AP ⬢ CollegeBoard

Biology
Practice Exam

NOTE: This is a modified version of the 2017 AP Biology Exam.

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Contents

Note: This publication shows the page numbers that appeared in the *2016–17 AP Exam Instructions* book and in the actual exam. This publication was not repaginated to begin with page 1.

Exam Instructions

AP® Biology Exam

Regularly Scheduled Exam Date: Monday morning, May 8, 2017
Late-Testing Exam Date: Friday afternoon, May 19, 2017

Section I **Total Time:** 1 hour 30 minutes
Number of Questions: 69*
(63 multiple-choice questions plus 6 grid-in questions; 1 hour 30 minutes)
Percent of Total Score: 50%
Writing Instrument: Pencil required

The number of questions may vary slightly depending on the form of the exam.

Section II **Total Time:** 1 hour 30 minutes
Number of Questions: 8 questions
(2 ten-point questions, 3 four-point questions, and 3 three-point questions, 10-minute reading period, 1-hour and 20-minute writing period)
Percent of Total Score: 50%
Writing Instrument: Pen with black or dark blue ink

Note: Four-function calculators (with square root) may be used on all sections of the AP Biology Exam.

What Proctors Need to Bring to This Exam

- Exam packets
- Answer sheets
- AP Student Packs
- *2016-17 AP Coordinator's Manual*
- This book — *AP Exam Instructions*
- AP Exam Seating Chart template
- School Code and Home-School/Self-Study Codes
- Extra calculators
- Pencil sharpener

- Container for students' electronic devices (if needed)
- Extra No. 2 pencils with erasers
- Extra pens with black or dark blue ink
- Lined paper
- Stapler
- Watch
- Signs for the door to the testing room
  – "Exam in Progress"
  – "Cell phones are prohibited in the testing room"

Before Distributing Exams: Check that the title on all exam covers is **Biology**. If there are any exam booklets with a different title, contact the AP coordinator immediately.

SECTION I: Multiple Choice and Grid-In

Students are allowed to use four-function (with square root) calculators throughout the entire AP Biology Exam. Graphing calculators and scientific calculators are not permitted for use on the AP Biology Exam. See pages 46–49 of the *2016-17 AP Coordinator's Manual* for more information.

Before starting the exam administration, make sure each student has an appropriate calculator. If a student does not have a calculator, you may provide one from your supply. If the student does not want to use the calculator you provide or does not want to use a calculator at all, he or she must hand copy, date, and sign the release statement on page 47 of the *2016-17 AP Coordinator's Manual*. Students may have no more than two calculators on their desks. Calculators may not be shared.

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▌● **Do not begin the exam instructions below until you have completed the appropriate General Instructions for your group.**

Make sure you begin the exam at the designated time. Remember, you must complete a seating chart for this exam. See pages 325–326 for a seating chart template and instructions. See the *2016-17 AP Coordinator's Manual* for exam seating requirements (pages 51–54).

If you are giving the regularly scheduled exam, say:

> **It is Monday morning, May 8, and you will be taking the AP Biology Exam.**

If you are giving the alternate exam for late testing, say:

> **It is Friday afternoon, May 19, and you will be taking the AP Biology Exam.**

> **In a moment, you will open the packet that contains your exam materials. By opening this packet, you agree to all of the AP Program's policies and procedures outlined in the *2016-17 Bulletin for AP Students and Parents*.**

> **Look at your exam packet and confirm that the exam title is "AP Biology." Raise your hand if your exam packet contains any title other than "AP Biology" and I will help you.**

Once you confirm that all students have the correct exams, say:

> **You may now remove the shrinkwrap from your exam packet and take out the Section I booklet, but do not open the booklet or the shrinkwrapped Section II materials. Put the white seals aside. . . .**

> **Carefully remove the AP Exam label found near the top left of your exam booklet cover. Now place it on page 1 of your answer sheet on the light blue box near the top right corner that reads "AP Exam Label."**

If students accidentally place the exam label in the space for the number label or vice versa, advise them to leave the labels in place. They should not try to remove the label; their exam can still be processed correctly.

> **Read the statements on the front cover of Section I and look up when you have finished. . . .**

> **Sign your name and write today's date. Look up when you have finished. . . .**

> **Now print your full legal name where indicated. Are there any questions? . . .**

> **Turn to the back cover of your exam booklet and read it completely. Look up when you have finished. . . .**

> **Are there any questions? . . .**

> **You will now take Section I of the exam. Section I is the multiple-choice and grid-in portion of the exam. You may never discuss the multiple-choice exam content at any time in any form with anyone, including your teacher and other students. If you disclose the multiple-choice exam content through any means, your AP Exam score will be canceled.**

For the multiple-choice questions, the answer sheet has circles marked A–E for each question. For Biology, you will use only the circles marked A–D. You must complete the answer sheet using a No. 2 pencil only. Open your answer sheet to page 2. Mark all of your responses beginning on page 2 of your answer sheet, one response per question. No credit will be given for anything written in the exam booklet. Scratch paper is not allowed, but you may use the margins or any blank space in the exam booklet for scratch work. If you need to erase, do so carefully and completely. Your score on the multiple-choice section will be based solely on the number of questions answered correctly. Four-function calculators (with square root) are allowed.

For the grid-in questions, you will solve each problem, write your final numeric answer in the boxes at the top of the grid, and fill in the corresponding circles. Enter your responses for the grid-in questions on page 3 of the answer sheet beginning with number 121. You will receive credit <u>only</u> if the circles are filled in correctly. Please pay close attention to the directions in your exam booklet for completing the grid-in questions.

Are there any questions? . . .

You have 1 hour and 30 minutes for this section. Open your Section I booklet and begin.

🕐 Note Start Time here _____. Note Stop Time here _____. Check that students are marking their answers in pencil on their answer sheets and that they are not looking at their shrinkwrapped Section II booklets. After 1 hour and 20 minutes, say:

There are 10 minutes remaining.

After 10 minutes, say:

Stop working. Close your booklet and put your answer sheet on your desk, face up. Make sure you have your AP number label and an AP Exam label on page 1 of your answer sheet. Sit quietly while I collect your answer sheets.

Collect an answer sheet from each student. Check that each answer sheet has an AP number label and an AP Exam label. After all answer sheets have been collected, say:

Now you must seal your exam booklet using the white seals you set aside earlier. Remove the white seals from the backing and press one on each area of your exam booklet cover marked "PLACE SEAL HERE." Fold each seal over the back cover. When you have finished, place the booklet on your desk, face up. I will now collect your Section I booklet. . . .

Collect a Section I booklet from each student. Check that each student has signed the front cover of the sealed Section I booklet.

There is a 10-minute break between Sections I and II. When all Section I materials have been collected and accounted for and you are ready for the break, say:

Please listen carefully to these instructions before we take a 10-minute break. All items you placed under your chair at the beginning of this exam must stay there, and you are not permitted to open or access them in any way. Leave your shrinkwrapped Section II packet on your desk during the break. You

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are not allowed to consult teachers, other students, notes, or textbooks during the break. You may not make phone calls, send text messages, use your calculators, check email, use a social networking site, or access any electronic or communication device. Remember, you may never discuss the multiple-choice exam content at any time in any form with anyone, including your teacher and other students. If you disclose the multiple-choice exam content through any means, your AP Exam score will be canceled. Are there any questions? . . .

🕘 **You may begin your break. Testing will resume at _____.**

SECTION II: Free Response

After the break, say:

May I have everyone's attention? Place your Student Pack on your desk. . . .

You may now remove the shrinkwrap from the Section II packet, but do not open the exam booklet until you are told to do so. . . .

Read the bulleted statements on the front cover of the exam booklet. Look up when you have finished. . . .

Now take an AP number label from your Student Pack and place it on the shaded box. If you don't have any AP number labels, write your AP number in the box. Look up when you have finished. . . .

Read the last statement. . . .

Using a pen with black or dark blue ink, print the first, middle, and last initials of your legal name in the boxes and print today's date where indicated. This constitutes your signature and your agreement to the statements on the front cover. . . .

Turn to the back cover and, using your pen, complete Item 1 under "Important Identification Information." Print the first two letters of your <u>last</u> name and the first letter of your <u>first</u> name in the boxes. Look up when you have finished. . . .

In Item 2, print your date of birth in the boxes. . . .

In Item 3, write the school code you printed on the front of your Student Pack in the boxes. . . .

Read Item 4. . . .

Are there any questions? . . .

I need to collect the Student Pack from anyone who will be taking another AP Exam. You may keep it only if you are not taking any other AP Exams this year. If you have no other AP Exams to take, place your Student Pack under your chair now. . . .

Read the information on the back cover of the exam booklet. Do not open the booklet until you are told to do so. Look up when you have finished. . . .

Collect the Student Packs. Then say:

Are there any questions? . . .

The total Section II time is 1 hour and 30 minutes. This includes a 10-minute reading period. The reading period is designed to provide you with time to develop thoughtful, well-organized responses. You are advised to spend the 10-minute period reading all the questions, and to use the unlined pages to sketch graphs, make notes, and plan your answers. The focus of the reading period should be the organization of questions 1 and 2. You may begin writing your exam responses before the reading period is over. You may make notes on the pages that contain the exam questions, but your responses must be written on the designated lined pages using a pen with black or dark blue ink. Are there any questions? . . .

You are responsible for pacing yourself and may proceed freely from one question to the next. Be sure that you answer all of the questions. If you need more paper to complete your responses, raise your hand. At the top of each extra sheet of paper you use, be sure to write only:

- **your AP number, and**
- **the question number you are working on.**

You may now open the Section II booklet and begin the 10-minute reading period.

🕐 Note Start Time here —————. Note Stop Time here —————. After 10 minutes, say:

The reading period is over. You have 1 hour and 20 minutes remaining to complete Section II.

🕐 Note Start Time here —————. Note Stop Time here —————. Check that students are using pens to write their answers in their exam booklets. After 1 hour and 10 minutes, say:

There are 10 minutes remaining.

After 10 minutes, say:

Stop working and close your exam booklet. Place it on your desk, face up.

If any students used extra paper for a question in the free-response section, have those students staple the extra sheet(s) to the first page corresponding to that question in their exam booklets. Complete an Incident Report. A single Incident Report may be completed for multiple students per exam subject per administration (regular or late testing) as long as all of the required information is provided. Include all exam booklets with extra sheets of paper in an Incident Report return envelope (see page 62 of the *2016-17 AP Coordinator's Manual* for complete details). Then say:

Remain in your seat, without talking, while the exam materials are collected. . . .

Collect a Section II exam booklet from each student. Check for the following:

- Exam booklet front cover: The student placed an AP number label on the shaded box and printed his or her initials and today's date.
- Exam booklet back cover: The student completed the "Important Identification Information" area.

When all exam materials have been collected and accounted for, return to students any electronic devices you may have collected before the start of the exam.

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If you are giving the regularly scheduled exam, say:

> **You may not discuss or share the free-response exam content with anyone unless it is released on the College Board website in about two days. Your AP Exam score results will be available online in July.**

If you are giving the alternate exam for late testing, say:

> **None of the content in this exam may ever be discussed or shared in any way at any time. Your AP Exam score results will be available online in July.**

If any students completed the AP number card at the beginning of this exam, say:

> **Please remember to take your AP number card with you. You will need the information on this card to view your scores and order AP score reporting services online.**

Then say:

> **You are now dismissed.**

Post-Exam Tasks

Be sure to give the completed seating chart to the AP coordinator. Schools must retain seating charts for at least six months (unless the state or district requires that they be retained for a longer period of time). Schools should not return any seating charts in their exam shipments unless they are required as part of an Incident Report.

The exam proctor should complete the following tasks if asked to do so by the AP coordinator. Otherwise, the AP coordinator must complete these tasks.

All exam materials must be placed in secure storage until they are returned to the AP Program after your school's last administration. Before storing materials, check the "School Use Only" section on page 1 of the answer sheet and:

- Fill in the appropriate section number circle in order to access a separate AP Instructional Planning Report (for regularly scheduled exams only) or subject score roster at the class section or teacher level. See "Post-Exam Activities" in the *2016-17 AP Coordinator's Manual*.

- Check your list of students who are eligible for fee reductions and fill in the appropriate circle on their registration answer sheets.

Student Answer Sheet for the Multiple-Choice and Grid-In Section

Use this section to capture student responses. (Note that the following answer sheet is a sample, and may differ from one used in an actual exam.)

AP Answer Sheet 2017

AP Number Label
(from Student Pack)

123456789

AP Exam Label
(from Section I Booklet)

◆ CollegeBoard

COMPLETE THIS AREA AT EVERY EXAM.   USE NO. 2 PENCIL ONLY

To maintain the security of the exam and the validity of my AP score, I will allow no one else to see the multiple-choice exam content. I will seal the multiple-choice booklet when asked to do so, and I will not discuss the exam content with anyone at any time after completing the section. I am aware of and agree to the AP Program's policies and procedures as outlined in the *2016-17 Bulletin for AP Students and Parents*, including using testing accommodations (e.g., extended time, computer, etc.) only if I have been preapproved by College Board Services for Students with Disabilities.

A. SIGNATURE   Sign your legal name as it will appear on your college applications.   Date

B. LEGAL NAME   Omit apostrophes, Jr., II.

Legal Last Name — First 15 Letters   Legal First Name — First 12 Letters   MI

C. YOUR AP NUMBER

D. EXAM DATE Month Day

E. EXAM START TIME AM PM
6 12
7 1
8 2
9 3
10 4
11 5

F. MULTIPLE-CHOICE BOOKLET SERIAL NUMBER S

G. ONLINE PROVIDER CODE

COMPLETE THIS AREA ONLY ONCE.

I. AREA CODE AND PHONE NUMBER

INTERNATIONAL PHONE

J. SCHOOL YOU ATTEND

SCHOOL CODE   School Name

City

State

Country

K. DATE OF BIRTH
Month Day Year

○ Jan
○ Feb
○ Mar
○ Apr
○ May
○ Jun
○ Jul
○ Aug
○ Sep
○ Oct
○ Nov
○ Dec

L. SOCIAL SECURITY NUMBER (Optional)

M. COLLEGE TO RECEIVE YOUR AP SCORE REPORT

COLLEGE CODE   Using the college code listed in the AP Student Pack, indicate the **ONE** college that you want to receive your AP score report.

College Name

City

State

Country

N. CURRENT GRADE LEVEL

○ Not yet in 9th grade   ○ 11th
○ 9th   ○ 12th
○ 10th   ○ No longer in high school

O. STUDENT SEARCH SERVICE®

Colleges and scholarship programs may request your information to inform you of educational opportunities and financial aid.

Would you like us to supply your information?

○ Yes   ○ No

If you don't answer and previously chose to participate in this service, we will continue providing your information.

H. AP EXAM I AM TAKING USING THIS ANSWER SHEET   Exam Name: Form: Form Code:

792107

SCHOOL USE ONLY

Section Number   ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨

Fee Reduction Granted   ① Option 1   ② Option 2

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COMPLETE THIS AREA AT EACH EXAM (IF APPLICABLE).

P. SURVEY QUESTIONS — Answer the survey questions in the AP Student Pack. Do not put responses to exam questions in this section.

1 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	4 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	7 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ
2 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	5 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	8 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ
3 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	6 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	9 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ

Q. LANGUAGE — Do not complete this section unless instructed to do so.

If this answer sheet is for the French Language and Culture, German Language and Culture, Italian Language and Culture, Spanish Language and Culture, or Spanish Literature and Culture Exam, please answer the following questions. Your responses will not affect your score.

1. Have you lived or studied for one month or more in a country where the language of the exam you are now taking is spoken?

○ Yes ○ No

2. Do you regularly speak or hear the language at home?

○ Yes ○ No

QUESTIONS 1–75

Indicate your answers to the exam questions in this section (pages 2 and 3). Mark only one response per question for Questions 1 through 120. If a question has only four answer options, do not mark option E. Answers written in the multiple-choice booklet will not be scored.

COMPLETE MARK ● **EXAMPLES OF INCOMPLETE MARKS** Ⓐ ⊗ ⊖ Ⓓ / Ⓐ ∅ ∅ Ⓓ

You must use a No. 2 pencil and marks must be complete. Do not use a mechanical pencil. It is very important that you fill in the entire circle darkly and completely. If you change your response, erase as completely as possible. Incomplete marks or erasures may affect your score.

1 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	26 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	51 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
2 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	27 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	52 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
3 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	28 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	53 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
4 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	29 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	54 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
5 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	30 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	55 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
6 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	31 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	56 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
7 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	32 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	57 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
8 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	33 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	58 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
9 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	34 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	59 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
10 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	35 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	60 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
11 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	36 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	61 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
12 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	37 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	62 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
13 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	38 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	63 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
14 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	39 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	64 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
15 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	40 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	65 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
16 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	41 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	66 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
17 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	42 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	67 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
18 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	43 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	68 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
19 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	44 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	69 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
20 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	45 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	70 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
21 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	46 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	71 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
22 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	47 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	72 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
23 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	48 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	73 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
24 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	49 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	74 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
25 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	50 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	75 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ

ETS USE ONLY

	R	W	O		R	W	O
SELECTED MEDIA EXAMS				**OTHER EXAMS**			
PT02				TOTAL			
PT03				Subscore (if applicable)			
PT04				Subscore (if applicable)			

Exam ⓪①②③④⑤⑥⑦⑧⑨
⓪①②③④⑤⑥⑦⑧⑨

Exam ⓪①②③④⑤⑥⑦⑧⑨
⓪①②③④⑤⑥⑦⑧⑨

DO NOT WRITE IN THIS AREA

QUESTIONS 76–120

Be sure each mark is dark and completely fills the circle. If a question has only four answer options, do not mark option E.

76 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	91 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	106 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
77 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	92 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	107 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
78 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	93 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	108 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
79 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	94 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	109 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
80 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	95 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	110 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
81 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	96 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	111 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
82 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	97 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	112 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
83 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	98 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	113 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
84 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	99 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	114 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
85 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	100 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	115 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
86 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	101 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	116 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
87 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	102 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	117 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
88 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	103 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	118 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
89 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	104 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	119 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
90 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	105 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	120 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ

QUESTIONS 121–126

For Students Taking AP Biology

Write your answer in the boxes at the top of the griddable area and fill in the corresponding circles.
Mark only one circle in any column. You will receive credit only if the circles are filled in correctly.

121   122   123   124   125   126

(griddable answer grids with digits 0–9 for each of six questions)

QUESTIONS 131–142

For Students Taking AP Computer Science Principles, AP Physics 1, or AP Physics 2

Mark two responses per question. You will receive credit only if both correct responses are selected.

131 Ⓐ Ⓑ Ⓒ Ⓓ	135 Ⓐ Ⓑ Ⓒ Ⓓ	139 Ⓐ Ⓑ Ⓒ Ⓓ
132 Ⓐ Ⓑ Ⓒ Ⓓ	136 Ⓐ Ⓑ Ⓒ Ⓓ	140 Ⓐ Ⓑ Ⓒ Ⓓ
133 Ⓐ Ⓑ Ⓒ Ⓓ	137 Ⓐ Ⓑ Ⓒ Ⓓ	141 Ⓐ Ⓑ Ⓒ Ⓓ
134 Ⓐ Ⓑ Ⓒ Ⓓ	138 Ⓐ Ⓑ Ⓒ Ⓓ	142 Ⓐ Ⓑ Ⓒ Ⓓ

DO NOT WRITE IN THIS AREA

R. YOUR MAILING ADDRESS

Use the address abbreviations from your AP Student Pack. Fill in only one circle per column. Indicate a space in your address by leaving a blank box; do not grid that column.

STREET ADDRESS (include street number, street name, apartment number, etc.)   **CITY**   **ZIP OR POSTAL CODE**   **COUNTRY CODE**

(Grid of bubbles A–Z, 0–9, and / for each column)

STATE

AK	HI	MI	NY	VT
AL	IA	MN	OH	WA
AR	ID	MO	OK	WI
AZ	IL	MS	OR	WV
CA	IN	MT	PA	WY
CO	KS	NC	RI	Puerto Rico
CT	KY	ND	SC	
DC	LA	NE	SD	AA
DE	MA	NH	TN	AE
FL	MD	NJ	TX	AP
GA	ME	NM	UT	Other
		NV	VA	

S. FOR STUDENTS OUTSIDE THE UNITED STATES ONLY

If your address does not fit in the spaces provided in Item R, fill in as many circles as you can, then fill in the circle in Item S and print the remainder of your address in the spaces provided.

Address   City   State or Province   Country   ZIP or Postal Code

T. STUDENT IDENTIFIER (Student ID Number)

U. EMAIL ADDRESS

By providing your email address, you are granting the College Board permission to use your email address in accordance with the policies in the *2016-17 Bulletin for AP Students and Parents*.

V. SEX

○ Female   ○ Male

W. WHICH LANGUAGE DO YOU KNOW BEST?

○ English
○ English and another language about the same
○ Another language

X. RACIAL/ETHNIC GROUP

Please answer both questions about Hispanic origin and about race. For the following questions about your identity, Hispanic origins are not races.

(You may mark all that apply.)

a. Are you of Hispanic, Latino, or Spanish origin?
○ No, not of Hispanic, Latino, or Spanish origin
○ Yes, Cuban
○ Yes, Mexican
○ Yes, Puerto Rican
○ Yes, another Hispanic, Latino, or Spanish origin

b. What is your race?
○ American Indian or Alaska Native
○ Asian (including Indian subcontinent and Philippines origin)
○ Black or African American (including Africa and Afro-Caribbean origin)
○ Native Hawaiian or other Pacific Islander
○ White (including Middle Eastern origin)

Y. PARENTAL EDUCATION LEVEL

In the first column, indicate the highest level of education of one parent/guardian, and indicate whether this is your mother/female guardian or father/male guardian. Then, if applicable, indicate the highest level of education of your other parent/guardian in the second column, and indicate whether this is your mother/female guardian or father/male guardian.

○ ○ **Mother or female guardian**
○ ○ **Father or male guardian**
○ ○ Grade school
○ ○ Some high school
○ ○ High school diploma or equivalent
○ ○ Vocational or trade school
○ ○ Some college
○ ○ Associate or two-year degree
○ ○ Bachelor's or four-year degree
○ ○ Some graduate or professional school
○ ○ Graduate or professional degree

Section I:
Multiple-Choice and Grid-In Questions

This is the multiple-choice and grid-in section of the 2017 AP exam.
It includes cover material and other administrative instructions
to help familiarize students with the mechanics of the exam.
(Note that future exams may differ in look from the following content.)

For purposes of test security and/or statistical analysis, some questions
have been removed from the version of the exam that was administered
in 2017. Therefore, the timing indicated here may not be appropriate
for a practice exam.

AP® Biology Exam

SECTION I: Multiple Choice and Grid-In

2017

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

At a Glance

Total Time
1 hour, 30 minutes
Number of Questions
58
Percent of Total Score
50%
Writing Instrument
Pencil required
Electronic Device
Four-function calculator
(with square root)

Instructions

Section I of this exam contains 53 multiple-choice questions and 5 grid-in questions. Indicate all of your answers to the Section I questions on the answer sheet. No credit will be given for anything written in this exam booklet, but you may use the booklet for notes or scratch work.

For questions 1 through 53, after you have decided which of the suggested answers is best, completely fill in the corresponding circle on the answer sheet. Fill in only the circles for questions 1 through 53. Because this section offers only four answer options for each question, do not mark the (E) answer circle for any question.

Give only one answer to each question. If you change an answer, be sure that the previous mark is erased completely. Here is a sample question and answer.

Sample Question   Sample Answer

Chicago is a   Ⓐ ● Ⓒ Ⓓ Ⓔ
(A) state
(B) city
(C) country
(D) continent

For questions 121 through 125, follow the instructions after question 53 to enter your numeric answers. Write your numeric answer in the boxes at the top of the grid and fill in the corresponding circles for questions 121 through 125.

Use your time effectively, working as quickly as you can without losing accuracy. Do not spend too much time on any one question. Go on to other questions and come back to the ones you have not answered if you have time. It is not expected that everyone will know the answers to all of the multiple-choice questions.

Your total score on Section I is based only on the number of questions answered correctly. Points are not deducted for incorrect answers or unanswered questions.

Form I
Form Code 4NBP4-S

20

AP® BIOLOGY EQUATIONS AND FORMULAS

Statistical Analysis and Probability

Mean

$$\overline{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Standard Deviation

$$s = \sqrt{\frac{\sum(x_i - \overline{x})^2}{n-1}}$$

Standard Error of the Mean

$$SE_{\overline{x}} = \frac{s}{\sqrt{n}}$$

Chi-Square

$$\chi^2 = \sum \frac{(o-e)^2}{e}$$

Chi-Square Table

p value	Degrees of Freedom							
	1	2	3	4	5	6	7	8
0.05	3.84	5.99	7.82	9.49	11.07	12.59	14.07	15.51
0.01	6.64	9.21	11.34	13.28	15.09	16.81	18.48	20.09

$\overline{x}$ = sample mean

n = size of the sample

s = sample standard deviation (i.e., the sample-based estimate of the standard deviation of the population)

o = observed results

e = expected results

Degrees of freedom are equal to the number of distinct possible outcomes minus one.

Laws of Probability

If A and B are mutually exclusive, then:

$$P(\text{A or B}) = P(\text{A}) + P(\text{B})$$

If A and B are independent, then:

$$P(\text{A and B}) = P(\text{A}) \times P(\text{B})$$

Hardy-Weinberg Equations

$$p^2 + 2pq + q^2 = 1$$

$$p + q = 1$$

p = frequency of the dominant allele in a population

q = frequency of the recessive allele in a population

Metric Prefixes

Factor	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Mode = value that occurs most frequently in a data set

Median = middle value that separates the greater and lesser halves of a data set

Mean = sum of all data points divided by number of data points

Range = value obtained by subtracting the smallest observation (sample minimum) from the greatest (sample maximum)

Rate and Growth

Rate

$$\frac{dY}{dt}$$

Population Growth

$$\frac{dN}{dt} = B - D$$

Exponential Growth

$$\frac{dN}{dt} = r_{max}N$$

Logistic Growth

$$\frac{dN}{dt} = r_{max}N\left(\frac{K-N}{K}\right)$$

Temperature Coefficient Q10

$$Q_{10} = \left(\frac{k_2}{k_1}\right)^{\frac{10}{T_2-T_1}}$$

Primary Productivity Calculation

$$\frac{\text{mg O}_2}{\text{L}} \times \frac{0.698\ \text{mL}}{\text{mg}} = \frac{\text{mL O}_2}{\text{L}}$$

$$\frac{\text{mL O}_2}{\text{L}} \times \frac{0.536\ \text{mg C fixed}}{\text{mL O}_2} = \frac{\text{mg C fixed}}{\text{L}}$$

(at standard temperature and pressure)

---

dY = amount of change

dt = change in time

B = birth rate

D = death rate

N = population size

K = carrying capacity

r_{max} = maximum per capita growth rate of population

T_2 = higher temperature

T_1 = lower temperature

k_2 = reaction rate at T_2

k_1 = reaction rate at T_1

Q_{10} = the factor by which the reaction rate increases when the temperature is raised by ten degrees

---

Water Potential (Ψ)

$$\Psi = \Psi_P + \Psi_S$$

Ψ_P = pressure potential

Ψ_S = solute potential

The water potential will be equal to the solute potential of a solution in an open container because the pressure potential of the solution in an open container is zero.

The Solute Potential of a Solution

$$\Psi_S = -iCRT$$

i = ionization constant (this is 1.0 for sucrose because sucrose does not ionize in water)

C = molar concentration

R = pressure constant (R = 0.0831 liter bars/mole K)

T = temperature in Kelvin (ºC + 273)

Surface Area and Volume

Volume of a Sphere

$$V = \frac{4}{3}\pi r^3$$

Volume of a Rectangular Solid

$$V = \ell wh$$

Volume of a Right Cylinder

$$V = \pi r^2 h$$

Surface Area of a Sphere

$$A = 4\pi r^2$$

Surface Area of a Cube

$$A = 6s^2$$

Surface Area of a Rectangular Solid

$$A = \Sigma\ \text{surface area of each side}$$

---

r = radius

ℓ = length

h = height

w = width

s = length of one side of a cube

A = surface area

V = volume

Σ = sum of all

Dilution (used to create a dilute solution from a concentrated stock solution)

$$C_iV_i = C_fV_f$$

i = initial (starting) C = concentration of solute
f = final (desired) V = volume of solution

Gibbs Free Energy

$$\Delta G = \Delta H - T\Delta S$$

ΔG = change in Gibbs free energy

ΔS = change in entropy

ΔH = change in enthalpy

T = absolute temperature (in Kelvin)

$$pH = -\log_{10}[H^+]$$

Directions: Each of the questions or incomplete statements below is followed by four suggested answers or completions. Select the one that is best in each case and then fill in the corresponding circle on the answer sheet.
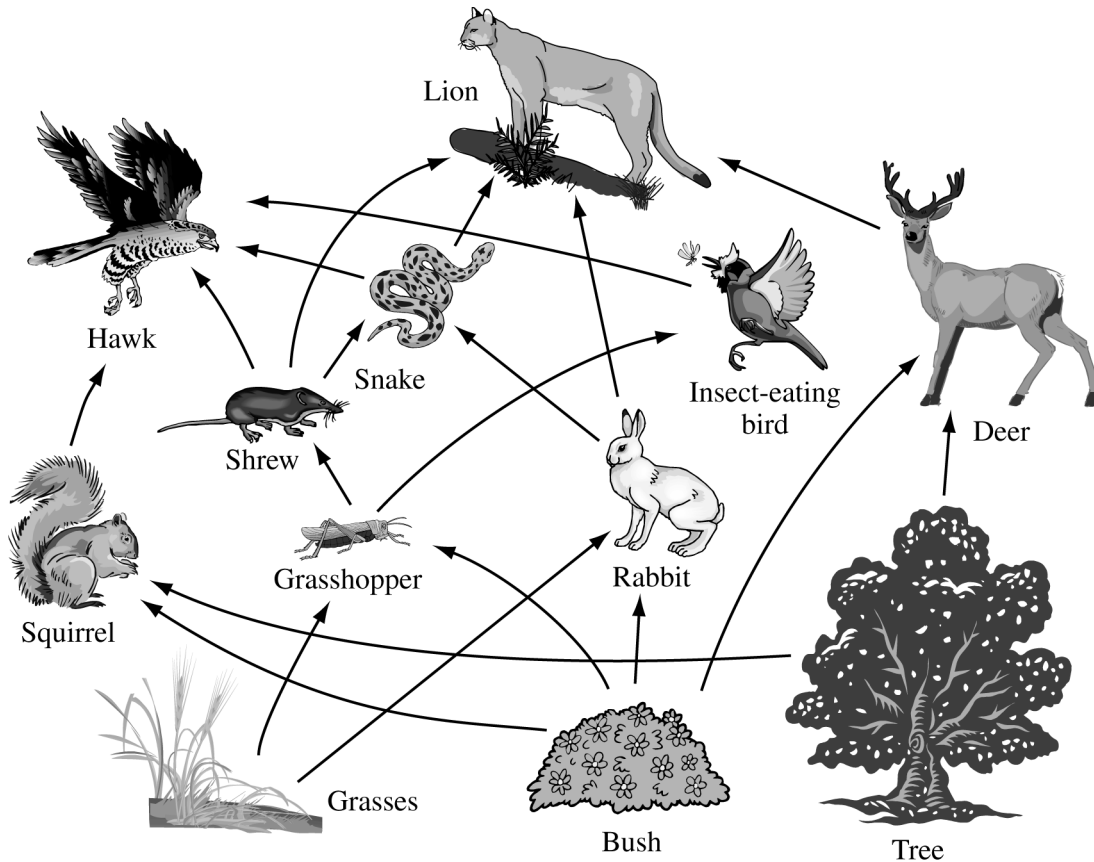
1. The food web represented above does not include bacteria and fungi. Which of the following best describes a consequence of having no bacteria and fungi in the food web?

   (A) Grasses will have no direct access to chemical components recycled from dead organisms.
   (B) Rabbits will have no direct access to energy absorbed from secondary consumers.
   (C) Shrews will have no direct access to matter transferred from tertiary consumers.
   (D) Hawks will have no direct access to nitrogen acquired from the atmosphere.

2. The following DNA sequence is a small part of the coding (nontemplate) strand from the open reading frame of the *β-hemoglobin* gene. Given the codon chart listed below, what would be the effect of a mutation that deletes the G at the beginning of the DNA sequence?

5′ - GTT TGT CTG TGG TAC CAC GTG GAC TGA - 3′

Second Base in Codon

	U	C	A	G	
U	UUU UUC } Phe UUA UUG } Leu	UCU UCC UCA UCG } Ser	UAU UAC } Tyr UAA Stop UAG Stop	UGU UGC } Cys UGA Stop UGG Trp	U C A G
C	CUU CUC CUA CUG } Leu	CCU CCC CCA CCG } Pro	CAU CAC } His CAA CAG } Gln	CGU CGC CGA CGG } Arg	U C A G
A	AUU AUC AUA } Ile AUG Met or Start	ACU ACC ACA ACG } Thr	AAU AAC } Asn AAA AAG } Lys	AGU AGC } Ser AGA AGG } Arg	U C A G
G	GUU GUC GUA GUG } Val	GCU GCC GCA GCG } Ala	GAU GAC } Asp GAA GAG } Glu	GGU GGC GGA GGG } Gly	U C A G

First Base in Codon (left axis) — Third Base in Codon (right axis)

(A) The mutation precedes the gene, so no changes would occur.

(B) Lysine (lys) would replace glutamine (gln), but there would be no other changes.

(C) The first amino acid would be missing, but there would be no other change to the protein.

(D) The reading frame of the sequence would shift, causing a change in the amino acid sequence after that point.

GO ON TO THE NEXT PAGE.

3. A widely accepted hypothesis about the origin of life on Earth is that life arose approximately 3.5 billion years ago as the result of a complex sequence of chemical reactions that took place spontaneously in Earth's atmosphere. Another hypothesis about the origin of life suggests that life began somewhere else in the universe and arrived on Earth by chance.

Which of the following questions might scientists ask to most reliably determine if there has ever been life on Mars?

(A) How far from Earth was Mars 3.5 billion years ago?
(B) Is there scientific proof that Earth ever had an oxygen-free atmosphere?
(C) Did Mars have the elements present in its atmosphere to support life?
(D) Was there oxygen gas on Mars 3.5 billion years ago?

4. Cortisol is a hormone produced in response to stress, including starvation, in humans. Which of the following is most likely an immediate effect of a starvation-induced increase in cortisol secretion?

(A) Increased activation of the immune system
(B) Increased urine production by the kidneys
(C) Increased bone and collagen formation
(D) Increased mobilization of fatty acids from fat cells

5. Ciprofloxacin is given as an antibiotic to healthy livestock to promote efficient weight gain. Strains of the bacterium *Campylobacter jejuni* naturally colonize the digestive tracts of livestock, and the *C. jejuni* can be transferred to people through the handling and consumption of contaminated meat. People infected with *C. jejuni* also are treated with ciprofloxacin.

Which of the following is the most likely consequence of adding ciprofloxacin to animal feed?

(A) Naturally occurring strains of *C. jejuni* will reproduce more rapidly in the digestive tracts of livestock, reducing the risk of food-borne illnesses in people.
(B) Ciprofloxacin-resistant strains of *C. jejuni* will have a selective advantage in the digestive tracts of livestock, increasing the risk of serious infections in people.
(C) Ciprofloxacin-sensitive strains of *C. jejuni* will be consumed in meat that contains a chemical that inhibits bacterial growth, reducing the risk of food poisoning in people.
(D) Actively growing strains of *C. jejuni* will metabolize the nutrients in meat produced by livestock operations, increasing the risk of protein deficiencies in people.

GO ON TO THE NEXT PAGE.

Organisms	Derived Characters (+ indicates the character is present)					
	Hair	Jaws	Feathers	Amniotic Eggs	Two Pairs of Limbs	β-Keratin Scales
Mammals	+	+		+	+	
Crocodilians		+		+	+	+
Fish		+				
Amphibians		+			+	
Birds		+	+	+	+	+

6. The table above shows derived characters for selected organisms. Based on the information in the table, which of the following cladograms best represents the evolutionary relationships among the organisms?

(A) Fish Amphibians Crocodilians   Birds Mammals
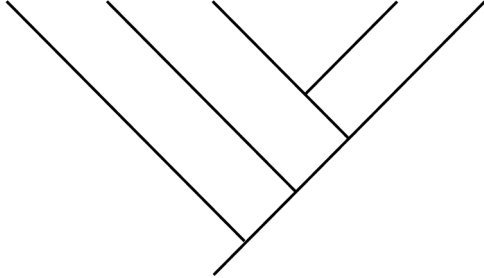
(B) Mammals Birds Crocodilians Amphibians   Fish
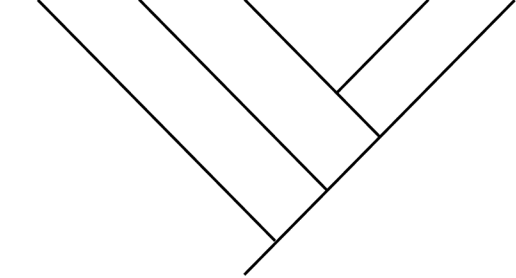
(C) Amphibians Fish   Birds   Crocodilians Mammals
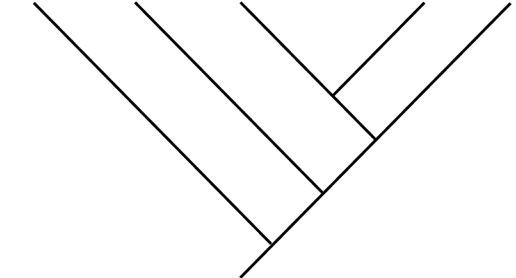
(D) Crocodilians Amphibians Birds   Fish Mammals

GO ON TO THE NEXT PAGE.
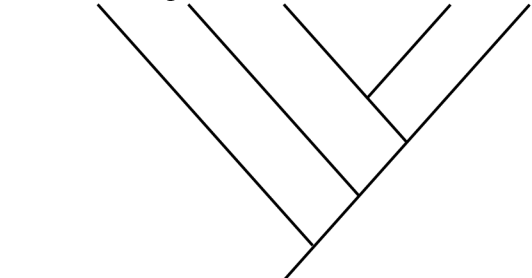
7. Damaged tissue releases chemicals that activate platelets and stimulate the formation of blood clots. Which of the following predictions about the activity of platelets best describes a positive feedback mechanism?

(A) Activated platelets release chemicals that inhibit blood clot formation.
(B) Activated platelets release signaling molecules that inhibit cell division in damaged tissue.
(C) Activated platelets constrict the blood vessels, stopping blood flow.
(D) Activated platelets release chemicals that activate more platelets.

8. Bacteriophages are viruses that infect bacteria. In an experiment, bacteriophages were labeled with either radioactive phosphorus or radioactive sulfur. The labeled bacteriophages were incubated with bacteria for a brief amount of time and then removed. The infected bacteria cells were found to contain significant amounts of radioactive phosphorus but not radioactive sulfur.

Based on the results of the experiment, which of the following types of molecules did the bacteriophages most likely inject into the bacteria cells?

(A) Simple carbohydrate
(B) Amino acid
(C) DNA
(D) Polypeptide

GO ON TO THE NEXT PAGE.

Questions 9-13

In an investigation of interspecies competition, researchers grew the unicellular protozoan *Paramecium aurelia* in a 5 mL culture and *Paramecium caudatum* in a separate 5 mL culture. *P. aurelia* and *P. caudatum* were grown together in a third 5 mL culture. Each day a small sample of each culture was removed so the total number of individuals could be estimated, and the remainder of the population was transferred to fresh growth medium. The experimental results are represented in the graphs below.
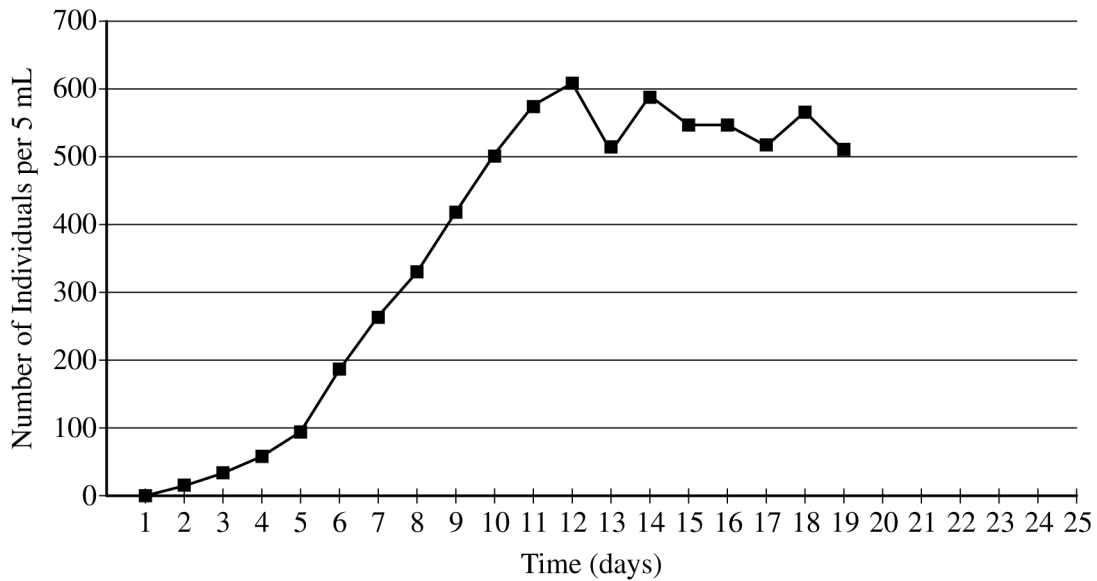
Figure 1. Population of *P. aurelia* cultured alone
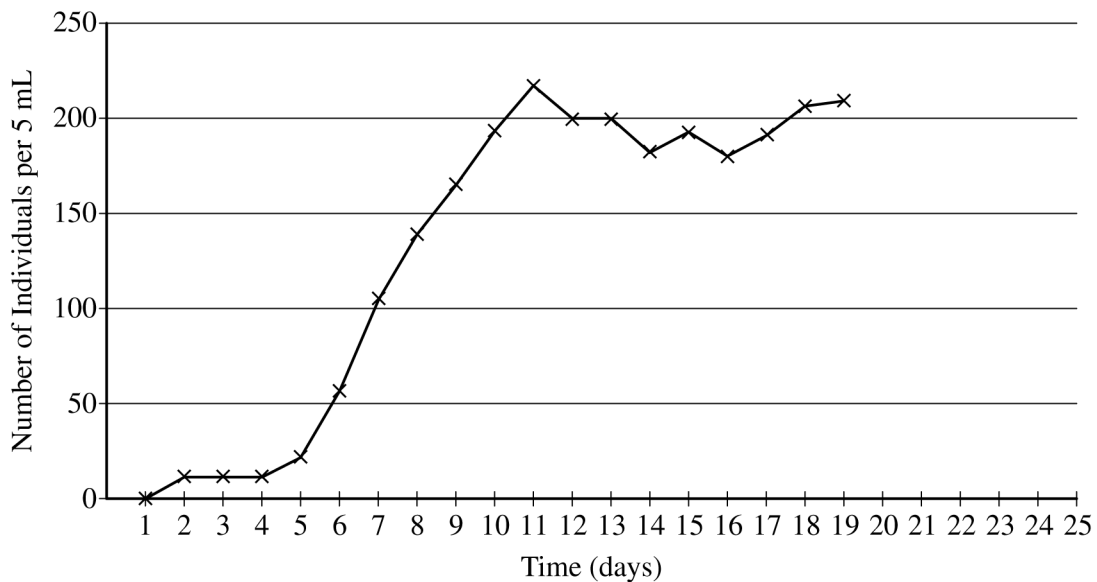
Figure 2. Population of *P. caudatum* cultured alone

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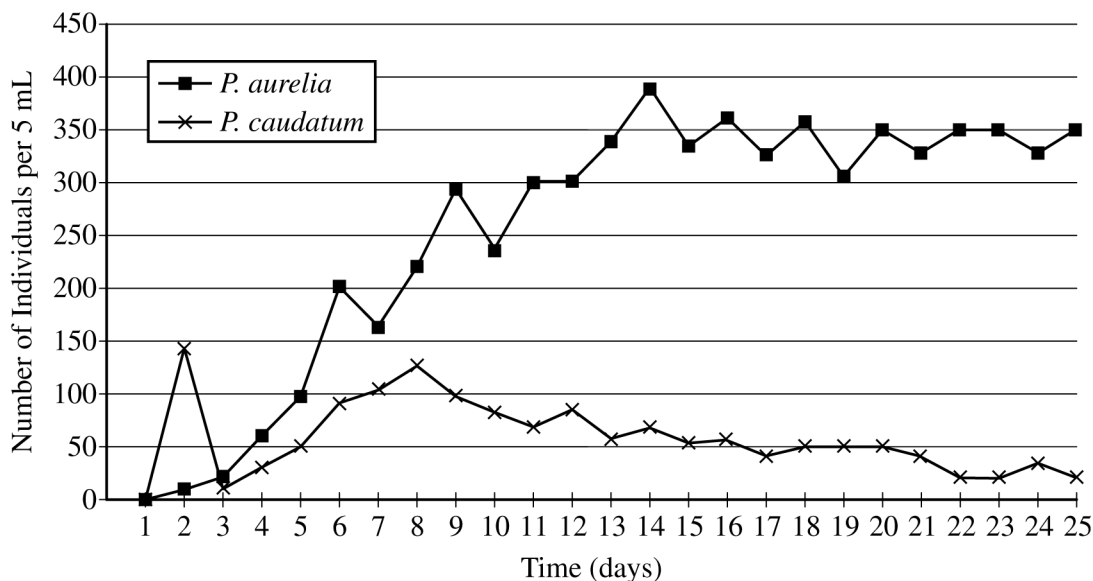
Figure 3. Populations of *P. aurelia* and *P. caudatum* cultured together

9. Which of the following conclusions is best supported by the results of the experiment?

   (A) Neither population grows as large when cultured together as each does when cultured separately.
   (B) *P. caudatum* prefers different food when cultured with *P. aurelia* than when cultured separately.
   (C) Competition for mates increases when the species are cultured together compared with when they are cultured separately.
   (D) Individuals of the species *P. caudatum* are smaller when cultured together with *P. aurelia* than when cultured separately.

10. The difference in carrying capacity between the two species when cultured separately is closest to which of the following values?

   (A)   0 individuals per 5.0 mL
   (B)   60 individuals per 5.0 mL
   (C)   150 individuals per 5.0 mL
   (D)   350 individuals per 5.0 mL

11. Which of the following statements best justifies the use of the experimental results in an investigation of interspecies competition?

   (A) When two populations use different sources of energy, one of the populations will thrive in a shared environment and the other will become extinct.
   (B) When two populations use the same sources of energy, resource availability in a shared environment limits the growth of both populations.
   (C) Because the change in entropy of a system containing two different species is always positive, populations typically grow faster in shared environments.
   (D) Because the free energy of a system containing two different species is always negative, populations that utilize similar resources cannot coexist in nature.

Questions 12-13 are on the next page.

GO ON TO THE NEXT PAGE.

12. If the mixed populations were cultured for an additional 25 days, which of the following predictions would be consistent with the data?

(A) Both populations would stabilize at a small size.
(B) Both populations would stabilize at a large size.
(C) Both populations would be eliminated from the culture.
(D) One population would stabilize at a large size, and the other population would be eliminated from the culture.

13. Based on the experimental results, which of the following statements best describes the relationship of the two populations that were studied in the investigation?

(A) The populations have a parasitic relationship in which one species requires the presence of the other to reproduce.
(B) The populations have a symbiotic relationship in which both species require the presence of the other to reproduce.
(C) The populations have a competitive relationship in which each species limits the ability of the other to reproduce.
(D) The populations have a predator/prey relationship in which one species positively influences the ability of the other to reproduce.

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PERCENT OF MOTHS RECAPTURED IN TWO DIFFERENT ENVIRONMENTS		
Trial	Moth Color and Environment	Percent of Released Moths Recaptured
I	Light-colored moths were released in an unpolluted environment.	13%
II	Light-colored moths were released in a polluted environment.	12%
III	Dark-colored moths were released in an unpolluted environment.	7%
IV	Dark-colored moths were released in a polluted environment.	28%

14. A researcher released large numbers of moths into different environments in an attempt to better understand a mechanism of evolution. The moths were released in four trials as described in the table above. Each of the released moths had a small mark on the underside of a wing for identification. After an appropriate amount of time, the researcher recaptured as many of the released moths as possible. Data from the experiment are included in the table above. Which of the following claims is best supported by the data?

(A) Light-colored moths were more likely to be recaptured in the polluted environment than in the unpolluted environment, suggesting an increased chance of reproductive success.
(B) Dark-colored moths were more likely to be recaptured in the polluted environment than in the unpolluted environment, suggesting an increased chance of reproductive success.
(C) Light-colored moths were less likely to be recaptured in the polluted environment than in the unpolluted environment, suggesting an increased chance of reproductive success.
(D) Dark-colored moths were less likely to be recaptured in the polluted environment than in the unpolluted environment, suggesting an increased chance of reproductive success.

15. Which of the following questions about the origin of life on Earth is most scientifically testable?

   (A) Why were the earliest life-forms created using only twenty amino acids?
   (B) Did life originate to make the universe a better place?
   (C) Was catalytic RNA used by ancient organisms as a stepping stone to acquire protein enzymes?
   (D) Can simple organic molecules form spontaneously in an oxygen-free atmosphere?

16. A microelectrode is inserted into a neuron. A voltage recorder then measures the voltage difference between the microelectrode inside the cell and an electrode placed outside the cell. Which of the following plots most accurately represents the changes in membrane potential throughout a single action potential?

   (A)

   (B)

   (C)

   (D)

GO ON TO THE NEXT PAGE.

SEX RATIO OF REPTILE HATCHLINGS
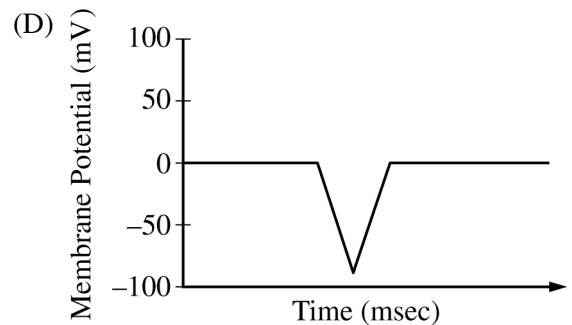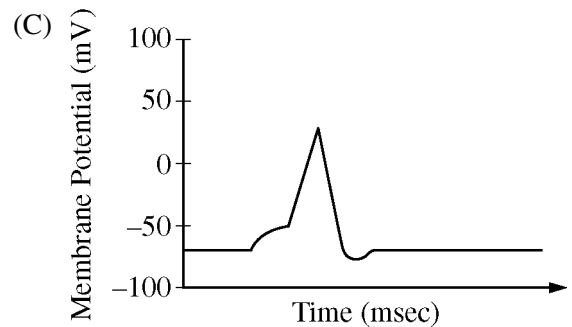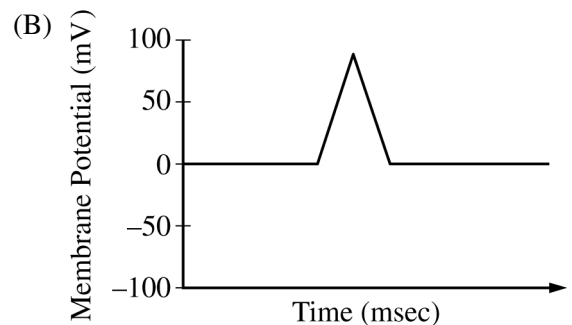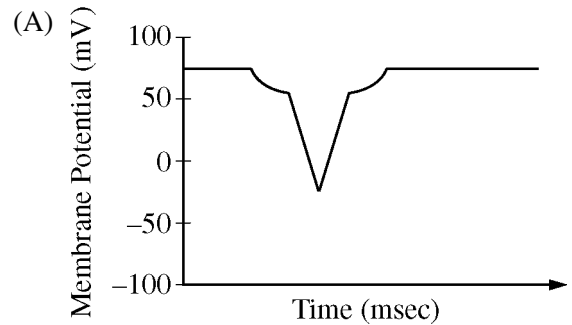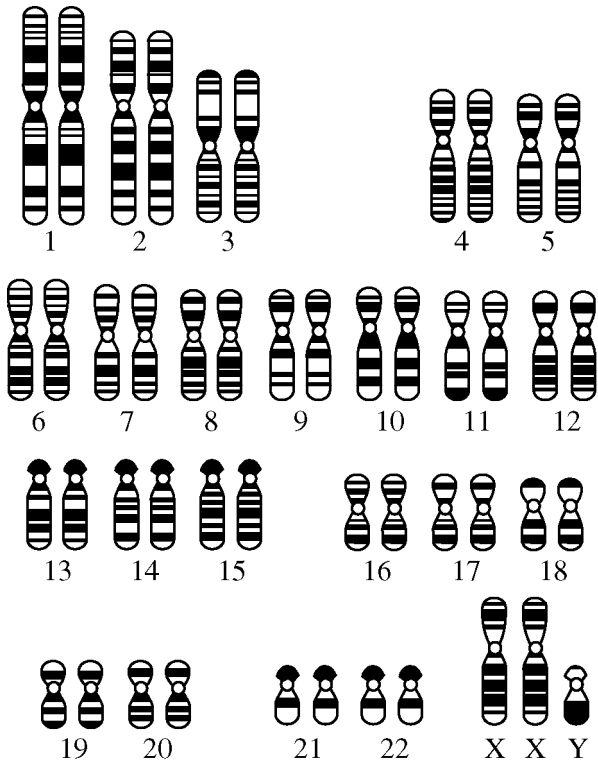
17. The diagram above depicts a karyotype of an individual human. Which of the following statements concerning the karyotype in the diagram is true?

(A) The diagram illustrates a genetic condition found in females.
(B) The diagram indicates a mechanism for increasing genetic diversity in subsequent generations.
(C) The diagram illustrates the results of nondisjunction during gamete formation.
(D) The diagram indicates Down syndrome, a genetic condition.

18. The graph above represents the proportions of hatchlings of certain types of reptiles that are male at different egg incubation temperatures. Which of the following claims is best supported by the data?

(A) The expression of sex-determination genes in certain reptiles is influenced by temperature.
(B) Green turtle eggs do not hatch at temperatures above 35°C.
(C) In reptiles, sex determination is influenced by the sex ratio of the existing population.
(D) Incubating lizard eggs at constant low temperatures produces a large proportion of males.

GO ON TO THE NEXT PAGE.

In response to elevated blood glucose levels, beta (β) cells in the pancreas release insulin, a regulatory hormone. Insulin signals body cells to take up glucose from the blood, which returns blood glucose levels back to normal. Type 1 diabetes is an autoimmune disorder that destroys β-cells, resulting in elevated blood glucose levels.

Researchers have proposed that diabetes could be treated by implanting human embryonic stem cells (hESCs) that have been induced to develop into β-cells (hESC-β). To test the proposed treatment, the researchers set up two groups of genetically identical mice and implanted the mice from one group with hESC-β cells. Several weeks after the hESC-β implant, both groups of mice were given a drug (STZ) that selectively destroys the naturally occurring mouse β-cells but does not affect the implanted hESC-β cells. Figure 1 shows a comparison of average blood glucose levels in both groups of mice.
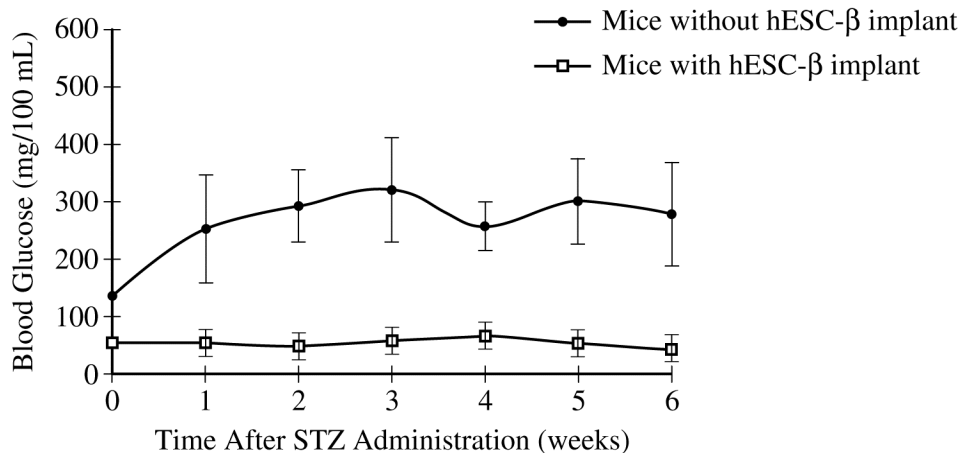
Figure 1. Average blood glucose levels in mice after STZ treatment. Error bars indicate standard deviation.

In a continuation of the experiment, the researchers removed the hESC-β implant from one of the mice 16 weeks after STZ treatment. Figure 2 shows the blood glucose levels in the mouse over the duration of the experiment.
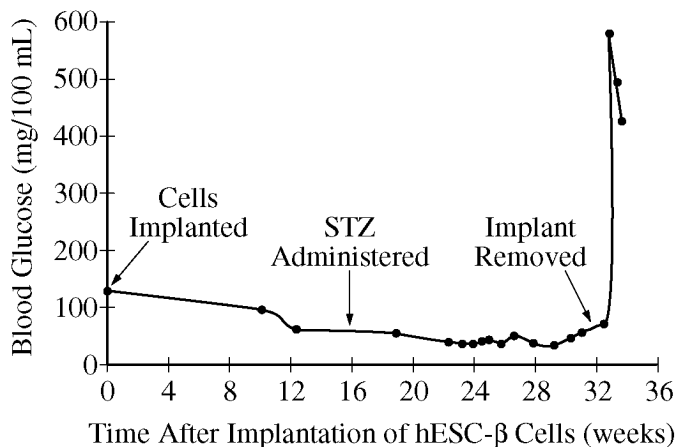
Figure 2. Blood glucose levels for an individual mouse over the duration of the experiment.

19. Which of the following modifications to the experimental design would improve the reliability of the results presented in Figure 1 ?

(A) Measuring blood glucose levels in human patients who have type 1 diabetes
(B) Measuring blood glucose levels in a group of mice that were not given STZ
(C) Using a drug that destroys both mouse β-cells and hESC-β cells
(D) Injecting the mice in the experiment with sucrose or fructose

20. Which of the following conclusions is best supported by the data presented in Figure 1 ?

(A) Mouse β-cells are more effective than implanted hESC-β cells at regulating blood glucose levels.
(B) Implanted hESC-β cells are effective at regulating blood glucose levels in the absence of mouse β-cells.
(C) Mouse β-cells do not regulate blood glucose levels in the presence of implanted hESC-β cells.
(D) Implanted hESC-β cells cause type 1 diabetes in laboratory mice.

21. Based on the data in Figure 2, which of the following best justifies the researchers' claim that hESC-β implants can functionally replace the mouse's naturally occurring β-cells?

(A) The mouse with an hESC-β implant demonstrated a decrease in blood glucose levels for the duration of the experiment.
(B) The mouse with an hESC-β implant demonstrated an increase in blood glucose levels before STZ treatment.
(C) The mouse with an hESC-β implant successfully regulated blood glucose levels by regenerating its naturally occurring β-cells.
(D) The mouse with an hESC-b implant successfully regulated blood glucose levels after STZ treatment but not after the implant was removed.

22. In contrast to type 1 diabetes, where there is no insulin production, type 2 diabetes is characterized by a failure of body cells to respond normally to insulin. Based on the results of the experiment, which of the following best predicts the effectiveness of using hESC-β implantation to treat type 2 diabetes?

(A) The treatment would fail because insulin produced by implanted hESC-β cells will not stimulate glucose uptake by body cells.
(B) The treatment would fail because the implanted hESC-β cells would require more glucose than the body can produce.
(C) The treatment would succeed because the implanted hESC-β cells can express the gene that codes for human insulin.
(D) The treatment would succeed because the body cells would secrete more insulin in the presence of the implanted hESC-β cells.

23. Based on the data, which of the following best represents how the mice with the implanted hESC-β cells use negative feedback to return blood glucose levels to normal if blood glucose levels increase?

(A) Decreased insulin secretion by body cells $\rightarrow$ increased glucose uptake by mouse β-cells $\rightarrow$ increased insulin secretion by body cells
(B) Increased insulin production by mouse β-cells $\rightarrow$ increased glucose uptake by hESC-β cells $\rightarrow$ decreased glucose metabolism by body cells
(C) Increased insulin secretion by hESC-β cells $\rightarrow$ increased glucose uptake by body cells $\rightarrow$ decreased insulin secretion by hESC-β cells
(D) Increased metabolism of glucose by hESC-β cells $\rightarrow$ differentiation of hESC-β cells into body cells $\rightarrow$ increased glucose production by body cells

Pathogen/Antigen

B Cells $\underset{+}{\overset{+}{\rightleftarrows}}$ T$_H$ $\overset{+}{\longleftarrow}$ Antigen-Presenting Cells

Memory B Cells $\overset{+}{\longrightarrow}$ Plasma Cells

Antigen + T$_H$ Antibody Secretion
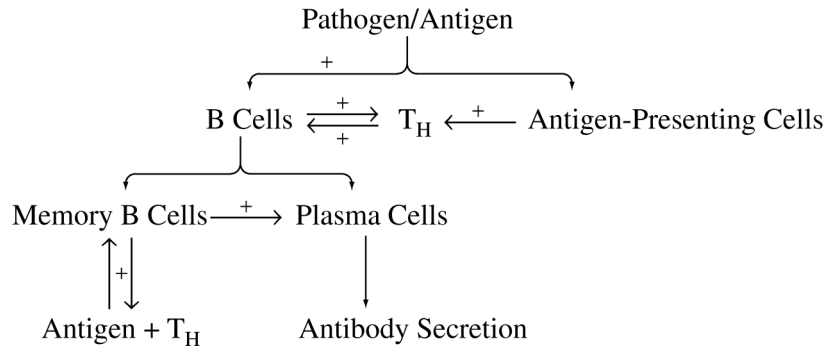
24. As represented in the model above, B cells are activated by direct contact with antigens or stimulated helper T cells (T$_H$). Based on the model, which of the following best describes an outcome of B cell activation?

(A) Activated B cells differentiate into plasma cells and memory cells.
(B) Activated B cells stimulate T$_H$ cells to secrete antibodies.
(C) Both B cells and T$_H$ cells release chemical signals that negatively regulate antigen-presenting cells.
(D) Plasma cells produce antibodies that activate additional B cells by a positive feedback mechanism.

GO ON TO THE NEXT PAGE.

25. A student analyzed a viral genome and found that the genome had the following nucleotide composition.

- 28% adenine

- 20% thymine

- 35% cytosine

- 17% guanine

Which of the following best describes the structure of the viral genome?

(A) Double-stranded DNA
(B) Single-stranded DNA
(C) Double-stranded RNA
(D) Single-stranded RNA

26. Which of the following communities is likely to be most stable?

(A) One where a keystone predator has been removed
(B) One with uniformly spaced vegetation
(C) One with high species diversity
(D) One that lacks decomposers
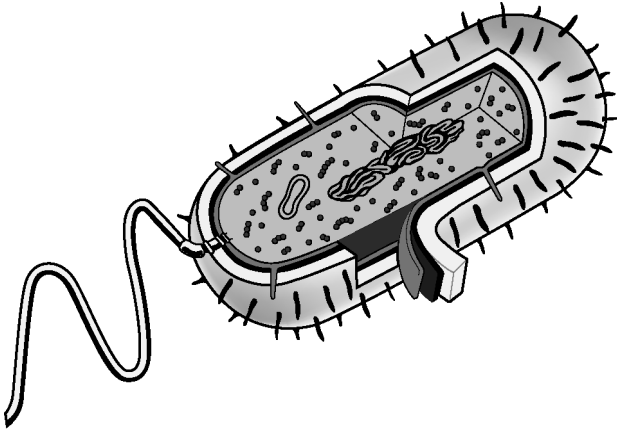
27. Which of the following is true about the structure of the prokaryotic cell represented in the figure?

(A) It possesses cilia and lysosomes.
(B) It has a diploid genome and contains linear DNA.
(C) It has a cell wall exterior to the plasma membrane and contains ribosomes.
(D) It possesses membrane-bound organelles and a flagellum.

28. Blackcap birds (*Sylvia atricapilla*) migrate out of Germany before wintertime. Prior to the 1960s, all members of a particular blackcap population flew to Spain, which had an abundant natural food source. Now, some members of the same blackcap population fly to the United Kingdom, where food placed in feeders by humans is abundant. The blackcaps return to the same forests in Germany to nest during the breeding season.

Some blackcaps that migrate to the United Kingdom have become distinguishable by certain physical and behavioral traits from blackcaps that migrate to Spain. Which of the following best predicts the effect on the blackcap population if humans in the United Kingdom continue to place food in feeders during the winter?

(A) The blackcaps that migrate to Spain will selectively mate with the blackcaps that migrate to the United Kingdom, resulting in increased genetic variation in the blackcap population.
(B) The blackcaps that migrate to the United Kingdom will become reproductively isolated from the blackcaps that migrate to Spain, resulting in speciation in the blackcap population.
(C) The blackcaps in Spain and the United Kingdom will migrate to other geographical locations in search of potential mating partners, resulting in a smaller blackcap population in Germany.
(D) The blackcaps will begin nesting at their wintering sites in Spain or the United Kingdom, resulting in a larger blackcap population migrating back to Germany after the breeding season has ended.

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LAC OPERON STRUCTURE
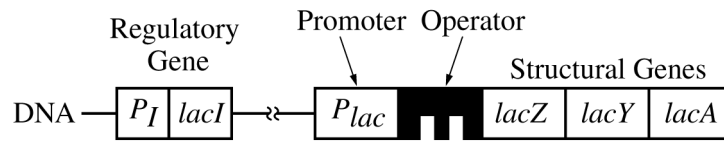
The functions of the loci of the *lac* operon shown in the diagram are described in the table below.

Locus	Function
P_I	Attachment site for RNA polymerase
lacI	Encodes a repressor protein that prevents transcription of the structural genes of the *lac* operon
P_{lac}	Attachment site for RNA polymerase
Operator	Binding site for the repressor protein
lacZ	Encodes beta-galactosidase, the enzyme that digests lactose to glucose and galactose
lacY	Encodes lactose permease, the channel through which lactose moves into the cell
lacA	Encodes galactoside transacetylase

The diagram above represents a segment of the *E. coli* chromosome that contains the *lacI* gene and part of the *lac* operon, a coordinately regulated set of genes that are required for the metabolism of lactose. The presence of lactose, which causes the repressor to be released from the operator, results in increased transcription of the *lac* operon.

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29. Which of the following is the most likely consequence of a mutation at the operator locus that prevents binding of the repressor protein?

(A) Expression of the structural genes will be repressed, even in the presence of lactose.
(B) Beta-galactosidase will be produced, even in the absence of lactose.
(C) RNA polymerase will attach at the P_{lac} locus, but transcription will be blocked.
(D) The operator locus will code for a different protein and thereby prevent transcription of the structural gene.

30. Which of the following describes the most likely consequence of a negative feedback pathway involving the *lac* operon?

(A) The breakdown products of lactose block cell division.
(B) Diffusion of lactose across the plasma membrane would stop in the presence of lactose.
(C) Expression of the *lac* operon diminishes as lactose is depleted.
(D) Binding of DNA by the repressor would increase in the presence of lactose.

31. Which of the following best explains the contribution of the *lac* operon to the metabolic efficiency of a bacterial cell?

(A) Expression of the *lacI* gene requires lactose.
(B) RNA polymerase is rapidly degraded by the product of the *lacP* locus.
(C) The repressor binds to DNA only when the cellular concentration of glucose is low.
(D) The *lacZ* gene is highly expressed only when lactose is available.

32. Bacterial cells that contain green fluorescent protein (GFP) will fluoresce under ultraviolet light. Which of the following is the most likely outcome of replacing the *lacZ* gene in the *E. coli lac* operon with the gene encoding GFP?

(A) Bacteria growing in the presence of lactose will fluoresce under ultraviolet light.
(B) Beta-galactosidase will be made only when bacteria are cultured under ultraviolet light.
(C) Ultraviolet light will cause a bond to form between glucose and galactose monomers.
(D) Ultraviolet light will cause a duplication of the *lac* operon.

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33. Evolutionary biologists have observed variation in the average age and size of mature individuals in a population of small freshwater guppies. Guppies found in pools with pike cichlids—a predator fish that preys primarily on larger guppies—reproduce at a young age and are small at maturity. Guppies found in pools with killifish—a different predator fish that preys primarily on smaller guppies—reproduce at an older age and are larger at maturity.

Which of the following predicts the most likely outcome of moving a population of guppies from a pool with pike cichlids to a pool with killifish?

(A) The introduced guppy population will remain phenotypically similar to the original population because the killifish will not recognize them as prey.

(B) Because the introduced population was in Hardy-Weinberg equilibrium, successive generations in the new population will continue to display the same allele frequencies as the original population.

(C) After many generations, the offspring of the introduced guppies will mature at an older age and larger size because of selective pressure from the new predator.

(D) Within two or three generations, the introduced guppies will become extinct because the killifish prefer the juveniles.

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ATP SYNTHASE

High [H^+]

ATP

ADP + P_i

Low [H^+]
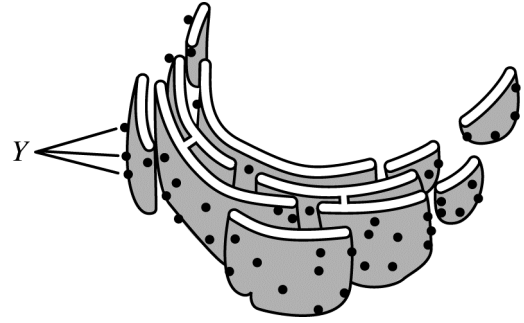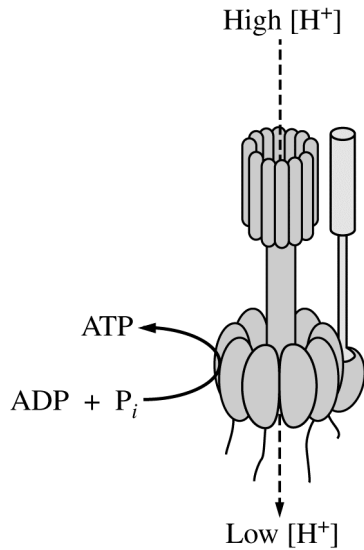
34. Which of the following questions will best direct an investigation of the mechanism of ATP synthase?

(A) What is the source of the inorganic phosphate that is used to generate ATP from ADP?
(B) Is the phosphorylation of ADP by ATP synthase dependent on the formation of a proton gradient?
(C) Can ATP synthase use the energy released by phosphorylation of ADP to pump protons against a concentration gradient?
(D) Can oxidative phosphorylation be uncoupled from the electron transport chain?

Y

35. The figure above represents a rough endoplasmic reticulum. Which of the following best describes the role of the structure labeled Y ?

(A) Structure Y contributes the raw materials required for the synthesis of proteins.
(B) Structure Y packages proteins for export from the cell.
(C) Structure Y is the location where proteins are synthesized.
(D) Structure Y contains enzymes that cut and activate proteins.

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Questions 36-40

The *TAS2R38* gene encodes a receptor protein that influences the ability to taste bitterness. The gene has two alleles: a dominant, wild-type allele that enables an individual (taster) to taste bitterness and a recessive, mutant allele that interferes with the ability of an individual (nontaster) to taste bitterness. Three single nucleotide mutations in the coding region of the *TAS2R38* gene are associated with the nontaster allele. The nucleotides present at the three positions are shown in the table below.

NUCLEOTIDE VARIATION IN THE *TAS2R38* GENE

	Position in the Nucleotide Sequence		
	145	785	886
Human nontaster	G	T	A
Human taster	C	C	G
Bonobo	C	C	G
Chimpanzee	C	C	G
Gorilla	C	C	G

A cladogram representing the evolutionary relatedness of selected primates is shown below.

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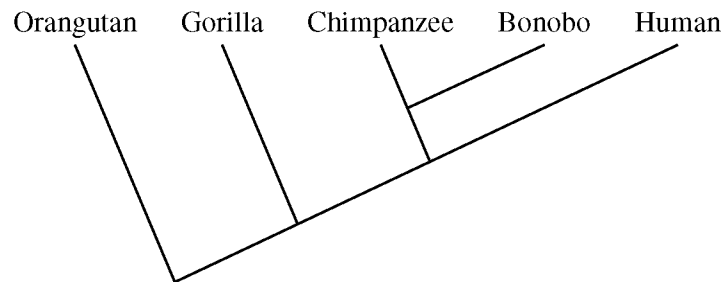
36. In a sample of 2,400 people, 1,482 were found to have the dominant (taster) phenotype. Assuming that the population is in Hardy-Weinberg equilibrium, approximately how many individuals in the sample are expected to be heterozygous for *TAS2R38* ?

(A)   741
(B)   918
(C) 1,133
(D) 1,482

37. Which of the following scientific questions will best help researchers determine when the nontaster allele arose in the evolutionary history of the selected primates?

(A) How does the nontaster allele contribute to individual fitness?
(B) Does the nontaster allele exist in any nonhuman primate populations?
(C) What caused the mutations in the *TAS2R38* gene?
(D) How do the mutations in the nontaster allele affect the structure of the resulting protein?

38. Which of the following conclusions is supported by the data?

(A) Humans and bonobos belong to the same genus because the nucleotide sequence of the *TAS2R38* gene is the same.
(B) Chimpanzees are equally related to humans and bonobos because all three groups possess variants of the *TAS2R38* gene.
(C) Humans are more closely related to bonobos than to chimpanzees because the branch of the tree with humans is closest to the branch of the tree with bonobos.
(D) Bonobos are more closely related to humans than to gorillas because bonobos and humans share a more recent common ancestor than bonobos and gorillas do.

39. The TAS2R38 receptor protein has been detected on the surface of cells from individuals who are homozygous for the nontaster allele of the *TAS2R38* gene. Which of the following is the most likely effect of the mutations associated with the nontaster allele on *TAS2R38* gene expression?

(A) The mutations change the primary structure of the encoded receptor protein.
(B) The mutations increase the stability of the *TAS2R38* mRNA.
(C) The mutations prevent transcription of the *TAS2R38* gene.
(D) The mutations prevent translation of the *TAS2R38* mRNA.

40. Toxic substances often have a bitter taste that causes animals who try to eat such substances to spit them out rather than swallow them. Additional data suggest that gorilla populations have a very low frequency of nontasters. Which of the following best describes the likely evolution of the *TAS2R38* locus in the gorilla population?

(A) Gorillas who could taste bitter toxins were more likely to survive and reproduce than nontasters.
(B) Gorillas who could taste bitter toxins became resistant to the toxins, so the taster gene was no longer under selective pressure.
(C) Gorillas acquired the taster allele by horizontal gene transfer from chimpanzees.
(D) Gorillas who could taste bitter toxins could utilize food resources that nontasters could not.

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Solution Surrounding Cell

High O_2 High Na^+ High Glucose   High Na^+ Low K^+

Low O_2 Low Na^+ Low Glucose   Low Na^+ High K^+

Cytoplasm
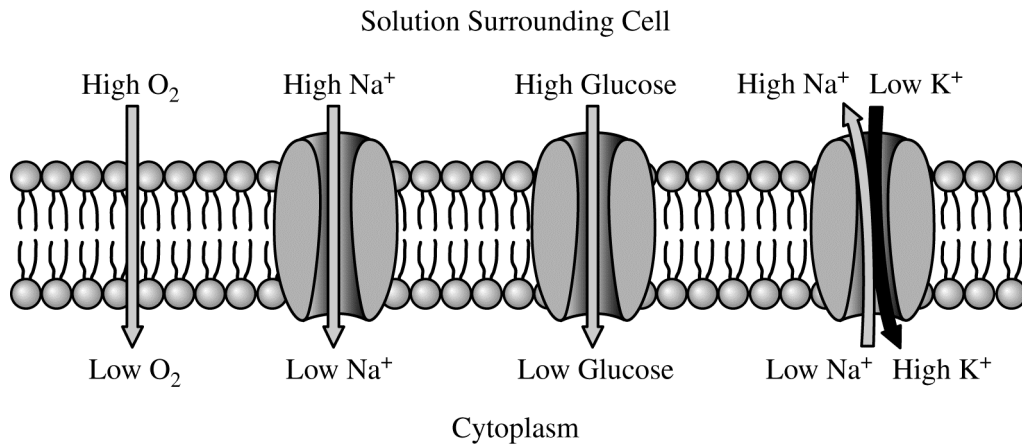
41. The manner in which several different ions and molecules move through a cell membrane is shown in the diagram above. For each ion or molecule, the relative concentration on each side of the membrane is indicated. Which of the following accurately describes one of the movements taking place?

(A) Glucose is transported into the cell by active transport.
(B) Na^+ is transported into the cell by active transport.
(C) The movement of glucose through the membrane requires ATP hydrolysis.
(D) Na^+ transport out of the cell requires ATP hydrolysis.

42. Which of the following best describes how myelination affects the transmission of nerve impulses?

(A) It speeds up the transmission of impulses by acting as an electrical insulator.
(B) It speeds up the transmission of impulses by integrating signal information more quickly.
(C) It slows down the transmission of impulses by forming gaps of unsheathed axons.
(D) It slows down the transmission of impulses by impeding the movement of ions across the neuronal membrane.

43. The fossils in a layer of rock are significantly different from those in the rock layer directly above it. One hypothesis to explain the difference is that a major extinction event occurred at the point in time represented by the transition between the two rock layers.

Which of the following is the best plan for collecting data to use in a test of the hypothesis?

(A) Examining the upper part of the lower rock layer for evidence of a catastrophic event, such as the presence of shocked quartz, iridium, or soot particles
(B) Digging farther into the hillside to look for a section of sedimentary rock that has a third layer below the two layers that were already identified
(C) Comparing the genomes of organisms from different evolutionary lineages to estimate the relative geologic age of the upper rock layer
(D) Searching fossil collections in several museums for examples of the types of features once shared among organisms that are now extinct

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Questions 44-48

In the American Southwest, annually emerging cicadas are dependent upon the cottonwood trees in the floodplain. Adult male cicadas perch in the cottonwood trees and chirp to attract females. Females lay their eggs in the branches of the cottonwoods, and, upon hatching, the cicada nymphs drop to the ground, burrow into the soil, feed on the tree roots, and later emerge as adults. Other organisms in the floodplain community prey on the cicadas, as shown in the food web.
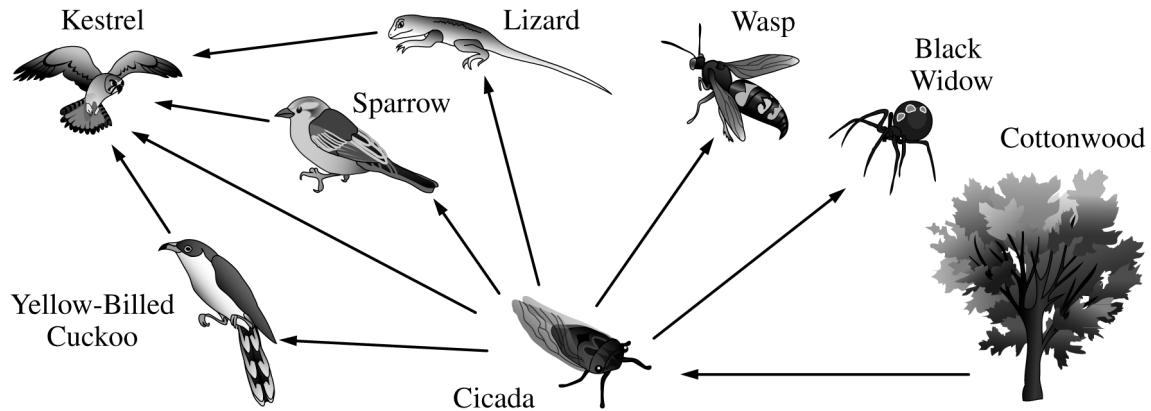

Figure 1. Food web in floodplain community

Human activity has caused a decrease in the amount of flooding and an increase in the incidence of wildfires in the floodplain. In an investigation into the recent changes in the floodplain ecosystem, researchers monitored the soil temperature, amount of cottonwood ground coverage (i.e., area of the ground that is shaded by leaves), and cicada emergence for a period from mid-June until late July. The results of the investigation are represented in Figure 2 and Figure 3.
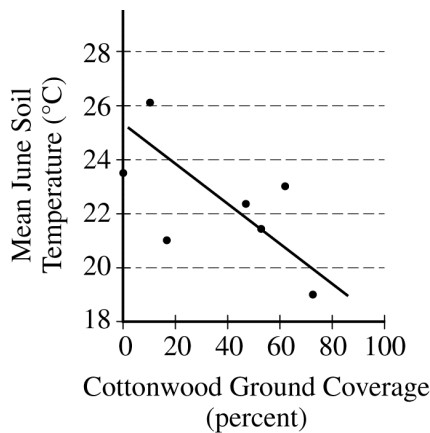
Figure 2. Effect of cottonwood ground coverage on soil temperature
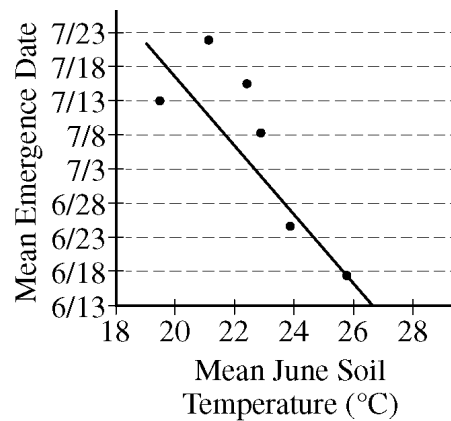
Figure 3. Relationship between soil temperature and cicada emergence date

To assess the impact of wildfires on soil temperature and cicada emergence, the researchers compared mean emergence dates for two natural sites where portions had been affected by wildfire. In addition, cicada emergence was monitored at an experimental site where the soil temperature was experimentally maintained. The data are shown in the table.

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MEAN CICADA EMERGENCE DATES AT SITES AFFECTED BY WILDFIRES OR WITH EXPERIMENTALLY CONTROLLED SOIL TEMPERATURE

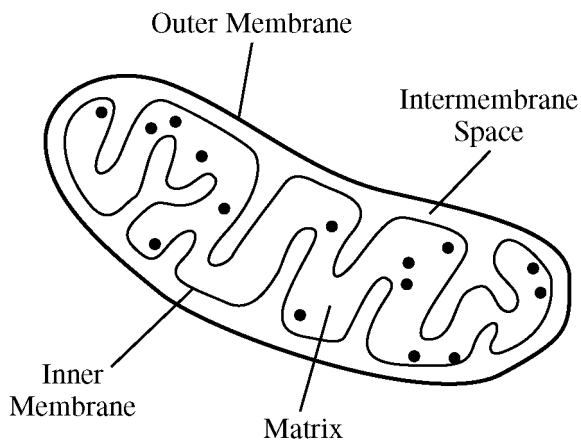|	Natural Site 1		Natural Site 2		Experimental Site	
	Unburned	Burned	Unburned	Burned	24°C	27°C
Mean Emergence Date	July 8	June 18	July 15	July 3	July 14	July 5

44. Which of the following statements best predicts the effect of increased cottonwood growth on the food web?

(A) Increased cottonwood growth will lead to an increase in the number of primary consumers, resulting in more competition between kestrels and sparrows for food.
(B) Increased cottonwood growth will decrease the habitat available for lizards, resulting in a decline in the number of kestrels.
(C) Increased cottonwood growth will provide more resources for cicadas, resulting in an increase in the kestrel population.
(D) Increased cottonwood growth will lead to a large accumulation of dead wood that serves as fuel for wildfires, resulting in the collapse of the food web.

45. Based upon the data, which of the following best describes the effect on the timing of cicada emergence if the cottonwood ground cover decreases from 50 percent to 25 percent?

(A) Cicadas will emerge approximately 10 days earlier.
(B) Cicadas will emerge approximately 2 days earlier.
(C) Cicadas will emerge approximately 10 days later.
(D) Cicadas will emerge approximately 2 days later.

46. Based on the data, which of the following describes the most likely relationship between wildfires, soil temperature, and the timing of cicada emergence in the same year?

(A) Wildfires caused a reduction in ground cover, which in turn caused increased soil temperatures leading to earlier emergence of cicadas.
(B) Wildfires caused an increase in ground cover, which in turn caused increased soil temperatures delaying the emergence of cicadas.
(C) Wildfires caused an increase in growth of new plants, which in turn caused a decrease in soil temperatures which led to earlier emergence of cicadas.
(D) Wildfires caused a decrease in ground cover, which in turn caused a decrease in soil temperatures leading to later emergence of cicadas.

47. Yellow-billed cuckoos typically hatch in mid-July. Emerging cicadas are a primary food source for nesting cuckoos. Which of the following best predicts the effect of wildfires on yellow-billed cuckoo populations?

(A) The yellow-billed cuckoo population will decline because the decreased ground cover will allow lizards to prey on cuckoo nests.
(B) The yellow-billed cuckoo population will decline because the cicadas will emerge before the hatching season begins.
(C) The yellow-billed cuckoo population will grow because the adults will more easily see and eat the cicada nymphs.
(D) The yellow-billed cuckoo population will remain unchanged because cuckoos do not nest in areas affected by wildfires.

Question 48 is on the next page.

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48. The data from the temperature-controlled
    experimental plots can best be used to support
    which of the following conclusions about cicada
    development?

    (A) Adult cicadas lay more eggs when the soil is
        warmer than when the soil is cooler.
    (B) Adult cicadas mate more frequently when the
        soil is warmer than when the soil is cooler.
    (C) Cicada nymphs grow larger in warmer soil
        than in cooler soil.
    (D) Cicada nymphs mature to adults faster in
        warmer soil than in cooler soil.

Representative Vertebrate	Primary Nitrogenous Waste Product		
	Ammonia	Urea	Uric Acid
Fish	X		
Tadpole	X		
Frog		X	
Reptile			X
Bird			X
Mammal		X	
Property of Nitrogenous Waste Product			
Solubility in Water	High	High	Low
Toxicity	High	Medium	Low

49. The table above shows the types and properties of nitrogen-
    containing wastes produced by several vertebrates. Which of
    the following is the best evolutionary explanation of the data?

    (A) The data support convergent evolution for nitrogen
        excretion in organisms occupying dramatically different
        environmental niches.
    (B) The nitrogenous waste excreted by each vertebrate is the
        result of evolutionary adaptations that have decreased
        vulnerability to predators.
    (C) Nitrogen homeostasis in terrestrial vertebrates reflects
        an adaptation for more frequent and higher-volume
        urination than that occurring in aquatic vertebrates.
    (D) Ammonia secretion requires a large volume of water and
        was therefore selected against in terrestrial vertebrates.

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Outer Membrane

Intermembrane Space

Inner Membrane

Matrix

50. The figure above shows an organelle typically found in eukaryotic cells. Which of the following best describes the function of the double membrane system of this organelle?

(A) The outer membrane allows the transport of all molecules into the intermembrane space, while the inner membrane serves as the regulatory boundary.
(B) The inner membrane has specialized proteins that create a hydrogen ion concentration gradient between the intermembrane space and the matrix.
(C) The outer membrane contains transport proteins that establish a sodium ion concentration gradient used for ATP production, while the inner membrane contains transport proteins that establish a hydrogen ion concentration gradient used for glucose production.
(D) The toxins and wastes entering a cell cross the outer membrane and are detoxified by digestive enzymes stored within the intermembrane space.

Step 1 Step 2 Step 3

DNA ⟶ Pre-mRNA ⟶ mRNA ⟶ Protein

51. Which of the following best describes an event during step 2 in the simplified model above?

(A) A new RNA molecule is synthesized using a DNA template.
(B) A new polypeptide is synthesized using an RNA template.
(C) Thymine nucleotides in an RNA molecule are replaced with uracil nucleotides.
(D) Noncoding sequences are removed from a newly synthesized RNA molecule.

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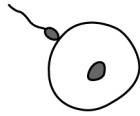
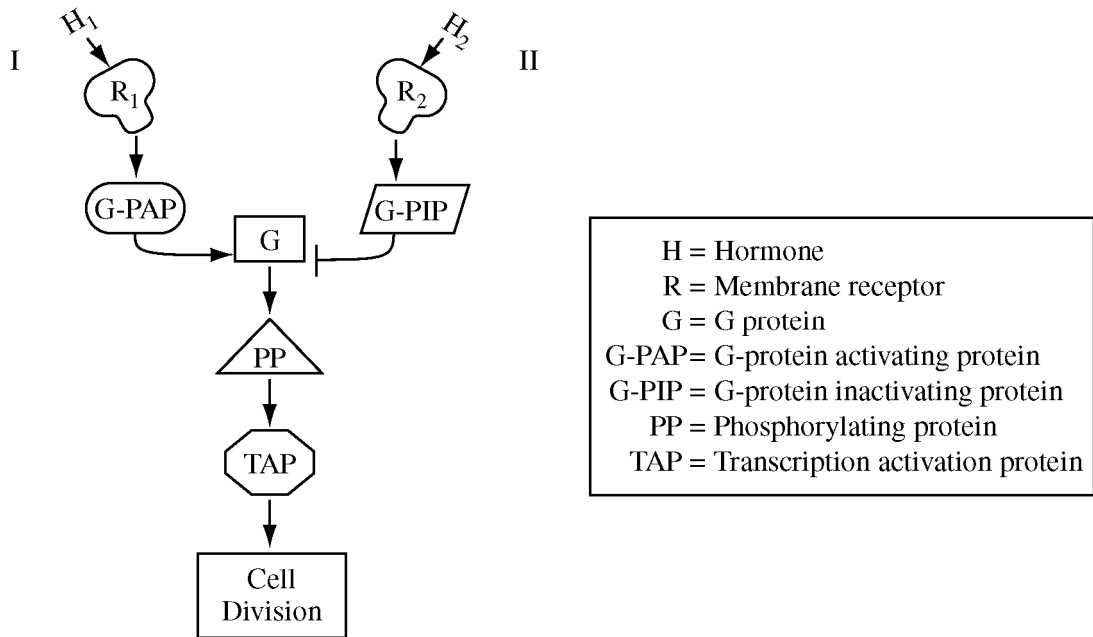Fertilization   Transduction
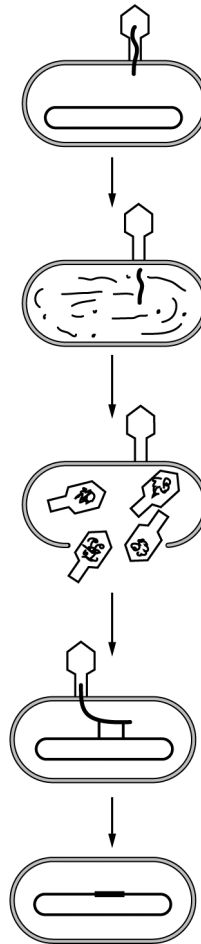
52. Which of the following correctly compares the two processes shown above?

   (A) Both processes increase genetic variation.
   (B) Both processes represent aspects of sexual reproduction.
   (C) Both processes require partitioning of genetic material and organelles.
   (D) The amount of genetic material per cell remains constant in both processes.

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H = Hormone
R = Membrane receptor
G = G protein
G-PAP= G-protein activating protein
G-PIP = G-protein inactivating protein
PP = Phosphorylating protein
TAP = Transcription activation protein

53. The diagram above represents a model of signal transduction pathways (I and II) in a cell that is targeted by two different hormones (H_1 and H_2). The components of the signal transduction pathways are identified in the figure legend. Each cellular molecule in both pathways can exist in an inactive or active form. When the components in pathway I are sequentially activated, the TAP molecules promote cell division. When the components in pathway II are sequentially activated, downstream signaling by the G protein is inhibited. Based on the model, which of the following mutations is most likely to result in a cell that will generate a cancerous tumor?

(A) A mutation in the gene encoding PP that results in a nonfunctional protein
(B) A mutation in the gene encoding G-PIP that results in a nonfunctional protein
(C) A mutation in the gene encoding R_1 so that it is inactive even in the presence of H_1
(D) A mutation in the gene encoding R_2 so that it is active even in the absence of H_2

GO ON TO THE NEXT PAGE.

Directions: The next five questions, numbered 121–125, require numeric answers.
Determine the correct answer for each question and enter it in the grid on page 3 of the answer sheet.
Use the following guidelines for entering your answers.

- Start your answer in any column, space permitting. Unused columns should be left blank.
- Write your answer in the boxes at the top of the grid and fill in the corresponding circles. Mark only one circle in any column. You will receive credit only if the circles are filled in completely.
- Provide your answer in the format specified by the question. The requested answer may be an integer, a decimal, or a fraction, and it may have a negative value.
- To enter a fraction, use one of the division slashes to separate the numerator from the denominator, as shown in the example below. Fractions only need to be reduced enough to fit in the grid.
- Do not enter a mixed number, as this will be scored as a fraction. For example, 2 1/2 (two and one-half) will be scored as 21/2 (twenty-one halves).

Integer answer: 5024
(either position is correct)

Decimal answer:
−4.13

Fraction answer: −2/10
(does not have
to be reduced)

GENETIC MAKEUP OF A MOUSE POPULATION

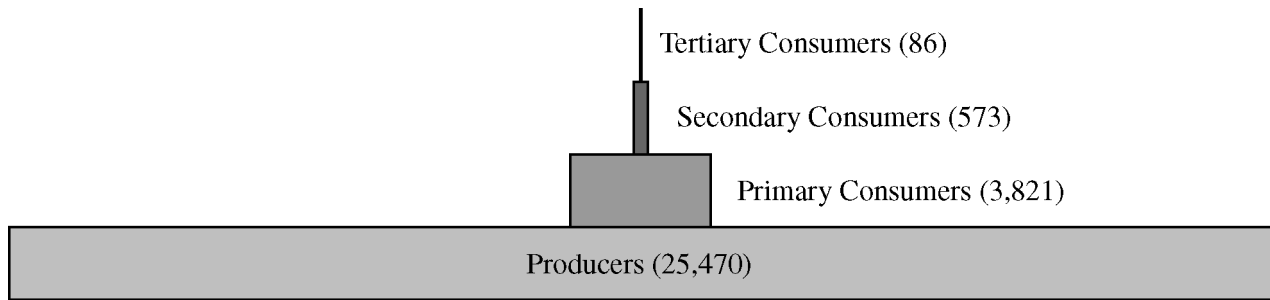| Genotype	Phenotype	Number of Individuals in Original Population	Number of Individuals in New Population
BB	Brown	841	841
Bb	Tan	1,218	1,218
bb	Gray	441	0
		2,500	2,059

121. The genetic makeup of a mouse population is provided in the table above. At the start of an experiment, researchers remove all the gray mice from the population, resulting in a population that is not in Hardy-Weinberg equilibrium. Calculate the frequency of the recessive allele in the remaining population of mice. Give your answer as a decimal to two places.

122. A cell has a surface area of 32 μm^2 and a volume of 8 μm^3. A different cell has a surface area of 36 μm^2 and a volume of 12 μm^3. What is the ratio of surface area to volume for the cell that is predicted to exchange materials with the surrounding environment at a faster rate by diffusion? Enter your answer as a fraction or a whole number.

123. A researcher proposes that the transmembrane portion of a certain protein consists of 24 amino acids. Based on the proposed model, calculate the number of nucleotides in the mRNA that encode only the amino acids in the transmembrane portion of the protein.

124. Male chickens carry two Z sex chromosomes, while female chickens carry one Z sex chromosome and one W sex chromosome. Located on the Z chromosome is a gene for barring. Barred feathers have black and white stripes. The barred trait is dominant to the unbarred trait.

Chickens have a fleshy growth on top of the head called a comb. An autosomal trait called rose comb is dominant to a trait called single comb.

An unbarred male heterozygous for the rose-comb trait is crossed with a barred female with a single comb. What proportion of the resulting progeny are expected to be barred males with single combs? Give your answer as a fraction or as a decimal to the nearest hundredth.

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Tertiary Consumers (86)

Secondary Consumers (573)

Primary Consumers (3,821)

Producers (25,470)

125. A student proposes a model of an energy pyramid for an isolated ecosystem, as shown above. The amount of energy available at each trophic level is given in kcal/m^2/year. According to the proposed model, what percent of the available energy is transferred from one trophic level to the next? Round your answer to the nearest whole percent, and disregard the percent sign when gridding your answer.

GO ON TO THE NEXT PAGE.

END OF SECTION I

**IF YOU FINISH BEFORE TIME IS CALLED,
YOU MAY CHECK YOUR WORK ON THIS SECTION.**

DO NOT GO ON TO SECTION II UNTIL YOU ARE TOLD TO DO SO.

_____

MAKE SURE YOU HAVE DONE THE FOLLOWING.

- **PLACED YOUR AP NUMBER LABEL ON YOUR ANSWER SHEET**

- **WRITTEN AND GRIDDED YOUR AP NUMBER CORRECTLY ON YOUR ANSWER SHEET**

- **TAKEN THE AP EXAM LABEL FROM THE FRONT OF THIS BOOKLET AND PLACED IT ON YOUR ANSWER SHEET**

Section II: Free-Response Questions

AP® Biology Exam

SECTION II: Free Response

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

At a Glance

Total Time
1 hour, 30 minutes
Number of Questions
8
Percent of Total Score
50%
Writing Instrument
Pen with black or dark blue ink
Electronic Device
Four-function calculator (with square root)

Reading Period

Time
10 minutes. Use this time to read the questions and plan your answers. You may begin writing your responses before the reading period is over.

Writing Period

Time
1 hour, 20 minutes
Suggested Time
Approximately 22 minutes per long question, and 6 minutes per short question.
Weight
Approximate weights Questions 1 and 2: 25% each
Questions 3 — 5: 10% each
Questions 6 — 8: 7% each

Instructions

The questions for Section II are printed in this booklet. You may use the unlined pages to organize your answers and for scratch work, but you must write your answers on the labeled pages provided for each question.

The proctor will announce the beginning and end of the reading period. You are advised to spend the 10-minute period reading all the questions, and to use the unlined pages to sketch graphs, make notes, and plan your answers. The focus of the reading period should be the organization of questions 1 and 2. You may begin writing your responses before the reading period is over.

Each answer should be written in paragraph form; an outline or bulleted list alone is not acceptable. Do not spend time restating the questions or providing more than the number of examples called for. For instance, if a question calls for two examples, you can earn credit only for the first two examples that you provide. Labeled diagrams may be used to supplement discussion, but unless specifically called for by the question, a diagram alone will not receive credit. Write clearly and legibly. Begin each answer on a new page. Do not skip lines. Cross out any errors you make; crossed-out work will not be scored.

Manage your time carefully. You may proceed freely from one question to the next. You may review your responses if you finish before the end of the exam is announced.

Form I
Form Code 4NBP4-S

20

AP® BIOLOGY EQUATIONS AND FORMULAS

Statistical Analysis and Probability

Mean

$$\overline{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Standard Deviation

$$s = \sqrt{\frac{\sum(x_i - \overline{x})^2}{n-1}}$$

Standard Error of the Mean

$$SE_{\overline{x}} = \frac{s}{\sqrt{n}}$$

Chi-Square

$$\chi^2 = \sum \frac{(o-e)^2}{e}$$

Chi-Square Table

p value	Degrees of Freedom							
	1	2	3	4	5	6	7	8
0.05	3.84	5.99	7.82	9.49	11.07	12.59	14.07	15.51
0.01	6.64	9.21	11.34	13.28	15.09	16.81	18.48	20.09

$\overline{x}$ = sample mean

n = size of the sample

s = sample standard deviation (i.e., the sample-based estimate of the standard deviation of the population)

o = observed results

e = expected results

Degrees of freedom are equal to the number of distinct possible outcomes minus one.

Laws of Probability

If A and B are mutually exclusive, then:

$$P(A \text{ or } B) = P(A) + P(B)$$

If A and B are independent, then:

$$P(A \text{ and } B) = P(A) \times P(B)$$

Hardy-Weinberg Equations

$p^2 + 2pq + q^2 = 1$

$p + q = 1$

p = frequency of the dominant allele in a population

q = frequency of the recessive allele in a population

Metric Prefixes

Factor	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Mode = value that occurs most frequently in a data set

Median = middle value that separates the greater and lesser halves of a data set

Mean = sum of all data points divided by number of data points

Range = value obtained by subtracting the smallest observation (sample minimum) from the greatest (sample maximum)

Rate and Growth

Rate

$$\frac{dY}{dt}$$

Population Growth

$$\frac{dN}{dt} = B - D$$

Exponential Growth

$$\frac{dN}{dt} = r_{max}N$$

Logistic Growth

$$\frac{dN}{dt} = r_{max}N\left(\frac{K-N}{K}\right)$$

Temperature Coefficient Q10

$$Q_{10} = \left(\frac{k_2}{k_1}\right)^{\frac{10}{T_2-T_1}}$$

Primary Productivity Calculation

$$\frac{\text{mg O}_2}{\text{L}} \times \frac{0.698\ \text{mL}}{\text{mg}} = \frac{\text{mL O}_2}{\text{L}}$$

$$\frac{\text{mL O}_2}{\text{L}} \times \frac{0.536\ \text{mg C fixed}}{\text{mL O}_2} = \frac{\text{mg C fixed}}{\text{L}}$$

(at standard temperature and pressure)

---

dY = amount of change

dt = change in time

B = birth rate

D = death rate

N = population size

K = carrying capacity

r_{max} = maximum per capita
        growth rate of population

T_2 = higher temperature

T_1 = lower temperature

k_2 = reaction rate at T_2

k_1 = reaction rate at T_1

Q_{10} = the factor by which the
      reaction rate increases when
      the temperature is raised by
      ten degrees

Water Potential (Ψ)

$$\Psi = \Psi_P + \Psi_S$$

Ψ_P = pressure potential

Ψ_S = solute potential

The water potential will be equal to the solute potential of a solution in an open container because the pressure potential of the solution in an open container is zero.

The Solute Potential of a Solution

$$\Psi_S = -iCRT$$

i = ionization constant (this is 1.0 for
    sucrose because sucrose does not
    ionize in water)

C = molar concentration

R = pressure constant
    (R = 0.0831 liter bars/mole K)

T = temperature in Kelvin (ºC + 273)

Surface Area and Volume

Volume of a Sphere

$$V = \frac{4}{3}\pi r^3$$

Volume of a Rectangular Solid

$$V = \ell wh$$

Volume of a Right Cylinder

$$V = \pi r^2 h$$

Surface Area of a Sphere

$$A = 4\pi r^2$$

Surface Area of a Cube

$$A = 6s^2$$

Surface Area of a Rectangular Solid

$$A = \Sigma \text{ surface area of each side}$$

---

r = radius

ℓ = length

h = height

w = width

s = length of one
    side of a cube

A = surface area

V = volume

Σ = sum of all

Dilution (used to create a dilute solution from a concentrated stock solution)

$$C_iV_i = C_fV_f$$

i = initial (starting) C = concentration of solute
f = final (desired) V = volume of solution

Gibbs Free Energy

$$\Delta G = \Delta H - T\Delta S$$

ΔG = change in Gibbs free energy

ΔS = change in entropy

ΔH = change in enthalpy

T = absolute temperature (in Kelvin)

$$pH = -\log_{10}[H^+]$$

BIOLOGY

Section II

8 Questions

Total Time—90 minutes

Reading Period—10 minutes

Writing Period—80 minutes

Directions: Questions 1 and 2 are long free-response questions that require about 22 minutes each to answer and are worth 10 points each. Questions 3–8 are short free-response questions that require about 6 minutes each to answer. Questions 3–5 are worth 4 points each and questions 6–8 are worth 3 points each.

Read each question carefully and completely. You are advised to spend the 10-minute reading period planning your answers. You may begin writing your responses before the reading period is over. Write your response in the space provided for each question. Only material written in the space provided will be scored. Answers must be written out in paragraph form. Outlines, bulleted lists, or diagrams alone are not acceptable.

Question 1 is on the following page.

ATP
O_2 CO_2

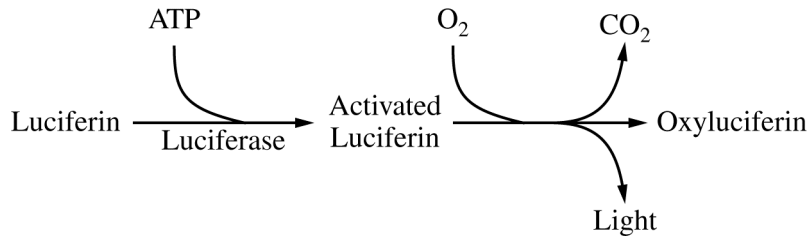Luciferin → Activated → Oxyluciferin
Luciferase Luciferin

Light

Figure 1. Production of light in the lantern organ of fireflies

Flash Duration

Interflash Interval

├──Flash Pattern Interval──┤

Figure 2. Flash pattern characteristics in fireflies

Male Flash Pattern

P. brimleyi

P. pyralis

P. dimissus

P. punctulatus

P. knulli

P. consanguineous

0 1 2 3 4 5 6 7 8 9 10
Time (s)

Figure 3. Flash pattern characteristics of selected firefly species

P. brimleyi
P. pyralis
P. dimissus
P. punctulatus
P. knulli
P. consanguineous

Figure 4. Evolutionary relatedness among
selected firefly species

GO ON TO THE NEXT PAGE.

1. Fireflies are a group of insects that possess a lantern organ composed of numerous light-producing cells (photocytes) in their abdomens. The light is produced by a chemical reaction involving the light-emitting organic compound luciferin. In each photocyte, luciferin is activated in an ATP-dependent reaction that is catalyzed by the enzyme luciferase. In the presence of oxygen, the activated luciferin emits light as it is converted to oxyluciferin (Figure 1).
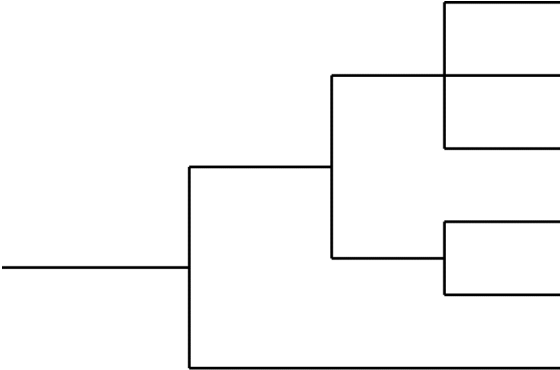
   The flashes of light are controlled by neurons that innervate the lantern organ. Activated neurons stimulate the release of nitric oxide (NO), an inhibitor of the electron transport chain. The pattern of light flashes (Figure 2) emitted by males is a signal to attract females as a component of mating behavior. Different species of firefly display different patterns of flashes (Figure 3). The evolutionary relatedness of these species, as determined using multiple morphological characteristics, is shown in Figure 4.

   (a) **Identify** the main source of the ATP used for activating luciferin, as shown in Figure 1, and **describe** the effect of the release of NO on oxygen levels in the photocyte during flashing.

   (b) **Describe** TWO differences in the flash patterns of *P. pyralis* and *P. knulli*. **Justify** the use of differences in flash signal patterns as evidence to support the claim that *P. pyralis* and *P. knulli* are different species.

   (c) Use the template provided to **construct** a cladogram based on the data in Figure 3. **Circle** the position on the cladogram that represents the outgroup.

   (d) **Evaluate** the data used to construct the cladogram in Figure 4 and the cladogram you constructed in part (c) and **identify** which cladogram is most likely to represent a more accurate phylogeny of the organisms. **Propose** ONE type of additional data that that could be used to refine the phylogeny of these species.

THIS PAGE MAY BE USED FOR TAKING NOTES AND PLANNING YOUR ANSWERS.

NOTES WRITTEN ON THIS PAGE WILL NOT BE SCORED.

WRITE ALL YOUR RESPONSES ON THE LINED PAGES.

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

EFFECT OF ENVIRONMENTAL FACTORS ON DNA

Treatment	Mean Percent of DNA with Double-Strand Breaks	$2SE_{\bar{X}}$
Untreated control	9.8	2.4
BaP only	9.7	3.2
UVA only	10.1	3.4
UVA and BaP	35.1	5.0

2. Environmental mutagens can affect DNA in cells. Benzo[a]pyrene (BaP) is a mutagen that is commonly found in urban air pollution. Researchers claim that the effect of UVA radiation (UVA), another known mutagen, is amplified by the presence of BaP. To test their claim, the researchers exposed cultured eukaryotic cells to either BaP, UVA radiation, or both mutagens. The researchers then determined the percent of chromosomal DNA that contained damage in the form of double-strand breaks. The results are shown in the table.

(a) On the template below **construct** a graph using the data in the table to represent the effect of UVA and BaP on DNA.

(b) Using the results from all treatments, **describe** the effect of BaP alone and UVA alone compared with the effect of the combined treatment of BaP and UVA on DNA.

(c) **Predict** the most likely effect on cell division for a cell containing DNA with double-strand breaks. **Justify** your prediction.

(d) Point mutations alter the DNA sequence at a single nucleotide. **Describe** how point mutations affect the genetic makeup of the population AND impact the evolution of the population.

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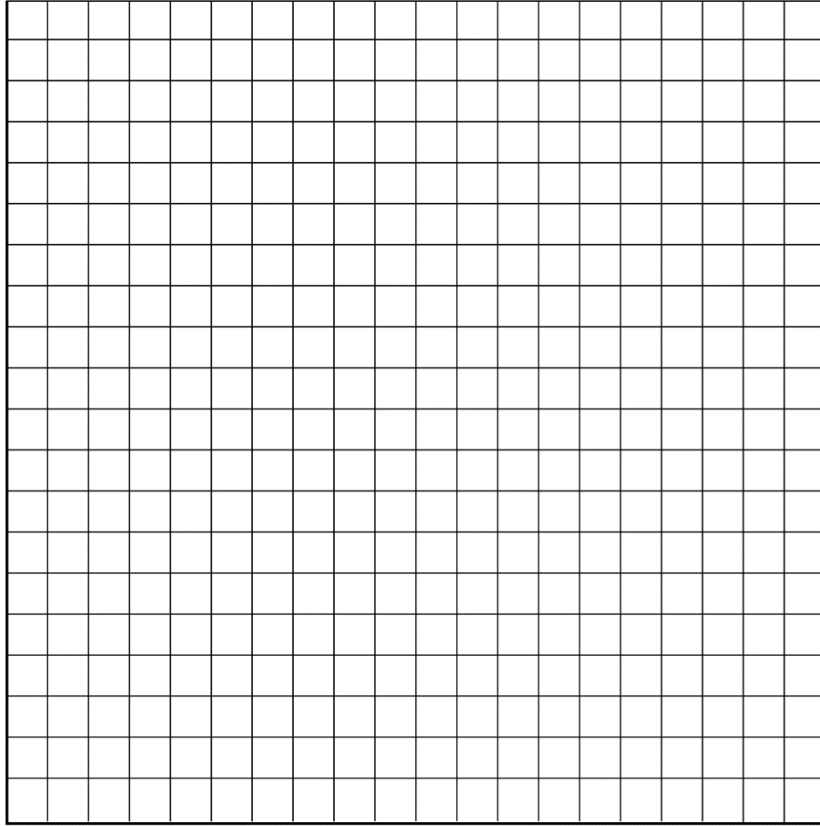
WRITE ALL YOUR RESPONSES ON THE LINED PAGES.

THIS PAGE MAY BE USED FOR TAKING NOTES AND PLANNING YOUR ANSWERS.

NOTES WRITTEN ON THIS PAGE WILL NOT BE SCORED.

WRITE ALL YOUR RESPONSES ON THE LINED PAGES.

ADDITIONAL PAGE FOR ANSWERING QUESTION 2

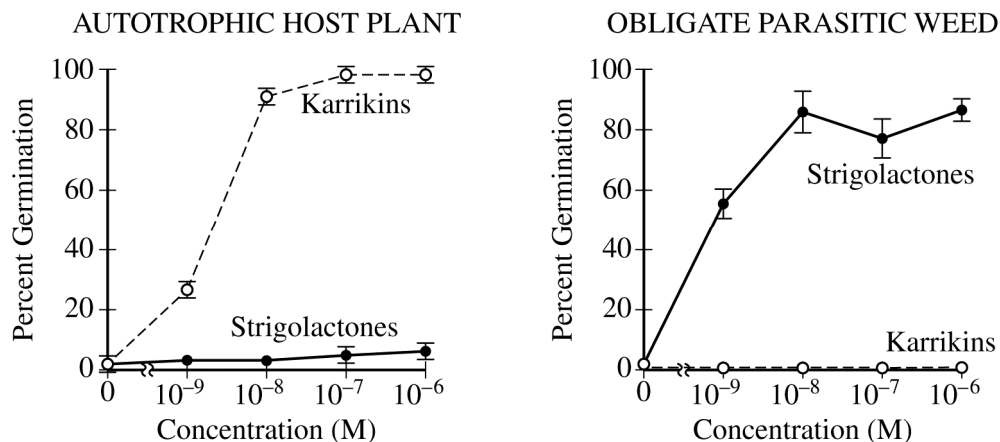ADDITIONAL PAGE FOR ANSWERING QUESTION 2

Figure 1. Effect of karrikins and strigolactones on seed germination in an autotrophic host plant and its obligate parasitic weed

3. Strigolactones and karrikins are structurally similar compounds that can affect seed germination in certain species of plants. However, plants with different life strategies (autotrophic plants or obligate parasitic weeds) germinate in response to the presence of different compounds in the soil. After germination, many species of autotrophic plant release strigolactones from their roots into the soil, which promotes uptake of nutrients.

The graphs above represent the results of a laboratory experiment to test the effect of different concentrations of strigolactones or karrikins on the seed germination of an autotrophic host plant and of an obligate parasitic weed.

(a) Based on an analysis of the data, **describe** the effect of karrikins on seed germination in the autotrophic host plants <u>and</u> the obligate parasitic weed plants.

(b) A researcher proposes that the obligate parasitic weed requires exposure to a signal from the host plant before it can germinate. Using the data as evidence, **provide support** for the researcher's claim and **give ONE reason** the response would be an advantage for the weed plants.

PAGE FOR ANSWERING QUESTION 3

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ADDITIONAL PAGE FOR ANSWERING QUESTION 3

$$H \text{---} C \equiv N$$
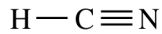
Figure 1. Chemical structure of cyanide

4. The secondary compound cyanide (Figure 1) is a toxic, bitter-tasting chemical that is found in apple seeds. Cyanide in seeds is only released and tasted if the seed is crushed. When animals eat apples, they typically eat the sweet fleshy part of the fruit and spit out the seeds or swallow them whole.

   (a) Based on the chemical structure of cyanide, **identify** ONE type of biological macromolecule that could serve as a chemical precursor for the production of cyanide in a plant. **Justify** your choice.

   (b) It has been proposed that apple trees are in a mutualistic relationship with the animals who eat the apples. **Describe** ONE benefit to each organism in the mutualistic relationship.

PAGE FOR ANSWERING QUESTION 4

5. *Caenorhabditis elegans* is a species of soil-dwelling nematode (roundworm) that feeds on soil bacteria, including *Bacillus thuringiensis*. *B. thuringiensis* is a virulent bacterial pathogen that produces BT toxin, a protein that can kill different invertebrate species, including *C. elegans*.

In a laboratory experiment, *C. elegans* and *B. thuringiensis* were cultured individually (control) or together (experimental) for 150 days. Under optimal conditions, the generation time of *C. elegans* is approximately 3.5 days and the generation time of *B. thuringiensis* is approximately 25 minutes. At the end of the experiment, the change in virulence of *B. thuringiensis* and the change in resistance of *C. elegans* to BT toxin were determined.

(a) **Calculate** the maximum number of generations that is possible in individual cultures of *C. elegans* AND the maximum number of generations that is possible in individual cultures of *B. thuringiensis* in 150 days.

(b) The researchers found that after 150 days, the magnitude of the change in both *B. thuringiensis* virulence and *C. elegans* resistance was less when they were cultured individually (control) than when they were cultured together (experimental). **Provide ONE reason** for the difference in results between the two treatments.

(c) The researchers also found that after 150 days, the relative change in virulence of *B. thuringiensis* was greater than the relative change in the resistance in *C. elegans* when the organisms were cultured together. **Provide ONE reason** that the relative change in *B. thuringiensis* virulence was greater than the relative change in *C. elegans* resistance.

PAGE FOR ANSWERING QUESTION 5

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ADDITIONAL PAGE FOR ANSWERING QUESTION 5

Time 1. Sperm and Egg Fuse   Time 2. Cortical Granules Fuse with Plasma Membrane   Time 3. Fertilization Envelope Forms
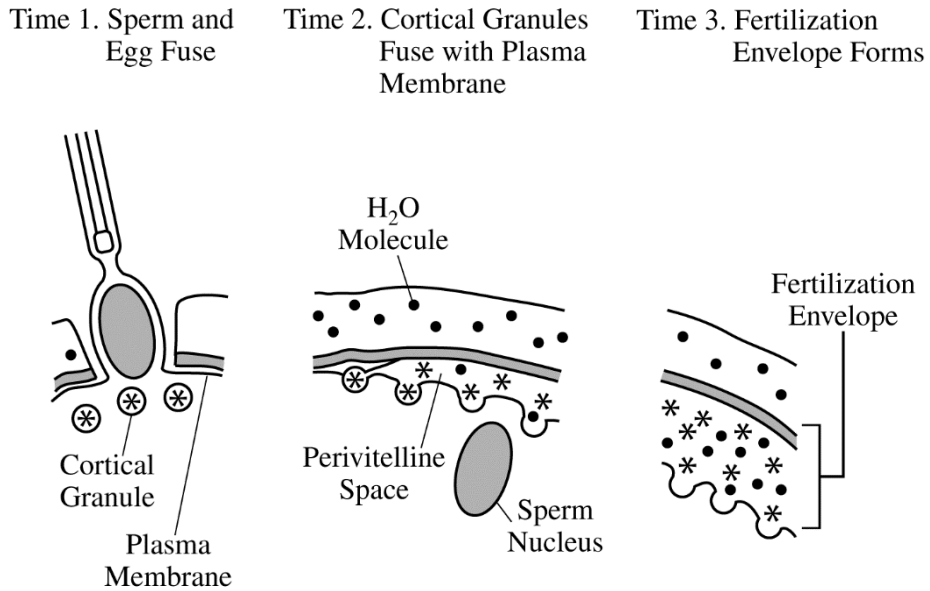
Figure 1. Time course of events during fertilization of a sea urchin egg

6. Figure 1 shows the events during and immediately following fertilization of a sea urchin egg. Sexual reproduction relies on the successful fusion of only one sperm with one egg (time 1) during fertilization. In sea urchins, a diploid organism, several events prevent additional sperm from fertilizing the egg. One of the first events following fertilization is the fusion of secretory vesicles called cortical granules with the egg plasma membrane (time 2). The cortical granules release their contents, a mixture of polysaccharides and proteins, into the perivitelline space. Subsequent to this, water moves into the perivitelline space, causing it to expand and physically separate the fertilization envelope from the egg plasma membrane (time 3). The fertilization envelope prevents fusion of more than one sperm with the egg.

(a) **Provide ONE reason** that preventing fusion of multiple sperm with one egg in sea urchins has provided a survival advantage over evolutionary time.

(b) **Describe** how the release of the contents of the cortical granules into the perivitelline space results in the movement of water <u>and</u> causes the subsequent expansion of the perivitelline space.

PAGE FOR ANSWERING QUESTION 6

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ADDITIONAL PAGE FOR ANSWERING QUESTION 6

7. Cyanobacteria are a large group of prokaryotic organisms. Cyanobacteria are found in marine microbial mats that include many species of eukaryotic and prokaryotic organisms that can participate in mutualistic symbiotic relationships. One recently discovered species of cyanobacteria, UCYN-A, lacks the genes that encode ribulose bisphosphate carboxylase/oxygenase (RuBisCo), components of photosystem II, and the Krebs cycle. UCYN-A contains genes enabling nitrogen fixation, which allows the enzymatic conversion of atmospheric nitrogen to biologically available nitrogen compounds such as nitrate. Within the microbial community there is relatively little available nitrogen. The majority of organisms in the microbial mat cannot fix nitrogen.

(a) **Identify** the metabolic process whereby UCYN-A is most likely to produce ATP.

(b) In low-nitrogen conditions, UCYN-A participates in a mutualistic symbiotic relationship with other organisms in the microbial mat. **Predict** the most likely type of symbiotic relationship between UCYN-A and the other organisms in the microbial mat if nitrogen becomes readily available from another source. **Provide reasoning** to support your prediction.

PAGE FOR ANSWERING QUESTION 7

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ADDITIONAL PAGE FOR ANSWERING QUESTION 7
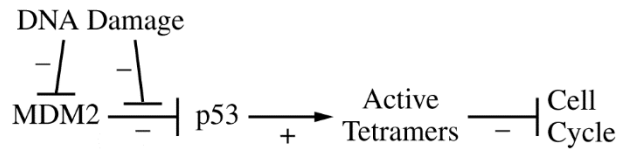
DNA Damage

Figure 1. MDM2 and p53 signaling in response to DNA
damage controls cell cycle progression.

8. The p53 and MDM2 proteins are involved in the DNA damage response pathway (Figure 1). In the absence of DNA damage, MDM2 mediates the degradation of p53. In the presence of DNA damage, p53 is not broken down and forms active tetramers that stimulate the expression of genes that block cell cycle progression.

Red blood cells are produced by the division and differentiation of multipotent stem cells. Researchers have observed that mice with a partial loss-of-function mutation in the *MDM2* gene have a lower concentration of red blood cells in the blood than do mice that express the wild-type *MDM2* allele.

(a) Using the model of the p53/MDM2 pathway, **connect** the reduction of MDM2 function in mutant mice to the observed concentration of red blood cells.

(b) **Predict** how a loss-of-function mutation in the *p53* gene is most likely to affect the cell cycle in response to DNA damage. **Justify** your predictions.

PAGE FOR ANSWERING QUESTION 8

ADDITIONAL PAGE FOR ANSWERING QUESTION 8

STOP

END OF EXAM

**IF YOU FINISH BEFORE TIME IS CALLED,
YOU MAY CHECK YOUR WORK ON THIS SECTION.**

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**THE FOLLOWING INSTRUCTIONS APPLY TO THE COVERS OF THE
SECTION II BOOKLET.**

- **MAKE SURE YOU HAVE COMPLETED THE IDENTIFICATION
  INFORMATION AS REQUESTED ON THE FRONT <u>AND</u> BACK
  COVERS OF THE SECTION II BOOKLET.**

- **CHECK TO SEE THAT YOUR AP NUMBER LABEL APPEARS
  IN THE BOX ON THE FRONT COVER.**

- **MAKE SURE YOU HAVE USED THE SAME SET OF AP
  NUMBER LABELS ON <u>ALL</u> AP EXAMS YOU HAVE TAKEN
  THIS YEAR.**

Multiple-Choice and Grid-In Answer Key

The following contains the answers to
the multiple-choice and grid-in questions in this exam.

Answer Key for AP Biology
Practice Exam, Section I

Question 1: A	Question 19: B	Question 37: B
Question 2: D	Question 20: B	Question 38: D
Question 3: C	Question 21: D	Question 39: A
Question 4: D	Question 22: A	Question 40: A
Question 5: B	Question 23: C	Question 41: D
Question 6: A	Question 24: A	Question 42: A
Question 7: D	Question 25: B	Question 43: A
Question 8: C	Question 26: C	Question 44: C
Question 9: A	Question 27: C	Question 45: A
Question 10: D	Question 28: B	Question 46: A
Question 11: B	Question 29: B	Question 47: B
Question 12: D	Question 30: C	Question 48: D
Question 13: C	Question 31: D	Question 49: D
Question 14: B	Question 32: A	Question 50: B
Question 15: D	Question 33: C	Question 51: D
Question 16: C	Question 34: B	Question 52: A
Question 17: C	Question 35: C	Question 53: B
Question 18: A	Question 36: C	

Question 121: 0.29 through 0.30, 29/100 through 30/100

Question 122: 4/1, 4

Question 123: 72

Question 124: 1/4, 0.25

Question 125: 14 through 15

Free-Response Scoring Guidelines

The following contains the scoring guidelines
for the free-response questions in this exam.
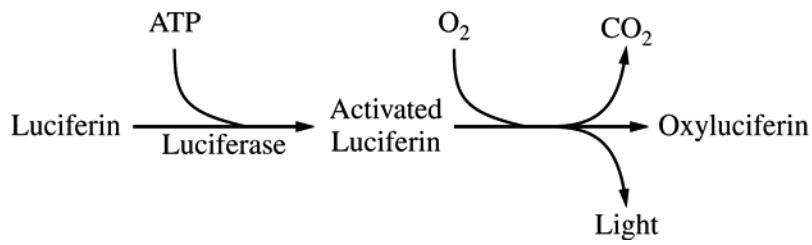
Question 1

Figure 1. Production of light in the lantern organ of fireflies

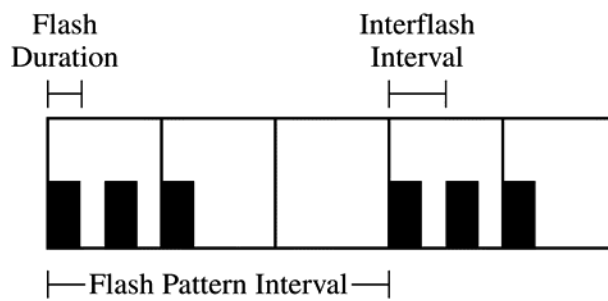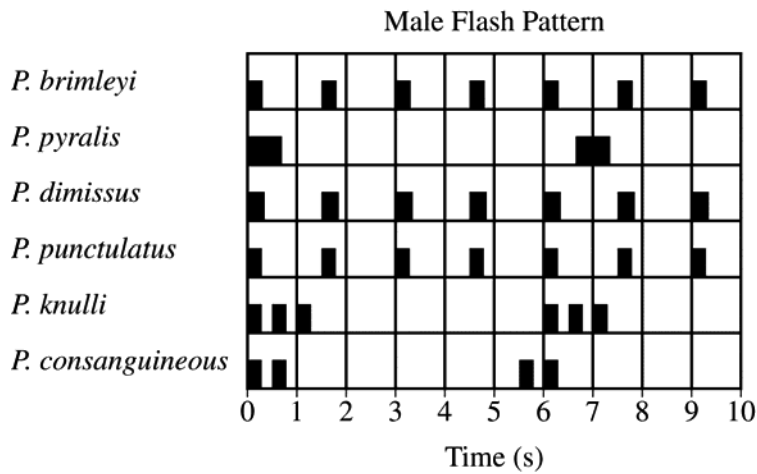

Figure 2. Flash pattern characteristics in fireflies

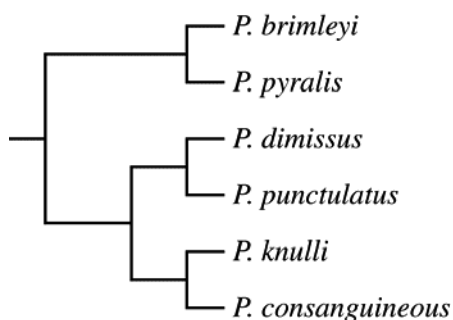Figure 3. Flash pattern characteristics of selected firefly species

Figure 4. Evolutionary relatedness among selected firefly species

Fireflies are a group of insects that possess a lantern organ composed of numerous light-producing cells (photocytes) in their abdomens. The light is produced by a chemical reaction involving the light-emitting organic compound luciferin. In each photocyte, luciferin is activated in an ATP-dependent reaction that is catalyzed by the enzyme luciferase. In the presence of oxygen, the activated luciferin emits light as it is converted to oxyluciferin (Figure 1).

The flashes of light are controlled by neurons that innervate the lantern organ. Activated neurons stimulate the release of nitric oxide (NO), an inhibitor of the electron transport chain. The pattern of light flashes (Figure 2) emitted by males is a signal to attract females as a component of mating behavior. Different species of firefly display different patterns of flashes (Figure 3). The evolutionary relatedness of these species, as determined using multiple morphological characteristics, is shown in Figure 4.

(a) **Identify** the main source of the ATP used for activating luciferin, as shown in Figure 1, and **describe** the effect of the release of NO on oxygen levels in the photocyte during flashing. (**2 points**)

Identification (1 point)
- Mitochondria
- Cellular respiration
- Oxidative phosphorylation/electron transport chain

Description (1 point)
- Oxygen levels increase

(b) **Describe** TWO differences in the flash patterns of *P. pyralis* and *P. knulli*. **Justify** the use of differences in flash signal patterns as evidence to support the claim that *P. pyralis* and *P. knulli* are different species. (**3 points**)

Description (2 points maximum; 1 point per row)

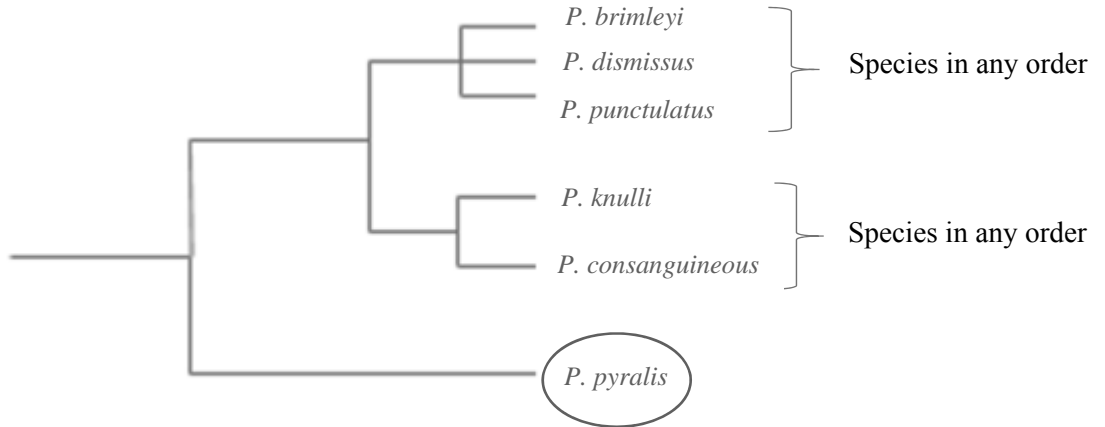| Signal characteristic	*P. pyralis*		*P. knulli*
Flash duration	Longer		Shorter
Interflash interval	Not present		Present
Flash pattern interval	Longer	OR	Shorter
Rate of flashes per unit of time	Lower		Higher
Flashes per flash pattern interval	Fewer		More
	One	AND	Three

Question 1 (continued)

Justification (1 point)
- Different flash patterns serve as a reproductive barrier

(c) Use the template provided to **construct** a cladogram based on the data in Figure 3. **Circle** the position on the cladogram that represents the outgroup. (**2 points**)

Construct Cladogram (1 point)

P. brimleyi
P. dismissus   Species in any order
P. punctulatus

P. knulli   Species in any order
P. consanguineous

P. pyralis

Identify outgroup (1 point)
- Circle bottom-most position in the cladogram

(d) **Evaluate** the data used to construct the cladogram in Figure 4 and the cladogram you constructed in part (c) and **identify** which cladogram is most likely to represent a more accurate phylogeny of the organisms. **Propose** ONE type of additional data that that could be used to refine the phylogeny of these species. (**3 points**)

Evaluation (1 point)
- Multiple characteristics provide more evidence than does a single characteristic

Identification (1 point)
- Figure 4

Proposed type of data (1 point)
- Evidence from DNA/protein

Question 2

EFFECT OF ENVIRONMENTAL FACTORS ON DNA

Treatment	Mean Percent of DNA with Double-Strand Breaks	$2SE_{\bar{X}}$
Untreated control	9.8	2.4
BaP only	9.7	3.2
UVA only	10.1	3.4
UVA and BaP	35.1	5.0

Environmental mutagens can affect DNA in cells. Benzo[a]pyrene (BaP) is a mutagen that is commonly found in urban air pollution. Researchers claim that the effect of UVA radiation (UVA), another known mutagen, is amplified by the presence of BaP. To test their claim, the researchers exposed cultured eukaryotic cells to either BaP, UVA radiation, or both mutagens. The researchers then determined the percent of chromosomal DNA that contained damage in the form of double-strand breaks. The results are shown in the table.

(a) On the template below **construct** a graph using the data in the table to represent the effect of UVA and BaP on DNA. (**3 points**)

Contruct graph (3 points)
- Appropriate labels, units and scaling
- Correctly plotted means on a bar graph/modified bar graph
- Correctly plotted error bars

(b) Using the results from all treatments, **describe** the effect of BaP alone and UVA alone compared with the effect of the combined treatment of BaP and UVA on DNA. **(3 points)**

Description (3 points)

Treatment	Effect (1 point per box)
UVA alone	Did not cause damage
BaP alone	Did not cause damage
BaP plus UVA	• Caused damage • Caused more damage than did BaP alone or UVA alone

(c) **Predict** the most likely effect on cell division for a cell containing DNA with double-strand breaks. **Justify** your prediction. **(2 points; points may only be earned from one row)**

Prediction (1 point)	Justification (1 point per box)
Cell division will not occur	• DNA replication cannot be completed • The cell cannot pass through a cell cycle checkpoint with DNA damage • Cell enters apoptosis pathway
Cell division will be delayed	The cell requires time to repair DNA

Question 2 (continued)

(d) Point mutations alter the DNA sequence at a single nucleotide. **Describe** how point mutations affect the genetic makeup of the population AND impact the evolution of the population. **(2 points)**

	Description (1 point each; 2 points maximum)
Genetic makeup	• Increase genetic diversity • Introduce new alleles • Introduce new protein/amino acid
Evolution	• Mutant/new phenotypes are subject to natural selection • Mutation is subject to evolutionary forces

AP® BIOLOGY
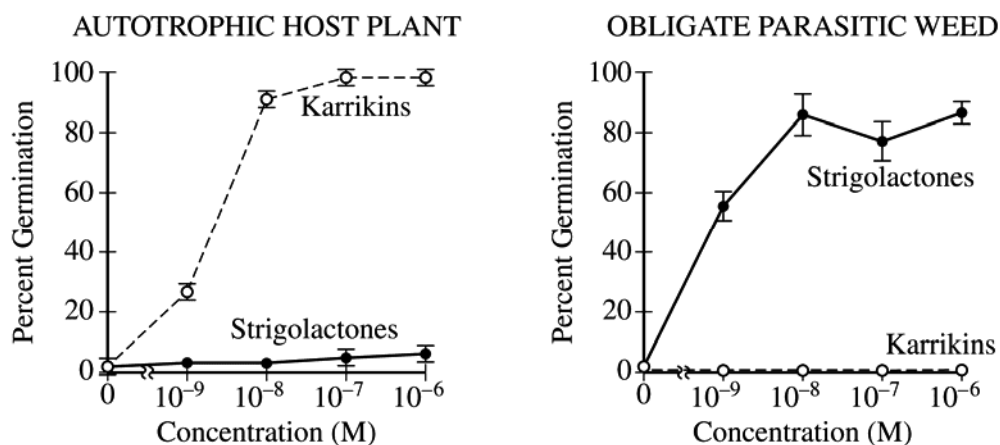# 2017 SCORING GUIDELINES

Question 3

Figure 1. Effect of karrikins and strigolactones on seed germination in an autotrophic host plant and its obligate parasitic weed

Strigolactones and karrikins are structurally similar compounds that can affect seed germination in certain species of plants. However, plants with different life strategies (autotrophic plants or obligate parasitic weeds) germinate in response to the presence of different compounds in the soil. After germination, many species of autotrophic plant release strigolactones from their roots into the soil, which promotes uptake of nutrients.

The graphs above represent the results of a laboratory experiment to test the effect of different concentrations of strigolactones or karrikins on the seed germination of an autotrophic host plant and of an obligate parasitic weed.

(a) Based on an analysis of the data, **describe** the effect of karrikins on seed germination in the autotrophic host plants <u>and</u> the obligate parasitic weed plants. (**2 points**)

Type of plant	Description (2 points; 1 point per box)
Autotrophic host plant	Promoted germination
Obligate parasitic weed	- Did not promote germination - Inhibited germination - Did not affect germination

(b) A researcher proposes that the obligate parasitic weed requires exposure to a signal from the host plant before it can germinate. Using the data as evidence, **provide support** for the researcher's claim and **give ONE reason** the response would be an advantage for the weed plants. (**2 points**)

Support (1 point)
- Strigolactones promote germination (of the obligate parasitic weed)

Reasoning (1 point)
- Seeds only germinate when host plant/food source is present
- Seeds do not germinate when host plant/food source is not present
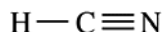
Question 4

$$H - C \equiv N$$

Figure 1. Chemical structure of cyanide

The secondary compound cyanide (Figure 1) is a toxic, bitter-tasting chemical that is found in apple seeds. Cyanide in seeds is only released and tasted if the seed is crushed. When animals eat apples, they typically eat the sweet fleshy part of the fruit and spit out the seeds or swallow them whole.

(a) Based on the chemical structure of cyanide, **identify** ONE type of biological macromolecule that could serve as a chemical precursor for the production of cyanide in a plant. **Justify** your choice. (**2 points**)

Identification (1 point)
- Amino acids OR proteins/polypeptides
- Nucleotides OR nucleic acids

Justification (1 point)
- Macromolecule contains nitrogen

(b) It has been proposed that apple trees are in a mutualistic relationship with the animals who eat the apples. **Describe** ONE benefit to each organism in the mutualistic relationship. (**2 points**)

Organism	Description of benefit (2 points; 1 point per row)
Plant	- Seed dispersal - Animal feces provides nutrients for the plant
Animal	Nutrient/energy acquisition

Question 5

Caenorhabditis elegans is a species of soil-dwelling nematode (roundworm) that feeds on soil bacteria, including *Bacillus thuringiensis*. *B. thuringiensis* is a virulent bacterial pathogen that produces BT toxin, a protein that can kill different invertebrate species, including *C. elegans*.

In a laboratory experiment, *C. elegans* and *B. thuringiensis* were cultured individually (control) or together (experimental) for 150 days. Under optimal conditions, the generation time of *C. elegans* is approximately 3.5 days and the generation time of *B. thuringiensis* is approximately 25 minutes. At the end of the experiment, the change in virulence of *B. thuringiensis* and the change in resistance of *C. elegans* to BT toxin were determined.

(a) **Calculate** the maximum number of generations that is possible in individual cultures of *C. elegans* AND the maximum number of generations that is possible in individual cultures of *B. thuringiensis* in 150 days. (**2 points**)

Calculations (2 points; 1 point per calculation)
- *C. elegans*: 150/3.5 = 42 or 43
- *B. thuringiensis*: 150*24*60/25 = 8,640

(b) The researchers found that after 150 days, the magnitude of the change in both *B. thuringiensis* virulence and *C. elegans* resistance was less when they were cultured individually (control) than when they were cultured together (experimental). **Provide ONE reason** for the difference in results between the two treatments. (**1 point**)

Reasoning (1 point)
- Selection for the traits is present/stronger when both organisms are cultured together

(c) The researchers also found that after 150 days, the relative change in virulence of *B. thuringiensis* was greater than the relative change in the resistance in *C. elegans* when the organisms were cultured together. **Provide ONE reason** that the relative change in *B. thuringiensis* virulence was greater than the relative change in *C. elegans* resistance. (**1 point**)

Reasoning (1 point)
- More generations for *B. thuringiensis*/shorter generation time for *B. thuringiensis*
- Generally larger population size of *B. thuringiensis*
- More opportunity for mutation in *B. thuringiensis*
- *B. thuringiensis* are haploid and *C. elegans* are diploid

Question 6

Time 1. Sperm and Egg Fuse

Time 2. Cortical Granules Fuse with Plasma Membrane
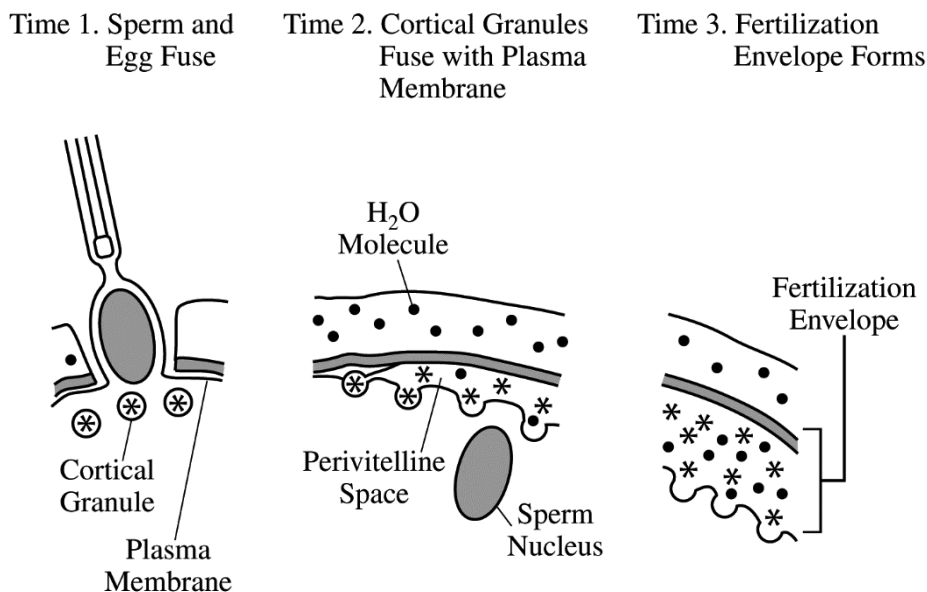
Time 3. Fertilization Envelope Forms

Figure 1. Time course of events during fertilization of a sea urchin egg

Figure 1 shows the events during and immediately following fertilization of a sea urchin egg. Sexual reproduction relies on the successful fusion of only one sperm with one egg (time 1) during fertilization. In sea urchins, a diploid organism, several events prevent additional sperm from fertilizing the egg. One of the first events following fertilization is the fusion of secretory vesicles called cortical granules with the egg plasma membrane (time 2). The cortical granules release their contents, a mixture of polysaccharides and proteins, into the perivitelline space. Subsequent to this, water moves into the perivitelline space, causing it to expand and physically separate the fertilization envelope from the egg plasma membrane (time 3). The fertilization envelope prevents fusion of more than one sperm with the egg.

(a) **Provide ONE reason** that preventing fusion of multiple sperm with one egg in sea urchins has provided a survival advantage over evolutionary time. (**1 point**)

Reasoning (1 point)
- Cells with too many chromosomes do not live
- Organisms with too many chromosomes are likely sterile

(b) **Describe** how the release of the contents of the cortical granules into the perivitelline space results in the movement of water <u>and</u> causes the subsequent expansion of the perivitelline space. (**2 points**)

Description of movement (1 point)
- Increased osmolarity/decreased water potential (of perivitelline space)
- (Perivitelline space becomes) hypertonic to its surroundings

Description of expansion (1 point)
- Water movement adds volume
- Water movement increases pressure

Question 7

Cyanobacteria are a large group of prokaryotic organisms. Cyanobacteria are found in marine microbial mats that include many species of eukaryotic and prokaryotic organisms that can participate in mutualistic symbiotic relationships. One recently discovered species of cyanobacteria, UCYN-A, lacks the genes that encode ribulose bisphosphate carboxylase/oxygenase (RuBisCo), components of photosystem II, and the Krebs cycle. UCYN-A contains genes enabling nitrogen fixation, which allows the enzymatic conversion of atmospheric nitrogen to biologically available nitrogen compounds such as nitrate. Within the microbial community there is relatively little available nitrogen. The majority of organisms in the microbial mat cannot fix nitrogen.

(a) **Identify** the metabolic process whereby UCYN-A is most likely to produce ATP. (**1 point**)

Identification (1 point)
- Glycolysis
- Photosystem I
- Electron transport chain/system
- Fermentation
- Anaerobic respiration

(b) In low-nitrogen conditions, UCYN-A participates in a mutualistic symbiotic relationship with other organisms in the microbial mat. **Predict** the most likely type of symbiotic relationship between UCYN-A and the other organisms in the microbial mat if nitrogen becomes readily available from another source. **Provide reasoning** to support your prediction. (**2 points; points may only be earned from one row**)

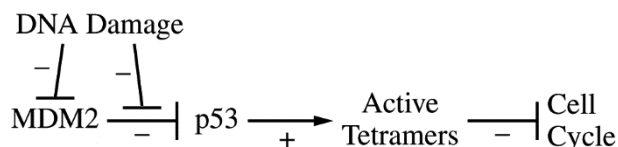| Predicted relationship (1 point)	**Reasoning (1 point)** – requires effects on both organisms	
	Effect on UCYN-A	Effect on other microbes
Parasitism (+/-)	Receives nutrients	Not dependent on UCYN-A for fixed nitrogen AND harmed by loss of nutrients
Commensalism (+/0)	Receives nutrients	Not dependent on UCYN-A for fixed nitrogen AND not harmed by loss of nutrients

Question 8

Figure 1. MDM2 and p53 signaling in response to DNA damage controls cell cycle progression.

8. The p53 and MDM2 proteins are involved in the DNA damage response pathway (Figure 1). In the absence of DNA damage, MDM2 mediates the degradation of p53. In the presence of DNA damage, p53 is not broken down and forms active tetramers that stimulate the expression of genes that block cell cycle progression.

   Red blood cells are produced by the division and differentiation of multipotent stem cells. Researchers have observed that mice with a partial loss-of-function mutation in the *MDM2* gene have a lower concentration of red blood cells in the blood than do mice that express the wild-type *MDM2* allele.

   (a) Using the model of the p53/MDM2 pathway, **connect** the reduction of MDM2 function in mutant mice to the observed concentration of red blood cells. (**1 point**)

   Connection (1 point)
   - p53 is (constitutively/always) active (in MDM2 mutant)
   - p53 is not degraded (regardless of DNA damage)

   (b) **Predict** how a loss-of-function mutation in the *p53* gene is most likely to affect the cell cycle in response to DNA damage. **Justify** your predictions. (**2 points**)

Prediction (1 point)	Justification (1 point)
Cell cycle will proceed (even in the presence of DNA damage)	Nonfunctional p53 (protein) cannot regulate the cell cycle

Scoring Worksheet

The following provides a scoring worksheet and conversion table used for calculating a composite score of the exam.

2017 AP Biology Scoring Worksheet

Section I: Multiple Choice and Grid-In

_____ × 1.0344 = _____
Number Correct   Weighted Section I Score
(out of 58)   (Do not round)

Section II: Free Response

Question 1   _____ × 1.5000 = _____
                  (out of 10)   (Do not round)

Question 2   _____ × 1.5000 = _____
                  (out of 10)   (Do not round)

Question 3   _____ × 1.4285 = _____
                  (out of 4)   (Do not round)

Question 4   _____ × 1.4285 = _____
                  (out of 4)   (Do not round)

Question 5   _____ × 1.4285 = _____
                  (out of 4)   (Do not round)

Question 6   _____ × 1.4285 = _____
                  (out of 3)   (Do not round)

Question 7   _____ × 1.4285 = _____
                  (out of 3)   (Do not round)

Question 8   _____ × 1.4285 = _____
                  (out of 3)   (Do not round)

Sum = _____
Weighted
Section II Score
(Do not round)

Composite Score

_____ + _____ = _____
Weighted   Weighted   Composite Score
Section I Score   Section II Score   (Round to nearest
                                            whole number)

AP Score Conversion Chart
Biology

Composite Score Range	AP Score
93-120	5
75-92	4
51-74	3
29-50	2
0-28	1

Question Descriptors and Performance Data

The following contains tables showing the content assessed,
the correct answer, and how AP students performed on each question.

2017 AP Biology

Question Descriptors and Performance Data

Multiple-Choice Questions

Question	Learning Objectives	Essential Knowledge	Science Practices	Key	% Correct
1	4.15	4A6	1.4	A	92
2	3.6	3A1	6.4	D	87
3	1.30	1D1	6.5	C	91
4	2.28	2D3	1.4	D	87
5	3.24	3C1	6.4	B	75
6	1.19	1B2	1.1	A	81
7	2.19	2C1	6.4	D	64
8	3.2	3A1	4.1	C	64
9	4.19	4B3	5.2	A	70
10	4.14	4A6	2.2	D	74
11	4.11	4A5	1.4|4.1	B	76
12	4.13	4A5	6.4	D	91
13	2.24	2D1	5.1	C	90
14	1.26	1C3	5.3	B	87
15	1.28	1D1	3.3	D	80
16	3.49	3E2	1.1	C	59
17	3.27	3C2	7.2	C	50
18	4.23	4C2	6.2	A	79
19	2.23	2D1	4.2|7.2	B	75
20	2.24	2D1	5.1	B	82
21	2.15	2C1	6.1	D	77
22	2.18	2C1	6.4	A	70
23	2.16	2C1	7.2	C	61
24	2.29	2D4	1.1|1.2	A	73
25	3.3	3A1	1.2	B	50
26	4.27	4C4	6.4	C	80
27	2.14	2B3	1.4	C	54
28	1.22	1C2	6.4	B	80
29	3.6	3A1	6.4	B	39
30	2.18	2C1	6.4	C	58
31	3.20	3B1	6.2	D	55
32	3.21	3B1	1.4	A	72
33	1.5	1A2	7.1	C	68
34	2.4	2A2	1.4|3.1	B	52
35	4.6	4A2	1.4	C	63
36	1.6	1A3	1.4|2.1	C	47
37	1.17	1B2	3.1	B	54
38	1.18	1B2	5.3	D	66

2017 AP Biology

Question Descriptors and Performance Data

Question	Learning Objectives	Essential Knowledge	Science Practices	Key	% Correct
39	3.6	3A1	6.4	A	48
40	1.25	1C3	1.2	A	79
41	2.12	2B2	1.4	D	58
42	3.45	3E2	1.2	A	54
43	1.21	1C1	4.2	A	67
44	4.16	4A6	6.4	C	83
45	4.12	4A5	2.2	A	56
46	2.37	2E2	7.2	A	67
47	4.13	4A5	6.4	B	70
48	2.24	2D1	5.1	D	52
49	2.27	2D2	7.1	D	37
50	2.12	2B2	1.4	B	43
51	3.4	3A1	1.2	D	45
52	3.27	3C2	7.2	A	41
53	3.38	3D4	1.5	B	47
121	1.3	1A1	2.2	0.29 – 0.30, 29/100 – 30/100	16
122	2.6	2A3	2.2	4/1, 4	46
123	3.4	3A1	1.2	72	47
124	3.14	3A3	2.2	¼, 0.25	50
125	4.14	4A6	2.2	14 – 15	68

Free-Response Questions

Question	Learning Objectives	Essential Knowledge	Science Practices	Mean Score
1	1.13|1.10|1.19|1.18|1.23|2.24|4.6	1A4|1B2|1C2|2D1|4A2	1.1|2.1|5.2|1.1|5.3|4.1|5.1|1.4	4.53
2	1.13|2.15|2.24|3.8|3.7|3.10|3.27|4.17	1A4|2C1|2D1|3A2|3C2|4B1	1.1|2.1|6.1|5.1|1.2|6.4|7.1|7.2|5.1	4.24
3	2.1|2.38|3.40	2A1|2E3|3E1	6.2|5.1|5.1	1.84
4	1.25|4.3	1C3|4A1	1.2|6.1|6.4	2.09
5	1.5|1.13|4.12	1A2|1A4|4A5	7.1|1.1|2.1|2.2	1.93
6	2.11|2.12|3.9	2B1|2B2|3A2	1.1|7.1|7.2|1.4|6.2	0.47
7	2.41|2.22|2.40|4.16	2A2|2D1|2E3|4A6	5.3|7.1|1.3|3.2|7.2|6.4	0.51
8	2.15|3.7|3.19	2C1|3A2|3B1	6.1|6.4|7.1	0.98

AP Biology

The College Board

The College Board is a mission-driven not-for-profit organization that connects students to college success and opportunity. Founded in 1900, the College Board was created to expand access to higher education. Today, the membership association is made up of over 6,000 of the world's leading educational institutions and is dedicated to promoting excellence and equity in education. Each year, the College Board helps more than seven million students prepare for a successful transition to college through programs and services in college readiness and college success — including the SAT® and the Advanced Placement Program®. The organization also serves the education community through research and advocacy on behalf of students, educators, and schools. The College Board is committed to the principles of excellence and equity, and that commitment is embodied in all of its programs, services, activities, and concerns.