SCIENCE TEST

35 Minutes—40 Questions

DIRECTIONS: There are several passages in this test. Each passage is followed by several questions. After reading a passage, choose the best answer to each question and fill in the corresponding oval on your answer document. You may refer to the passages as often as necessary.

You are NOT permitted to use a calculator on this test.

Passage I

Researchers studied how diet and the ability to smell food can affect the life span of normal fruit flies (Strain N) and fruit flies unable to detect many odors (Strain X).

Study 1

Three tubes (Tubes 1–3), each with *15% sugar yeast* (SY) *medium* (a diet with 15% sugar and 15% killed yeast), were prepared. Then, 200 virgin female Strain N fruit flies less than 24 hr old were added to each tube. No additional substance was added to Tube 1. Additional odors from live yeast were added to Tube 2, and live yeast was added to Tube 3. The percent of fruit flies alive was determined every 5 days for 75 days (see Figure 1).
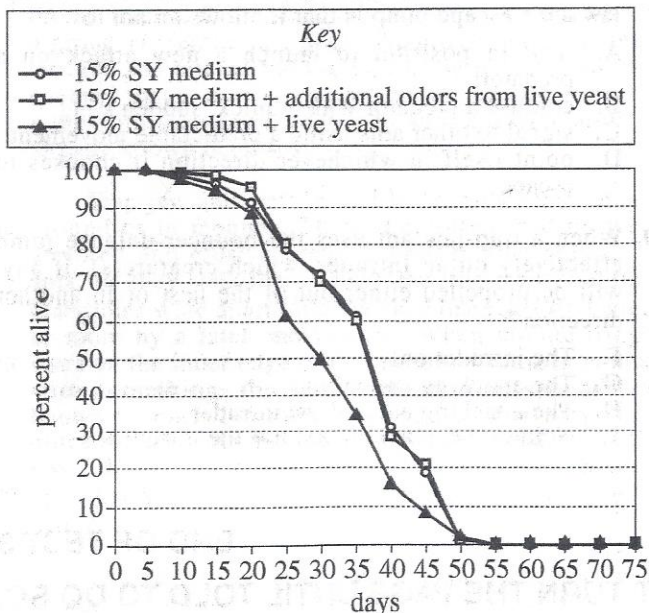
Study 2

Three tubes (Tubes 4–6), each with 5% SY medium (a diet with 5% sugar and 5% killed yeast), were prepared. Then, 200 virgin female Strain N fruit flies less than 24 hr old were added to each tube. No additional substance was added to Tube 4. Additional odors from live yeast were added to Tube 5, and live yeast was added to Tube 6. The percent of fruit flies alive was determined every 5 days for 75 days (see Figure 2).
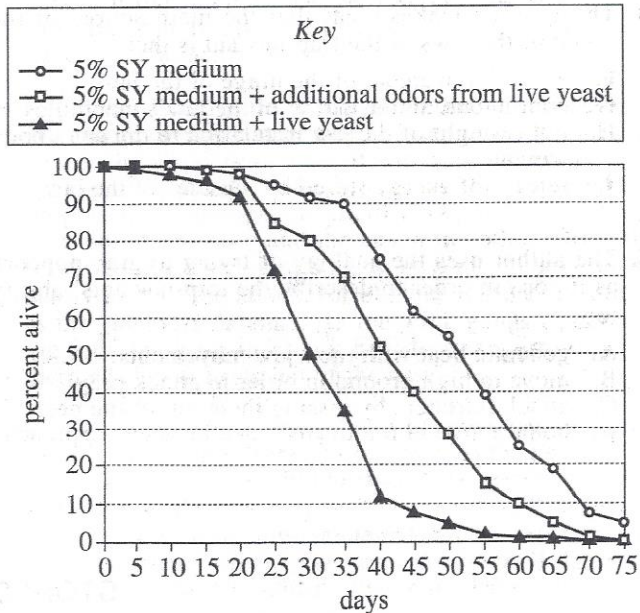

Figure 1

Figure 2

Study 3

Strain N fruit flies were modified to produce Strain X fruit flies. Strain X fruit flies lack *Or83b* (a protein required to detect a wide range of odors); therefore, they cannot detect many odors. The average life span was determined for virgin female Strain N and virgin female Strain X fruit flies fed with various SY media (see Table 1).

Table 1			
	SY medium		Average life span (days)
Strain	% sugar	% killed yeast	
Strain N	3	3	50.1
	5	5	50.1
	7.5	7.5	43.9
	10	10	44.8
	15	15	41.6
Strain X	3	3	61.6
	5	5	62.5
	7.5	7.5	58.9
	10	10	58.6
	15	15	55.6

Table and figures adapted from Sergiy Libert et al., "Regulation of *Drosophila* Life Span by Olfaction and Food-Derived Odors." ©2007 by the American Association for the Advancement of Science.

1. In which of Studies 1 and 2 did some of the fruit flies live for more than 75 days, and what diet were those fruit flies fed?

   A. Study 1; 5% SY medium
   B. Study 1; 15% SY medium
   C. Study 2; 5% SY medium
   D. Study 2; 15% SY medium

2. During Studies 1 and 2, why did the size of the fruit fly population in each tube decrease rather than increase?

   F. The birthrate was 0, because the initial population contained only males.
   G. The birthrate was 0, because the initial population contained only virgin females.
   H. The death rate was 0, because the initial population contained only males.
   J. The death rate was 0, because the initial population contained only virgin females.

3. Suppose that an additional trial in Study 3 had been performed using a 12% SY medium (a diet with 12% sugar and 12% killed yeast). The average life span of the Strain X fruit flies in this trial would most likely have been:

   A. less than 55.6 days.
   B. between 55.6 days and 58.6 days.
   C. between 58.6 days and 61.6 days.
   D. greater than 61.6 days.

4. The researchers had predicted that decreasing a fruit fly's ability to detect odors would increase its life span. Are the results of Study 3 consistent with this prediction?

   F. No; for each SY medium tested, the average life span of Strain X fruit flies was longer than the average life span of Strain N fruit flies.
   G. No; for each SY medium tested, the average life span of Strain N fruit flies was longer than the average life span of Strain X fruit flies.
   H. Yes; for each SY medium tested, the average life span of Strain X fruit flies was longer than the average life span of Strain N fruit flies.
   J. Yes; for each SY medium tested, the average life span of Strain N fruit flies was longer than the average life span of Strain X fruit flies.

5. Suppose the researchers wanted to determine whether a defect in the ability to detect odors would change the life span of fruit flies fed 15% SY medium when live yeast is added to the diet or when additional odors from live yeast are added to the diet. Which of the following experiments should be performed?

   A. Repeat Study 1 except with Strain X fruit flies
   B. Repeat Study 1 except with Strain N fruit flies
   C. Repeat Study 2 except with Strain X fruit flies
   D. Repeat Study 2 except with Strain N fruit flies

6. The results for which 2 tubes should be compared to determine how a reduced calorie diet affects life span in the absence of live yeast and additional odors from live yeast?

   F. Tube 1 and Tube 4
   G. Tube 1 and Tube 2
   H. Tube 2 and Tube 5
   J. Tube 5 and Tube 6

Passage II

In the fall, monarch butterflies (*Danaus plexippus*) in eastern North America migrate to Mexico, where they overwinter in high-altitude forests of *oyamel fir* (an evergreen conifer). The butterflies store (accumulate) body lipids to use as a source of energy at a later time. Consider the following 3 hypotheses pertaining to when the butterflies store lipids and when the energy from the stored lipids is used, with respect to migration and overwintering.

Hypothesis 1

Monarch butterflies require energy from stored lipids for migration and during the overwintering period. The butterflies first store lipids before they begin their migration. During migration, as stored lipids are converted to energy, lipid mass continuously decreases. When the butterflies reach the overwintering sites, ending their migration, they must store lipids again before beginning the overwintering period.

Hypothesis 2

Monarch butterflies require energy from stored lipids for migration but not during the overwintering period. The butterflies store lipids before they begin their migration. During migration, as stored lipids are converted to energy, lipid mass continuously decreases. Because energy from stored lipids is not required during the overwintering period, the butterflies do not store lipids while at the overwintering sites.

Hypothesis 3

Monarch butterflies require energy from stored lipids during the overwintering period but not for migration. The butterflies do not store lipids before they begin their migration. Instead, lipids are stored during migration; therefore, lipid mass continuously increases from the beginning of migration until the end of migration. The butterflies arrive at the overwintering sites with enough lipids to provide themselves with energy during the overwintering period, so they do not store lipids while at the overwintering sites.

7. Which hypothesis, if any, asserts that monarch butterflies store lipids during 2 distinct periods?
   A. Hypothesis 1
   B. Hypothesis 2
   C. Hypothesis 3
   D. None of the hypotheses

8. Which hypothesis, if any, asserts that monarch butterflies require energy from stored lipids neither for migration nor during the overwintering period?
   F. Hypothesis 1
   G. Hypothesis 2
   H. Hypothesis 3
   J. None of the hypotheses

9. Based on Hypothesis 3, which of the following figures best depicts the change in the lipid mass of a monarch butterfly from the beginning of migration to the end of migration?

   (Note: In each figure, B represents the beginning of migration and E represents the end of migration.)
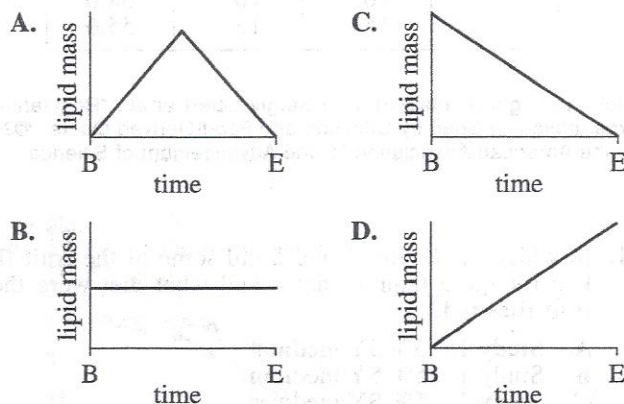
10. Assume that changes in the body mass of a monarch butterfly are caused only by changes in the mass of the butterfly's stored lipids. The statement "The percent of a monarch butterfly's body mass that is made up of lipids is greater at the beginning of migration than at the end of migration" is supported by which of the hypotheses?

   F. Hypothesis 1 only
   G. Hypothesis 2 only
   H. Hypotheses 1 and 2 only
   J. Hypotheses 1, 2, and 3

11. To store lipids, monarch butterflies convert sugar from nectar they have consumed into lipids. A supporter of which hypothesis, if any, would be likely to claim that to ensure the butterflies can store lipids for the overwintering period, nectar must be present at the butterflies' overwintering sites?

   A. Hypothesis 1
   B. Hypothesis 2
   C. Hypothesis 3
   D. None of the hypotheses

12. Which of the following statements about lipids in monarch butterflies is consistent with all 3 hypotheses?

   F. The butterflies' lipid masses do not change during the overwintering period.
   G. The butterflies' lipid masses change during migration.
   H. The butterflies use energy from stored lipids during the overwintering period.
   J. The butterflies use energy from stored lipids for migration.

13. When the monarch butterflies use their stored lipids, the lipids must be broken down to produce energy-rich molecules that can be readily used by cells. Which of the following molecules is produced as a direct result of the breakdown of the lipids?

   A. ATP
   B. Starch
   C. DNA
   D. Amino acids

Passage III

Greenhouse gases such as methane (CH_4) warm Earth's climate. Figure 1 shows the concentration of CH_4 in Earth's atmosphere and the solar radiation intensity at Earth's surface for tropical Europe and Asia over the past 250,000 years. As the figure shows, the CH_4 concentration and the solar radiation intensity have increased and decreased at the same times over most of this period. Figure 2 shows the same types of data for the same region over the past 11,000 years. This figure is consistent with the hypothesis that the greenhouse gases from human activities may have begun warming Earth's climate thousands of years earlier than once thought.

Key
----- solar radiation
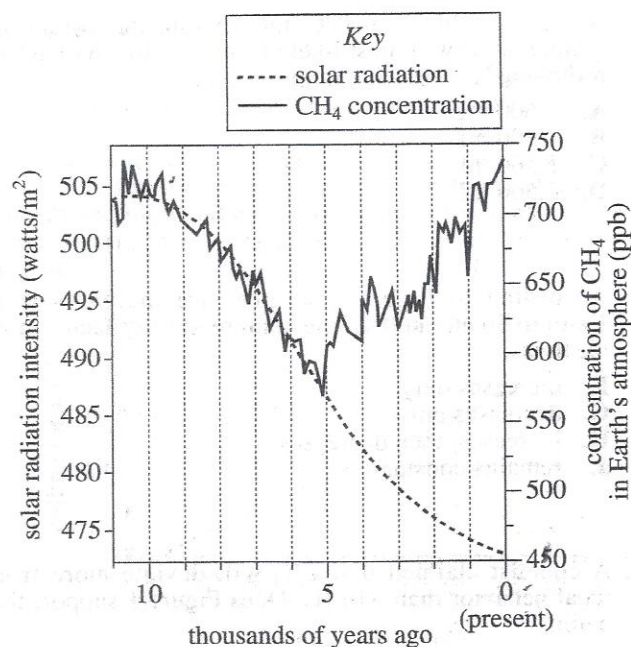—— CH_4 concentration
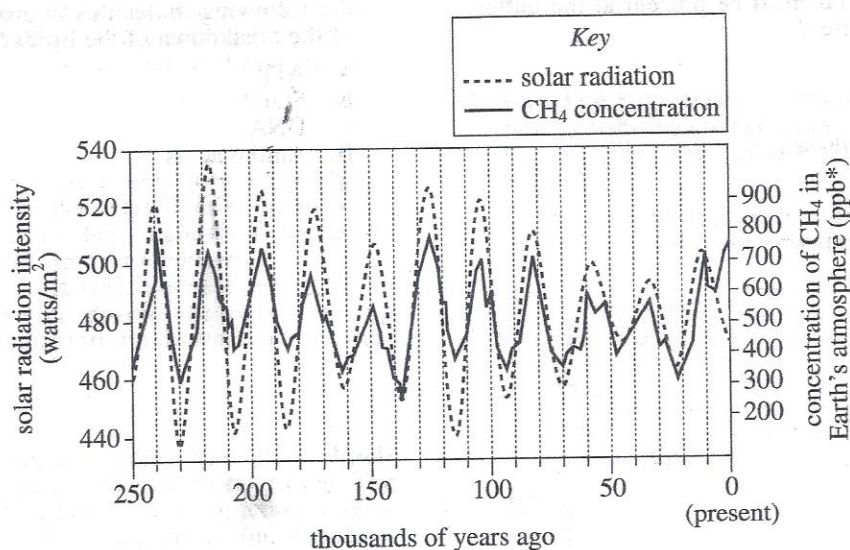
*ppb = parts per billion

Figure 1

Figure 2

Figures adapted from William Ruddiman, *Plows, Plagues & Petroleum*. ©2005 by Princeton University Press.

14. According to Figure 2, the solar radiation intensity 8,000 years ago was closest to which of the following?

   F. 490 watts/m^2
   G. 495 watts/m^2
   H. 500 watts/m^2
   J. 505 watts/m^2

15. According to Figure 2, if the trend in the CH_4 concentration had continued to match the trend in the solar radiation intensity, the CH_4 concentration at present would most likely be:

   A. less than 550 ppb.
   B. between 550 ppb and 600 ppb.
   C. between 600 ppb and 650 ppb.
   D. greater than 650 ppb.

16. Suppose that whenever the CH_4 concentration increases, a corresponding, immediate increase in average global temperature occurs, and that whenever the CH_4 concentration decreases, a corresponding, immediate decrease in average global temperature occurs. Based on Figure 2, which of the following graphs best represents a plot of average global temperature over the past 11,000 years?
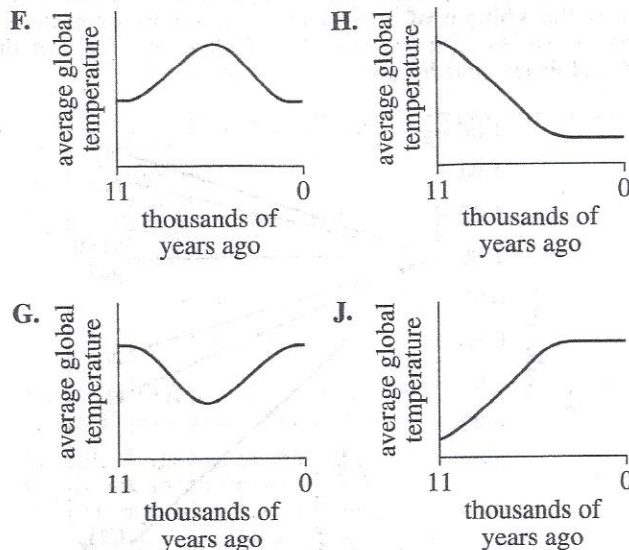
17. Based on Figure 1, the average solar radiation intensity over the past 250,000 years was closest to which of the following?

   A. 400 watts/m^2
   B. 440 watts/m^2
   C. 480 watts/m^2
   D. 520 watts/m^2

18. One *solar radiation cycle* is the time between a maximum in the solar radiation intensity and the next maximum in the solar radiation intensity. According to Figure 1, the average length of a solar radiation cycle during the past 250,000 years was:

   F. less than 15,000 years.
   G. between 15,000 years and 35,000 years.
   H. between 35,000 years and 55,000 years.
   J. greater than 55,000 years.

Passage IV

An *ideal gas* is a hypothetical gas that behaves exactly as predicted by the ideal gas law. Depending on the conditions, an ideal gas may or may not be a good model for a real gas. The *compressibility factor* (z) is a value that quantifies the deviation of a gas from ideal behavior. Figure 1 shows, for an ideal gas and for 5 real gases, how z varies with pressure (in atmospheres, atm) at 0°C. Table 1 shows how the volume of 1 *mole* (6×10^{23} atoms or molecules) of gas varies with pressure for an ideal gas, for 3 of those 5 real gases, and for air.
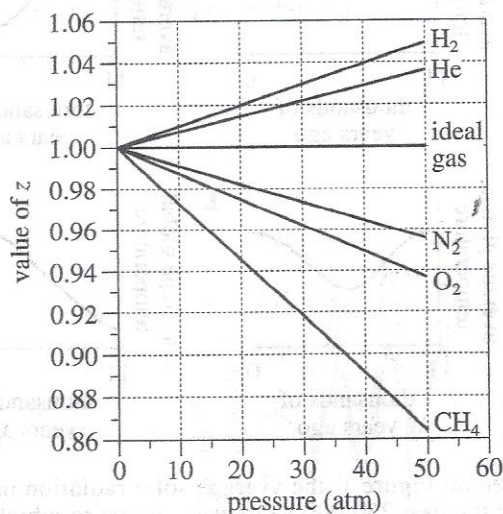

Figure 1

	Volume (in mL) of gas at 0°C				
Pressure (atm)	ideal gas	He	N_2	CH_4	air
10	2,241	2,258	2,219	2,180	2,216
20	1,121	1,136	1,098	1,061	1,096
30	747.2	763.7	725.4	686.0	723.4
40	560.4	577.0	539.5	499.2	536.8

Table 1

Figure and table adapted from E. D. Eastman and G. R. Rollefson, *Physical Chemistry*, 1st ed. ©1947 by McGraw-Hill Book Co.

19. Based on Table 1, at 0°C and 15 atm, the volume of 1 mole of air will most likely be closest to which of the following?

   A. 600 mL
   B. 900 mL
   C. 1,500 mL
   D. 2,500 mL

20. According to Figure 1, as pressure increases from 1 atm to 50 atm at 0°C, the compressibility factor of an ideal gas:

   F. increases only.
   G. decreases only.
   H. increases, then decreases.
   J. remains constant.

21. A chemist claimed that CH_4 will deviate more from ideal behavior than will H_2. Does Figure 1 support this claim?

   A. Yes, because the magnitude of the slope of the line for CH_4 is less than it is for H_2.
   B. Yes, because the magnitude of the slope of the line for CH_4 is greater than it is for H_2.
   C. No, because the magnitude of the slope of the line for CH_4 is less than it is for H_2.
   D. No, because the magnitude of the slope of the line for CH_4 is greater than it is for H_2.

22. Based on Figure 1 and Table 1, at 0°C and 30 atm, the volume of 1 mole of O_2 will most likely be:

   F. less than 686 mL.
   G. between 686 mL and 725 mL.
   H. between 725 mL and 764 mL.
   J. greater than 764 mL.

23. Based on Table 1, at 40 atm, the volume of 1 mole of CH_4 at a temperature of −30°C will most likely be:

   A. less than 500 mL.
   B. between 500 mL and 1,000 mL.
   C. between 1,000 mL and 2,000 mL.
   D. greater than 2,000 mL.

Passage V

In 2 experiments, a student pulled each of 3 blocks in a straight line across a flat, horizontal surface.

In Experiment 1, the student measured the *pulling force* (the force required to move each block at a constant speed) and plotted the pulling force, in newtons (N), versus block mass, in kilograms (kg). The results are shown in Figure 1.
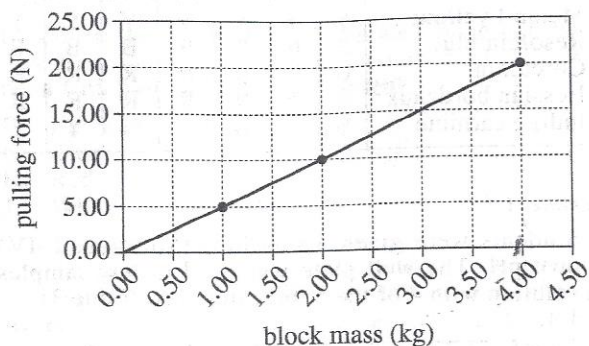

Figure 1

In Experiment 2, the student measured the speed versus time of a 2.00 kg block, a 2.50 kg block, and a 3.00 kg block as each block was pulled across the surface with a constant 30 N force. The results are shown in Figure 2.
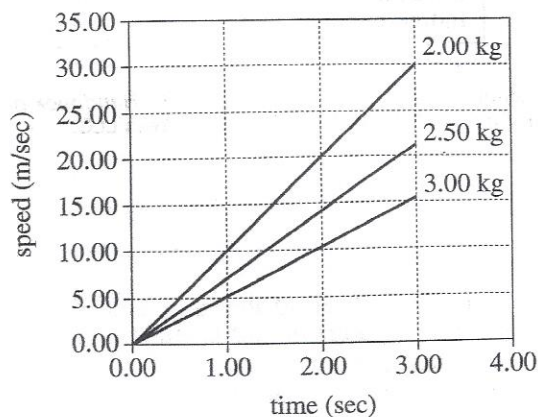

Figure 2

24. Based on Figure 2, what is the order of the 3 blocks, from the block that required the shortest time to reach 15 m/sec to the block that required the longest time to reach 15 m/sec ?

F. 2.00 kg block, 2.50 kg block, 3.00 kg block
G. 2.00 kg block, 3.00 kg block, 2.50 kg block
H. 3.00 kg block, 2.00 kg block, 2.50 kg block
J. 3.00 kg block, 2.50 kg block, 2.00 kg block

25. Based on Figure 2, what was the approximate value of the acceleration of the 3.00 kg block?

A. 0.0 m/sec^2
B. 5.0 m/sec^2
C. 15.0 m/sec^2
D. 20.0 m/sec^2

26. Based on Figure 1, the results of Experiment 1 are best modeled by which of the following equations?

F. Block speed (m/sec) = 0.2 × time (sec)
G. Block speed (m/sec) = 5.0 × time (sec)
H. Pulling force (N) = 0.2 × block mass (kg)
J. Pulling force (N) = 5.0 × block mass (kg)

27. At each of the times plotted in Figure 2 (except 0.00 sec), as block mass increased, block speed:

A. increased only.
B. decreased only.
C. varied, but with no general trend.
D. remained the same.

28. Based on Figure 1, an applied force of 30.00 N would most likely have been required to maintain the constant speed of a block having a mass of:

F. 4.00 kg.
G. 5.00 kg.
H. 6.00 kg.
J. 7.00 kg.

Passage VI

A typical *acid-base indicator* is a compound that will be one color over a certain lower pH range but will be a different color over a certain higher pH range. In the small range between these pH ranges—the *transition range*—the indicator's color will be an intermediate of its other 2 colors.

Students studied 5 acid-base indicators using colorless aqueous solutions of different pH and a *well plate* (a plate containing a matrix of round depressions—*wells*—that can hold small volumes of liquid).

Experiment 1

The students added a pH = 0 solution to 5 wells in the first column of the well plate, then added a pH = 1 solution to the 5 wells in the next column, and so on, up to pH = 7. Next, they added a drop of a given indicator (in solution) to each of the wells in a row, and then repeated this process, adding a different indicator to each row. The color of the resulting solution in each well was then recorded in Table 1 (B = blue, G = green, O = orange, P = purple, R = red, Y = yellow).

Table 1								
	Color in solution with a pH of:							
Indicator	0	1	2	3	4	5	6	7
Metanil yellow	R	R	O	Y	Y	Y	Y	Y
Resorcin blue	R	R	O	R	R	P	P	B
Curcumin	Y	Y	Y	Y	Y	Y	Y	Y
Hessian bordeaux	B	B	B	B	B	B	B	B
Indigo carmine	B	B	B	B	B	B	B	B

Experiment 2

Experiment 1 was repeated with solutions that had a pH of 8 or greater (see Table 2).

Table 2							
	Color in solution with a pH of:						
Indicator	8	9	10	11	12	13	14
Metanil yellow	Y	Y	Y	Y	Y	Y	Y
Resorcin blue	B	B	B	B	B	B	B
Curcumin	O	R	R	R	R	R	R
Hessian bordeaux	B	R	R	R	R	R	R
Indigo carmine	B	B	B	B	G	Y	Y

Experiment 3

Students were given 4 solutions (Solutions I–IV) of unknown pH. The well plate was used to test samples of each solution with 4 of the 5 indicators (see Table 3).

Table 3				
	Color in Solution:			
Indicator	I	II	III	IV
Metanil yellow	Y	Y	Y	O
Resorcin blue	B	B	R	R
Curcumin	R	R	Y	Y
Indigo carmine	B	Y	B	B

Tables adapted from David R. Lide, ed., *CRC Handbook of Chemistry and Physics,* 78th ed. ©1997 by CRC Press LLC.

29. One way Experiment 2 differed from Experiment 3 was that in Experiment 2:

 A. the solutions to which indicators were added were of known pH.
 B. the solutions to which indicators were added were of unknown pH.
 C. metanil yellow was used.
 D. metanil yellow was not used.

30. Based on the description of the well plate and how it was used, the empty well plate would most likely have been which of the following colors?

 F. Black
 G. Blue
 H. Red
 J. White

31. Based on the results of Experiments 1 and 2, which of the following is a possible transition range for curcumin?

 A. pH = 3.9 to pH = 7.3
 B. pH = 4.2 to pH = 6.6
 C. pH = 7.4 to pH = 8.6
 D. pH = 8.4 to pH = 9.5

32. A chemist has 2 solutions, one of pH = 1 and one of pH = 6. Based on the results of Experiments 1 and 2, could indigo carmine be used to distinguish between these solutions?

 F. No; indigo carmine is blue at both pH = 1 and pH = 6.
 G. No; indigo carmine is blue at pH = 1 and is yellow at pH = 6.
 H. Yes; indigo carmine is blue at both pH = 1 and pH = 6.
 J. Yes; indigo carmine is blue at pH = 1 and is yellow at pH = 6.

33. A student claimed that Solution III has a pH of 7.3. Are the results of Experiments 1–3 consistent with this claim?

 A. No, because in Solution III metanil yellow was yellow.
 B. No, because in Solution III resorcin blue was red.
 C. Yes, because in Solution III metanil yellow was yellow.
 D. Yes, because in Solution III resorcin blue was red.

34. Based on the results of Experiments 1–3, which of Solutions I–IV has the *lowest* pH ?

 F. Solution I
 G. Solution II
 H. Solution III
 J. Solution IV

Passage VII

Drilling mud (DM) is a suspension of clay particles in water. When a well is drilled, DM is injected into the hole to lubricate the drill. After this use, the DM is brought back up to the surface and then disposed of by spraying it on adjacent land areas.

A cover of DM on plants and soil can affect the *albedo* (proportion of the total incoming solar radiation that is reflected from a surface), which in turn can affect the soil temperature. The effect of a cover of DM on the albedo and the soil temperature of an unsloped, semiarid grassland area was studied from July 1 to August 9 of a particular year.

On June 30, 3 plots (Plots 1–3), each 10 m by 40 m, were established in the grassland area. For all the plots, the types of vegetation present were the same, as was the density of the vegetation cover. At the center of each plot, a soil temperature sensor was buried in the soil at a depth of 2.5 cm. An instrument that measures incoming and reflected solar radiation was suspended 60 cm above the center of each plot.

An amount of DM equivalent to 40 cubic meters per hectare (m³/ha) was then sprayed evenly on Plot 2. (One hectare equals 10,000 m².) An amount equivalent to 80 m³/ha was sprayed evenly on Plot 3. No DM was sprayed on Plot 1.

For each plot, the albedo was calculated for each cloudless day during the study period using measurements of incoming and reflected solar radiation taken at noon on those days (see Figure 1).
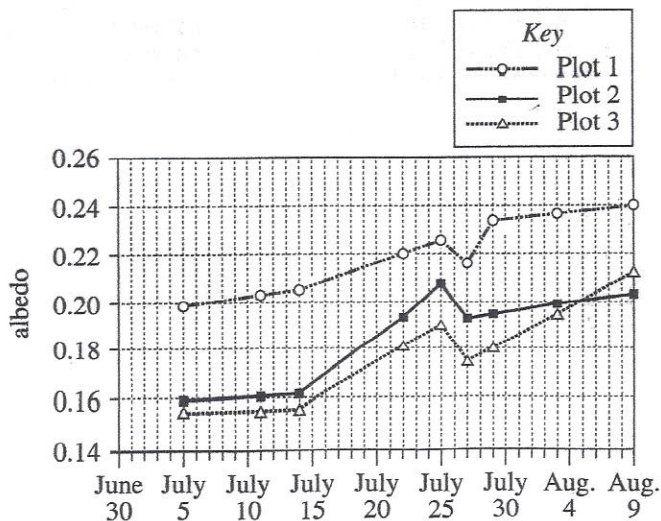

Figure 1

For each plot, the sensor recorded the soil temperature every 5 sec over the study period. From these data, the average soil temperature of each plot was determined for each day (see Figure 2).
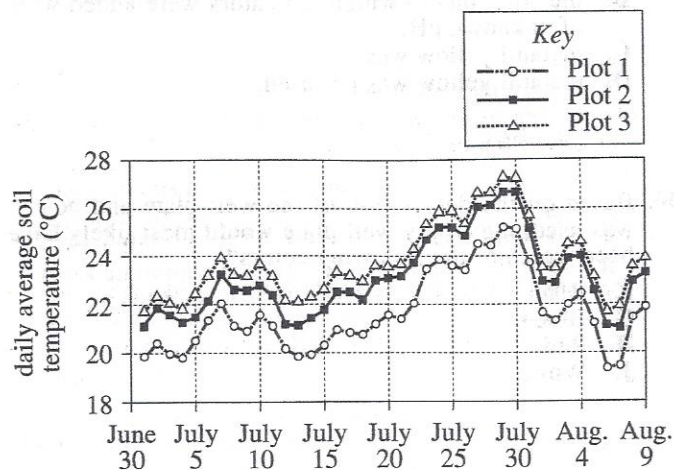

Figure 2

Figures adapted from Francis Zvomuya et al., "Surface Albedo and Soil Heat Flux Changes Following Drilling Mud Application to a Semiarid, Mixed-Grass Prairie." ©2008 by the Soil Science Society of America.

35. Albedo was measured at noon because that time of day is when solar radiation reaching the ground is:

A. 100% reflected.
B. 100% absorbed.
C. least intense.
D. most intense.

36. Why was the study designed so that the 3 plots had the same types of vegetation present and the same density of vegetation cover? These conditions ensured that any variations in albedo and soil temperature would most likely be attributable only to variations among the plots in the:

F. amount of DM sprayed.
G. type of soil present.
H. plot area.
J. plot slope.

37. For each plot, the number of temperature readings recorded by the soil temperature sensor every minute was closest to which of the following?

    A. 5
    B. 12
    C. 50
    D. 60

38. According to Figure 1 and the description of the study, was July 20 a cloudless day?

    F. No, because albedo data were not collected on that day.
    G. No, because albedo data were collected on that day.
    H. Yes, because albedo data were not collected on that day.
    J. Yes, because albedo data were collected on that day.

39. According to the results of the study, did the presence of a cover of DM increase or decrease the albedo, and did the presence of a cover of DM increase or decrease the soil temperature?

	albedo	soil temperature
A.	increase	increase
B.	increase	decrease
C.	decrease	decrease
D.	decrease	increase

40. Based on Figure 1, on August 3, what percent of incoming solar radiation was NOT reflected from Plot 2 ?

    F. 20%
    G. 40%
    H. 60%
    J. 80%

END OF TEST 4

STOP! DO NOT RETURN TO ANY OTHER TEST.