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

If a gum is added to water (such as the water in a food product), the *viscosity* (resistance to flow) of the resulting aqueous mixture changes. Table 1 shows, for each of 4 gums (Gums W, X, Y, and Z), the viscosity, in centipoise (cP), of a 1.0% by mass aqueous mixture of the gum at 3 temperatures and at 3 resting times. A *resting time* is a period of time an aqueous mixture of a gum sits at rest just after having been prepared.

Table 1

Gum	Temperature (°C)	Viscosity (cP) of a 1.0% aqueous gum mixture at a resting time of:		
		30 min	75 min	120 min
W	25	4,826	8,300	11,288
	45	3,250	6,825	9,282
	65	2,549	3,849	5,158
X	25	2,562	4,058	5,534
	45	2,100	3,462	4,686
	65	1,640	2,509	3,387
Y	25	1,201	1,994	2,771
	45	781	1,639	2,279
	65	531	802	1,075
Z	25	1,064	1,879	2,668
	45	512	1,562	2,233
	65	384	626	864

Figure 1 shows, for a certain temperature and a certain resting time, how the viscosity of aqueous mixtures of each of the 4 gums varies with gum concentration in percent by mass.

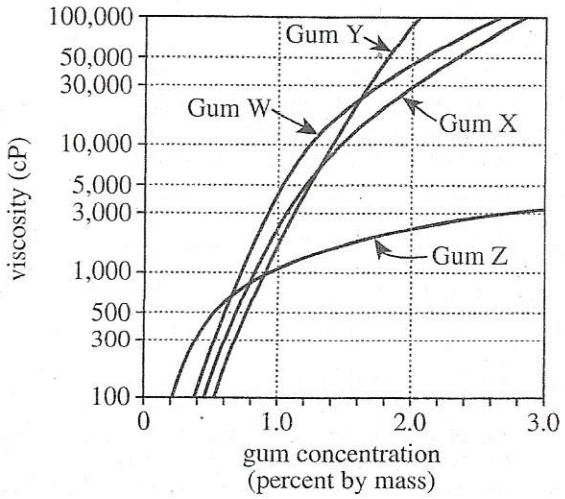
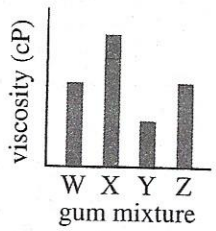


Figure 1

Table and figure adapted from G. O. Phillips and P. A. Williams, eds., *Handbook of Hydrocolloids*, 2nd ed. ©2009 by CRC Press and Woodhead Publishing, Ltd.

1. Based on Table 1, which of the following graphs best compares the viscosities of 1.0% aqueous mixtures of Gums W, X, Y, and Z at 45°C and a resting time of 75 min ?

A.



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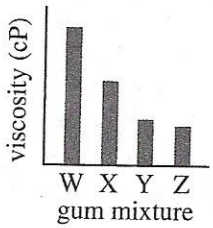
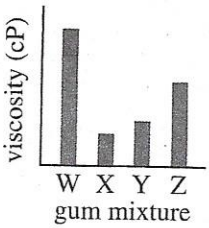
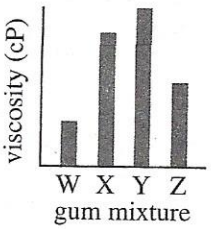


B.



D.



2. Based on Table 1, if a just-prepared 1.0% aqueous mixture of Gum Y is allowed to sit at rest for 100 min at 65°C, its viscosity will most likely be:

F. less than 500 cP.
G. between 500 cP and 800 cP.
H. between 800 cP and 1,100 cP.
J. greater than 1,100 cP.

3. Consider the viscosities shown in Figure 1 for a gum concentration of 2.0%. What is the order of the gums corresponding to those viscosities, from lowest viscosity to highest viscosity?

A. Gum W, Gum Y, Gum X, Gum Z
B. Gum W, Gum Z, Gum X, Gum Y
C. Gum Z, Gum X, Gum W, Gum Y
D. Gum Z, Gum Y, Gum W, Gum X

4. Under the conditions that are the basis for Figure 1, a 1.3% aqueous mixture of which gum has the highest viscosity?

F. Gum W
G. Gum X
H. Gum Y
J. Gum Z

5. Based on Table 1, a 1.0% aqueous mixture of Gum Z at 30°C and a resting time of 75 min would most likely have a viscosity closest to which of the following?

A. 1,250 cP
B. 1,750 cP
C. 2,050 cP
D. 2,350 cP

6. Under the conditions that are the basis for Figure 1, an aqueous mixture of which gum has a viscosity of 100,000 cP at a *lower* concentration than any of the other 3 gums?

F. Gum W
G. Gum X
H. Gum Y
J. Gum Z

Passage II

Biodiesel (BD) is a renewable alternative to traditional petroleum diesel (PD). BD is typically prepared by reacting soybean oil with methanol in the presence of a catalyst, forming compounds called *fatty acid methyl esters* (FAMEs). In contrast, PD contains no FAMEs. The presence of FAMEs in BD causes BD to absorb infrared light differently than does PD. This difference allows pure BD, pure PD, and mixtures of BD and PD to be distinguished by analyzing the absorbance of infrared light.

Students performed 3 studies in which they determined the infrared absorbance characteristics of pure BD, pure PD, and mixtures of BD and PD.

Study 1

The students measured the absorbance, A, of a sample of pure BD and a sample of pure PD at *wavenumbers* from 600 cm^{-1} through 1,800 cm^{-1}. The wavenumber corresponding to a given wavelength is defined as $\frac{1}{\text{the wavelength}}$, where the wavelength is given in cm and the resulting wavenumber is given in cm^{-1}. They plotted the results for each sample (see Figure 1).

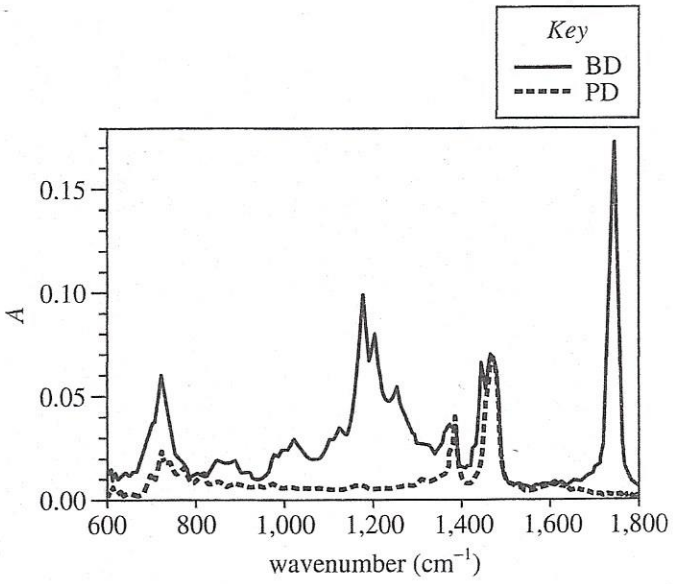


Figure 1

Study 2

The students prepared 7 different mixtures of BD and PD, each containing a different percent by volume of BD. Then, they measured A at 1,746 cm^{-1} for a sample of each of the 7 mixtures, a sample of pure BD, and a sample of pure PD (see Figure 2).

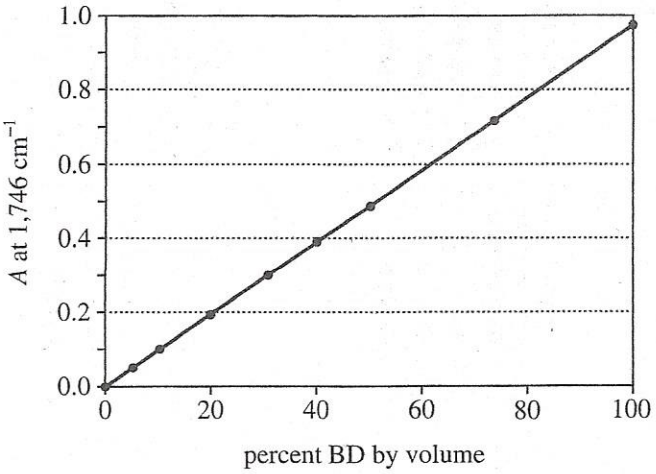


Figure 2

Figures 1 and 2 adapted from A. P. Ault and R. Pomery, "Quantitative Investigations of Biodiesel Fuel Using Infrared Spectroscopy: An Instrumental Analysis Experiment for Undergraduate Chemistry Students." ©2011 by Division of Chemical Education, Inc., American Chemical Society.

Study 3

The students obtained 4 different samples of commercial fuel blends of BD and PD (Samples W–Z). They measured A at 1,746 cm^{-1} for each sample, and then used Figure 2 to calculate the percent BD by volume of each sample (see Table 1).

Table 1

Sample	Percent BD by volume
W	4.0
X	6.0
Y	4.8
Z	4.7

Table 1 adapted from Z. V. Feng and J. T. Buchman, "Instrumental Analysis of Biodiesel Content in Commercial Diesel Blends: An Experiment for Undergraduate Analytical Chemistry." ©2012 by Division of Chemical Education, Inc., American Chemical Society.

7. If the students had tested a 60% BD by volume sample in Study 2, A at 1,746 cm^{-1} would most likely have been:

   A. less than 0.45.
   B. between 0.45 and 0.55.
   C. between 0.55 and 0.65.
   D. greater than 0.65.

8. In Study 2, among the samples tested, as the percent by volume of BD increased, A at 1,746 cm^{-1}:

   F. increased only.
   G. decreased only.
   H. increased and then decreased.
   J. decreased and then increased.

9. Based on the results of Study 2, which fuel sample in Study 3 most likely had the smallest A at 1,746 cm^{-1} ?

   A. Sample W
   B. Sample X
   C. Sample Y
   D. Sample Z

10. The production of BD as described in the passage is best represented by which of the following chemical equations?

    F. FAMEs + catalyst $\rightarrow$ soybean oil + methanol
    G. FAMEs + methanol $\rightarrow$ soybean oil + catalyst
    H. Soybean oil + methanol $\xrightarrow{\text{catalyst}}$ FAMEs
    J. Soybean oil + FAMEs $\xrightarrow{\text{catalyst}}$ methanol

11. Suppose that in Study 1 the students had measured the absorbance at wavenumbers from 600 cm^{-1} through only 1,600 cm^{-1} (instead of through 1,800 cm^{-1}). Based on Figure 1, would the students more likely have measured the absorbance in Study 2 at a wavenumber of 1,172 cm^{-1} or at a wavenumber of 1,464 cm^{-1} ?

    A. A wavenumber of 1,172 cm^{-1}, because PD, but not BD, absorbs strongly at this wavenumber.
    B. A wavenumber of 1,172 cm^{-1}, because BD, but not PD, absorbs strongly at this wavenumber.
    C. A wavenumber of 1,464 cm^{-1}, because PD, but not BD, absorbs strongly at this wavenumber.
    D. A wavenumber of 1,464 cm^{-1}, because BD, but not PD, absorbs strongly at this wavenumber.

12. Consider a sample that contains only FAMEs. Based on the results of Study 1, would the sample more strongly absorb light at a wavenumber of 900 cm^{-1} or light at a wavenumber of 1,250 cm^{-1} ?

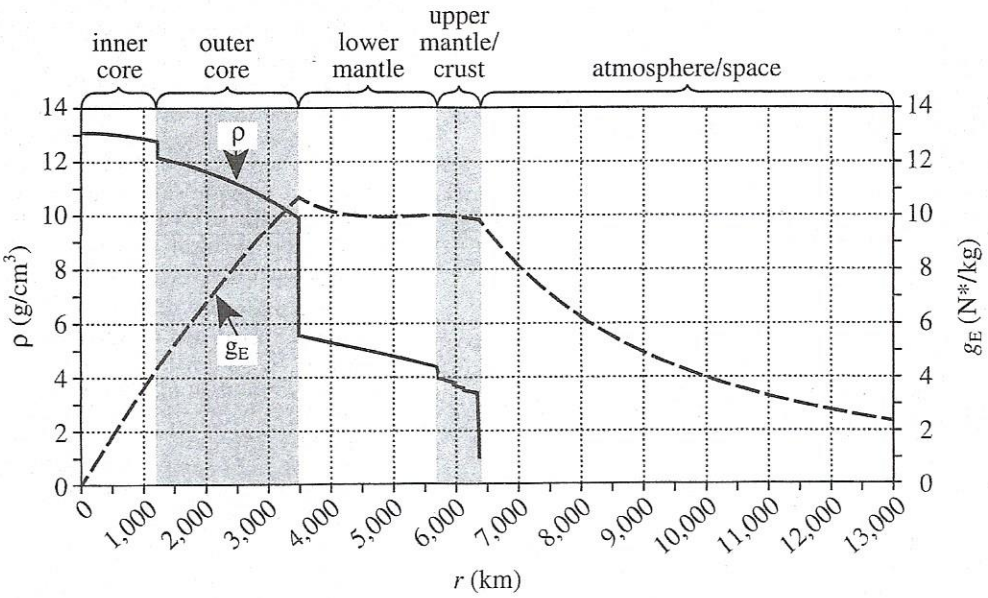
    F. A wavenumber of 900 cm^{-1}; PD contains FAMEs, and PD absorbed more strongly at 900 cm^{-1} than it did at 1,250 cm^{-1}.
    G. A wavenumber of 900 cm^{-1}; BD contains FAMEs, and BD absorbed more strongly at 900 cm^{-1} than it did at 1,250 cm^{-1}.
    H. A wavenumber of 1,250 cm^{-1}; PD contains FAMEs, and PD absorbed more strongly at 1,250 cm^{-1} than it did at 900 cm^{-1}.
    J. A wavenumber of 1,250 cm^{-1}; BD contains FAMEs, and BD absorbed more strongly at 1,250 cm^{-1} than it did at 900 cm^{-1}.

13. Consider the percent BD by volume listed in Table 1 for Sample Y. A 10 liter (L) volume of Sample Y would contain approximately what volume of BD, in liters and in milliliters (mL) ?

	L	mL
A.	0.5	500
B.	0.5	5,000
C.	5	500
D.	5	5,000

Passage III

Earth's gravitational field extends both above and below Earth's surface. In Figure 1, both the value of this field, g_E, and the average density, ρ, of matter within Earth are graphed versus distance, r, from Earth's center. In addition, Figure 1 identifies 5 regions, each of which is located either above or below Earth's surface.



*newtons, a unit of force

Figure 1

Figure 2 shows the percent of Earth's mass located within a given distance r from Earth's center. For example, 10% of Earth's mass is located within 2,300 km of Earth's center, 20% of Earth's mass is located within 2,900 km of Earth's center, and so on.

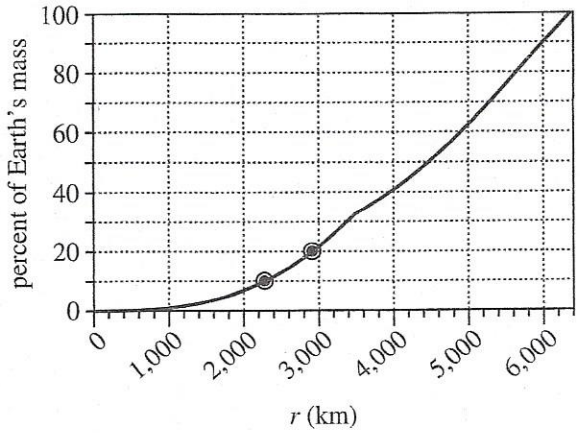


Figure 2

Figures adapted from A. M. Dziewonski and D. L. Anderson, "Preliminary Reference Earth Model." ©1981 by Elsevier B.V.

14. According to Figure 1, which 2 regions are most similar in thickness?

F. The inner core and the outer core
G. The inner core and the upper mantle/crust
H. The outer core and the lower mantle
J. The outer core and the upper mantle/crust

15. According to Figure 2, the innermost 30% of Earth's mass is located between $r = 0$ km and:

A. $r = 3{,}400$ km.
B. $r = 3{,}900$ km.
C. $r = 4{,}500$ km.
D. $r = 5{,}300$ km.

16. Figures 1 and 2 indicate that Earth's radius is approximately:

F. 1,400 km.
G. 3,500 km.
H. 5,700 km.
J. 6,400 km.

17. Based on Figure 1, the approximate value of Earth's gravitational field at $r = 14{,}000$ km is most likely:

A. less than 0.5 N/kg.
B. between 0.5 N/kg and 1.5 N/kg.
C. between 1.5 N/kg and 2.5 N/kg.
D. greater than 2.5 N/kg.

18. On average, Earth's crust is about 30 km thick. Based on Figure 2, the crust accounts for approximately what percent of Earth's mass?

F. 1%
G. 10%
H. 90%
J. 99%

19. Consider 2 hypothetical 1 kg rocks: one located at $r = 2{,}000$ km and the other located at $r = 4{,}000$ km. Based on Figure 1, which of these 2 rocks, if either, more likely weighs *less* ?

A. The rock located at $r = 2{,}000$ km; the value of g_E is less at that location so the rock there has a smaller gravitational force exerted on it.
B. The rock located at $r = 4{,}000$ km; the value of ρ is less at that location so the rock there has a smaller mass.
C. Neither rock; the rocks have identical masses so they have the same weight.
D. Neither rock; the value of g_E is the same for both rocks so they have the same weight.

Passage IV

Biological aging is the process by which the functions within an animal cell gradually decline, causing the cell to age. Four students each proposed an explanation for how this process occurs.

Student 1

Biological aging is caused solely by the *reactive oxygen species* (ROS) produced by cellular respiration. ROS are molecules that damage the proteins and lipids in a cell. A cell produces antioxidants, which eliminate ROS before they cause cell damage. However, the amount of antioxidants produced by a cell is always less than what is needed to eliminate all the ROS produced by that cell. Therefore, ROS damage accumulates in a cell, causing it to age.

Student 2

Biological aging is caused solely by the formation of *cross-links* (a type of chemical bond) between the proteins in a cell, causing these proteins to form clumps. These clumps accumulate in a cell, interfering with the cell's functions, causing it to age. Although ROS is damaging to proteins and lipids, this damage never occurs in a cell because the amount of antioxidants produced by a cell is always greater than what is needed to eliminate all the ROS produced by that cell.

Student 3

Biological aging is caused solely by the DNA damage that results from cell exposure to certain environmental agents. The extent of DNA damage caused by these agents eventually exceeds the cell's ability to repair this damage. Therefore, DNA damage accumulates in a cell, causing it to age. Although cells do produce ROS, ROS damage never accumulates in a cell. While cross-linked proteins do form clumps in a cell, these clumps never affect cell function.

Student 4

Biological aging is caused solely by the *lipofuscin* (a brown pigment made of oxidized lipids) produced by cellular respiration. Lipofuscin forms clumps that accumulate in a cell, interfering with the cell's functions, causing it to age. Although cells do produce ROS, ROS damage never accumulates in a cell. Because protein cross-links are short-lived, protein clumps never accumulate in a cell. The extent of DNA damage that occurs in a cell never exceeds the cell's ability to repair that damage.

20. Which of the students, if any, claimed that biological aging is caused by a substance produced by cellular respiration?

F. Student 1 only
G. Students 1 and 4 only
H. Students 2 and 3 only
J. None of the students

21. Suppose it were determined that the rate of biological aging in an animal cell is directly proportional to the number of chemical bonds formed between the proteins in that cell. This finding would be most consistent with the explanation given by:

A. Student 1.
B. Student 2.
C. Student 3.
D. Student 4.

22. Based on Student 2's explanation, the substances present in cells that are most directly involved with biological aging are composed of what type of subunits?

F. Amino acids
G. Fatty acids
H. Monosaccharides
J. Nucleotides

23. *Carnosine* is a substance that prevents protein cross-linking in animal cells. Which student would be most likely to predict that the average concentration of carnosine in the cells of young adults would be greater than the average concentration of carnosine in the cells of elderly adults?

A. Student 1
B. Student 2
C. Student 3
D. Student 4

24. Which of the students claimed that biological aging occurs because a substance accumulates into clumps that interfere with cellular function?

F. Students 1 and 2 only
G. Students 2 and 4 only
H. Students 1, 3, and 4 only
J. Students 1, 2, 3, and 4

25. Student 1's explanation would be most strongly supported if which of the following observations were made?

A. Increasing the number of protein cross-links in animal cells increases the rate at which those cells age.
B. Decreasing the number of protein cross-links in animal cells increases the rate at which those cells age.
C. Increasing the antioxidant concentration in animal cells increases the rate at which those cells age.
D. Decreasing the antioxidant concentration in animal cells increases the rate at which those cells age.

26. *Compound X* is a chemical that causes genetic mutations in human cells. Suppose it were determined that human neurons grown in the presence of Compound X age at the same rate as human neurons grown in the absence of Compound X. This finding would *weaken* the explanation(s) given by which of the students?

F. Student 2 only
G. Student 3 only
H. Students 1 and 3 only
J. Students 2 and 4 only

Passage V

In a lake, water *leaches* (dissolves out) soluble organic compounds from decaying tree leaves, producing *dissolved organic carbon* (DOC). DOC is subsequently removed from the water if it is *adsorbed* by (becomes adhered to the surface of) clay mineral particles that are suspended in the water. Three studies done at a lake examined DOC adsorption by 3 clay minerals—CM1, CM2, and CM3—found in the lake's sediment.

Green leaves were collected from 5 types of trees around the lake (maple, oak, pine, magnolia, and rhododendron). A 5 L volume of lake water was filtered to remove all solid particles. The following procedures were performed for each type of leaf: A 100 g sample of the leaves was mixed with a 1 L volume of the filtered lake water. The mixture was then placed in the dark for 10 weeks at 4°C while leaching occurred. At 10 weeks, the mixture was filtered to remove all solid particles. The resulting liquid (the *leachate*) was analyzed for DOC.

Study 1

The following procedures were performed for each leachate: A 100 mL volume of the leachate was mixed with 10 g of CM1. The mixture was stirred continuously for 2 hr, then filtered to remove all solid particles. The resulting liquid (the *filtrate*) was analyzed for DOC. The percent of the leachate DOC that had been adsorbed by CM1 was calculated (see Figure 1).

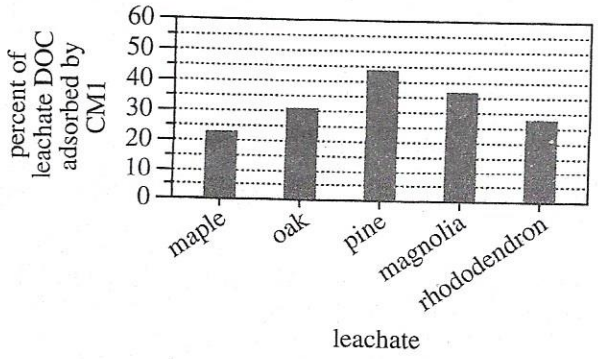


Figure 1

Study 2

Study 1 was repeated, substituting CM2 for CM1 (see Figure 2).

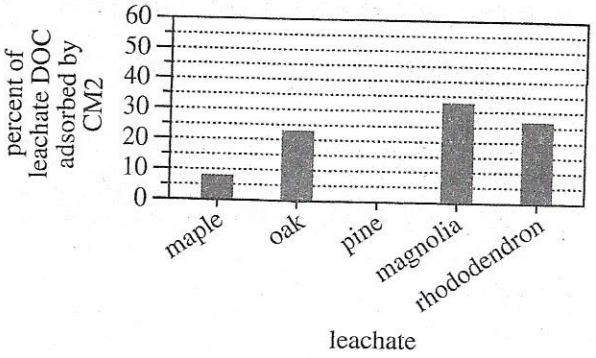


Figure 2

Study 3

Study 1 was repeated, substituting CM3 for CM1 (see Figure 3).

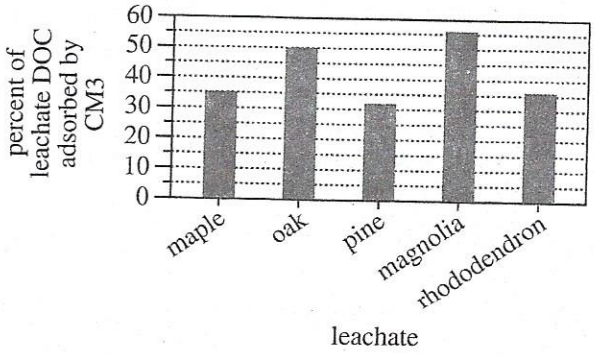


Figure 3

Figures and table adapted from Todd Tietjen, Anssi Vähätalo, and Robert Wetzel, "Effects of Clay Mineral Turbidity on Dissolved Organic Carbon and Bacterial Production." ©2005 by the Swiss Federal Institute for Environmental Science and Technology.

27. According to the results of the studies, from which of the 5 leachates was the greatest percent of DOC adsorbed by CM1, CM2, and CM3, respectively?

	CM1	CM2	CM3
A.	maple	maple	rhododendron
B.	oak	pine	magnolia
C.	pine	magnolia	rhododendron
D.	pine	magnolia	magnolia

28. According to the results of Study 3, the percent of leachate DOC adsorbed by CM3, averaged across the 5 types of leaves, is closest to which of the following?

F. 10%
G. 20%
H. 30%
J. 40%

29. Is the statement "CM2 adsorbed a greater percent of the DOC in the maple leachate than did CM3" supported by the results of Studies 2 and 3 ?

A. Yes; CM2 adsorbed 35% of the leachate DOC, whereas CM3 adsorbed 7%.
B. Yes; CM2 adsorbed 55% of the leachate DOC, whereas CM3 adsorbed 17%.
C. No; CM2 adsorbed 7% of the leachate DOC, whereas CM3 adsorbed 35%.
D. No; CM2 adsorbed 17% of the leachate DOC, whereas CM3 adsorbed 55%.

30. What was the independent (manipulated) variable in each of the 3 studies and what was the independent variable across the 3 studies?

	in each study	across the studies
F.	type of lake water	type of clay mineral
G.	type of leaf leachate	type of clay mineral
H.	volume of leaf leachate	mass of clay mineral
J.	volume of filtrate	mass of leaves

31. According to the results of the studies, which of the 3 clay minerals, if any, reduced the DOC in the oak leachate by more than 50% ?

A. CM1 only
B. CM2 only
C. CM1 and CM3 only
D. None of the 3 clay minerals

32. Is a mixture of any one of the leachates and any one of the clay minerals properly considered a solution?

F. Yes, because the clay mineral particles are dissolved in the leachate.
G. Yes, because the clay mineral particles are not dissolved in the leachate.
H. No, because the clay mineral particles are dissolved in the leachate.
J. No, because the clay mineral particles are not dissolved in the leachate.

33. In lake water, DOC is broken down into simpler compounds by electromagnetic energy in the visible wavelength range. What action was taken in the studies to prevent this process from occurring?

A. Each mixture of leaves and filtered lake water was placed in the dark.
B. Each mixture of filtrate and clay mineral was placed in the dark.
C. Each mixture of leaves and lake water was filtered.
D. Each mixture of leachate and clay mineral was filtered.

Passage VI

Plant roots can respond to a stimulus. Response to light is *phototropism*; response to gravity is *gravitropism*. Growth toward a stimulus is a *positive tropism*; growth away from a stimulus is a *negative tropism*.

For 2 experiments with *wild-type* (WT) and *mutant* (M) *Arabidopsis* seeds, nutrient agar was put into each of 8 petri dishes (PD1–PD8).

Experiment 1

Six WT *Arabidopsis* seeds were placed in each of PD1 and PD2. Six M *Arabidopsis* seeds were placed in each of PD3 and PD4. Then, PD1 and PD3 were placed in the dark for 70 hr, and PD2 and PD4 were exposed to light from above for 70 hr. Figure 1 shows the growth of the *hypocotyls* (seedling stems) above the surface of the nutrient agar and the growth of the *radicles* (seedling roots) below the surface of the nutrient agar in each dish at 70 hr.

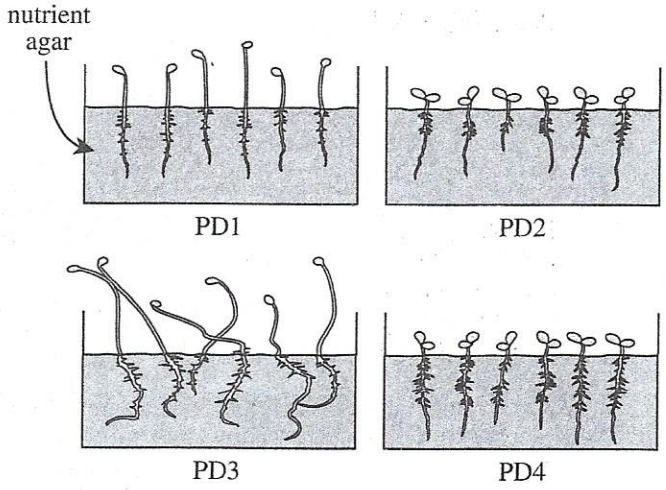


Figure 1

Experiment 2

Six WT *Arabidopsis* seeds were placed in each of PD5 and PD6. Six M *Arabidopsis* seeds were placed in each of PD7 and PD8. Then, PD5–PD8 were exposed to light from above for 70 hr. After 70 hr, each petri dish was turned 90° such that each dish was vertical and the seedlings in each dish were approximately horizontal (see Figure 2).

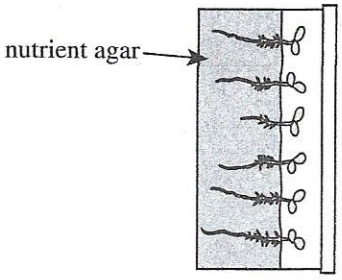


Figure 2

Then, PD5 and PD7 were exposed to light from above for 25 hr while PD6 and PD8 were exposed to light from below for 25 hr. At various times during the 25 hr, the downward curvature, in degrees (°), of the radicle (relative to its starting position) of each seedling in each dish was measured. The average downward curvature of the radicles in each dish at each measurement time is shown in Figure 3.

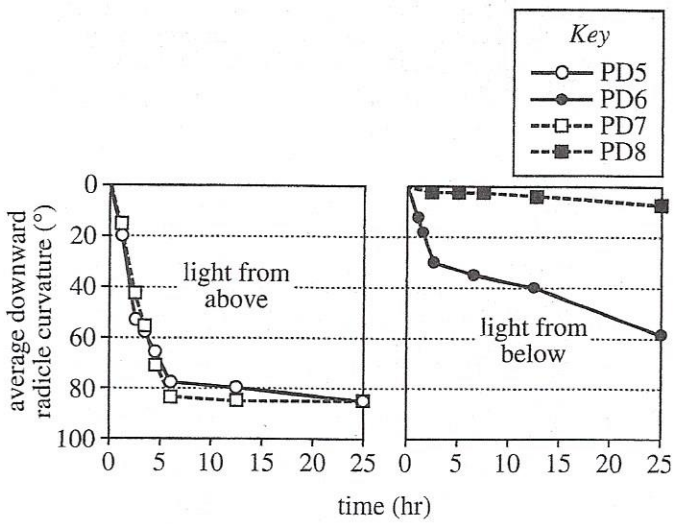
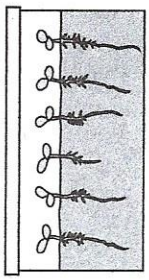


Figure 3

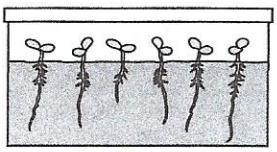
Figures adapted from Stanislav Vitha, Liming Zhao, and Fred David Sack, "Interaction of Root Gravitropism and Phototropism in Arabidopsis Wild-Type and Starchless Mutants." ©2000 by American Society of Plant Physiologists.

34. Which of the following figures best shows the orientation of PD5 before the petri dish was turned 90° ?

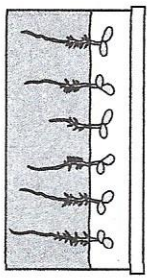
F.



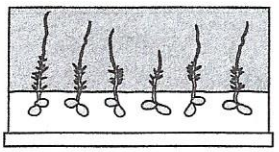
H.



G.



J.



35. PD8 contained the same type of seeds, and was subject to the same growth conditions before being turned 90°, as which petri dish in Experiment 1 ?

A. PD1
B. PD2
C. PD3
D. PD4

36. Based on the results of Experiment 1, in the absence of light, did the radicles of the M *Arabidopsis* seedlings have the same response to gravity as did the radicles of the WT seedlings?

F. No; the variation in the orientation of the radicles in PD3 was greater than that of the radicles in PD1.
G. No; the variation in the orientation of the radicles in PD4 was greater than that of the radicles in PD2.
H. Yes; the variation in the orientation of the radicles in PD3 was the same as that of the radicles in PD1.
J. Yes; the variation in the orientation of the radicles in PD4 was the same as that of the radicles in PD2.

37. During the 25 hr in Experiment 2 that WT *Arabidopsis* seedlings were exposed to light from below, did the hypocotyls of the seedlings more likely exhibit positive phototropism or negative phototropism?

A. Positive, because seedling hypocotyls typically grow away from a light stimulus.
B. Positive, because seedling hypocotyls typically grow toward a light stimulus.
C. Negative, because seedling hypocotyls typically grow away from a light stimulus.
D. Negative, because seedling hypocotyls typically grow toward a light stimulus.

38. Based on the results shown in Figure 1 for PD2, is *Arabidopsis* a monocot or a dicot?

F. Monocot; seedlings have 1 cotyledon.
G. Monocot; seedlings have 2 cotyledons.
H. Dicot; seedlings have 1 cotyledon.
J. Dicot; seedlings have 2 cotyledons.

39. In Experiment 2, each petri dish had how many different orientations?

A. 1
B. 2
C. 3
D. 4

40. To evaluate the effect of light on the growth of WT *Arabidopsis* seedlings, the results for which 2 petri dishes in Experiment 1 should be compared?

F. PD1 and PD2
G. PD1 and PD3
H. PD2 and PD3
J. PD2 and PD4

END OF TEST 4

STOP! DO NOT RETURN TO ANY OTHER TEST.