 42                    |
| 13       | B              | 87                       | 72 | 59 | 49 | 33 | 56                    |
| 14       | E              | 93                       | 88 | 83 | 77 | 63 | 78                    |
| 15       | C              | 89                       | 72 | 57 | 43 | 22 | 52                    |
| 16       | A              | 100                      | 99 | 99 | 97 | 88 | 96                    |
| 17       | D              | 98                       | 95 | 90 | 84 | 67 | 84                    |
| 18       | B              | 78                       | 51 | 33 | 24 | 17 | 36                    |
| 19       | D              | 96                       | 87 | 73 | 58 | 34 | 65                    |
| 20       | A              | 52                       | 42 | 34 | 28 | 20 | 33                    |
| 21       | C              | 71                       | 52 | 40 | 32 | 25 | 41                    |
| 22       | E              | 99                       | 97 | 95 | 91 | 77 | 90                    |
| 23       | A              | 66                       | 49 | 40 | 33 | 24 | 39                    |

| Item No. | Correct Answer | Percent Correct by Score |    |    |    |    | Total Percent Correct |
|----------|----------------|--------------------------|----|----|----|----|-----------------------|
|          |                | 5                        | 4  | 3  | 2  | 1  |                       |
| 24       | E              | 84                       | 77 | 70 | 60 | 40 | 63                    |
| 25       | C              | 52                       | 36 | 27 | 23 | 22 | 30                    |
| 26       | E              | 92                       | 83 | 75 | 68 | 50 | 70                    |
| 27       | B              | 91                       | 78 | 65 | 54 | 35 | 61                    |
| 28       | E              | 75                       | 56 | 42 | 31 | 16 | 39                    |
| 29       | D              | 97                       | 87 | 73 | 59 | 35 | 66                    |
| 30       | B              | 92                       | 85 | 78 | 72 | 52 | 73                    |
| 31       | B              | 91                       | 85 | 80 | 74 | 59 | 76                    |
| 32       | E              | 95                       | 87 | 78 | 67 | 42 | 70                    |
| 33       | B              | 84                       | 72 | 63 | 53 | 37 | 58                    |
| 34       | B              | 97                       | 91 | 84 | 75 | 51 | 76                    |
| 35       | E              | 94                       | 85 | 76 | 66 | 45 | 69                    |
| 36       | B              | 70                       | 51 | 41 | 36 | 30 | 43                    |
| 37       | B              | 82                       | 66 | 52 | 42 | 29 | 50                    |
| 38       | D              | 96                       | 93 | 89 | 85 | 68 | 84                    |
| 39       | E              | 90                       | 79 | 69 | 59 | 40 | 64                    |
| 40       | B              | 92                       | 77 | 61 | 46 | 28 | 56                    |
| 41       | C              | 56                       | 31 | 21 | 17 | 17 | 26                    |
| 42       | B              | 81                       | 60 | 47 | 38 | 29 | 47                    |
| 43       | A              | 50                       | 39 | 30 | 24 | 14 | 29                    |
| 44       | B              | 71                       | 62 | 55 | 50 | 37 | 53                    |
| 45       | E              | 98                       | 93 | 88 | 81 | 57 | 80                    |
| 46       | D              | 66                       | 50 | 40 | 32 | 21 | 38                    |

continued on the next page



## Section I Answer Key and Percent Answering Correctly (continued)

| Item No. | Correct Answer | Percent Correct by Score |    |    |    |    | Total Percent Correct |
|----------|----------------|--------------------------|----|----|----|----|-----------------------|
|          |                | 5                        | 4  | 3  | 2  | 1  |                       |
| 47       | D              | 80                       | 72 | 65 | 62 | 52 | 64                    |
| 48       | B              | 96                       | 88 | 79 | 68 | 51 | 73                    |
| 49       | B              | 91                       | 88 | 85 | 82 | 68 | 81                    |
| 50       | D              | 77                       | 64 | 56 | 49 | 36 | 53                    |
| 51       | B              | 89                       | 79 | 68 | 55 | 34 | 61                    |
| 52       | A              | 47                       | 24 | 14 | 10 | 9  | 18                    |
| 53       | D              | 96                       | 90 | 81 | 72 | 53 | 75                    |
| 54       | D              | 76                       | 51 | 34 | 25 | 17 | 37                    |
| 55       | E              | 86                       | 79 | 71 | 62 | 39 | 64                    |
| 56       | A              | 99                       | 98 | 96 | 92 | 69 | 88                    |
| 57       | E              | 60                       | 53 | 53 | 55 | 46 | 52                    |
| 58       | E              | 99                       | 99 | 97 | 95 | 70 | 89                    |
| 59       | B              | 98                       | 95 | 90 | 84 | 64 | 84                    |
| 60       | C              | 70                       | 54 | 43 | 34 | 24 | 41                    |
| 61       | C              | 98                       | 94 | 90 | 84 | 63 | 83                    |
| 62       | D              | 98                       | 95 | 91 | 84 | 62 | 83                    |
| 63       | B              | 74                       | 59 | 47 | 38 | 31 | 47                    |
| 64       | E              | 88                       | 70 | 53 | 41 | 24 | 51                    |
| 65       | D              | 82                       | 68 | 57 | 49 | 31 | 54                    |
| 66       | B              | 85                       | 73 | 62 | 55 | 40 | 60                    |
| 67       | E              | 76                       | 65 | 56 | 51 | 40 | 55                    |
| 68*      | —              | —                        | —  | —  | —  | —  | —                     |
| 69       | E              | 81                       | 68 | 56 | 46 | 27 | 52                    |
| 70       | C              | 54                       | 48 | 46 | 46 | 41 | 46                    |
| 71       | D              | 77                       | 59 | 45 | 34 | 19 | 43                    |
| 72       | B              | 64                       | 44 | 30 | 22 | 15 | 32                    |

\*Although 100 multiple-choice items were administered in Section I, item #68 was not used in scoring.

| Item No. | Correct Answer | Percent Correct by Score |    |    |    |    | Total Percent Correct |
|----------|----------------|--------------------------|----|----|----|----|-----------------------|
|          |                | 5                        | 4  | 3  | 2  | 1  |                       |
| 73       | C              | 72                       | 53 | 39 | 29 | 18 | 38                    |
| 74       | E              | 35                       | 20 | 12 | 9  | 7  | 15                    |
| 75       | C              | 95                       | 90 | 85 | 77 | 52 | 76                    |
| 76       | C              | 94                       | 80 | 66 | 52 | 37 | 62                    |
| 77       | C              | 86                       | 68 | 53 | 43 | 31 | 53                    |
| 78       | D              | 97                       | 92 | 84 | 73 | 43 | 73                    |
| 79       | C              | 75                       | 65 | 55 | 46 | 31 | 51                    |
| 80       | E              | 49                       | 36 | 28 | 23 | 17 | 28                    |
| 81       | B              | 90                       | 88 | 86 | 85 | 73 | 83                    |
| 82       | A              | 95                       | 83 | 70 | 58 | 35 | 64                    |
| 83       | B              | 84                       | 80 | 77 | 71 | 55 | 71                    |
| 84       | E              | 90                       | 77 | 64 | 48 | 21 | 55                    |
| 85       | B              | 70                       | 51 | 38 | 28 | 18 | 37                    |
| 86       | B              | 87                       | 61 | 38 | 24 | 14 | 40                    |
| 87       | C              | 54                       | 48 | 44 | 40 | 34 | 43                    |
| 88       | B              | 73                       | 48 | 32 | 22 | 17 | 35                    |
| 89       | A              | 86                       | 72 | 62 | 53 | 38 | 59                    |
| 90       | E              | 99                       | 96 | 92 | 86 | 61 | 84                    |
| 91       | A              | 60                       | 42 | 31 | 24 | 14 | 31                    |
| 92       | D              | 69                       | 53 | 41 | 30 | 18 | 39                    |
| 93       | D              | 58                       | 41 | 32 | 25 | 18 | 32                    |
| 94       | A              | 97                       | 94 | 91 | 85 | 61 | 83                    |
| 95       | A              | 85                       | 67 | 52 | 39 | 21 | 48                    |
| 96       | B              | 87                       | 72 | 59 | 48 | 30 | 55                    |
| 97       | C              | 100                      | 99 | 96 | 91 | 64 | 87                    |
| 98       | B              | 82                       | 60 | 45 | 37 | 24 | 45                    |
| 99       | D              | 55                       | 48 | 47 | 43 | 34 | 44                    |
| 100      | D              | 55                       | 38 | 28 | 21 | 15 | 29                    |

### Analyzing Your Students' Performance on the Multiple-Choice Section

If you give your students the 2008 exam for practice, you may want to analyze the results to find overall strengths and weaknesses in their understanding of AP Environmental Science. The following diagnostic worksheet will help you do this. You are permitted to photocopy and distribute it to your students for completion.

1. In each section, students should insert a check mark for each correct answer.
2. Add together the total number of correct answers for each section.

3. To compare the student's number of correct answers for each section with the average number correct for that section, copy the number of correct answers to the "Number Correct" table at the end of the Diagnostic Guide.

In addition, under each question, the percent of AP students who answered correctly is shown, so students can analyze their performance on individual questions. This information will be helpful in deciding how students should plan their study time. Please note that one question may appear in several different categories, as questions can cross over different topics.

# Diagnostic Guide for the 2008 AP Environmental Science Exam

## Earth Systems and Resources (Average number correct = 6.7)

|                                         |    |    |    |    |    |    |    |    |    |    |    |    |    |
|-----------------------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Question #                              | 1  | 2  | 3  | 7  | 8  | 9  | 14 | 19 | 28 | 51 | 54 | 87 | 99 |
| Correct/Incorrect                       |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Percent of Students Answering Correctly | 42 | 35 | 56 | 44 | 72 | 58 | 78 | 65 | 39 | 61 | 37 | 43 | 44 |

## The Living World (Average number correct = 7.1)

|                                         |    |    |    |    |    |    |    |    |    |    |    |    |
|-----------------------------------------|----|----|----|----|----|----|----|----|----|----|----|----|
| Question #                              | 15 | 22 | 29 | 34 | 46 | 55 | 59 | 71 | 78 | 85 | 93 | 96 |
| Correct/Incorrect                       |    |    |    |    |    |    |    |    |    |    |    |    |
| Percent of Students Answering Correctly | 52 | 90 | 66 | 76 | 38 | 64 | 84 | 43 | 73 | 37 | 32 | 55 |

## Population (Average number correct = 8.5)

|                                         |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|-----------------------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Question #                              | 17 | 21 | 23 | 27 | 32 | 43 | 44 | 48 | 67 | 70 | 75 | 77 | 81 | 90 |
| Correct/Incorrect                       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Percent of Students Answering Correctly | 84 | 41 | 39 | 61 | 70 | 29 | 53 | 73 | 55 | 46 | 76 | 53 | 83 | 84 |

## Land and Water Use (Average number correct = 5.1)

|                                         |    |    |    |    |    |    |    |    |    |    |
|-----------------------------------------|----|----|----|----|----|----|----|----|----|----|
| Question #                              | 20 | 25 | 33 | 53 | 58 | 66 | 74 | 91 | 92 | 94 |
| Correct/Incorrect                       |    |    |    |    |    |    |    |    |    |    |
| Percent of Students Answering Correctly | 33 | 30 | 58 | 75 | 89 | 60 | 15 | 31 | 39 | 83 |

## Energy Resources and Consumption (Average number correct = 7.7)

|                                         |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|-----------------------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Question #                              | 16 | 31 | 38 | 41 | 42 | 56 | 57 | 63 | 65 | 73 | 80 | 84 | 88 | 98 |
| Correct/Incorrect                       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Percent of Students Answering Correctly | 96 | 76 | 84 | 26 | 47 | 88 | 52 | 47 | 54 | 38 | 28 | 55 | 35 | 45 |

# Diagnostic Guide for the 2008 AP Environmental Science Exam (continued)

## Pollution (Average number correct = 13.8)

|                                         |    |    |    |    |    |    |    |    |    |    |    |    |
|-----------------------------------------|----|----|----|----|----|----|----|----|----|----|----|----|
| Question #                              | 4  | 5  | 6  | 10 | 11 | 12 | 13 | 24 | 26 | 30 | 37 | 45 |
| Correct/Incorrect                       |    |    |    |    |    |    |    |    |    |    |    |    |
| Percent of Students Answering Correctly | 71 | 67 | 16 | 74 | 61 | 42 | 56 | 63 | 70 | 73 | 50 | 80 |

|                                         |    |    |    |    |    |    |    |    |    |    |    |    |
|-----------------------------------------|----|----|----|----|----|----|----|----|----|----|----|----|
| Question #                              | 47 | 49 | 52 | 60 | 62 | 64 | 72 | 76 | 79 | 82 | 89 | 95 |
| Correct/Incorrect                       |    |    |    |    |    |    |    |    |    |    |    |    |
| Percent of Students Answering Correctly | 64 | 81 | 18 | 41 | 83 | 51 | 32 | 62 | 51 | 64 | 59 | 48 |

## Global Change (Average number correct = 6.8)

|                                         |    |    |    |    |    |    |    |    |    |    |    |     |
|-----------------------------------------|----|----|----|----|----|----|----|----|----|----|----|-----|
| Question #                              | 18 | 35 | 36 | 39 | 40 | 50 | 61 | 69 | 83 | 86 | 97 | 100 |
| Correct/Incorrect                       |    |    |    |    |    |    |    |    |    |    |    |     |
| Percent of Students Answering Correctly | 36 | 69 | 43 | 64 | 56 | 53 | 83 | 52 | 71 | 40 | 87 | 29  |

## Quantitative/Calculations (Average number correct = 3.8)

|                                         |    |    |    |    |    |    |    |    |
|-----------------------------------------|----|----|----|----|----|----|----|----|
| Question #                              | 21 | 27 | 41 | 42 | 44 | 77 | 84 | 98 |
| Correct/Incorrect                       |    |    |    |    |    |    |    |    |
| Percent of Students Answering Correctly | 41 | 61 | 26 | 47 | 53 | 53 | 55 | 45 |

## Graph/Data Interpretation (Average number correct = 4.4)

|                                         |    |    |    |    |    |    |    |    |
|-----------------------------------------|----|----|----|----|----|----|----|----|
| Question #                              | 41 | 42 | 44 | 48 | 58 | 78 | 87 | 93 |
| Correct/Incorrect                       |    |    |    |    |    |    |    |    |
| Percent of Students Answering Correctly | 26 | 47 | 53 | 73 | 89 | 73 | 43 | 32 |

## Diagnostic Guide for the 2008 AP Environmental Science Exam *(continued)*

### Number Correct

|                           | Earth Systems<br>and Resources | The Living World | Population     | Land and<br>Water Use | Energy Resources<br>and Consumption |
|---------------------------|--------------------------------|------------------|----------------|-----------------------|-------------------------------------|
| Number of Questions       | 13                             | 12               | 14             | 10                    | 14                                  |
| Average Number<br>Correct | 6.7<br>(51.5%)                 | 7.1<br>(59.2%)   | 8.5<br>(60.7%) | 5.1<br>(51.0%)        | 7.7<br>(55.0%)                      |
| My Number Correct         |                                |                  |                |                       |                                     |

|                           | Pollution       | Global Change  | Quantitative/<br>Calculations | Graph/Data<br>Interpretation |
|---------------------------|-----------------|----------------|-------------------------------|------------------------------|
| Number of Questions       | 24              | 12             | 8                             | 8                            |
| Average Number<br>Correct | 13.8<br>(57.5%) | 6.8<br>(56.7%) | 3.8<br>(47.5%)                | 4.4<br>(55.0%)               |
| My Number Correct         |                 |                |                               |                              |



## Section II: Free Response

### Comments from the Chief Reader

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Below are some observations and suggestions arising from the scoring of the four free-response questions on the 2008 AP Environmental Science Exam, gleaned from discussions with Readers and Table and Question Leaders at the AP Reading.

**Question 1**, the document-based question, concerned alternative energy sources, the carbon cycle, and the use of food products to produce energy. Students performed fairly well on this question.

In part (a) most calculated the correct acreage required to produce 1,000 gallons of oil in one year from microalgae and soybeans. In parts (b) and (c) many students began, but did not complete, thorough descriptions of the environmental advantages of biodiesel production from microalgae (part [b]) and the impact of burning biodiesel fuel on atmospheric CO<sub>2</sub> (part [c]); and in part (e) many did not include two complete discussions of two economic or societal problems associated with producing fuel from corn.

The most striking lack of accomplishment on this question was in part (c). Few students indicated an understanding of the difference between the impact of biodiesel fuel and fossil fuels on CO<sub>2</sub> concentrations. Many students wrote that biodiesel fuel releases no CO<sub>2</sub> when burned or that biodiesel fuel reduces CO<sub>2</sub> concentration in the atmosphere. 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 as fuel.

**Question 2** required students to analyze environmental information in a schematic diagram, as well as in text, and to make computations 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' knowledge of viable methods of waste stream reduction for cadmium and the inherent shortcomings associated with the implementation of these methods.

A significant number of students chose not to answer this question. Integrating the questions with the schematic and the descriptive text appeared difficult for many, perhaps due to the time constraints of the exam.

In parts (a), (b), and (c), students often omitted calculations or had difficulty with the calculations. Mathematically many students struggled with deciphering the correct formulas and setup from 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 municipal waste input with cadmium-bearing leachate already in the waste stream, and they inappropriately suggested filtering as a method. Students were often vague in descriptions of methods (e.g., screening waste).

**Question 3** was on 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. Additionally, students were asked to identify another plant community or biome maintained by fire other than forests. Performance was good, with almost all students attempting to answer the question, and some even writing several pages.

Many students in part (a) indicated "dry" as a condition of suppressed forests. Fire-suppressed forests are not dry but have an accumulation of combustible materials, increased understory growth, stored terpenes in older trees, and other conditions that cause 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 may not have read the question carefully, as many responded with fire-reduction methods, which the question specifically excluded, when describing positive and negative effects of implementing the Healthy Forests Initiative.

Students who did not receive full credit in part (c) failed to identify an ecosystem service benefiting humans—in order to earn credit for the suggestion of clear-cutting, the response had to 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 impact. Many students incorrectly stated that oxygen is released from carbon dioxide during photosynthesis.

Some students did not read the question for part (d) carefully or else they did not know a specific plant community, other than forests, maintained by fire; they did not earn points by responding with forest biomes or other forested plant communities.

**Question 4** assessed students' knowledge of contemporary issues related to human population growth and its impact on the environment. Overall, students performed well.

Lack of care in plotting the data was a common error in part (a), where students had to create a graph of worldwide total fertility rate (TFR) on the axes provided in the exam booklet. In part (b) students often did not specify the role played by increasing educational opportunities for women—instead, they simply gave “increasing education” as a cause of the trend in TFR identified in part (a). Another common error was to link the end of the baby boom to the Korean, Vietnam, and Iraq Wars to explain decreased worldwide TFR since 1950.

In part (c), where student were asked to discuss factors accounting for the difference in TFR between Kenya and the United States, students sometimes did not qualify their statements by stating which country they were describing and therefore did not earn points. Students often stated causes without responding with an adequate discussion—they were required to discuss causes in part (b) and factors in part (c), but they often only identified them.

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. Often, students mentioned marriage between people of two different races as a factor that would increase biodiversity, or they used answers that would have been appropriate in parts (b) or (c).

To improve students' performance on the AP Exam, teachers are encouraged to:

- Teach students to read questions carefully and note where linkage and exclusions are specified within the questions. When students miss this subtlety, they may earn no points on one or more parts of a question.
- Encourage students to follow through on their ideas when answering questions, 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. Teach students to write complete descriptions and discussions.
- Remind students to answer the questions that have been asked. For example, when asked to describe an *environmental* advantage in Question 1, students did not earn points for descriptions of *nonenvironmental* advantages.

- Provide students with opportunities to practice writing explanations of environmental concepts (when answering Question 1, many students were largely unable to explain the difference between old and new carbon).
- Give students opportunities to discuss and write about environmental issues in the news. Exam questions occasionally cover subject matter inspired by recent world events.
- Teach students about the ecological services provided by ecosystems and the impact of humans on ecosystems.
- Give students practice with answering sample questions in class, and ensure that their responses are thorough and specific to the question asked.
- Remind students that when calculations are required on the exam, they must clearly show how they arrived at their answer. Encourage them to show all computational work on the pages of the exam booklet. Teach students to complete all computational sets, so that they can earn points where possible.
- Work with students on organizing computational problems using a variety of methods to include dimensional analysis.
- Remind students to review their computational answers to determine if they have produced realistic results, with the right order of magnitude.
- Encourage development of analytical skills: work with students on data analysis and the application of quantitative analysis of environmental problems.
- Train students to accurately plot data on a graph, and be sure that they know how to plot points and bars and how to draw pie charts. Stress attention to detail. Focus on the interpretation of drawn graphs.

## Scoring Guidelines, Sample Student Responses, and Commentary

The responses on the following pages are actual student responses, reproduced with the permission of the writers at the time they took the exam. Each essay was read and scored by the Chief Reader, Question Leader, and Table Leaders. Each one appeared in the sample responses used for the training of Readers during the AP Reading. Each question is represented by three responses that illustrate three distinct score points at upper and lower ranges.

A copy of the scoring guideline for each question precedes the samples. Following each response is commentary that explains how the response met the criteria for the assigned score.



## 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. Students performed fairly well, with most attempting to answer the question. The mean score was 4.10 out of a possible 10 points. (For a discussion of student performance and suggestions for improving scores, see Comments from the Chief Reader beginning on page 46.)

### Scoring Guidelines for 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.)

$$\frac{10,000 \text{ gal}}{1 \text{ acre}} = \frac{1,000 \text{ gal}}{x \text{ acres}} = \mathbf{0.1 \text{ acre}}$$

OR

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

(ii) soybeans

(One point is earned for the correct answer.)

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

OR

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

(A third point is earned in part (a) for a correct setup of both the microalgae and soybean calculations.)

## Scoring Guidelines for Question 1 (continued)

- 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.)

| Advantage                                                                                                                          | Description                                                                                                                                                                                                                     |
|------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Less land use                                                                                                                      | <ul style="list-style-type: none"><li>Less habitat destruction and/or less loss of biodiversity</li><li>Protection of watersheds from agricultural runoff</li></ul>                                                             |
| Decreased tilling of soil                                                                                                          | <ul style="list-style-type: none"><li>Less soil erosion</li></ul>                                                                                                                                                               |
| Decreased pesticide and/or fertilizer use                                                                                          | <ul style="list-style-type: none"><li>Less runoff of pesticides and/or fertilizers</li></ul>                                                                                                                                    |
| Decreased fossil fuel consumption for tilling soil, harvesting crops, and/or manufacturing and applying fertilizers and pesticides | <ul style="list-style-type: none"><li>Less mining and drilling for fossil fuels, resulting in less habitat destruction and less loss of biodiversity</li><li>Less air pollution (e.g., NO<sub>x</sub>, O<sub>3</sub>)</li></ul> |
| Decreased energy consumption for extracting oils from microalgae                                                                   | <ul style="list-style-type: none"><li>Less mining and drilling for fossil fuels, resulting in less habitat destruction and less loss of biodiversity</li><li>Less air pollution (e.g., NO<sub>x</sub>, O<sub>3</sub>)</li></ul> |
| Decreased irrigation of land                                                                                                       | <ul style="list-style-type: none"><li>Less soil salinization and/or less desertification</li><li>Less aquifer depletion</li></ul>                                                                                               |
| Less nutrient depletion of soil                                                                                                    | <ul style="list-style-type: none"><li>Less land under cultivation</li></ul>                                                                                                                                                     |
| Microalgae may be grown in wastewater                                                                                              | <ul style="list-style-type: none"><li>Less runoff and less infiltration of wastewater</li></ul>                                                                                                                                 |

- Explain why burning biodiesel fuel has a different impact on atmospheric CO<sub>2</sub> 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.



## Scoring Guidelines for Question 1 *(continued)*

- (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.
- One point is earned for two correct benefits with no 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.

| Benefit                                             | Sample Discussion                                                                                                                                                                    |
|-----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Biofuels are renewable resources                    | <ul style="list-style-type: none"> <li>▪ Fossil fuels are nonrenewable</li> <li>▪ Renewable resources are less likely to be exhausted</li> </ul>                                     |
| Increased jobs                                      | <ul style="list-style-type: none"> <li>▪ More labor needed in the agricultural sector</li> </ul>                                                                                     |
| Increased profits for companies                     | <ul style="list-style-type: none"> <li>▪ Industries in the agricultural sector will increase sales</li> </ul>                                                                        |
| Decreased reliance on imported fossil fuels         | <ul style="list-style-type: none"> <li>▪ Decreases political instability</li> <li>▪ Results in a self-sufficient supply of energy</li> </ul>                                         |
| Increased global political stability                | <ul style="list-style-type: none"> <li>▪ Reliance on imported fossil fuels decreases</li> <li>▪ Disputes over oil are frequently the cause of disagreements among nations</li> </ul> |
| Reduced transportation costs                        | <ul style="list-style-type: none"> <li>▪ Fewer oil spills during transport</li> <li>▪ Fossil fuels must be transported over greater distances</li> </ul>                             |
| Reduced land disturbance                            | <ul style="list-style-type: none"> <li>▪ Result of less fossil fuel extraction</li> </ul>                                                                                            |
| Preservation of petroleum                           | <ul style="list-style-type: none"> <li>▪ For nonenergy uses (e.g., plastics, petrochemicals, medical purposes)</li> </ul>                                                            |
| Reduced insecurity as fossil fuel reserves decrease | <ul style="list-style-type: none"> <li>▪ Enhances a shift to alternate energy sources</li> </ul>                                                                                     |
| Reduced petroleum use                               | <ul style="list-style-type: none"> <li>▪ Petroleum reserves will dwindle over the next 50 years</li> </ul>                                                                           |
| Increased nutrient capture from wastewater          | <ul style="list-style-type: none"> <li>▪ Less escapes into the environment</li> <li>▪ Reduced eutrophication of waterways</li> </ul>                                                 |
| Increased availability of waste products            | <ul style="list-style-type: none"> <li>▪ Increased availability for use as animal feed or soil amendment</li> </ul>                                                                  |
| Decreased disposal of used cooking oil              | <ul style="list-style-type: none"> <li>▪ Results in less waste disposal</li> </ul>                                                                                                   |

## Scoring Guidelines for Question 1 (continued)

(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.)

| Problem                                                                                | Description                                                                                                                                                                                     |
|----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Increase (or decrease) in corn prices                                                  | <ul style="list-style-type: none"> <li>As corn is used for energy production, the demand for corn will become greater</li> <li>Increased corn growing may flood market</li> </ul>               |
| Increased prices for food (e.g., beef, chicken, anything made with corn syrup)         | <ul style="list-style-type: none"> <li>Result of increased corn prices</li> <li>Increased demand for corn</li> </ul>                                                                            |
| Increased prices for commodities other than corn                                       | <ul style="list-style-type: none"> <li>Increased corn production reduces land area for other crops, reducing supply of commodities</li> </ul>                                                   |
| Shortages of food for human consumption                                                | <ul style="list-style-type: none"> <li>Decreased supply of corn</li> <li>Decreased availability of crops displaced by corn production</li> </ul>                                                |
| Cultural extinction                                                                    | <ul style="list-style-type: none"> <li>Rainforest destruction for the production of crops displaced by corn production displaces indigenous cultures</li> </ul>                                 |
| Decreased aesthetic value of land                                                      | <ul style="list-style-type: none"> <li>Natural areas converted to farmland have less aesthetic value</li> </ul>                                                                                 |
| Loss of jobs                                                                           | <ul style="list-style-type: none"> <li>Lower demand for energy production jobs not associated with corn (e.g., coal mining, petroleum engineering)</li> </ul>                                   |
| Energy shortages                                                                       | <ul style="list-style-type: none"> <li>Poor crop yields resulting from drought, pestilence, etc., result in less corn to produce energy</li> </ul>                                              |
| Increased land costs                                                                   | <ul style="list-style-type: none"> <li>Due to increased demand for agricultural lands</li> </ul>                                                                                                |
| Decreased availability of land for nonagricultural use leading to less land for cities | <ul style="list-style-type: none"> <li>Due to increased demand for agricultural lands</li> </ul>                                                                                                |
| Decreased availability of land for nonagricultural use leading to public opposition    | <ul style="list-style-type: none"> <li>Due to increased demand for agricultural lands</li> </ul>                                                                                                |
| Reduced water supply for cities                                                        | <ul style="list-style-type: none"> <li>Due to increased agricultural water consumption</li> </ul>                                                                                               |
| Increased societal risks associated with exposure to agricultural chemicals            | <ul style="list-style-type: none"> <li>Increased pesticide and fertilizer use</li> </ul>                                                                                                        |
| Higher costs to cultivate and maintain agricultural land                               | <ul style="list-style-type: none"> <li>Increased use of marginal lands to grow more corn</li> </ul>                                                                                             |
| Overuse of agricultural land                                                           | <ul style="list-style-type: none"> <li>Loss of productive land</li> </ul>                                                                                                                       |
| Increased taxes or unavailable public money                                            | <ul style="list-style-type: none"> <li>Subsidies that divert public money to pay for corn production</li> </ul>                                                                                 |
| The need to convert combustion engines to burn ethanol or biodiesel                    | <ul style="list-style-type: none"> <li>Using corn for fuel will result in fuel that is not compatible with current engines</li> </ul>                                                           |
| More expensive than alternatives                                                       | <ul style="list-style-type: none"> <li>Higher cost for resources (e.g., fertilizer, pesticides, land, water) needed to produce fuel from corn as compared with producing other fuels</li> </ul> |

Sample Student Responses for Question 1  
Student Response 1 (Score: 9)

$$A.i. \quad \frac{10000 \text{ gallons}}{\text{acre year}} \times \frac{\text{acre}}{\text{year}} = 1000 \frac{\text{gallons}}{\text{year}}$$

$$x \text{ acre} = \frac{1}{10} = .1$$

.1 acres are required to produce 1000  $\frac{\text{gallons}}{\text{year}}$   
using microalgae

$$ii. \quad \frac{50 \text{ gallons}}{\text{acre year}} \times \text{acre} = 1000 \frac{\text{gallons}}{\text{year}}$$

$$x \text{ acre} = 20 \text{ acre}$$

20 acres of soybeans are required to produce 1000  $\frac{\text{gallons}}{\text{year}}$

B. According to the article microalgae are the "most efficient organism at converting sunlight to energy". As such, they offer the largest oil per acre ratio of any biodiesel production. This means that more oil can be produced in a smaller space using microalgae. Thus microalgae is more energy efficient and space efficient. This allows for less crop land and less intrusion upon native habitats.

Additionally, microalgae has several ~~of~~ alternate uses that other methods of biofuel production do not.

After being pressed for oil, microalgae can be used as "animal feed or soil amendment". These alternate uses allow ~~for the~~ microalgae to be ~~substituted~~ substituted for land-intensive feed crops thus enabling the use of less land.

Microalgae also provides a possible means of carbon



B. sequestration. By housing the carbon in the microalgae and then permanently using it as construction material, the carbon ~~remains in the soil of the~~ cannot enter the atmosphere and further global warming.

C. Biodiesel fuel's carbon was taken from the atmosphere and placed into the fuel. ~~For~~ When it is burned only carbon that was originally in the atmosphere is released and there is ~~not~~ no net shift in ~~atmospheric~~ ~~CO<sub>2</sub>~~ levels. Fossil fuels however are sequestered carbon resources. Burning these releases carbon that was not previously in the atmosphere.

D. Biodiesel is a renewable energy supply; ~~oil~~ oil is not. ~~It is~~ Eventually the oil ~~supply~~ and coal supplies will be depleted, but biodiesel presents a permanent replacement that will never be ~~used up~~ used up. ~~Biodiesel will continue to be supplied~~  
Biodiesel allows us to be independent of foreign oil distributors. ~~and~~ This independence ensures a more stable economy and society.

E. Use of corn ~~will cause~~ for biodiesel will cause a drastic increase in corn prices. This increase will ~~is~~ translate to increased food prices. Increased food prices cause economic ~~and~~ ~~hardship~~ hardship for the impoverished.

Corn can only be efficiently grown in specific climates. Many countries and parts of the world ~~do~~ cannot ~~efficiently~~ grow corn and thus would not be able to take advantage or use the fuel produced from it.

~~For~~ Corn is not an efficient producer of fuel and would require ~~more energy and~~ a considerable amount of energy and land for a small amount of fuel.

### Commentary

In part (a) 3 points were earned: 1 point each for the correct answers and 1 point for the two correct setups.

In part (b) 1 point was earned for the indication that there is "less crop land and less intrusion upon native habitats."

The second description, that "microalgae has several alternate uses," does not involve an environmental advantage of microalgae over the other listed crops. The third description, "Microalgae also provides a possible means of carbon sequestration," was not scored as the question asked for only two advantages.

In part (c) 1 point was earned for the correct explanation that carbon in biodiesel "was originally in the atmosphere" and "there is no net shift in CO<sub>2</sub> levels," while fossil fuels "are sequestered carbon resources."

In part (d) 3 points were earned for correctly identifying and discussing two benefits: "Biodiesel is a renewable energy supply; oil is not," and "[b]iodiesel allows us to be independent of foreign oil distributors. This independence ensures a more stable economy and society."

In part (e) 1 point was earned for indicating that "[u]se of corn for biodiesel will cause a drastic increase in corn prices."



a) microalgae: gallons of oil per acre: 10,000  
 $1,000 \text{ gallons} \div 10,000 \text{ gallons} = .1 \text{ acres}$

soybeans: gallons of oil per acre: 50  
 $1,000 \text{ gallons} \div 50 \text{ gallons} = 20 \text{ acres}$

b) Making biodiesel fuels from microalgae instead of corn and other food products eliminates the concern of interfering with food production. Many people advertise the global food shortage as a reason why biodiesel fuels can never become a significant ~~part~~ energy source but using microalgae counters this argument.

Since microalgae requires fewer acres than any other known biodiesel contributor, ~~if~~ using it proves far more efficient and less detrimental to the land.

c) Biodiesel fuels do not have the sulfur and other toxic compound content that fossil fuels like coal do. They burn much cleaner without releasing harmful emissions in the atmosphere. This eases the problem of CO<sub>2</sub> emissions, making biodiesel use very beneficial.



d) Since biodiesel fuels are a mostly renewable source of energy, we would not have to worry so much about depleting our natural resources. Coal, oil and other fossil fuels are nonrenewable and therefore we are running out of them very quickly. ~~It~~ It is crucial that we switch our reliance on nonrenewables to a reliance on renewables so that we can become a sustainable society.

Not only do biodiesel fuels offer a cleaner method of energy production but they also eliminate the need for mining. Mining is expensive, as well as detrimental to the environment. It produces a mass amount of waste, contributes to erosion, increases sediment run off and decreases biodiversity through the fragmentation of habitats. Since biodiesel use is not based off the burning of materials from the earth's crust, it does not require such harmful measures.

e) Producing fuel from corn contributes to the problem of food shortages. Both ~~people, it~~ people and animals rely on ~~food~~ corn as an important source of food. Limiting the production of corn for food and using it instead for fuels such as ethanol could certainly contribute to a global food shortage.

Corn also has a relatively low yield per acre of oil. In one acre, you only get 20 gallons of oil. This lack of efficient production could cause economical problems.

## Commentary

In part (a) 3 points were earned: 1 point each for the correct answers and 1 point for the two correct setups.

No points were earned in part (b). The first advantage the student describes (Making biodiesel fuels from microalgae instead of corn and other food products eliminates the concern of interfering with food production") is not environmental, and the second advantage listed is not clearly described; "less detrimental to the land" is not an adequate description.

No points were earned in part (c) because the answer confuses sulfur and CO<sub>2</sub>.

In part (d) 3 points were earned for correctly identifying and discussing each of two benefits: "biodiesel fuels are a mostly renewable source of energy," "[c]oal, oil and other fossil fuels are nonrenewable," and "biodiesel fuels . . . also eliminate the need for mining . . . [which is] detrimental to the environment."

In part (e) 1 point was earned for the correct observation that "[p]roducing fuel from corn contributes to the problem of food shortages." The second description, that "low yield... could cause economical problems," is not adequately described and did not earn a point.



(a) .10 acres are required to produce 1,000 gallons of oil in one year <sup>from microalgae</sup> whereas 200 acres are required to produce that from soybeans.

(b) If only .10 acres are needed to produce 1,000 gallons of oil from microalgae, then one obvious advantage of biodiesel production from microalgae is the ~~the~~ <sup>small</sup> amount of land needed for production. By not needing a lot of land for production, concerns over extensive land use, pollution, and living near the production land is avoided. Another environmental advantage to using this microalgae to produce biofuel is that after the oil is removed, the remaining material can be used as animal feed or soil amendment.

~~(c) Biodiesel is a renewable fuel source.~~

(d) If reliance on biodiesel increased over the next 50 years then people wouldn't have to pay so much money to fuel their cars (like they are using gasoline). Also, if people understood the positive impact that using biodiesel has on the environment, they would begin to be more environmentally conscious and therefore may take steps to protect the environment in other ways.



(e) one problem associated with producing fuel from corn is the fear that by using this corn, we would be taking a food resource from people who rely on corn for nutrition. An economic problem associated w/ producing fuel from corn is that corn isn't cost efficient.

→ calculations for (a)

(i) microalgae

$$\begin{array}{rcl} 10,000 \text{ gal} & = & 1,000 \text{ gal} \\ 1 \text{ acre} & & \times \text{ 2 acre} \\ \hline 10,000 x & = & 1,000 \\ \hline 10,000 & & 10,000 \\ x & = & .10 \text{ acres} \end{array}$$

(ii) soybeans

$$\begin{array}{rcl} 50 \text{ gal} & = & 1000 \\ 1 \text{ acre} & & \times \text{ 2 acre} \\ \hline 50 x & = & 1000 \\ \hline 50 & & 50 \\ x & = & 200 \text{ acres} \end{array}$$

## Commentary

In part (a) 2 points were earned: 1 point for correctly answering that .10 acre of land would be required and 1 point for two correct setups. (The work is shown on the second page of the response.)

No points were earned in part (b). The student lists one environmental advantage ("the small amount of land needed for production"), but the description of why this is an environmental advantage is too vague to earn a point. The second advantage ("the remaining material can be used as animal feed") is not, as presented, an environmental advantage.

The student does not attempt part (c) and thus earned no points.

No points were earned in part (d). It is not clear that biodiesel will be cheaper than gasoline, nor that its use will change people's environmental consciousness.

In part (e) 1 point was earned for the correct statement that using corn for fuel "would be taking a food resource from people who rely on corn for nutrition."

## Question 2—Overview

The question assessed the 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. Overall, performance was fair: the mean score was 2.27 out of a possible 10 points. (For a discussion of student performance and suggestions for improving scores, see Comments from the Chief Reader beginning on page 46.)

## Scoring Guidelines for Question 2

(a) Calculate the volume, in m<sup>3</sup>, 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

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

|                       |       |                       |                        |
|-----------------------|-------|-----------------------|------------------------|
| 10,000 m <sup>2</sup> | 0.2 m | 50% infiltrated water | = 1,000 m <sup>3</sup> |
|                       |       | 100% water            |                        |

(i) 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/m<sup>3</sup>, 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.

|                                   |                  |         |                  |
|-----------------------------------|------------------|---------|------------------|
| 100 m <sup>3</sup> drainage water | 0.2 g Cd         | 1 kg    | = 0.2 kg Cd/year |
| 1 year                            | 1 m <sup>3</sup> | 1,000 g |                  |

(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).

|                                       |                           |                     |
|---------------------------------------|---------------------------|---------------------|
| 900 m <sup>3</sup> treatable leachate | \$10                      | = \$ 9,000 per year |
|                                       | 1 m <sup>3</sup> leachate |                     |

## Scoring Guidelines for Question 2 (continued)

(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.)

| Category of Reduction                            | Method or Action                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|--------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Disposal options                                 | <ul style="list-style-type: none"><li>Sort waste stream for cadmium-containing products (batteries, e-waste, paints and pigments, stabilizers, pesticides) headed to landfills</li><li>Deposit these materials at a dropoff site or recycling facility, or return to manufacturer</li></ul>                                                                                                                                                                                              |
| New/substitute technology or alternate materials | <p>Avoid use of cadmium-containing products by:</p> <ul style="list-style-type: none"><li>using rechargeable batteries (e.g., lithium rechargeable)</li><li>applying new technology and/or alternate materials that do not use cadmium</li></ul>                                                                                                                                                                                                                                         |
| Incentives and/or disincentives                  | <ul style="list-style-type: none"><li>Place restrictions on disposal of materials that contain cadmium (batteries, e-waste, paints and pigments, stabilizers, pesticides)</li><li>Pass cradle-to-grave (RCRA) legislation</li><li>Provide rebate incentives for using cadmium-free products</li><li>Provide incentives for manufacturing cadmium-free products (e.g., research grants)</li><li>Place a deposit (payable on return) or surcharge on cadmium-containing products</li></ul> |
| Education                                        | <p>Make the public aware of (any one of the following):</p> <ul style="list-style-type: none"><li>concerns (health, environmental) associated with cadmium</li><li>methods of cadmium-containing product/battery reduction/recycling</li><li>availability of new/substitute technology</li></ul>                                                                                                                                                                                         |

(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



## Sample Student Responses for Question 2

### Student Response 1 (Score: 10)

a) i:  $200 \text{ mm/year} \times \frac{50 \text{ percent}}{100 \text{ percent}} \times \frac{1 \text{ m}}{1000 \text{ mm}} \times 10,000 \text{ m}^2 = 1000 \text{ m}^3$   
 $1000 \text{ m}^3$  of water infiltrates through the landfill each year.

ii:  $1000 \text{ m}^3 \times \frac{90\% \text{ treated}}{100\%} = 900 \text{ m}^3$

The amount of leachate treated is  $900 \text{ m}^3$  per year.

b)  $1000 \text{ m}^3 \times \frac{10\% \text{ not treated}}{100\%} \times \frac{2.0 \text{ g}}{1 \text{ m}^3} \times \frac{1 \text{ kg}}{1000 \text{ g}} = .2 \text{ kg of}$

There is .2 kg of cadmium released into the soil each year.

c)  $1000 \text{ m}^3 \times \frac{90\% \text{ treated}}{100\%} \times \frac{\$10}{\text{m}^3} = \$9000$  spent

The annual cost of treatment is \$9000.

d) One way to reduce cadmium is to not allow batteries into the landfill. Batteries contain cadmium, like other e-waste, and this is then released as the batteries corrode and enters the leachate and possibly groundwater. Another possible solution is a MRF or Material Recovery Facility. This can be used to separate out not only cadmium containing products but recyclables as well then the recyclables can be recycled and the cadmium wastes can be properly disposed.

e) A shortfall of preventing batteries is enforcement. How will you know if a truck has batteries or other e-waste? You won't! This makes prevention of dumping cadmium-containing products into the landfill very difficult and even nearly impossible.

## Commentary

In part (a) 2 points were earned for correct setups for parts (i) and (ii), and 2 points were earned for the correct answers in cubic meters ( $1000 \text{ m}^3$  of water and  $900 \text{ m}^3$  of leachate).

In part (b) 1 point was earned for the setup, using  $1/10$  of the value in part (a)(i), and 1 point was earned for the correct final value in kg of Cd ( $0.2 \text{ kg}$ ).

In part (c) 1 point was earned for the setup of multiplying cost per meter times the amount of treatable leachate from part (a)(ii), and 1 point was earned for the correct value in dollars ( $\$9,000$  annual cost).

In part (d) 1 point was earned for the statement that "[o]ne way to reduce cadmium is to not allow batteries into the landfill. Batteries contain cadmium ... and this is then released as the batteries corrode." Another point was earned for the discussion about a Material Recovery Facility separating out cadmium wastes for proper disposal.

If 10 points had not already been earned, the student also could have earned 1 point in part (e) for citing the difficulty of enforcement and explaining that it is virtually impossible to know if trucks contain batteries or other e-waste, since this discussion relates to a viable method of reduction from part (d).

$$a) i) 50\% \times \frac{200 \text{ mm}}{\text{yr}} = \frac{100 \text{ mm}}{\text{yr}}$$

$$\frac{100 \text{ mm}}{\text{yr}} \cdot \frac{1 \text{ m}}{1000 \text{ mm}} = \frac{.1 \text{ m}}{\text{yr}}$$

$$\frac{.1 \text{ m}}{\text{yr}} \times 10,000 \text{ m}^2 = \frac{1000 \text{ m}^3}{\text{yr}}$$

$$ii) 90\% \times \frac{1000 \text{ m}^3}{\text{yr}} = \frac{900 \text{ m}^3}{\text{yr}}$$

$$b) \frac{2.0 \text{ g}}{\text{m}^3} \cdot \frac{\text{kg}}{1000 \text{ g}} = \frac{200 \text{ kg}}{\text{m}^3}$$

$$\frac{200 \text{ kg}}{\text{m}^3} \cdot \frac{900 \text{ m}^3}{\text{yr}} = \frac{180,000 \text{ kg}}{\text{yr}}$$

$$c) \$ \frac{10}{\text{m}^3} \cdot \frac{900 \text{ m}^3}{\text{yr}} = \$9,000/\text{yr}$$

d) Two viable methods for reducing the amount of reducing the amount of cadmium waste input would be setting laws to limit the amount of cadmium allowed in products and screening the waste before it enters the municipal waste input.

The first method could be like the clean water Act, where limits are set for the amount of allowed cadmium. That way, with the lesser amount in products, the waste would not have so much.

The second method would cost more, in that there has to be a screening device that blocked the entering of cadmium into the municipal waste input. Also at the screening process, there can be bacteria that are



## Student Response 2 (continued)

genetically modified to eat away the cadmium. This way, almost all of the cadmium would be reduced by the time it hits the land fill.

(c) One of the shortcomings of ~~using~~ <sup>using</sup> a screening and bacteria method to reduce the amount of cadmium is the cost. It would take a lot of money to make sure the intricate screen will indeed detect the cadmium. Also, the bacteria that will be genetically modified will be expensive and will take time to create them.

### Commentary

In part (a) 2 points were earned for correct setups for parts (i) and (ii), and 2 points were earned for the correct answers in cubic meters ( $1000 \text{ m}^3$  of water and  $900 \text{ m}^3$  of leachate).

No points were earned in part (b). The setup is incorrectly based on the amount of treated leachate rather than the amount released to the surrounding soil, and the calculation is incorrect.

In part (c) 1 point was earned for the setup of multiplying cost per meter times the amount of treatable leachate from part (a)(ii), and 1 point was earned for the correct value in dollars (\$9,000 per year).

In part (d) 1 point was earned for the statement "setting laws to limit the amount of cadmium allowed in products." As described, the second proposed method ("screening") is not viable.

No points were earned in part (e) because the shortcomings are associated with a nonviable method of reduction from part (d).

**Student Response 3 (Score: 4)**

- (a) The volume of water filtrated through the landfill per year is  $1000 \text{ m}^3$ , the leachate is  $900 \text{ m}^3$ . (b) The mass in kg of cadmium released into the surrounding soil is  $0.2 \text{ kg}$ .
- (c) The annual cost of treating the leachate from the drainage system will be  $\$9000$ .
- (d) A method for reducing the cadmium would be to create a filter at the drainage system. (e) A short coming of the filtration method is that it would need to be replaced maybe monthly or more.

**Commentary**

In part (a) 2 points were earned for correct answers in cubic meters ( $1000 \text{ m}^3$  of water and  $900 \text{ m}^3$  of leachate). The student does not show how the numbers are calculated, so no setup points were earned.

In part (b) 1 point was earned for the correct final value in kg of Cd ( $0.2 \text{ kg}$ ). The student does not show how the numbers are calculated, so no setup point was earned.

In part (c) 1 point was earned for the correct final value in dollars ( $\$9,000$  annual cost). The student does not show how the numbers are calculated, so no setup point was earned.

No points were earned in part (d). As described, the proposed method (filtering) is not viable.

The student earned no points in part (e) because the shortcoming is associated with a nonviable method of reduction from part (d).



### 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 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. Almost all students attempted to answer the question, and overall performance was good. The mean score was 4.61 out of a possible 10 points. (For a discussion of student performance and suggestions for improving scores, see Comments from the Chief Reader beginning on page 46.)

### Scoring Guidelines for Question 3

- (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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>▪ Accumulation of combustible materials (layer of leaf litter and debris on forest floor, dead trees, etc.)</li> <li>▪ Increase in understory growth (grasses, shrubs, brush, ladder trees)</li> <li>▪ Larger trees develop</li> <li>▪ Even-aged stands develop</li> <li>▪ Tree density increases</li> <li>▪ Fire-intolerant species increase in number in the understory</li> <li>▪ Fire-tolerant species that need fire to germinate seeds decrease in population</li> <li>▪ Increased canopy coverage eliminates understory growth</li> <li>▪ Increase or decrease in the rate of nutrient cycling (e.g., release of nutrients of litter, lack of nutrient-rich ash)</li> <li>▪ No loss of nutrients to burning in intense fires</li> <li>▪ Increased susceptibility to disease/parasites</li> </ul> |

| Explanations for Increased Fire Risk                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Adds to fuel load [intensity]</p> <ul style="list-style-type: none"> <li>▪ Increased leaf litter</li> <li>▪ Increased density of large trees</li> <li>▪ Increased size of trees</li> <li>▪ Increase in brush and small trees</li> <li>▪ Species composition change</li> </ul> <p>Adds to spreading of fire [extent]</p> <ul style="list-style-type: none"> <li>▪ Increased density of trees</li> <li>▪ Increased density of understory growth</li> <li>▪ Ladder trees leading to crown fires</li> </ul> |



## Scoring Guidelines for Question 3 *(continued)*

- (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.)

| Positive Effect and Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Negative Effect and Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Increased removal of medium and large trees/small tree brush removal will:</p> <ul style="list-style-type: none"> <li>▪ lead to economic growth in the lumber industry</li> </ul> <p>Increased removal of medium and large trees will:</p> <ul style="list-style-type: none"> <li>▪ allow understory to develop into larger trees, potentially enhancing forest habitat</li> <li>▪ make additional timber available to use (must indicate usage)</li> <li>▪ result in thinned trees resistant to pests and disease/impede spread of diseases and pests</li> <li>▪ enhance economic value of the surrounding areas (housing, lower insurance)</li> <li>▪ lower the cost of timber</li> <li>▪ result in a change of aesthetics (with explanation)</li> </ul> | <p>The removal of medium and large trees/small tree brush removal will:</p> <ul style="list-style-type: none"> <li>▪ reduce available habitat for other organisms in the forest biome</li> <li>▪ allow timber companies to cut in areas remote from forest communities not threatened by forest fires</li> <li>▪ cause a reduction in biodiversity (must include a specific example: reduction in nest sites, decrease in seed trees, etc.)</li> <li>▪ increase soil erosion</li> <li>▪ increase logging practices (e.g., roads providing access to new areas)</li> <li>▪ reduce public input</li> <li>▪ result in a change in aesthetics (with explanation)</li> </ul> |

## Scoring Guidelines for 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.)

| Ecosystem Service                                                                                                      | Impact of Clear-Cutting                                                                                                                                                                                 |
|------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Carbon that is removed from the atmosphere by trees helps to limit the magnitude of the atmospheric greenhouse effect. | <ul style="list-style-type: none"> <li>Some carbon will be released to the atmosphere or will not be removed</li> </ul>                                                                                 |
| Forests provide oxygen (via photosynthesis).                                                                           | <ul style="list-style-type: none"> <li>Some loss of oxygen, without which we cannot live</li> </ul>                                                                                                     |
| Forests provide food products for human consumption (deer, nuts, fungi).                                               | <ul style="list-style-type: none"> <li>Can change available browsing places and sighting of animals due to species composition change, increasing their availability for humans (e.g., deer)</li> </ul> |
| Forests provide habitat for many species, some of which provide food and goods for humans, some of which cause harm.   | <ul style="list-style-type: none"> <li>Loss of habitat (biodiversity)</li> </ul>                                                                                                                        |
| Forests provide wood (e.g., construction material, paper).                                                             | <ul style="list-style-type: none"> <li>Increase in the short-term availability of wood, but potential long-term loss of availability</li> </ul>                                                         |
| Forests provide wood for fuel.                                                                                         | <ul style="list-style-type: none"> <li>Increase in the short-term availability of wood, but potential long-term loss of availability</li> </ul>                                                         |
| Many products, such as glue, rubber, and medicines, are produced with forest products.                                 | <ul style="list-style-type: none"> <li>Increase in the short-term availability of these products, but potential long-term loss of availability</li> </ul>                                               |
| Forests influence the local microclimate affecting humans (change in temperature, shade, UV, wind breaks).             | <ul style="list-style-type: none"> <li>Change in the microclimate</li> </ul>                                                                                                                            |
| Forests have aesthetic value (hiking, camping, photography, tourism, etc.).                                            | <ul style="list-style-type: none"> <li>Decreases in natural beauty</li> </ul>                                                                                                                           |
| Forests improve the quality of soil and water used by humans. (Soil and water must be linked to a specific human use.) | <ul style="list-style-type: none"> <li>Increases in erosion and runoff and decreases in groundwater recharge, changing water quality</li> </ul>                                                         |
| Forests maintain watershed integrity (e.g., flood control with specific human application).                            | <ul style="list-style-type: none"> <li>Decreases in watershed integrity</li> </ul>                                                                                                                      |

### Scoring Guidelines for Question 3 *(continued)*

- (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, maquis, garigue—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.



**Sample Student Responses for Question 3**  
**Student Response 1 (Score: 10)**

a. When forest fires do not occur, dead trees are left standing and large amounts of dry, decomposing material accumulate on the forest floor. These piles can be subject to spontaneous combustion due to the natural heat of decomposition, and when fires do start, there is enough fuel accumulated to make them extremely intense and ~~long-lasting~~ persistent.

b. Clearing underbrush and some larger trees can give saplings a chance to grow and help protect mature trees from competition, but if too much open space is left, invasive species can take over and out-compete native ones, destroying natural biodiversity.

c. Forests limit erosion, keeping rivers ~~clean~~ <sup>clear</sup> enough for use as a water source, for fishing, and for transportation. They also act as carbon sinks, reducing the amount of carbon in the atmosphere and helping to counteract the greenhouse effect. Clear cutting would ~~cause~~ increase erosion into water bodies, limiting their usefulness to humans, and increase the amount of carbon dioxide in the atmosphere, ~~exacerbating global warming~~ contributing to global warming.  
~~And in coniferous forests, seeds can only~~

d. Grasslands depend on fire to enrich the soil with nutrients from ash, and to give new generations of plants a chance to grow.

### Commentary

In part (a) 2 points were earned: 1 point for the characteristic “large amounts of dry, decomposing material accumulate on the forest floor” and 1 point for the explanation that this accumulated fuel makes fires “extremely intense and persistent.”

In part (b) 1 point was earned for the statement “can give saplings a chance to grow” (positive) and 1 point was earned for “if too much open space is left, invasive species can take over and out-compete native ones, destroying natural biodiversity” (negative).

In part (c) 1 ecosystem service point was earned for this statement: “Forests limit erosion, keeping rivers clear enough for use as a water source, for fishing, and for transportation.” An additional ecosystem service point was earned for stating, “They also act as carbon sinks, reducing the amount of carbon in the atmosphere and helping to counteract the greenhouse effect.” A clear-cutting point was earned for explaining that “[c]lear cutting would increase erosion into water bodies, limiting their usefulness [*sic*] to humans,” and a second point was earned for the statement that clear-cutting would “increase the amount of carbon dioxide in the atmosphere, contributing to global warming.”

In part (d) 1 point was earned for identifying grasslands as a biome maintained by fire and 1 point for the explanation that “[g]rasslands depend on fire to enrich the soil with nutrients from ash.”



a. Fire suppression by humans disrupts the natural ecosystem; artificial fire suppression alters the balance of the ecosystem, putting in additional chemicals likely to react with others in the forest. Furthermore, when ~~forests~~ are suppressed, trees with ~~fires~~ dry leaves even further litter the ground, making eventual fires likely to be worse because of artificially extensive dry leaf accumulation.

b. On the positive side, ~~the~~ HFI helps maintain the growth of moisture-rich plants. However, HFI artificially and unpredictably alters the ecosystems in the forests.

c. The plants in forests provide oxygen for animal ~~and~~ (including human) livelihood. Clearcutting would reduce this oxygen concentration. In addition, forest-grown bees pollinate crops that humans eat. If their habitat is cut down, they will decrease in population.



[d.] The prairie or dryland biome is maintained by naturally-occurring fires. The fires burn nutrient-rich plants that thus become part of the soil, intensively enriching the soil for future plants.

### Commentary

In part (a) 2 points were earned: 1 point for the characteristic “dry leaves even further litter the ground” and 1 point for the explanation “making eventual fires likely to be worse because of artificially extensive dry leaf accumulation.”

No points were earned in part (b). The explanation of a positive effect, “helps maintain the growth of moisture-rich plants,” is incorrect, and the negative effect, “artificially and unpredictably alters the ecosystems,” is too vague to earn a point.

In part (c) 1 ecosystem service point was earned for this statement: “The plants in forests provide oxygen for animal (including human) livelihood [sic].” A clear-cutting point was earned for the statement that “clearcutting would reduce this oxygen concentration.” An ecosystem service point was earned for the statement that “forest-grown bees pollinate crops that humans eat.” A clear-cutting point was earned for the explanation that “[i]f their habitat is cut down, they will decrease in population.”

In part (d) 1 point was earned for identifying the prairie as a biome maintained by fire and 1 point for the explanation that “fires burn nutrient rich plants that thus become part of the soil, intensively enriching the soil.”

Student Response 3 (Score: 4)

- a) A characteristic that developed when fires are suppressed includes a ~~disruption~~ disrupted natural flow of organisms in the forest. Another characteristic influenced by suppressed fires includes a weak dispersal of seeds of trees, which brings many tall and old trees, but no or little new ones. Suppressing fires increase the risk of a serious fire because of the intermediate disturbance hypothesis, which states that a little disturbance naturally every now and then, say for instance a natural forest fire, will benefit the ecosystem and stabilize it as well.
- b) A positive effect resulting from the HFI includes less pollution <sup>by human activities</sup> ~~human disturbances~~ on forests, yielding a more stable forest ecosystem. However, as stated above in the question, if timber companies are encouraged to harvest medium and large size trees, that is a negative effect of the HFI on the forests.
- c) One ecosystem service provided by forests for humans is the production of oxygen, which we need to live. Another ecosystem service is that it provides flood control and stoppage, including mud and landslide protection. Clear-cutting would slow down oxygen production b/c they are being cut down. As for flood control and landslide prevention, since they are being cut down, floods and landslides will occur more frequently.
- d) A biome that is naturally maintained by fire is the grasslands. If not for fire, the ecosystem would become more susceptible to larger fires. Due to the intermediate disturbance hypothesis, ~~for~~ natural fires benefit and maintain the biome and prevent a serious disaster from occurring.



### **Commentary**

No points were earned in part (a) because “disrupted natural flow of organisms in the forest” is too vague an explanation for a characteristic, and “weak dispersal of seeds” is not valid.

No points were earned in part (b) because “less pollution by human activities” is not an effect likely to result from the implementation of the Healthy Forests Initiative.

In part (c) 1 ecosystem service point was earned for describing “the production of oxygen, which we need to live.” A clear-cutting point was earned for the statement that “[c]lear-cutting would slow down oxygen production.” A second clear-cutting point was earned for stating that “floods and landslides will occur more frequently.” No ecosystem service point was earned for the reference to flood control as no human service is identified.

In part (d) 1 point was earned for identifying grasslands as a biome maintained by fire. The explanation proposed (“the ecosystem would become more susceptible to larger fires”) does not explain how fire maintains the biome.



Question 4—Overview

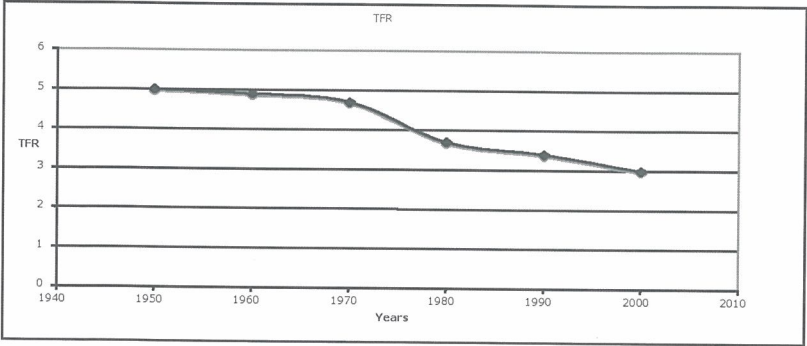
The aim of this question was to assess students’ knowledge of contemporary issues related to human population growth and its impact on the environment. Students were required to graph and analyze Total Fertility Rate data (TFR), which should have shown a decreasing trend, and then to give two causes for this decrease over the past 50 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. Overall, students performed well: the mean score was 5.81 out of a possible 10 points. (For a discussion of student performance and suggestions for improving scores, see Comments from the Chief Reader beginning on page 46.)

Scoring Guidelines for Question 4

(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.



## Scoring Guidelines for Question 4 (continued)

(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.)

| Cause                                                                                 | Discussion                                                                 |
|---------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Increased/improved family planning                                                    | ▪ Fewer pregnancies/control of fertility/choice in number of children born |
| Increased education for women (stay in school longer)/improved social status of women | ▪ Delay having children/choosing to have fewer children                    |
| More women enter the workforce                                                        | ▪ Delay having children                                                    |
| Reduced need for children in workforce/on farm                                        | ▪ More industrialization/less agriculture/increased urbanization           |
| More industrialization/less agriculture/increased urbanization                        | ▪ Reduced need for children in workforce/on farm                           |
| Improved health care (lower infant mortality)                                         | ▪ More children will survive to adulthood                                  |
| People marry later                                                                    | ▪ Childbearing delayed/fewer children                                      |
| Changing cultural values                                                              | ▪ Socially acceptable to have fewer children                               |
| Government policies that restrict number of children allowed per woman                | ▪ Countries are facing overpopulation issues                               |
| Increased cost of raising children                                                    | ▪ Standard of living and education costs have increased                    |
| Increased urbanization                                                                | ▪ Lessens living space for more children                                   |

## Scoring Guidelines for Question 4 (continued)

- (c) Consider the data in table 2 above [table 2 in the exam]. 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.)

| Factors (Societal or Economic)                                                        | Discussion                                                                                                                                                                                                                                                                                                                                      |
|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Kenya has a much higher infant mortality rate.                                        | <ul style="list-style-type: none"> <li>There is a shortage of prenatal and pediatric care due to poverty in Kenya.</li> <li>Kenyans have more children to ensure that some survive.</li> </ul>                                                                                                                                                  |
| Kenya is more agricultural (second stage of demographic transition).                  | <ul style="list-style-type: none"> <li>In Kenya more children are needed to help farm.</li> </ul>                                                                                                                                                                                                                                               |
| Kenya is a less-developed country (lower per-capita income)/poorer/nonindustrialized. | <ul style="list-style-type: none"> <li>Children provide income to the family.</li> <li>Contraceptives are not affordable.</li> </ul>                                                                                                                                                                                                            |
| Women in Kenya lack education and job opportunities.                                  | <ul style="list-style-type: none"> <li>Women in Kenya have fewer career/work choices so they have children at an earlier age than women in the United States do.</li> <li>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.</li> </ul> |
| There is no pension system to support people as they age in Kenya.                    | <ul style="list-style-type: none"> <li>More children are needed to support parents in old age.</li> </ul>                                                                                                                                                                                                                                       |
| There is less education about family planning in Kenya.                               | <ul style="list-style-type: none"> <li>There is less ability to control fertility.</li> </ul>                                                                                                                                                                                                                                                   |
| Cultural values favor larger families in Kenya.                                       | <ul style="list-style-type: none"> <li>More children mean greater social status.</li> </ul>                                                                                                                                                                                                                                                     |
| Women in Kenya have a low social status/marry at an earlier age.                      | <ul style="list-style-type: none"> <li>Women have little or no choice/control of their fertility; they have more years of childbearing.</li> </ul>                                                                                                                                                                                              |
| There is a preference for male children in Kenya.                                     | <ul style="list-style-type: none"> <li>People have more children to get as many sons as possible, because sons will continue to support the family.</li> </ul>                                                                                                                                                                                  |
| The cost of raising a child in the United States is much higher than in Kenya.        | <ul style="list-style-type: none"> <li>People in the United States choose to have smaller families.</li> </ul>                                                                                                                                                                                                                                  |
| Abortion is illegal in Kenya.                                                         | <ul style="list-style-type: none"> <li>Results in more births.</li> </ul>                                                                                                                                                                                                                                                                       |
| Religious values in Kenya prohibit contraception/abortion.                            | <ul style="list-style-type: none"> <li>Results in more births.</li> </ul>                                                                                                                                                                                                                                                                       |



## Scoring Guidelines for Question 4 (*continued*)

- (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).

## Sample Student Responses for Question 4

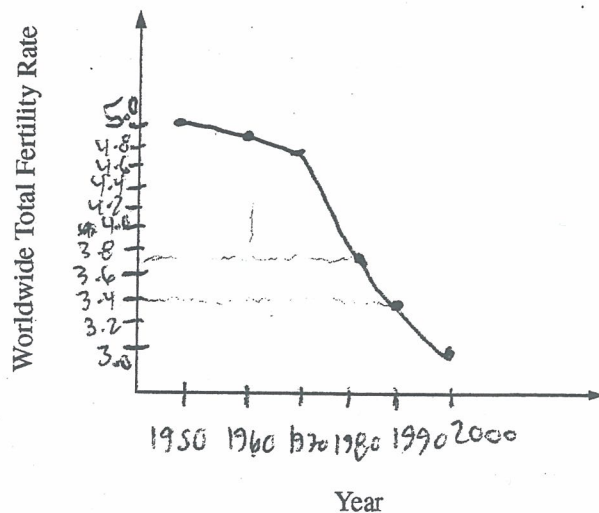
### Student Response 1 (Score: 9)

4. Answer the following regarding world human population.

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

Table 1:  
Worldwide  
Total Fertility  
Rate (TFR)

| Year | TFR * |
|------|-------|
| 1950 | 5.0   |
| 1960 | 4.9   |
| 1970 | 4.7   |
| 1980 | 3.7   |
| 1990 | 3.4   |
| 2000 | 3.0   |



(b) One cause for the trend displayed in part A is that birth control use has increased which allows for women to have less children by mistake which lowers the world wide Total Fertility Rate. Secondly, more women have joined the work force (in recent history) due to the increase in education opportunities for women which decreases the amount of time for women to spend with potential children which causes women to not want to have many children which lowers the worldwide TFR.

(c) 1 economic factor that accounts for a higher TFR in Kenya than the USA is that less women in Kenya can afford birth control because ~~Kenya~~ Kenya is a developing nation which causes many women in Kenya to have more kids <sup>than</sup> ~~women~~ women in the USA. <sup>& increases the TFR</sup> Secondly, women in Kenya get married at a ~~much~~ much younger age than women in the USA which means that they are sexually active for a longer period of time which gives them more opportunities to get pregnant & have kids which raises their TFR.

(d) ~~1 human activity is the increase in medicine practice which leads to advancements in medicine which leads to less deaths which increases the population which increases the Earth's biodiversity.~~ 1 human activity is the increase in medicine practice which leads to advancements in medicine which leads to less deaths which increases the population which increases the Earth's biodiversity. Secondly, education opportunities have increased which allows for people to get better jobs which allows for people to make more money which allows for people to have good living conditions for children which increases the population which increases the Earth's biodiversity.



## **Commentary**

In part (a) 2 points were earned: 1 point for correctly plotting all data points and 1 point for correctly setting up both axes.

In part (b) 1 cause point was earned for the statement that “birth control use has increased,” and 1 linked discussion point was earned for the statement that birth control “allows for women to have less children.” A cause point was earned for stating that “more women have joined the work force.” The linked discussion point could have been earned for the explanation that increased educational opportunities cause “women to not want to have many children,” but the maximum of 3 points for part (b) had already been earned.

In part (c) 4 points were earned: 1 point for stating that “less women in Kenya can afford birth control” and 1 linked discussion point for the explanation that this “causes many women in Kenya to have more kids.” A point was earned for the statement that “women in Kenya get married at a much younger age,” and 1 linked discussion point was earned for explaining that this “gives them more opportunities to get pregnant.”

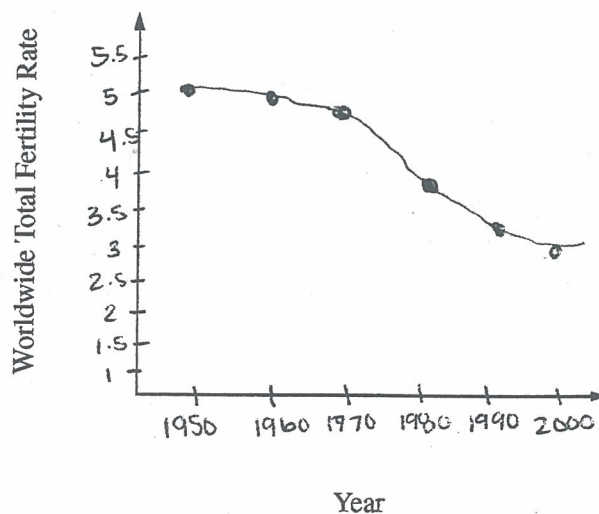
No points were earned in part (d) for the discussions of medicine and education.

4. Answer the following regarding world human population.

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

Table 1:  
Worldwide  
Total Fertility  
Rate (TFR)

| Year | TFR |
|------|-----|
| 1950 | 5.0 |
| 1960 | 4.9 |
| 1970 | 4.7 |
| 1980 | 3.7 |
| 1990 | 3.4 |
| 2000 | 3.0 |



b) Worldwide fertility rate decreased over time because of a rise in awareness of family planning and growth of educational and occupational opportunities for women.

c) As the average income in the United States far surpasses that of the people in Kenya the United States infant mortality rate is much lower because better health care can be afforded. The crude birth rate in the United States is also much lower than Kenya's. This is because of more advanced family planning in the United States due to education and effective methods of birth control.

a) As the world's total population grows, so does the space that humans need to occupy. This reduces biodiversity as other habitats are being destroyed to make room for people. In addition the amount of food needed increases as the population increases. This also decreases biodiversity as humans rapidly consume without allowing much time for regeneration.



### **Commentary**

In part (a) 2 points were earned: 1 point for correctly plotting all data points and 1 point for correctly setting up both axes.

In part (b) 1 cause point was earned for identifying the “rise in awareness of family planning,” and 1 cause point was earned for “growth of educational and occupational opportunities for women.” No discussion was linked to these causes and thus that point was not earned.

In part (c) 3 points were earned: 1 factor point for stating that “the United States infant mortality rate is much lower” and 1 linked discussion point for the explanation that “better health care can be afforded.” A factor point was earned for the statement that there is “more advanced family planning in the United States due to education and effective methods of birth control.” No discussion links the availability of family planning to the TFR so the discussion point was not earned.

No points were earned in part (d) because no specific human activity is identified.

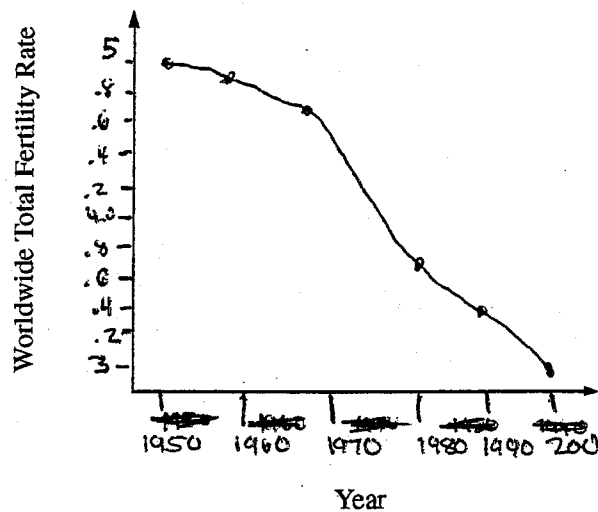
### Student Response 3 (Score: 2)

4. Answer the following regarding world human population.

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

Table 1:  
Worldwide  
Total Fertility  
Rate (TFR)

| Year | TFR |
|------|-----|
| 1950 | 5.0 |
| 1960 | 4.9 |
| 1970 | 4.7 |
| 1980 | 3.7 |
| 1990 | 3.4 |
| 2000 | 3.0 |



B) The trend of in the TFR occurred because many countries reached ~~maximum~~ population sustainable yield whether it be the amount of land they had available to house the people, or the amount of food and water the country had to provide the people in the country.

- Disease <sup>and war</sup> is also responsible for the decrease, because many countries that are home to the mass population, are also the places were disaster struck, like the AIDS epidemic in Africa.

C) In Kenya, people need to have children to help provide for the family. More children means more hands to help around the home or on the farm. In America, only one person is really needed to provide for the whole family.

D) People are having many children to either please their religious beliefs, or social standards.

### Commentary

In part (a) 1 point was earned for correct setup of both axes. Two data points are misaligned.

No points were earned in part (b) for two invalid causes of decreased TFR: "many countries reached sustainable yield" and "[d]isease and war is [sic] also responsible for the decrease."

In part (c) 1 point was earned for the statement that children provide "more hands to help around the home or on the farm."

No points were earned in part (d) as no specific human activities are provided.