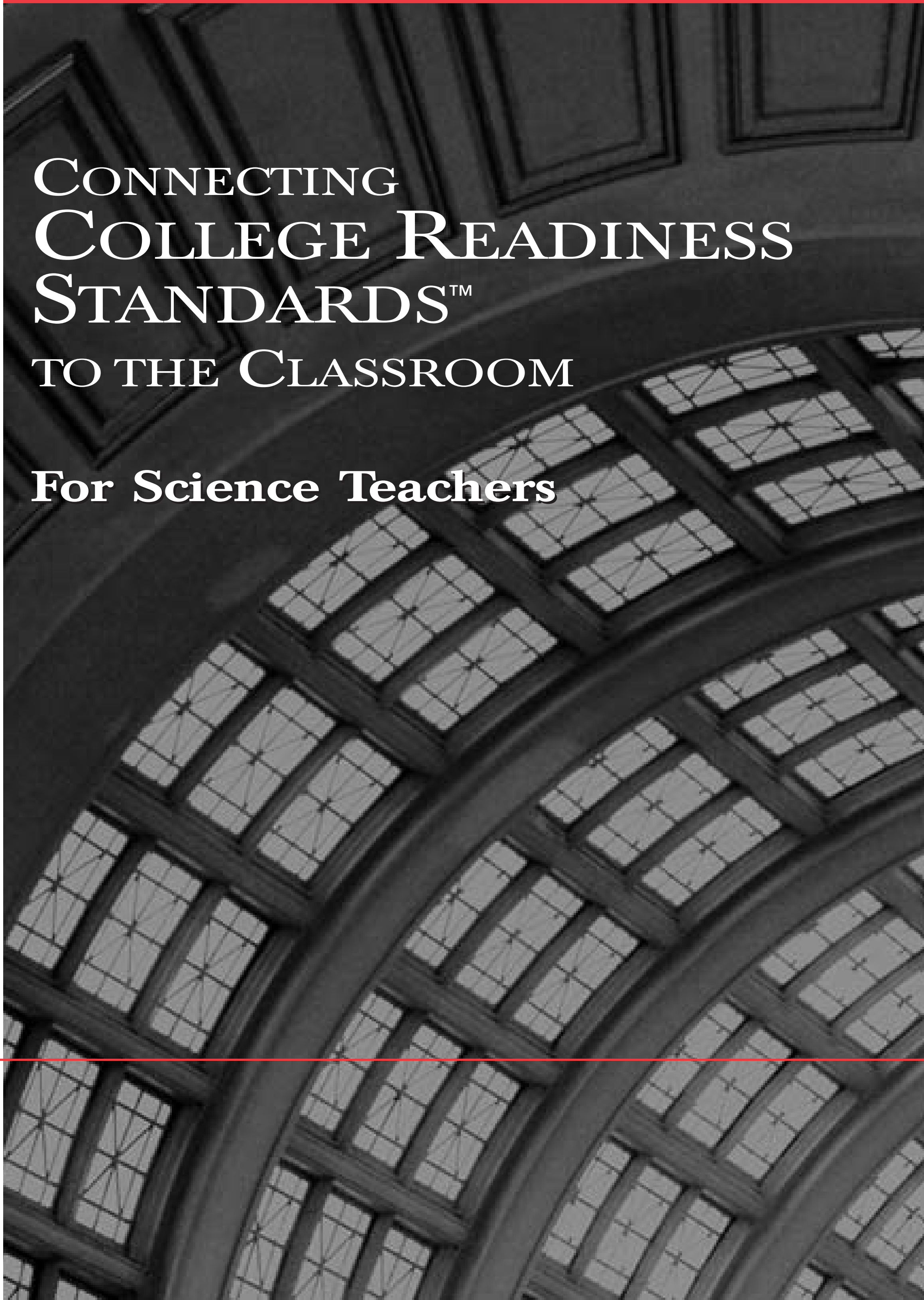
The ACT®



CONNECTING COLLEGE READINESS STANDARDS™ TO THE CLASSROOM

For Science Teachers

ACT®

ACT endorses the *Code of Fair Testing Practices in Education* and the *Code of Professional Responsibilities in Educational Measurement*, guides to the conduct of those involved in educational testing. ACT is committed to ensuring that each of its testing programs upholds the guidelines in each *Code*.

A copy of each *Code* may be obtained free of charge
from ACT Customer Services (68), P.O. Box 1008,
Iowa City, IA 52243-1008, 319/337-1429.

Visit ACT's website at: **www.act.org**

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INTRODUCTION

ACT has developed this guide to help classroom teachers, curriculum coordinators, and counselors interpret the College Readiness Standards™ report for ACT Science. The guide includes:

- A description of the **College Readiness Standards** for the ACT®
- A description of the **ACT Science Test**
- A set of sample **test questions**
- A description of the **Assessment-Instruction Link**
- A set of classroom **instructional activities**

The College Readiness Standards for the ACT are statements that describe what students who score in the six score ranges 13–15, 16–19, 20–23, 24–27, 28–32, and 33–36 on the multiple-choice tests and in the five score ranges 3–4, 5–6, 7–8, 9–10, and 11–12 on the Writing Test are *likely* to know and to be able to do. The statements are generalizations based on the performance of many students. College Readiness Standards have not been developed for students whose scores fall in the 1–12 range for the multiple-choice tests and at score point 2 for the Writing Test because these students, as a group, do not demonstrate skills similar to each other consistently enough to permit useful generalizations.

The College Readiness Standards for the ACT are accompanied by ideas for progress that help teachers identify ways of enhancing students' learning based on the scores students receive.

The College Readiness Standards Information Services provide six aggregate reports for the ACT. Five of these reports are content specific: each presents the scores of your most recent graduates in one of the five content areas the ACT test measures—English, Mathematics, Reading, Science, and Writing. These five content-specific reports present the ACT results using ACT's College Readiness Standards. The sixth report, the Summary Profile, summarizes the scores, across all five content areas, of your most recent graduating class who tested as tenth, eleventh, or twelfth graders. All six reports provide data that compare the performance of your school's most recent graduating class with the performance of two norm groups: national and state. The data in the reports reflect the characteristics of those students who either took the ACT on a national test date or as part of a state testing initiative and who reported that they plan to graduate from high school during the most recent academic year.

The ACT is a curriculum-based assessment program developed by ACT to help students prepare for the transition to postsecondary education while providing a measure of high school outcomes for college-bound students. As part of ACT's Educational Planning and Assessment System (EPAS™), the ACT is complemented by EXPLORE®, ACT's eighth- and ninth-grade program, and by PLAN®, for tenth graders. We hope this guide helps you assist your students as they plan and pursue their future studies.

> **"The role of standardized testing is to let parents, students, and institutions know what students are ready to learn next."**
>
> — Ralph Tyler, October 1991
> Chairman Emeritus of
> ACT's Board of Trustees

THE COLLEGE READINESS STANDARDS REPORT FOR ACT SCIENCE

The College Readiness Standards report for ACT Science allows you to compare the performance of students in your school with the performance of students at the national and state levels. The report provides summary information you can use to map the development of your students' knowledge and skills in science. Used along with your own classroom observations and with other resources, the test results can help you to analyze your students' progress in science and to identify areas of strength and areas that need more attention. You can then use the Standards as one source of information in the instructional planning process.

A sample report appears on the next page. An explanation of its features is provided below.

A This section briefly explains the uses of the report to help you interpret the test results.

B These are the seven score ranges reported for the College Readiness Standards for the ACT. To determine the number of score ranges and the width of each score range, ACT staff reviewed normative data, college admission criteria, and information obtained through ACT's Course Placement Service. For a more detailed explanation of the way the score ranges were determined, see page 5.

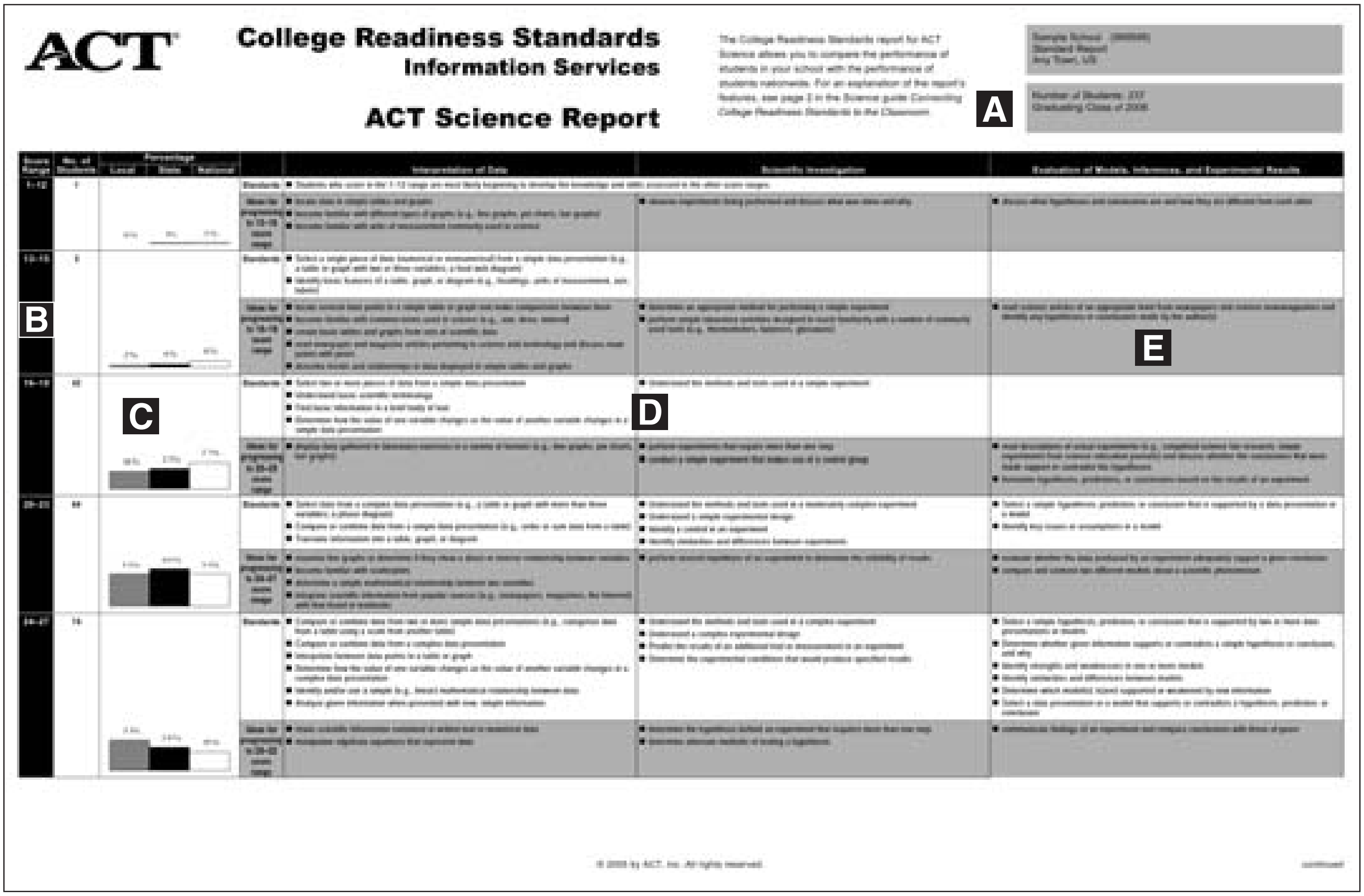
C This section compares the percent of graduating seniors who tested as tenth, eleventh, or twelfth graders and who scored in a particular score range at an individual school (Local) with the percent of all graduating students in the national and state norm groups who scored in the same range. The percent of students at the local school and for the national and state groups are based on the performance of students who either took the ACT on a national test date or as part of a state testing initiative and who reported that they plan to graduate from high school during the most recent academic year. The number of local school students who scored in each of the seven score ranges is provided in the column to the left of each bar graph; the total number of graduating students tested locally is provided at the top of the report.

D The College Readiness Standards were developed by identifying the knowledge and skills students need in order to respond successfully to questions on the ACT Science Test. As you review the report for ACT Science, you will note that the Standards are cumulative, which means that if students score, for example, in the 20–23 score range, they are likely to be able to demonstrate most or all of the knowledge and skills in the 13–15, 16–19, and 20–23 score ranges. Students may be able to demonstrate some of the skills in the next score range, 24–27, but not consistently enough as a group to reach that score range. A description of the way the College Readiness Standards were developed can be found on pages 5–6.

E The "ideas for progress" are statements that provide suggestions for learning experiences that students might benefit from. These ideas for progress are arranged by score range and strand. Although many of the ideas cross more than one strand, a primary strand has been identified for each in order to facilitate their use in the classroom. Ideas for progress are not provided for the 33–36 score range, the highest score range for the ACT. Students who score in this range on the ACT Science Test have demonstrated proficiency in all or almost all of the skills measured by the test.

F Page 2 of the report profiles the test results, College Readiness Standards, and ideas for progress for score ranges 28–32 and 33–36.

G The Science College Readiness Standards are measured in the context of science topics students encounter in science courses. This section of the report lists representative topics. These topics can be found on page 11.



College Readiness Standards Information Services

ACT Science Report

The College Readiness Standards report for ACT Science allows you to compare the performance of students in your school with the performance of students nationwide. For an explanation of the report's features, see page 2 in the Science guide *Connecting College Readiness Standards in the Classroom.*

Sample School (000000)
Standard Report
Any Town, US

Number of Students: 237
Graduating Class of 2006

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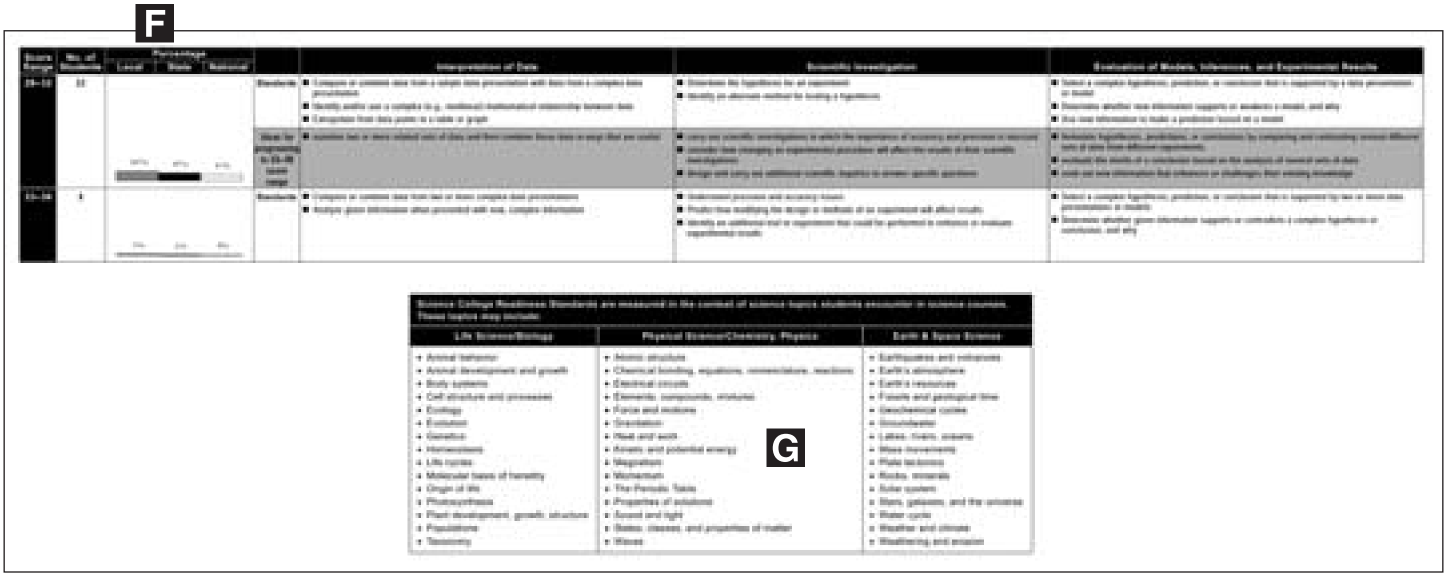


Science College Readiness Standards are measured in the context of science topics students encounter in science courses. These topics may include:

Life Science/Biology

- Animal behavior
- Animal development and growth
- Body systems
- Cell structure and processes
- Ecology
- Evolution
- Genetics
- Homeostasis
- Life cycles
- Molecular basis of heredity
- Origin of life
- Photosynthesis
- Plant development, growth, structure
- Populations
- Taxonomy

Physical Science/Chemistry, Physics

- Atomic structure
- Chemical bonding, equations, nomenclature, reactions
- Electrical circuits
- Elements, compounds, mixtures
- Force and motions
- Gravitation
- Heat and work
- Kinetic and potential energy
- Magnetism
- Momentum
- The Periodic Table
- Properties of solutions
- Sound and light
- States, classes, and properties of matter
- Waves

Earth & Space Science

- Earthquakes and volcanoes
- Earth's atmosphere
- Earth's resources
- Fossils and geological time
- Geochemical cycles
- Groundwater
- Lakes, rivers, oceans
- Mass movements
- Plate tectonics
- Rocks, minerals
- Solar system
- Stars, galaxies, and the universe
- Water cycle
- Weather and climate
- Weathering and erosion

DESCRIPTION OF THE COLLEGE READINESS STANDARDS

WHAT ARE THE COLLEGE READINESS STANDARDS?

The College Readiness Standards communicate educational expectations. Each Standard describes what students who score in the designated range are *likely* to be able to do with what they know. Students can typically demonstrate the skills and knowledge within the score ranges preceding the range in which they scored, so the College Readiness Standards are cumulative.

In helping students make the transition from high school to postsecondary education or to the world of work, teachers, counselors, and parents can use the College Readiness Standards for the ACT to interpret students' scores and to understand which skills students need to develop to be better prepared for the future.

HOW WERE THE SCORE RANGES DETERMINED?

To determine the number of score ranges and the width of each score range for the ACT, ACT staff reviewed ACT normative data and considered the relationship among EXPLORE, PLAN, and the ACT.

In reviewing the ACT normative data, ACT staff analyzed the distribution of student scores across the score scale, 1–36. Because the ACT is used for college admission and course-placement decisions, differing admission criteria (e.g., open, liberal, traditional, selective, and highly selective) and the course-placement research that ACT has conducted over the last forty years were also reviewed. ACT's Course Placement Service provides colleges and universities with cutoff scores that are used to place students into appropriate entry-level courses in college; and these cutoff scores were used to help define the score ranges.

After analyzing all the data and reviewing different possible score ranges, ACT staff concluded that using the seven score ranges 1–12, 13–15, 16–19, 20–23, 24–27, 28–32, and 33–36 would best distinguish students' levels of achievement so as to assist teachers, administrators, and others in relating ACT test scores to students' skills and understandings.

HOW WERE THE COLLEGE READINESS STANDARDS DEVELOPED?

After a review of normative data, college admission criteria, and information obtained through ACT's Course Placement Service, content experts wrote the College Readiness Standards based on their analysis of the skills and knowledge students need in order to successfully respond to the test questions in each score range. Experts analyzed numerous test questions that had been answered correctly by 80% or more of the examinees within each score range. The 80% criterion was chosen because it offers those who use the College Readiness Standards a high degree of confidence that students scoring in a given score range will most *likely* be able to demonstrate the skills and knowledge described in that range.

> **"The examination should describe the student in meaningful terms– meaningful to the student, the parent, and the elementary and high school teacher–meaningful in the sense that the profile scores correspond to recognizable school activities, and directly suggest appropriate distributions of emphasis in learning and teaching."**
>
> — E. F. Lindquist, February 1958
> Cofounder of ACT

As a content validity check, ACT invited nationally recognized scholars from high school and university Science and Science Education departments to review the College Readiness Standards for the ACT Science Test. These teachers and researchers provided ACT with independent, authoritative reviews of the ways the College Readiness Standards reflect the skills and knowledge students need to successfully respond to the questions on the ACT Science Test.

Because the ACT is curriculum based, ACT and independent consultants conduct a review every three to four years to ensure that the knowledge and skills described in the Standards and outlined in the test specifications continue to reflect those being taught in classrooms nationwide.

HOW SHOULD THE COLLEGE READINESS STANDARDS BE INTERPRETED AND USED?

The College Readiness Standards reflect the progression and complexity of the skills measured in the ACT. Because no ACT test form measures all of the skills and knowledge included in the College Readiness Standards, the Standards must be interpreted as skills and knowledge that *most* students who score in a particular score range are *likely* to be able to demonstrate. Since there were relatively few test questions that were answered correctly by 80% or more of the students who scored in the lower score ranges, the Standards in these ranges should be interpreted cautiously. The skills and understandings of students who score in the 1–12 score range may still be evolving. For these students the skills and understandings in the higher score ranges could become their target achievement outcomes.

It is important to recognize that the ACT does not measure everything students have learned nor does any test measure everything necessary for students to know to be successful in college or in the world of work. The ACT Science Test includes questions from a large domain of skills and from areas of knowledge that have been judged important for success in college and beyond. Thus, the College Readiness Standards should be interpreted in a responsible way that will help students understand what they need to know and do if they are going to make a successful transition to college, vocational school, or the world of work. Students can use the Standards to identify the skills and knowledge they need to develop to be better prepared for their future. Teachers and curriculum coordinators can use the Standards to learn more about their students' academic strengths and weaknesses and can then modify their instruction and guide students accordingly.

HOW ARE THE COLLEGE READINESS STANDARDS ORGANIZED?

As content experts reviewed the test questions connected to each score range, distinct yet overlapping areas of knowledge and skill were identified. For example, there are many types of questions in which students are asked to demonstrate that they understand the components of a scientific investigation. Therefore, *Scientific Investigation* is one area, or *strand*, within the College Readiness Standards for ACT Science. The other two strands are *Interpretation of Data* and *Evaluation of Models, Inferences, and Experimental Results.*

The strands provide an organizational framework for the College Readiness Standards statements. As you review the Standards, you will note a progression in complexity within each strand. For example, in the 13–15 range for the Interpretation of Data strand, students are able to "select a single piece of data (numerical or nonnumerical) from a simple data presentation (e.g., a table or graph with two or three variables; a food web diagram)," while in the 33–36 range, students demonstrate that they are able to "compare or combine data from two or more complex data presentations."

The Standards are complemented by brief descriptions of learning experiences from which high school students might benefit. Based on the College Readiness Standards, these ideas for progress are designed to provide classroom teachers with help for lesson plan development. These ideas, which are given in Table 1, demonstrate one way that information learned from standardized test results can be used to inform classroom instruction.

Because students learn over time and in various contexts, it is important to use a variety of instructional methods and materials to meet students' diverse needs and to help strengthen and build upon their knowledge and skills. The ideas for progress offer teachers a variety of suggestions to foster learning experiences from which students would likely benefit as they move from one level of learning to the next.

Because learning is a complex and individual process, it is especially important to use multiple sources of information—classroom observations and teacher-developed assessment tools, as well as standardized tests—to accurately reflect what each student knows and can do. The Standards and ideas for progress, used in conjunction with classroom-based and curricular resources, help teachers and administrators to guide the whole education of every student.

WHAT ARE THE ACT SCIENCE TEST COLLEGE READINESS STANDARDS?

Table 1 on pages 8–11 suggests links between what students are *likely* to be able to do (the College Readiness Standards) and what learning experiences students would likely benefit from.

The College Readiness Standards are organized both by score range (along the left-hand side) and by strand (across the top). The lack of a College Readiness Standards statement in a score range indicates that there was insufficient evidence with which to determine a descriptor.

The ideas for progress are also arranged by score range and by strand. Although many of the ideas cross more than one strand, a primary strand has been identified for each in order to facilitate their use in the classroom. For example, the statement in the 20–23 score range "evaluate whether the data produced by an experiment adequately support a given conclusion" brings together concepts from all three strands, Interpretation of Data; Scientific Investigation; and Evaluation of Models, Inferences, and Experimental Results. However, this idea is primarily linked to the Evaluation of Models, Inferences, and Experimental Results strand.

As you review the table, you will note that in the Scientific Investigation strand and the Evaluation of Models, Inferences, and Experimental Results strand, ideas for progress based on the knowledge and skills being tested are provided even where there are no standards in the next higher range. Ideas for progress have not been provided for the 33–36 score range, the highest score range for the ACT. Students who score in this range on the ACT Science Test have demonstrated proficiency in all, or almost all, of the skills measured by the test. These students will, however, continue to refine and expand their knowledge and skills as they engage in science activities that require critical, logical, and creative thinking.

Table 1: The College Readiness Standards

The Standards describe what students who score in the specified score ranges are *likely* to know and to be able to do. The ideas for progress help teachers identify ways of enhancing students' learning based on the scores students receive.

		Interpretation of Data	***Scientific Investigation***	***Evaluation of Models, Inferences, and Experimental Results***
1–12	**Standards**	■ Students who score in the 1–12 range are most likely beginning to develop the knowledge and skills assessed in the other score ranges.		
	ideas for progress	■ locate data in simple tables and graphs ■ become familiar with different types of graphs (e.g., line graphs, pie charts, bar graphs) ■ become familiar with units of measurement commonly used in science	■ observe experiments being performed and discuss what was done and why	■ discuss what hypotheses and conclusions are and how they are different from each other
13–15	**Standards**	■ Select a single piece of data (numerical or nonnumerical) from a simple data presentation (e.g., a table or graph with two or three variables; a food web diagram) ■ Identify basic features of a table, graph, or diagram (e.g., headings, units of measurement, axis labels)		
	ideas for progress	■ locate several data points in a simple table or graph and make comparisons between them ■ become familiar with common terms used in science (e.g., *star, force, mineral*) ■ create basic tables and graphs from sets of scientific data ■ read newspaper and magazine articles pertaining to science and technology and discuss main points with peers ■ describe trends and relationships in data displayed in simple tables and graphs	■ determine an appropriate method for performing a simple experiment ■ perform simple laboratory activities designed to teach familiarity with a number of commonly used tools (e.g., thermometers, balances, glassware)	■ read science articles of an appropriate level from newspapers and science newsmagazines and identify any hypotheses or conclusions made by the author(s)

Table 1 (continued): **The College Readiness Standards**

The Standards describe what students who score in the specified score ranges are *likely* to know and to be able to do. The ideas for progress help teachers identify ways of enhancing students' learning based on the scores students receive.

		Interpretation of Data	*Scientific Investigation*	*Evaluation of Models, Inferences, and Experimental Results*
16–19	**Standards**	■ Select two or more pieces of data from a simple data presentation ■ Understand basic scientific terminology ■ Find basic information in a brief body of text ■ Determine how the value of one variable changes as the value of another variable changes in a simple data presentation	■ Understand the methods and tools used in a simple experiment	
	ideas for progress	■ display data gathered in laboratory exercises in a variety of formats (e.g., line graphs, pie charts, bar graphs)	■ perform experiments that require more than one step ■ conduct a simple experiment that makes use of a control group	■ read descriptions of actual experiments (e.g., completed science fair research, simple experiments from science education journals) and discuss whether the conclusions that were made support or contradict the hypotheses ■ formulate hypotheses, predictions, or conclusions based on the results of an experiment
20–23	**Standards**	■ Select data from a complex data presentation (e.g., a table or graph with more than three variables; a phase diagram) ■ Compare or combine data from a simple data presentation (e.g., order or sum data from a table) ■ Translate information into a table, graph, or diagram	■ Understand the methods and tools used in a moderately complex experiment ■ Understand a simple experimental design ■ Identify a control in an experiment ■ Identify similarities and differences between experiments	■ Select a simple hypothesis, prediction, or conclusion that is supported by a data presentation or a model ■ Identify key issues or assumptions in a model
	ideas for progress	■ examine line graphs to determine if they show a direct or inverse relationship between variables ■ become familiar with scatterplots ■ determine a simple mathematical relationship between two variables ■ integrate scientific information from popular sources (e.g., newspapers, magazines, the Internet) with that found in textbooks	■ perform several repetitions of an experiment to determine the reliability of results	■ evaluate whether the data produced by an experiment adequately support a given conclusion ■ compare and contrast two different models about a scientific phenomenon

Table 1 (continued): **The College Readiness Standards**

The Standards describe what students who score in the specified score ranges are *likely* to know and to be able to do. The ideas for progress help teachers identify ways of enhancing students' learning based on the scores students receive.

		Interpretation of Data	*Scientific Investigation*	*Evaluation of Models, Inferences, and Experimental Results*
24–27	**Standards**	■ Compare or combine data from two or more simple data presentations (e.g., categorize data from a table using a scale from another table) ■ Compare or combine data from a complex data presentation ■ Interpolate between data points in a table or graph ■ Determine how the value of one variable changes as the value of another variable changes in a complex data presentation ■ Identify and/or use a simple (e.g., linear) mathematical relationship between data ■ Analyze given information when presented with new, simple information	■ Understand the methods and tools used in a complex experiment ■ Understand a complex experimental design ■ Predict the results of an additional trial or measurement in an experiment ■ Determine the experimental conditions that would produce specified results	■ Select a simple hypothesis, prediction, or conclusion that is supported by two or more data presentations or models ■ Determine whether given information supports or contradicts a simple hypothesis or conclusion, and why ■ Identify strengths and weaknesses in one or more models ■ Identify similarities and differences between models ■ Determine which model(s) is(are) supported or weakened by new information ■ Select a data presentation or a model that supports or contradicts a hypothesis, prediction, or conclusion
	ideas for progress	■ relate scientific information contained in written text to numerical data ■ manipulate algebraic equations that represent data	■ determine the hypothesis behind an experiment that requires more than one step ■ determine alternate methods of testing a hypothesis	■ communicate findings of an experiment and compare conclusions with those of peers
28–32	**Standards**	■ Compare or combine data from a simple data presentation with data from a complex data presentation ■ Identify and/or use a complex (e.g., nonlinear) mathematical relationship between data ■ Extrapolate from data points in a table or graph	■ Determine the hypothesis for an experiment ■ Identify an alternate method for testing a hypothesis	■ Select a complex hypothesis, prediction, or conclusion that is supported by a data presentation or model ■ Determine whether new information supports or weakens a model, and why ■ Use new information to make a prediction based on a model
	ideas for progress	■ examine two or more related sets of data and then combine those data in ways that are useful	■ carry out scientific investigations in which the importance of accuracy and precision is stressed ■ consider how changing an experimental procedure will affect the results of their scientific investigations ■ design and carry out additional scientific inquiries to answer specific questions	■ formulate hypotheses, predictions, or conclusions by comparing and contrasting several different sets of data from different experiments ■ evaluate the merits of a conclusion based on the analysis of several sets of data ■ seek out new information that enhances or challenges their existing knowledge

Table 1 (continued): **The College Readiness Standards**

The Standards describe what students who score in the specified score ranges are *likely* to know and to be able to do. The ideas for progress help teachers identify ways of enhancing students' learning based on the scores students receive.

		Interpretation of Data	***Scientific Investigation***	***Evaluation of Models, Inferences, and Experimental Results***
33–36	**Standards**	■ Compare or combine data from two or more complex data presentations ■ Analyze given information when presented with new, complex information	■ Understand precision and accuracy issues ■ Predict how modifying the design or methods of an experiment will affect results ■ Identify an additional trial or experiment that could be performed to enhance or evaluate experimental results	■ Select a complex hypothesis, prediction, or conclusion that is supported by two or more data presentations or models ■ Determine whether given information supports or contradicts a complex hypothesis or conclusion, and why

Science College Readiness Standards are measured in the context of science topics students encounter in science courses. These topics may include:

Life Science/Biology

- Animal behavior
- Animal development and growth
- Body systems
- Cell structure and processes
- Ecology
- Evolution
- Genetics
- Homeostasis
- Life cycles
- Molecular basis of heredity
- Origin of life
- Photosynthesis
- Plant development, growth, structure
- Populations
- Taxonomy

Physical Science/Chemistry, Physics

- Atomic structure
- Chemical bonding, equations, nomenclature, reactions
- Electrical circuits
- Elements, compounds, mixtures
- Force and motions
- Gravitation
- Heat and work
- Kinetic and potential energy
- Magnetism
- Momentum
- The Periodic Table
- Properties of solutions
- Sound and light
- States, classes, and properties of matter
- Waves

Earth & Space Science

- Earthquakes and volcanoes
- Earth's atmosphere
- Earth's resources
- Fossils and geological time
- Geochemical cycles
- Groundwater
- Lakes, rivers, oceans
- Mass movements
- Plate tectonics
- Rocks, minerals
- Solar system
- Stars, galaxies, and the universe
- Water cycle
- Weather and climate
- Weathering and erosion

DESCRIPTION OF THE ACT SCIENCE TEST

WHAT DOES THE ACT SCIENCE TEST MEASURE?

The ACT Science Test is a 40-question, 35-minute test designed to assess the knowledge and the thinking skills, processes, and strategies students acquire in high school science courses. These skills include analyzing and interpreting data, comparing experimental designs and methods, comparing assumptions underlying experiments, making generalizations, and identifying and evaluating conflicting points of view. The test presents seven sets of scientific information, each followed by a number of multiple-choice test questions. The scientific information is conveyed in one of three different formats:

Data Representation. This format, which accounts for 38% of the test, presents students with graphic and tabular materials similar to those found in science journals and texts. The test questions associated with this format measure skills such as graph reading, interpretation of scatterplots, and interpretation of information presented in tables.

Research Summaries. This format, which accounts for 45% of the test, provides students with descriptions of one or more experiments. The test questions focus upon the design of experiments and the interpretation of experimental results.

Conflicting Viewpoints. This format, which accounts for 17% of the test, presents students with expressions of hypotheses, models, or views that, being based on differing premises or on incomplete data, are inconsistent with one another. The test questions focus upon the understanding, analysis, comparison, and evaluation of the alternative viewpoints.

> **“The test should measure what students can do with what they have learned.”**
>
> — (ACT, 1996b, p.1)

The ACT Science Test is based upon the type of content that is typically covered in high school general science courses. Materials are drawn from biology, chemistry, Earth/space science, and physics. Each test activity uses stimulus materials from one of these areas. Materials are produced specifically for the Science Test to match the level of complexity of those used in the classroom. The intent is to present students with a situation to engage their reasoning skills, rather than to invite their recall of a classroom activity. Some of the topics included in each content area are summarized below.

Biology. The stimulus materials and questions in this content area cover such topics as cell biology, botany, zoology, microbiology, ecology, genetics, and evolution.

Chemistry. The stimulus materials and questions in this content area cover such topics as atomic theory, inorganic chemical reactions, chemical bonding, reaction rates, solutions, equilibriums, gas laws, electrochemistry, and properties and states of matter.

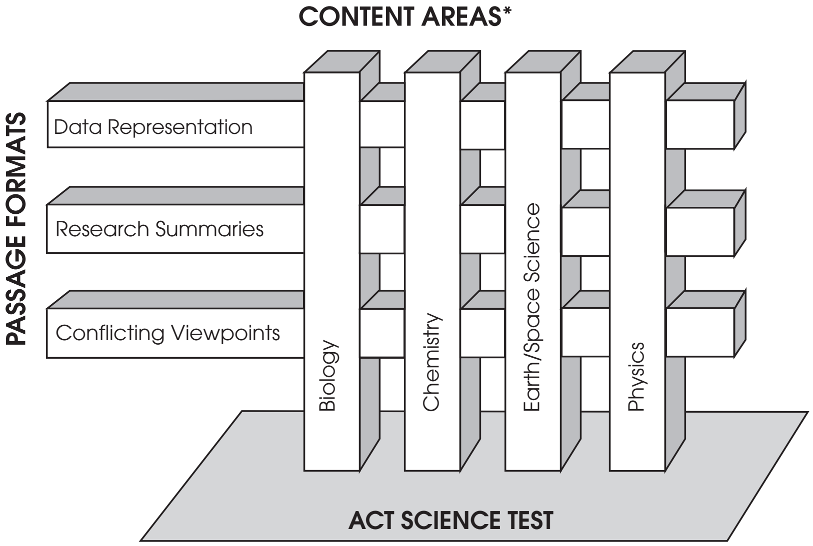
Earth/Space Science. The stimulus materials and questions in this content area cover such topics as geology, meteorology, astronomy, environmental science, and oceanography.

Physics. The stimulus materials and questions in this content area cover such topics as mechanics, energy, thermodynamics, electromagnetism, fluids, solids, and light waves.

Figure 1 on page 13 provides an overview of the structure of the ACT Science Test.

The questions in the Science Test are classified according to three primary cognitive levels: understanding, analysis, and generalization. *Understanding* questions test students' ability to comprehend the information presented and, to a limited extent, their understanding of how it fits into the general scheme of the particular stimulus format.

Analysis questions go beyond the level of understanding questions by testing students' ability to relate a number of components of the presented material to each other on a higher, more abstract level. *Generalization* questions test students' ability to think beyond the presented materials and to see how the stimulus material relates to the rest of the world.



*All four content areas are represented in the test. The content areas are distributed over the different formats in such a way that at least one set of scientific information, and no more than two sets, represents each content area.

Adapted from *Mathematics Framework for the 1996 National Assessment of Education Progress* (p.11)

Figure 1: ACT Science Test Content Areas and Passage Formats

THE NEED FOR THINKING SKILLS

Every student comes to school with the ability to think, but to achieve their goals students need to develop skills such as learning to make new connections between texts and ideas, to understand increasingly complex concepts, and to think through their assumptions. Because of technological advances and the fast pace of our society, it is increasingly important that students not only know information but also know how to critique and manage that information. Students must be provided with the tools for ongoing learning; understanding, analysis, and generalization skills must be developed so that the learner is able to adapt to a variety of situations.

HOW ARE ACT TEST QUESTIONS LINKED TO THINKING SKILLS?

Our belief in the importance of developing thinking skills in learners was a key factor in the development of the ACT. ACT believes that students' preparation for further learning is best assessed by measuring, as directly as possible, the academic skills that students have acquired and that they will need to perform at the next level of learning. The required academic skills can most directly be assessed by reproducing as faithfully as possible the complexity of the students' schoolwork. Therefore, the ACT test questions are designed to determine how skillfully students solve problems, grasp implied meanings, draw inferences, evaluate ideas, and make judgments in subject-matter areas important to success in intellectual work both inside and outside school.

> **"Learning is not attained by chance, it must be sought for with ardour and attended to with diligence."**
>
> — Abigail Adams in a letter to
> John Quincy Adams

Table 2 on pages 15–21 provides sample test questions, organized by score range, that are linked to specific skills within each of the three Science strands. It is important to note the increasing level of science reasoning skills that students scoring in the higher score ranges are able to demonstrate. The questions were chosen to illustrate the variety of content as well as the range of complexity within each strand. The sample test questions for the 13–15, 16–19, 20–23, 24–27, 28–32, and 33–36 score ranges are examples of items answered correctly by 80% or more of the ACT examinees who obtained scores in each of these five score ranges.

As you review the sample test questions, you will note that each correct answer is marked with an asterisk. Also note that each sample test question includes the passage content area (biology, chemistry, Earth/space science, or physics) and format (data representation, research summaries, or conflicting viewpoints) for the corresponding passage as well as the page number where the passage is located in the appendix.

Table 2: **ACT Sample Test Questions by Score Range**
Interpretation of Data Strand

Score Range	**Interpretation of Data**	**Sample Test Questions**	**Passage Information**
13–15	Select a single piece of data (numerical or nonnumerical) from a simple data presentation (e.g., a table or graph with two or three variables; a food web diagram)	According to Figure 1, at normal body conditions, when P_{O_2} is 50mm Hg, the percent saturation of Hb is closest to: **A.** 30%. **B.** 45%. ***C.** 85%. **D.** 90%.	page 54 Biology Data Representation
16–19	Find basic information in a brief body of text	Figure 2 shows an ear of modern corn and a teosinte spike. What type of reproductive organs are found in these 2 structures? **A.** Male reproductive organs are found in both the spike and the ear. ***B.** Female reproductive organs are found in both the spike and the ear. **C.** Female reproductive organs are found in the spike and male reproductive organs are found in the ear. **D.** Female reproductive organs are found in the ear and male reproductive organs are found in the spike.	page 55 Biology Conflicting Viewpoints
	Determine how the value of one variable changes as the value of another variable changes in a simple data presentation	In Experiment 1, as the reaction temperature increased, the time until the purple color disappeared: **A.** remained the same. ***B.** decreased only. **C.** increased only. **D.** increased, then decreased.	page 56 Chemistry Research Summaries
20–23	Select data from a complex data presentation (e.g., a table or graph with more than three variables; a phase diagram)	The amount of energy required to melt 1 mole of benzene at 5.5°C and a constant pressure of 1 atm is: **A.** 6.1 kJ. ***B.** 10.9 kJ. **C.** 31.0 kJ. **D.** 80.1 kJ.	page 57 Chemistry Data Representation
	Compare or combine data from a simple data presentation (e.g., order or sum data from a table)	A student wanted to produce the greatest number of flowers from 4 P1 plants, using the procedures employed in Experiment 2. Accordingly, these 4 P1 plants should be grown in bottomless containers at which of the following sites and with 4 plants from which of the following populations? ***A.** S1 and P4 **B.** S3 and P5 **C.** S4 and P2 **D.** S5 and P3	page 58 Biology Research Summaries

Table 2: **ACT Sample Test Questions by Score Range**
Interpretation of Data Strand, *continued*

Score Range	***Interpretation of Data***	***Sample Test Questions***	***Passage Information***
24–27	Compare or combine data from a complex data presentation	Different track conditions account for the difference between the departure speeds in all of the following pairs of trials in Study 2 EXCEPT: **A.** Trials 1 and 3. **B.** Trials 1 and 5. ***C.** Trials 3 and 4. **D.** Trials 3 and 5.	page 59 Physics Research Summaries
	Interpolate between data points in a table or graph	The boiling point of pentane is 36.1°C. If pentane follows the general pattern of the other substances in the table, its molar heat of vaporization will be: **A.** below 6 kJ/mol. **B.** between 6 kJ/mol and 9 kJ/mol. **C.** between 9 kJ/mol and 26 kJ/mol. ***D.** between 26 kJ/mol and 40 kJ/mol.	page 57 Chemistry Data Representation
	Identify and/or use a simple (e.g., linear) mathematical relationship between data	If a plant from Experiment 1 had an aboveground dry mass of 21 mg, the number of flowers produced by the plant would most likely be closest to which of the following values? **A.** 1 **B.** 4 ***C.** 7 **D.** 10	page 58 Biology Research Summaries
28–32	Compare or combine data from a simple data presentation with data from a complex data presentation	According to Figure 1 and Table 1, which of the following statements best describes the relationship between the sodium content of a plagioclase feldspar and its crystallization temperature? **A.** As sodium content increases, the crystallization temperature increases. ***B.** As sodium content increases, the crystallization temperature decreases. **C.** As sodium content increases, the crystallization temperature increases, then decreases. **D.** As sodium content increases, the crystallization temperature decreases, then increases.	page 60 Earth/Space Science Data Representation
	Extrapolate from data points in a table or graph	If Experiment 4 had been conducted for 2 hours, the number of particles detected would have been approximately: **A.** 4,550. **B.** 12,330. **C.** 56,780. ***D.** 160,600.	page 61 Physics Research Summaries

Table 2: **ACT Sample Test Questions by Score Range**
Interpretation of Data Strand, *continued*

Score Range	***Interpretation of Data***	***Sample Test Questions***	***Passage Information***
33–36	Analyze given information when presented with new, complex information	According to the *collision theory* of reaction rates, 2 molecules or ions must collide in order to react with one another. Based on this information and the results of Experiment 1, the frequency of collisions was most likely the lowest at a temperature of: ***A.** 25°C. **B.** 35°C. **C.** 45°C. **D.** 55°C.	page 56 Chemistry Research Summaries

Table 2: **ACT Sample Test Questions by Score Range**
Scientific Investigation Strand

Score Range	***Scientific Investigation***	***Sample Test Questions***	***Passage Information***
13–15			
16–19	Understand the methods and tools used in a simple experiment	In Experiment 2, how many seedlings were planted in each container? **A.** 2 **B.** 4 ***C.** 8 **D.** 16	page 58 Biology Research Summaries
20–23	Understand a simple experimental design	Which of the following was the independent variable in Experiment 3 ? ***A.** Shielding material **B.** Particle detection rate for Source B **C.** Particle detection rate for Source C **D.** Distance of Source B or Source C from the Geiger counter	page 61 Physics Research Summaries
	Identify similarities and differences between experiments	How is the experimental design of Experiment 1 different from that of Experiment 2 ? In Experiment 1: ***A.** $MnSO_4$ was not added to the reaction; in Experiment 2 $MnSO_4$ was added. **B.** the concentration of $KMnO_4$ was less than that used in Experiment 2. **C.** reaction temperatures were varied; in Experiment 2 they remained constant. **D.** the concentration of $H_2C_2O_4$ was varied; in Experiment 2 it remained constant.	page 56 Chemistry Research Summaries
24–27	Understand a complex experimental design	Each of the following factors was investigated in the experiments EXCEPT: **A.** adding a catalyst to the reaction mixture. ***B.** changing the reaction solvent. **C.** varying the reaction temperature. **D.** changing the concentration of a reactant.	page 56 Chemistry Research Summaries
	Determine the experimental conditions that would produce specified results	If the procedure described in Experiment 2 was repeated and a reaction time of 6 sec was measured, the temperature of the reaction was most likely: **A.** less than 25°C. **B.** greater than 25°C and less than 40°C. **C.** greater than 40°C and less than 55°C. ***D.** greater than 55°C.	page 56 Chemistry Research Summaries

Table 2: **ACT Sample Test Questions by Score Range**
Scientific Investigation Strand, *continued*

Score Range	***Scientific Investigation***	***Sample Test Questions***	***Passage Information***
28–32	Identify an alternate method for testing a hypothesis	In Study 1, instead of measuring stopping distance, the students could have measured which of the following as an indicator of road safety? **A.** The time it took for the signal from the remote control to reach the brakes of the test car **B.** The distance between the track and the brakes of the test car after the car came to a stop ***C.** The time it took for the test car to come to a stop after its brakes were locked **D.** The distance traveled by the test car from the point where the car was traveling at 25 m/sec to the point where its brakes were locked	page 59 Physics Research Summaries
33–36	Predict how modifying the design or methods of an experiment will affect results	A student repeating Trial 9 unknowingly used a graduated cylinder that already contained 1.0 mL of H_2O to measure the $H_2C_2O_4$ solution. Based on the results of Experiment 3, the reaction time that she measured was most likely: **A.** less than 415 sec. **B.** greater than 415 sec and less than or equal to 625 sec. **C.** greater than 625 sec and less than or equal to 837 sec. ***D.** greater than 837 sec.	page 56 Chemistry Research Summaries
	Identify an additional trial or experiment that could be performed to enhance or evaluate experimental results	Suppose the students are designing a study to determine how the departure speed of a test car depends on the radius of the circular track. In each trial of the study, the radius of the circular track will be different. How should the study be designed in regard to track material and track condition? ***A.** Track material should be the same in all the trials and track condition should be the same in all the trials. **B.** Track material should be the same in all the trials, but track condition should be different in each trial. **C.** Track material should be different in each trial, but track condition should be the same in all the trials. **D.** Track material should be different in each trial and track condition should be different in each trial.	page 59 Physics Research Summaries

Table 2: **ACT Sample Test Questions by Score Range**
Evaluation of Models, Inferences, and Experimental Results Strand

<table>
<tr><th>Score Range</th><th>Evaluation of Models, Inferences, and Experimental Results</th><th>Sample Test Questions</th><th>Passage Information</th></tr>
<tr><td>13–15</td><td></td><td></td><td></td></tr>
<tr><td>16–19</td><td></td><td></td><td></td></tr>
<tr><td>20–23</td><td>Select a simple hypothesis, prediction, or conclusion that is supported by a data presentation or a model</td><td>If scientists could successfully sample a magma that had partially cooled to a temperature of 1,150°C, which of the following groups of crystallized minerals would they be most likely to find?
A. Potassium feldspar, muscovite mica, and quartz
*B. Olivine, bytownite, and augite
C. Augite, biotite mica, and quartz
D. Andesine and hornblende</td><td>page 60
Earth/Space Science
Data Representation</td></tr>
<tr><td>24–27</td><td>Select a simple hypothesis, prediction, or conclusion that is supported by two or more data presentations or models</td><td>According to the results of Studies 1 and 2, the addition of water or ice to a dry track results in which of the following changes in the stopping distance and the departure speed?
A. Increases in both the stopping distance and the departure speed
B. Decreases in both the stopping distance and the departure speed
*C. An increase in the stopping distance and a decrease in the departure speed
D. A decrease in the stopping distance and an increase in the departure speed</td><td>page 59
Physics
Research Summaries</td></tr>
<tr><td></td><td>Identify similarities and differences between models</td><td>Which of the following pairs of statements best explains the cause of the rock fracturing responsible for deep earthquakes according to the viewpoints of the 2 scientists?
<table>
<tr><th></th><th><u>Scientist 1</u></th><th><u>Scientist 2</u></th></tr>
<tr><td>A.</td><td>Change of olivine to spinel</td><td>Dehydration of serpentine</td></tr>
<tr><td>B.</td><td>Change of serpentine to spinel</td><td>Dehydration of olivine</td></tr>
<tr><td>*C.</td><td>Dehydration of serpentine</td><td>Change of olivine to spinel</td></tr>
<tr><td>D.</td><td>Dehydration of olivine</td><td>Change of serpentine to spinel</td></tr>
</table></td><td>page 62
Earth/Space Science
Conflicting Viewpoints</td></tr>
<tr><td></td><td>Determine which model(s) is(are) supported or weakened by new information</td><td>If it were discovered that plates, as they descend, instantly rise to the same temperature as the surrounding mantle, how would this discovery affect the viewpoints, if at all?
A. It would strengthen the viewpoint of Scientist 1 only.
B. It would weaken the viewpoint of Scientist 2 only.
C. It would strengthen the viewpoints of both scientists.
*D. It would weaken the viewpoints of both scientists.</td><td>page 62
Earth/Space Science
Conflicting Viewpoints</td></tr>
</table>

Table 2: **ACT Sample Test Questions by Score Range**
Evaluation of Models, Inferences, and Experimental Results Strand, *continued*

Score Range	***Evaluation of Models, Inferences, and Experimental Results***	***Sample Test Questions***	***Passage Information***
28–32	Select a complex hypothesis, prediction, or conclusion that is supported by a data presentation or model	In a lab, the masses of 2 mineral samples, one of olivine and one of spinel, of the same size and shape were determined. Which of the following statements about the samples is most consistent with the information in Scientist 2's viewpoint? The mass of the olivine sample would be: **A.** greater than the mass of the spinel sample because spinel is more dense than olivine. ***B.** less than the mass of the spinel sample because spinel is more dense than olivine. **C.** greater than the mass of the spinel sample because olivine is more dense than spinel. **D.** less than the mass of the spinel sample because olivine is more dense than spinel.	page 62 Earth/Space Science Conflicting Viewpoints
	Determine whether new information supports or weakens a model, and why	Which of the following hypotheses would be best supported by the discovery of a plant that existed over 9,500 years ago and that looked like an intermediate between teosinte and modern corn? ***A.** Hypothesis 1, because this discovery would suggest that modern corn evolved from teosinte over a long period of time. **B.** Hypothesis 1, because this discovery would suggest that modern corn evolved from wild corn over a long period of time. **C.** Hypothesis 3, because this discovery would suggest that modern corn and teosinte share a common ancestor. **D.** Hypothesis 3, because this discovery would suggest that when mated, modern corn and teosinte produce hybrid offspring.	page 55 Biology Conflicting Viewpoints
33–36	Determine whether given information supports or contradicts a complex hypothesis or conclusion, and why	A researcher has claimed that the ability of Hb to bind with O_2 at a given P_{O_2} will decrease as temperature is increased. Do the data in Figure 3 support his claim? **A.** No; as the temperature increased, the percent saturation of Hb increased. **B.** No; as the temperature increased, the percent saturation of Hb decreased. **C.** Yes; as the temperature increased, the percent saturation of Hb increased. ***D.** Yes; as the temperature increased, the percent saturation of Hb decreased.	page 54 Biology Data Representation

THINKING YOUR WAY THROUGH THE ACT TEST

In our increasingly complex society, students' ability to think critically and make informed decisions is more important than ever. The workplace demands new skills and knowledge and continual learning; information bombards consumers through media and the Internet; familiar assumptions and values often come into question. More than ever before, students in today's classrooms face a future when they will need to adapt quickly to change, to think about issues in rational and creative ways, to cope with ambiguities, and to find means of applying information to new situations.

Classroom teachers are integrally involved in preparing today's students for their futures. Such preparation must include the development of thinking skills such as problem solving, decision making, and inferential and evaluative thinking. These are, in fact, the types of skills and understandings that underlie the test questions on the ACT.

HOW CAN ANALYZING TEST QUESTIONS BUILD THINKING SKILLS?

On pages 23–25, you will find an additional passage and sample test questions. The sample test questions provide a link to a strand, a Standard, and a score range. Each sample test question includes a description of the skills and understandings students must demonstrate in order to arrive at the best answer. The descriptions provide a series of strategies students typically might employ as they work through each test question. Possible flawed strategies leading to the choice of one or more incorrect responses also are offered. Analyzing test questions in this way, as test developers do to produce a Test Question Rationale, can provide students with a means of understanding the knowledge and skills embedded in the test questions and an opportunity to explore why an answer choice is correct or incorrect.

Providing students with strategies such as these encourages them to take charge of their thinking and learning. The sample test questions that appear in Table 2 on pages 15–21 can be used to develop additional Test Question Rationales.

> **"Learning is fundamentally about *making and maintaining connections* . . . among concepts, ideas, and meanings."**
>
> — American Association for Higher Education, American College Personnel Association, & National Association of Student Personnel Administrators, June 1998

The following passage is an example of a Research Summaries format.
The passage is followed by three questions.

A pendulum is made by suspending a mass by a thin wire from a fixed support (see Figure 1 below). If the mass is pulled out such that the wire is at some small angle from the vertical direction and released it will *oscillate* (swing back and forth between the position at which it was released and a position opposite that at which it was released). The time required for one such oscillation (over and back) is the *period* of the pendulum. The purpose of the following experiments is to determine how particular physical variables affect the measured period of a pendulum.

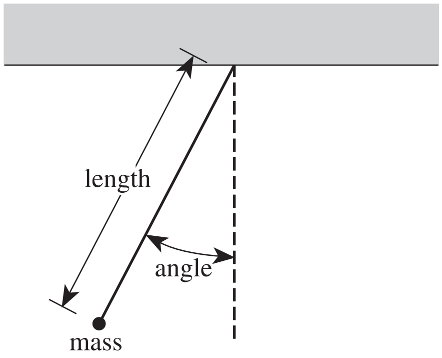


Figure 1

Experiment 1

The experimenter used three objects of different mass as pendulum weights. The wire length and the angle of initial displacement are held constant. The results of this experiment are presented in Table 1.

Table 1

Mass (kg)	Period (sec)
0.50	1.40
1.00	1.39
2.00	1.41

Experiment 2

The experimenter used three different lengths of wire to suspend the mass. The amount of mass suspended and the angle of initial displacement are held constant. The results are presented in Table 2.

Table 2

Length (m)	Period (sec)
0.50	1.40
1.00	1.98
2.00	2.81

Experiment 3

The experimenter varied the angle of initial displacement. The length of wire and the amount of mass suspended are held constant. The results are presented in Table 3.

Table 3

Angle	Period (sec)
2°	1.41
3°	1.39
4°	1.40

Experiment 4

The experimenter used the same procedure to measure the period of a single pendulum three times in a row without changing any of the variables. This is to determine the precision with which this experimental procedure can determine the period of a pendulum. The results are presented in Table 4.

Table 4

Trial	Period (sec)
1	1.98
2	1.97
3	1.99

From this passage, students gain a basic understanding of the operation of a pendulum. The introductory paragraph describes how the pendulum works and explains the period of the pendulum. New vocabulary terms, such as *oscillate* and *period* are defined. The students should also realize through reading the passage that the experimenter simply changed the physical variables that might affect the period of the pendulum. When reading the information provided for Experiments 1–4, the students must determine what is varied and what is held constant.

Test Question Rationale	
Scientific Investigation	■ Understand the methods and tools used in a moderately complex experiment ■ 20–23 score range

1. Which of the following pairs of variables was *directly* controlled by the experimenter in at least one of the experiments?

A. The amount of suspended mass and the period of oscillation
***B.** The amount of suspended mass and the length of wire
C. The length of wire and the period of oscillation
D. The initial displacement angle and the period of oscillation

Question 1 tests Understanding skills. In each experiment, a directly controlled quantity (such as mass in Experiment 1) was purposely varied to determine if and how another quantity (in these experiments, the period of the pendulum) would respond. To eliminate the possibility that other controllable quantities would affect the results, the other variables were held constant.

To answer this question, the student would need to read the descriptions of all four experiments and identify the variables that were either purposely varied or held constant: the amount of suspended mass, the initial displacement angle, and the length of wire. The products of each experiment were measurements of the period of the pendulum. Therefore, the period was the variable that was NOT directly controlled. Choice B is correct since it lists the amount of suspended mass and the length of the wire as the variables directly controlled by the experimenter. Choices A, C, and D are incorrect because they include the period of oscillation.

Test Question Rationale	
Evaluation of Models, Inferences, and Experimental Results	■ Select a simple hypothesis, prediction, or conclusion that is supported by two or more data presentations or models ■ 24–27 score range

2. The results of Experiments 1–3 are most consistent with the hypothesis that the period of a pendulum is determined by which of the following variables?

F. The amount of suspended mass only
***G.** The length of wire only
H. The amount of suspended mass and the length of wire only
J. The angle of initial displacement and the length of wire only

Question 2 tests Analysis skills. To solve this problem, the student must analyze the relationships, if any exist, between the pendulum's period and the other variables tested. To arrive at the correct relationships, a student must take into account the precision of the measurements, which was determined in Experiment 4.

In each experiment, the measurements of period were made to the nearest 0.01 sec. In Experiment 4, each of the three measurements of the period deviated from the average by 0.01 sec or less. Therefore, the experimental uncertainty in a measurement of the period could be taken to be 0.01 sec. For example, in Experiment 1, the average of the three measurements was 1.40 sec; variations of 0.01 sec or less from this average were interpreted to be experimental uncertainty, rather than indicators of a relationship between the amount of suspended mass and the period.

According to Experiment 1, when the suspended mass was varied, the period varied from the average by ±0.01 sec; this variation was within the experimental uncertainty. Therefore, one could conclude that there was no significant variation of the period when the suspended mass was varied. Said another way, the pendulum's period was *independent* of the suspended mass. By a similar analysis of the results of Experiment 3, one could also conclude that the pendulum's period was independent of the angle of initial displacement. (Note: This conclusion is valid for displacements less than a few degrees. Larger initial displacements increasingly affect the period.)

However, according to Experiment 2, as the length of wire increased, the period of the pendulum significantly increased. (That is, the period increased by more than the experimental uncertainty—in this case, by much more).

Since the period of the pendulum was affected by the wire's length but not by the amount of suspended mass or the angle of initial displacement, choice G is the only possible key. Choice F is incorrect because the amount of the suspended mass did not affect the period of the pendulum. Choice H is incorrect because only the length of the wire, and not the amount of suspended mass, affected the period of the pendulum. Choice J is incorrect because only the length of the wire, and not the initial displacement, affected the period of the pendulum.

Test Question Rationale	
Interpretation of Data	■ Extrapolate from data points in a table or graph ■ 28–32 score range

3. Based on Experiment 2, if the length of the wire is 4.00 m, the period of the pendulum will be closest to:

A. 1.40 sec.
B. 2.81 sec.
***C.** 3.97 sec.
D. 5.62 sec.

Question 3 tests Generalization skills. This question asks the students to extrapolate the results of Experiment 2. According to Table 2, as the wire's length increased, the pendulum's period also increased. Therefore, choices A and B can be eliminated, because both choices indicate that the period decreased as the wire's length increased. The rate of increase of the period with the wire's length can be estimated from the data. When the length was doubled from 0.50 m to 1.00 m, if the period also doubled, the period would have increased from 1.40 sec to 2.80 sec. Instead, the period increased from 1.40 sec to 1.98 sec, an increase that represents less than a doubling of the period. Similarly, when the length was doubled from 1.00 m to 2.00 m, had the period also doubled, the period would have increased from 1.98 sec to 3.96 sec. Instead, the period increased by less than a factor of 2, from 1.98 sec to 2.81 sec. In either case, the period increased, but it increased by less than a factor of 2. Therefore, one can predict that if the length is doubled from 2.00 m to 4.00 m, the period will increase, but it will not double. This eliminates choice D. The only possible answer is choice C. (In fact, whenever the wire's length was doubled, the period was multiplied by a factor of approximately 1.41.)

THE ASSESSMENT-INSTRUCTION LINK

WHY IS IT IMPORTANT TO LINK ASSESSMENT WITH INSTRUCTION?

Assessment provides feedback to the learner and the teacher. It bridges the gap between expectations and reality. Assessment can gauge the learners' readiness to extend their knowledge in a given area, measure knowledge gains, identify needs, and determine the learners' ability to transfer what was learned to a new setting.

When teachers use assessment tools to gather information about their students, then modify instruction accordingly, the assessment process becomes an integral part of teaching and learning. Using assessment to inform instruction can help teachers create a successful learning environment.

Students can use assessment as a tool to help them revise and rethink their work, to help integrate prior knowledge with new learning, and to apply their knowledge to new situations. Connecting assessment to classroom instruction can help both teachers and students take charge of thinking and learning.

As teachers review student performances on various measures, they can reexamine how to help students learn. As Peter Airasian, the author of *Classroom Assessment,* says, "Assessment is not an end in itself, but a means to another end, namely, good decision making" (p. 19). Linking assessment and instruction prompts both teachers and students to take on new roles and responsibilities. Through reflecting together on their learning, students and teachers can reevaluate their goals and embark on a process of continuous growth.

> **"*Every* objective, *every* lesson plan, *every* classroom activity, and *every* assessment method should focus on helping students achieve those [significant] outcomes that will help students both in the classroom and beyond."**
>
> — Kay Burke, editor of *Authentic Assessment: A Collection*

ARE YOUR STUDENTS DEVELOPING THE NECESSARY SKILLS?

Many high schools monitor the effectiveness of their educational program by tracking the success of their graduates after they leave high school. Some of the criteria by which schools measure success are the number of graduates who enroll in postsecondary institutions, the courses into which those students are placed, and the attrition rate of those students.

Because many colleges use ACT scores as one piece of information in making decisions about admissions and course placement, high schools can use students' ACT scores as they review their schools' performance. It is important to tie all the assessment information you gather to the goals of your science program and to discuss how these goals are aligned with information about postsecondary institutions. With an ever-increasing number of high school graduates entering college, it becomes the school's responsibility to ensure that its graduates have mastered the prerequisite skills necessary for success in entry-level courses. ACT's Educational Planning and Assessment System, of which EXPLORE, PLAN, and the ACT are each a part, can help provide information about students' level of knowledge and skills that can be used to guide students' secondary school learning experiences.

EXPLORE and PLAN are developmentally and conceptually linked to the ACT and thus provide a coherent framework for students and counselors and a consistent skills focus for teachers from Grades 8 through 12.

As students and others review test scores from EXPLORE, PLAN, and the ACT, they should be aware that ACT's data clearly reveal that students' ACT test scores are directly related to preparation for college. Students who take rigorous high school courses, which ACT has defined as core college preparatory courses, achieve much higher test scores than students who do not. ACT has defined core college preparatory course work as four or more years of English, and three or more years each of mathematics, social studies, and natural science.

ACT works with colleges to help them develop guidelines that place students in courses that are appropriate for their level of achievement as measured by the ACT. In doing this work, ACT has gathered course grade and test score data from a large number of first-year students across a wide range of postsecondary institutions. These data provide an overall measure of what it takes to be successful in a standard first-year college course. Data from 98 institutions and over 90,000 students were used to establish the ACT College Readiness Benchmark Scores, which are median course placement scores achieved on the ACT that are directly reflective of student success in a college course.

Success is defined as a 50 percent chance that a student will earn a grade of B or better. The courses are the ones most commonly taken by first-year students in the areas of English, mathematics, social studies, and science, namely English Composition, College Algebra, an entry-level College Social Studies/Humanities course, and College Biology. The ACT scores established as the ACT College Readiness Benchmark Scores are 18 on the English Test, 22 on the Mathematics Test, 21 on the Reading Test, and 24 on the Science Test. The College Readiness Benchmark Scores were based upon a sample of postsecondary institutions from across the United States. The data from these institutions were weighted to reflect postsecondary institutions nationally. The Benchmark Scores are median course placement values for these institutions and as such represent a *typical* set of expectations.

College Readiness Benchmark Scores have also been developed for EXPLORE and for PLAN, to indicate a student's probable readiness for college-level work, in the same courses named above, by the time the student graduates from high school. The EXPLORE and PLAN College Readiness Benchmark Scores were developed using records of students who had taken EXPLORE, PLAN, and the ACT (four years of matched data). Using either EXPLORE subject-area scores or PLAN subject-area scores, we estimated the conditional probabilities associated with meeting or exceeding the corresponding ACT Benchmark Score. Thus, each EXPLORE (1–25) or PLAN (1–32) score was associated with an estimated probability of meeting or exceeding the relevant ACT Benchmark Score. We then identified the EXPLORE and PLAN scores, at Grades 8, 9, 10, and 11, that came the closest to a 0.5 probability of meeting or exceeding the ACT Benchmark Score, by subject area. These scores were selected as the EXPLORE and PLAN Benchmark Scores.

All the Benchmark Scores are given in Table 3. Note that, for example, the first row of the table should be read as follows: An eighth-grade student who scores 13, or a ninth-grade student who scores 14, on the EXPLORE English Test has a 50 percent probability of scoring 18 on the ACT English Test; and a tenth-grade student who scores 15, or an eleventh-grade student who scores 17, on the PLAN English Test has a 50 percent probability of scoring 18 on the ACT English Test.

Table 3: **College Readiness Benchmark Scores**

	EXPLORE Test Score		**PLAN Test Score**		**ACT**
Subject Test	**Grade 8**	**Grade 9**	**Grade 10**	**Grade 11**	**Test Score**
English	13	14	15	17	18
Mathematics	17	18	19	21	22
Reading	15	16	17	19	21
Science	20	20	21	23	24

USING ASSESSMENT INFORMATION TO HELP SUPPORT LOW-SCORING STUDENTS

Students who receive a Composite score of 16 or below on the ACT will most likely require additional guidance and support from their teachers and family in order to meet their post-high school goals, particularly if one of their goals is to attend a four-year college or university.

College admission policies vary widely in their level of selectivity. Students who score at or below 16 on the ACT might best be served by exploring those institutions that have an open or liberal admission policy. ACT Composite scores typically required by colleges having varying levels of selectivity are shown in Table 4. This information provides only general guidelines. There is considerable overlap among admission categories, and colleges often make exceptions to their stated admission policies.

A student's score on each content-area test on the ACT should also be reviewed with respect to his or her future goals. For example, a student who wishes to become an engineer will need a solid science background. A high Science Test score can be used as evidence that the goal is realistic. A low score suggests the student should consider ways of improving his or her science knowledge and skills through additional course work and/or additional assistance in the area.

WHAT ARE SOME FACTORS THAT AFFECT STUDENT PERFORMANCE?

Many factors affect student achievement. Diane Ravitch, a research professor at New York University, has identified several positive factors in her book *The Schools We Deserve: Reflections on the Educational Crisis of Our Time* (1985, pp. 276 and 294). These factors, which were common to those schools that were considered effective in teaching students, include

- a principal who has a clearly articulated vision for the school, and the leadership skills to empower teachers to work toward that vision;
- a strong, clearly thought-out curriculum in which knowledge gained in one grade is built upon in the next;
- dedicated educators working in their field of expertise;
- school-wide commitment to learning, to becoming a "community of learners";
- a blend of students from diverse backgrounds;
- "high expectations for all" students; and
- systematic monitoring of student progress through an assessment system.

There are also factors that have a negative impact on student achievement. For example, some students "may not know about, know how, or feel entitled to take academic advantage of certain opportunities, like college preparatory courses, college entrance exams, and extracurricular learning opportunities" (Goodwin, 2000, p. 3).

All students need to be motivated to perform well academically, and they need informed guidance in sorting out their educational/career aspirations. Teachers who challenge their students by providing a curriculum that is rigorous and relevant to their world and needs (Brewer, Rees, & Argys, 1995; Gay, 2000), and who have a degree and certification in the area in which they teach (Ingersoll, 1998) and ample opportunities to collaborate with their peers (McCollum, 2000), are more likely to engender students' success in school.

MAKING THE INVISIBLE VISIBLE

Using assessment information, such as ACT's Educational Planning and Assessment System (EPAS), can help bring into view factors that may affect—either positively or negatively—student performance. Reviewing and interpreting assessment information can encourage conversations between parents and teachers about what is best for students.

Table 4: **The Link Between ACT Composite Scores and College Admission Policies**

Admission Policy	Typical Class Rank of Admitted Students	Typical ACT Composite Scores of Admitted Students
Highly Selective	Majority of accepted freshmen in top 10% of high school graduating class	25–30
Selective	Majority of accepted freshmen in top 25% of high school graduating class	21–26
Traditional	Majority of accepted freshmen in top 50% of high school graduating class	18–24
Liberal	Some of accepted freshmen from lower half of high school graduating class	17–22
Open	All high school graduates accepted to limit of capacity	16–21

Using data is one way of making the assumptions you have about your students and school, or the needs of students, visible.

Collecting assessment information in a systematic way can help teachers in various ways. It can help teachers see more clearly what is happening in their classrooms, provide evidence that the method of teaching they're using really works, and determine what is most important to do next. As teachers become active teacher-researchers, they can gain a sense of control and efficacy that contributes to their sense of accomplishment about what they do each day.

There are many different types of assessment information that a school or school district can collect. Some types yield quantitative data (performance described in numerical terms), others qualitative data (performance described in nonnumerical terms, such as text, audio, video, or photographs, etc.). All types, when properly analyzed, can yield useful insights into student learning. For example, schools and teachers can collect information from

- standardized tests (norm- or criterion-referenced tests);
- performance assessments (such as portfolios, projects, artifacts, presentations);
- peer assessments;
- progress reports (qualitative, quantitative, or both) on student skills and outcomes;
- self-reports, logs, journals; and
- rubrics and rating scales.

Reviewing student learning information in the context of demographic data may also provide insight and information about specific groups of students, like low-scoring students. Schools therefore would benefit by collecting data about

- enrollment, mobility, and housing trends;
- staff and student attendance rates and tardiness rates;
- dropout, retention, and graduation rates;
- gender, race, ethnicity, and health;
- percent of free/reduced lunch and/or public assistance;
- level of language proficiency;
- staff/student ratios;
- number of courses taught by teachers outside their endorsed content area;
- retirement projections and turnover rates; and
- teaching and student awards.

WHAT DOES IT MEAN TO BE A LOW-SCORING STUDENT?

Low-achieving students tend to be those students who score low on standardized tests. Students who slip behind are the likeliest to drop out and least likely to overcome social and personal disadvantages.

According to Judson Hixson, a researcher at the North Central Regional Educational Laboratory (NCREL), students who are at risk should be considered in a new light:

> Students are placed "at risk" when they experience a significant mismatch between their circumstances and needs, and the capacity or willingness of the school to accept, accommodate, and respond to them in a manner that supports and enables their maximum social, emotional, and intellectual growth and development.
>
> As the degree of mismatch increases, so does the likelihood that they will fail to either complete their elementary and secondary education, or more importantly, to benefit from it in a manner that ensures they have the knowledge, skills, and dispositions necessary to be successful in the next stage of their lives—that is, to successfully pursue post-secondary education, training, or meaningful employment and to participate in, and contribute to, the social, economic, and political life of their community and society as a whole.
>
> The focus of our efforts, therefore, should be on enhancing our institutional and professional capacity and responsiveness, rather than categorizing and penalizing students for simply being who they are. (Hixson, 1993, p. 2)

Hixson's views reveal the necessity of looking at all the variables that could affect students' performance, not just focusing on the students themselves.

Low-achieving students may demonstrate some of the following characteristics:

- difficulty with the volume of work to be completed;
- low reading and writing skills;
- low motivation;
- low self-esteem;
- poor study habits;
- lack of concentration;
- reluctance to ask for help with tasks/assignments; and
- test anxiety.

Many of these characteristics are interconnected. A low-scoring student cannot do the volume of work a successful student can do if it takes a much longer time to decipher text passages because of low reading skills. There is also the issue of intrinsic motivation in that students have little desire to keep trying to succeed if they habitually do not experience success.

But again, we must not focus only on the students themselves, but also consider other variables that could affect their academic performance, such as

- job or home responsibilities that take time away from school responsibilities;
- parental attitude toward and involvement in students' school success;
- students' relationships with their peers;
- lack of opportunities to engage in complex problems that are meaningful to students; and
- lack of adequate support and resources.

For example, some students who score low on tests are never introduced to a curriculum that challenges them or that addresses their particular needs: "Much of the student stratification within academic courses reflects the social and economic stratification of society. Schools using tracking systems or other methods that ultimately place low-income and marginal students in lower-level academic courses are not adequately preparing them to plan for postsecondary education, succeed in college, and prepare for lifelong learning" (Noeth & Wimberly, 2002, p. 18).

As Barbara Means and Michael Knapp have suggested, many schools need to reconstruct their curricula, employing instructional strategies that help students to understand how experts think through problems or tasks, to discover multiple ways to solve a problem, to complete complex tasks by receiving support (e.g., cues, modifications), and to engage actively in classroom discussions (1991).

Many individuals and organizations are interested in helping students succeed in the classroom and in the future. For example, the Network for Equity in Student Achievement (NESA), a group of large urban school systems, and the Minority Student Achievement Network (MSAN), a group of school districts in diverse suburban areas and small cities, are organizations that are dedicated to initiating strategies that will close the achievement gap among groups of students. Many schools and districts have found participation in such consortia to be helpful.

According to Michael Sadowski, editor of the *Harvard Education Letter,* administrators and teachers who are frustrated by persistent achievement gaps within their school districts "have started to look for answers within the walls of their own schools. They're studying school records, disaggregating test score and grade data, interviewing students and teachers, administrating questionnaires—essentially becoming researchers—to identify exactly where problems exist and to design solutions" (Sadowski, 2001, p. 1).

A student may get a low score on a standardized test for any of a number of reasons. To reduce the probability of that outcome, the following pages provide some suggestions about what educators and students can do before students' achievement is assessed on standardized tests like the ACT.

WHAT CAN EDUCATORS AND STUDENTS DO BEFORE STUDENTS TAKE THE ACT?

Integrate assessment and instruction. Because the ACT is curriculum based, the most important prerequisite for optimum performance on the test is a sound, comprehensive educational program. This "preparation" begins long before any test date. Judith Langer, the director of the National Research Center on English Learning and Achievement, conducted a five-year study that compared the English programs of typical schools to those that get outstanding results. Schools with economically disadvantaged and diverse student populations in California, Florida, New York, and Texas predominated the study. Langer's study revealed that in higher performing schools "test preparation has been integrated into the class time, as part of the ongoing English language arts learning goals." This means that teachers discuss the demands of high-stakes tests and how they "relate to district and state standards and expectations as well as to their curriculum" (Langer, Close, Angelis, & Preller, 2000, p. 6).

Emphasize core courses. ACT research conducted in urban schools both in 1998 and 1999 shows that urban school students can substantially improve their readiness for college by taking a tougher sequence of core academic courses in high school. Urban students taking a more rigorous sequence of courses in mathematics and science and finding success in those courses score at or above national averages on the ACT. Regardless of gender, ethnicity, or family income, those students who elect to take four or more years of rigorous English courses and three or more years of rigorous course work in mathematics, science, and social studies earn higher ACT scores and are more successful in college than those who have not taken those courses (ACT & Council of Great City Schools, 1999). Subsequent research has substantiated these findings and confirmed the value of rigor in the core courses (ACT, 2004; ACT & The Education Trust, 2004).

Teach test-taking strategies. Students may be helped by being taught specific test-taking strategies, such as the following:

- Learn to pace yourself.
- Know the directions and understand the answer sheet.
- Read carefully and thoroughly.
- Answer easier questions first; skip harder questions and return to them later.
- Review answers and check work, if time allows.
- Mark the answer sheet quickly and neatly; avoid erasure marks on the answer sheet.
- Answer every question (you are not penalized for guessing on the ACT).
- Become familiar with test administration procedures.
- Read all the answer choices before you decide which is the best answer.

Students are more likely to perform at their best on a test if they are comfortable with the test format, know appropriate test-taking strategies, and are aware of the test administration procedures. Test preparation activities that help students perform better in the short term will be helpful to those students who have little experience taking standardized tests or who are unfamiliar with the format of the ACT.

Search out other sources of help. School personnel in urban or high-poverty middle schools can investigate programs such as GEAR UP, which “provides federal funds for schools to prepare low-income middle school students for high school and college preparation through multiple school reform efforts. School districts, colleges, community organizations, and businesses often form partnerships to provide teachers with enhanced professional development opportunities to ensure they have the necessary tools and strategies to teach middle school and high school effectively” (Noeth & Wimberly, 2002, p. 18).

WHAT DO THE ACT SCIENCE TEST RESULTS INDICATE ABOUT LOW-SCORING STUDENTS?

Students who score below 16 on the ACT Science Test are likely to have some or all of the knowledge and skills described in the ACT Science College Readiness Standards for the 13–15 range. In fact, they may well have some of the skills listed in the 16–19 range. However, these students need to become more consistent in demonstrating these skills in a variety of contexts or situations.

The Science College Readiness Standards indicate that students who score below 16 tend to have the ability to

- Select a single piece of data (numerical or nonnumerical) from a simple data presentation (e.g., a table or graph with two or three variables; a food web diagram)
- Identify basic features of a table, graph, or diagram (e.g., headings, units of measurement, axis labels)

In other words, these students typically can read basic graphs, uncomplicated diagrams, or tables of data displaying two different variables. They can read and comprehend information in a written description of a simple science experiment or in a text that describes or discusses an uncomplicated scientific observation. They can understand some basic scientific terminology and know the most familiar units of measure. These students typically demonstrate an ability to work with straightforward, simple displays of data similar to those they have seen in their textbooks and classes.

These students likely need assistance in applying simple data interpretation skills to more unfamiliar or complex presentations of data. They also generally need help in developing facility in reading and interpreting text written specifically to describe scientific observations, research, and results.

WHAT DOES RESEARCH SAY ABOUT SCIENTIFICALLY LITERATE STUDENTS?

It is important to distinguish between *science literacy* and *scientific literacy.* Science literacy focuses on gaining specific scientific or technical knowledge. Science literacy emphasizes practical results and stresses short-term goals, such as training members of society with specific facts and skills (Maienschein, 1998). Scientific literacy, in comparison, entails scientific ways of knowing and the processes of thinking critically and creatively. Scientific literacy can only be achieved over the long term. Scientific literacy has emerged as a central goal of science education. The thought processes developed during the education of a scientifically literate population help individuals to be adaptable, to be able to critically examine issues, to solve problems, to realize the impact of science knowledge on their lives, and to develop communication skills with respect to science topics. As students grow in scientific literacy by learning science thinking and process skills such as analyzing, formulating models, and inferring, they improve their reading, mathematics, and oral and written communication skills at the same time (Ostlund, 1998).

There are different types of scientific literacy. In a narrow sense, scientifically literate students are able to read and interpret graphs displaying scientific information, read and write passages that include scientific vocabulary, and use scientific terminology appropriately. Some have applied the term *functional scientific literacy* to these skills and abilities. A second type of scientific literacy is *conceptual procedural literacy,* in which students are familiar with the concepts and principles of science and possess an understanding of the procedures and processes that make science a unique way of knowing. Students who exhibit conceptual procedural literacy are able to design an experiment that is a valid test of a hypothesis or to pose a question that can be tested by scientific methods. *Multidimensional scientific literacy* is a third type of scientific literacy, one in which students develop an understanding of the different aspects of science, such as the nature of science and technology, the history of scientific ideas, and the role of science in personal life and society (Yager, 1993). Students who exhibit this last type of scientific literacy can engage in a scientific discussion of controversial issues and apply scientific information in personal decision making.

Science reasoning, such as that assessed by the ACT Science Test, is a common thread across these three types of scientific literacy. Development of a familiarity with science, of science reasoning skills, and of the ability to use scientific concepts empowers students for lifelong learning. Teaching and learning science in ways that reflect how science is practiced lead to a greater understanding of the connections that make the concepts and theories of science manageable.

WHAT CAN BE DONE TO HELP STUDENTS EFFECTIVELY DEVELOP SCIENTIFIC LITERACY?

George Nelson, Director for Project 2061, states that “Effective education for science literacy requires that every student be frequently and actively involved in exploring nature in ways that resemble how scientists work” (Nelson, 1999, p. 16). Some of the qualities of this “effective education” are science activities that

- are inquiry-based/problem-centered/hands-on;
- allow learning from the concrete to the abstract;
- allow learning from the local to the global;
- require both cooperative and individual performance;
- give opportunities for learner self-evaluation;
- use interdisciplinary connections;
- give students a sense of ownership of the inquiry;
- focus on applying appropriate investigational and analytical strategies;
- emphasize attitudes, problem solving, critical thinking, decision making, applications, technology, and societal issues; and
- reflect current understanding of the nature of the learner.

(adapted from Bybee & DeBoer, 1994)

Another way to develop students’ scientific literacy is to conclude a science inquiry by requiring students to rephrase the primary concepts in their own words and to support their ideas with data or information.

WHAT KNOWLEDGE AND SKILLS ARE LOW-SCORING STUDENTS READY TO LEARN?

For students who score below 16 on the ACT Science Test, their target achievement outcomes could be the College Readiness Standards listed in the 16–19 range of the Interpretation of Data and Scientific Investigation strands. Those students should also have target achievement outcomes that help them begin to develop the skills and understandings included in the 20–23 range of the Evaluation of Models, Inferences, and Experimental Results strand. The list below summarizes the desirable target achievements.

- Select two or more pieces of data from a simple data presentation
- Understand basic scientific terminology
- Find basic information in a brief body of text
- Determine how the value of one variable changes as the value of another variable changes in a simple data presentation
- Understand the methods and tools used in a simple experiment

In addition to working toward these skills, students could learn how to create simple graphic presentations of data. These presentations should include, but are not limited to, vertical and horizontal bar graphs and line graphs (using linear scales and displaying one or more plots). Students could learn how to use any of the types of graphics mentioned above to compare data points, interpret trends in the data, or make basic conclusions or predictions. They likely need practice reading and understanding uncomplicated written descriptions of scientific phenomena and basic experiments and identifying at least one variable and, perhaps, a control in an experiment. They should also become familiar with basic scientific terminology and units of measure and work to perform simple experiments and gather data.

By no means should these be seen as limiting or exclusive goals. As stated earlier, it is important to use multiple sources of information to make instructional decisions. And individual students learn at different rates and in different sequences. What's important is to get students doing science.

WHAT STRATEGIES/MATERIALS CAN TEACHERS USE IN THEIR CLASSROOMS?

According to Bryan Goodwin, senior program associate at the Mid-continent Research Education Laboratory (McREL), "it is important to note that improving the performance of disenfranchised students does not mean ignoring other students. Indeed, many of the changes advocated—such as making curricula more rigorous and creating smaller school units—will benefit all students" (Goodwin, 2000, p. 6). Means and Knapp (1991) express a similar view:

> A fundamental assumption underlying much of the curriculum in America's schools is that certain skills are "basic" and must be mastered before students receive instruction on more "advanced" skills, such as reading comprehension, written composition, and mathematical reasoning. . . . Research from cognitive science questions this assumption and leads to a quite different view of children's learning and appropriate instruction. By discarding assumptions about skill hierarchies and attempting to understand children's competencies as constructed and evolving both inside and outside of school, researchers are developing models of intervention that start with what children know and provide access to explicit models of thinking in areas that traditionally have been termed "advanced" or "higher order." (p. 1)

At-risk students can benefit from the same types of strategies used to develop scientific literacy in any student. Horton and Hutchinson (1997) state that scientific literacy continuously develops when the science curriculum incorporates a wide variety of learning episodes. Keefer (1998) lists some criteria for designing an inquiry-based activity. These include:

- Students must have a problem to solve.
- Students must know they can solve the initial problem.
- Students must have background information that is either provided to them or that they can acquire themselves.
- Students should experience success.

Schwartz (1987) states that hands-on experience, begun early and continuing throughout the schooling of at-risk students, is important in successfully developing scientific literacy in that population. Other successful strategies for at-risk students include providing a cooperative classroom environment that uses student groups, smaller classes, adequate time-on-task, and extracurricular learning opportunities.

Pages 36–38 exemplify the kind of teacher-developed activity that could be used in a classroom for all students, not just those who have scored low on a standardized assessment like the ACT. The students are asked to perform a simple science investigation involving the concept of surface tension. In this activity, the students are asked to collect and graph data, and to draw conclusions from the results. A simple scoring rubric is included that could be used by the teacher to assess student learning and by the students for self-evaluation. Also included are suggestions for other related investigations.

HOW IS THE ACTIVITY ORGANIZED?

The primary strands addressed in the activity are displayed across the top of the page. Next is a box that contains *Guiding Principles*—statements about instruction, assessment, thinking skills, student learning, and other educationally relevant topics. (The bibliography beginning on page 51 of this guide includes the source for each statement referenced.) Following the *Guiding Principles* box is the title of the activity, followed by the relevant *College Readiness Standards,* then the *Description of the Instructional Activity.* The description is followed by *Suggestions for Assessment,* the applicable *Ideas for Progress,* and *Suggested Strategies/Activities.*

- The *College Readiness Standards* section lists the skill statements tied directly to the strands that will be focused on in the activity.
- The *Description of the Instructional Activity* section provides suggestions for engaging students in the activity. The activity addresses a range of objectives and modes of instruction, but it emphasizes providing students with experiences that focus on reasoning and making connections, use community resources and real-life learning techniques, and encourage students to ask questions.

- The *Suggestions for Assessment* section offers an idea for documenting and recording students' learning during the instructional activity.
- The *Ideas for Progress* section provides statements that suggest learning experiences that are connected to the *Suggested Strategies/Activities*.
- The *Suggested Strategies/Activities* section provides an elaboration on the central activity or ideas for investigating related topics or issues. The suggestions are connected to one or more ideas for progress.

This teacher-developed activity provides suggestions, not prescriptions. You are the best judge of what is necessary and relevant for your students. Therefore, we encourage you to review the activity, modifying and using those suggestions that apply, and disregarding those that are not appropriate for your students. As you select, modify, and revise the activity, you can be guided by the statements that appear in the *Guiding Principles* box at the beginning of the activity.

Guiding Principles

- "The inquisitive spirit of science is assimilated by students who participate in meaningful laboratory activities." (National Science Teachers Association [NSTA], 1996, p. 209)
- "Science is for all students." (National Research Council [NRC], 1996, p. 19)
- "Learning science is an active process." (NRC, 1996, p. 19)

SURFACE TENSION

College Readiness Standards

- Determine the hypothesis for an experiment
- Understand a simple experimental design
- Translate information into a table, graph, or diagram
- Identify basic features of a table, graph, or diagram (e.g., headings, units of measurements, axis labels)
- Understand basic scientific terminology

Description of the Instructional Activity

How can water bugs walk on water? Why do water droplets "bead up" on wax paper? These questions can be answered by investigating the concept of *surface tension.* Surface tension is the property of water that causes its surface to contract and to resemble a thin, invisible, elastic skin.

In this activity, students can investigate the concept of water surface tension by seeing how many paper clips can be added to a full glass of water, observing how high the water will mound up above the rim before the water overflows.

Divide the students into groups of three and have each group discuss and record their prediction of how many paper clips they can put into a full glass of water before it overflows. After the prediction, the group will construct an "If . . . then" hypothesis about the properties of water and the conditions that allowed it to overflow (e.g., If the mounding up of the water being displaced by the paper clips overcomes the surface tension of the water, then the water will overflow). Each group will be given an identical glass filled with the same amount of water. One member of the group will be the recorder and will write down the prediction and keep a tally of the number of paper clips dropped into the glass of water. A second student will be the experimenter and will add the paper clips to the water by holding them approximately 2 centimeters above the surface and dropping the clips straight down. The third member will be the observer and will record experimental conditions, including any water spillage, variations among paper clips, and height and angle of drop, to help identify potential sources of experimental error. This information will be used in a class discussion to explain variations in data from group to group.

Students could be asked to prepare a simple report about the experiment. Students can organize the averaged class results into one class chart and prepare a graphic presentation of the data. Some possible graphic presentations are bar graphs and line graphs. Students can also quantify their results in different ways, such as percentages, data ranges, differences between predicted and obtained values, and percent error. This activity could culminate in a class discussion of the results, conclusions, sources of error, use of controls, and further questions about the investigation.

Suggestions for Assessment

Scoring Rubric—A dichotomous scoring rubric is a simple way to provide students with a list of indicators they must complete when writing their report about the experiment. A sample Surface Tension Assessment Rubric can be found on page 38. After each listed indicator are three columns. Two of the columns provide space to indicate the presence (Yes) or absence (No) of the indicator. A check mark should be placed in the appropriate column. The fourth column provides a place for comments. The number of check marks in the "Yes" column determines a student's level of achievement according to the following rating scale: Novice (0–3); Apprentice (4–6); Practitioner (7–8); and Expert (9–10).

Ideas for Progress

- Locate several data points in a simple table or graph and make comparisons between them
- Create basic tables and graphs from sets of scientific data
- Become familiar with common terms used in science (e.g., *star, force, mineral*)
- Consider how changing an experimental procedure will affect the results of their scientific investigations

Suggested Strategies/Activities

Some additional activities could include comparing the results of the original experiment with those of a new experiment using:

- heated water;
- water containing a drop of liquid detergent;
- other liquids, such as olive oil;
- water containing various concentrations of salt; and
- water mixed with other solvents.

Students could also tap the table upon which the glass is sitting to see if vibrations disrupt the surface tension of the water.

Students could be asked to use quarters, nickels, or dimes instead of paper clips so that the concept of volume displacement could be introduced and explored.

Another corollary activity might be predicting and observing how many drops of water can be placed on a penny.

These activities may serve as a segue to interest in water striders and other insects that walk/move about on water surfaces.

Additional Terms:

The terms listed below are commonly used to describe the molecular forces involved with water surface tension. They are included as a background knowledge aid for the instructor and as a possible bridge to related topics (e.g., capillary action).

Cohesion—intermolecular attractive forces between like molecules (e.g., the molecules of a water droplet are held together by cohesive forces, and the strong cohesive forces at the surface constitute surface tension).

Adhesion—intermolecular attractive forces between unlike molecules or between the surfaces of bodies in contact (e.g., the adhesive forces between water molecules and the walls of a glass tube are stronger than the cohesive forces).

Surface Tension Assessment Rubric

Name: ______________________________ Period: ______________ Date: ______________

Read each indicator and place a check mark in either the “Yes” or “No” column.
Explanatory comments can be written in the “Comments” column.

Indicator	Yes	No	Comments
Student-generated hypotheses were relevant to the activity.			
Data was organized correctly.			
Calculations were consistently accurate.			
Plots on the graphs were correct.			
Graph layout was correct and included necessary/appropriate labels and title.			
Conclusion was supported by data.			
Surface tension was given as part of the explanation.			
Constants were identified, e.g., size and type of paper clips.			
Accurate reasons for differences in data were given.			
Properties of liquids were mentioned.			

Total Number of “Yes” Checks ☐

Rating Scale

Novice	Apprentice	Practitioner	Expert
0–3	4–6	7–8	9–10

INSTRUCTIONAL ACTIVITIES FOR ACT SCIENCE

WHY ARE ADDITIONAL INSTRUCTIONAL ACTIVITIES INCLUDED?

The set of instructional activities that begins on page 40 was developed to illustrate the link between classroom-based activities and the skills and understandings embedded in the ACT Science Test questions. The activities are provided as examples of how classroom instruction and assessment, linked with an emphasis on reasoning, can help students practice skills and understandings they will need in the classroom and in their lives beyond the classroom. It is these skills and understandings that are represented on the ACT Science Test.

A variety of thought-provoking activities, such as short- and long-term collaborative projects for both small and large groups, are included to help students develop and refine their skills in many types of situations.

The instructional activities that follow have the same organizational structure as the ones in the previous section. *Like the other activities, these activities were not developed to be a ready-to-use set of instructional strategies.* ACT's main purpose is to illustrate how the skills and understandings embedded in the ACT Science Test questions can be incorporated into classroom activities.

For the purpose of this part of the guide, we have tried to paint a picture of the ways in which the activities could work in the classroom. We left room for you to envision how the activities might best work for you and your students. We recognize that as you determine how best to serve your students, you take into consideration your teaching style as well as the academic needs of your students; state, district, and school standards; and available curricular materials.

The instructional activities are not intended to help drill students in skills measured by the ACT Science Test. It is never desirable for test scores or test content to become the sole focus of classroom instruction. However, considered with information from a variety of other sources, the results of standardized tests can help you identify areas of strength and weakness. The activities that follow are examples of sound educational practices and imaginative, integrated learning experiences. As part of a carefully designed instructional program, these activities may result in improved performance on the ACT Science Test—not because they show how to drill students in specific, isolated skills but because they encourage thinking and integrated learning. These activities can help because they encourage the kind of thinking processes and strategies the ACT Science Test requires.

Linking Instruction and Assessment

Strands: *Interpretation of Data; Scientific Investigation; Evaluation of Models, Inferences, and Experimental Results*

Guiding Principles

- "The ability to engage in the presentation of evidence, reasoned argument, and explanation comes from practice. Teachers [should] encourage informal discussion and structure science activities so that students are required to explain and justify their understanding, argue from data and defend their conclusions, and critically assess and challenge the scientific explanations of one another." (National Research Council [NRC], 1996, p. 50)
- "[Teachers should] structure and facilitate ongoing formal and informal discussion based on a shared understanding of rules of scientific discourse." (NRC, 1996, p. 50)
- "Skilled teachers guide students to understand the purposes for their own learning and to formulate self-assessment strategies." (NRC, 1996, p. 42)

FOOD IRRADIATION

College Readiness Standards

- Analyze given information when presented with new, complex information
- Identify strengths and weaknesses in one or more models
- Identify similarities and differences between models
- Identify key issues or assumptions in a model
- Determine whether new information supports or weakens a model, and why

Description of the Instructional Activity

This activity revolves around a question we may face at the local supermarket: Should I eat irradiated food? In this activity, students can try to consider all of the issues involved with food irradiation, including scientific, technological, economic, and political factors.

The class can be divided into three groups. One group can be the investigative team that is in favor of food irradiation and another group can comprise an investigative team that is opposed to irradiating food. The third group can act as an independent research team that will also serve as a jury for final recommendations.

A certain amount of time can be allotted so that each team can *thoroughly* investigate as many issues as possible related to the topic. The team that is in favor of food irradiation will focus on its virtues, and the team opposed to food irradiation will focus on the problems or unanswered questions associated with irradiating food. Each team will need to know the weaknesses in their case and develop lines of reasoning to lessen the impact. The independent team will need to gather data on both sides of the issue so that they can intelligently consider the information they receive. Following is a list of factors (Avakian et al., 1996, and Schwarz et al., 1994) students may consider in building their cases, but students should be encouraged to expand this list and dig deeper into the issue:

- *Does irradiation leave radioactive materials in food?*
- *Does irradiation alter substances in food, making them harmful to humans?*
- *Does irradiation lessen the nutritional value of food?*
- *Is irradiation an efficient way to protect food from contamination?*
- *Are there safer and/or more effective ways to do what irradiation is supposed to do for food?*

- *Does the process used for irradiating foods endanger workers at food processing plants?*
- *Will food irradiation significantly lessen the amount of illness and the loss of lives due to food contamination?*

More information about this topic can be obtained from Internet sites such as http://www.cdc.gov/ncidod/eid/vol7no3_supp/tauxe.htm.

One possibility for generating ideas for investigation is to have students make concept maps related to the task. Students can visit libraries, speak with farmers, grocers, and food scientists, search the Internet, and use any other related source available. Students from each team can gather evidence into a comprehensive report or portfolio, including charts and graphs.

The investigation can culminate in a mock public hearing in which each team presents its case to the independent team. Throughout the trial, the independent team can question the validity of the data that is presented. Part of the duty of the independent team can be to make recommendations to the public at the conclusion of the hearing.

Suggestions for Assessment

Written Report—The teams' reports could be assessed on their depth of investigation and how the report demonstrates the students' ability to interpret the scientific and technological information they have included.

Scoring Rubric—Prior to the hearing, the teacher can share with students the criteria that will be used for assessing their performances. This could be in the form of a rubric, containing elements such as accuracy of information presented, the strength and logic of their arguments, public presentation, persuasiveness, preparedness, participation, and diplomacy. Each team can also examine the reports generated by the other teams. This would provide the possibility for each student to do a peer evaluation of each team's work.

Ideas for Progress

- Determine alternate methods of testing a hypothesis
- Evaluate whether the data produced by an experiment adequately support a given conclusion
- Seek out new information that enhances or challenges their existing knowledge

Suggested Strategies/Activities

Students could obtain irradiated and nonirradiated versions of the same food products, then design and carry out experiments to evaluate and compare the appearance of the two versions over time. If possible, students could contact a local laboratory that analyzes food and see if they would help students assay the foods for nutritional value. Consumer opinions could also be evaluated with surveys. A related topic that could also be explored is the current controversy over genetically altered fruits and vegetables.

Guiding Principles

- "An important stage of inquiry and of student science learning is the oral and written discourse that focuses the attention of students on how they know what they know and how their knowledge connects to larger ideas, other domains, and the world beyond the classroom. Teachers directly support and guide this discourse in two ways: They require students to record their work—teaching the necessary skills as appropriate—and they promote many different forms of communication (for example, spoken, written, pictorial, graphic, mathematical, and electronic)." (NRC, 1996, p. 36)
- "Well-conceived school laboratory experiences . . . provide opportunities for students to become familiar with the phenomena that the science concepts being studied try to account for." (American Association for the Advancement of Science [AAAS], 1993, p. 9)
- "Challenge students to accept and share responsibility for their own learning." (NRC, 1996, p. 36)

SEED GERMINATION

College Readiness Standards

- Identify a control in an experiment
- Understand a complex experimental design
- Compare or combine data from a simple data presentation (e.g., order or sum data from a table)
- Determine how the value of one variable changes as the value of another variable changes in a simple data presentation
- Translate information into a table, graph, or diagram

Description of the Instructional Activity

Seed germination is the initial step in the growth of a plant. What factors affect the rate and/or success of seed germination? Temperature, water, light, and soil are factors associated with plant growth, so these might all be possible avenues for investigation. In this activity, students can study how different colors of light may affect the germination of different types of grass seed. It may be useful to have students try to state the hypothesis of the experiment before starting.

The investigation could be carried out with many different types of seed, but four readily available types of grass seed that can be used are bermuda, rye, fescue, and bluegrass. The following equipment is used in the investigation.

- 4 different types of grass seed (at least 200 seeds each)
- 20 petri dishes
- filter paper
- blue, red, green, and clear cellophane (other colors could be used)

This activity may work more smoothly if students are divided into groups, each with different assigned duties. Students can count out 200 seeds of each seed type, and further divide these amounts into five groups of 40 seeds each. Place moistened circles of filter paper in each of the 20 petri dishes (be sure to keep the lid on the petri dish to prevent drying of the paper). Place each group of 40 seeds in its own petri dish, directly on the moistened filter paper. Be careful to label each petri dish. Place four of the petri dishes (one from each seed type) in a dark room or under something that will keep them from getting any light.

Carefully wrap each dish from another set of four petri dishes (one from each seed type) in clear cellophane, taking care that approximately the same amount or thickness of cellophane is used to wrap each dish. Continue this process with the other colors of cellophane. Place these 16 dishes in a place near a window where they will all receive the same amount of sunlight (plant lights could also be used). Over the next 7 to 14 days at regular intervals, students can count the number of seeds that have germinated. They can also be encouraged to make general observations about the seeds. Students can construct tables such as the one below in which to record each day's results:

Grass type	Number of seeds germinated on day __ under:				
	no light	blue light	green light	red light	white light
Bluegrass					
Bermuda					
Fescue					
Rye					
General observations					

After 7 to 14 days, students can organize their data and translate the results into different forms. Some possible presentations are bar graphs, line graphs, and pie charts. Students can also quantify their results in different ways (raw data, percentages, etc.) This activity could culminate in a presentation of results to the class, or in mock journal articles, detailing all aspects of the investigation.

If the experiment seems too complex for students, it can be simplified by looking at only one species of grass. Pea seeds are also commonly used for germination demonstrations and experiments.

Suggestions for Assessment

Performance Assessment—Assessment criteria that encourage students to present their data in as many unique ways as possible will help students gain comfort with graphing and encourage them to explore different formats for data presentation. Students can also be assessed with questions such as:

- *Why were the petri dishes receiving white light covered with cellophane?*
- *In what way did some of the treatments serve as controls?*
- *How could the results of this experiment be used in a practical way?*
- *What are the strengths and weaknesses of this experimental design? How could the experiment be improved?*

Ideas for Progress

- Design and carry out additional scientific inquiries to answer specific questions
- Consider how changing an experimental procedure will affect the results of their scientific investigations
- Seek out new information that enhances or challenges their existing knowledge

Suggested Strategies/Activities

Students could be asked to consider how they might change the experimental design or procedures they used in this activity. They could submit proposals detailing and defending their changes that would also include their predictions about how these changes would affect the results of the inquiry. As mentioned above, light is only one factor that may affect germination. Many other factors could be studied, such as water, temperature, plant species (annuals vs. perennials, forest vs. prairie species), water pH, etc.

Guiding Principles

- "The physical environment in and around the school can be used as a living laboratory for the study of natural phenomena." (NRC, 1996, p. 45)
- "The school science program must extend beyond the walls of the school to the resources of the community." (NRC, 1996, p. 45)
- "[Teachers should] use student data, observations of teaching, and interactions with colleagues to reflect on and improve teaching practice." (NRC, 1996, p. 42)

SOIL AND TOPOGRAPHY

College Readiness Standards

- Understand basic scientific terminology
- Select data from a complex data presentation (e.g., a table or graph with more than three variables; a phase diagram)
- Compare or combine data from a complex data presentation
- Select a simple hypothesis, prediction, or conclusion that is supported by two or more data presentations or models
- Determine whether given information supports or contradicts a simple hypothesis or conclusion, and why

Description of the Instructional Activity

Where should we build the soccer field? Will this area flood in the spring? Geologists are often sought for advice on these types of questions and many more. Geologists use many different tools to help answer questions concerning the land and its soil, two of which are *soil maps* and *topographic maps.* This activity can involve a collaboration with local agencies to help students learn to use soil maps and topographic maps to better understand the geology of their local area.

Ideally, this activity should involve one or more geologists from a local agency involved with land management (Department of Natural Resources, Geological Survey, Soil and Water Conservation Agency, civil engineer, or a university professor). See if a geologist would be able to provide (or help you to find) soil and topographic maps of the local area. If possible, have a geologist come to the class to speak about his or her profession and education, and show the class how geologists use topographic maps. If these resources are not available, most Earth science and geology textbooks provide examples of each, or students could search a library or the Internet.

In this activity students will construct 3-dimensional models of local areas using topographic maps. Some topographic maps may be too detailed for this activity. It may be necessary to have students choose a small segment of the map or to simplify the detail by considering only every third, fourth, or fifth contour line. This will be a challenging activity for most students, so be sure that students work at a level of detail that they can fully interpret. Students can work in groups, using materials of their choice. Some possibilities for materials include layers of cardboard or modeling clay.

Linking Instruction and Assessment

Strands: *Interpretation of Data; Scientific Investigation; Evaluation of Models, Inferences, and Experimental Results*

Suggestions for Assessment

Multiple-Choice Questions—Before doing the activity, students could be given a multiple-choice test to assess prior knowledge of the terms and concepts embedded in this activity. They could also be asked to provide justifications for why they chose each answer. This can help provide insights about student misconceptions that may be addressed with additional instruction and guidance. Various criteria could be used to assess their models (accuracy of scaling, quality of the model, originality of materials used). The students can be asked to use this model in conjunction with their soil maps to answer questions such as:

- *What types of soil are typically present at different elevations? Is there a pattern?*
- *What areas might tend to flood during storms or when winter snows melt?*
- *In what areas will erosion be more likely to occur? Are there any ways to lessen or stop the erosion?*
- *What advice could be given to someone who was planning to build in this area?*
- *Based on the soil types and elevations, what types of plants and animals are most likely present in the area?*
- *How did geological factors (soil types, water, wind, volcanic activity, etc.) influence the topography of the area?*

Ideas for Progress

- Formulate hypotheses, predictions, or conclusions based on the results of an experiment
- Examine two or more related sets of data and then combine those data in ways that are useful
- Evaluate the merits of a conclusion based on the analysis of several sets of data

Suggested Strategies/Activities

Students could verify their predictions by visiting and mapping the area they studied. To gain a better understanding of how erosion works to form river valleys and other features, students could use stream tables, identifying the landforms created by running water.

Guiding Principles

- "By fostering student curiosity about scientific, mathematical, and technological phenomena, teachers can reinforce the trait of curiosity generally and show that there are ways to go about finding answers to questions about how the world works." (AAAS, 1993, p. 284)
- "Assessment tasks are not afterthoughts to instructional planning but are built into the design of the teaching." (NRC, 1996, p. 38)
- "[Teachers should] use student data, observations of teaching, and interactions with colleagues to reflect on and improve teaching practice." (NRC, 1996, p. 42)

ELECTROCHEMICAL CELLS

College Readiness Standards

- Understand the methods and tools used in a moderately complex experiment
- Determine the hypothesis for an experiment
- Predict how modifying the design or methods of an experiment will affect results
- Determine how the value of one variable changes as the value of another variable changes in a simple data presentation

Description of the Instructional Activity

The quality and variety of batteries being produced increases daily. With computers, telephones, and stereos becoming smaller and smaller, the demand for more compact and inexpensive power sources continues to grow. The current push for viable electrically powered automobiles has had researchers working overtime on developing lighter, yet more powerful, batteries. Batteries are *electrochemical cells,* and the scientists who study batteries use their knowledge of *electrochemistry* to guide their research.

Electrochemical cells are commonly used in laboratory exercises in the classroom, so there are numerous sources explaining how to construct cells with readily available lab equipment (American Chemical Society, 1993, or almost any chemistry laboratory manual). In this activity, students can examine how a variety of factors influences the voltages produced by an electrochemical cell.

This activity will serve well as an adjunct to a discussion on electrochemistry. Before starting, students should have some understanding of terms such as *voltage, current, anode, cathode, salt, anion, cation, electrolyte, resistance, conductor, oxidation,* and *reduction.* Students could also be introduced to the activity series for metals. Students will need access (either in the classroom or in the library) to laboratory manuals in chemistry. Students will also need access to strips of a variety of metals (iron, zinc, copper, silver, etc.) and the typical equipment needed to build crude electrochemical cells (including a voltmeter).

Students could work in groups on their designs, each testing different factors, or the class could all be given the same general task. Students can design studies that will independently test different factors in electrochemical cells. Below is a list of different factors that could be tested and the types of questions that students should consider when designing a study to test each factor.

Types of metals used for each electrode:

- *What pairings of metals produce the greatest voltage?*
- *Which metal serves as the anode and which metal serves as the cathode in each cell?*
- *How do the voltages calculated for the cell match with the voltages measured? Why are they not the same?*
- *What is being oxidized and what is being reduced in each cell?*

The size of the electrodes:

- *Which factor has a greater effect on the cell voltage, mass or surface area?*
- *Based on the results of this experiment, what would you predict the results would be using different metals as electrodes?*

The salt concentrations used:

- *How does the concentration of salt in the solution containing the anode affect voltage?*
- *How does the concentration of salt in the solution containing the cathode affect voltage?*
- *Does the type of anion in the salt solution affect voltage?*

Temperature:

- *How does the temperature of the solution containing the anode affect voltage?*
- *How does the temperature of the solution containing the cathode affect voltage?*

Suggestions for Assessment

Written Reports—Along with the types of questions listed above, each group could be assessed on the originality, thoroughness, and sound scientific reasoning put into their design and hypotheses. The actual data that are collected can be plotted in various ways, possibly showing how calculated quantities compare with collected data. Calculated quantities could be assessed based on accuracy, including whether or not students correctly showed the balanced half-reactions and reactions occurring in each of the cells they studied. Students can be asked to develop written procedures (with diagrams) that will provide adequate instructions for someone in their age group who is inexperienced with electrochemical cells to easily repeat the experiment. These procedures could be assessed on their clarity, attention to detail, logical flow, and audience appropriateness. Students could also develop posters showing their experimentally determined activity series for the metals with which they worked.

Ideas for Progress

- Read newspaper and magazine articles pertaining to science and technology and discuss main points with peers
- Integrate scientific information from popular sources (e.g., newspapers, magazines, the Internet) with that found in textbooks
- Relate scientific information contained in written text to numerical data

Suggested Strategies/Activities

This activity already offers a wide variety of factors that can be studied, but students could be encouraged to study electrochemistry and its applications in more depth. Students could learn the workings of common batteries, such as alkaline and flashlight batteries, automobile batteries, rechargeable batteries, etc. They could also examine the environmental impact of batteries, from production to disposal. Students could also examine the factors affecting the production of an electric automobile, from both a science/technology perspective and a social/political perspective.

Guiding Principles

- “The teacher of science chooses the form of the assessment in relationship to the particular learning goals of the class and the experiences of the students.” (NRC, 1996, p. 38)
- “Preparing students to become effective problem solvers, alone and in concert with others, is a major purpose of schooling.” (AAAS, 1993, p. 282)

INDEX OF REFRACTION

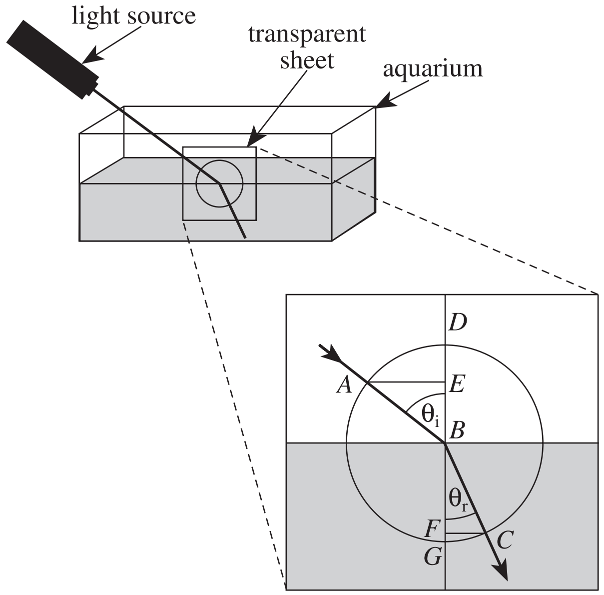
College Readiness Standards

- Understand the methods and tools used in a complex experiment
- Determine how the value of one variable changes as the value of another variable changes in a simple data presentation
- Interpolate between data points in a table or graph
- Identify and/or use a simple (e.g., linear) mathematical relationship between data

Description of the Instructional Activity

A light beam is *refracted* (bent) when it passes from air into a different medium. In this activity, students can study how refraction is affected by the *angle of incidence* (the angle at which the beam strikes the boundary between air and the second medium) and the density of the second medium. The following materials will be needed for this activity: a laser or laser pointer, a small aquarium tank, milk and sugar, overhead transparency sheets, and chalk dust.

For the first part of the activity, fill the aquarium about half full with water and add a small amount of milk to make the refracted beam visible in water. On each of several transparent sheets, draw a circle 10 to 20 centimeters in diameter. Draw a line representing the diameter through the circle (line *DG* in the figure on this page) and mark the center of the circle (point *B*). Mount the light source so that the source can be moved in order to vary the angle of incidence over several values that are between 0° and 90°. For each position of the light source, scatter chalk dust in the beam so that the beam is visible, and place the transparent sheet on the front of the aquarium so that line *DG* is perpendicular to the air-water boundary and point *B* coincides with the point at which the beam enters the water. (One student, standing back several feet from the front of the aquarium, can direct a second student as to the placement of the sheet.) Tape the sheet in place on the aquarium. Under the direction of the student standing several feet from the front of the aquarium, mark the point on the circle at which the incident beam intersects the circle (point *A*), and the point at which the refracted beam intersects the circle (point *C*). Remove the sheets from the aquarium and draw lines *AB* and *BC* on the sheet. The angle of incidence, θ_i, and the angle of refraction, θ_r, can be directly measured with a protractor or determined using trigonometry.



To interpret the results, students can make a graph of θ_r versus θ_i. They can interpolate to predict values of θ_r for various values of θ_i. Students can also find the mathematical relationship between θ_i and θ_r (Snell’s law). Using the data they collected for each θ_i, they can compute the ratios *AE/EB*, *EB/FB*, and *AE/FC*, and determine which ratio is constant for all of the θ_i values they measured (*AE/FC*). For the second part of this activity, add sugar to water to make several solutions of different concentrations (densities). For each solution, carry out the procedure described above, using the same values of θ_i. Students can plot the data on the graph constructed in the first part of the activity. They can interpolate to predict the values of θ_r that will result from various values of θ_i for solutions with different densities. They can also compute *AE/FC* for each solution.

Suggestions for Assessment

Multiple-Choice Questions—Before beginning the activity, students could be given a multiple-choice test to assess their prior knowledge of the terms and concepts embedded in this activity. They could also be asked to provide justifications for why they chose their answers. This can help provide insights about student misconceptions that may be addressed with additional instruction.

Written Report—Throughout the exercise, students can take notes and draw diagrams that detail the entire procedure. Students can then use these notes and drawings, along with the data they collected, to write a formal report of their findings. Students can consult scientific journals to find guidelines for preparing scientific papers, then follow these guidelines for presenting the text and graphics in their papers. They can submit the papers to the teacher and their peers for review. Peer reviews can be guided by a rubric created by the students or by the teacher. Following are some questions students can be asked during or after the activity.

- *What was the purpose of adding milk to the water and scattering chalk dust in the light beam?*
- *How are the angle of incidence and the angle of refraction related based on your data?*
- *Is a light beam with a greater angle of refraction bent more or less than a beam with a smaller angle of refraction?*
- *For a given angle of incidence, as the density of the solution increases, how does the angle of refraction change?*
- *How does the ratio* AE/FC *vary as the density of the solution increases?*

Ideas for Progress

- Determine a simple mathematical relationship between two variables
- Perform experiments that require more than one step
- Manipulate algebraic equations that represent scientific relationships

Suggested Strategies/Activities

This activity could be extended by studying how using different colors (wavelengths) of light affects the extent of refraction. Light from a mercury lamp can be separated into its different wavelengths with a prism or diffraction grating, and then a slit can be used to select a particular wavelength. The selected beam can then be sent into a piece of glass, and the angle of refraction can be determined. The students can also explore other examples of refraction, such as why a pencil in water appears bent, or why the sun appears higher than it actually is at sunset or sunrise.

PUTTING THE PIECES TOGETHER

ACT developed this guide to show the link between the ACT Science Test results and daily classroom work. The guide serves as a resource for teachers, curriculum coordinators, and counselors by explaining what the College Readiness Standards say about students' academic progress.

The guide explains how the test questions on the ACT Science Test are related to the College Readiness Standards and describes what kinds of reasoning skills are measured. The sample instructional activities and classroom assessments suggest some approaches to take to help students develop and apply their reasoning skills.

WHERE DO WE GO FROM HERE?

ACT recognizes that teachers are the essential link between instruction and assessment. We are committed to providing you with assistance as you continue your efforts to provide quality instruction.

ACT is always looking for ways to improve its services. We welcome your comments and questions. Please send them to:

College Readiness Standards Information Services
Elementary and Secondary School Programs (32)
ACT
P.O. Box 168
Iowa City, IA 52243-0168

> **"A mind, stretched to a new idea, never goes back to its original dimensions."**
>
> — Oliver Wendell Holmes

WHAT OTHER ACT PRODUCTS AND SERVICES ARE AVAILABLE?

In addition to the College Readiness Standards Information Services, ACT offers many products and services that support school counselors, students and their parents, and others. Here are some of these additional resources:

ACT's Website—**www.act.org** contains a host of information and resources for parents, teachers, and others. Students can visit **www.actstudent.org**, which is designed to aid students as they prepare for their next level of learning.

PLAN—a comprehensive assessment program designed to improve tenth-grade students' postsecondary planning and preparation and to enable schools to assist students and their parents in this important process.

EXPLORE— an eighth- and ninth-grade assessment program designed to stimulate career explorations and facilitate high school planning.

WorkKeys®—a system linking workplace skill areas to instructional support and specific requirements of occupations.

ACT Online Prep™—an online test preparation program that provides students with real ACT tests and an interactive learning experience.

The Real ACT Prep Guide—the official print guide to the ACT, containing three practice ACTs.

DISCOVER®—a computer-based career planning system that helps users assess their interests, abilities, experiences, and values, and provides instant results for use in investigating educational and occupational options.

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(Please note that in 1996 the corporate name "The American College Testing Program" was changed to "ACT.")

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Eisenhower National Clearinghouse. Inquiry & Problem Solving. http://www.enc.org/topics/inquiry

The Franklin Institute Science Museum. Learn—The Franklin Institute Online. http://sln.fi.edu/learning.html

The Gateway to Educational Materials. http://www.thegateway.org/

National Science Teachers Association. http://www.nsta.org

Northwest Regional Educational Laboratory. Mathematics and Science Education Center: Science Inquiry Model. http://www.nwrel.org/msec/science_inq/index.html

Appendix
Passages Corresponding to Sample Test Questions

Biology Data Representation passage for sample test question found on pages 15 and 21

The amount of O_2 present in blood and tissues can be measured, in mm Hg, as the *partial pressure of* O_2 (P_{O_2}). The *percent saturation of Hb* is the percent of hemoglobin in the blood that is bound with O_2. Figure 1 shows the relationship between percent saturation of Hb and P_{O_2} at normal body conditions.

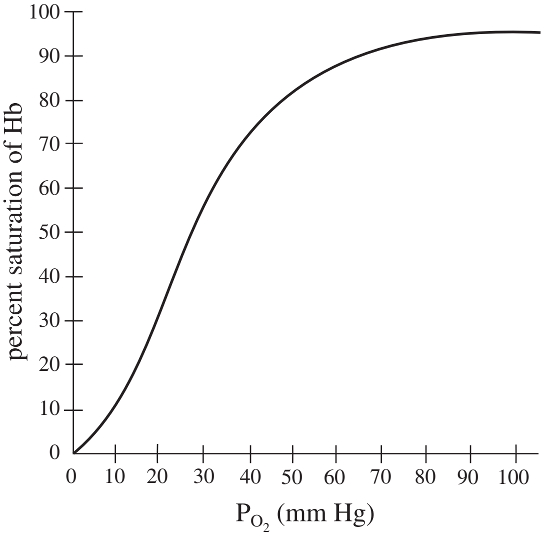


Figure 1

Figure 2 shows the relationship between percent saturation of Hb and P_{O_2} at different pHs. The pH of blood is affected by the partial pressure of CO_2 (P_{CO_2}).

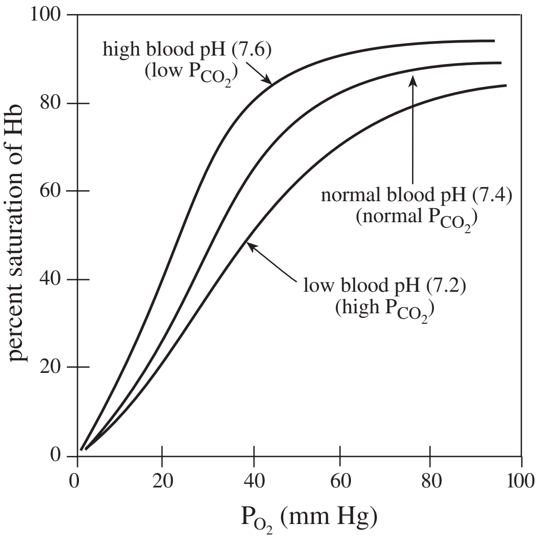


Figure 2

Figure 3 shows the relationship between percent saturation of Hb and P_{O_2} at different blood temperatures.

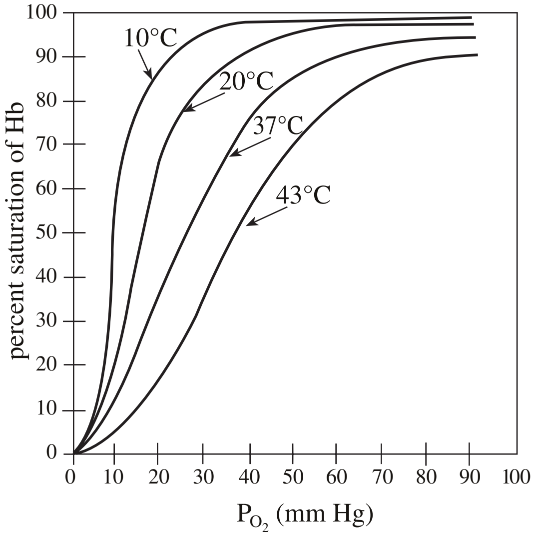


Figure 3

Figures adapted from Robert Carola, John P. Harley, and Charles R. Noback, *Human Anatomy and Physiology*. ©1990 by McGraw-Hill, Inc.

Appendix

Passages Corresponding to Sample Test Questions

Biology Conflicting Viewpoints passage for sample test questions found on pages 15 and 21

Modern corn as a species has existed for about 7,000 years. Three hypotheses exist to explain modern corn's evolution and its relationship to a wild grass called *teosinte*.

Figure 1 shows a type of modern corn and teosinte. The male reproductive organs are found in the *tassels* of both plants. The female reproductive organs are found in the *ear* in modern corn and the *spike* in teosinte. Figure 2 shows a teosinte spike and an ear of modern corn.

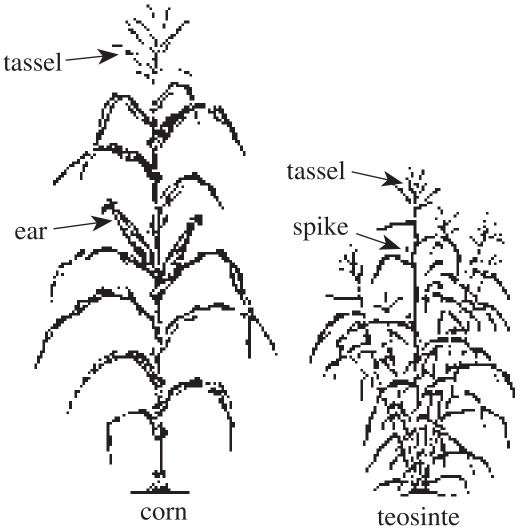


Figure 1

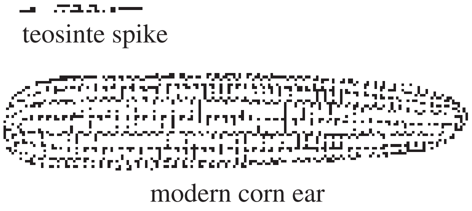


Figure 2

Figures adapted from George W. Beadle, "The Ancestry of Corn." ©1980 by Scientific American, Inc.

Hypothesis 1

Modern corn evolved from teosinte through a series of gradual changes. Humans first cultivated teosinte over 7,000 years ago. Through selective breeding, the thin, female spike of teosinte was slowly transformed into the large, female ear of modern corn. When mated, teosinte and modern corn should produce healthy offspring with small ears, since teosinte and modern corn are closely related.

Hypothesis 2

Both teosinte and modern corn evolved independently, over a long period of time and without human interference, from a species of wild corn. This species of wild corn resembled modern corn, but it produced ears that were much smaller than the ears of modern corn. When mated, teosinte and modern corn should produce unhealthy offspring with small ears, since teosinte and modern corn are only distantly related.

Hypothesis 3

Modern corn evolved from teosinte in a single generation due to a genetic mutation. As Figure 1 shows, teosinte plants have a tassel at the tip of each branch and spikes along the side of the branch. However, when the growth of teosinte branches is stunted, a single, female ear grows at the tip of each branch in place of the male tassel, and spikes do not develop. About 7,000 years ago a genetic mutation caused the branches of a plant derived from teosinte to shorten. Due to this shortening, the tassels of the plant were transformed into small ears, producing modern corn. This new species was then selectively bred by humans to produce larger ears. When mated, teosinte and modern corn should produce healthy offspring with small ears, since teosinte and modern corn are closely related.

Chemistry Research Summaries passage for sample test questions found on pages 15, 17, 18, and 19

The *rate* of a chemical reaction can be measured as the change in the concentration of its products over a period of time. The following experiments were performed to investigate factors that influence the rate at which potassium permanganate ($KMnO_4$) reacts with oxalic acid ($H_2C_2O_4$) to form Mn^{2+} and other products.

Experiment 1

A 4.0 mL sample of 0.1 M (moles/liter) aqueous $KMnO_4$, which was purple in color, was measured with a clean graduated cylinder and poured into a test tube. A 4.0 mL sample of 1.0 M aqueous $H_2C_2O_4$ was then measured with a clean graduated cylinder and poured into a second test tube. The 2 test tubes were placed in a 25°C water bath. After 5 minutes the $H_2C_2O_4$ solution was mixed with the $KMnO_4$ solution and placed back in the water bath. The time until the purple color disappeared was recorded. This procedure was repeated at 3 other temperatures. The results are shown in Table 1.

Table 1

Trial	Temperature (°C)	Reaction time (sec)
1	25	210
2	35	105
3	45	48
4	55	25

Experiment 2

The procedure from Experiment 1 was repeated in every way except that 0.1 mg of manganous sulfate ($MnSO_4$), a *catalyst*, was added to each test tube containing $KMnO_4$ before the $H_2C_2O_4$ was added. Catalysts are substances that increase the rate of reactions without being used up. The results are shown in Table 2.

Table 2

Trial	Temperature (°C)	Reaction time (sec)
5	25	66
6	35	43
7	45	20
8	55	12

Experiment 3

The procedure from Experiment 1 was repeated at a constant temperature of 25°C and various concentrations of $H_2C_2O_4$. The results are shown in Table 3.

Table 3

Trial	Concentration of $H_2C_2O_4$ (M)	Reaction time (sec)
9	0.125	837
10	0.250	625
11	0.500	415

Chemistry Data Representation passage for sample test question found on pages 15 and 16

The *molar heat of vaporization* (ΔH_{vap}) is defined as the energy in kilojoules (kJ) required to vaporize 1 mole of a liquid at its boiling point at constant pressure. The energy required to melt 1 mole of a solid at its melting point is called the *molar heat of fusion* (ΔH_{fus}). The *molar heat of sublimation* is the sum of the molar heats of fusion and vaporization.

The following table lists molar heats of vaporization and molar heats of fusion, as well as the boiling points and melting points for selected substances.

Substance	Melting point* (°C)	ΔH_{fus} (kJ/mol)	Boiling point* (°C)	ΔH_{vap} (kJ/mol)
Argon	–190.0	1.3	–164.0	6.3
Methane	–182.0	0.8	–159.0	9.2
Ethyl ether	–116.2	6.9	34.6	26.0
Ethanol	–117.3	7.6	78.3	39.3
Benzene	5.5	10.9	80.1	31.0
Water	0.0	6.1	100.0	40.8
Mercury	–39.0	23.4	357.0	59.0

*Measured at a pressure of 1 atmosphere (atm)

Biology Research Summaries passage for sample test questions found on pages 15, 16, and 18

A researcher conducted 2 experiments to investigate flower production in *Phlox drummondii* (a plant species).

Experiment 1

Phlox drummondii seeds were collected from 5 populations (P1, P2, P3, P4, and P5), each of which was from a different site (S1, S2, S3, S4, and S5, respectively).

The seeds were grown in a greenhouse, and 200 seedlings from each population were randomly selected. Each population set was divided equally into 25 groups of 8 seedlings per group. Each group was planted in a bottomless container. Five containers from each population were then planted at each of the 5 sites. Figure 1 illustrates this procedure for P1.

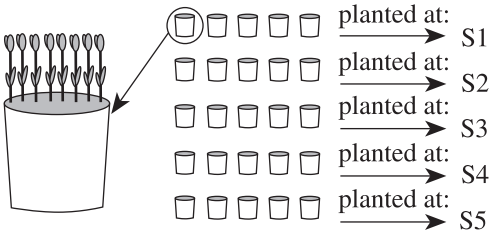


Figure 1

Table 1 shows the number of flowers produced per plant.

Table 1

Site	Flowers produced per plant by:				
	P1	P2	P3	P4	P5
S1	5.7	3.6	3.5	3.3	3.6
S2	3.4	4.9	2.6	3.6	3.0
S3	2.4	1.7	4.0	2.6	1.8
S4	0.7	0.8	0.5	0.4	0.4
S5	1.9	1.5	3.4	2.0	1.1

The researchers also collected data on the aboveground dry mass of the plants. From this, they deduced the following equation relating a plant's dry mass in milligrams (mg) and the number of flowers it produced:

$$\text{number of flowers} = 0.068 + 0.331(\text{dry mass})$$

Statistical analysis indicated this equation was extremely accurate.

Experiment 2

Phlox drummondii seeds were collected and grown in a greenhouse as in Experiment 1. When the plants became seedlings, 100 containers were prepared, each containing 4 P1 seedlings and 4 seedlings from either P2, P3, P4, or P5. Five containers for each of the 4 combinations were planted at each site.

Table 2 shows the number of flowers produced per P1 plant.

Table 2

Site	Flowers produced per P1 plant when planted with:			
	P2	P3	P4	P5
S1	5.5	6.1	6.9	3.7
S2	4.4	2.7	2.5	2.1
S3	1.0	4.2	1.7	1.5
S4	0.3	0.7	0.5	0.3
S5	0.7	1.2	1.0	0.9

Tables 1 and 2 adapted from Keith Clay and Donald A. Levin, "Environment-Dependent Intraspecific Competition in *Phlox drummondii*." ©1986 by the Ecological Society of America.

Appendix

Passages Corresponding to Sample Test Questions

Physics Research Summaries passage for sample test questions found on pages 16, 19, and 20

Engineering students performed 2 studies to collect data on several factors affecting road safety. In each trial of the studies, the students used a different test car. Each test car was a new Model J car.

Study 1

In each trial, the test car was initially stationary on a straight flat track. The speed of the car was then increased by remote control. When the car reached a speed of 25 meters per second (m/sec), its brakes were locked and the car skidded on the track, eventually coming to a stop. The *stopping distance*, the distance the car skidded from the instant its brakes were locked, was recorded. Table 1 shows the track material, track condition, and stopping distance for each trial.

Table 1

Trial	Track material	Track condition	Stopping distance (m)
1	X	dry	43.7
2	X	wet	52.4
3	X	icy	131.1
4	Y	dry	65.5
5	Y	wet	85.2
6	Z	dry	88.5
7	Z	icy	265.5

Study 2

In each trial, the test car was initially stationary on a circular track with a *banking angle* of either 0° or 10°. The speed of the car was then increased by remote control. Eventually, the speed of the car was so great that the car was no longer able to stay on its circular path (see Figure 1). The *departure speed*, the speed of the car at the instant the car began to depart from its circular path, was recorded. Table 2 shows the banking angle of the track, track material, track condition, and departure speed for each trial.

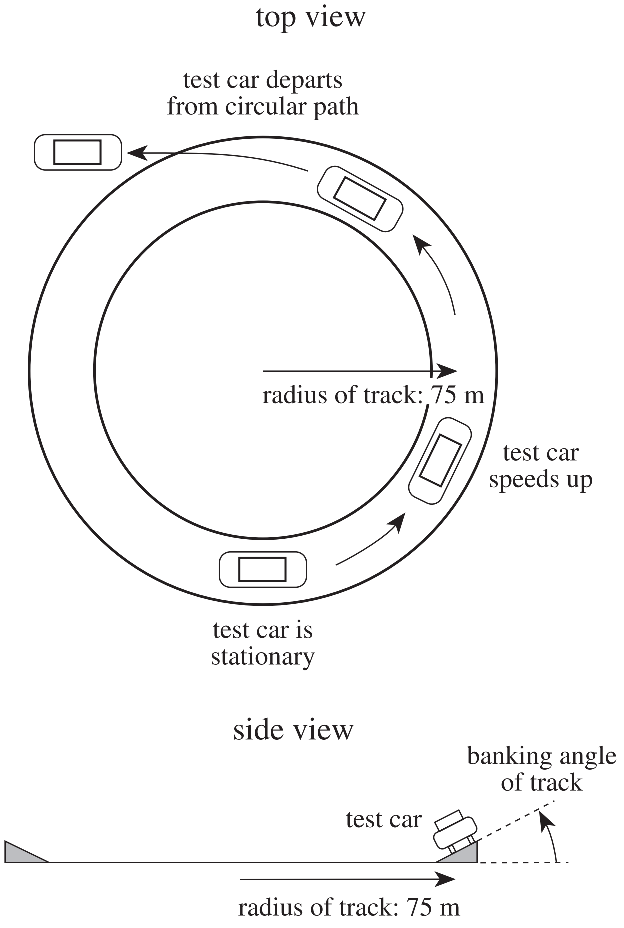


Figure 1

Table 2

Trial	Banking angle of track (°)	Track material	Track condition	Departure speed (m/sec)
1	0	X	dry	24.0
2	10	X	dry	28.6
3	0	X	wet	21.9
4	10	X	wet	26.2
5	0	X	icy	13.9
6	0	Y	dry	19.6
7	10	Y	wet	21.4
8	0	Z	dry	16.9

Appendix

Passages Corresponding to Sample Test Questions

Earth/Space Science Data Representation passage for sample test questions found on pages 16 and 20

Magma (molten rock) forms deep below the surface of Earth and cools as it rises toward the surface. Minerals in magma *crystallize* (solidify) as the magma cools along either or both of 2 paths: the *mafic mineral path* and the *plagioclase feldspar path* (see Figure 1). Figure 1 also shows the temperature at which various minerals crystallize and their relative densities.

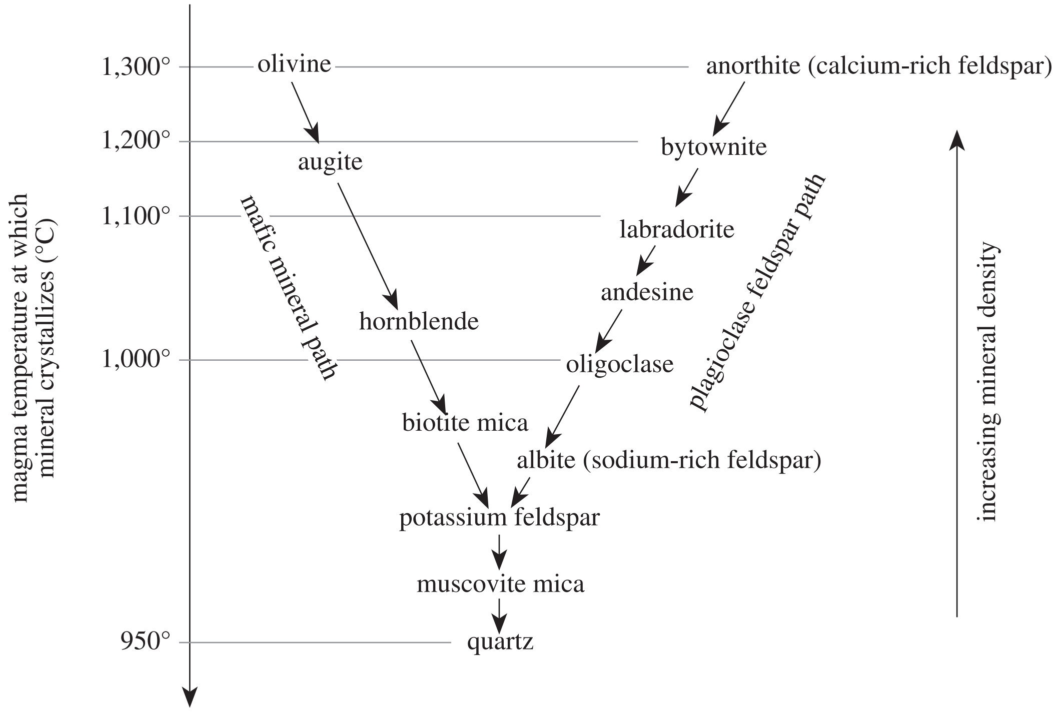


Figure 1

Table 1 lists the relative percents (%) of sodium and calcium in the various plagioclase feldspars.

Table 1

Plagioclase feldspar	Sodium content (%)	Calcium content (%)
Anorthite	0–10	90–100
Bytownite	10–30	70–90
Labradorite	30–50	50–70
Andesine	50–70	30–50
Oligoclase	70–90	10–30
Albite	90–100	0–10

Table 2 shows the percent of various minerals that compose granite and basalt, 2 rock types formed from cooled magma.

Table 2

	Percent of mineral in:	
Mineral	granite	basalt
Olivine	0	6
Labradorite	0	45
Augite	0	43
Biotite mica	4	0
Albite	5	0
Potassium feldspar	55	5
Muscovite mica	5	0
Quartz	30	0
Magnetite	1	1

Physics Research Summaries passage for sample test questions found on pages 16 and 18

The *nuclei* of some atoms can break apart and emit particles. These particles can be detected using an instrument called a *Geiger counter*. Each particle detection is called a *count*. Using a Geiger counter, scientists determined particle-detection rates (in counts/min) from Sources A, B, and C and their surroundings under a variety of conditions.

Experiment 1

The scientists measured the *background* (the rate detected from the laboratory in the absence of Sources A, B, and C). The background was 18 counts/min. In the results of the following experiments, the background was not removed from the particle-detection rates for Sources A, B, and C.

Experiment 2

The scientists determined the particle-detection rates at distances of 1 cm, 2 cm, and 4 cm from Source A. The results are given in Table 1.

Table 1

Distance from Source A (cm)	Particle-detection rate (counts/min)
1	3,321
2	883
4	228

Experiment 3

Source B was placed 10 cm from the Geiger counter. Equally thick sheets of various shielding materials were placed between Source B and the counter. For each shielding material, the particle-detection rate was measured. Source B was then replaced by Source C and the procedure was repeated. The results are given in Table 2.

Table 2

Shielding material	Particle-detection rate for Source B (counts/min)	Particle-detection rate for Source C (counts/min)
None	1,284	1,462
Plastic	1,162	1,452
Paper	1,140	1,458
Wood	862	1,410
Aluminum	412	1,326
Glass	363	1,302
Lead	24	1,265

Experiment 4

Using the same amount of Source C as in Experiment 3, the scientists measured the total number of particles detected as a function of time. The results are given in Table 3.

Table 3

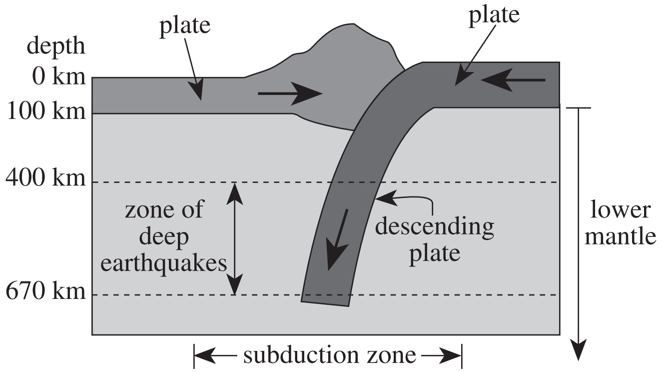
Time (min)	Total number of particles detected (counts)
1	1,368
5	6,840
30	40,840
60	81,600

Appendix

Passages Corresponding to Sample Test Questions

Earth/Space Science Conflicting Viewpoints passage for sample test questions found on pages 20 and 21

Earthquakes occur when rocks under stress suddenly fracture and fault, releasing seismic energy from the *focus* (the location of the rocks' initial fracture). In *subduction zones* (see figure below), where 2 plates (composed of crust and upper mantle) collide and the edge of 1 plate is forced down into the lower mantle below, some earthquake foci are located at depths of 400 km to 670 km (*deep earthquakes*).



Scientists have wondered what causes deep earthquakes. Below 400 km depth, rocks are under high pressure and at temperatures greater than 1,500°C, so they should bend in response to stress rather than break, as they do above 400 km depth. Two scientists discuss possible causes of deep earthquakes.

Scientist 1

Common minerals in plate rocks, such as *serpentine*, contain water. As the edge of a plate descends into the lower mantle and is heated, these minerals dehydrate. This makes the rocks brittle and easier to fracture. The released water also helps lubricate existing fractures, allowing them to move. Dehydration usually occurs at depths shallower than 400 km. However, when the edge of a plate is forced down into the lower mantle, it may descend so rapidly that it remains much cooler than the surrounding mantle. In that descending plate, minerals retain water in their crystal structure to much greater depths. When they are heated to a point where they dehydrate, somewhere between 400 km and 670 km depth, the rocks become brittle and fracture, releasing seismic energy.

Scientist 2

Another common mineral in plate rocks, called *olivine*, changes to a denser mineral called *spinel* when subjected to the high temperatures in the lower mantle. This process usually occurs at mantle depths shallower than 400 km. However, when the edge of a plate is forced down into the lower mantle, it may descend so rapidly that it remains much cooler than the surrounding mantle. This allows olivine to exist well below the depths where it is normally found. At some depth below 400 km, the plate reaches a temperature that allows olivine in the rocks to suddenly change to spinel. This change causes a rapid compaction and fracturing of the rocks, releasing seismic energy.