ENVIRONMENTAL SCIENCE

SECTION I

Time—1 hour and 30 minutes

80 Questions

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 circle 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 following.

(A) Indicator species
(B) Keystone species
(C) Pioneer species
(D) Invasive species

C 1. These species are the first to colonize a disturbed area and may facilitate the colonization of other organisms by stabilizing soil.

A 2. The abundance or scarcity of this species type signals a change in the abiotic conditions of a particular ecosystem.

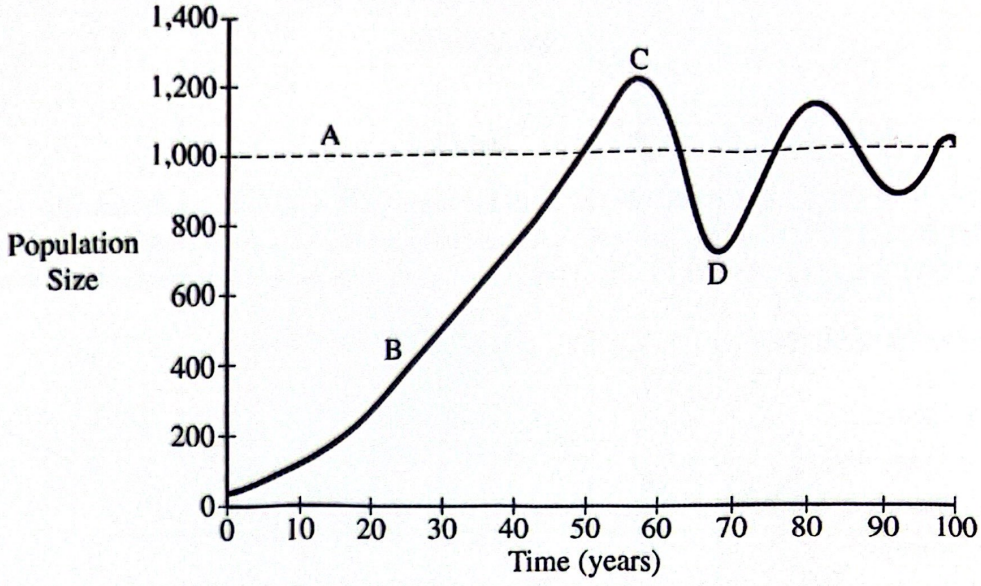
B 3. An example of this species type is the bumblebee, whose population decline leads to a change in community structure and reduced biodiversity.

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Questions 4 - 6 refer to the following diagram.

The diagram represents a population size over a 100-year period.



a

4. This represents the carrying capacity (K) of the population.

b

5. This represents the population when resources needed for growth are abundant and the population size increases rapidly.

c

6. This represents the culmination of a population dieback.

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Questions 7 - 9 refer to the following atmospheric processes or components.

(A) Thermal inversion
(B) El Niño
(C) Hadley cell
(D) Rain shadow

b

7. This is a periodic phenomenon associated with changing surface temperatures in the Pacific Ocean that can lead to global changes to rainfall, wind, and ocean circulation patterns.

d

8. Reduced rainfall on the downwind or leeward side of a mountain range results in the formation of dry, desertlike conditions.

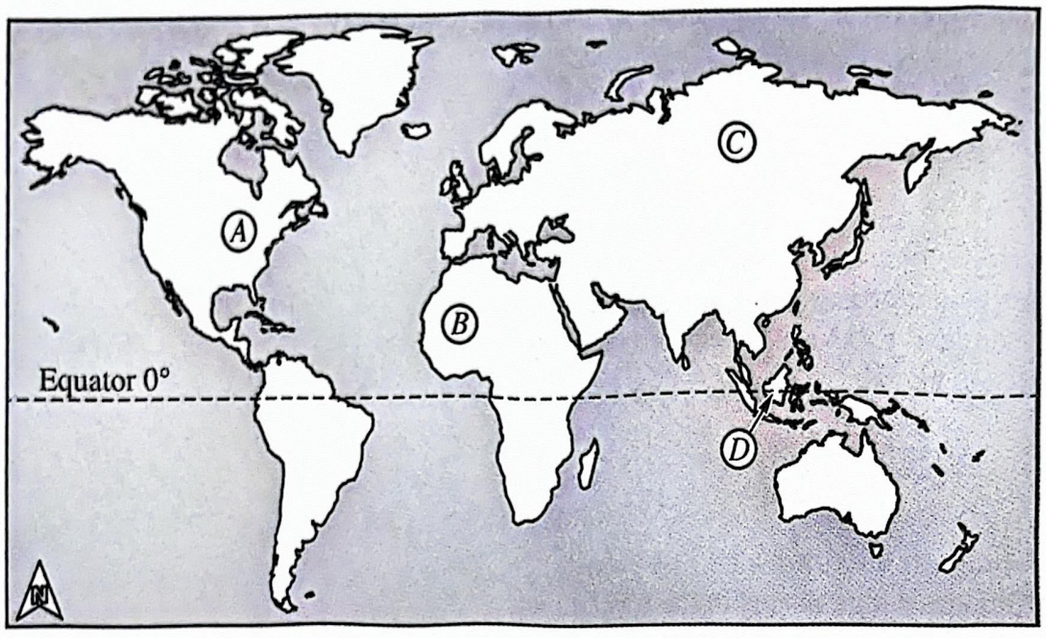
A

9. This process is a local reversal of the typical tropospheric pattern of temperature decreasing as altitude increases.

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Questions 10 - 12 refer to the following map.



A 10. This area on the map is located in a temperate seasonal forest biome.

C 11. This area on the map has the highest primary productivity compared to the other areas.

C 12. This area on the map is likely to be the first affected by a rise in sea level.

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Part B

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

13. Which of the following best describes a benefit of clear cutting?

(A) Clear cutting increases the amount of land available for crop growth.

(B) Trees are a natural source of VOCs, so clear cutting leads to a reduction in the amount of stratospheric ozone.

(C) Clear cutting releases carbon stored in trees and other plants, increasing soil fertility.

(D) Clear cutting allows trees to be sustainably harvested for lumber annually.

14. Which of the following strategies would best maintain the regulating ecosystem services of coastal wetlands?

(A) Increasing the water-storage capacity of upstream dams

(B) Increasing the minimum distance from shore for new development

(C) Issuing more fishing licenses for coastal wetlands

(D) Filling in low-lying wetlands along lake shorelines with silt

15. Which of the following identifies exposure to an indoor air pollutant that is the second leading cause of lung cancer in the United States?

(A) Acute exposure to chlorofluorocarbons

(B) Acute exposure to mercury

(C) Chronic exposure to carbon monoxide

(D) Chronic exposure to radon

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Questions 16 - 20 refer to the article below.

World's Largest Collection of Ocean Garbage Is Twice the Size of Texas

...

The Great Pacific Garbage Patch, a collection of plastic ... floating trash halfway between Hawaii and California, has grown to more than 600,000 square miles, a study found. That's twice the size of Texas. Winds and converging ocean currents funnel the garbage into a central location, said study lead author Laurent Lebreton of the Ocean Cleanup Foundation, a non-profit organization that spearheaded the research.

First discovered in the early 1990s, the trash in the patch comes from around the Pacific Rim, including nations in Asia and North and South America, Lebreton said.

The patch is not a solid mass of plastic. It includes about 1.8 trillion pieces and weighs 88,000 tons — the equivalent of 500 jumbo jets.... The research — the most complete study undertaken of the garbage patch — was published in March in the peer-reviewed journal Scientific Reports.

...

The study was based on a three-year mapping effort by an international team of scientists affiliated with the Ocean Cleanup Foundation, six universities and an aerial sensor company.

...

No governments have stepped up to clean the trash, which is in international waters, so it's up to privately funded groups such as the Ocean Cleanup Foundation to take the lead in getting rid of the garbage. There's a sense of urgency, said Joost Dubois, a spokesman with the foundation. "It's a ticking time bomb of larger material," Dubois said. "We've got to get it before it breaks down into a size that's too small to collect and also dangerous for marine life."

Since plastic has been around only since the 1950s, there's no way of knowing exactly how long it will last in the ocean. If left alone, the plastic could remain there for decades, centuries or even longer.

...

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16. Which of the following best describes the author's claim about the Great Pacific Garbage Patch?

    (A) It will be cleaned up by the countries surrounding the Pacific Ocean.

    (B) It covers a smaller area than previous studies indicated.

    (C) It will not be a threat to marine life in a few decades.

    (D) It needs to be cleaned up before the plastic gets too small to collect.

17. Based on the article, which of the following best describes one assumption that the author made about the plastic?

    (A) Plastic is more expensive than glass is.

    (B) Plastic is difficult to manufacture.

    (C) Plastic is not easily decomposed.

    (D) Plastic is recycled less often than glass is.

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18. Which of the following is the best supporting evidence that the longitudinal study described in the article was the most thoroughly researched study to date of the Great Pacific Garbage Patch?

(A) The study concluded that the Great Pacific Garbage Patch covered 600,000 square miles.

(B) The study was published in March 2018 in the peer-reviewed journal *Scientific Reports*.

(C) The study was based on a three-year mapping effort by an international team of scientists.

(D) The study was conducted after the 1950s when plastics were first manufactured.

19. Which of the following would be the most effective strategy to use in countries surrounding the Pacific Ocean to prevent the Great Pacific Garbage Patch from increasing in size?

(A) Use plastic instead of paper for packing material when shipping fragile items in boxes.

(B) Reduce the number of landfills in areas along the Pacific Ocean.

(C) Improve plastic manufacturing methods to decrease the cost of plastic production.

(D) Institute incentives for plastic recycling.

20. Based on the article, what is the average weight of a piece of plastic in "the Great Pacific Garbage Patch?"

(A) 4.9×10^{-8} ton

(B) 1.8×10^{-4} ton

(C) 2.1×10^{-2} ton

(D) 2.0×10^{7} ton

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21. Iceland is an island in the northern Atlantic Ocean with unique geology. The island is formed by a hot spot but is also located on a divergent plate boundary.

Which of the following energy sources can be used as a result of Iceland's geology?

(A) Solar
(B) Nuclear
(C) Geothermal
(D) Wind

22. A student investigated the effect of climate change on marine species. The student placed equal volumes of marine algae in three identical tanks with the same amount of water and nutrients. Tank 1 had a water temperature of 5°C, Tank 2 had a water temperature of 15°C, and Tank 3 had a water temperature of 25°C. Productivity rates of the algae were determined by measuring dissolved oxygen levels for each tank.

Which of the following best identifies the independent variable in the experiment?

(A) The amount of water and nutrients in each tank
(B) The three identical tanks with marine algae
(C) The water temperature of each tank
(D) The amount of dissolved oxygen

23. Which of the following best explains why biomass, such as wood, is often used as a fuel source in developing countries?

(A) Harvesting wood has minimal short-term environmental impacts.
(B) Wood can be converted into different fuel sources, such as anthracite.
(C) Burning wood as a heat source releases low amounts of greenhouse gases.
(D) Wood is easily accessible and inexpensive to obtain.

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Questions 24 - 27 refer to the following table.

A herd of deer was introduced to an island in the 1950s, and its population had grown to over 2,000 individuals by 1980. Researchers began taking a yearly census of the deer and of an introduced population of a predator species of wolves.

Year	Deer Population	Wolf Population
1980	2,150	0
1981	2,100	0
1982	2,200	0
1983	1,750	10
1984	1,500	15
1985	1,100	25
1986	750	21
1987	700	18
1988	725	15
1989	715	16

24. Which of the following best explains what happened to the wolf population after 1985 ?

(A) The population declined rapidly as a result of a bioaccumulation of toxins because the wolves were top predators.

(B) As the wolves continued to eat the deer, there was no longer enough food to support them, resulting in their extinction.

(C) The wolf population's carrying capacity was reached in 1985, and there was no longer any change in the population size.

(D) The wolf population began to decrease because of a shortage of available resources.

25. Based on the data in the table, in which year was the deer population greatest?

(A) 1980

(B) 1982

(C) 1985

(D) 1989

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26. The amount of local vegetation and its health increased dramatically after the introduction of wolves to the island. Which of the following best explains why this change in the vegetation occurred?

(A) As the wolves consumed the deer, there was a decrease in the consumption of the plants by the deer.

(B) The wolves are herbivores, which reduced the pressure on the plants on the island and increased the survivorship of most producer species.

(C) There was an increase in agriculture in the area, which decreased competition for plant species and decreased biodiversity in local plants.

(D) The introduction of wolves initiated primary succession in the island's ecosystems.

27. Which of the following best explains why there are so few wolves relative to the number of deer on the island?

(A) Since wolves are so much larger than deer, they require more food to support their bodies.

(B) The deer are a specialist species and the wolves are a generalist species.

(C) Only about 10 percent of the energy from the deer can be passed on to the wolves.

(D) The wolves are an invasive species and are not able to compete with the native deer for food.

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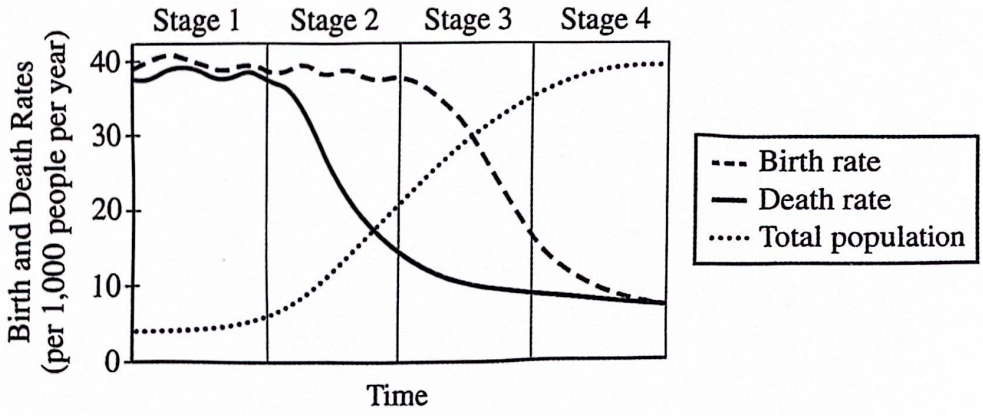
28. The following table shows the toxicity ratings of four different insecticides on organisms. The toxicity ratings range from 1 to 5, with 1 being minimally toxic and 5 being highly toxic.

Relative Toxicity of Insecticides to Organisms

Insecticide	Rat	Fish	Bird	Honeybee
Permethrin	2	4	2	5
DDT	3	4	2	2
Lindane	2	3	2	4
Malathion	2	2	1	4

Based on the data in the table, which of the following insecticides is most toxic to organisms?

(A) Permethrin
(B) DDT
(C) Lindane
(D) Malathion



29. Which of the following would best help a country progress from stage 2 to stage 3 of the demographic transition model shown?

(A) Greater availability of birth control methods
(B) Access to vaccines and antibiotics
(C) Development of wastewater treatment facilities
(D) Increased availability of healthier food options

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30. European rabbits were introduced into Australia in the 1800s. The rabbit population grew quickly and became an environmental hazard. The rabbits consumed native plants and threatened Australia's croplands.

Which of the following is the best example of a biological control method the Australian government could use to reduce rabbit populations?

(A) Spraying rabbit-infested croplands with pesticides that significantly reduce the food supply

(B) Planting more native plants in areas with large rabbit populations

(C) Introducing pathogens that naturally target the rabbits but would not affect other mammals

(D) Fumigating rabbit burrows with poison that is designed to reduce mammal reproduction

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Questions 31 - 33 refer to the following graphs.

Researchers conducted an experiment to determine the effects of applying manure-based compost on crop fields. To study the short-term effects of compost application, the researchers applied the compost to experimental fields each spring for three consecutive years. To study the long-term effects of compost application, the researchers continued monitoring the fields for an additional three years without any additional application of compost. The average sediment loss and runoff volume over three years is shown in the following graphs for each condition.

Figure 1

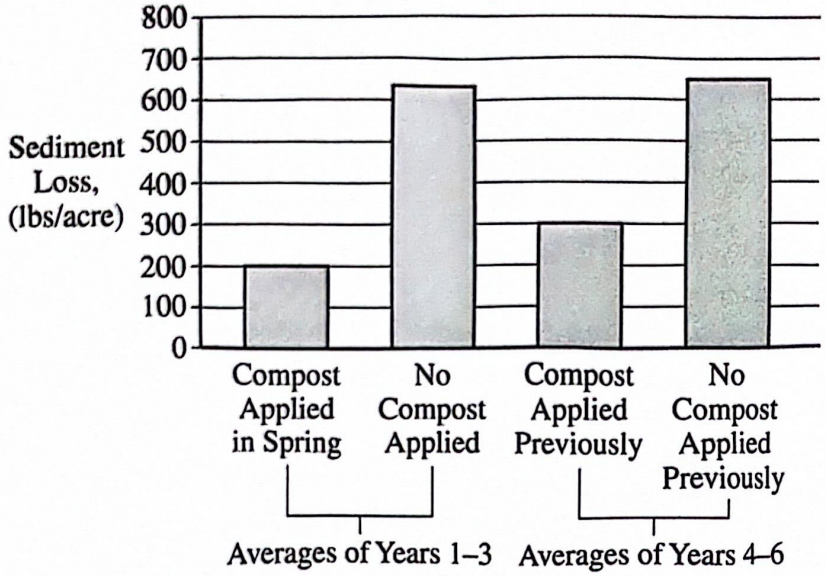
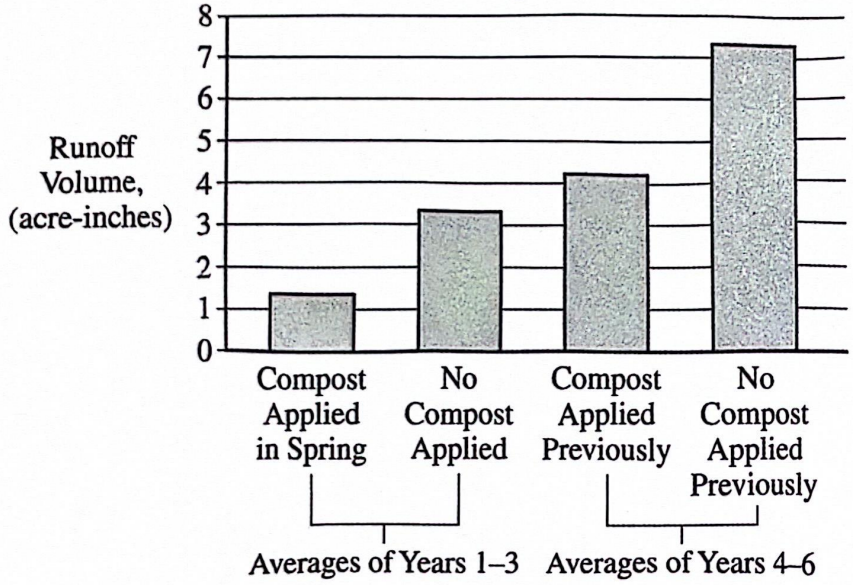


Figure 2



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31. Based on the data in the graphs, which of the following best describes the short-term effects of applying compost to the crop fields?

(A) Applying compost increased sediment loss and decreased runoff from the fields.

(B) Applying compost increased sediment loss and increased runoff from the fields.

(C) Applying compost decreased sediment loss and increased runoff from the fields.

(D) Applying compost decreased sediment loss and decreased runoff from the fields.

32. Based on the data in the graphs, which of the following values represents the average sediment loss in the experimental fields with compost applied previously in years 4 through 6 ?

(A) 200 lbs/acre

(B) 300 lbs/acre

(C) 600 lbs/acre

(D) 700 lbs/acre

33. Which of the following best identifies the control group in the study?

(A) Fields with compost applied in the spring

(B) Fields with no compost applied

(C) Sediment loss (lbs/acre)

(D) Runoff volume (acre-inches)

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34. Eastern gray squirrels have an average life span of about six years, and populations typically display a Type II survivorship curve.

Based on the information given, which of the following best describes the chance of mortality for eastern gray squirrels?

(A) The chance of mortality is highest when they are first born.

(B) The chance of mortality is highest when they are 3 to 4 years old.

(C) The chance of mortality is lowest when they are 3 to 4 years old.

(D) The chance of mortality is constant throughout their life span.

35. Which of the following best explains why ocean acidification is damaging to corals?

(A) Corals cannot easily extract the nutrients from food in acidic ocean waters because the nutrients dissolve too quickly.

(B) Coral reproduction stops in acidic ocean waters because the algae that live inside corals can no longer produce reproductive cells.

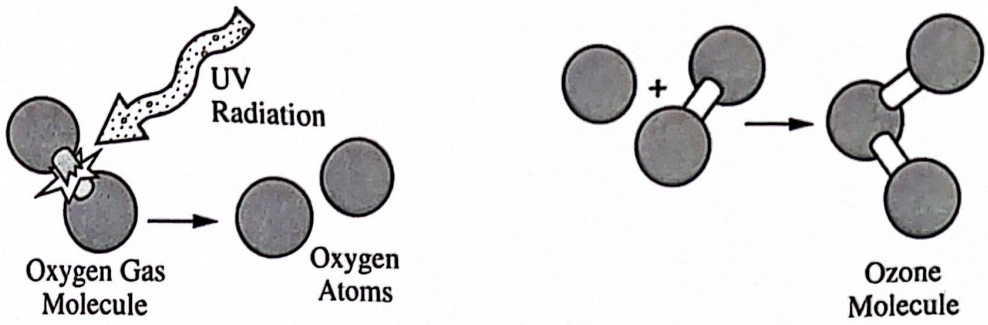
(C) Corals are more susceptible to harmful ultraviolet rays in acidic ocean waters because of a decrease in ozone.

(D) Corals are less able to build their outer shells in acidic ocean waters because of a decrease in carbonate ions.

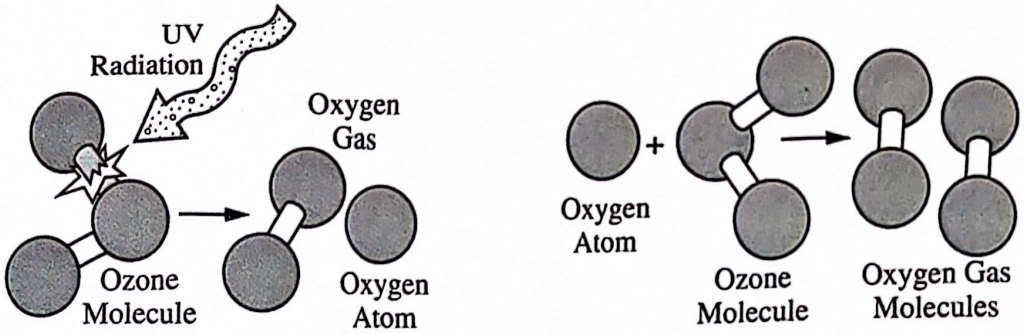
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Questions 36 and 37 refer to the following diagrams.

REACTION A



REACTION B



36. Which of the following is illustrated by the reactions in the diagram?

(A) The production of oxygen during photosynthesis

(B) The formation of ozone in the troposphere

(C) The production and destruction of ozone in the stratosphere

(D) The release of oxygen during incomplete combustion of fossil fuels

37. Which of the following molecules can interfere with the process shown in the diagram?

(A) Methane

(B) Chlorofluorocarbons

(C) Volatile organic compounds

(D) Lead

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38. European honeybees are a nonnative species to North America. Many of the domesticated colonies in the United States have suffered a recent loss of honeybees, while wild colonies have not experienced a decline.

Which of the following best explains why there has been a decline in domesticated honeybee colonies?

(A) Since domesticated honeybees are raised by humans, they are less fearful and more likely to be captured by poachers than those in wild colonies are.

(B) Domesticated colonies are likely suffering from decreased farmland fragmentation, leading to fewer crops being available for pollination.

(C) Domesticated colonies are experiencing a decrease in genetic diversity from selective breeding by humans, making them more vulnerable to sudden environmental changes than honeybees from wild colonies are.

(D) Wild colonies are populated by an invasive honeybee species that can outcompete the domesticated, nonnative European honeybees for resources.

39. Which of the following is a disadvantage of hydrologic fracturing or fracking?

(A) The machinery used in the injection process can produce waste heat that supports native soil organisms.

(B) The minerals removed during the injection process can produce mining waste called slag and tailings.

(C) The fluids used in the injection process can cause groundwater contamination and the release of VOCs.

(D) The injection process can produce overburden that damages vegetation and increases soil erosion.

40. The western bluebird (*Sialia mexicana*) is a small thrush that is negatively affected when exposed to noise pollution as a juvenile. The western bluebird is found primarily in forested areas and around farmlands. Which of the following strategies would most effectively reduce the noise pollution affecting the western bluebird?

(A) Shifting from diesel buses to electric buses in urban areas

(B) Replacing solar panels with wind turbines

(C) Increasing the fuel efficiency of motor vehicles

(D) Restricting automobile traffic in parks and preserves

41. Which of the following is a source of renewable energy that releases carbon dioxide and other greenhouse gases into the atmosphere during energy production?

(A) Passive solar

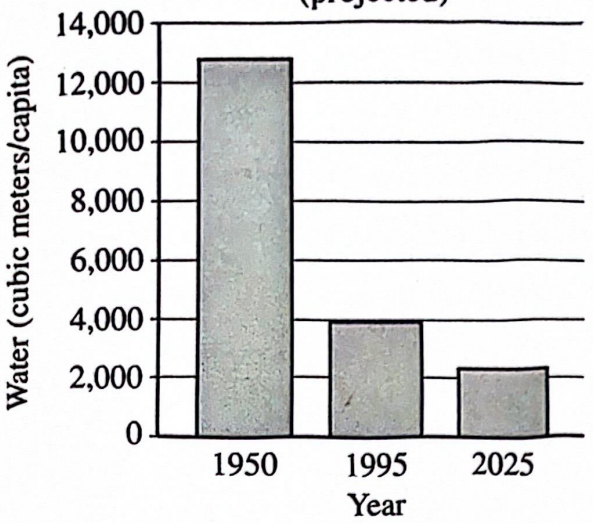
(B) Biomass

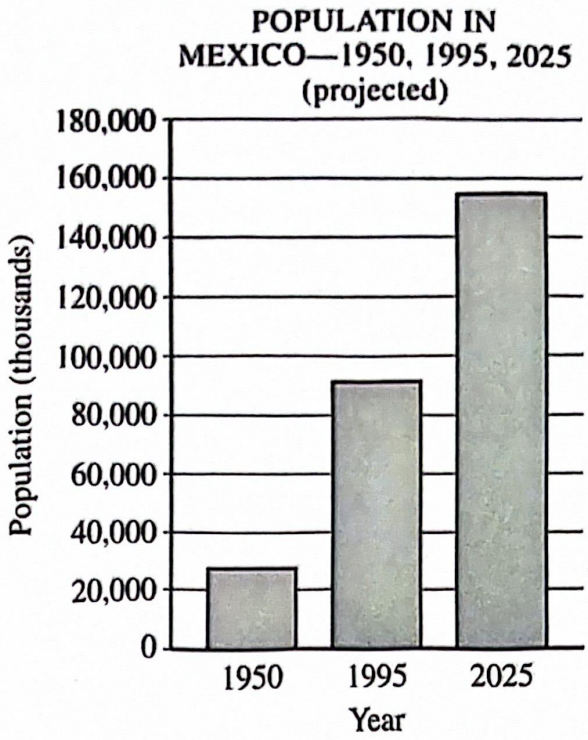
(C) Nuclear

(D) Hydropower

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42. Which of the following conclusions is best supported by the data in the graphs?

(A) Population growth in Mexico has led to an increase in tropical deforestation.

(B) The availability of freshwater resources per capita decreased as the population in Mexico increased.

(C) Increased population size in Mexico caused a decrease in water quality.

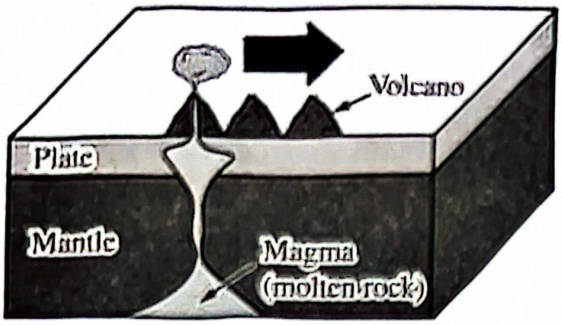
(D) The amount of water available for recreation has increased as the population of Mexico has decreased.

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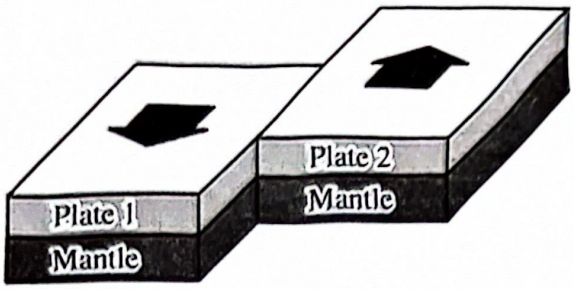
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43. The following diagrams show different types of tectonic plate movement with the arrows indicating the direction. Which of the following diagrams shows a divergent plate boundary that results in seafloor spreading?

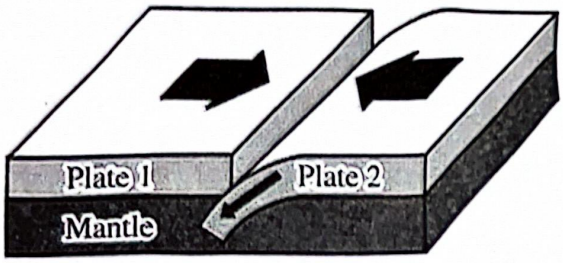
(A)



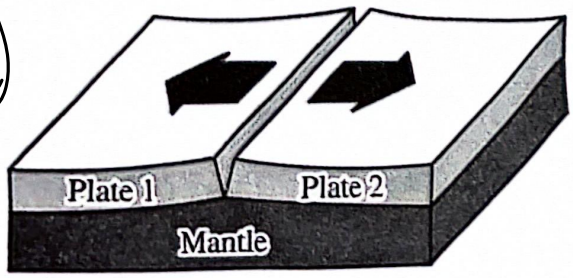
(B)



(C)



(D)



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44. A homeowner in North Carolina uses an average of 1,077 kWh of electricity per month. The current price of electricity from a power company is $0.13 per kWh.

Which of the following approaches should be used to calculate the annual cost of electricity for the homeowner?

(A) $\frac{1{,}077 \text{ kWh per month}}{\$0.13 \text{ per kWh}} \times 12 \text{ months}$

(B) $1{,}077 \text{ kWh per month} \times 12 \text{ months} \times \$0.13 \text{ per kWh}$

(C) $\frac{1{,}077 \text{ kWh per month} \times \$0.13 \text{ per kWh}}{365 \text{ days}}$

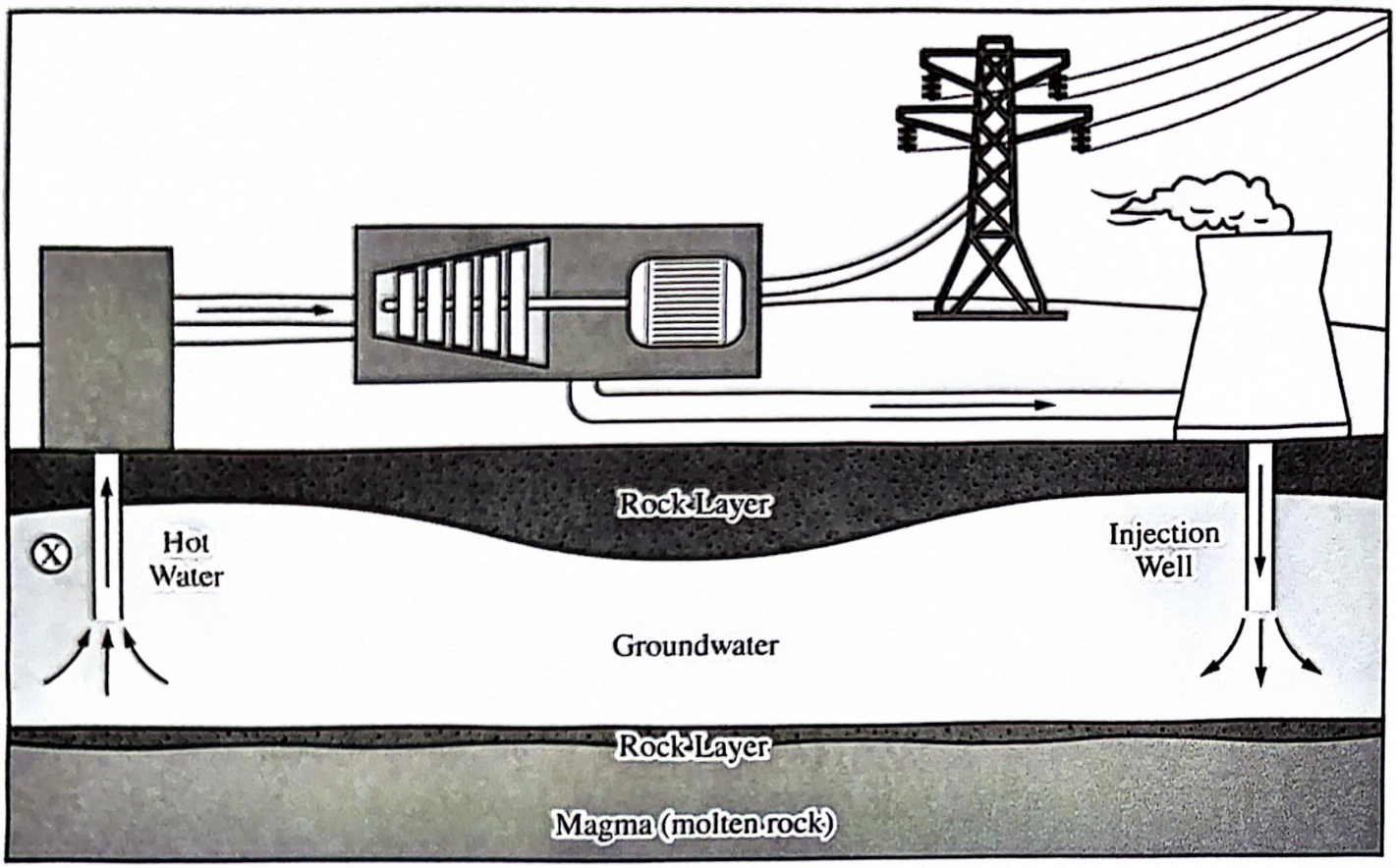
(D) $1{,}077 \text{ kWh per month} \times \$0.13 \text{ per kWh} \times \frac{365 \text{ days}}{1 \text{ year}}$

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Question 45 - 48 refer to the following diagram.

The following diagram shows one way that electricity can be produced using the energy from Earth.



45. Which of the following types of energy production is illustrated in the diagram?

(A) Biomass
(B) Nuclear
(C) Hydroelectric
(D) Geothermal

46. Based on the diagram, which of the following best explains why the water at location X is hot?

(A) As the water moves up through the ground, pressure is released, which causes the water to heat up.
(B) The groundwater is being heated by near-surface magma, or molten rock, which is below it.
(C) Underground rock layers get warmer near the surface, easily heating the groundwater.
(D) The water injected back into the ground is much warmer than the water pulled up at location X.

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47. Which of the following best explains how water is used to generate electricity in the diagram?

(A) After the hot water comes to the surface, it passes over a waterwheel, which turns a generator that rotates a turbine.

(B) The water is first cooled and then pumped into a water tower for future use.

(C) When the hot water is brought to the surface as steam, it is used to turn a turbine, which rotates a generator.

(D) The heat from the water is extracted by a fuel cell and then used to make electricity in the turbine.

48. If pollution is being released into the atmosphere from the electricity production illustrated in the diagram, which of the following pollutants is most likely to be released?

(A) Hydrogen sulfide

(B) NO_x

(C) Uranium-235

(D) Mercury

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49. All the trees are cut down along a small stream.

Which of the following changes in water temperature and dissolved oxygen would be predicted to occur in the stream following the clear cutting?

	Water Temperature	Dissolved Oxygen
(A)	Increase	Increase
(B)	Increase	Decrease
(C)	Decrease	Increase
(D)	Decrease	Decrease

50. Which of the following is an advantage of generating electricity from solar energy?

(A) Large solar energy farms placed in desert ecosystems increase biodiversity of desert organisms.

(B) Using photovoltaic cells to produce electricity releases minimal amounts of greenhouse gases into the atmosphere.

(C) The installation of panels that contain photovoltaic cells is less expensive than using other forms of electricity generation.

(D) Passive solar energy systems can collect and store energy for use when sunlight is not present.

51. The cheetah, an African predator, currently has a range spanning much of eastern and southern Africa. Historically, the cheetah existed throughout much of Africa, the Middle East, and southern Asia. As a consequence of habitat fragmentation, the cheetah population has declined such that the species is now considered vulnerable to extinction. One reason for their vulnerability is a lack of genetic diversity in the species.

Based on the information given, which of the following has most likely led to the loss of genetic diversity in the cheetah population?

(A) Demographic transition

(B) Biomagnification

(C) Population bottleneck

(D) Carrying capacity

52. Which of the following best describes how salinization occurs?

(A) The nitrates from fertilizers combine with water in the soil to create toxic saline conditions for plants.

(B) Drip irrigation systems are highly efficient and can lead to waterlogging in arid climates.

(C) High rates of evaporation leave traces of salt in soil that build up over time.

(D) The spring snowmelt increases the concentration of salt in soil downstream.

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53. In 1973, there were approximately 2 grams of lead in each gallon of gasoline and approximately 200,000 tons of lead were released into the atmosphere from the combustion of gasoline in vehicles around the world. How many gallons of gasoline would have to be combusted to release that amount of lead?

(Note: Assume that 1 U.S. ton = 900,000 grams)

(A) 4.0×10^5 gallons

(B) 9.0×10^{10} gallons

(C) 1.8×10^{11} gallons

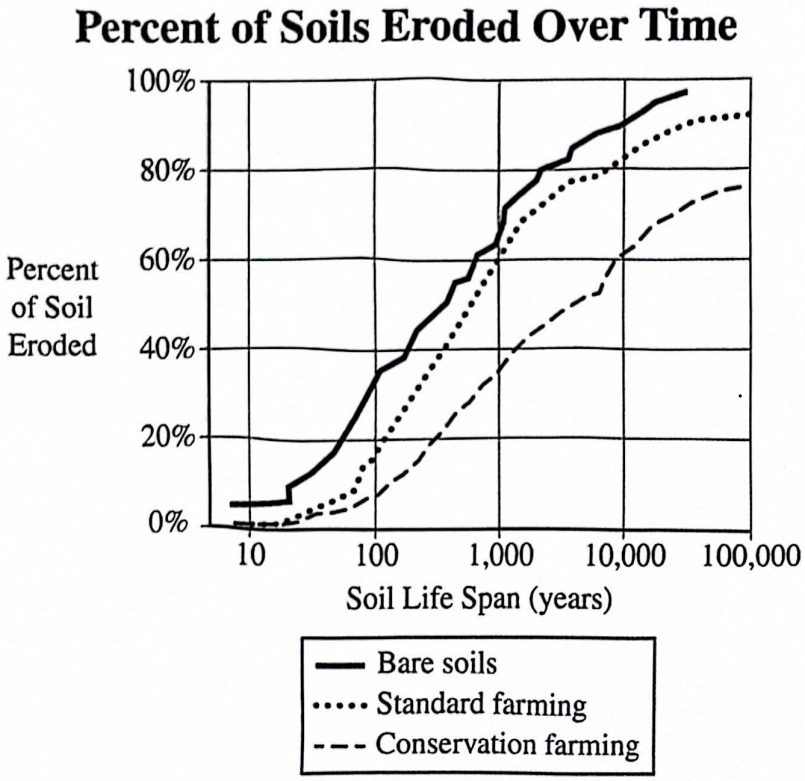
(D) 3.6×10^{11} gallons

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Questions 54 - 57 refer to the following.

Soil life spans are measured by the number of years it would take to erode 30 centimeters of topsoil based on current erosion rates. The following graph shows soil life spans based on three different conditions. Bare soils have no vegetation, standard farming does not use soil conservation practices, and conservation farming uses soil conservation practices.



54. Based on the data in the graph, which of the following is the approximate number of years it would take to erode 60% of soils in areas where standard farming is practiced?

(A) 100 years
(B) 500 years
(C) 1,000 years
(D) 10,000 years

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55. Based on the data in the graph, which of the following statements best describes the difference at 100 years between soils where standard farming was used and soils where conservation farming was used?

(A) A greater percentage of soils where standard farming was practiced than soils where conservation farming was practiced was eroded by 100 years.

(B) More than 35% of soils where standard farming was practiced was eroded by 100 years compared with 15% for soils where conservation farming was practiced.

(C) A greater percentage of soils where conservation farming was practiced than soils where standard farming was practiced was eroded by 100 years.

(D) More than 20% of soils where conservation farming was practiced was eroded by 100 years compared with 5% for soils where standard farming was practiced.

56. Which of the following is an example of a farming technique practiced specifically to prevent soil erosion?

(A) Application of pesticides

(B) Slash-and-burn farming

(C) Flood irrigation

(D) No-till agriculture

57. Which of the following best describes an environmental problem associated with soil erosion that could affect aquatic environments?

(A) A loss of topsoil from aquaculture farming can result in decreased productivity.

(B) Increased sedimentation can lead to decreased primary productivity.

(C) An addition of soil can lead to increased activity by visual predators.

(D) Decreased sedimentation can lead to the accumulation of new wetlands.

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Questions 58 - 61 refer to the following article.

Warmer Water Could Cool Montana's Trout Fishing Economy

Scientists with the U.S. Geological Survey [USGS], Montana Fish, Wildlife & Parks and the University of Montana studied how climate change affected trout fisheries across 3,100 miles of rivers in Montana from 1983 to 2017. They found that over the past several decades, Montana's trout fishing economy was resilient in the face of climate extremes. However, they also found that 35% of Montana's cold-water habitats may no longer be suitable for trout by 2080, resulting in the loss of $192 million per year in state revenue.

"Trout fisheries have enormous cultural, economic and ecological importance in Montana and worldwide, yet even Montana's resilient trout fisheries could be vulnerable to future climate change," said Timothy Cline, a USGS scientist and the study's lead author.

The study found that several extreme droughts reduced [streamflows] and increased water temperatures, causing stressful conditions for trout and numerous fishing site closures in Montana. Anglers [fishers] responded to droughts by moving to cooler fishing locations that were more favorable to trout during extreme conditions.

"By moving to other fishing areas that were more favorable during drought, visitors kept trout fishing revenue in the state rather than choosing to travel elsewhere," Cline said. "Trout fishing in Montana has been remarkably resilient to changing conditions."

The concentration of anglers fishing in the region doubled during the study period. Cold-water sections of river, where trout were dominant, had 10 times the number of anglers than nearby warmer-water sections, and most of those anglers were visitors from out of state. These findings demonstrate that trout fishing was a significant recreational draw and economic contributor to Montana despite drought conditions.

However, the continued loss of suitable trout habitat could further test the resiliency of the state's fishing economy in coming decades. Montana could lose almost $200 million per year in angling revenue, or about 30% of its current trout fishing economy, according to the study.

"Our findings underscore the importance of maintaining a diversity of cold-water habitats and [streamflows] that provide options for anglers to move to as conditions change," said Clint Muhlfeld, a USGS scientist and co-author on the study. "Such diversity could help mitigate the socioeconomic impacts of climate change on valuable freshwater fisheries."

Credit: U.S. Geological Survey

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58. Which of the following best states the author's primary claim in the article?

(A) Climate change has resulted in lower water levels and higher temperatures in Montana waterways and has economically destroyed the trout fishing industry.

(B) The increase in water temperature has reduced trout populations, pushing Montana fisheries to begin catching other species of fish.

(C) The warming of the rivers in Montana have caused trout to migrate to new locations, stimulating the fishing industry outside of Montana.

(D) Changes in the water temperatures have not yet had a negative impact on Montana's trout fishing economy, but continued warming could cost Montana fisheries millions of dollars in revenue.

59. According to the information in the article, which of the following best describes how the rivers in Montana provide cultural ecosystem services?

(A) The trout in the rivers were resilient in the face of climate extremes.

(B) The rivers provided significant recreational opportunities for fishers.

(C) The water in the rivers can be used as a public water supply.

(D) The river ecosystem regulates and protects against floods and droughts.

60. Which of the following is the most likely perspective that the author has in the article?

(A) Climate change is responsible for the increase in drought and higher water temperatures.

(B) There will be an increase in the number of fishers on Montana rivers even if the rising water temperatures remove trout habitat.

(C) Climate change is negatively affecting the Montana fisheries more than it is affecting other trout fisheries across the country.

(D) The number of fisheries in Montana will increase tenfold as river temperatures continue to rise.

61. Which of the following pieces of evidence does the author use to conclude that further warming could have a major impact on the Montana trout fishing economy in the future?

(A) During the study period, scientists monitored 3,100 miles of river in Montana for changes in water temperature and migration patterns of the trout populations.

(B) Since current warming has led to the closure of some fishing sites, future warming could cause a 35% decline in suitable cold-water habitats for trout by 2080.

(C) As warming has occurred, fishers are finding new sites for trout fishing within Montana, increasing revenue by about $200 million per year.

(D) The trout fishing industry has been resilient to the effects of climate change by offsetting losses in revenue by 30%, which is expected to continue through 2080.

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62. Which of the following is most likely to increase species survival rates in the northern hemisphere as temperatures increase from global climate change?

(A) A species shifting its mating season to later in the spring

(B) A species shifting its diet to primarily consume invasive species

(C) A species shifting its habitat to higher latitudes than it previously occupied

(D) A species shifting to become more of a specialist species than a generalist species

63. In the global population, the number of people older than 64 years old recently surpassed the number of children under 5 years old. Which of the following best explains this phenomenon?

(A) The global human population is beginning to decline and there are fewer people in all age classes.

(B) Countries across the world are undergoing a demographic transition leading to aging populations.

(C) A rapidly growing population has a lower proportion of younger people than a stable population has.

(D) Higher fertility rates and lower life expectancies have led to a reduced number of children under five.

64. Which of the following would most likely become an invasive species after being introduced into a new environment?

(A) A bird species that has a mutualistic relationship to a specific flower species

(B) A tree species that has seeds dispersed by a specific rodent species

(C) A rodent species that has a varied diet and that reproduces multiple times per year

(D) A mammal species that has a broad diet and that produces one offspring every four years

65. The El Niño-Southern Oscillation (ENSO) is known for causing global changes in precipitation patterns. For example, in 1998 a strong ENSO event led to the second wettest rainfall season in the history of San Francisco, California. In 1998 San Francisco received 119.94 centimeters (cm) of rain, while the annual average for the city is 57.20 cm.

Which of the following methods would correctly calculate the percent increase in rainfall that San Francisco received in 1998 compared to the annual average?

(A) $\frac{119.94\,\text{cm}}{57.20\,\text{cm}} \times 100\%$

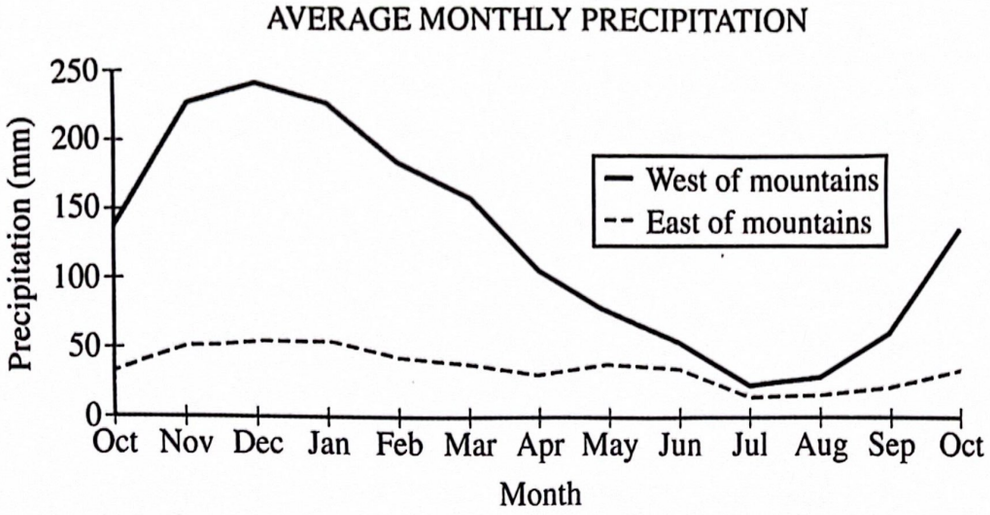
(B) $\frac{57.20\,\text{cm} + 119.94\,\text{cm}}{57.20\,\text{cm}} \times 100\%$

(C) $\frac{119.94\,\text{cm} - 57.20\,\text{cm}}{119.94\,\text{cm}} \times 100\%$

(D) $\frac{119.94\,\text{cm} - 57.20\,\text{cm}}{57.20\,\text{cm}} \times 100\%$

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66. Which of the following statements is best supported by the data in the graph?

(A) Urban sprawl has increased the amount of impermeable surface area west of the mountains.
(B) The areas east of the mountains are dominated by temperate rain forests.
(C) The area east of the mountains lies in a rain shadow caused by the mountains.
(D) Desertification resulting from overgrazing occurs in areas west of the mountains.

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67. Researchers studying golf courses hypothesize that long-term recycled wastewater (RWW) irrigation will negatively affect the quality of soil and the health of plants used for landscaping. Researchers tested soil from ten golf courses with similar ranges in age, soil texture, and landscape management practices. Five of the golf courses were irrigated with surface water, and five were irrigated with recycled wastewater for an average of seventeen years. The average results collected during the study are shown in the following table.

Soil Test	RWW Irrigation	Surface Water Irrigation
pH	7.7	7.0
Sodium concentration (mg/L)	419	141
Organic matter (%)	3.1	3.1
Salinity (ppm)	2,752	960

Which of the following statements best interprets the results based on the researchers' hypothesis?

(A) The results support the researchers' hypothesis because golf courses irrigated with RWW have the same pH as those irrigated with surface water, which is desirable for most landscaping plants.

(B) The results support the researchers' hypothesis because golf courses irrigated with RWW have higher salinity than those irrigated with surface water, which is harmful to most landscaping plants.

(C) The results refute the researchers' hypothesis because golf courses irrigated with RWW contain less organic matter than those irrigated with surface water, which is harmful to most landscaping plants.

(D) The results refute the researchers' hypothesis because golf courses irrigated with RWW have lower salinity than those irrigated with surface water, which is desirable to most landscaping plants.

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68. Zebra mussels, an invasive aquatic species, have spread rapidly across large areas of the United States. Both the microscopic eggs and larvae of zebra mussels can be spread by objects that are transferred from a contaminated body of water to another.

Which of the following strategies would best prevent the spread of zebra mussels to uninfected bodies of water?

(A) Enforce a requirement that boaters drain and clean boats upon removal from the water.

(B) Post lists of endangered species near fishing docks and boat launches.

(C) Rotate food crops along the shore of bodies of water infected with zebra mussels.

(D) Manually collect zebra mussel larvae in infected bodies of water using large nets.

69. Changes in the arctic tundra are expected to accelerate climate change in the future. Which of the following statements best describes the most likely impact of these changes on the global climate?

(A) Increased global temperatures will cause frozen soils to thaw and release stored carbon into the atmosphere, increasing global temperature.

(B) Increased solar radiation will cause sea levels to rise and flood the tundra, decreasing global temperature.

(C) Increased levels of carbon dioxide in the atmosphere will cause tundra to become more productive, increasing global temperature.

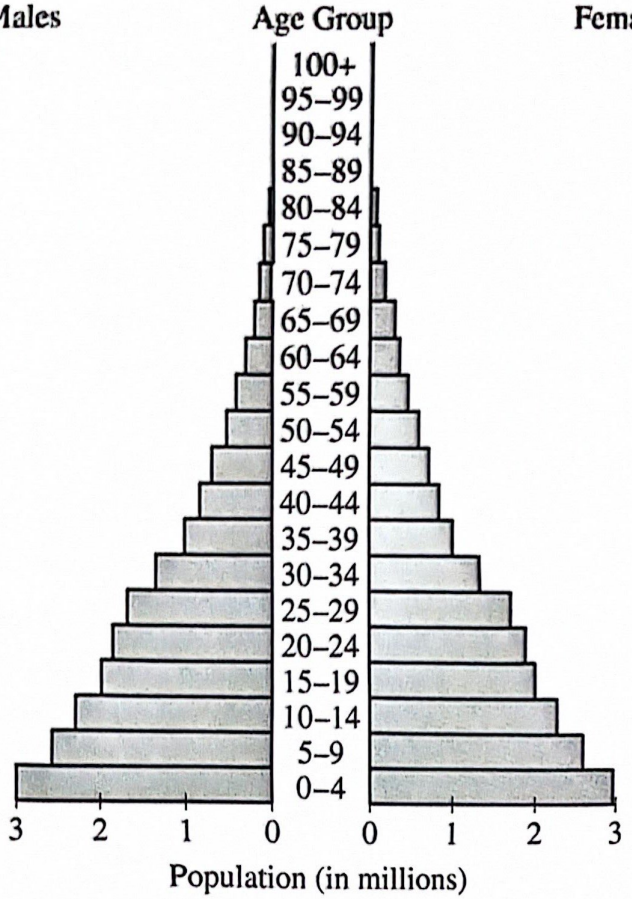
(D) Increased levels of methane in the atmosphere will accelerate bacterial decomposition of tundra, decreasing global temperature.

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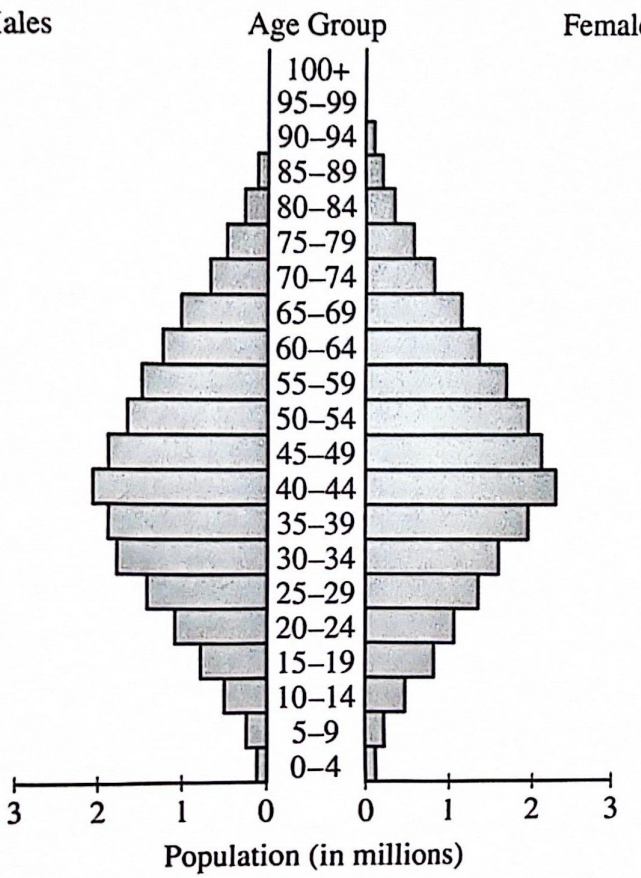
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70. Which of the following age structure diagrams represents a population with a fertility rate closest to replacement level?

(A) Males



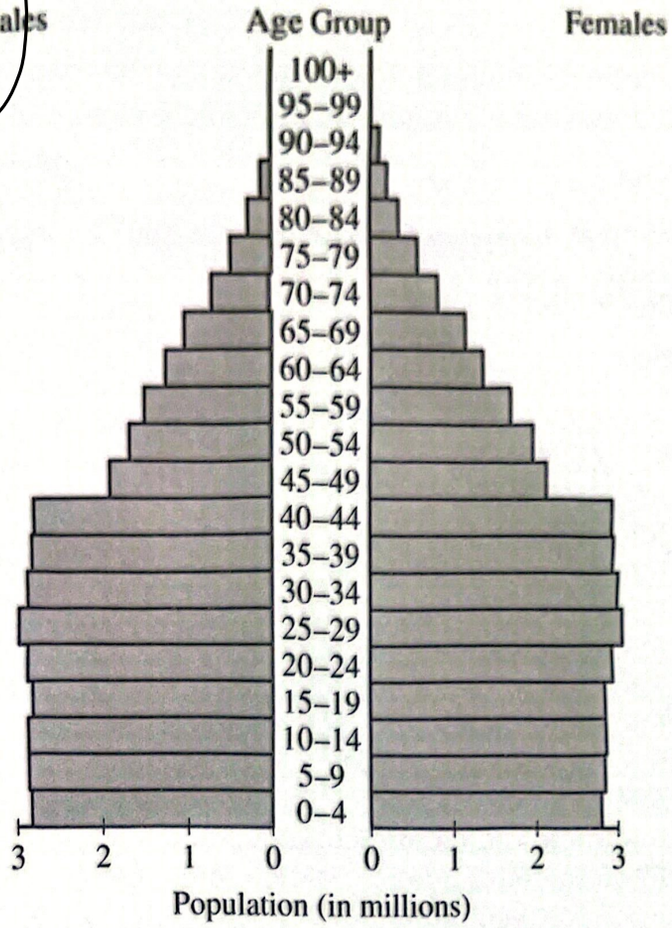
(B) Males



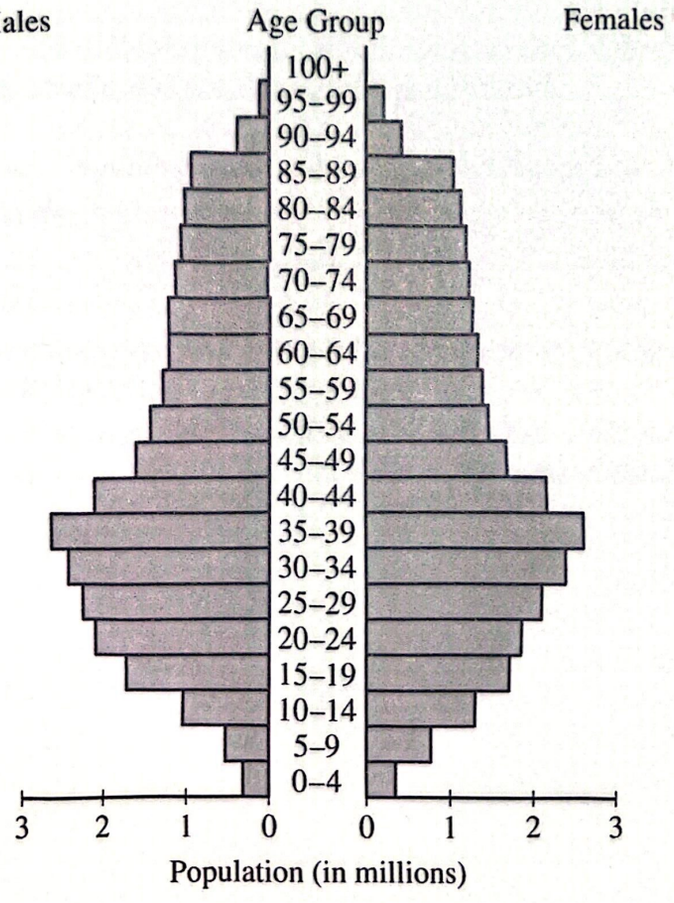
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(C)



(D)



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71. In which of the following situations would an insect pest population be most likely to develop pesticide resistance in a greenhouse?

(A) After pesticide application, a small number of the pests survived to reproduce.

(B) Greenhouse temperatures remain consistent throughout the winter months.

(C) Different pesticides are rotated throughout the growing season.

(D) Ladybugs, a natural predator of the pest, are released into the greenhouse after eight weeks.

72. A motorcycle is driven for 250 miles a month and releases 0.021 grams of particulate matter per mile driven. Which of the following methods would correctly calculate the amount of particulate matter that would be released by the motorcycle over one year?

(A) $\frac{0.021 \text{ grams}}{1 \text{ mile}} \times \frac{250 \text{ miles}}{1 \text{ month}} \times \frac{12 \text{ months}}{1 \text{ year}}$

(B) $\frac{0.021 \text{ grams}}{1 \text{ mile}} \times \frac{1 \text{ month}}{250 \text{ miles}}$

(C) $\frac{1 \text{ mile}}{0.021 \text{ grams}} \times \frac{250 \text{ miles}}{1 \text{ month}} \times \frac{365 \text{ days}}{1 \text{ year}}$

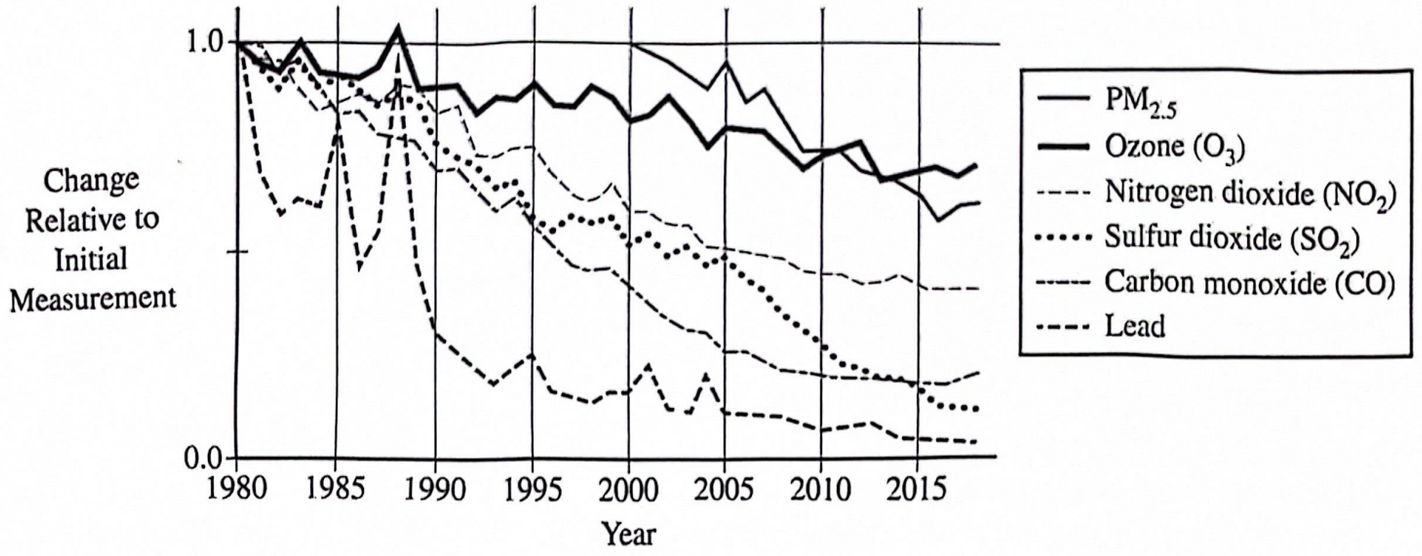
(D) $\frac{1 \text{ mile}}{0.021 \text{ grams}} \times \frac{250 \text{ miles}}{1 \text{ month}}$

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73. The graph shows the relative concentration of six common air pollutants in the United States between 1980 and 2018. The index begins at 1 in the year that data collection began (1980 for most pollutants and 2000 for $PM_{2.5}$). The graph shows the relative change in pollutant concentrations over time compared to the initial measurement.

Relative Change in Six Common Air Pollutants in the United States, 1980–2018



Which of the following statements best uses the data in the graph to support the claim that the Clean Air Act has been an effective solution in the United States?

(A) $PM_{2.5}$ was not present in the atmosphere before 2000 but has shown the greatest decline in relative value in the shortest amount of time since regulation began.

(B) Implementation of the Clean Air Act has led to a substantial reduction in emissions in all six common air pollutants.

(C) Application of the Clean Air Act varies among regions and has not been successful in reducing lead or ozone levels.

(D) Carbon monoxide levels have decreased since 1980, but global temperatures continue to increase because other countries do not have legislation similar to the Clean Air Act.

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74. Arctic wolves in Canada prey upon elk. As predation increases, the size of elk herds decreases. Smaller herds are more difficult for wolves to find. Thus, the wolves are less successful at hunting and fewer wolf pups are born. Fewer wolves in the pack means reduced hunting, so fewer elk are eaten. As a result, the elk herds grow larger.

Which of the following explains why the size of the elk herds changes through time?

(A) The mutualistic relationship between wolves and elk creates a positive feedback loop.

(B) The 10% rule leads to a loss of available energy and causes biomagnification.

(C) The elk population often overshoots the carrying capacity of the ecosystem when the number of wolves increases.

(D) Predation from wolves causes a negative feedback loop within the food chain.

75. The Chesapeake Bay experiences periodic dead zones in which fish and other marine organisms die.

Which of the following explains why increased nutrients in the Chesapeake Bay can lead to dead zone conditions?

(A) Excess nutrients promote algal blooms, and when the algae die, bacteria that consume the algae deplete the oxygen in the water.

(B) Excess nutrients, such as phosphorus and nitrogen, bond with the oxygen in the water, forming molecules that organisms cannot use, leading to suffocation of marine fish.

(C) Algal blooms that form as a result of excess nutrients consume all of the available carbon dioxide in the water, reducing the ability of marine plants to photosynthesize.

(D) Because they are not soluble, nutrients accumulate as sediment on the bottom, which reduces habitat for fish and other organisms.

76. Which of the following best explains why the practice of aquaculture has increased in recent years?

(A) Consumer demand for fish has increased as wild fish catches have decreased.

(B) Aquaculture improves the quality in the water surrounding the fish enclosures.

(C) The high density of fish in aquaculture helps to decrease disease in the enclosures.

(D) Aquaculture uses wild food sources and does not use antibiotics.

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Questions 77 through 79 refer to the population data in the following table.

The table shows 2019 data from four different countries.

Country	Crude Birth Rate (per 1,000 people)	Crude Death Rate (per 1,000 people)
Trinidad and Tobago	12.58	8.50
Jamaica	15.91	7.59
Haiti	24.35	8.57
Bermuda	8.30	7.80

77. Based on the data in the table and assuming the birth rates and the death rates remain constant, which of the following countries would have the most stable population size?

(A) Trinidad and Tobago
(B) Jamaica
(C) Haiti
(D) Bermuda

78. Based on the data in the table, which of the following values best represents the natural rate of increase in Jamaica in 2019 ?

(A) $\frac{8.32}{1{,}000 \text{ people}}$
(B) $\frac{15.91}{1{,}000 \text{ people}}$
(C) $\frac{23.50}{1{,}000 \text{ people}}$
(D) $\frac{84.10}{1{,}000 \text{ people}}$

79. Immigration is the act of entering a country to permanently live, and emigration is the act of leaving one country to permanently live in a different country. Which of the following will result in the greatest increase in the population size in a country?

(A) The birth rate is greater than the death rate, and emigration is greater than immigration.
(B) The birth rate is less than the death rate, and emigration is greater than immigration.
(C) The birth rate is less than the death rate, and emigration is less than immigration.
(D) The birth rate is greater than the death rate, and emigration is less than immigration.

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80. Which of the following methods would most likely reduce the accumulation of indoor carbon monoxide emissions from a gas stove?

(A) Replacing the gas stove with an electric stove

(B) Attaching a catalytic converter to the stove

(C) Using glass cookware instead of metal

(D) Installing a smoke detector in the ceiling

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ENVIRONMENTAL SCIENCE

SECTION II

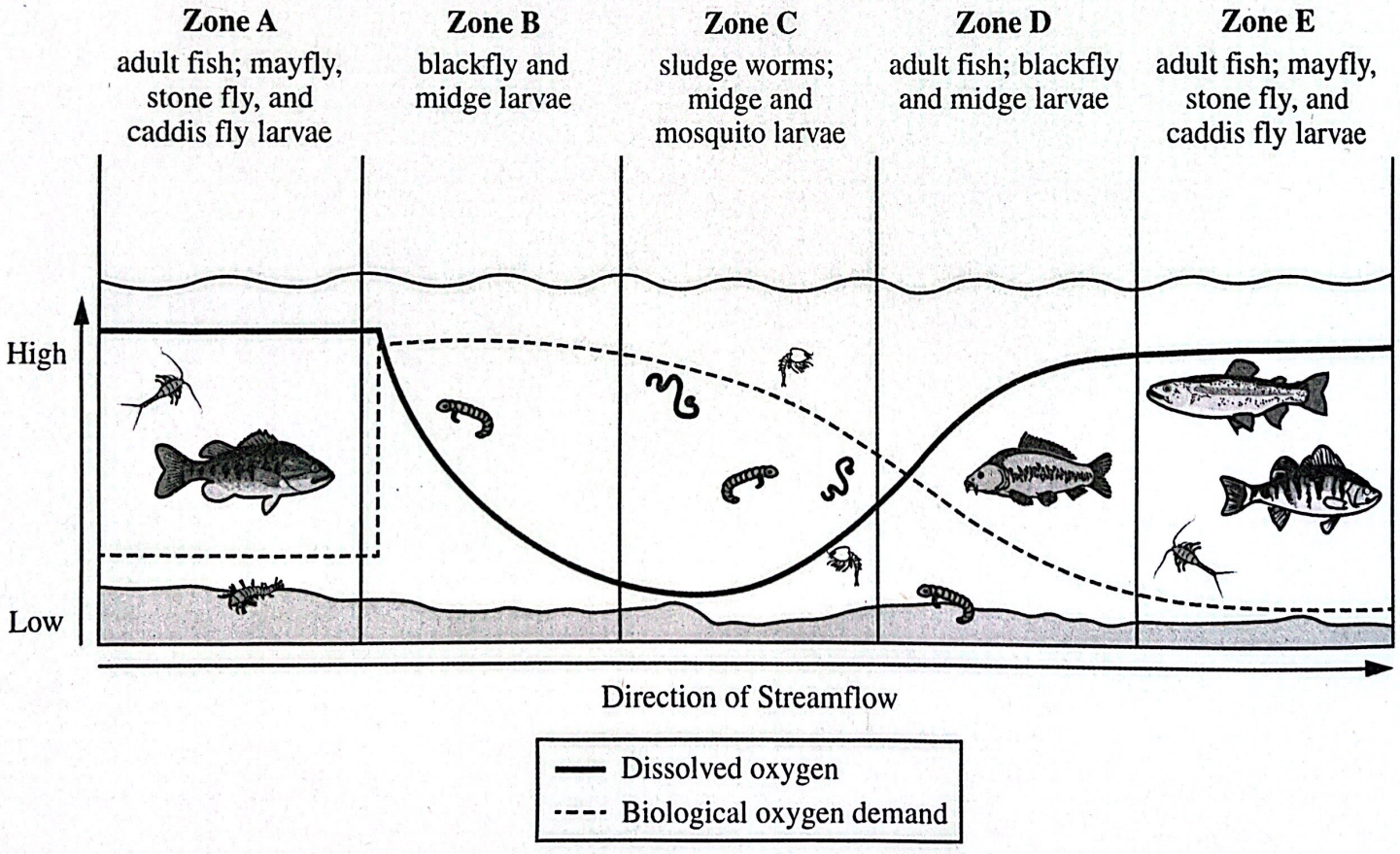
Time—1 hour and 10 minutes

3 Questions

Directions: Answer all three questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers in the Free Response 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. You may plan your answers in this orange booklet, but no credit will be given for anything written in this booklet. **You will only earn credit for what you write in the separate Free Response booklet.**

1. Researchers are studying the stream ecosystem shown in the following diagram. They have identified five different zones based on the dissolved oxygen levels and biological oxygen demand as the water flows downstream. Biological oxygen demand is the amount of oxygen needed by bacteria and other microorganisms to break down organic material in water. Some of the most common fish and macroinvertebrate species found in each zone are listed in the diagram.

Dissolved Oxygen and Biological Oxygen Demand in a Stream Ecosystem



(a) Based on the information in the diagram, **identify** the zone with the lowest level of dissolved oxygen.

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(b) Based on the information in the diagram, **describe** the relationship between biological oxygen demand and dissolved oxygen.

(c) Based on the information in the diagram, **identify** the zone where there is most likely point-source water pollution discharged into the stream.

The research team is interested in investigating the relationship between dissolved oxygen levels and macroinvertebrate species richness in the stream. Researchers counted the number of macroinvertebrate species in zones A, B, and C during the summer months. The researchers selected zone A to serve as the control in the investigation.

(d) **Identify** the dependent variable in the researchers' investigation.

(e) **Identify** a testable hypothesis for the researchers' investigation.

(f) **Describe** the reason the researchers selected zone A to serve as the control in the investigation.

The researchers decided to repeat their data collection during the winter months.

(g) **Explain** how the modification to collect data in the winter months could alter the results of the investigation.

Stream ecosystems are affected by point-source organic pollution in a variety of ways.

(h) **Describe** the effect that the introduction of raw sewage into the stream could have on the population of bacteria in the stream.

(i) **Identify** an abiotic factor other than dissolved oxygen and organic pollution that could also influence the population size of bacteria in the stream.

(j) **Explain** how persistent organic pollutants can affect higher trophic levels in an aquatic food web.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

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2. As the human population continues to grow, the demand for animal protein is expected to double by 2050. Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent (kg CO_2-eq). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared (m^2).

Global Warming Potential and Land Use from Animal Protein Production

Figure 1

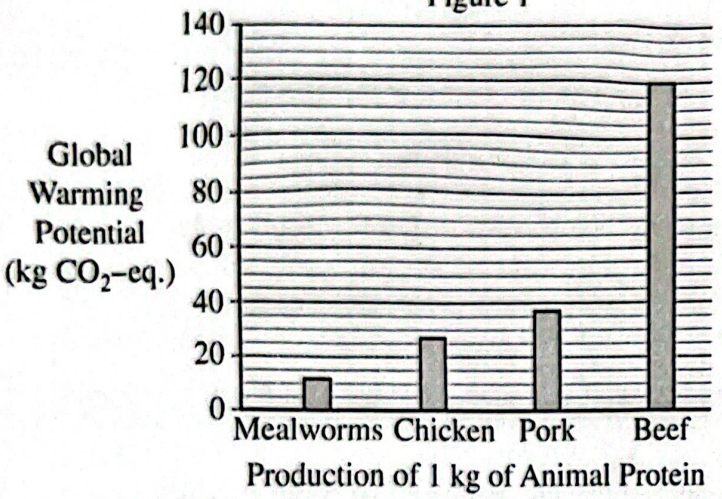
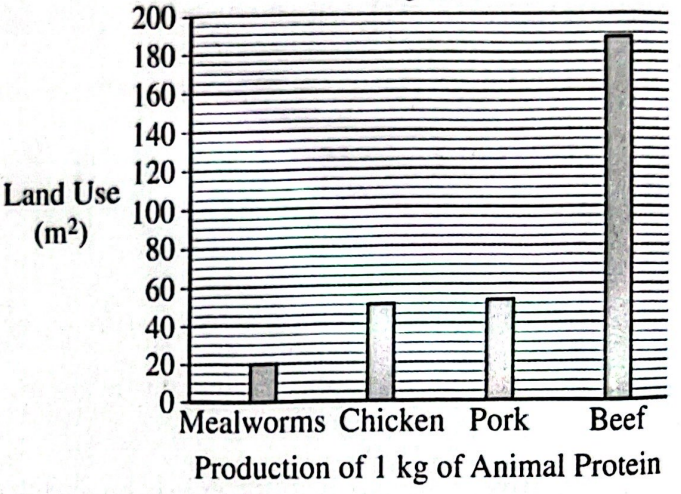


Figure 2



(a) Based on the data in the graphs, **identify** the amount of land required to produce 1 kilogram of chicken protein.

Mealworms, the larvae of the darkling beetle, consume grains and decaying plant material. Darkling beetles are an *r*-selected species, and the entire mealworm can be consumed by humans for protein.

(b) Based on the information provided, **identify** the type of survivorship curve exhibited by the darkling beetle.

(c) **Explain** why the reproductive strategy of the darkling beetle is an advantage for using mealworms as an alternative protein source for the rapidly growing human population.

An individual's diet choices affect greenhouse gas emissions and land use.

(d) Based on the data in the graphs, **explain** whether producing 1 kilogram of chicken protein or 1 kilogram of pork protein would cause less environmental damage.

Cattle emit methane from fermentation in their digestive systems. The other animals do not emit methane.

(e) Based on the data in the graphs, **explain** why the production of 1 kilogram of beef protein has a different impact on global warming than the production of 1 kilogram of protein from any of the other animals studied would have.

Agricultural practices can have negative impacts on rivers and streams.

(f) **Describe** how water quality can be altered by cattle grazing that occurs near a stream or river.

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(g) **Propose** a solution to reduce the negative impacts on waterways that result from cattle grazing, while still allowing cattle to graze.

(h) Crop production can cause soil erosion. **Describe** a sustainable agricultural practice used to reduce soil erosion.

(i) **Justify** the use of the sustainable practice described in part (h) by describing an additional advantage, other than the reduction of soil erosion.

(j) Crop production around the world is affected by climate change. **Describe** how crop production could be negatively affected by climate change.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

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3. Earth's climate has changed over time by the addition of greenhouse gasses to the atmosphere. One approach to mitigate climate change is the use of nuclear power, rather than coal-burning power plants, for electricity generation.

(a) **Identify** a fuel used in a nuclear power plant.

(b) **Describe** a negative environmental impact on nearby bodies of water that is caused by using water for cooling in nuclear power plants.

(c) In 2021, 4.1×10^{12} kilowatt hours (kWh) of commercial electricity was generated in the United States. Nuclear power accounted for 18.9% of the total commercial electricity. **Calculate** the amount of electricity in kWh generated by nuclear power in the United States in 2021. **Show** your work.

Another approach to reduce greenhouse gas emissions is to switch from coal-burning power plants to natural gas power plants.

(d) In addition to reducing greenhouse gas emissions, **describe** how switching from coal-burning power plants to natural gas power plants will improve air quality.

Researchers have proposed large-scale tree planting as a solution to reduce the effects of fossil fuel combustion on global climate change.

(e) **Justify** the proposed solution by explaining an additional advantage, other than the reduction of atmospheric greenhouse gases.

(f) 7.4×10^{7} cubic meters of natural gas were extracted from a large deposit in 2020. An average of 4.76 kWh of electricity can be generated from each cubic meter of natural gas combusted. In 2020, an average home consumed 10,715 kWh of electricity. **Calculate** how many homes could have been provided with electricity by natural gas extracted from the large deposit in 2020. **Show** your work.

(g) In 2021, 8.99×10^{11} kWh of electricity was generated through the combustion of coal. One kilogram of carbon dioxide is produced per kWh of electricity generated by combusting coal, while 0.42 kilograms of carbon dioxide is produced by combusting natural gas. **Calculate** how much less carbon dioxide would have been produced in 2021 if all coal-burning power plants were replaced with natural gas-burning power plants. **Show** your work.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

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