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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

Two measures of water quality are the number of *Escherichia coli* bacteria present and the *biotic index*, BI (a numerical value based on the type, diversity, and pollution tolerance of aquatic invertebrate animals). Both of these measures can be affected by water flow.

E. coli levels that are above 100 colonies formed per 100 mL of water indicate reduced water quality. Figure 1 shows the *E. coli* levels on 5 collection days at Sites 1 and 2 in a river.

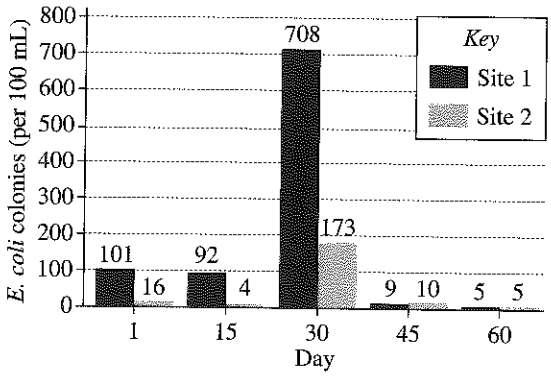

Figure 1

Table 1 shows how water quality rating varies with BI. Table 2 shows the average BI of each site during the collection period.

Table 1

BI	Water quality rating
≥ 3.6	excellent
2.6 to 3.5	good
2.1 to 2.5	fair
1.0 to 2.0	poor

Table 2

Location	Average BI
Site 1	6.3
Site 2	2.5

Figure 2 shows the water flow at each site on the 5 collection days.

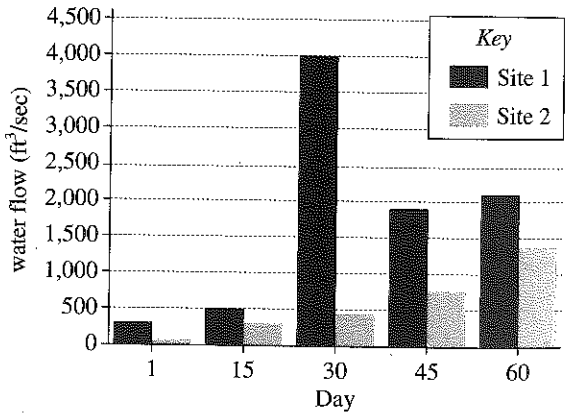

Figure 2

Figures adapted from Stephen C. Landry and Michele L. Tremblay, "State of the Upper Merrimack 1995–1997: A River Quality Report." ©2000 by Upper Merrimack River Local Advisory Committee.

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1. If an *E. coli* level of over 400 colonies formed per 100 mL of water is unsafe for swimming, on which of the following collection days and at which site would it have been unsafe to swim?

   A. Day 1 at Site 1
   B. Day 30 at Site 1
   C. Day 1 at Site 2
   D. Day 30 at Site 2

2. Based on Figures 1 and 2, consider the average water flow and the average *E. coli* level for Site 1 and Site 2 over the collection period. Which site had the higher average water flow, and which site had the higher average *E. coli* level?

	Higher water flow	Higher *E. coli* level
F.	Site 1	Site 1
G.	Site 1	Site 2
H.	Site 2	Site 1
J.	Site 2	Site 2

3. According to Table 1, what is the relationship between water quality and biotic index?

   A. As water quality improves, biotic index increases.
   B. As water quality improves, biotic index remains the same.
   C. As water quality degrades, biotic index increases.
   D. As water quality degrades, biotic index remains the same.

4. As water quality improves, the number of *stone fly larvae* (a type of aquatic invertebrate) increases. Students hypothesized that more stone fly larvae would be found at Site 1 than at Site 2. Are the data presented in Table 2 consistent with this hypothesis?

   F. Yes; based on BI, Site 1 had a water quality rating of good and Site 2 had a water quality rating of poor.
   G. Yes; based on BI, Site 1 had a water quality rating of excellent and Site 2 had a water quality rating of fair.
   H. No; based on BI, Site 1 had a water quality rating of poor and Site 2 had a water quality rating of good.
   J. No; based on BI, Site 1 had a water quality rating of fair and Site 2 had a water quality rating of excellent.

5. Which set of data best supports the claim that Site 1 has *lower* water quality than Site 2 ?

   A. Figure 1
   B. Figure 2
   C. Table 1
   D. Table 2

6. Suppose large amounts of fertilizer from adjacent fields begin to enter the river at Site 1. The BI of this site will most likely change in which of the following ways? The BI will:

   F. increase, because water quality is likely to increase.
   G. increase, because water quality is likely to decrease.
   H. decrease, because water quality is likely to increase.
   J. decrease, because water quality is likely to decrease.

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4 ○ ○ ○ ○ ○ ○ ○ ○ ○ 4

Passage II

Aluminum water-based paints (AWPs) contain aluminum (Al) flakes that give surfaces a shiny, metallic appearance. If the flakes corrode, a dull coating of aluminum hydroxide forms on them:

$$2Al + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2$$

Table 1 shows the volume of H_2 gas produced over time (at 25°C and 1 atm) from 100 mL samples of freshly made AWPs 1–3 in 3 separate trials. AWPs 1–3 were identical except that each had a different concentration of DMEA, an AWP ingredient that increases pH.

Table 1

AWP	pH of AWP	Volume (mL) of H_2 produced by:			
		Day 2	Day 4	Day 6	Day 8
1	8	4	33	81	133
2	9	21	187	461	760
3	10	121	1,097	2,711	4,480

The AWP 3 trial was repeated 4 times, but for each trial, the sample had the same concentration of 1 of 4 corrosion inhibitors (see Figure 1).

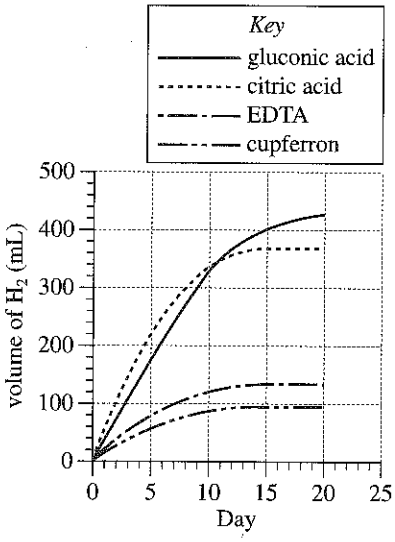
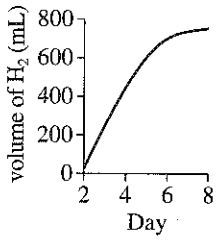
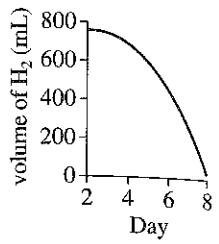


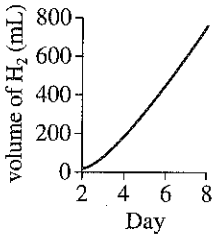
Figure 1

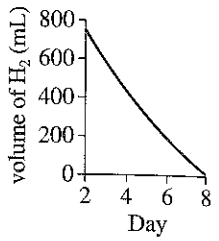
Figure 1 adapted from Bodo Müller, "Corrosion Inhibitors for Aluminum." ©1995 by Division of Chemical Education, Inc., American Chemical Society.

7. Based on Table 1, which of the following graphs best shows how the volume of H_2 produced by AWP 2 changed over time?

A.


C.


B.


D.


8. Based on Table 1, if the volume of H_2 produced by Day 10 from the AWP 1 sample had been measured, it would most likely have been:

F. less than 133 mL.
G. between 133 mL and 461 mL.
H. between 461 mL and 760 mL.
J. greater than 760 mL.

9. According to Table 1, what volume of H_2 was produced by AWP 1 from the time the volume was measured on Day 6 until the time the volume was measured on Day 8 ?

A. 52 mL
B. 81 mL
C. 133 mL
D. 214 mL

10. In the trials represented in Table 1 and Figure 1, by measuring the volume of H_2, the experimenters were able to monitor the rate at which:

F. H_2O is converted to Al.
G. Al is converted to H_2O.
H. Al is converted to $Al(OH)_3$.
J. $Al(OH)_3$ is converted to Al.

GO ON TO THE NEXT PAGE.

4 ○ ○ ○ ○ ○ ○ ○ ○ ○ 4

11. Based on the passage, is DMEA most likely an acid or a base?

A. An acid, because DMEA decreases pH.
B. An acid, because DMEA increases pH.
C. A base, because DMEA decreases pH.
D. A base, because DMEA increases pH.

12. Consider the volume of H_2 produced by Day 2 from the AWP 3 sample that contained no corrosion inhibitor. Based on Table 1 and Figure 1, the AWP 3 sample containing EDTA produced approximately the same volume of H_2 by which of the following days?

F. Day 1
G. Day 4
H. Day 7
J. Day 10

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Passage III

Students studied forces by using 2 identical platform scales, Scale A and Scale B, one of which is shown in Figure 1.

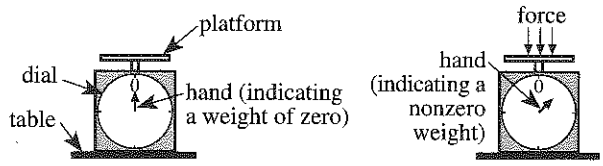


Figure 1

The weight of the platform of each scale was insignificant. When a force (such as that produced by a weight) was exerted on the surface of the platform, the hand rotated clockwise away from the zero point on the dial. The amount of rotation was directly proportional to the strength of the force.

Study 1

Prior to each of Trials 1–3, the students set the dial readings of both Scales A and B to zero. In each of these 3 trials, Scale A was stacked on top of Scale B (see Figure 2). In Trial 1, no weight was placed on the platform of Scale A; in Trial 2, a 5.0 newton (N) weight was placed on the platform of Scale A; and in Trial 3, a 10.0 N weight was placed on the platform of Scale A. The dial readings for the 3 trials are also shown in Figure 2.

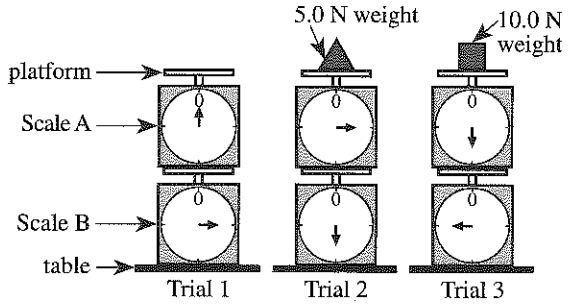


Figure 2

Study 2

The students placed a pencil on the platform of each scale and positioned on top of the pencils a board that spanned the 0.40 m distance between the 2 scales. Prior to each of Trials 4–6, the students set the dial readings of Scales A and B to zero (see Figure 3).

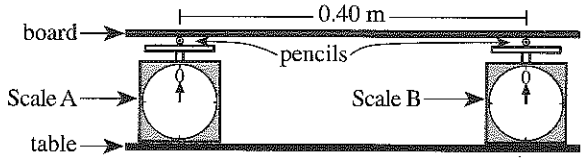


Figure 3

In each of these 3 trials, a 10.0 N weight was placed on the board at various distances from the pencil on Scale B (see Figure 4). In Trial 4, the weight was 0.10 m from the pencil; in Trial 5, the weight was 0.20 m from the pencil; and in Trial 6, the weight was 0.30 m from the pencil. The dial readings for the 3 trials are also shown in Figure 4.

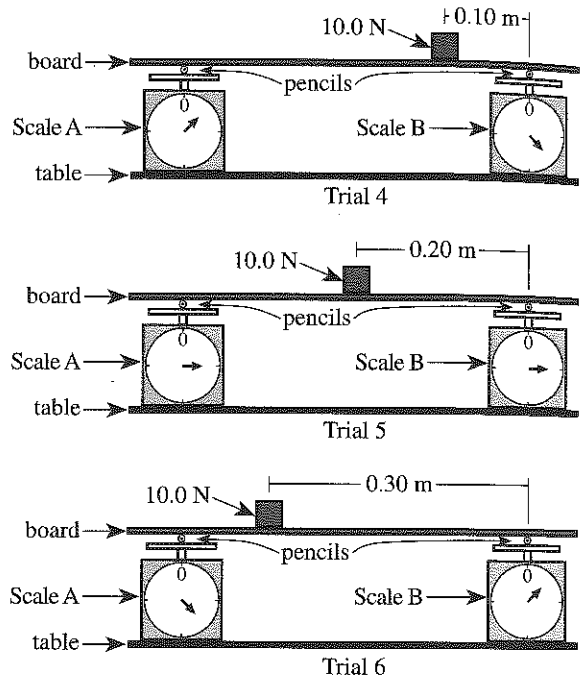


Figure 4

13. In which of the trials in Study 2, if any, was the force of the 10.0 N weight equally distributed between Scales A and B ?

    A. Trial 4
    B. Trial 5
    C. Trial 6
    D. None of the trials

14. Based on the results of Trials 1 and 2, Scale A and Scale B each weighed:

    F. 2.5 N.
    G. 5.0 N.
    H. 7.5 N.
    J. 10.0 N.

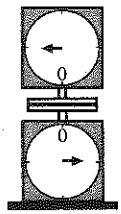
GO ON TO THE NEXT PAGE.

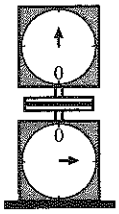
4 ○ ○ ○ ○ ○ ○ ○ ○ ○ 4

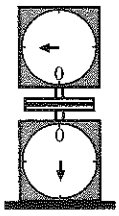
15. Assume that whenever a weight was placed on a scale's platform, a spring inside the scale was compressed. Assume also that the greater the added weight, the greater the amount of compression. Was the amount of potential energy stored in Scale A's spring greater in Trial 1 or in Trial 3 ?

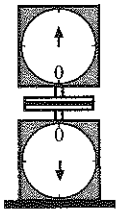
A. In Trial 1, because the amount of weight on the platform of Scale A was greater in Trial 1.
B. In Trial 1, because the amount of weight on the platform of Scale A was less in Trial 1.
C. In Trial 3, because the amount of weight on the platform of Scale A was greater in Trial 3.
D. In Trial 3, because the amount of weight on the platform of Scale A was less in Trial 3.

16. In a new study, suppose Scale A were placed upside down atop Scale B, so that the platform of Scale A rested directly on the platform of Scale B. Which of the following drawings best represents the results that would most likely be obtained for this arrangement?

F.


H.


G.


J.


17. The main reason the pencils were placed on the scales in Study 2 was most likely:

A. so that the line of contact between each pencil and its platform could be used as a reference line for distance measurements.
B. so that the board would roll from side to side, rather than sliding from side to side over the scales' platforms.
C. to add additional weight to the scales.
D. to provide extra room for air above each scale's platform, so that the air pressure would be the same above and below the platform.

18. In Study 2, as the distance between the 10.0 N weight and the pencil on Scale B increased, the amount of force exerted on the surface of Scale B's platform:

F. remained the same.
G. increased only.
H. decreased only.
J. varied, but with no general trend.

19. Which of the following statements most likely describes an important reason for setting the dial readings of both scales to zero after Study 1, prior to each of Trials 4–6 ?

A. To add the weights of the scales to each weight measurement
B. To add the weights of the board and pencils to each weight measurement
C. To subtract the weights of the scales from each weight measurement
D. To subtract the weights of the board and pencils from each weight measurement

GO ON TO THE NEXT PAGE.

4

Passage IV

The *octane number* of a fuel is a measure of how smoothly the fuel burns in a gasoline engine. Lower octane fuels *knock* (explode) when burned, which lowers fuel efficiency and can cause engine damage. Heptane knocks considerably when burned and is given an octane number of 0. Isooctane knocks very little and is given an octane number of 100.

Different proportions of heptane and isooctane were mixed to obtain mixtures with octane numbers between 0 and 100 (see Table 1).

Table 1

Volume of heptane (mL)	Volume of isooctane (mL)	Octane number
0	100	100
10	90	90
25	75	75
50	50	50
90	10	10
100	0	0

Experiment 1

A sample of each fuel mixture listed in Table 1 was burned in a test engine at an engine speed of 600 revolutions per minute (rpm). The number of knocks per minute was determined for each mixture. This was done so that an octane number could be assigned to any fuel by measuring its knock rate.

Experiment 2

Adding tetraethyllead (TEL) to a fuel changes its octane number. Different amounts of TEL were added to 1,000 mL samples of isooctane. Each fuel mixture was tested under the same conditions used in Experiment 1, and the measured knock rate was used to determine the octane number (see Figure 1).

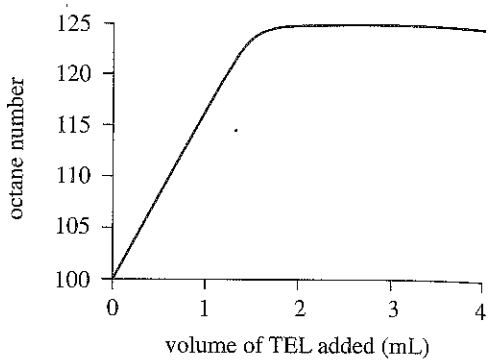


Figure 1

Experiment 3

The *engine octane requirement* (EOR) is the minimum octane number of a fuel required for an engine to operate without becoming damaged. Fuels A and B were burned separately in an engine at different speeds. Table 2 shows the octane number determined for each fuel at each engine speed and the known EOR of the engine at each speed.

Table 2

Engine speed (rpm)	EOR	Octane number in engine of:	
		Fuel A	Fuel B
1,500	97.4	98.4	96.7
2,000	95.3	96.6	96.1
2,500	93.5	95.0	95.4
3,000	91.9	92.3	93.8
3,500	90.6	90.9	92.5

GO ON TO THE NEXT PAGE

4 ○ ○ ○ ○ ○ ○ ○ ○ ○ 4

20. Based on Experiment 3, as engine speed increases, the minimum octane number of fuel required for an engine to operate without becoming damaged:

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

21. Suppose a trial had been performed in Experiment 3 at an engine speed of 2,200 rpm. At this engine speed, which of the following sets of octane numbers would most likely have been determined for Fuel A and Fuel B ?

	Fuel A	Fuel B
A.	95.0	95.4
B.	96.1	95.8
C.	96.6	96.1
D.	97.6	96.4

22. Which of the following expressions is equal to the octane number of each fuel mixture listed in Table 1 ?

F. $\frac{\text{volume of isooctane}}{\text{volume of heptane}} \times 100$

G. $\frac{\text{volume of heptane}}{\text{volume of isooctane}} \times 100$

H. $\frac{\text{volume of isooctane}}{(\text{volume of heptane} + \text{volume of isooctane})} \times 100$

J. $\frac{\text{volume of heptane}}{(\text{volume of heptane} + \text{volume of isooctane})} \times 100$

23. Based on Table 1 and Experiment 2, if 3 mL of TEL were added to a mixture of 100 mL of heptane and 900 mL of isooctane, the octane number of the resulting fuel would most likely be:

A. less than 55.
B. between 55 and 90.
C. between 90 and 125.
D. greater than 125.

24. Which of the 2 fuels from Experiment 3 would be better to use in an engine that will run at all engine speeds between 1,500 rpm and 3,500 rpm ?

F. Fuel A, because its octane number was lower than the EOR at each of the engine speeds tested.
G. Fuel A, because its octane number was higher than the EOR at each of the engine speeds tested.
H. Fuel B, because its octane number was lower than the EOR at each of the engine speeds tested.
J. Fuel B, because its octane number was higher than the EOR at each of the engine speeds tested.

25. Based on Table 1, if 2 mL of heptane were mixed with 8 mL of isooctane, the octane number of this mixture would be:

A. 2.
B. 8.
C. 20.
D. 80.

26. Suppose that 1 mL of TEL is added to 1,000 mL of heptane. Based on Experiment 2, one would predict that the octane number of the TEL/heptane mixture would be:

F. higher than the octane number of pure heptane, but lower than 115.
G. higher than the octane number of pure heptane, and higher than 115.
H. lower than the octane number of pure heptane, but higher than 115.
J. lower than octane number of pure heptane, and lower than 115.

GO ON TO THE NEXT PAGE.

4 ○ ○ ○ ○ ○ ○ ○ ○ ○ 4

Passage V

Introduction

Comets are complex mixtures of ices and dust that orbit the Sun. They can be classified by orbital period as either *long-period comets* or *short-period comets*.

Long-period comets have orbital periods of more than 200 yr and originate within our solar system in the *Oort Cloud*, a spherical shell of many icy bodies located at an average distance of 40,000 A.U. from the Sun (1 A.U. = average distance of Earth from the Sun). Long-period comets approach the Sun from all directions.

Short-period comets have orbital periods of 200 yr or less, and their orbital planes have *inclinations* 30° or less with respect to the *ecliptic plane*, the plane of Earth's orbit around the Sun. Portions of these planes are shown in Figure 1.

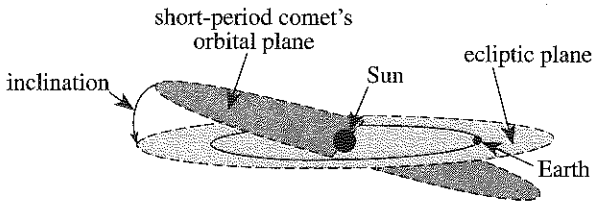


Figure 1

Two scientists present their viewpoints about the origin of short-period comets.

Scientist A

Short-period comets in our solar system originate within a thin ring-shaped region called the *Kuiper Belt* (KB). The KB has a small inclination with respect to the ecliptic plane and is located in the solar system between 30 A.U. and 50 A.U. from the Sun. The KB contains billions of icy bodies with diameters between 10 km and 30 km. These comet-size objects are too small to be clearly discerned at that distance with telescopes located on Earth's surface. Such telescopes have gathered indirect evidence, but not clear images, of much larger icy bodies that are part of the KB. The small inclinations of short-period comets' orbital planes with respect to the ecliptic plane are consistent with an origin in the KB. It has been discovered that other nearby stars have similar regions of icy bodies surrounding them.

Scientist B

The KB does not exist. Short-period comets were once long-period comets. Some long-period comets pass close enough to the giant planets (for example, Jupiter) to be influenced by the gravitational fields of the giant planets and are forced into orbits with orbital periods less than 200 yr. These altered orbits have orbital planes that have small inclinations with respect to the ecliptic plane. Also, most of the studied short-period comets have orbital planes with small inclinations with respect to the orbital planes of the giant planets, which, in turn, have small inclinations with respect to the ecliptic plane.

GO ON TO THE NEXT PAGE.

4 ○ ○ ○ ○ ○ ○ ○ ○ ○ 4

27. Which of the following generalizations about comets is most consistent with Scientist B's viewpoint?

A. Long-period comets cannot become short-period comets.
B. Short-period comets cannot become long-period comets.
C. Long-period comets can become short-period comets.
D. No long-period comets or short-period comets orbit the Sun.

28. Scientist A would most likely suggest that a new telescope more powerful than previous telescopes be used to search which of the following regions of space for objects in the KB ?

F. The region 100,000 A.U. beyond our solar system
G. The region 30 A.U. to 50 A.U. from the Sun at an angle of 90° with respect to the ecliptic plane
H. The region 30 A.U. to 50 A.U. from the Sun at angles of 0° to 30° with respect to the ecliptic plane
J. The region closely surrounding the planet Jupiter

29. Given the information about short-period comets in the introduction, which of the following inclinations with respect to the ecliptic plane would most likely NOT be observed for the orbital planes of short-period comets?

A. 5°
B. 15°
C. 30°
D. 45°

30. According to Scientist B, which of the following planets in our solar system is most likely capable of changing the orbit of a long-period comet over time?

F. Mercury
G. Earth
H. Mars
J. Saturn

31. Comet Halley currently has an orbital period of 76 yr. According to the information provided, Scientist B would most likely currently classify Comet Halley as a:

A. short-period comet that originated in the Oort Cloud.
B. short-period comet that originated in the KB.
C. long-period comet that originated in the Oort Cloud.
D. long-period comet that originated in the KB.

32. Based on Scientist A's viewpoint, the "much larger icy bodies" in the KB most likely have diameters of:

F. less than 10 km.
G. between 10 km and 20 km.
H. between 20 km and 30 km.
J. greater than 30 km.

33. Suppose a study of 1 nearby star revealed that it had no spherical shell of material similar to the Oort Cloud surrounding it. How would this discovery most likely affect the scientists' viewpoints, if at all?

A. It would weaken Scientist A's viewpoint only.
B. It would strengthen Scientist B's viewpoint only.
C. It would strengthen both scientists' viewpoints.
D. It would have no effect on either scientist's viewpoint.

GO ON TO THE NEXT PAGE.

4 ○ ○ ○ ○ ○ ○ ○ ○ ○ 4

Passage VI

Tomato plants grow poorly in high-salt environments. This effect is caused by 2 processes:

- A net movement of H_2O between the cytoplasm of the plants' cells and the environment via osmosis
- An increase in the cytoplasmic Na^+ concentration

The plant *Arabidopsis thaliana* carries a gene, *AtNHX1*. The product of this gene, *VAC*, facilitates uptake of cytoplasmic Na^+ by the plant's vacuoles.

A researcher created 4 genetically identical lines of tomato plants (L1–L4). An *AtNHX1* gene from *Arabidopsis thaliana* was isolated and 2 identical copies of this gene were incorporated into L1's genome. This process was repeated with L2 and L3 using a different *AtNHX1* allele for each line, so that L1, L2, and L3 had different genotypes for *AtNHX1*. The researcher then did an experiment.

Experiment

Fifty seedlings from each of the 4 lines were grown in 10 L of nutrient solution for 80 days. The 10 L nutrient solution contained H_2O, 12 g of fertilizer, and 3 g of NaCl. The nutrient solution was replaced every 5 days. After 80 days, average height, average mass (without fruit), and average fruit mass (per plant) were measured (see Table 1).

Table 1

3 g of NaCl/10 L nutrient solution

Line	Height (cm)	Mass (kg)	Fruit mass (kg)
L1	124	1.2	2.1
L2	128	1.2	2.0
L3	120	1.2	2.1
L4	124	1.2	2.0

This process was repeated except the 10 L nutrient solution contained 60 g of NaCl instead of 3 g of NaCl (see Table 2).

Table 2

60 g of NaCl/10 L nutrient solution

Line	Height (cm)	Mass (kg)	Fruit mass (kg)
L1	119	1.1	1.9
L2	121	1.1	1.9
L3	61	0.4	1.1
L4	63	0.5	1.0

The process was repeated again except the 10 L nutrient solution contained 120 g of NaCl instead of 3 g of NaCl (see Table 3).

Table 3

120 g of NaCl/10 L nutrient solution

Line	Height (cm)	Mass (kg)	Fruit mass (kg)
L1	118	1.0	1.8
L2	115	1.0	1.7
L3	34	0.2	0
L4	36	0.3	0

Tables 1–3 adapted from Hong-Xia Zhang and Eduardo Blumwald, "Transgenic Salt-Tolerant Tomato Plants Accumulate Salt in Foliage But Not in Fruit." ©2001 by Nature Publishing Group.

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4 ○ ○ ○ ○ ○ ○ ○ ○ ○ 4

34. One plant produced no fruit and had a height of 21 cm. Which of the following most likely describes this plant?

F. It was from L2 and was grown in a 10 L nutrient solution containing 60 g of NaCl.
G. It was from L2 and was grown in a 10 L nutrient solution containing 120 g of NaCl.
H. It was from L4 and was grown in a 10 L nutrient solution containing 60 g of NaCl.
J. It was from L4 and was grown in a 10 L nutrient solution containing 120 g of NaCl.

35. During osmosis, water migrates through a semipermeable barrier. The osmosis referred to in the passage occurs through which of the following structures?

A. Chromosomes
B. Nuclear envelope
C. Cell membrane
D. Rough endoplasmic reticulum

36. For each line, as the concentration of salt in the nutrient solutions increased, average plant mass:

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

37. Which of the following was an independent variable in the experiment?

A. Whether a line received *AtNHX1*
B. Whether a tomato plant was used
C. Plant mass without fruit
D. Plant height

38. Which of the following best characterizes the genotype of L1 for *AtNHX1* after L1 was genetically modified?

F. It was heterozygous, since its 2 *AtNHX1* alleles were different.
G. It was heterozygous, since its 2 *AtNHX1* alleles were identical.
H. It was homozygous, since its 2 *AtNHX1* alleles were different.
J. It was homozygous, since its 2 *AtNHX1* alleles were identical.

39. Suppose the data for all of the plants were plotted on a graph with height on the x-axis and mass (without fruit) on the y-axis. Suppose also that the best-fit line for these data was determined. Which of the following would most likely characterize the slope of this line?

A. The line would not have a slope, because the line would be vertical.
B. The slope of the line would be zero.
C. The slope of the line would be negative.
D. The slope of the line would be positive.

40. The researchers included 1 of the 4 lines to serve as a control. This line was most likely which one?

F. L1
G. L2
H. L3
J. L4

END OF TEST 4

STOP! DO NOT RETURN TO ANY OTHER TEST.