SCIENCE TEST

35 Minutes—40 Questions

DIRECTIONS: There are seven 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

A 1-*hectare* (10,000 m^2) area of forest was equally divided into Plots X and Y. The *herbaceous layer* (all non-woody plants ≤ 1 m tall) in Plot Y was then killed using an herbicide. Next, equal numbers of seeds from 5 tree species were evenly dispersed throughout both plots. Figure 1 shows, for each tree species, the *seedling emergence* (average number of seedlings per m^2 that emerged from the forest floor) for each plot. Figure 2 shows, for each tree species, the percent of the seedlings that were surviving in each plot 1 yr after emergence. Figure 3 shows, for each plot, the percent distribution of the 5 tree species among those 1-year-old seedlings.

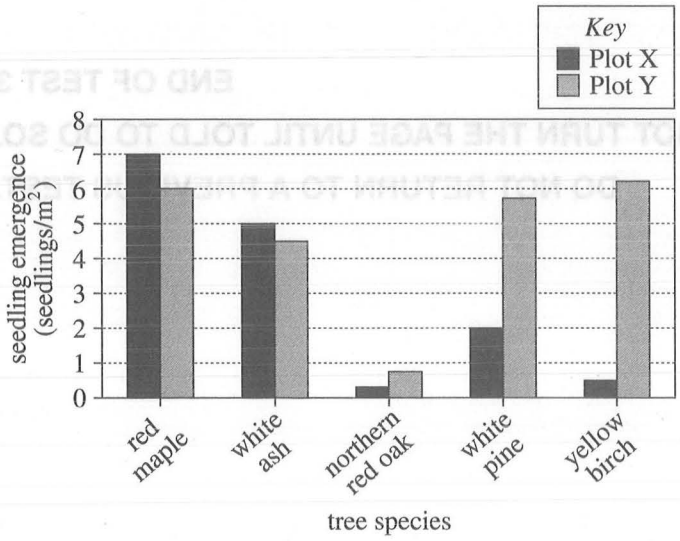


Figure 1

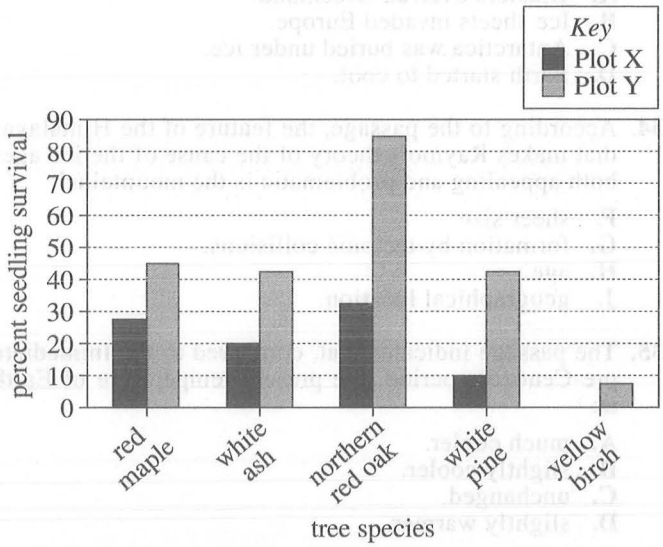


Figure 2

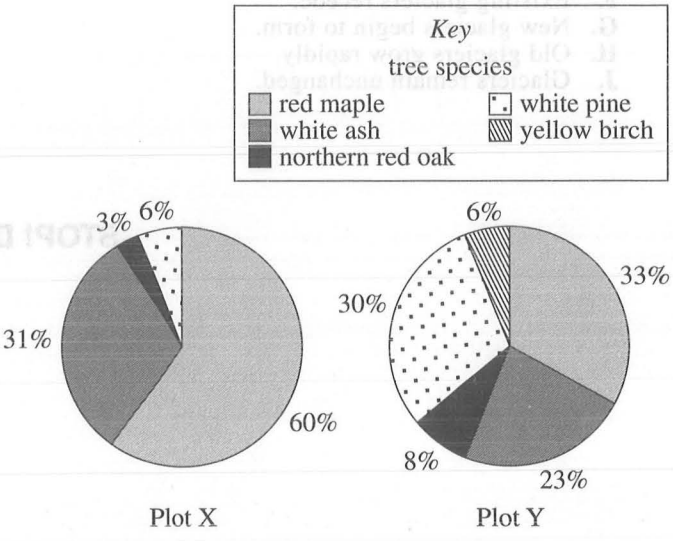


Figure 3

Figures adapted from Frank S. Gilliam and Mark R. Roberts, *The Herbaceous Layer in Forests of Eastern North America.* ©2003 by Oxford University Press, Inc.

1. Which of the 5 tree species had no surviving seedlings 1 yr after emergence in the plot for which the herbaceous layer was undisturbed?

   A. White ash
   B. Northern red oak
   C. White pine
   D. Yellow birch

2. According to Figure 3, 1 yr after emergence, the greatest percent of the seedlings were from which of the tree species in Plot X and Plot Y, respectively?

	Plot X	Plot Y
F.	red maple	red maple
G.	red maple	white ash
H.	white ash	red maple
J.	white ash	white ash

3. According to the data in Figure 3, what effect, if any, did removing the herbaceous layer have on the percent distribution among the 1-year-old seedlings in the 1-hectare area of the forest? The removal of the herbaceous layer:

   A. changed the percent for the northern red oak only.
   B. changed the percent for the red maple and the percent for the white pine only.
   C. changed the percent for each of the 5 tree species.
   D. did not change the percent for any of the 5 tree species.

4. According to Figure 1, the difference in seedling emergence between Plots X and Y was greatest for which tree species?

   F. Red maple
   G. White ash
   H. White pine
   J. Yellow birch

5. Based on Figure 1, for each tree species, the number of seeds that were dispersed per m^2 in Plot X must have been:

   A. 2 or less.
   B. between 2 and 4.
   C. between 5 and 7.
   D. 7 or greater.

Passage II

A *lahar* is a flow of water-saturated volcanic ash and rock. A *lahar deposit*, formed once the flow stops, consists of *clasts* (rocks having diameters ≥ 16 mm) embedded in a *matrix* (a mixture of particles having diameters ≤ 8 mm).

A sample of a lahar deposit was collected at each of 7 distances from a volcano's crater. For each sample, Figure 1 shows the percent by mass of the clasts by composition, and Figure 2 shows the percent by mass of the matrix by particle size class. For the 7 samples combined, Figure 3 shows the cumulative percent by mass of clasts and matrix particles, or of clasts alone, as diameter decreases.

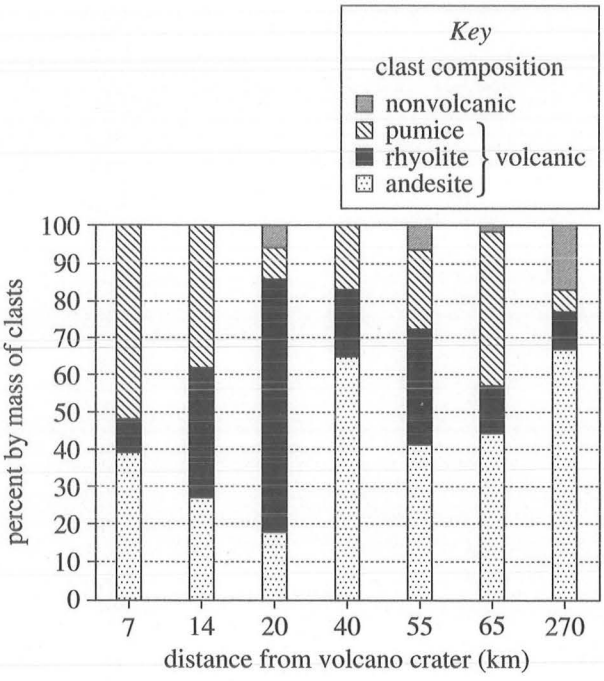


Figure 1

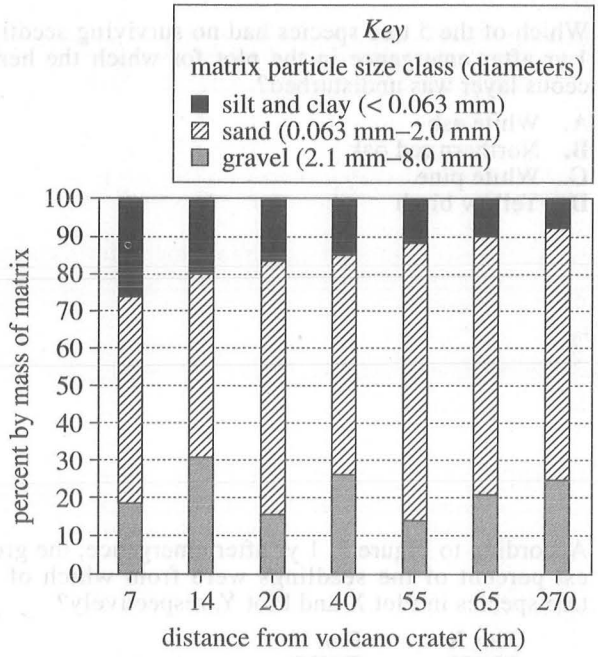
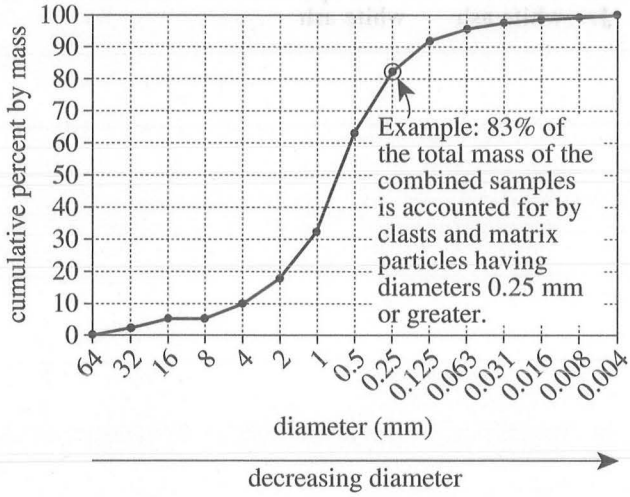


Figure 2



Note: The cumulative percent by mass for a particular diameter x is the percent of the total mass of the combined samples that is accounted for by clasts and matrix particles, or by clasts alone, having diameters greater than or equal to the value of x. (See example in the graph above.)

Figure 3

Figures adapted from P. A. Mothes, M. L. Hall, and R. J. Janda, "The Enormous Chillos Valley Lahar: An Ash-Flow-Generated Debris Flow from Cotopaxi Volcano, Ecuador." ©1998 by Springer-Verlag.

6. According to Figure 2, as the distance from the volcano's crater increased, the percent by mass of silt- and clay-size particles in the matrix of the samples:

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

7. According to Figure 3, the largest increase in cumulative percent by mass was between which of the following diameters?

   A. 4 mm and 2 mm
   B. 2 mm and 1 mm
   C. 1 mm and 0.5 mm
   D. 0.5 mm and 0.25 mm

8. According to Figure 3, clasts and matrix particles having diameters greater than or equal to 0.5 mm made up approximately what percent of the total mass of the combined samples?

   F. 13%
   G. 33%
   H. 63%
   J. 83%

9. Consider the information in Figures 1 and 2 about the lahar deposit sample collected 270 km from the volcano's crater. Clasts of which composition accounted for more than 50 percent by mass of the clasts in the sample, and matrix particles of what size class accounted for more than 50 percent by mass of the matrix in the sample?

	clast composition	matrix particle size class
A.	rhyolite	silt and clay
B.	rhyolite	sand
C.	andesite	silt and clay
D.	andesite	sand

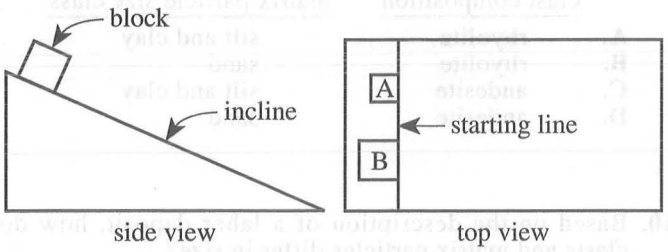
10. Based on the description of a lahar deposit, how do clasts and matrix particles differ in size?

    F. Any clast is larger than the largest matrix particle.
    G. Any clast is smaller than the smallest matrix particle.
    H. Some, but not all, clasts are smaller than the largest matrix particle.
    J. Some, but not all, matrix particles are larger than the smallest clast.

Passage III

A science teacher presents the following scenario.

Block A and Block B are released at precisely the same instant from the same starting line on a frictionless inclined plane (see the figure below).



The mass of Block A is 1 kg, and the mass of Block B is 2 kg. Earth's gravity is the only force causing the 2 blocks to accelerate down the incline. (Note: A block sliding down the incline can be considered to be falling toward Earth along the incline.)

The teacher asks 3 students to predict which block, if either, will reach the bottom of the incline first.

Student 1

The force of gravity exerted by Earth on Block A, F_A, is equal to the force of gravity exerted by Earth on Block B, F_B. Moreover, the force of gravity on a block equals the block's mass times the block's acceleration due to Earth's gravity. Thus, the mass of Block A times the acceleration of Block A must equal the mass of Block B times the acceleration of Block B. Because the mass of Block A is less than the mass of Block B, the acceleration of Block A must be greater than the acceleration of Block B. Therefore, the average speed of Block A will be greater than the average speed of Block B, so Block A will reach the bottom of the incline first.

Student 2

Because Block B has more mass than Block A, the force of gravity exerted by Earth on Block B, F_B, is greater than the force of gravity exerted by Earth on Block A, F_A. Therefore, Block B is heavier than Block A, so the acceleration of Block B will be greater than the acceleration of Block A, and Block B will slide down the incline with a greater average speed than will Block A. Thus, Block B will reach the bottom of the incline first.

Student 3

In the absence of forces other than gravity, any 2 objects falling toward Earth from the same height above Earth's surface will have the same acceleration. Because the 2 blocks will be released from the same starting line, they will be released from the same height above Earth's surface; so the blocks will slide down the incline with the same acceleration. Consequently, the 2 blocks will have the same average speed and will reach the bottom of the incline at the same time.

11. Suppose that a feather and a brick were dropped from the same height above the surface of the Moon. Based on the 3 students' discussions, what prediction would each student make regarding whether the feather or the brick would be the first to reach the Moon's surface or whether they would reach the surface at the same time?

	Student 1	Student 2	Student 3
A.	feather	brick	brick
B.	brick	feather	brick
C.	same time	brick	feather
D.	feather	brick	same time

12. Which of the students agree that the acceleration due to gravity varies with the mass of a block?

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

13. According to Student 2, as the force of gravity exerted by Earth on a block increases, will the average speed of the block increase or decrease, and why?

A. Increase, because the weight of the block will increase.
B. Increase, because the weight of the block will decrease.
C. Decrease, because the weight of the block will increase.
D. Decrease, because the weight of the block will decrease.

14. Based on Student 1's discussion, how will the acceleration of Block A compare to the acceleration of Block B ? The acceleration of Block A will be:

F. $\frac{1}{4}$ as great as the acceleration of Block B.
G. $\frac{1}{2}$ as great as the acceleration of Block B.
H. equal to the acceleration of Block B.
J. twice as great as the acceleration of Block B.

15. Two new blocks, Block X and Block Y, have the same mass. Assume that the relationship between F_X and F_Y is the same as the relationship stated by Student 1 between F_A and F_B. Consider also Student 1's statement relating the force of Earth's gravity on a block to the block's mass and its acceleration due to Earth's gravity. Will Block X have the same acceleration or a different acceleration down the incline as Block Y, and why?

A. The same acceleration, because the force of Earth's gravity on each block will be the same.
B. The same acceleration, because the force of Earth's gravity on each block will be different.
C. A different acceleration, because the force of Earth's gravity on each block will be the same.
D. A different acceleration, because the force of Earth's gravity on each block will be different.

16. The force of gravity on a block equals the block's mass times the block's acceleration due to Earth's gravity. Based on this information and Student 3's assertion about the blocks' acceleration, is the force on Block A greater than or less than the force on Block B, and why?

    F. Greater, because Block A's mass is greater than Block B's mass.
    G. Greater, because Block A's mass is less than Block B's mass.
    H. Less, because Block A's mass is greater than Block B's mass.
    J. Less, because Block A's mass is less than Block B's mass.

17. Based on Student 1's discussion, as acceleration increases, will the time it takes a block to reach the bottom of the incline increase or decrease, and why?

    A. Increase, because average speed will increase.
    B. Increase, because average speed will decrease.
    C. Decrease, because average speed will increase.
    D. Decrease, because average speed will decrease.

Passage IV

To increase corn crop *yield* (amount produced), *fertilizer nitrogen* (fertilizer N) is added to soil to supplement *soil test N* (various naturally occurring N sources in soil). In a *responsive* soil, the yield is greater when fertilizer N is added than when fertilizer N is not added. In a *nonresponsive* soil, the yield does not change when fertilizer N is added.

A soil's *amino sugar N* (a naturally occurring N source different from soil test N) content can determine whether a soil will be responsive. Two studies were done over 2 consecutive years in 25 cornfields in the same 1,000-hectare area. The soils' amino sugar N and soil test N contents were examined, as well as how the yield was affected by adding fertilizer N.

Study 1

For each field, just before the spring planting, samples of the top 15 cm of soil were collected in several locations, then thoroughly mixed and oven-dried for 24 hr. The dried mixed soil for each field was analyzed for amino sugar N content and soil test N content, in milligrams per kilogram (mg/kg). The results are shown in Figure 1. No fertilizer N was added to any of the fields. At harvest, the yield for each field was recorded.

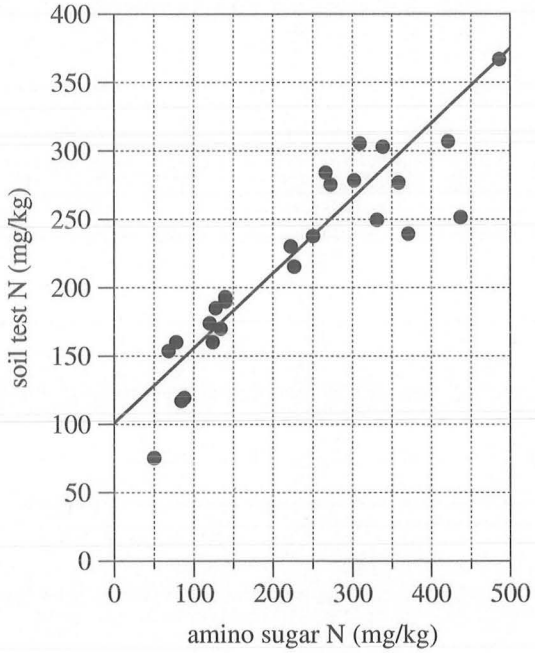


Figure 1

Study 2

The next spring, for each field, soil samples were collected, mixed, dried, and analyzed for amino sugar N as in Study 1. After collection and before spring planting, fertilizer N was added to each field at a rate of 120 kg N/hectare. No other fertilizer N was added over the growing season. At harvest, the yield for each field was recorded. Then, for each field, the percent increase in yield from the previous year was determined and plotted against the soil amino sugar N content (see Figure 2).

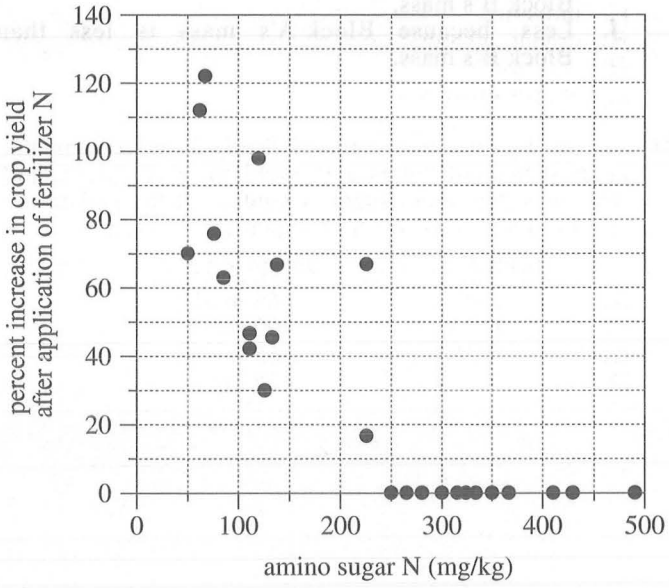


Figure 2

Figures adapted from S. A. Khan, R. L. Mulvaney, and R. G. Hoeft, "A Simple Soil Test for Detecting Sites that are Nonresponsive to Nitrogen Fertilization." ©2001 by the Soil Science Society of America.

18. Suppose another cornfield in the same area had been included in Study 1 and that the soil in this field had been found to have a soil test N content of 200 mg/kg. Based on Figure 1, this soil's amino sugar N content would most likely have been closest to which of the following?

F. 75 mg/kg
G. 175 mg/kg
H. 275 mg/kg
J. 375 mg/kg

19. Consider the cornfield with soil that had an amino sugar N content of 350 mg/kg in Study 2. Based on Figure 2 and other information provided, was the soil in the cornfield responsive or nonresponsive?

A. Responsive, because the yield did not increase.
B. Responsive, because the yield increased.
C. Nonresponsive, because the yield did not increase.
D. Nonresponsive, because the yield increased.

20. In the 2 studies, the purpose of oven-drying the mixed soil was to remove all the:

F. moisture.
G. organic matter.
H. soil test N.
J. amino sugar N.

21. According to the results of Study 2, what was the greatest percent increase in yield for a cornfield, and what was the amino sugar N content of the soil in the cornfield with this increase in percent yield?

	% increase in yield	amino sugar N
A.	100%	65 mg/kg
B.	112%	100 mg/kg
C.	122%	65 mg/kg
D.	122%	125 mg/kg

22. By selecting cornfields that were all located in the same 1,000-hectare area, the researchers who performed the studies ensured that which of the factors listed below would be nearly identical for all the fields?

I. Rainfall
II. Amount of sunlight
III. Amino sugar N content

F. I only
G. I and II only
H. II and III only
J. I, II, and III

23. One of the cornfields involved in the studies had an area of 2.5 hectares. In Study 2, how many kg N was added to that field as fertilizer N ?

A. 60 kg N
B. 100 kg N
C. 240 kg N
D. 300 kg N

Passage V

A *zinc-air battery* (ZAB) produces an electrical current when O_2 in the air flowing into the ZAB reacts with zinc metal to produce solid zinc oxide:

$$2Zn + O_2 \rightarrow 2ZnO$$

Two experiments were done using the apparatus shown in the diagram below.

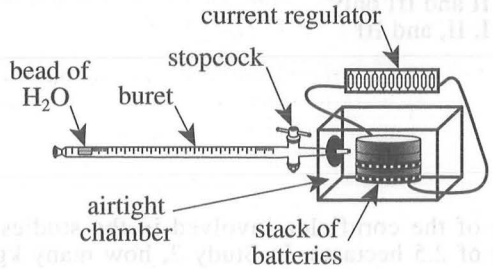


diagram of apparatus

For each trial, Steps 1–5 were followed:

1. Three 1.4-volt batteries were stacked in *series* (so that their voltages added together) in the airtight chamber. Each battery was either a ZAB or an SLB, a *sealed lithium battery* (the type of battery used in watches).

2. A small *buret* (a graduated tube that could be opened or closed using a stopcock) was inserted through a port into the chamber. A bead of H_2O was introduced into the buret to act as a free-moving barrier to the surrounding air.

3. A current regulator was connected to the batteries to ensure they would generate a constant current.

4. The chamber was sealed, and then the stopcock was opened (at time = 0 sec) to allow only the air from the buret to enter the chamber. As the Zn in a ZAB reacted with O_2, more air was drawn into the chamber.

5. As each 0.050 mL of air entered the chamber—indicated by the movement of the bead toward the chamber—the elapsed time was recorded. When 0.40 mL of air had entered the chamber, the stopcock was closed.

Experiment 1

Three trials were done at a current of 20 milliamps (mA). In Trial 1, 1 ZAB and 2 SLBs were tested. In Trial 2, 2 ZABs and 1 SLB were tested. In Trial 3, 3 ZABs were tested (see Figure 1).

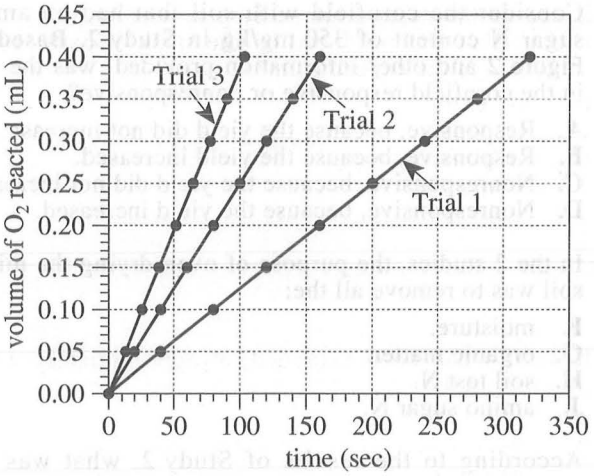


Figure 1

Experiment 2

Trial 3 was repeated in 2 trials except that in Trial 4 the current was 10 mA, and in Trial 5 the current was 30 mA (see Figure 2).

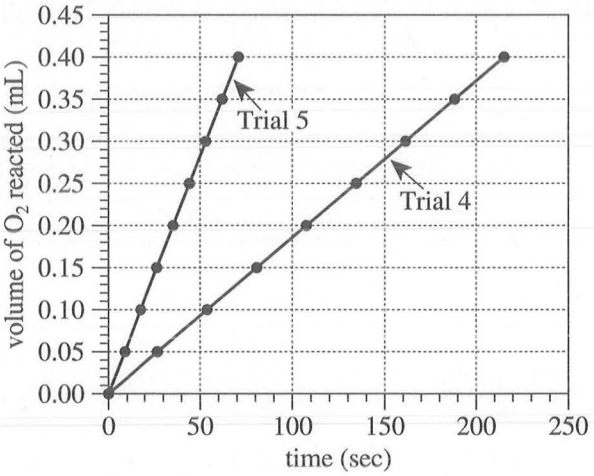


Figure 2

Diagram and figures adapted from Masahiro Kamata and Miei Paku, "Exploring Faraday's Law of Electrolysis Using Zinc-Air Batteries with Current Regulative Diodes." ©2007 by Division of Chemical Education, Inc., American Chemical Society.

24. Based on the description of Step 1, what was the total voltage that was produced by the stack of batteries in each trial of the experiments?

F. 1.4 volts
G. 4.2 volts
H. 10 volts
J. 20 volts

25. If Trial 4 had been extended, at approximately what time would 0.45 mL of O_2 have reacted?

A. 70 sec
B. 140 sec
C. 240 sec
D. 270 sec

26. How many SLBs, if any, were tested in Experiment 2 ?

F. 0
G. 1
H. 2
J. 3

27. A chemist predicted that the volume of O_2 reacted would increase at a faster rate if the number of ZABs present in the stack of 3 batteries was increased. Do the results of Trials 1 and 3 support this prediction?

A. Yes, because the final volume was reached sooner in Trial 3 than it was in Trial 1.
B. Yes, because the final volume was reached sooner in Trial 1 than it was in Trial 3.
C. No, because the final volume was reached sooner in Trial 3 than it was in Trial 1.
D. No, because the final volume was reached sooner in Trial 1 than it was in Trial 3.

28. Based on the chemical equation in the passage, in a ZAB, as 5 O_2 molecules are consumed, how many Zn atoms, if any, must also be consumed?

F. 0
G. 2
H. 5
J. 10

29. Suppose Trial 1 is repeated except at a current of 10 mA. At 200 sec, the volume of O_2 reacted will most likely be:

A. less than 0.25 mL.
B. between 0.25 mL and 0.32 mL.
C. between 0.32 mL and 0.39 mL.
D. 0.40 mL, because the stopcock will be closed much sooner than 200 sec.

Passage VI

Threespine sticklebacks are fish that can live in *marine* (saltwater) and freshwater environments. Marine sticklebacks and freshwater sticklebacks have *plates* (bony scales) that provide protection from predators, such as fish and birds. However, due to the low number of these predators in freshwater environments, freshwater sticklebacks typically have fewer plates than do marine sticklebacks.

The *Eda gene* regulates plate formation and has 2 alleles: *E* and *e*. Table 1 describes the phenotype associated with each Eda genotype.

Table 1

Genotype	Phenotype	Description
EE	complete	30–36 plates, head to tail, continuous
Ee	partial	9–18 plates, head to tail, gap in midsection
ee	low	0–9 plates, head only

Two studies were done to determine how moving a marine stickleback population to a freshwater environment affects the Eda genotypes of the population's offspring and how Eda genotype relates to the length and the *breeding status* of the offspring.

Study 1

Two hundred adult marine sticklebacks with the Eda genotype *Ee* were tagged and placed in an artificial freshwater pond on June 1, 2006, during their breeding season. At the beginning of each month from September 2006 to July 2007, 200 stickleback offspring were collected and their Eda genotypes were determined. Figure 1 shows the *fraction of the collected offspring* (FCO) with a particular genotype for each month, as well as the developmental stages of the offspring during the study.

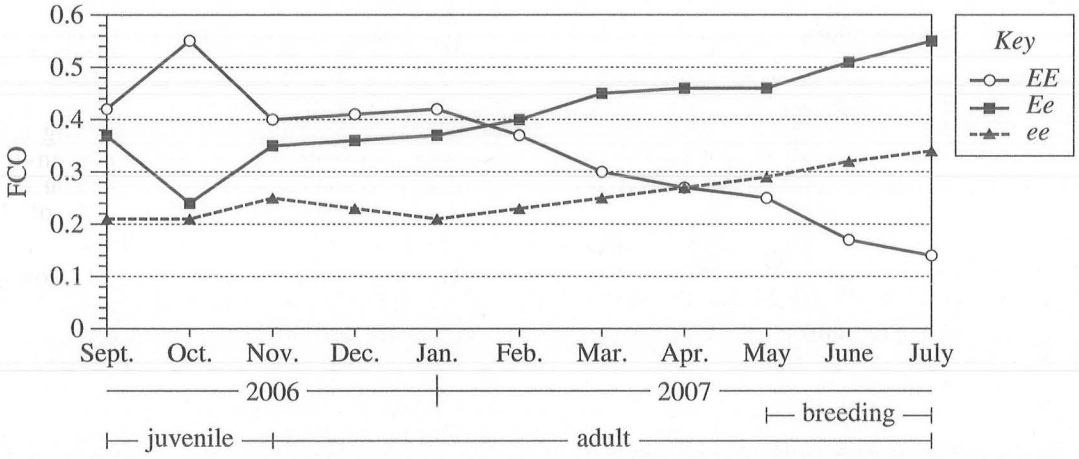


Figure 1

Study 2

The length and the breeding status—sexually immature (SI) or sexually mature (SM)—of each of the offspring collected in May 2007 were determined. Figure 2 shows the results by Eda genotype.

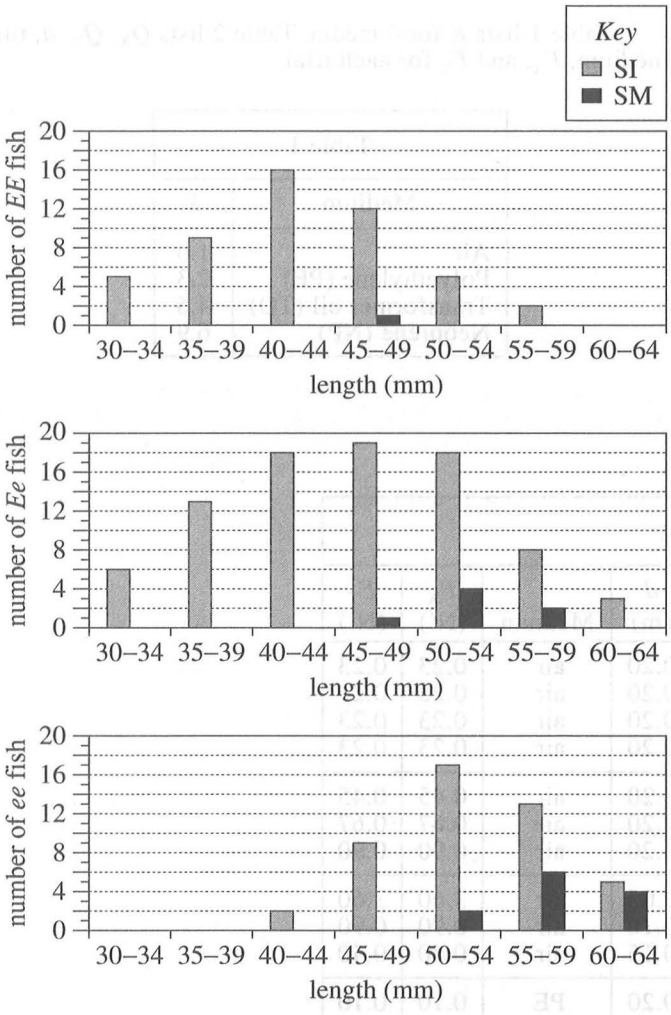


Figure 2

Figures 1 and 2 adapted from Rowan D. H. Barrett, Sean M. Rogers, and Dolph Schluter, "Natural Selection on a Major Armor Gene in Threespine Stickleback." ©2008 by the American Association for the Advancement of Science.

30. One of the offspring collected during Study 1 in June 2007 had 7 plates. According to Table 1, this fish had which phenotype and which genotype?

	phenotype	genotype
F.	low	*Ee*
G.	low	*ee*
H.	partial	*Ee*
J.	partial	*ee*

31. Which of the offspring listed below were collected in Study 1 ?

I. Juveniles
II. Adults that were breeding
III. Adults that were not breeding

A. I only
B. III only
C. I and III only
D. I, II, and III

32. One of the offspring measured in Study 2 was 62 mm in length. Based on the results of the study, was the genotype of this fish more likely *EE* or *ee* ?

F. *EE*, because, on average, *EE* offspring were shorter than *ee* offspring.
G. *EE*, because, on average, *EE* offspring were longer than *ee* offspring.
H. *ee*, because, on average, *ee* offspring were shorter than *EE* offspring.
J. *ee*, because, on average, *ee* offspring were longer than *EE* offspring.

33. According to the results of Study 2, of the sexually mature offspring that were collected in May 2007, the greatest number had which of the 3 genotypes?

A. *EE*
B. *Ee*
C. *ee*
D. Cannot be determined from the given information

34. A researcher predicted that moving a marine stickleback population to a freshwater environment would result in an increase in the fraction of offspring with the low phenotype. Do the results of Study 1 support this prediction?

F. Yes, because the FCO for the low phenotype was about 0.13 greater in July 2007 than it was in September 2006.
G. Yes, because the FCO for the low phenotype was about 0.18 greater in July 2007 than it was in September 2006.
H. No, because the FCO for the low phenotype was about 0.21 less in July 2007 than it was in September 2006.
J. No, because the FCO for the low phenotype was about 0.28 less in July 2007 than it was in September 2006.

35. In Study 1, the most likely reason the marine sticklebacks that were placed in the pond were tagged was to ensure that the:

A. length of each stickleback could be measured.
B. parents could be differentiated from the offspring.
C. number of plates on each stickleback could be counted.
D. offspring collected would be genotyped only once.

Passage VII

Identical spheres, X and Y, had electrical charges Q_X and Q_Y, respectively. Throughout each of 13 trials, the spheres remained fastened to the horizontal floor of a vessel a distance d apart, with X due east of Y (see Figure 1).

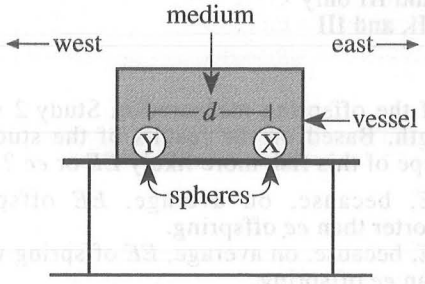


Figure 1

The vessel was filled with a medium having a *dielectric constant*, K. (K reflects a medium's ability to modify the electrical force between charges.) X exerted an electrical force of magnitude F_Y on Y, and Y exerted an electrical force of magnitude F_X on X. Each force was directed either east or west.

Table 1 lists K for 4 media. Table 2 lists Q_X, Q_Y, d, the medium, F_X, and F_Y for each trial.

Table 1

Medium	K
Air	1.0
Polyethylene (PE)	2.3
Transformer oil (TO)	4.6
Neoprene (NP)	6.9

Table 2

Trial	Q_X (10^{-6} C*)	Q_Y (10^{-6} C*)	d (m)	Medium	F_X (N†)	F_Y (N†)
1	+1.0	+1.0	0.20	air	0.23	0.23
2	+1.0	−1.0	0.20	air	0.23	0.23
3	−1.0	+1.0	0.20	air	0.23	0.23
4	−1.0	−1.0	0.20	air	0.23	0.23
5	+1.0	+2.0	0.20	air	0.45	0.45
6	+1.0	+3.0	0.20	air	0.67	0.67
7	+1.0	+4.0	0.20	air	0.90	0.90
8	+1.0	+1.0	0.05	air	3.60	3.60
9	+1.0	+1.0	0.10	air	0.90	0.90
10	+1.0	+1.0	0.15	air	0.40	0.40
11	+1.0	+1.0	0.20	PE	0.10	0.10
12	+1.0	+1.0	0.20	TO	0.05	0.05
13	+1.0	+1.0	0.20	NP	0.03	0.03

*C = coulombs
†N = newtons

36. Based on Table 1 and the results of Trial 1 and Trials 11–13, as K increased, F_X:

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

37. Suppose that Sphere X had become unfastened from the floor of the vessel during Trials 1 and 7. During which of these trials would Sphere X more likely have undergone the *lesser* amount of acceleration?

- **A.** Trial 1, because the magnitude of the electrical force exerted by Sphere Y on Sphere X was greater in Trial 1 than in Trial 7.
- **B.** Trial 1, because the magnitude of the electrical force exerted by Sphere Y on Sphere X was less in Trial 1 than in Trial 7.
- **C.** Trial 7, because the magnitude of the electrical force exerted by Sphere Y on Sphere X was greater in Trial 7 than in Trial 1.
- **D.** Trial 7, because the magnitude of the electrical force exerted by Sphere Y on Sphere X was less in Trial 7 than in Trial 1.

38. In each of the 13 trials, how did the magnitude of the electrical force exerted by Sphere X on Sphere Y compare to the magnitude of the electrical force exerted by Sphere Y on Sphere X ?

- **F.** The magnitude of the electrical force exerted by Sphere X on Sphere Y was greater than the magnitude of the electrical force exerted by Sphere Y on Sphere X.
- **G.** The magnitude of the electrical force exerted by Sphere X on Sphere Y was less than the magnitude of the electrical force exerted by Sphere Y on Sphere X.
- **H.** The magnitude of the electrical force exerted by Sphere X on Sphere Y was the same as the magnitude of the electrical force exerted by Sphere Y on Sphere X.
- **J.** Cannot be determined from the given information

39. Suppose that, in each trial, either electrons or protons had been added to each sphere to produce its charge. In Trial 3, which of the 2 types of particles would have been added to Sphere X, and which of the 2 types of particles would have been added to Sphere Y ?

	Sphere X	Sphere Y
A.	electrons	protons
B.	protons	electrons
C.	electrons	electrons
D.	protons	protons

40. In Trial 9, the electrical force exerted by Sphere Y on Sphere X and the electrical force exerted by Sphere X on Sphere Y were exerted in which direction(s)?

	electrical force on Sphere X	electrical force on Sphere Y
F.	east	east
G.	east	west
H.	west	west
J.	west	east

END OF TEST 4

STOP! DO NOT RETURN TO ANY OTHER TEST.