SCHOOL	Year Joined
Carnegie Mellon University	2008
College of William & Mary	2008
Hope College	2008
James Madison University	2008
Oregon State University	2008*
Spelman College	2008**
University of California, San Diego#	2008
University of California, Santa Cruz	2008
University of Louisiana at Monroe	2008
University of Mary Washington	2008
University of Maryland, Baltimore County	2008
Washington University in St. Louis	2008
Brigham Young University	2009
Cabrini College	2009
Calvin College	2009
Culver-Stockton College	2009
Georgia State University	2009***
Lehigh University	2009
North Carolina State University	2009
Queens College, CUNY	2009
Saint Joseph's University	2009
University of Colorado at Boulder	2009
University of Montana	2009***
University of North Texas	2009
University of Puerto Rico at Cayey	2009
Virginia Commonwealth University	2009
Western Kentucky University	2009
Baylor University	2010
Bucknell University	2010
College of Charleston	2010
Gonzaga University	2010
Jacksonville State University	2010
Loyola Marymount University	2010
North Carolina Central University	2010
Purdue University	2010
Queensborough Community College#	2010
University of Alabama at Birmingham	2010
University of Texas at El Paso	2010
University of Wisconsin-River Falls	2010
Brown University	2011
Carthage College	2011
College of St. Scholastica	2011
Del Mar College	2011

Georgia Gwinnett College	**2011**
Gettysburg College	**2011**
Hampden-Sydney College	**2011**
Illinois Wesleyan University	**2011**
Johns Hopkins University	**2011**
Miami University	**2011**
Montclair State University	**2011**
Morehouse College	**2011**
Ohio State University	**2011**
Ouachita Baptist University	**2011**
Providence College	**2011**
Smith College	**2011**
Southern Connecticut State University	**2011**
Southern Maine Community College	**2011**
Trinity College	**2011**
University of Florida	**2011**
University of Maine at Fort Kent	**2011**
University of Maine at Machias	**2011**
University of Maine Honors College	**2011**
Washington State University	**2011**
Xavier University of Louisiana	**2011**
Chadron State College	**2012**
College of Idaho	**2012**
Howard University	**2012**
Montana Tech of the University of Montana	**2012**
Nyack College	**2012**
Seton Hill University	**2012**
University of Pittsburgh	**2012**
Doane College	**2013**
Evergreen State College	**2013**
Florida Gulf Coast University	**2013**
La Salle University	**2013**
Merrimack College	**2013**
Nebraska Wesleyan University	**2013**
University of Houston, Downtown	**2013**
Wilkes University	**2013**

Table S1. Institutions offering the SEA-PHAGES course from 2008 to 2013.

*Institution left the program in 2011
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***Institution left the program in 2012

#Course offered as a one semester bioinformatics course

Figure S2. Biological Concept Survey (BCS) questions.

The Biology Concepts Survey (BCS)

The BCS is designed to measure student's content knowledge in four general categories: content, data analysis/interpretation, experimental design and quantitative. The survey was conducted twice each academic year: the pre-course surveys at the beginning of the Fall semester and the post-course surveys at the end of the Spring semester. In academic year 2010-2011, 311 SEA-PHAGES students matched (students too both pre and post course surveys) and 225 students from the Comparison group matched. Systemic Research developed the online forms using Vovici EFM Community Professional website. The pre and post-course survey invitations were emailed to individual students according to their academic calendars. Using Vovici's follow-up feature, three reminder emails are sent after the initial invitations. Students received an invitation to complete either version A or B of the survey in the fall, in the spring students who received an invitation to complete Survey A receive an invitation to complete Survey B and vice versa. Data analysis was performed using Minitab Version 13, a statistical software package. A two-sample T-test for independent groups was performed comparing the Pre and Post-course BCS mean scores.

Scientific Reasoning (5)

1. You have isolated a bacterial strain that is unable to grow without the amino acid tryptophan. You expose these bacteria to a known mutagen and now one of the bacterial colonies can grow without the added amino acid. What has happened?

A. A mutation has occurred in the amino acid tryptophan enabling the bacterium to grow.
B. A mutation has occurred in a gene encoding one of the enzymes for the synthesis of tryptophan, making that enzyme nonfunctional.
C. **A second mutation has occurred in a gene encoding one of the enzymes for the synthesis of tryptophan, making that enzyme functional again.**
D. A mutation has occurred so that the bacterium no longer requires the amino acid tryptophan for survival.
E. A mutation occurred in the bacteria in response to the removal of tryptophan from the growth medium.

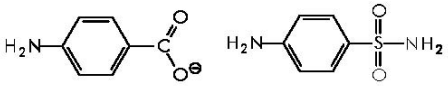
2. The pathway for *Rhizopus stolonifer* phenylalanine biosynthesis is:

X → R → B → A → D → Phenylalanine

Enzymes catalyze each step in the pathway. You isolate a mutant that accumulates substrate B. The mutation is located in the enzyme that converts ____.

A. X → R
B. R → B
C. **B → A**
D. A → D
E. Could be either answer B or C

3. *p*-Aminobenzoic acid (PABA) can be used by some bacteria in a metabolic pathway to produce folic acid, which is required for their growth and division. Sulfanilamide is an antibacterial drug in the sulfa group of antibiotics. Its structure is similar to PABA. When sulfanilamide is present, it will bind to the enzyme dihydrofolate synthetase, the enzyme responsible for folate synthesis in bacteria. The structures of sulfanilamide and PABA are shown in the Figure. What is a probable mechanism of action of the drug sulfanilamide?



p-Aminobenzoate Sulfanilamide

A. It destroys the bacterial cell wall.
B. It disperses the phospholipids in the bacterial cell membrane.
C. **It is a competitive inhibitor.**
D. It is an allosteric inhibitor.
E. It blocks a cell-signaling pathway that results in the release of folate from the cell.

4. The empirical formula for the sugar glucose is CH_2O. Glucose has 6 carbon atoms. How many hydrogen atoms does glucose have?

A. 2
B. 12
C. 6
D. 14
E. The precise number depends on whether it is naturally occurring or synthetic.

5. Certain kinds of birds prey upon land snails by breaking the snails' shells on rocks and eating the soft inner bodies. The snails have shells that occur in the either striped or unstriped forms and each form of snails reproduces at the same rate. Scientists counted both the live snails and the broken shells in a particular area. Their findings could be summarized as follows:

SNAILS	STRIPED	UNSTRIPED	TOTAL	% STRIPED
Living	**402**	**410**	**812**	**49.3**
Broken	**524**	**323**	**847**	**61.9**

Over many years, assuming conditions are constant, which snail form would most likely have a greater increase in numbers?

A. neither form
B. both forms
C. striped
D. unstriped
E. each form would increase then decrease

Computation (4)

6. A person's average daily intake of glucose is 0.0833 pound (lb). What is this mass in milligrams? (1 lb=453.6 grams)

A. 3.78×10^{-3} mg
B. 3.78×10^{-1} mg
C. 3.78 mg
D. 3.78×10^{1} mg
E. 3.78×10^{4} mg

7. You have a yeast culture that is at a density of 2×10^{8} cells /mL. You have 2 tubes filled with 900 μL of distilled water. You perform a serial dilution adding 100 μL of the initial yeast culture to the first tube (#1) containing 900 μL of distilled water. You mix those cells and then remove 100 μL from that tube (#1) and add it to the next tube (#2) containing 900 μL of distilled water. What is the concentration of yeast cells in tube #2?

A. **2×10^{6} cells/mL**
B. 2×10^{7} cells/mL
C. 2×10^{4} cells/ mL
D. 2×10^{8} cells/ mL
E. 2×10^{5} cells/ mL

8. How many grams of Na_2SO_4 (MW=142 grams/mol) are required to make 0.350 liter of 0.500M Na_2SO_4?

A. **24.9 grams**
B. 0.249 grams
C. 0.175 grams
D. 49.7 grams
E. None of the above is correct.

9. You need to make a 1% ($^{weight}/_{volume}$) agarose solution for your DNA gel. What $^{weight}/_{volume}$ of agarose and buffer would you use to accomplish this?

A. **1 gram of agarose in 100 mL of buffer**
B. 1 gram of agarose in 1 liter of buffer
C. 100 grams of agarose in 1 liter of buffer
D. 1 mol of agarose in 100 mL of buffer
E. The quantities cannot be determined without knowing the molecular weight of agarose.

Experimental Design/Data Interpretation (8)

10. You are involved in a clinical trial to see the effects that a new drug has on diabetes. You predict that the drug will reduce symptoms associated with diabetes better than drugs currently on the market. You divide your test subjects into three groups: one group gets the new drug, one group gets no drug treatment at all, and the final group gets the best drug currently on the market. This experiment includes ____.

A. a positive control only
B. a negative control only
C. **both a positive and a negative control**
D. neither a positive nor a negative control
E. The controls can only be determined after the results are obtained.

11. Which conclusion is supported by the data shown in the following graph?

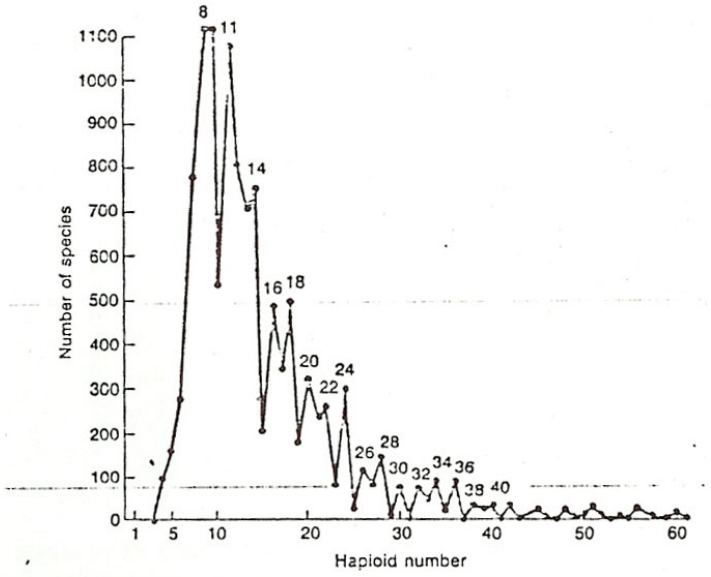


Figure 24-8. Frequency distribution of haploid chromosome numbers in dicotyledonous plants. (From Verne Grant, *The Origin of Adaptation*. Copyright © 1963 by Columbia University Press.)

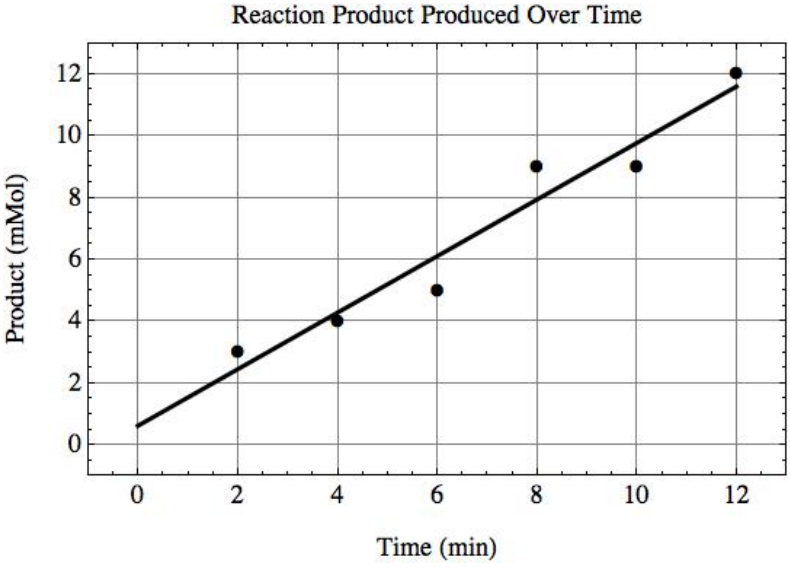
A. Most dicotyledonous plants have haploid chromosome numbers greater than 30.

B. The majority of the species have haploid chromosome numbers of less than six.
C. The most important agricultural species of dicotyledonous plants have a haploid number of eight.
D. **A large number of the species have diploid chromosome numbers between seven and fourteen.**
E. More species have a haploid number of 40 than species with a haploid number of 20.

12. You need to pipette 350 μl. Which of the following combinations represents the correct micropipette to use (Column II) and its corresponding digital display (Column II)?

	Column I	Column II
A.	P-20	350
B.	P-200	350
C.	P-20	035
D.	P-200	035
E.	**P-1000**	**035**

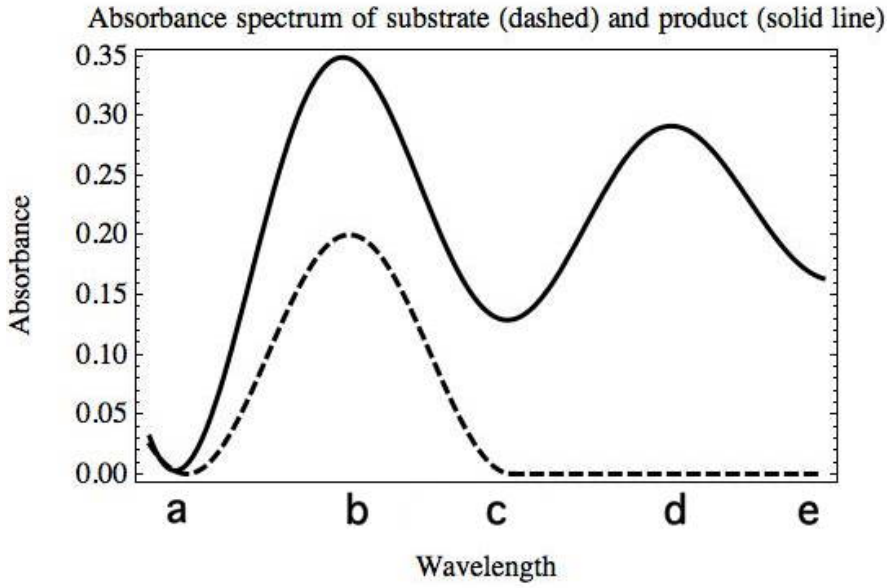
13. When an enzyme is added to a pure substrate, it produces an increasing amount of product from the substrate for a period of time. The graph below shows the amount of product produced by the enzyme over a 12 minute time period after addition of the enzyme to a pure substrate. Using this graph, estimate the amount of product that would have been produced after 1 minute.



A. 4 mMol
B. 3 mMol

C. 2 mMol
D. 1 mMol
E. The amount of product cannot be estimated after 1 minute because the data do not extend that far.

14. An enzyme converts a substrate into a product. The production of the product can be measured by spectrophotometry. Below is a spectrum of substrate and product absorption at various wavelengths. What wavelength would be best to monitor the increase in product in the presence of the substrate during the enzymatic reaction?



A. A
B. B
C. C
D. D
E. E

15. You are studying a cell and have identified the following molecules and structures: enzymes, DNA, ribosomes, plasma membrane, and mitochondria. It could be a cell from ____.

A. a plant, but not an animal
B. an animal, but not a plant
C. a plant or an animal
D. a prokaryote, but not a eukaryote
E. a prokaryote or a plant, but not an animal

16. You have been given a sample of bacteria that was found growing in pure culture on the wall of a deep, cool (13°C), underground limestone ($CaCO_3$) cave and need to establish its laboratory

growth conditions. You have five types of media available on which to test the growth of the bacteria, all of which contain $CaCO_3$. You can incubate the bacteria at five possible temperatures, 5°C, 15°C, 35°C, 55°C, 75°C in either light or dark conditions. Which light conditions would ensure growth of these bacteria?

A. Ultraviolet light
B. Bright light
C. Dim light
D. **Dark (no light)**
E. Any of the above because light should not be a factor.

17. You are setting up a restriction digest of genomic DNA using the enzyme *Eco*RI. You include additional reactions with *Eco*RI using (a) the supplied control plasmid DNA and (b) your genomic DNA and water instead of enzyme as in the following table.

Reagent	Tube 1	Tube 2	Tube 3
Genomic DNA	-	5 μL	5 μL
Plasmid DNA	5 μL	-	-
Buffer	1 μL	1 μL	1 μL
Water	3 μL	3 μL	4 μL
*Eco*RI	1 μL	1 μL	-
Total volume	10 μL	10 μL	10 μL

Which reaction is the negative control?

A. Tube 1
B. Tube 2
C. Tube 3
D. Both Tube 1 and Tube 3.
E. The control cannot be identified until the experimental results are obtained.

Concepts (8)

Cell classification structure, & function

18. Select which of the following is TRUE.

A. Plant cells and animal cells have cell walls.
B. Plant cells, unlike animal cells, generate all their ATP in chloroplasts rather than in mitochondria.
C. **Plant cells and animal cells carry out electron transport on internal membranes.**
D. Plant cells are non motile, animal cells are motile.
E. Plant cells can fix carbon dioxide and nitrogen, animal cells can only fix nitrogen.

19. Which of the following is NOT a property shared by viruses and cells (both bacterial and eukaryotic)?

A. All can be surrounded by a lipid membrane.
B. All possess a genome.
C. All utilize the same genetic code.
D. **All possess the machinery to decipher and express the genetic code.**
E. All possess both proteins and nucleic acids.

Proteins

20. Select which of the following is TRUE about enzymes.

A. Enzymes alter the overall free energy (ΔG) of a chemical reaction.
B. **RNA molecules can be enzymes.**
C. Enzymes are only required for chemical reactions where the free energy (ΔG) is positive.
D. Enzymes catalyze chemical reactions by increasing the temperature of those reactions.
E. Enzymes are only regulated if the reaction is energetically unfavorable.

21. Which suffix do enzymes commonly end in?

A. –ese
B. –ose
C. –ase
D. –ise
E. -ing

Nucleic acid structure, function, and regulation

22. All of the steps involved in expressing a gene can in principle be regulated. For most genes, the most important point of control is ____.

A. **transcription initiation**
B. RNA processing
C. RNA transport and localization
D. mRNA degradation
E. mRNA translation

23. From the cross Aa *X* Aa where "A" is dominant over "a", we should expect to get ____.

A. $^1/_4$ showing the dominant phenotype
B. **$^1/_4$ homozygous dominant**
C. $^1/_4$ heterozygous
D. $^1/_2$ with the dominant phenotype and $^1/_2$ with the recessive
E. All offspring with the dominant phenotype.

General/Basic

24. You are looking at the DNA and amino acid sequence of an unknown gene from an organism you have been studying. You search the BLAST DNA/protein database for similar genes to try to

determine what the function of the gene is. You are most likely to find a homology with another organism if you use the ____.

A. **protein database**
B. nucleotide database
C. Twitter network database
D. eukaryotic genome database
E. drosophila genome database

25. A network of distinct populations interacting with each other by exchanging individuals (gene flow) is called a/an ____.

A. sympatric species
B. allopatric species
C. biome
D. ecosystem
E. **metapopulation**

Figure S3. Biological Concepts Survey results.

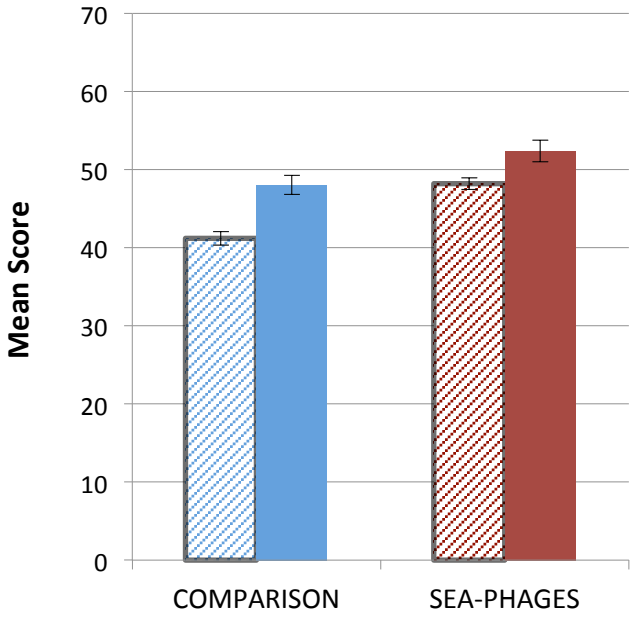


Figure S3. Biological Concepts Survey results. Comparison (blue; 225) and SEA-PHAGES students (red; 311) were administered the test before (lined) and after (solid) the laboratory course. The mean scores for each group are shown on tests that had a maximum possible score of 100. Inferential testing with t-tests indicates that both groups improved from pretest to posttest; cross-comparison between groups indicates significantly higher means for the SEA-PHAGES group than for the comparison group for both pre- and posttests. The error bars in the figure represent one standard error above and below the mean.

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James Madison University	2008
Oregon State University	2008*
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Brigham Young University	2009
Cabrini College	2009
Calvin College	2009
Culver-Stockton College	2009
Georgia State University	2009***
Lehigh University	2009
North Carolina State University	2009
Queens College, CUNY	2009
Saint Joseph's University	2009
University of Colorado at Boulder	2009
University of Montana	2009***
University of North Texas	2009
University of Puerto Rico at Cayey	2009
Virginia Commonwealth University	2009
Western Kentucky University	2009
Baylor University	2010
Bucknell University	2010
College of Charleston	2010
Gonzaga University	2010
Jacksonville State University	2010
Loyola Marymount University	2010
North Carolina Central University	2010
Purdue University	2010
Queensborough Community College#	2010
University of Alabama at Birmingham	2010
University of Texas at El Paso	2010
University of Wisconsin-River Falls	2010
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