VIRGINIA BOARD OF EDUCATION
AGENDA ITEM

Agenda Item: **L**

Date: **October 20, 2022**

Title: **First Review of the Advisory Board on Teacher Education and Licensure's Recommendation for a Passing Score for the Praxis® Biology (5236) Test for the Science – Biology Endorsement**

Presenter: **Joan B. Johnson, Assistant Superintendent for Teacher Education and Licensure**

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Purpose of Presentation:
Action required by state or federal law or regulation.

Executive Summary:
The proposed recommendation from the Advisory Board on Teacher Education and Licensure (ABTEL) is to set a passing score for the **Praxis® Biology (5236) Test** for the Biology endorsement. The Praxis® Biology (5236) test will replace the Praxis® Biology: Content Knowledge (5235) test. This **new** assessment was designed and developed through work with practicing biology teachers, teacher educators, and higher education biology specialists to reflect the science knowledge teachers need to teach the biology curriculum and to reflect state and national standards, including the National Science Teaching Association Preparation Standards for biology. This test will be required for individuals seeking initial licensure unless exempted by holding a full, clear out-of-state license with no deficiencies and can be taken and passed to add an endorsement in Biology by individuals holding a valid renewable teaching license.

Educational Testing Service (ETS) provides a recommended passing score from the multistate standard-setting study to help education agencies determine an appropriate operational passing score. For the Praxis Biology test, the recommended passing score is 75 out of a possible 120 raw-score points. The scale score associated with a raw score of 75 is **154** on a 100–200 scale.

The current Praxis® Biology: Content Knowledge (5235) Test has a Board prescribed passing score of 155 on a 100-200 scale. The Praxis® Biology (5236) test is a **new** assessment and the

previous passing score was not a consideration of ETS or ABTEL when establishing this test's passing score. Because this is a **new** assessment, ABTEL is also recommending that a data review be conducted after one year to determine if the passing score is providing for the greatest opportunity of teachers entering the profession while maintaining rigor.

On September 19, 2022 information regarding the multistate standard-setting process was presented to ABTEL members by Malik K. McKinley, Sr., Director of Client Relations, Professional Educator Programs, Office for Teacher Licensure and Certification, Student and Teacher Assessment Division, Educational Testing Service. ABTEL members reviewed the standard-setting report and recommended that the Board approve the passing score of **154** (the standard setting panel's recommendation).

Attached are the Multistate Standard-Setting Technical Report - Praxis® Biology (5236) Test and the Praxis® Study Companion. Also attached is a literature review and analysis of licensure assessment and student outcomes that was provided to the Virginia Board of Education (Board) in January 2022 that might provide useful information regarding the predictive value of teacher licensure assessments on student outcomes.

This item supports Priority 2 of the Board's Comprehensive Plan: 2018-2023.

Action Requested:
Action will be requested at a future meeting. Specify anticipated date below:
November 17, 2022.

Superintendent's Recommendation
The Superintendent of Public Instruction recommends that the Board receive for first review the recommendation of the Advisory Board on Teacher Education and Licensure to establish a passing score of 154 for the Praxis® Biology (5236) Test.

Previous Review or Action:
No previous review or action.

Background Information and Statutory Authority:
Currently, the Board requires the following assessments for initial licensure:

- Virginia Communication and Literacy Assessment (VCLA);
- Praxis Subject Assessments; and
- Praxis® Teaching Reading: Elementary (5205) for specified endorsements.

The Board prescribes the Praxis Subject Assessments as a professional teacher's assessment requirement for initial licensure in Virginia. The current Board of Education's prescribed assessment for biology is the Praxis® Biology: Content Knowledge (5235).

The Praxis® Biology (5236) test will replace the Praxis® Biology: Content Knowledge (5235) test. This **new** assessment is designed and developed through work with practicing biology teachers, teacher educators, and higher education biology specialists to reflect the science knowledge teachers need to teach the biology curriculum and to reflect state and national standards, including the National Science Teaching Association Preparation Standards for biology. Content and practices measured reflect the Disciplinary Core Ideas (DCIs) and Science and Engineering Practices (SEPs) established by the National Research Council in A Framework for K-12 Science Education and included in the Next Generation Science Standards.

In November 2021, a multistate standard-setting study was designed and conducted by the Educational Testing Service (ETS) to support the decision-making process of education agencies establishing a passing score (cut score) for the Praxis® Biology (5236) test. Panelists from 14 states participated on the panel. The education agencies recommended panelists with (a) experience as either biology teachers and (b) familiarity with the knowledge and skills required of beginning biology teachers.

A detailed summary of the study, Multistate Standard-Setting Technical Report - Praxis® Biology (5236) is attached. The technical report contains three sections. The first section describes the content and format of the test. The second section describes the standard-setting processes and methods. The third section presents the results of the standard-setting study.

A copy of the Praxis® Biology Study Companion is attached. This document describes the purpose and structure of the test. In brief, the test measures knowledge and competencies that are important for safe and effective beginning practice as a biology teacher. The two-hour and 30 minute assessment contains 150 selected-response items covering five content areas: *Nature and Impact of Science and Engineering (approximately 19 items), Cell Biology: Cell Structure and Function* (approximately 33 items), *Genetics and Evolution* (approximately 39 items), *Diversity of Life and Organismal Biology* (approximately 20 items), and *Ecology: Organisms and Environments* (approximately 29 items). The reporting scale for the Praxis Biology test ranges from 100 to 200 scale-score points.

Multistate Standard-Setting Study

The Multistate standard-setting study for the Praxis® Biology (5236) test is detailed in the attached report.

The following table presents the estimated conditional standard error of measurement (CSEM) around the recommended passing score. A standard error represents the uncertainty associated with a test score. The scale scores associated with one and two CSEM above and below the recommended passing score are provided. The conditional standard error of measurement provided is an estimate.

Conditional Standard Error of Measurement Summaries
PRAXIS® BIOLOGY (5236)

	Raw Score	**Scale Score Equivalent**
Recommended passing score (CSEM)	***75 (5.33)***	***154***
- 2 CSEM	65	142
- 1 CSEM	70	148
+1 CSEM	81	161
+2 CSEM	86	167

ETS provides a recommended passing score from the multistate standard-setting study to help education agencies determine an appropriate operational passing score. For the Praxis Biology test, the recommended passing score is 75 out of a possible 120 raw-score points. The scale score associated with a raw score of 75 is **154** on a 100–200 scale.

The current Praxis® Biology: Content Knowledge (5235) Test has a Board prescribed passing score of 155 on a 100-200 scale. The Praxis® Biology (5236) test is a **new** assessment and the previous passing score was not a consideration of ETS or ABTEL when establishing this test's passing score. Because this is a **new** assessment, ABTEL is also recommending that a data review be conducted after one year to determine if the passing score is providing for the greatest opportunity of teachers entering the profession while maintaining rigor.

On September 19, 2022 information regarding the multistate standard-setting process was presented to the Advisory Board members by Malik K. McKinley, Sr., Director of Client Relations, Professional Educator Programs, Office for Teacher Licensure and Certification, Student and Teacher Assessment Division, Educational Testing Service. The Advisory Board members reviewed the standard-setting report and recommended that the Board approve the passing score of **154** (the standard setting panel's recommendation).

The *Code of Virginia* provides the authority for the Board of Education to promulgate *Licensure Regulations for School Personnel*.

Section **22.1-298.1** of the *Code of Virginia* states, in part, the following:

> § **22.1-298.1 Regulations governing licensure.**
> *C. The Board of Education's regulations shall include requirements that a person seeking initial licensure:*
> *1. Demonstrate proficiency in the relevant content area, communication, literacy, and other core skills for educators by achieving a qualifying score on professional assessments or meeting alternative evaluation standards as prescribed by the Board;*
> *2. Complete study in attention deficit disorder;*
> *3. Complete study in gifted education, including the use of multiple criteria to identify gifted students; and*
> *4. Complete study in methods of improving communication between schools and families and ways of increasing family involvement in student learning at home and at school.*

Code of Virginia, Section 22.1-16. Bylaws and regulations generally.
Code of Virginia, Section 22.1-299. License required of teachers.
Code of Virginia, Section 22.1-305.2. Advisory Board on Teacher Education and Licensure.

The *Licensure Regulations for School Personnel* state, in part, the following:

> 8VAC20-22-40. Conditions for Licensure.
> *... B. All candidates who hold at least a baccalaureate degree from a regionally accredited college or university and who seek an initial Virginia teaching license shall obtain passing scores on professional teacher's assessments prescribed by the Virginia Board of Education. With the exception of the career switcher program that requires assessments as prerequisites, individuals shall complete the professional teacher's assessment requirements within the three-year validity of the initial provisional license….*
>
> 8VAC20-22-70. Additional Endorsements.
> *A. An individual who holds a teaching license may add an additional teaching endorsement to the license by passing a rigorous academic subject test for endorsements in which a test is prescribed by the Virginia Board of Education. This testing option does not apply to individuals (i) who are seeking an early/primary education preK-3 or elementary education preK-6 endorsement, special education endorsements, or a reading specialist endorsement or (ii) who hold a Technical Professional License, Vocational Evaluator License, Pupil Personnel Services License, School Manager License, or Division Superintendent License.*

Timetable for Further Review/Action:
It is anticipated that this item will come back to the Board for final review on November 17, 2022.

Impact on Fiscal and Human Resources:
The individuals taking the Praxis® Biology (5236) Test will incur the costs for the test.

Multistate Standard-Setting Technical Report for the

Praxis® Biology (5236)

Student and Teacher Assessments: Validity and Test Use

ETS

Princeton, New Jersey

November 2021

Executive Summary

To support the decision-making process of education agencies establishing a passing score (cut score) for the *Praxis*® Biology (5236) test, research staff from Educational Testing Service (ETS) designed and conducted a multistate standard-setting study (Tannenbaum, 2011, 2012).

Participating States

Panelists from 14 states were recommended by their respective education agencies. The education agencies recommended panelists with (a) experience as either teachers of biology students or college faculty who prepare those biology teachers and (b) familiarity with the knowledge and skills required of beginning biology teachers.

Recommended Passing Score

ETS provides a recommended passing score from the multistate standard-setting study to help education agencies determine an appropriate operational passing score. For the *Praxis* Biology test, the recommended passing score[1] is 75 out of a possible 120 raw-score points. The scale score associated with a raw score of 75 is 154 on a 100–200 scale.

[1] Results from the two panels participating in the study were averaged to produce the recommended passing score.

Introduction

To support the decision-making process for education agencies establishing a passing score (cut score) for the *Praxis*® Biology (5236) test, research staff from ETS designed and conducted a multistate standard-setting study (Tannenbaum, 2011, 2012) in November 2021. Education agencies [2] recommended panelists with (a) experience as either biology teachers and (b) familiarity with the knowledge and skills required of beginning biology teachers. Fourteen states (Table 1) were represented by 21 panelists. (See Appendix A for the names and affiliations of the panelists.)

Table 1
Participating States and the Number of Panelists

Delaware (2 panelists)	Nevada (1 panelist)
Idaho (2 panelists)	Rhode Island (1 panelist)
Indiana (2 panelists)	Tennessee (2 panelists)
Kansas (1 panelist)	Utah (1 panelist)
Maryland (2 panelists)	Virginia (2 panelists)
North Carolina (2 panelists)	Vermont (1 panelist)
New Jersey (1 panelist)	West Virginia (1 panelist)

The following technical report contains three sections. The first section describes the content and format of the test. The second section describes the standard-setting processes and methods. The third section presents the results of the standard-setting study.

ETS provides a recommended passing score from the multistate standard-setting study to education agencies. In each state, the department of education, the board of education, or a designated educator licensure board is responsible for establishing the operational passing score in accordance with applicable regulations. This study provides a recommended passing score, which represents the combined judgments of a group of experienced educators. Each state may want to consider the recommended passing score but also other sources of information when setting the final *Praxis* Biology passing score (see Geisinger & McCormick, 2010). A state may accept the recommended passing score, adjust the score upward to reflect more stringent expectations, or adjust the score downward to reflect

[2] States and jurisdictions that currently use *Praxis* tests were invited to participate in the multistate standard-setting study.

more lenient expectations. There is no *correct* decision; the appropriateness of any adjustment may only be evaluated in terms of its meeting the state's needs.

Two sources of information to consider when setting the passing score are the standard error of measurement (SEM) and the standard error of judgment (SEJ). The former addresses the reliability of the *Praxis* Biology test score and the latter, the reliability of panelists' passing-score recommendation. The SEM allows states to recognize that any test score on any standardized test—including a *Praxis* Biology test score—is not perfectly reliable. A test score only *approximates* what a candidate truly knows or truly can do on the test. The SEM, therefore, addresses the question: How close of an approximation is the test score to the *true* score? The SEJ allows states to gauge the likelihood that the recommended passing score from the current panel would be similar to the passing scores recommended by other panels of experts similar in composition and experience. The smaller the SEJ, the more likely that another panel would recommend a passing score consistent with the recommended passing score. The larger the SEJ, the less likely the recommended passing score would be reproduced by another panel.

In addition to measurement error metrics (e.g., SEM, SEJ), each state should consider the likelihood of classification errors. That is, when adjusting a passing score, policymakers should consider whether it is more important to minimize a false-positive decision or to minimize a false-negative decision. A false-positive decision occurs when a candidate's test score suggests that they should receive a license/certificate, but their actual level of knowledge/skills indicates otherwise (i.e., the candidate does not possess the required knowledge/skills). A false-negative decision occurs when a candidate's test score suggests that they should not receive a license/certificate, but they actually do possess the required knowledge/skills. States needs to consider which decision error is more important to minimize.

Overview of the *Praxis*® Biology Test

The *Praxis*® Biology *Study Companion* document (ETS, in press) describes the purpose and structure of the test. In brief, the test measures whether entry-level biology teachers have the knowledge/skills believed necessary for competent professional practice.

The 2-hour and 30 minute assessment contains 150 selected-response[3] items covering five content areas: *Nature and Impact of Science and Engineering* (approximately 19 items), *Cell Biology: Cell*

[3] Thirty of the 150 selected-response items are pretest items and do not contribute to a candidate's score.

Structure and Function (approximately 33 items), *Genetics and Evolution* (approximately 39 items), *Diversity of Life and Organismal Biology* (approximately 20 items), and *Ecology: Organisms and Environments* (approximately 29 items).[4] The reporting scale for the *Praxis* Biology test ranges from 100 to 200 scale-score points.

Processes and Methods

The design of the standard-setting study included two, independent expert panels. Before the study, panelists received an email explaining the purpose of the standard-setting study and requesting that they review the content specifications for the test. This review helped familiarize the panelists with the general structure and content of the test.

For each panel, the standard-setting study began with a welcome and introduction by the meeting facilitator. The facilitator described the test, provided an overview of standard setting, and presented the agenda for the study. Appendix B shows the standard-setting study agenda.

Reviewing the Test

The standard-setting panelists first took the test and then discussed the content measured. This discussion helped bring the panelists to a shared understanding of what the test does and does not cover, which serves to reduce potential judgment errors later in the standard-setting process.

The test discussion covered the major content areas being addressed by the test. Panelists were asked to remark on any content areas that would be particularly challenging for entry-level biology teachers or areas that address content particularly important for entry-level biology teachers.

Defining the Just-Qualified Candidate

Following the review of the test, panelists described the just-qualified candidate. The *just-qualified candidate description* plays a central role in standard setting (Perie, 2008); the goal of the standard-setting process is to identify the test score that aligns with this description.

The panelists created a description of the just-qualified candidate, focusing on the knowledge/skills that differentiate a *just-qualified* from a *not quite-qualified* candidate. To create this description, the panelists from both panels were assigned to three smaller groups in order to create a

[4] The number of items for each content area may vary slightly from form to form of the test.

draft description. Then they reconvened and, through whole-group discussion of the three drafts, reached consensus on to determine the final version. This final description of the just-qualified candidate was used by both panels for the remainder of the study.

The description of the just-qualified candidate summarized the panels' discussion in a list format. The description was not intended to describe all the knowledge and skills of the just-qualified candidate but only highlight those that differentiate a *just-qualified candidate* from a *not-quite-qualified* candidate. A clean, PDF-version of the final description was distributed to panelists to use for the remaining phases of the study (see Appendix C for the just-qualified candidate description).

Given that the two-panel multistate standard-setting study was designed to provide two recommendations for the same performance standard, it was important that panels use a consistent just-qualified candidate description to frame their judgments. Therefore, the panelists from both panels worked together until the just-qualified candidate description was finalized.

Panelists' Judgments

The standard-setting process for the *Praxis* Biology test was a probability-based Modified Angoff method (Brandon, 2004; Hambleton & Pitoniak, 2006). Using this method, each panelist judged each item on the likelihood (probability or chance) that the just-qualified candidate would answer the item correctly. Panelists made their judgments using the following rating scale: 0, .05, .10, .20, .30, .40, .50, .60, .70, .80, .90, .95, 1. The lower the value, the less likely it is that the just-qualified candidate would answer the item correctly because the item is difficult for the just-qualified candidate. The higher the value, the more likely it is that the just-qualified candidate would answer the item correctly.

Panelists were asked to approach the judgment process in two stages. First, they reviewed both the description of the just-qualified candidate and the item and determined the probability that the just-qualified candidate would answer the question correctly. The facilitator encouraged the panelists to consider the following rules of thumb to guide their decision:

- Items in the 0 to .30 range were those the just-qualified candidate would have a *low chance* of answering correctly.
- Items in the .40 to .60 range were those the just-qualified candidate would have a *moderate chance* of answering correctly.

- Items in the .70 to 1 range were those that the just-qualified candidate would have a *high chance* of answering correctly.

Next, panelists decided how to refine their judgment within the range. For example, if a panelist thought that there was a *high chance* that the just-qualified candidate would answer the question correctly, the initial decision would be in the .70 to 1 range. The second decision for the panelist was to judge if the likelihood of answering it correctly is .70, .80, .90, .95 or 1.

After the training, panelists made practice judgments. They then discussed those judgments and their rationales. All panelists completed a post-training evaluation to confirm that they had received adequate training in the Modified Angoff method and felt prepared to continue; the standard-setting process continued only if all panelists confirmed their readiness. If panelists had any questions, those questions were addressed and retraining was provided, if necessary, before proceeding to the first round of judgments.

Following this first round of judgments (*Round 1*), panel-level summaries and item-level feedback were provided to each panel. For each panel, the panelists' judgments were displayed for each item and summarized across the panelists. Item-level data were highlighted to show when panelists converged in their judgments or diverged in their judgments (i.e., when at least two-thirds of the panelists' judgments were Each panel discussed their item-level judgments. These discussions helped panelists maintain a shared understanding of the knowledge/skills of the just-qualified candidate and helped to clarify aspects of items that might not have been clear to all panelists during the Round 1 judgments. The purpose of the discussion was not for panelists to conform to another's judgment, but for them to understand the different relevant perspectives among the panelists.

During Round 2, each panel discussed their Round 1 judgments and were encouraged by the facilitator to (a) share the rationales for their judgments and (b) consider their judgments in light of the rationales provided by the other panelists. Panelists recorded their Round 2 judgments only for items when they wished to change their Round 1 judgment. For each panel, the final judgments for the study, therefore, consist of the panelists' Round 1 judgments and any adjusted judgments made during Round 2.

Other than the description of the just qualified candidate, results from Panel 1 were not shared with Panel 2 and vice versa. The feedback (data), item-level judgments, and resulting discussions for each panel were independent from the other panel.

Results

Expert Panels

Table 2 presents a summary of the panelists' demographic information. The panel included 21 educators representing 14 states. (See Appendix A for a listing of panelists.) Sixteen panelists were teachers, one was an administrator or department head, three were college faculty, and one was a district secondary science academic coach. All of the educators currently, or previously, taught biology. All of the faculty members' job responsibilities included the training of biology teachers. The number of experts by panel and their demographic information are presented in Appendix D (Table D1).

Table 2
Panel Member Demographics (Across Panels)

Background Survey Question	Number	Percent
What is your current position?	**N**	**%**
Teacher	16	76
Administrator or Department head	1	5
College faculty	3	14
District Secondary Science Academic Coach	1	5
How do you describe yourself (i.e., race/ethnicity)?	**N**	**%**
Black or African American	4	19
Hispanic or Latino	1	5
White	14	67
Prefer not to respond	2	10
What is your gender?	**N**	**%**
Female	13	62
Male	8	38
Are you currently certified as a biology teacher in your state?	**N**	**%**
Yes	20	95
No	1	5
Are you currently teaching biology in your state?	**N**	**%**
Yes	15	71
No	6	29
Are you currently supervising or mentoring other biology teachers?	**N**	**%**
Yes	14	67
No	7	33

(table continues on the next page)

Table 2 (continued from the previous page)
Panel Member Demographics (Across Panels)

At what P–12 grade level are you currently teaching biology?	**N**	**%**
Middle school (6–8 or 7–9)	3	14
High school (9–12 or 10–12)	10	48
Other	2	10
Not currently teaching at the P–12 level	6	29
Including this year, how many years of experience do you have teaching biology?	**N**	**%**
3 years or less	0	0
4–7 years	5	24
8–11 years	5	24
12–15 years	2	10
16 years or more	9	43
Which best describes the location of your P–12 school?	**N**	**%**
Urban	3	14
Suburban	8	38
Rural	7	33
Not currently working at the P–12 level	3	14
If you are college faculty, are you currently involved in the training/ preparation of candidates in this subject?	**N**	**%**
Yes	3	14
No	0	0
Not college faculty	18	86

Standard-Setting Judgments

Table 3 summarizes the standard-setting judgments of each panel. Panelist-level results, for Rounds 1 and 2, are presented in Appendix D (Tables D2 – D4). The means represents each panel's passing score recommendation after Round 2. Table 4 also includes each panel's standard deviations (SD) and the standard errors of judgment (SEJ). The SEJ is one way of estimating the reliability or consistency of a panel's standard-setting judgments. It indicates how likely it would be for several other panels of educators similar in makeup, experience, and standard-setting training to the current panel to recommend the same passing score on the same form of the test. The confidence intervals created by adding/subtracting two SEJs to each panel's recommended passing score overlap, indicating that they may be comparable. (Appendix E provides the technical notes, which further describe the SEJ.)

Table 4

Summary of Round 2 Standard-setting Judgments by Panel

Statistic	Panel 1	Panel 2
Mean	74.85	74.97
Minimum	61.65	62.25
Maximum	91.10	85.65
SD	8.98	7.32
SEJ	2.84	2.21

Round 1 judgments are made without discussion among the panelists. The most variability in judgments, therefore, is typically present in the first round. Round 2 judgments, however, are informed by panel discussion; thus, it is common to see a decrease both in the standard deviation and SEJ. This decrease—indicating convergence among the panelists' judgments—was observed for each panel (see Appendix D, Table D4).

The Round 2 mean score is the panel's final recommended passing score. The panel's passing score recommendation for the *Praxis* Biology test are 74.85 for Panel 1 and 74.97 for Panel 2 (out of a possible 120 raw-score points). The values were rounded to the next highest whole number to determine the functional recommended passing score--75 for both Panel 1 and Panel 2. The scale score associated with 75 raw points is 154.

In addition to the recommended passing score for each panel, the average passing score across the two panels is provided to help education agencies determine an appropriate passing score. The panels' average passing score recommendation for the *Praxis* Biology test is 74.91 (out of a possible 120 raw-score points). The value was rounded to 75 (next highest raw score) to determine the functional recommended passing score. The scale score associated with 75 raw points is 154.

The conditional standard error of measurement (CSEM) around the recommended passing score is 5.33 raw points. A standard error represents the uncertainty associated with a test score (See Appendix E for further information about the CSEM.) Table 5 shows the raw scores and the scale scores associated with one and two CSEM below and above the recommended passing score.

Table 5

Scores 1 and 2 CSEM Around the Recommended Passing Score (RPS)

Scores	Raw Score Points out of 120	Praxis Scale Score Equivalent
RPS - 2 CSEM	65	142
RPS - 1 CSEM	70	148
RPS	**75**	**154**
RPS +1 CSEM	81	161
RPS +2 CSEM	86	167

Notes. CSEM = conditional standard error(s) of measurement. The CSEM of the recommended passing score is 5.33 raw points. The unrounded CSEM value is added to, or subtracted from, the rounded passing-score recommendation. The resulting values are rounded up to the next-highest whole number and then converted to scale scores.

Final Evaluations

The panelists completed an evaluation at the conclusion of the standard-setting study. The evaluation asked the panelists to provide feedback about the quality of the standard-setting implementation and the factors that influenced their decisions. The responses to the evaluation provided evidence of the validity of the standard-setting process, and, as a result, evidence of the reasonableness of the recommended passing score.

Panelists were shown the panel's recommended passing score after Round 2 and asked, in the evaluation, (a) how comfortable they are with the recommended passing score and (b) if they think the score was *too high*, *too low*, or *about right*. A summary of the final evaluation results, per panel, is presented in Appendix D (Tables D5 – D12).

All panelists strongly agreed that they understood the purpose of the study. All panelists strongly agreed or agreed that the facilitator's instructions and explanations were clear. All panelists strongly agreed that they were prepared to make their standard-setting judgments. All panelists strongly agreed or agreed that the standard-setting process was easy to follow.

All panelists reported that the description of the just-qualified candidate was very influential in guiding their standard-setting judgments. All of the panelists reported that round 2 discussions were at least somewhat influential in guiding their judgments. Thirteen of the 21 panelists indicated that their own professional experience was very influential in guiding their judgments.

Thirteen of the 21 panelists indicated they were *very comfortable* with the passing score they recommended. One panelist indicated that they were *very uncomfortable* with the passing score but also indicated that the score was *about right*. All but four of the panelists indicated the recommended

passing score was *about right*; two panelists felt that the passing score was *too low* and two felt that it was *too high*.

Summary

To support the decision-making process for education agencies establishing a passing score (cut score) for the *Praxis* Biology test, research staff from ETS designed and conducted a multistate standard-setting study.

ETS provides a recommended passing score from the multistate standard-setting study to help education agencies determine an appropriate operational passing score. For the *Praxis* Biology test, the recommended passing score[5] is 75 out of a possible 120 raw-score points. The scale score associated with a raw score of 75 is 154 on a 100–200 scale.

[5] Results from the two panels participating in the study were averaged to produce the recommended passing score.

References

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Appendix A: Panelists' Names & Affiliations

Participating Panelists With Affiliation and State

Panelist Name	**Panelists' Affiliation and State Abbreviation**
Shannon Bankston-Bell	Charlotte Mecklenburg Schools (NC)
Teresa Barton	PikeView High School (WV)
Lori Beasley	Seaford School District (DE)
Carrie Evick	Cape Henlopen School District (DE)
Rebecca Feekes	West Ada School District (ID)
Erika Frazier	Prince William County Public Schools (VA)
Lori Fretta	Vermont Virtual Learning Cooperative (VT)
Christy Gum	Gloucester High School (VA)
Will Hemminger	Western Alamance High School (NC)
Jenna Henry	Carroll County Public Schools (MD)
Jeremy Kelly	Giles County High School (TN)
James McCormick	North Plainfield High School (Harrison Bridge) (NJ)
Kawonia Mull	Tennessee State University/Williamson County School (TN)
Amanda Noble	Portsmouth High School (RI)
Benjamin Ott	Boise School District (Les Bois Junior High) (ID)
Elvia Solis	Indianapolis Public Schools (IN)
Cherry Steffen	Washburn University (KS)
Joshua Stowers	Brigham Young University (UT)
Brent Strong	Haiser Jr Sr High School (IN)
Sheikisha Thomas	Bowie High School (MD)
Brian Zeiszler	Great Basin College (NV)

Appendix B: Agenda

Praxis® Biology (5236)

Standard-Setting Study

Day 1 Agenda

Welcome and Introduction

Overview of Standard Setting and the *Praxis* Biology Test

Review the *Praxis* Biology Test

AM Break

Discuss the *Praxis* Biology Test

Lunch

Define the Knowledge/Skills of a Just-Qualified Candidate (small-group drafts)

PM Break

Define the Knowledge/Skills of a Just-Qualified Candidate (small-group drafts) *(continued)*

Collect Materials; End of Day 1

Praxis® Biology (5236)

Standard-Setting Study

Day 2 Agenda

Overview of Day 2

Define the Knowledge/Skills of a Just-Qualified Candidate (whole-group consensus)

AM Break - Split into two panels

Standard Setting Training in the Modified Angoff Method

Practice Round – Independent Judgments

Lunch

Practice Round –Discussion

Round 1 Standard Setting Judgments

PM Break

Round 1 Standard Setting Judgments *(continued)*

Collect Materials; End of Day 2

Praxis® Biology (5236)

Standard-Setting Study

Day 3 Agenda

Overview of Day 3

Honoraria Presentation

Round 1 Feedback – Panel Summary

Round 1 Feedback and Round 2 Judgments

AM Break

Round 1 Feedback and Round 2 Judgments *(continued)*

Lunch

Feedback on Round 2 Recommended Passing Score

Complete Final Evaluation

Collect Materials; End of Study

Appendix C: Just-Qualified Candidate Description

Description of the Just-Qualified Candidate[6]

A just-qualified candidate…

Tasks of Teaching Science / Science and Engineering Practices

1. Is familiar with inquiry-based instructional methods, scaffolding, and sequencing.
2. Understands how to use basic scientific formulas, convert units of measurements, and use proportional reasoning skills
3. Uses scientific language (vocabulary and definitions), models and basic representations to explain scientific concepts
4. Is familiar with how to analyze student ideas in order to identify misconceptions, lack of understanding and gaps of knowledge and can address these topics

I. Nature and Impact of Science and Engineering

5. Understands basic lab safety, general science equipment, and experimental design and the processes involved in scientific inquiry

II. Cell Biology: Cell Structure and Function

6. Understands how the structure of water and the four major macromolecules affects their functions and properties
7. Understands the enzyme-substrate model and the functions of enzymes and knows the factors that influences the rate of enzymatic reactions
8. Understands active and passive transport and their role in maintaining homeostasis
9. Understands the relationship between common cellular structures and functions and how they interact to perform cellular processes
10. Knows the major biochemical pathways and how they allow the cell to meet its matter and energy needs (i.e., aerobic respiration, anaerobic respiration, photosynthesis, chemosynthesis)

[6] Description of the just-qualified candidate focuses on the knowledge/skills that differentiate a *just* from a *not quite* qualified candidate.

Description of the Just-Qualified Candidate (continued)

A just-qualified candidate…

11. Knows how cells communicate with each other and respond to internal and external stimuli (i.e., cell signaling pathways, plasmodesmata, gap junctions)
12. Knows the different purposes and outcomes of mitosis and meiosis

III. Genetics and Evolution

13. Knows the complementary nature of nucleotide base pairs and the general processes and outcomes of replication, transcription, and translation (e.g., mRNA editing, prokaryotes vs. eukaryotes, basic enzymes)
14. Knows basic types and causes of gene (e.g., frame shift) and chromosomal (e.g., translocation) mutations and is familiar with their effects at the cellular (e.g., Sickle Cell) and organism (e.g., Down Syndrome) levels
15. Understands non-Mendelian patterns of inheritance like sex-linked, multiple alleles, co-dominance, incomplete dominance
16. Understands the mechanism of natural selection and is familiar with other mechanisms of evolution (e.g. genetic drift, geographic/reproductive isolation)
17. Knows how fossil records, molecular, structural, and developmental evidence are used to support the theory of evolution
18. Is familiar with basic biotechnology techniques (e.g., DNA extraction, gel electrophoresis, PCR, transformation)

IV. Diversity of Life and Organismal Biology

19. Knows the characteristics of living things (distinguishes viruses from cells) and how living things are classified (e.g., Domains, Kingdoms)
20. Knows the basic specialized parts (e.g., adaptations, organ systems, tissues) of plants and animals that function together to allow for survival

V. Ecology: Organisms and Environments

21. Knows how organisms interact and respond to their environment, including animal behavior and organismal adaptations

Description of the Just-Qualified Candidate (continued)

A just-qualified candidate…

22. Understands how biotic and abiotic components of an ecosystem influence population dynamics and relationships
23. Knows the differences between the flow of energy and the cycling of matter, including biogeochemical cycles and pyramids of biomass and energy
24. Understands how disturbances, natural or human, will affect ecosystems

Appendix D: Panel-Specific Results

Table D1

Panel Member Demographics per Panel

Background Survey Question	Panel 1 Number	Panel 1 Percent	Panel 2 Number	Panel 2 Percent
What is your current position?	**N**	**%**	**N**	**%**
Teacher	8	80	8	73
Administrator or Department head	1	10	0	0
College Faculty	1	10	2	18
District Secondary Science Academic Coach	0	0	1	9
How do you describe yourself (i.e., race/ethnicity)?	**N**	**%**	**N**	**%**
Black or African American	2	20	2	18
Hispanic or Latino	1	10	0	0
White	6	60	8	73
Prefer not to respond	1	10	1	9
What is your gender?	**N**	**%**	**N**	**%**
Female	6	60	7	64
Male	4	40	4	36
Are you currently certified as a biology teacher in your state?	**N**	**%**	**N**	**%**
Yes	10	100	10	91
No	0	0	1	9
Are you currently teaching biology in your state?	**N**	**%**	**N**	**%**
Yes	8	80	7	64
No	2	20	4	36
Are you currently supervising or mentoring other biology teachers?	**N**	**%**	**N**	**%**
Yes	6	60	8	73
No	4	40	3	27

(table continues on the next page)

Table D1 (continued from previous page)
Panel Member Demographics per Panel

Background Survey Question	Panel 1 Number	Panel 1 Percent	Panel 2 Number	Panel 2 Percent
At what P–12 grade level are you currently teaching biology?	**N**	**%**	**N**	**%**
Middle school (6–8 or 7–9)	1	10	2	18
High school (9–12 or 10–12)	6	60	4	36
Other	1	10	1	9
Not currently teaching biology at the P–12 level	2	20	4	36
Including this year, how many years of experience do you have teaching biology?	**N**	**%**	**N**	**%**
3 years or less	0	0	0	0
4–7 years	2	20	3	27
8–11 years	1	10	4	36
12–15 years	2	20	0	0
16 years or more	5	50	4	36
Which best describes the location of your P–12 school?	**N**	**%**	**N**	**%**
Urban	1	10	2	18
Suburban	3	30	5	45
Rural	5	50	2	18
Not currently working at the P–12 level	1	10	2	18
If you are college faculty, are you currently involved in the training/ preparation of biology teachers?	**N**	**%**	**N**	**%**
Yes	1	10	2	18
No	0	0	0	0
Not college faculty	9	90	9	82

Table D2

Panel 1 Passing Score Summary by Round of Judgments

Panelist	Round 1	Round 2
1	62.50	65.80
2	84.65	80.65
3	69.70	70.10
4	60.25	61.65
5	73.70	74.20
6	65.20	67.20
7	83.10	80.80
8	73.80	74.70
9	92.40	91.10
10	83.65	82.25

Table D3

Panel 2 Passing Score Summary by Round of Judgments

Panelist	Round 1	Round 2
1	82.10	79.05
2	92.95	85.65
3	61.45	62.25
4	71.40	68.10
5	90.35	83.90
6	69.65	70.85
7	83.80	83.30
8	73.20	74.10
9	69.75	71.45
10	74.80	75.10
11	68.50	70.95

Table D4

Summary of Standard-setting Judgments by Panel and by Round

Statistic	Panel 1, Round 1	Panel 1, Round 2	Panel 2, Round 1	Panel 2, Round 2
Mean	74.90	74.85	76.18	74.97
Minimum	60.25	61.65	61.45	62.25
Maximum	92.40	91.10	92.95	85.65
SD	10.74	8.98	9.84	7.32
SEJ	3.39	2.84	2.97	2.21

Table D5: Panel 1 Final Evaluation: Process Questions

Likert Statement	Strongly agree *N*	Strongly agree %	Agree *N*	Agree %	Disagree *N*	Disagree %	Strongly disagree *N*	Strongly disagree %
I understood the purpose of this study.	10	100	0	0	0	0	0	0
The instructions and explanations provided by the facilitators were clear.	10	100	0	0	0	0	0	0
The training and practice in the standard setting method was adequate to give me the information I needed to complete my assignment.	10	100	0	0	0	0	0	0
The explanation of how the recommended passing score is computed was clear.	9	90	1	10	0	0	0	0
The opportunity for feedback and discussion for round 2 judgments was helpful.	9	90	1	10	0	0	0	0
The process of making the standard-setting judgments was easy to follow.	7	70	3	30	0	0	0	0

Table D6: Panel 1 Final Evaluation: Standard-Setting Process

	Too much time ***N***	**Too much time** **%**	**About the right amount of time** ***N***	**About the right amount of time** **%**	**Too little time** ***N***	**Too little time** **%**
Small group JQC drafts	0	0	9	9	1	10
Whole group JQC consensus	0	0	10	100	0	0
Training and practice for making standard-setting judgments	0	0	9	90	1	10
Round 1 judgments (independent)	0	0	8	80	2	20
Round 2 judgments (with discussion)	1	10	8	80	1	10

Table D7: Panel 1 Final Evaluation: Influences in Standard-Setting Judgments

How influential was each of the following factors in guiding your standard-setting judgments?	**Very influential** ***N***	**Very influential** **%**	**Somewhat influential** ***N***	**Somewhat influential** **%**	**Not influential** ***N***	**Not influential** **%**
The description of the just-qualified candidate	10	100	0	0	0	0
The round 2 discussion	4	40	6	60	0	0
The knowledge/skills required to answer each test item	8	80	2	20	0	0
The passing scores of other panel members	1	10	8	80	1	10
My own professional experience	7	70	3	30	0	0

Table D8: Panel 1 Final Evaluation: Comfort with the Panel's Recommendation

Question	Very comfort-able *N*	Very comfort-able %	Somewhat comfort-able *N*	Somewhat comfort-able %	Somewhat uncom-fortable *N*	Somewhat uncom-fortable %	Very uncom-fortable *N*	Very uncom-fortable %
Considering the process you followed, how comfortable are you with the panel's recommended cut score?	5	50	5	50	0	0	0	0

Table D9: Panel 1 Final Evaluation: Opinion of the Final Recommendation

Statement	Too low *N*	Too low %	About right *N*	About right %	Too high *N*	Too high %
Overall, the recommended passing score is:	1	10	7	70	2	20

Table D10: Panel 2 Final Evaluation: Process Questions

Likert Statement	Strongly agree *N*	Strongly agree %	Agree *N*	Agree %	Disagree *N*	Disagree %	Strongly disagree *N*	Strongly disagree %
I understood the purpose of this study.	11	100	0	0	0	0	0	0
The instructions and explanations provided by the facilitators were clear.	10	91	1	9	0	0	0	0
The training and practice in the standard setting method was adequate to give me the information I needed to complete my assignment.	11	100	0	0	0	0	0	0
The explanation of how the recommended passing score is computed was clear.	10	91	1	9	0	0	0	0
The opportunity for feedback and discussion for round 2 judgments was helpful.	11	100	0	0	0	0	0	0
The process of making the standard-setting judgments was easy to follow.	10	91	1	9	0	0	0	0

Table D11: Panel 2 Final Evaluation: Standard-Setting Process

	Too much time *N*	Too much time %	About the right amount of time *N*	About the right amount of time %	Too little time *N*	Too little time %
Small group JQC drafts	1	9	10	91	0	0
Whole group JQC consensus	0	0	11	100	0	0
Training and practice for making standard-setting judgments	0	0	11	100	0	0
Round 1 judgments (independent)	1	9	7	64	3	27
Round 2 judgments (with discussion)	1	9	10	91	0	0

Table D12: Panel 2 Final Evaluation: Influences in Standard-Setting Judgments

How influential was each of the following factors in guiding your standard-setting judgments?	Very influential *N*	Very influential %	Somewhat influential *N*	Somewhat influential %	Not influential *N*	Not influential %
The description of the just-qualified candidate	11	100	0	0	0	0
The round 2 discussion	9	82	2	18	0	0
The knowledge/skills required to answer each test item	8	73	3	27	0	0
The passing scores of other panel members	3	27	4	36	4	36
My own professional experience	6	55	5	45	0	0

Table D13: Panel 2 Final Evaluation: Comfort with the Panel's Recommendation

Question	Very comfort-able *N*	Very comfort-able %	Somewhat comfort-able *N*	Somewhat comfort-able %	Somewhat uncom-fortable *N*	Somewhat uncom-fortable %	Very uncom-fortable *N*	Very uncom-fortable %
Considering the process you followed, how comfortable are you with the panel's recommended cut score?	8	73	2	18	0	0	1	9

Table D14: Panel 2 Final Evaluation: Opinion of the Final Recommendation

Statement	Too low *N*	Too low %	About right *N*	About right %	Too high *N*	Too high %
Overall, the recommended passing score is:	1	9	10	91	0	0

Appendix E: Technical Notes

Standard Error of Judgment (SEJ)

The standard error of judgment (SEJ) is one way of estimating the reliability or consistency of a panel's standard-setting judgments. It indicates how likely it would be for several other panels of educators similar in makeup, experience, and standard-setting training to the current panel to recommend the same threshold score on the same form of the assessment. The SEJ assumes that panelists are randomly selected and that standard-setting judgments are independent. It is seldom the case that panelists are randomly sampled, and only the first round of judgments may be considered independent. The SEJ, therefore, likely underestimates the uncertainty of threshold scores (Tannenbaum & Katz, 2013).

The SEJ is calculated by dividing the standard deviation of the panelists' judgments (*SD*) by the square root of the number of panelists (*n*). The result serves as an estimate of the standard error of the mean (Brennan, 2002).

$$SEJ = \mathrm{SD} / \sqrt{n}$$

Outlier Analysis

An analysis of the data is conducted per panel. Judgments that are above or below 1.5 times the interquartile range for that panel are identified as outliers (High, 2000). ETS makes recommendations on the removal of *specific* outliers based on the observations of the panel facilitator. The panel facilitator reports whether or not the specified panelist was faithfully participating in the standard-setting process. The decision to accept the panel recommendation with or without the outlier data is solely at the discretion of the state.

Conditional Standard Error of Measurement (CSEM)

The conditional standard error of measurement (*CSEM*) for a test is computed from the study value (*SV*) of the recommended passing score and the number of selected-response items (*n*) on the test (see Lord, 1984):

$$CSEM = \sqrt{(SV)(n - SV)/(n - 1)}$$

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Biology (5236)

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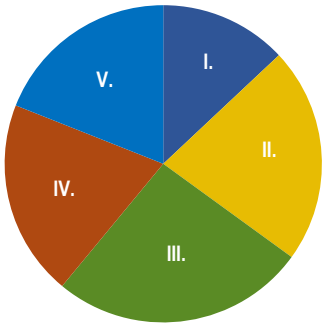
Biology (5236)

Test at a Glance

The *Praxis*® Biology test is designed to measure knowledge and competencies important for safe and effective beginning practice as a teacher of biology. Test takers have typically completed a bachelor's degree program with appropriate coursework in biology and education.

Test Name	Biology
Test Code	5236
Time	2.5 hours
Number of Questions	150 selected-response questions
Format	The test consists of a variety of selected-response questions, where you select one or more answer choices, and other types of questions. You can review the possible question types in "Understanding Question Types."
Test Delivery	Computer Delivered



Content Categories	Approximate Number of Questions	Approximate Percentage of Examination
I. Nature and Impact of Science and Engineering	19	13%
II. Cell Biology: Cell Structure and Function	33	22%
III. Genetics and Evolution	39	26%
IV. Diversity of Life and Organismal Biology	30	20%
V. Ecology: Organisms and Environments	29	19%

All questions assess content from the above Biology domains. More than 40 percent of questions integrate a Science and Engineering Practice, and approximately 25 percent of questions assess content applied to a Task of Teaching Science.

About The Test

On the Biology test, content topics span the biology curriculum, including content related to (I) Nature and Impact of Science and Engineering, (II) Cell Biology: Cell Structure and Function, (III) Genetics and Evolution, (IV) Diversity of Life and Organismal Biology, (V) Ecology: Organisms and Environments.

The assessment is designed and developed through work with practicing biology teachers, teacher educators, and higher education biology specialists to reflect the science knowledge teachers need to teach the biology curriculum and to reflect state and national standards, including the National Science Teaching Association Preparation Standards for biology. Content and practices measured reflect the Disciplinary Core Ideas (DCIs) and Science and Engineering Practices (SEPs) established by the National Research Council in A Framework for K-12 Science Education and included in the Next Generation Science Standards.

The 150 selected-response questions measure concepts, terms, phenomena, methods, applications, data analysis, and problem solving in science. A full list of the topics covered is provided in **Content Topics**.

Test takers can expect 40 percent or more of the questions on the test to integrate biology content knowledge with one or more of the SEPs, listed under **Science and Engineering Practices**.

Test takers will also find that approximately 25 percent of questions call for application of biology content and processes within a teaching scenario or an instructional task. Such questions—designed to measure applications of biology knowledge to the kinds of decisions and evaluations a teacher must make during work with students, curriculum, and instruction—situate biology content questions in tasks critical for teaching. Below, in **Tasks of Teaching Science**, is a list of tasks that are a routine part of biology instruction. These tasks, identified based on research on science instruction, have been confirmed by a national committee of teachers and teacher educators as important for effective teaching of secondary science.

This test may contain some questions that will not count toward your score.

Content Topics

This list details the topics that may be included on the test. All test questions cover one or more of these topics.

Discussion Questions

In this section, discussion questions are open-ended questions or statements intended to help test your knowledge of fundamental concepts and your ability to apply those concepts to classroom or real-world situations. We do **not** provide answers for the discussion questions but thinking about the answers will help improve your understanding of fundamental concepts and may help you answer a broad range of questions on the test. Most of the questions require you to combine several pieces of knowledge to formulate an integrated understanding and response. They are written to help you gain increased understanding and facility with the test's subject matter. You may want to discuss these questions with a teacher or mentor.

I. Nature and Impact of Science and Engineering

A. Nature of Science

1. Nature of scientific knowledge
   a. Observations and experiments provide evidence
   b. Understanding develops and changes over time in light of new evidence
   c. Science is interdisciplinary in nature (e.g., principles of chemistry and physics and earth science in biology)
   d. Scientific methodologies
   e. Scientific skills include observing, categorizing, comparing, generalizing, inferring, and concluding
   f. Distinguish between scientific laws, and scientific theories, and hypotheses
   g. Models are developed, revised, and applied to explain natural phenomena
2. Experimental design, data collection, and analysis
   a. Standard units of measurement, dimensional analysis, and unit conversion
   b. Scientific notation and use of significant figures
   c. Experimental design, including hypothesis development, identifying variables, and planning data collection
   d. Processing, organizing, and reporting of quantitative and qualitative data
   e. Error analysis, including identifying the sources and effects of error
   f. Interpreting, extrapolating, and drawing valid conclusions from data
3. Laboratory procedures
   a. Preparation of materials for classroom or field use
   b. Appropriate and safe use, storage, and disposal of chemicals and biological materials
   c. Appropriate and safe use and care of laboratory equipment
   d. Safety and emergency procedures for science laboratories

B. Science, Engineering, Technology, Society, and the Environment

1. Engineering design and the interdependence of science, engineering, and technology
   a. Defining problems, including identifying the success criteria and the constraints
   b. Designing solutions, including proposing and evaluating in terms of criteria, constraints, and limitations
   c. Optimizing the design, including systematic modification and refinement
   d. Engineering advances lead to important discoveries in science
   e. Science and technology drive each other forward
2. Impacts of science, technology, human activity, and natural phenomena on society and the environment
   a. Sources of air and water pollution
   b. Sources of greenhouse gases and impacts of global climate change
   c. Production, use, disposal, and recycling of consumer products
   d. Consequences of natural disasters, resource extraction, and industrial accidents
   e. Forestry, agriculture, wildlife, and fisheries practices
   f. Ocean, estuary, freshwater, and wetland degradation
   g. Conservation, including species protection and habitat preservation and restoration
   h. Renewable or sustainable use of energy and resource management
3. Applications of science in public health, medicine, and agriculture
   a. Epidemiology, disease, and medicine (e.g., epidemics/pandemics, HIV/AIDS, pathogens, vaccines)
   b. Biotechnology (e.g., genetic engineering, GMOs)
   c. Medical technologies for disease diagnosis and treatment (e.g., medical imaging, X-rays, radiation therapy)
   d. Ethical research concerns (e.g., use of stem cells and toxic chemicals)
   e. Ethical use of technology, genetic information, organisms, and cloning

Discussion Questions: Nature and Impact of Science and Engineering

- What is the most effective way to compare information obtained from television, a newspaper article, a Web site, and a scientific journal for accuracy? For understandability? For use in the classroom setting?
- A scientist studying nutrient requirements for a particular type of bacteria inoculates three flasks of culture medium with an equal number of bacteria. Extra glucose is added to one of the flasks, and extra lactose is added to another. The number of bacteria per milliliter is determined every two hours for a period of 12 hours. What type of graph is best used to represent the data?
- Describe how to prepare 1 liter of an 0.85% sodium chloride solution.

- If a solution is to be used to culture living cells, is it important to include a buffer in the solution? Explain.
- Name some of the most likely reasons for the increased number of emerging infectious diseases affecting humans in recent years.
- Why do many infectious diseases spread rapidly through temporary settlements established after an area is devastated by war or a natural disaster?
- Name a disease transmitted by aerosol spray of a sneeze, a disease transmitted through drinking water, and a disease transmitted by an insect or arthropod vector.
- What is the relationship between the materials of which many plastics are produced and nonrenewable resources?
- A significant threat to marine turtles is incidental capture, injury, or death as a result of commercial fishing practices. What procedure has been implemented to protect marine turtles that are caught in nets, and what government agencies have been involved in implementing the turtle protection?
- What are some potentially beneficial uses of embryonic stem cells? Why do some people object to the use of these cells in research and development?

II. Cell Biology: Cell Structure and Function

A. Basic biochemistry and metabolism of living organisms

1. Chemical structures and properties of biologically important molecules
   a. Atomic and molecular structures
   b. Chemical bonding
   c. Organic versus inorganic molecules
   d. Properties of water based on structure and bonding characteristics
   e. Major macromolecules, including nucleic acids, proteins, lipids, and carbohydrates
2. Dependency of biological processes on chemical principles developmental and content domains
   a. Chemical and physical gradients, and factors that influence the gradients
   b. Laws of thermodynamics
   c. Anabolic and catabolic reactions in metabolism
   d. Reduction-oxidation reactions in metabolism
3. Structure and function of enzymes and the factors that influence their activity
   a. Active site structure and substrate binding
   b. Energy profile of a reaction in the presence or absence of an enzyme
   c. Reaction kinetics, including the effects of temperature, pH, concentrations, and other molecules, including inhibitors

   d. Regulation, including cooperative binding and feedback inhibition
4. Major biochemical pathways and energy flow within an organism
   a. Cellular locations of biochemical pathways
   b. Structure and function of ATP
   c. Photosynthesis, including photosystems, electron transport, Calvin-Benson cycle
   d. Processes associated with aerobic and anaerobic cellular respiration and fermentation, including glycolysis, citric acid cycle, and oxidative phosphorylation
   e. Chemosynthesis as an alternative to photosynthesis

B. Structure and function of cells and the mechanisms of basic cellular processes

1. Characteristics of living versus nonliving things
   a. Cell theory
   b. Obtaining and transforming energy
   c. Growth and development
   d. Homeostasis: regulation and responses to the environment
   e. Reproduction
2. Structure and function of cells and organelles
   a. Prokaryotic versus eukaryotic cells, including organelles, cell walls, and chromosomes
   b. Plant cells versus animal cells
   c. Plasma/cell membranes
   d. Membrane-bound organelles and ribosomes
   e. Cytoskeleton and extracellular matrix
3. How cells maintain their internal environment and respond to external signals
   a. Selective permeability, including structure and function of phospholipid bilayer
   b. Active and passive transport
   c. Water movement, including osmolarity and water potential
   d. Cell surface proteins, cell communication, signal molecules, and signal transduction
   e. Exocytosis and endocytosis
   f. Negative-feedback and positive-feedback mechanisms
4. Eukaryotic cell division, the cell cycle, and regulation of the processes
   a. Cell cycle stages and checkpoints
   b. Mitosis, including functions, stages, and results
   c. Cytokinesis, including differences between animals and plants
   d. Cancer (e.g., unregulated checkpoints and cell proliferation)

Discussion Questions: Cell Biology: Cell Structure and Function

- What are the four most abundant elements in the human body?
- What are functional groups of organic molecules? How do the differing charges of functional groups influence the behavior of the functional groups, the structure of molecules bearing the functional groups, and the interactions of the molecules with water?
- Why are fats insoluble in water?

- Describe the structural and functional differences between starch and cellulose.
- What factors influence the rate at which an ion diffuses across a cell membrane?
- How is ATP involved in the transfer of usable energy between molecules?
- How do temperature, pH, and competitive or noncompetitive inhibitors influence enzyme activity?
- State some similarities and differences between aerobic and anaerobic respiration.
- Explain the benefit, at the cellular level, of producing ATP aerobically. After strenuous activity, one may feel a burning sensation in some muscles. What is responsible for the sensation?
- How does the consumption of too many carbohydrates lead to an increase in body fat?
- A rock is found with patches of an unfamiliar orange-colored flakey material on the surface. What possible features of the orange-colored material would indicate that the material is alive?
- What structures are likely to be found in a plant cell but not in an animal cell?
- What structures are likely to be found in an animal cell but not in a bacterium?
- What organelles are likely to be present in greater abundance in a cell that is secreting a large amount of protein than in a cell secreting very little protein?
- Describe the difference between active and passive transport. Compare simple diffusion, osmosis, and facilitated diffusion.
- If an individual is stranded in a lifeboat on an ocean, why is drinking seawater more harmful to the individual than drinking no water at all?
- Compare mitosis and meiosis: the stages, genetic makeup of daughter cells, unique features. Name the three cell cycle checkpoints. What criteria must be met at each of the checkpoints for a cell to progress through the cell cycle?
- In addition to killing many types of cancer cells, why does chemotherapy treatment cause side effects such as anemia, gastrointestinal distress, and hair loss?

III. Genetics and Evolution

A. Mechanisms of molecular biology and genetic transmission

1. Structure of nucleic acids and chromosomes
   a. Sugar-phosphate backbone and complementary base pairing
   b. DNA versus RNA
   c. Chromosome structure, including nucleosomes and telomeres
2. Transfer of genetic information
   a. Central dogma of molecular biology
   b. Process of DNA replication
   c. The process of RNA transcription
   d. Pre-mRNA processing in eukaryotes

e. The process of translation, including the role of mRNA, tRNA, rRNA and ribosomes
f. Gene regulation (e.g., promoters, enhancers, transcription factors, and posttranslational regulation)
g. Utilization of a genetic code chart
h. Protein synthesis in eukaryotes versus prokaryotes

3. Nature of mutations
   a. Causes of mutations, including recombination and mutagens
   b. Types of mutations, including substitution, deletion, insertion, inversion, and translocation
   c. Disorders resulting from point mutations, frameshift mutations, changes in chromosome structure, and changes in chromosome numbers
   d. Significance of somatic versus germ-line mutations
4. Laboratory techniques
   a. Microscopy
   b. Gel electrophoresis
   c. Spectrophotometry
   d. Polymerase chain reaction (PCR)
   e. Genome sequencing
   f. Gene therapy
   g. Protein sequence analysis
   h. Genetically engineered cells and transgenic organisms
   i. Chromosome analysis
5. Mendelian genetics
   a. Dominant and recessive alleles
   b. The law of independent assortment and the role of meiosis
   c. The law of segregation and the role of meiosis
   d. Monohybrid and dihybrid crosses
   e. Pedigree analysis
6. Non-Mendelian inheritance
   a. Gene linkage and mapping by recombination analysis
   b. Sex-linked inheritance
   c. Multiple alleles, codominance, and incomplete dominance
   d. Polygenic inheritance, epistasis, and pleiotropy
   e. Extranuclear inheritance, including mitochondrial and chloroplast inheritance
   f. Environmental influences, including epigenetics
   g. Pedigree analysis

B. Mechanisms of evolution as a consequence of genetic variation and factors affecting evolution

1. Sources of genetic variation
   a. Mutation
   b. Sexual reproduction, including crossing-over, random fertilization, segregation and independent assortment
   c. Horizontal genetic exchange, including conjugation, transformation, and transduction
2. Mechanisms of evolution
   a. Darwin-Wallace theories of reproductive fitness and natural selection
   b. Hardy-Weinberg equilibrium: calculations and factors that may alter the equilibrium

c. Effects of mutations, gene flow, genetic drift (including bottleneck and founder effects), and nonrandom mating (including sexual selection)
d. Artificial selection
e. Macroevolution versus microevolution
f. Patterns of evolution: convergent, divergent, coevolution, parallel evolution, adaptive radiation
g. Gradualism versus punctuated equilibrium
h. Mechanisms of speciation, including reproductive isolation and allopatric and sympatric speciation

3. Evidence supporting evolution
   a. Fossil record
   b. Biogeographical similarities
   c. Biodiversity over geological time
   d. Endosymbiosis
   e. Structural and developmental evidence, including homology, embryology and vestigial structures
   f. Molecular evidence, including universal genetic code, DNA, RNA, and amino acid sequence comparisons
   g. Direct observation of evolution (e.g., antibiotic resistance)
4. Models of evolution
   a. Molecular clock (mitochondrial DNA)
   b. Phylogenetic relationships, including cladograms and phylogenetic trees
5. Scientific explanations for the origin and early evolution of life on Earth
   a. Abiotic synthesis of organic compounds (e.g., the Miller-Urey experiment)
   b. Development of self-replicating molecules, including the RNA-first hypothesis
   c. Biological influences on atmospheric composition, including the role of photosynthesis
6. Factors that lead to the extinction of species
   a. Lack of genetic diversity
   b. Interspecific competition
   c. Meteorite impacts and the effects of geological processes, including tectonic plate movement and volcanism
   d. Human-caused environmental pressures, including climate and habitat change

Discussion Questions: Genetics and Evolution

- Compare the structure of DNA and RNA: number of strands, flexibility, molecular composition.
- During DNA synthesis at a replication fork, why is one new strand of DNA synthesized in a continuous fashion and the other new strand synthesized in a discontinuous fashion?
- What is the signal for the start site of transcription? What is the signal for the start site of translation?
- What causes human liver cells to be structurally and functionally different from human muscle cells?

- In what types of cells must a mutation be found for the mutation to be passed on to offspring? Mutations in what types of cells are not inherited by offspring?
- What types of molecules are typically separated by gel electrophoresis? Where are the largest molecules in a sample typically found with respect to the wells in which the samples are loaded onto the gel?
- What type of microscope is typically used to examine live, anaesthetized fruit flies? What type of microscope is typically used to examine thin sections of cells?
- What are the roles of plasmids and restriction endonucleases in DNA cloning?
- How are viruses used in gene therapy?
- To determine whether a plant with purple flowers is homozygous or heterozygous with respect to flower color, the plant should be crossed with another pea plant with what genotype and phenotype?
- Name a genetic disorder that is most commonly caused by fusion of a gamete with a normal chromosome number with another gamete that contains two copies of a particular chromosome. What is the most likely cause of the abnormal chromosome number in the gamete?
- Describe the relationship between DNA mutation, skin cancer, and prolonged exposure to the sun.
- A particular genetic trait is inherited in an autosomal recessive fashion. If one out of every 400 individuals has the trait, what percent of the population are expected to be carriers of the trait?
- A particular population exhibits variation in certain traits. For natural selection to act on the variations, what two requirements must be met by the variations?
- As a result of habitat fragmentation, a small population of leopards becomes isolated from the larger original population. As time progresses, are allele frequencies and genetic variation expected to differ between the original population and the isolated population? If so, describe how and why they will differ.
- What structural and functional characteristics of mitochondria and chloroplasts provide evidence to support the theory of endosymbiosis?
- Horses and donkeys can mate and produce viable offspring, but horses and donkeys are considered to be separate species. Explain why this is so.
- What organic compounds were produced in the Miller-Urey experiment? How did the design of the experiment support the hypothesis that organic compounds are likely to have arisen from abiotic materials present in the atmosphere of early Earth?

IV. Diversity of Life and Organismal Biology

A. Diversity of Life

1. Biological classification of organisms
   a. Taxonomic hierarchy, including domains and kingdoms
   b. Binomial nomenclature
2. Defining characteristics of viruses, eubacteria, archaea, protists, fungi, plants, and animals
   a. Structural characteristics of viruses, eubacteria, archaea, protists, fungi, plants, and animals
   b. Cellular organization, including unicellular versus multicellular
   c. Modes of nutrition, including autotrophic versus heterotrophic
   d. Modes of reproduction/replication
3. Organizational hierarchy
   a. Cells
   b. Tissues
   c. Organs
   d. Organ systems
4. Cell differentiation and specialization
   a. Differential gene expression
   b. Stem cells, including characteristics and sources

B. Animal Biology

1. Characteristics of animals
   a. Major evolutionary trends, including body plans, body cavities, cephalization and multicellularity
   b. Modes of reproduction (sexual versus asexual)
   c. Modes of temperature regulation (endotherm versus ectotherm)
2. Structure and function of major human organ systems
   a. Cardiovascular and respiratory
   b. Digestive and excretory
   c. Immune
   d. Musculoskeletal
   e. Nervous and endocrine
   f. Reproductive
3. How homeostasis is maintained in organisms
   a. Role of organs or tissues, such as the kidney, adrenals, and hypothalamus, and pituitary
   b. Role of hormones, such as insulin, antidiuretic hormone, and sex hormones
   c. Feedback mechanisms, including negative and positive
   d. Role of behaviors, including diurnal, nocturnal, hibernation, and basking
4. Reproduction, development, and growth in organisms
   a. Gamete formation, including the stages of meiosis and changes in chromosome number
   b. Fertilization, including internal versus external
   c. Embryonic development
   d. Patterns of growth and development, including metamorphosis
5. Behavior
   a. Innate versus learned behaviors
   b. Territoriality
   c. Group versus individual
   d. Social behavior (e.g., hunting, flocking, migration, altruism)

C. Plant Biology

1. Characteristics of plants
   a. Vascular versus nonvascular plants
   b. Angiosperms versus gymnosperms
   c. Tissues, including dermal, ground, and vascular (xylem and phloem)
   d. Structure of organs, including flowers, stems, leaves, and roots
2. How plants obtain, transport, and store materials
   a. Roles of roots, stems, and leaves
   b. Water and nutrient transport, including xylem and transpiration through stomata
   c. Production, transport, and storage of products of photosynthesis, including simple and complex carbohydrates, phloem transport, and storage structures
3. Reproduction, growth and development
   a. Gametogenesis
   b. Alternation of generations, including gametophyte and sporophyte
   c. Pollination/fertilization strategies and seed/spore propagation
   d. Germination and growth
4. How plants respond to the environment
   a. Plant tropisms
   b. Plant defenses, including physical and chemical
   c. Major plant hormones, including auxin, gibberellins, ethylene, and cytokinins

Discussion Questions: Diversity of Life and Organismal Biology

- Compare the structure of chromosomes in eukaryotes, bacteria, and archaea.
- Carl Woese based his phylogenetic classification on analyses of what macromolecule? As a result of Woese's analyses, how was the tree of life revised from that based on morphological similarities?
- What are the sources of carbon dioxide, oxygen, and water used by a plant in photosynthesis or cellular respiration? Through what structures and by what processes do these molecules enter and exit a plant?
- Describe the characteristics of mushrooms that distinguish them as fungi rather than viruses, bacteria, protists, plants, or animals.
- Give an example of an animal with radial symmetry and one with bilateral symmetry. Is cephalization likely to be a feature of either one of these forms of symmetry? If so, of which?
- Describe the features of body cavities by which triploblastic animals can be distinguished as coelomates, pseudocoelomates, or acoelomates. Give an example of an animal that is a coelomate, one that is a pseudocoelomate, and one that is an acoelomate.
- Trace the flow of a drop of blood from the right atrium of the heart as the blood passes through the heart, the lungs, and one complete circuit of the human circulatory system.

- Describe the two ways in which ventilation in birds is particularly efficient in comparison to ventilation in most mammals.
- Describe the digestion of proteins in the human digestive system, specifically the enzymes involved, the location of the cells that produce the enzymes, and the organs in which the digestion occurs.
- Name two ways by which the skin plays a role in thermoregulation in humans.
- Name four features of monocots that can frequently (although not always) be used to distinguish monocots from eudicots.
- What materials are transported in the xylem? What materials are transported in the phloem? In which direction does material flow in each type of vessel?
- In what root tissue are new root cells produced? Name four important functions of plant roots. Under what circumstance are stomata typically closed? Describe the mechanism by which ion flow and osmosis regulate the opening and closing of guard cells.
- Prairie dogs typically live in large colonies and dig extensive underground systems of burrows. If a predator approaches a colony, a prairie dog who spots the predator will sound a loud alarm that alerts the other members of the colony, most of whom will dive into the burrows and hide. The prairie dog that sounds the alarm is, however, drawing attention to itself and may be attacked by the predator. Explain why this behavior is often considered to be an example of altruism in animals.

V. Ecology: Organisms and Environment

A. Biosphere organization and factors affecting organism interactions and population size

1. Hierarchical structure of the biosphere
   a. Biomes
   b. Ecosystems
   c. Communities
   d. Populations
   e. Organisms
2. Relationships within and between species
   a. Symbiotic relationships including mutualism, parasitism, commensalism
   b. Predator – prey relationship, including evolutionary adaptations
   c. Competition
   d. Keystone species
3. Relationships among reproductive strategies, demographics, and population growth
   a. Sexual versus asexual reproduction
   b. r-strategists versus K-strategists
   c. Exponential growth
   d. Logistic growth and carrying capacity
   e. Population demographics
4. Influence of biotic and abiotic components on community structure
   a. Limiting factors

b. Habitat and niche
c. Competition and predation
d. Density-dependent versus density-independent factors

5. Human impacts on ecosystems
   a. Habitat destruction (e.g., deforestation, fragmentation, urbanization and agriculture)
   b. Pollution (e.g., plastics, acid precipitation, ozone layer destruction (CFCs))
   c. Climate change, including greenhouse gases and ocean acidification
   d. Introduced and reintroduced species and invasive species
   e. Overconsumption of resources
   f. Remediation (e.g., reforestation, movement corridors, captive breeding programs, and biotechnology)

B. Characteristics of biomes, energy flow in ecosystems, and major biogeochemical cycles

1. Ecological succession
   a. Primary versus secondary succession
   b. Biomass, diversity, productivity, and habitat changes during succession
   c. Temporal and spatial disturbances (e.g., climate, fire, and disease)
2. Types of biomes and energy flow in the biomes
   a. Characteristics of aquatic and terrestrial biomes
   b. Trophic levels, including pyramids of numbers, biomass, and energy
   c. Food chains and food webs and trophic cascades
   d. Flow of energy versus cycling of matter, including biomagnification
3. Biogeochemical cycles, including biotic and abiotic components
   a. Water cycle
   b. Carbon cycle
   c. Nitrogen cycle
   d. Phosphorus cycle

Discussion Questions: Ecology: Organisms and Environment

- Vegetable crops growing on a commercial farm are damaged by an unknown disease or pest with a 70 to 90 percent mortality rate. The farmer claims that he has not changed his procedures for watering and fertilizer application. Formulate a hypothesis about the causative agent, given the observations above. What type of experiments should be used to help support or falsify the hypothesis?
- Distinguish between a population of organisms and a community of organisms.
- Name the two most common limiting factors to primary production in aquatic ecosystems.
- Draw the predicted growth curve for a population introduced into a new environment in which resources are initially unlimited. How will the shape of the curve change as the population reaches carrying capacity? What factors might determine the carrying capacity?
- Compare primary and secondary succession. Is soil initially present in

the environments where each type of succession occurs? What are the first organisms that typically colonize the environment where each type of succession occurs?
- What types of natural disturbances are most likely to lead to primary ecological succession?
- What kind of natural disturbances are most likely to lead to secondary succession? In the immediate aftermath of a disturbance, what will be the most likely effect on biodiversity of the region?
- Why is the density of water important to freshwater pond ecosystems in temperate regions?
- Why is the air temperature along the coast generally higher than the air temperature of inland areas in the same regions? How does this influence the types of organisms present in each region?
- A large percent of the mice in a particular population are infected by a virus that is usually fatal. What is the relationship between the virus and the mice? How will the viral infection most likely ultimately affect other members of the ecosystem such as grasses and owls?
- What is meant by acid precipitation, and how is it harmful? How do human activities contribute to acid precipitation?
- How do lawn and agricultural fertilizers get into the natural water system? Why are the fertilizers harmful to many aquatic and semi-aquatic organisms or to any organisms that depend on the water supply?
- What are the major reservoirs of carbon in the biosphere?
- What is the major natural route by which nitrogen enters an ecosystem?
- What are the major biotic and abiotic processes that drive the water cycle?

Science and Engineering Practices

The SEPs represent eight practices that scientists and engineers—and students and teachers—use to investigate the world and to design and build systems. Many test questions will integrate one or more of these practices.

1. Asking questions (for science) and defining problems (for engineering)
   - Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
   - Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
   - Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables.
   - Ask questions to clarify and refine a model, an explanation, or an engineering problem.
   - Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.

- Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design.
- Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.

2. Developing and using models
   - Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria.
   - Design a test of a model to ascertain its reliability.
   - Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
   - Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.
   - Develop a complex model that allows for manipulation and testing of a proposed process or system.
   - Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.
3. Planning and carrying out investigations
   - Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.
   - Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
   - Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts.
   - Select appropriate tools to collect, record, analyze, and evaluate data.
   - Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.
   - Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.

4. Analyzing and interpreting data
   - Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
   - Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.
   - Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.
   - Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.
   - Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.
   - Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.
5. Using mathematics and computational thinking
   - Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.
   - Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.
   - Apply techniques of algebra and functions to represent and solve scientific and engineering problems.
   - Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world.
   - Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL , kg/m^3 , acre-feet, etc.).
6. Constructing explanations (for science) and designing solutions (for engineering)
   - Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.
   - Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
   - Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.

- Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

7. Engaging in argument from evidence
   - Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.
   - Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
   - Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions.
   - Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.
   - Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence.
   - Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).
8. Obtaining, evaluating, and communicating information
   - Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
   - Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
   - Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.
   - Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.

- Communicate scientific and/or technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Tasks of Teaching Science

This list includes instructional tasks that teachers engage in that are essential for effective General Science teaching. Many test questions will measure content through application to one or more of these tasks.

Scientific Instructional Goals, Big Ideas, and Topics

1. Selecting or sequencing appropriate instructional goals or big ideas for a topic
2. Identifying the big idea or instructional goal of an instructional activity
3. Choosing which science ideas or instructional activities are most closely related to a particular instructional goal
4. Linking science ideas to one another and to particular activities, models, and representations within and across units

Scientific Investigations and Demonstrations

5. Selecting investigations or demonstrations, including virtual, that facilitate understanding of disciplinary core ideas, scientific practices, or crosscutting concepts
6. Evaluating investigation questions for quality (e.g., testable, empirical)
7. Determining the variables, techniques, or tools that are appropriate for use by students to address a specific investigation question
8. Critiquing scientific procedures, data, observations, or results for their quality, accuracy, or appropriateness
9. Supporting students in generating questions for investigation or identifying patterns in data and observations

Scientific Resources (texts, curriculum materials, journals, and other print and media-based resources)

10. Evaluating instructional materials and other resources for their ability to address scientific concepts; engage students with relevant phenomena; develop and use scientific ideas; promote students' thinking about phenomena, experiences, and knowledge; take account of students' ideas and background; and assess student progress
11. Choosing resources that support the selection of accurate, valid, and appropriate goals for science learning

Student Ideas (including common misconceptions, alternate conceptions, and partial conceptions)

12. Analyzing student ideas for common misconceptions regarding intended scientific learning
13. Selecting diagnostic items and eliciting student thinking about scientific ideas and practices to identify common student

misconceptions and the basis for those misconceptions

14. Developing or selecting instructional moves, approaches, or representations that provide evidence about common student misconceptions and help students move toward a better understanding of the idea, concept, or practice

Scientific Language, Discourse, Vocabulary, and Definitions

15. Selecting scientific language that is precise, accurate, grade-appropriate, and illustrates key scientific concepts
16. Anticipating scientific language and vocabulary that may be difficult for students
17. Modeling the use of appropriate verbal and written scientific language in critiquing arguments or explanations, in describing observations, or in using evidence to support a claim, etc.
18. Supporting and critiquing students' participation in and use of verbal and written scientific discourse and argumentation

Scientific Explanations (includes claim, evidence, and reasoning)

19. Critiquing student-generated explanations or descriptions for their generalizability, accuracy, precision, or consistency with scientific evidence
20. Selecting explanations of natural phenomena that are accurate and accessible to students

Scientific Models and Representations (analogies, metaphors, simulations, illustrations, diagrams, data tables, performances, videos, animations, graphs, and examples)

21. Evaluating or selecting scientific models and representations that predict or explain scientific phenomena or address instructional goals
22. Engaging students in using, modifying, creating, and critiquing scientific models and representations that are matched to an instructional goal
23. Evaluating student models or representations for evidence of scientific understanding
24. Generating or selecting diagnostic questions to evaluate student understanding of specific models or representations
25. Evaluating student ideas about what makes for good scientific models and representations

Biology (5236) Sample Test Questions

The sample questions that follow represent a number of the types of questions and topics that appear on the test. They are not, however, representative of the entire scope of the test in either content or difficulty. Answers with explanations follow the questions.

Directions: Each of the questions or incomplete statements below is followed by suggested answers or completions. Select the one that is best in each case.

1. The transfer of pollen from one flower to another while a bee is collecting nectar is an example of which of the following relationships?

   (A) Commensalism
   (B) Mutualism
   (C) Competition
   (D) Parasitism

2. Taxonomic classification of two different organisms as members of the same order indicates that they are also members of the same

   (A) family
   (B) genus
   (C) phylum
   (D) species

3. Which of the following changes typically occurs in a eukaryotic cell as it progresses through the S phase of the cell cycle?

   (A) The nuclear membrane breaks down.
   (B) The quantity of DNA in the cell doubles.
   (C) The cell membrane pinches inward to form a cleavage furrow.
   (D) The duplicated chromosomes line up along the equatorial plate.

4. Which **TWO** of the following characteristics are shared by members of the kingdom Fungi?

   (A) Can perform photosynthesis
   (B) Have cell walls that contain chitin
   (C) Secrete digestive enzymes into the surrounding environment
   (D) Have circular chromosomes that are unprotected by a nuclear membrane

5. The population of a particular mammalian species has dwindled to less than 1,000 individuals. Which of the following is most likely to cause the population to become extinct?

   (A) Absence of interspecific competition
   (B) Increased gene flow
   (C) Presence of disruptive selection
   (D) Decreased genetic diversity

6. Which of the following visual aids will best support an investigation of energy flow through the organisms in a particular ecosystem?

   (A) A cladogram
   (B) A Punnett square
   (C) A diagram of a food web
   (D) A topographic map

7. Which of the following is a technique used to determine the three-dimensional structure of a protein at high resolution?

   (A) Flow cytometry
   (B) Immunoprecipitation
   (C) Polyacrylamide gel electrophoresis
   (D) X-ray crystallography

8. Which of the following terms refers to the collective evidence that links the origin of some eukaryotic organelles to prokaryotes?

   (A) Hybrid inviability
   (B) Heterozygote advantage
   (C) The endosymbiotic theory
   (D) The germ theory of disease

9. A segmented body is a key characteristic of the members of which of the following animal phyla?

   (A) Annelida
   (B) Cnidaria
   (C) Nematoda
   (D) Porifera

10. A teacher asks students to identify a type of organism that reproduces primarily through asexual reproduction. Which of the following is the most accurate response?

    (A) A whale
    (B) A shark
    (C) A maple tree
    (D) A bacterium

11. Students spread bacteria on several slabs of solid culture medium. Some of the slabs were prepared from a culture medium that contained glucose, whereas the remaining slabs were prepared from a culture medium that lacked glucose or any other simple sugar. The students placed the inoculated slabs in an incubator overnight and recorded observations the following day. The students found that colonies of bacteria were visible only on the glucose-containing slabs. Which of the following ideas is most closely linked to the results of the experiment?

    (A) Living things adapt to their environment.
    (B) Living things require a source of energy.
    (C) Living things are sensitive and respond to stimuli.
    (D) Living things can move from one location to another.

12. A teacher is preparing a lesson on how biotechnology is used in research. Which of the following is an example of how biotechnology is used to produce transgenic organisms?

    (A) Selectively breeding dogs to maximize specific behaviors
    (B) Editing the DNA of rice plants to introduce specific base-pair substitutions
    (C) Inserting a jellyfish gene into the genome of different strains of mice
    (D) Translocating deer from a large population to a small, isolated population

13. A segment of a messenger RNA molecule has the following nucleotide sequence.

    5′-AUGGCUCUCGAGAGAUAA-3′

    If the first codon is a start codon and the last codon is a stop codon, how many amino acids are encoded in the nucleotide sequence?

    (A) Three
    (B) Five
    (C) Six
    (D) Nine

14. To link a discussion about the mechanisms of evolution to a previous lesson on molecular biology, a teacher asks students to identify the principal mechanism by which new alleles of a gene are produced. Which of the following is the most accurate response?

    (A) Fertilization
    (B) Mutation
    (C) Transcription
    (D) Translation

15. A teacher asks students to describe what will likely happen to a body cell when the concentration of solutes in the extracellular fluid decreases as a result of excessive water consumption. Which of the following student responses provides the most accurate reasoning?

    (A) "The extracellular fluid will become hypotonic to the cytosol, resulting in a net movement of water into the cell by osmosis."
    (B) "The extracellular fluid will become hypotonic to the cytosol, resulting in a net movement of water out of the cell by osmosis."
    (C) "The extracellular fluid will become hypertonic to the cytosol, resulting in a net movement of water into the cell by osmosis."
    (D) "The extracellular fluid will become hypertonic to the cytosol, resulting in a net movement of water out of the cell by osmosis."

16. Students will isolate DNA from yeast cells that result from a genetic cross. The students will then determine which of two different alleles of a certain gene are present in each sample of DNA. Which **THREE** of the following techniques are most appropriate for the students to use for analyzing the results of the genetic cross?

    (A) Agarose gel electrophoresis
    (B) Restriction digestion
    (C) NMR spectroscopy
    (D) PCR

17. Students and their teacher are discussing different models that explain how concentration gradients are established and maintained across cell membranes. The teacher tells the students that a certain uncharged molecule has a higher concentration outside a cell than inside the cell. The teacher then asks the students to propose a way in which the cell can maintain the molecule's concentration gradient. Which of the following student responses demonstrates the most accurate reasoning?

    (A) "The cell can use cytosolic enzymes to convert the molecule to a different molecule."
    (B) "The cell can activate biochemical pathways that will produce more of the molecule inside the cell."
    (C) "The cell can turn on membrane proteins that pump the molecule from the surrounding environment to the inside of the cell."
    (D) "The cell can open channel proteins that will allow some of the molecules to diffuse across the plasma membrane into the cell."

18. Students conducted a survey of the invertebrates that were present at several different ponds. For each pond, the students recorded the different types of invertebrates that were observed and the relative abundance of each type. Which of the following characteristics can the students compare most directly using the data collected in the survey?

    (A) Dissolved oxygen levels in the different ponds
    (B) Diversity of the different communities
    (C) Primary productivity of the different ecosystems
    (D) Climate change at the different locations

19. A student wonders whether molecule X affects a particular enzyme-catalyzed reaction through competitive inhibition. To investigate, the student proposes an experiment in which the initial reaction velocity is the dependent variable. If the concentrations of molecule X and the enzyme are held constant, then the independent variable in the student's experiment should be which of the following?

    (A) The reaction temperature
    (B) The concentration of the buffer
    (C) The initial substrate concentration
    (D) The pH of the reaction solution

20. Students use a computer simulation to investigate the outcome of a genetic cross between a true-breeding line of fruit flies with sepia eyes and a true-breeding line of fruit flies with wild-type eyes. The teacher recommends that the students allow the flies in the F_1 generation to interbreed and produce an F_2 generation. The teacher then asks the students whether the results of the simulation support a claim that the sepia-eyes trait exhibits an autosomal recessive mode of inheritance.

    If the results support the claim, flies that have sepia eyes will make up approximately what percent of the F_2 generation?

    (A) 25%
    (B) 50%
    (C) 75%
    (D) 100%

21. A student is preparing a poster to show the proposed evolutionary relationships among several different species. Which of the following types of representations should the student use for the poster?

    (A) A histogram
    (B) A flow chart
    (C) A scatterplot
    (D) A phylogenetic tree

22. Recently, seasonal dead zones in low-oxygen waters have been occurring annually in the Gulf of Mexico near the mouth of the Mississippi River. The dead zones result from the rapid growth of photosynthetic phytoplankton and their subsequent decay by oxygen-depleting microbes in the water column. Which of the following changes most likely triggers the rapid growth of the photosynthetic phytoplankton?

    (A) A decrease in competition from other marine phytoplankton during the summer months
    (B) A decrease in the light level in surface waters as day length starts to shorten after the summer solstice
    (C) An increase in predation by marine larvae and other zooplankton during the summer months
    (D) An increase in the influx of nutrients derived from chemical fertilizers that are high in nitrogen and phosphorus

23. Damage to the sinoatrial node in the human heart is most likely to result in which of the following?

    (A) Disruption of the rate and timing of cardiac muscle contractions
    (B) Blockage of valve closure between the atria and the ventricles
    (C) Mixing of blood in the right and left atria
    (D) Decrease in blood pressure in the pulmonary artery

24. A teacher tells students that the hydrolysis of one molecule of lactose produces one molecule of glucose and one molecule of galactose. The teacher then asks the students to use the information to identify a term that describes a molecule of lactose. Which of the following responses is the most accurate?

    (A) Amino acid
    (B) Disaccharide
    (C) Fatty acid
    (D) Nucleotide

25. Which of the following scientific disciplines resulted primarily from the development of high-speed, low-cost methods for determining and analyzing DNA sequences?

    (A) Conservation ecology
    (B) Genomics
    (C) Histology
    (D) Plant breeding

26. A teacher asks students to explain how the presence of lignin is an adaptation that helps plants survive in terrestrial habitats. The teacher encourages the students to provide reasoning to support their explanations. Which of the following written responses provides the most accurate reasoning?

    (A) Lignin catalyzes the synthesis of amino acids inside cells, allowing plants to make proteins.
    (B) Lignin attracts pollinators like birds and insects, allowing plants to reproduce on land.
    (C) Lignin absorbs light energy, allowing plants to make sugars by the process of photosynthesis.
    (D) Lignin provides structural support, allowing plants to grow tall and compete better for sunlight.

27. If 35 percent of a sample of double-stranded DNA is adenine, what percent of the DNA is cytosine?

    (A) 10 percent
    (B) 15 percent
    (C) 30 percent
    (D) 70 percent

28. A teacher asks students to describe the most likely mechanism by which the seeds of a blueberry plant will be dispersed. Which of the following written responses demonstrates the most accurate understanding?

    (A) The blueberry plant will release the seeds into the air, and the blueberry seeds will be blown by the wind to a new location far away.
    (B) The plant's blueberries will disintegrate, and the seeds inside will fall to the ground and later stick to the fur of an animal that walks by.
    (C) The blueberries produced by the plant will be eaten by an animal, and the blueberry seeds will be excreted in the animal's droppings at a new location.
    (D) The blueberries on the plant will ripen and build up lots of gas, and eventually the seeds will be shot out of ripe blueberries to a location far away from the plant.

29. A teacher presents students with images of a cell. Which **TWO** of the following questions will best help the students determine whether the images are of a eukaryotic cell or a prokaryotic cell?

    (A) Does the cell contain ribosomes?
    (B) Does the cell contain mitochondria?
    (C) Does the cell contain chromosomal DNA?
    (D) Does the cell contain a membrane-enclosed nucleus?

30. Stomatal opening in plants requires an increase in the rate at which guard cells take up which of the following?

    (A) Iodine atoms
    (B) Nitrogen gas
    (C) Potassium ions
    (D) Sucrose molecules

31. Which of the following is the most likely benefit of periodic natural wildfires in some forest ecosystems?

    (A) The fires remove dead and decaying plant matter, reducing the risk of more intense and destructive fires.
    (B) The fires leach nutrients from the soil, preventing the germination of plants that might compete with native species.
    (C) The fires drive off herbivores whose plant-based diets reduce the amount of vegetation.
    (D) The fires dry out the soil and decrease the chance of flooding after heavy rains.

32. Students are creating a poster of a eukaryotic cell that shows the subcellular locations of metabolic processes associated with cellular respiration. The students should indicate on their poster that enzymes located in the mitochondrial matrix most directly facilitate which of the following processes?

    (A) Citric acid cycle
    (B) Fermentation
    (C) Glycolysis
    (D) Oxidative phosphorylation

33. A gas phase is generally absent from which of the following biogeochemical cycles?

    (A) Water
    (B) Carbon
    (C) Sulfur
    (D) Phosphorus

34. Hemophilia is a rare X-linked recessive disorder in which the body has a reduced ability to form blood clots. If a woman with hemophilia has a child with a man who does not have hemophilia, what is the chance that the child will be a carrier of the disorder?

    (A) 0%
    (B) 25%
    (C) 50%
    (D) 100%

35. Students designed an experiment for investigating how environmental conditions affect the rate of carbon dioxide release by corn seedlings. In the experiment, the students will put nearly identical corn seedlings into separate test tubes containing a carbon dioxide indicator solution. The students will then seal the test tubes and place them in different locations, as indicated in the following table. The students will determine the rates of carbon dioxide release by monitoring changes in the indicator solutions.

Test Tube	Location of the Test Tube	Light Source
1	In a refrigerator	Absent
2	On a table in a classroom	Present
3	In boiling water	Present

Which **THREE** of the following suggestions will best help the students improve their experimental design?

(A) Place a light source inside the refrigerator.
(B) Use seedlings of three different plant species.
(C) Use water maintained at 35°C instead of boiling water.
(D) Increase the number of seedlings in each treatment group.

36. A teacher asks students whether genetic drift is more likely to occur in a large population or a small population. The teacher specifies that the students should provide reasoning to support their answer. Which of the following written responses demonstrates the most accurate understanding of genetic drift?

(A) It is more likely to happen in a large population, because the population has more alleles to be lost.
(B) It is more likely to happen in a large population, because more offspring are produced than in a small population.
(C) It is more likely to happen in a small population, because the members of the small population are not as healthy as are the members of the large population.
(D) It is more likely to happen in a small population, because random events can have a greater effect on allele frequencies in a small population than in a large population.

37. A teacher asks students to describe a type of electric power generation that relies on a nonrenewable resource. Which of the following responses demonstrates the most accurate understanding of the term "nonrenewable resource"?

    (A) Generating electric power by burning natural gas
    (B) Producing electric power by allowing water to flow through a dam
    (C) Converting wind energy to electric energy by using wind turbines
    (D) Producing electric energy by harnessing light energy with solar panels

38. In vertebrate embryos, which of the following developmental processes most directly results in the formation of the three primary germ layers?

    (A) Neurulation
    (B) Blastula formation
    (C) Cleavage
    (D) Gastrulation

Biology (5236) Answers

1. Option (B) is correct. Because both the bee and the flowering plant benefit from the interaction, the ecological relationship is best described as mutualism.

Topic	V. Ecology: Organisms and Environment
Subtopic	A. Biosphere organization and factors affecting organism interactions and population size

2. Option (C) is correct. A phylum is a more inclusive level of classification than an order. As such, members of the same order are also members of the same phylum.

Task of Teaching Science	15. Selecting scientific language that is precise, accurate, grade-appropriate, and illustrates key scientific concepts
Topic	IV. Diversity of Life and Organismal Biology
Subtopic	A. Diversity of Life

3. Option (B) is correct. During the S phase of the cell cycle, the quantity of DNA in a eukaryotic cell doubles as a result of DNA replication. After the S phase, each of the cell's chromosomes is composed of two identical chromatids that will separate during cell division.

Topic	II. Cell Biology: Cell Structure and Function
Subtopic	B. Structure and function of cells and the mechanisms of basic cellular processes

4. Options (B) and (C) are correct. Fungi are heterotrophic eukaryotes that share the characteristics of having chitin-containing cell walls and carrying out external digestion by secreting digestive enzymes into the surrounding environment.

Topic	IV. Diversity of Life and Organismal Biology
Subtopic	A. Diversity of Life

5. Option (D) is correct. As a population of organisms gets smaller, the population's gene pool also gets smaller, resulting in a decrease in genetic diversity. With less genetic diversity, the population will be more vulnerable to disease, natural disasters, and extreme changes in the environment.

Topic	III. Genetics and Evolution
Subtopic	B. Mechanisms of evolution as a consequence of genetic variation and factors affecting evolution

6. Option (C) is correct. A diagram of a food web is typically used to represent the interconnected feeding relationships in a community. Students can use diagrams of food webs to investigate the flow of energy through the organisms of different ecosystems.

Science and Engineering Practice	8. Obtaining, evaluating, and communicating information
Task of Teaching Science	10. Evaluating instructional materials and other resources for their ability to address scientific concepts; engage students with relevant phenomena; develop and use scientific ideas; promote students' thinking about phenomena, experiences, and knowledge; take account of students' ideas and background; and assess student progress
Topic	V. Ecology: Organisms and Environment
Subtopic	B. Characteristics of biomes, energy flow in ecosystems, and major biogeochemical cycles

7. Option (D) is correct. X-ray crystallography is a technique that relies on an analysis of x-ray diffraction patterns to obtain a three-dimensional molecular structure from a crystal. If a protein can be isolated from a biological source and crystallized, a high-resolution structure of the protein can often be determined using x-ray crystallography.

Science and Engineering Practice	3. Planning and carrying out investigations
Topic	I. Nature and Impact of Science and Engineering
Subtopic	A. Nature of Science

8. Option (C) is correct. The endosymbiotic theory proposes that some eukaryotic organelles have a prokaryotic origin. Evidence in support of the theory includes the observation that organelles such as mitochondria, chloroplasts, and the nucleus have a double membrane. Also, mitochondria and chloroplasts have DNA genomes that are separate from the nuclear DNA genome, and the organelles reproduce by a process of binary fission.

Topic	III. Genetics and Evolution
Subtopic	B. Mechanisms of evolution as a consequence of genetic variation and factors affecting evolution

9. Option (A) is correct. Organisms in the phylum Annelida share the characteristic of body segmentation. The phylum Annelida includes earthworms, as well as leeches, bristle worms, and many other marine and freshwater species.

Topic	IV. Diversity of Life and Organismal Biology
Subtopic	B. Animal Biology

10. Option (D) is correct. Bacteria typically reproduce by a process of binary fission, which is a type of asexual reproduction.

Task of Teaching Science	18. Supporting and critiquing students' participation in and use of verbal and written scientific discourse and argumentation
Topic	V. Ecology: Organisms and Environment
Subtopic	A. Biosphere organization and factors affecting organism interactions and population size

11. Option (B) is correct. Glucose is a source of stored chemical energy that is accessible to many types of bacteria. The observation that colonies of bacteria were visible only on the glucose-containing slabs demonstrates that the bacteria are living things that require a source of energy.

Science and Engineering Practice	7. Engaging in argument from evidence
Task of Teaching Science	4. Linking science ideas to one another and to particular activities, models, and representations within and across units
Topic	II. Cell Biology: Cell Structure and Function
Subtopic	B. Structure and function of cells and the mechanisms of basic cellular processes

12. Option (C) is correct. A transgenic organism is an organism that contains genetic material from an unrelated organism. The foreign genetic material is often a gene that was isolated from the genome of one species and inserted into the genome of another species through the use of genetic engineering techniques. Inserting a jellyfish gene into the mouse genome is an example of using biological engineering to produce transgenic organisms.

Science and Engineering Practice	8. Obtaining, evaluating, and communicating information
Task of Teaching Science	3. Choosing which science ideas or instructional activities are most closely related to a particular instructional goal
Topic	I. Nature and Impact of Science and Engineering
Subtopic	B. Science, Engineering, Technology, Society, and the Environment

13. Option (B) is correct. A codon consists of three adjacent nucleotides. The nucleotide sequence has 18 nucleotides and begins with a start codon, so there are six codons in total. Although the start codon also codes for methionine, the stop codon does not code for an amino acid. As a result, the nucleotide sequence encodes five amino acids.

Science and Engineering Practice	5. Using mathematics and computational thinking
Topic	III. Genetics and Evolution
Subtopic	A. Mechanisms of molecular biology and genetic transmission

14. Option (B) is correct. A mutation is a change in the nucleotide sequence of an organism's genetic material, which is typically DNA. A change in the nucleotide sequence of the RNA genome of some viruses is also considered to be a mutation. Mutations can result in changes to the structure of individual genes, producing new alleles of that gene.

Task of Teaching Science	4. Linking science ideas to one another and to particular activities, models, and representations within and across units
Topic	III. Genetics and Evolution
Subtopic	B. Mechanisms of evolution as a consequence of genetic variation and factors affecting evolution

15. Option (A) is correct. A decrease in the concentration of solutes in the fluid outside the cell will result in the extracellular fluid becoming hypotonic with respect to the cell's cytosol. There will likely be a net movement of water across the cell's plasma membrane from the hypotonic extracellular fluid to the cytosol by the process of osmosis, which will result in an increase in the amount of water inside the cell.

Science and Engineering Practice	2. Developing and using models
Task of Teaching Science	12. Analyzing student ideas for common misconceptions regarding intended scientific learning
Topic	II. Cell Biology: Cell Structure and Function
Subtopic	B. Structure and function of cells and the mechanisms of basic cellular processes

16. Options (A), (B), and (D) are correct. The students can analyze the results of the genetic cross using a combination of PCR, restriction digestion, and agarose gel electrophoresis. For each DNA sample, the students can use PCR and a specific primer set to amplify the region of the yeast genome that contains the gene of interest. If the two alleles of the gene differ by the presence or absence of a specific restriction site, the students can treat each sample of PCR-amplified DNA with a restriction enzyme that recognizes the specific restriction site. The students can then use agarose gel electrophoresis to separate the DNA fragments in each sample on the basis of size. Finally, the students can analyze the resulting patterns of different restriction fragments to determine which of the two different alleles of the gene are present in each DNA sample.

Science and Engineering Practice	3. Planning and carrying out investigations
Task of Teaching Science	7. Determining the variables, techniques, or tools that are appropriate for use by students to address a specific investigation question
Topic	III. Genetics and Evolution
Subtopic	A. Mechanisms of molecular biology and genetic transmission

17. Option (A) is correct. Converting the molecule to a different molecule inside the cell will decrease the molecule's intracellular concentration, which will increase the difference between the molecule's extracellular concentration and its intracellular concentration.

Science and Engineering Practice	2. Developing and using models
Task of Teaching Science	24. Generating or selecting diagnostic questions to evaluate student understanding of specific models or representations
Topic	II. Cell Biology: Cell Structure and Function
Subtopic	A. Basic biochemistry and metabolism of living organisms

18. Option (B) is correct. Diversity refers to the number of different species in a community and the relative abundance of each species. The data collected by the students are best used to analyze the diversity of the community associated with each pond. The students can then compare the diversity of the different communities.

Science and Engineering Practice	4. Analyzing and interpreting data
Task of Teaching Science	9. Supporting students in generating questions for investigation or identifying patterns in data and observations
Topic	V. Ecology: Organisms and Environment
Subtopic	A. Biosphere organization and factors affecting organism interactions and population size

19. Option (C) is correct. Competitive inhibition can be overcome by increasing the initial substrate concentration while keeping the concentrations of the inhibitor and the enzyme constant. If molecule X affects the enzyme-catalyzed reaction through a mechanism of competitive inhibition, the initial reaction velocity will approach the maximum reaction velocity as the initial substrate concentration is increased.

Science and Engineering Practice	1. Asking questions and defining problems
Task of Teaching Science	7. Determining the variables, techniques, or tools that are appropriate for use by students to address a specific investigation question
Topic	II. Cell Biology: Cell Structure and Function
Subtopic	A. Basic biochemistry and metabolism of living organisms

20. Option (A) is correct. All the flies in the F_1 generation will be heterozygous at the genetic locus associated with the sepia-eyes phenotype. If the sepia-eyes trait has an autosomal recessive mode of inheritance, 75% of the F_2 generation will have wild-type eyes and 25% will have sepia eyes.

Science and Engineering Practice	5. Using mathematics and computational thinking
Task of Teaching Science	18. Supporting and critiquing students' participation in and use of verbal and written scientific discourse and argumentation
Topic	III. Genetics and Evolution
Subtopic	A. Mechanisms of molecular biology and genetic transmission

21. Option (D) is correct. A phylogenetic tree is typically used to represent the proposed evolutionary relationships among several different species.

Science and Engineering Practice	2. Developing and using models
Task of Teaching Science	21. Evaluating or selecting scientific models and representations that predict or explain scientific phenomena or address instructional goals
Topic	III. Genetics and Evolution
Subtopic	B. Mechanisms of evolution as a consequence of genetic variation and factors affecting evolution

22. Option (D) is correct. An increase in the influx of chemical fertilizers most likely triggers the rapid growth of the photosynthetic phytoplankton. Many chemical fertilizers used to stimulate crop growth contain high levels of nitrogen and phosphorus. Rainfall can wash the fertilizers off the fields into local waterways that drain into the Mississippi River, which connects with the Gulf of Mexico. The fertilizer accumulation at the mouth of the river promotes the rapid growth of photosynthetic phytoplankton. Subsequent degradation of dead phytoplankton by bacteria depletes the water of oxygen. Organisms cannot survive in the hypoxic waters, and terrestrial organisms that depend on the river-dwelling organisms are also negatively affected.

Topic	V. Ecology: Organisms and Environment
Subtopic	A. Biosphere organization and factors affecting organism interactions and population size

23. Option (A) is correct. The sinoatrial node is made up of a group of cells that are located in the wall of the heart's right atrium. The cells control cardiac muscle contractions through the production of action potentials that propagate throughout the heart. Damage to the sinoatrial node would likely disrupt the rate and timing of cardiac muscle contractions.

Topic	IV. Diversity of Life and Organismal Biology
Subtopic	B. Animal Biology

24. Option (B) is correct. Based on the information presented, lactose can be described as a disaccharide because it is made up of two monosaccharides, glucose and galactose.

Task of Teaching Science	18. Supporting and critiquing students' participation in and use of verbal and written scientific discourse and argumentation
Topic	II. Cell Biology: Cell Structure and Function
Subtopic	A. Basic biochemistry and metabolism of living organisms

25. Option (B) is correct. Genomics focuses on the study and manipulation of entire genomes. A genome is the complete set of DNA that contains all the genes and other genetic information needed for the development, growth, and reproduction of an organism. Advances in DNA sequencing technologies have allowed researchers to determine and analyze the genomic DNA sequences of a wide variety of organisms, including many different types of bacteria, plants, and animals.

Science and Engineering Practice	4. Analyzing and interpreting data
Topic	I. Nature and Impact of Science and Engineering
Subtopic	B. Science, Engineering, Technology, Society, and the Environment

26. Option (D) is correct. Lignin is a rigid component of some plant cell walls that provides structural support to certain tissues in vascular plants. The structural support provided by lignin allows vascular plants to grow taller than nonvascular plants, which provides an advantage when competing for limited resources such as sunlight.

Science and Engineering Practice	6. Constructing explanations and designing solutions
Task of Teaching Science	19. Critiquing student-generated explanations or descriptions for their generalizability, accuracy, precision, or consistency with scientific evidence
Topic	IV. Diversity of Life and Organismal Biology
Subtopic	C. Plant Biology

27. Option (B) is correct. Because adenine pairs with thymine, double-stranded DNA that is 35 percent adenine is also 35 percent thymine. The remaining 30 percent of the DNA is composed of guanine-cytosine base pairs, such that 15 percent of the DNA is guanine and 15 percent is cytosine.

Science and Engineering Practice	5. Using mathematics and computational thinking
Topic	III. Genetics and Evolution
Subtopic	A. Mechanisms of molecular biology and genetic transmission

28. Option (C) is correct. Blueberries are typically ingested by birds and other animals, and the seeds inside the fruit are dispersed through the feces of those animals.

Task of Teaching Science	19. Critiquing student-generated explanations or descriptions for their generalizability, accuracy, precision, or consistency with scientific evidence
Topic	IV. Diversity of Life and Organismal Biology
Subtopic	C. Plant Biology

29. Options (B) and (D) are correct. The presence of membrane-bound organelles, such as mitochondria, and the presence of a membrane-enclosed nucleus are typical features of a eukaryotic cell but not a prokaryotic cell. Ribosomes and chromosomal DNA are present in both eukaryotic and prokaryotic cells.

Science and Engineering Practice	1. Asking questions and defining problems
Task of Teaching Science	22. Engaging students in using, modifying, creating, and critiquing scientific models and representations that are matched to an instructional goal
Topic	II. Cell Biology: Cell Structure and Function
Subtopic	B. Structure and function of cells and the mechanisms of basic cellular processes

30. Option (C) is correct. The mechanism of stomatal opening in plants typically involves an increase in the volume and turgor pressure of guard cells. Changes in environmental conditions can trigger the opening of potassium ion channels in the plasma membrane of guard cells. The accumulation of potassium ions inside the guard cells results in a net movement of water into the cells by osmosis. The influx of water increases the volume and turgor pressure of the guard cells, resulting in an increase in the size of the stomatal opening.

Topic	IV. Diversity of Life and Organismal Biology
Subtopic	C. Plant Biology

31. Option (A) is correct. Typically, periodic natural wildfires are of relatively low intensity. They remove dead and decaying plant matter, including dead trees, leaf litter and pine needles, and shrubs. Without periodic wildfires, the material accumulates so that when a fire eventually does occur, it is much greater in intensity and size and potentially very destructive to living organisms.

Topic	V. Ecology: Organisms and Environment
Subtopic	B. Characteristics of biomes, energy flow in ecosystems, and major biogeochemical cycles

32. Option (A) is correct. The enzymes that facilitate the citric acid cycle are located in the mitochondrial matrix.

Science and Engineering Practice	8. Obtaining, evaluating, and communicating information
Task of Teaching Science	22. Engaging students in using, modifying, creating, and critiquing scientific models and representations that are matched to an instructional goal
Topic	II. Cell Biology: Cell Structure and Function
Subtopic	A. Basic biochemistry and metabolism of living organisms

33. Option (D) is correct. A gas phase is generally absent from the phosphorus cycle. The largest reservoir of phosphorus is in sedimentary rocks of marine origin. Most phosphorus cycles among rocks, soil, water, and living organisms.

Topic	V. Ecology: Organisms and Environment
Subtopic	B. Characteristics of biomes, energy flow in ecosystems, and major biogeochemical cycles

34. Option (C) is correct. Based on the information presented, the woman who has hemophilia is homozygous recessive. In contrast, the man has a single X chromosome that has the dominant allele. As a result, only a female child will be a carrier of the disorder, and all female children of the woman and the man will be carriers. There is a 50% chance that the child will be female.

Science and Engineering Practice	5. Using mathematics and computational thinking
Topic	III. Genetics and Evolution
Subtopic	A. Mechanisms of molecular biology and genetic transmission

35. Options (A), (C), and (D) are correct. Placing a light source inside the refrigerator will help make sure that environmental temperature is the only independent variable in the experiment. Using warm water instead of boiling water is more likely to provide useful data, because the environmental temperature will be more tolerable. Increasing the number of seedlings in each treatment group will help the students to determine the reproducibility of the experiment's results and to analyze variation both within and between treatment groups. Using seedlings of three different species is not recommended, because having more than one independent variable in the experiment will make the results more difficult to interpret.

Science and Engineering Practice	3. Planning and carrying out investigations
Task of Teaching Science	8. Critiquing scientific procedures, data, observations, or results for their quality, accuracy, or appropriateness
Topic	I. Nature and Impact of Science and Engineering
Subtopic	A. Nature of Science

36. Option (D) is correct. Genetic drift refers to changes in allele frequencies in a population that occur as a result of chance and not as a result of natural selection. Changes in allele frequencies are likely to be more significant in a small population than in a large population, because the small population has a comparatively smaller gene pool.

Science and Engineering Practice	6. Constructing explanations and designing solutions
Task of Teaching Science	19. Critiquing student-generated explanations or descriptions for their generalizability, accuracy, precision, or consistency with scientific evidence
Topic	III. Genetics and Evolution
Subtopic	B. Mechanisms of evolution as a consequence of genetic variation and factors affecting evolution

37. Option (A) is correct. Natural gas is considered to be a nonrenewable resource because it cannot be regenerated on a human timescale. The response that describes a type of electric power generation that relies on the burning of natural gas demonstrates the most accurate understanding of the term "nonrenewable resource."

Task of Teaching Science	18. Supporting and critiquing students' participation in and use of verbal and written scientific discourse and argumentation
Topic	I. Nature and Impact of Science and Engineering
Subtopic	B. Science, Engineering, Technology, Society, and the Environment

38. Option (D) is correct. During embryogenesis, after formation of the hollow ball of cells called the blastula, one end of the embryo folds in and expands to gradually fill the space in the blastula. This process is referred to as gastrulation and results in the formation of the three primary germ layers: the endoderm, the mesoderm, and the ectoderm.

Topic	IV. Diversity of Life and Organismal Biology
Subtopic	B. Animal Biology

Understanding Question Types

The *Praxis*® assessments include a variety of question types: constructed response (for which you write a response of your own); selected response, for which you select one or more answers from a list of choices or make another kind of selection (e.g., by selecting a sentence in a text or by selecting part of a graphic); and numeric entry, for which you enter a numeric value in an answer field. You may be familiar with these question formats from taking other standardized tests. If not, familiarize yourself with them so you don't spend time during the test figuring out how to answer them.

Understanding Selected-Response and Numeric-Entry Questions

For most questions, you respond by selecting an oval to select a single answer from a list of answer choices.

However, interactive question types may also ask you to respond by:

- Selecting more than one choice from a list of choices.
- Typing in a numeric-entry box. When the answer is a number, you may be asked to enter a numerical answer. Some questions may have more than one entry box to enter a response. Numeric-entry questions typically appear on mathematics-related tests.
- Selecting parts of a graphic. In some questions, you will select your answers by selecting a location (or locations) on a graphic such as a map or chart, as opposed to choosing your answer from a list.
- Selecting sentences. In questions with reading passages, you may be asked to choose your answers by selecting a sentence (or sentences) within the reading passage.
- Dragging and dropping answer choices into targets on the screen. You may be asked to select answers from a list of choices and to drag your answers to the appropriate location in a table, paragraph of text or graphic.
- Selecting answer choices from a drop-down menu. You may be asked to choose answers by selecting choices from a drop-down menu (e.g., to complete a sentence).

Remember that with every question you will get clear instructions.

Understanding Constructed-Response Questions

Some tests include constructed-response questions, which require you to demonstrate your knowledge in a subject area by writing your own response to topics. Essays and short-answer questions are types of constructed-response questions.

For example, an essay question might present you with a topic and ask you to discuss the extent to which you agree or disagree with the opinion stated. You must support your position with specific reasons and examples from your own experience, observations, or reading.

Review a few sample essay topics:

- *Brown v. Board of Education of Topeka*

  "We come then to the question presented: Does segregation of children in public schools solely on the basis of race, even though the physical facilities and other 'tangible' factors may be equal, deprive the children of the minority group of equal educational opportunities? We believe that it does."

  A. What legal doctrine or principle, established in *Plessy v. Ferguson* (1896), did the Supreme Court reverse when it issued the 1954 ruling quoted above?
  B. What was the rationale given by the justices for their 1954 ruling?

- *In his self-analysis, Mr. Payton says that the better-performing students say small-group work is boring and that they learn more working alone or only with students like themselves. Assume that Mr. Payton wants to continue using cooperative learning groups because he believes they have value for all students.*

  - Describe **TWO** strategies he could use to address the concerns of the students who have complained.
  - Explain how each strategy suggested could provide an opportunity to improve the functioning of cooperative learning groups. Base your response on principles of effective instructional strategies.

- *"Minimum-wage jobs are a ticket to nowhere. They are boring and repetitive and teach employees little or nothing of value. Minimum-wage employers take advantage of people because they need a job."*

  - Discuss the extent to which you agree or disagree with this opinion. Support your views with specific reasons and examples from your own experience, observations, or reading.

Keep these things in mind when you respond to a constructed-response question:

1. **Answer the question accurately.** Analyze what each part of the question is asking you to do. If the question asks you to describe or discuss, you should provide more than just a list.
2. **Answer the question completely.** If a question asks you to do three distinct things in your response, you should cover all three things for the best score. Otherwise, no matter how well you write, you will not be awarded full credit.
3. **Answer the question that is asked.** Do not change the question or challenge the basis of the question. You will receive no credit or a low score if you answer another question or if you state, for example, that there is no possible answer.
4. **Give a thorough and detailed response.** You must demonstrate that you have a thorough understanding of the subject matter. However, your response should be straightforward and not filled with unnecessary information.
5. **Take notes on scratch paper** so that you don't miss any details. Then you'll be sure to have all the information you need to answer the question.
6. **Reread your response.** Check that you have written what you thought you wrote. Be sure not to leave sentences unfinished or omit clarifying information.

General Assistance For The Test

Praxis® Interactive Practice Test

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Helpful Links

Ready to Register – How to register and the information you need to know to do so.

Disability Accommodations – Testing accommodations are available for test takers who meet ETS requirements.

PLNE Accommodations (ESL) – If English is not your primary language, you may be eligible for extended testing time.

What To Expect on Test Day – Knowing what to expect on test day can make you feel more at ease.

Getting Your Scores – Find out where and when you will receive your test scores.

State Requirements – Learn which tests your state requires you to take.

Other Praxis Tests – Learn about other *Praxis* tests and how to prepare for them.

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