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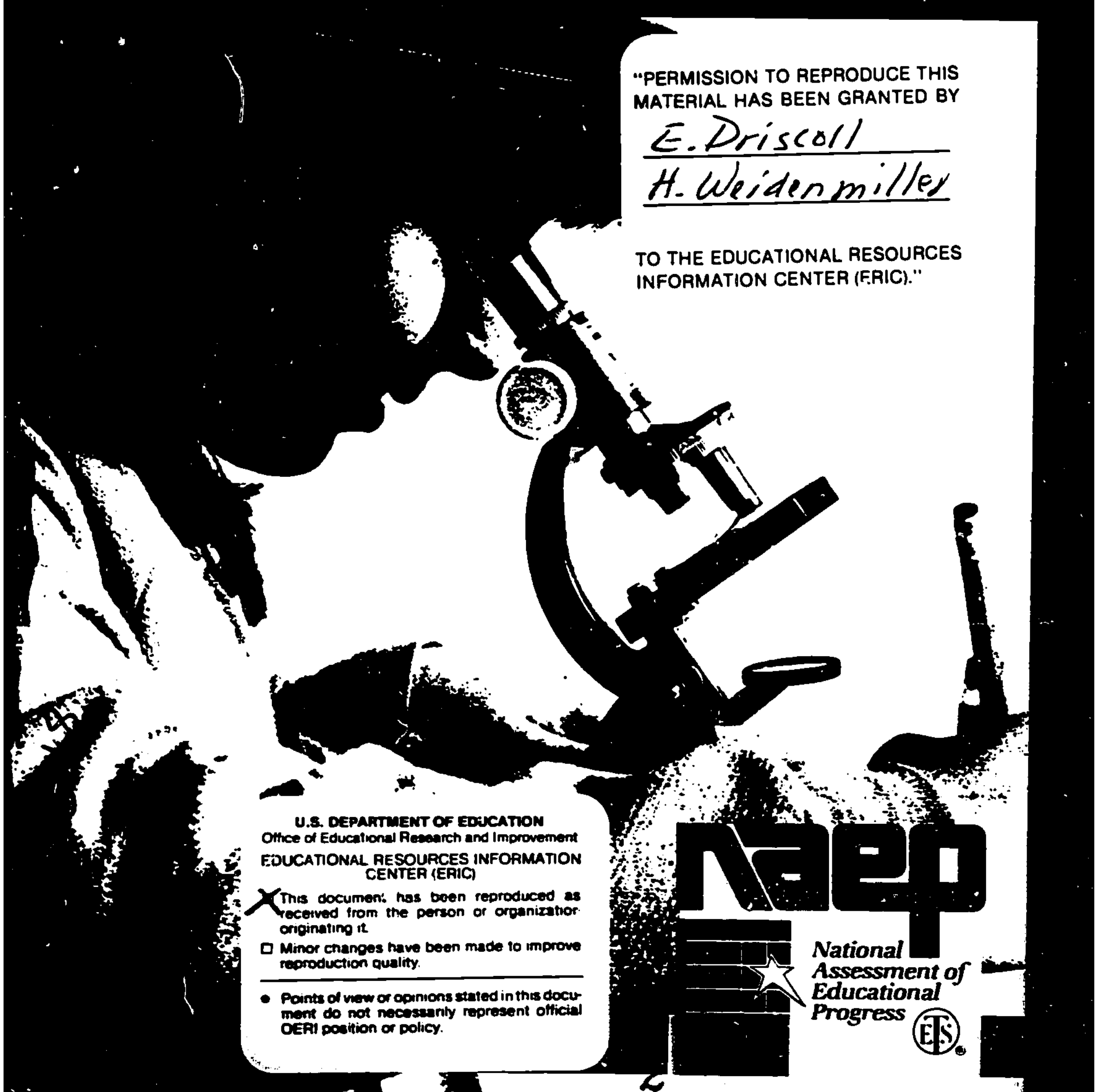
ABSTRACT

In 1985-86, the National Assessment of Educational Progress (NAEP) will undertake the fifth national assessment of science knowledge, skills, and attitudes in 9-, 13-, and 17-year old Americans. The science objectives have been developed and reviewed by committees of scientists and educators. The objectives presented in this document are grouped into three categories: (1) content--life sciences; physics; chemistry; earth and space sciences; history of science; and nature of science; (2) context--scientific; personal; societal; and technological; (3) cognition--knowledge; application; and integration; and (4) attitudes--toward science classes; career and educational objectives; socioscientific responsibility; science as a personal tool; value of science; societal issues; and experiences in science. A number of topics are presented with an indication of their appropriateness for testing students aged 9, 13, or 17. Ten sample questions are also appended. (GDC)

SCIENCE OBJECTIVES

1985-86 ASSESSMENT



naep

National Assessment of Educational Progress

ETS

SCIENCE OBJECTIVES
1985-86 ASSESSMENT

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The Objectives Development Process for the 1985-86 Assessment of Science

In 1985-86, the National Assessment of Educational Progress (NAEP) will undertake the fifth national assessment of science. Since 1969, NAEP has provided periodic report cards for the nation, collecting and interpreting information about the knowledge, skills, and attitudes of 9-, 13-, and 17-year-old students in most of the subjects in the school curriculum. The planning for the 1985-86 national assessment of science took place as public concern focused on the quality of elementary and secondary education in the United States. A number of prestigious reports critical of the schools sparked unprecedented public debate and calls for improvement across the country.

A Nation at Risk, the report of the President's Commission on Excellence, called for increased attention to science and for emphasis on the development of higher-order thinking and problem-solving skills. *Educating Americans for the 21st Century,* the report of the National Science Board Commission on Precollege Education in Mathematics, Science, and Technology, stated, "We must return to the basics, but the 'basics' of the 21st century are nc* only reading, writing, and arithmetic. They include communication and higher problem-solving skills, and scientific and technological literacy—the *thinking* tools that allow us to understand the technological world around us. These new basics are needed by *all* students. . ." The Assessment Policy Committee, which governs NAEP and includes teachers, school superintendents, state legislators, school board members, and representatives from business and industry, also called for increased emphasis on problem-solving and higher-order skills in the 1985-86 assessment.

According to the first NAEP science objectives, formulated in 1965, the major purpose of science education is to develop scientifically literate individuals. For each successive National Assessment of Science, objectives have been developed as a framework for measuring the attainments in science of students in the United States at ages 9, 13, and 17. Collectively, these objectives—revised and refined over the years—provide one definition of scientific literacy. The objectives for 1985-86 build on what has gone before, taking into account recent developments and new emphases.

As in the past, these objectives resulted from a consensus process involving many people. Development began with a review of the objectives from the 1976-77 assessment by 25 practicing scientists and educators, including college teachers of science, specialists in science education, school science coordinators, classroom teachers, and school administrators from all parts of the country. Their comments and suggestions for change were considered by the Science Learning Area Committee (see Appendix C), which met to formulate the objectives and design of the 1985-86 assessment. Successive drafts of the booklet were reviewed not only by the committee but also by other practitioners in the schools. The objectives also were reviewed by the Assessment Policy Committee and by a group representative of the interested lay public not directly involved with science education. The committee considered these reviews at each of its meetings in order to respond to the broad range of opinions, interests, and priorities concerning science education.

The material that follows presents the framework and specifications that guided the development of new exercises for the assessment. At the same time, it indicates what the Science Learning Area Committee and reviewers agreed is appropriate for the assessment to measure in science attainment and in attitudes toward science. This consensus is one view of the objectives of American science education.

CHAPTER 1

The Framework for Science Objectives

A matrix in three dimensions—Content, Context, and Cognition—represents the broad objectives of science education. Exhibit 1 presents the matrix in visual form, showing that each dimension is divided into major categories. Each exercise in the assessment can be classified into a cell of the matrix that matches the category of content it assesses, the context in which it is presented, and the cognitive skill it measures. However, exercises cannot be devised for every cell because a few combinations, such as history in a personal context, are meaningless.

This three-dimensional framework is a departure from the two-dimensional one developed for the 1976-77 assessment and used again for the 1981-82 assessment. The concepts underlying the two frameworks, however, are similar enough to permit easy reclassification of previously administered exercises into cells of the three-dimensional matrix. Thus, it is possible to maintain continuity in reporting trends over time by reusing a subset of previously administered exercises in the new assessment. (Unlike the 1985-86 framework described in the following pages, the dimensions of the matrix used in the 1976-77 and 1981-82 science assessments included an abbreviated Bloom taxonomy and a dimension with three subdivisions: content, processes, and science and society.)

Major Categories in the Framework

CONTENT

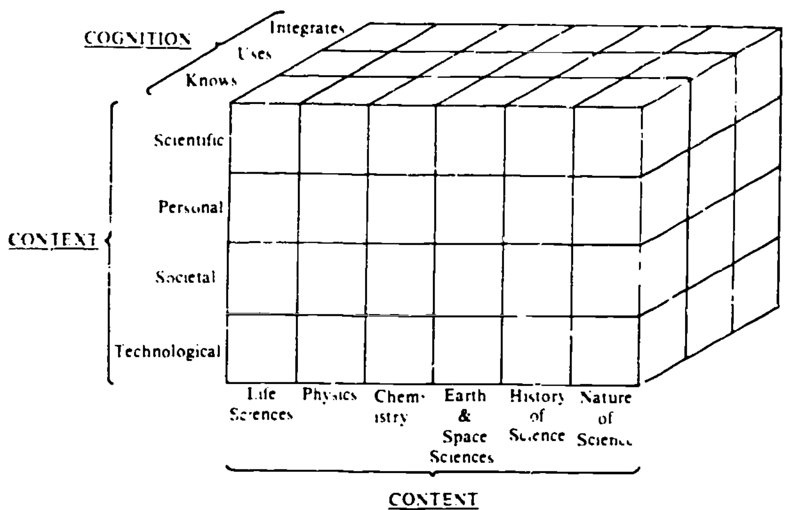
The content dimension of the matrix includes both the body of knowledge in the traditional disciplines of science and knowledge about science, its nature and processes, and its history. The content dimension contains six major categories:

- Life Sciences
- Physics
- Chemistry
- Earth and Space Sciences
- History of Science
- Nature of Science

For a discussion of these categories and the topics appropriate for assessment within them, see Chapter 2.

Exhibit 1

Framework for Science Assessment Exercises



CONTEXT

The context dimension of the matrix defines four types of situations for presenting assessment exercises: scientific, personal, societal, and technological. The definitions of these four categories are:

Scientific context: These exercises assess students' understanding of the body of knowledge of science. This category includes the descriptive facts, principles, conceptual schemes, models, and inquiry skills needed to acquire mastery of the disciplines and to attain an intellectual appreciation of the natural world.

Personal context: These exercises assess the students' knowledge of the ways in which scientific facts and principles are useful in their everyday lives and the extent to which their decision-making is based on the application of science to matters related to general safety, health, well-being, habits, and life-style.

Societal context: These exercises deal with the role and use of the content and methods of science in decision-making on societal issues and questions of public policy. This category also includes exercises that deal with the impact of scientific and technological developments on people, both individually and collectively, through the management or manipulation of the biological and physical worlds. These exercises require an understanding of the potential benefits and/or risks to individuals and to society of various scientific and technological endeavors.

Technological context: These exercises focus on the application of the knowledge and methods of science to commercial or utilitarian purposes. Technology, which is both the process of development and the products of that development, relies on concepts from science and mathematics to create new products and procedures. It includes tools, devices, and techniques that can have considerable influence upon individuals and the environments in which they live. Examples of the technology area include biotechnology, food production, medical care, energy production and consumption, transportation, communication, and nuclear power. Tools and devices include such things as windmills, microscopes, x-ray machines, television, computers, and nuclear submarines.

COGNITION

The Learning Area Committee designed the cognition dimension of the matrix so that exercises could be classified according to the cognitive processes required to deal with science content at different levels of complexity. The committee defined three generic categories—knows, uses, and integrates—and based the following descriptions of these categories on cognitive theory that defines three types of knowledge, each of which has a different function in problem-solving.

Knows: These exercises test primarily factual knowledge. Successful performance depends on the ability to recall specific facts, concepts, principles, and methods of science; to show familiarity with scientific terminology; to recognize these basic ideas in a different context; and to translate information into other words or another format. This category generally involves a one-step cognitive process.

Uses: These exercises test the ability to combine factual knowledge with rules, formulas, and algorithms for a specified purpose. Successful performance depends on the ability to apply basic scientific facts and principles to concrete and/or unfamiliar situations; to interpret information or data using the basic ideas of the natural sciences; and to recognize relationships of concepts, facts, and principles to phenomena observed and data collected. This category generally involves a two-step cognitive process.

Integrates: These exercises test the ability to organize the component processes of problem solving and learning for the attainment of more complex goals. Successful performance depends on the ability to analyze a problem in a manner consistent with the body of scientific concepts and principles, to organize a series of logical steps, to draw conclusions on the basis of available data, to evaluate the best procedure under specified conditions, and to employ other higher-order skills needed for reaching the solution to a problem.

This category generally involves multi-step cognitive processes. In particular, it requires such mental processes as generalizing; hypothesizing; interpolating and extrapolating; reasoning by analogy, induction and deduction; and synthesizing and modeling.

Specifications for Assessment Exercises

A national assessment of science can cover only a small sample of the domain included in science education throughout the school years. Therefore, the committee needed to consider how much weight to give to each of the major categories in the matrix. Weights were assigned separately to each age level, because the emphases and expectations appropriate for 9-, 13-, and 17-year-old students are different.

The committee assigned an approximate percentage of the assessment to each major category for each of the three dimensions, in order to define how students' knowledge of science should be sampled and to guide exercise development. The percentages were selected taking into account information about what the school curriculum typically includes, and a consensus about what the focus and outcomes of science education should be.

In the context category, the committee decided on a combined percentage for personal, societal, and technological exercises rather than specific percentages for each, because many exercises will involve both personal and technological or societal and technological contexts. For 9-year-olds, personal contexts will probably dominate, with more emphasis on societal and technological contexts at the older age levels.

In the cognition dimension, the committee assigned the same percentages to all three ages, with the understanding that what is expected of 9-year-olds in the "integrates" category (which calls for multi-step processes and higher-order skills) will be significantly different from what is expected of older students. Since it is not possible to know precisely what knowledge and processes any individual student will apply to a given exercise, the classification of the exercises as "knows" or "uses" or even "integrates" was based on informed judgment about the factual knowledge and cognitive processes that an average student in the target population is most likely to apply to obtain the correct answer. For example, for one student, answering a particular question may simply involve knowing the factual information needed. Another who does not have that specific information may arrive at the correct answer by a mental process that involves different but related information. Everyone who classified exercises needed to consider the age of the intended population as well as its probable academic experience. An exercise can be in the "knows" category for older students and in the "integrates" category for younger ones, because what older students may know as a fact younger students probably can arrive at only by multi-step reasoning.

The percentages assigned are shown in the following tables.

Table 1

Content: Approximate Percentages

Category	9-year-olds	13-year-olds	17-year-olds
Life Sciences	35%	25%	25%
Physics	15	15	20
Chemistry	10	15	20
Earth and Space Sciences	20	20	15
History of Science	5	10	5
Nature of Science	15	15	15
	100	100	100

Table 2

Context: Approximate Percentages

Category	9-year-olds	13-year-olds	17-year-olds
Scientific	50%	55%	60%
Personal / Societal / Technological	50	45	40
	100	100	100

Table 3

Cognition: Approximate Percentages

Category	9-year-olds	13-year-olds	17-year-olds
Knows	40%	40%	40%
Uses	30	30	30
Integrates	30	30	30
	100	100	100

Other Aspects of the Assessment

In addition to the assessment of students' knowledge of science, the assessment will collect information from students on their backgrounds in science, their attitudes toward science, and their scientific experiences, both in school and outside. NAEP will also ask teachers and school administrators about such things as science curriculum, laboratory facilities, time devoted to science, backgrounds of teachers, and teaching methods. The collection of these data has two important purposes: to report on these subjects to the public, which is concerned about the status of science education, and to improve the usefulness of the assessment results by studying and reporting on the relationship of these factors to science achievement.

Since self-report questions on attitudes, values, and experiences do not fit into the matrix, the committee considered them separately. It identified seven categories of questions for students: attitudes toward science classes, career and education intentions, socioscientific responsibility, science as a personal tool, value of science, societal issues, and experiences in science. This portion of the assessment is described in more detail in Chapter 3.

Science Content

This chapter describes the major categories of the content dimension in more detail by subdividing them.

The content dimension of the matrix represents the facts, concepts, conceptual schemes, inquiry skills, and other aspects of science content subsumed in the major categories. Since the amount of material in this area is so extensive, the Learning Area Committee divided each of the major categories into a set of narrower, although still broad, topics appropriate for inclusion in the assessment. Some of the topics in the lists that follow are not appropriate for 9-year-olds; a few are appropriate only for 17-year-olds.

The first four major content categories—Life Sciences, Physics, Chemistry, Earth and Space Sciences—represent the content of the traditional scientific disciplines. Each of the broad topics within each of these major categories has been further subdivided into a list of important concepts or subtopics, to guide the writing and selection of exercises. These lists appear as Appendix A, with indication of the age level(s) for which each item is considered appropriate. In developing these lists, the committee recognized that many topics cross discipline lines.

History of Science is a new area for the assessment. The committee considered it important for students to know and understand something about how scientific ideas and theories develop and change over time, about how society has influenced scientific development, and how developments in science have affected society, and about some of the outstanding figures in science. The sixth category, the Nature of Science, is designed to measure students' understanding of the characteristics and methods of scientific inquiry and their ability to apply the processes of science to the solution of problems.

These six major categories of science content contain the following topics:

- ***Life Sciences***
  - —Cellular and molecular biology
  - —Energy transformations (photosynthesis and cellular metabolism)
  - —Structure and functions of organisms (protists, plants, animals)
  - —Diversity of organisms (classification)
  - —Genetics and development
  - —Evolution
  - —Ecology
  - —Behavior
- ***Physics***
  - —Mechanics (motion, forces, principles of conservation)
  - —Waves and optics
  - —Electricity and magnetism
  - —Modern physics (atomic, nuclear, relativity)
  - —Heat and kinetic theory
- ***Chemistry***
  - —Structure of matter (nuclear, atomic, and molecular)
  - —Periodic classification
  - —States of matter and nature of solutions
  - —Reactions of matter (chemical transformations)
  - —Stoichiometry
- ***Earth and Space Sciences***
  - —The Earth's history
  - —Materials of the Earth
  - —Agents and processes of change in the Earth's surface
  - —Earth's atmosphere and weather
  - —Describing and measuring time and location
  - —The oceans
  - —The solar system, galaxies, and the universe

- ***History of Science***
  - —Development of scientific ideas
  - —History of science—society interactions
  - —Pioneers in science
- ***Nature of Science***
  - —Processes of science
  - —Assumptions of science
  - —Characteristics and limitations of scientific methods
  - —Ethics in science

Knowledge of the processes of science and the ability to apply them is basic to the attainment of scientific literacy. The processes of scientific inquiry include activities such as observing, measuring, experimenting, communicating, as well as mental processes such as interpreting data; generalizing; interpolating, hypothesizing; reasoning by analogy, by metaphor, by induction and deduction; synthesizing; and modeling.

The mental, or cognitive, processes essential to successful scientific inquiry are not unique to science. They overlap with the generic categories in the cognition dimension of the matrix, especially with the "integrates" category, which calls for multi-step processes and higher-order skills. The committee distinguished two types of exercises for classification. Exercises that focus solely on knowledge of science processes and their application were classified under Nature of Science and the comparable cognition category. Exercises that require the student to recall and apply factual knowledge from one of the disciplines of science were classified under the particular discipline (Life Sciences, Physics, Chemistry, Earth and Space Sciences) and the appropriate cognition category.

CHAPTER 3

Attitudes, Values, and Experience

The collection and reporting of information about students' attitudes and values with respect to science and scientific endeavors are important parts of the assessment. Because it is inappropriate to make statements about how people *should* feel or think about a subject, questions in these areas have no right or wrong answers. Rather, NAEP regards its attitudinal questions as primarily investigative and the results descriptive of the attitudes and values students hold. The assessment monitors trends by repeating some questions from previous assessments and reporting how students' attitudes have changed over the years.

This component of the assessment includes seven categories of questions for self-reporting by students. Descriptions of the categories follow:

Attitudes toward science classes: Attitudes assessed in these questions are all related to classroom experiences. NAEP has typically used this category to obtain answers to such questions as: Do students perceive science classes to be enjoyable and useful? Do students believe their teachers enjoy science, know a lot about it, make it interesting? How do students feel about different types of activities in science classes? Why do they feel the way they do?

Career and education intentions: Questions in this category address students' attitudes and intentions or expectations regarding further study of science and the possibility of entering careers in science-related fields. Since the attitudes and intentions of students today may affect the numbers of workers in science, engineering, and related fields tomorrow, it is important to find out what attitudes and expectations students hold, and why.

Socioscientific responsibility: The intent of questions in this category is to ascertain whether students believe that societal problems related to science affect them personally and whether they believe that they themselves can contribute to the solution of such problems. For example, the intent of some questions is to find out if students believe that current problems in energy, food production, or overpopulation touch their lives. The assessment asks students whether they believe they can do something personally to help with a specific problem such as energy shortage. Other questions deal with such things as whether or not students are willing to help solve societal problems.

Science as a personal tool: Questions in this category assess students' opinions about the utility of scientific knowledge and the skills and processes of scientific investigation in their daily lives. Some of these questions try to ascertain whether students believe that what they learn in science classes is useful for activities outside school, and whether they use this knowledge.

Value of Science: The primary object of questions in this category is to find out whether students have confidence in science and value scientific investigation as a beneficial activity. This inquiry addresses such questions as: Do students believe applications of science can help solve world problems? Has use of science improved the quality of life? This category also includes students' attitudes toward the conduct and support of research in basic and applied scientific fields and their opinions on the extent to which science and scientific activities should be controlled by the government or other social institutions.

Societal Issues: A major purpose of questions in this category is to ascertain students' opinions and attitudes about important and controversial scientific research directions and developments that could have an impact on society. Questions also seek students' opinions on the relative value and importance of disparate research and development thrusts that may be in competition for limited financial support. It is important to determine the older students' opinions on critical societal issues and any shifts in their opinions over the years. A scientifically literate population should be able to participate in decision-making on such issues and be aware of the potential risks and gains in new research. (Questions in this category do not apply to nine-year-olds.)

Experiences in Science: One intent of questions in this category is to assess students' experiences in science-related activities, both in school and out. The inclusion of questions that measure the extent of students' extracurricular science activities provides some indication of whether or not they value exploring science as an intellectual exercise. The second intent is to determine the extent to which students receive opportunities for observations of the natural world and for hands-on laboratory experiences.

APPENDIX A

Concepts Appropriate for the 1985-86 Assessment

Recognizing that the topics listed in Chapter 2 under each of the science disciplines were still very broad, the Learning Area Committee identified specific subtopics and concepts within each topic to guide the development of exercises for the assessment. The committee did not intend the following lists to be complete or definitive or to imply that any curriculum should include all the topics. The development of the lists followed the usual NAEP consensus procedure, under which a broad spectrum of reviewers commented on draft lists of science topics and on their appropriateness for students of different ages.

Because not all subtopics and concepts are appropriate for all age levels, the lists use a dot (●) in the column under a particular age to indicate that some aspect of that subtopic or concept could be a potential source of exercises for that age level. A blank indicates that the particular subtopic or concept is not appropriate for that age group.

Given time and other limitations, the assessment cannot include exercises on all the appropriate subtopics. The final selection of exercises for the assessment required the careful balancing of a number of requirements: the need to repeat enough exercises from previous assessments to be able to report on changes over time; the need to meet the distribution specifications with respect to content, context, and cognition; and the need to offer exercises over a wide range of difficulty. Within these constraints, the choice among exercises was based on professional judgments with respect to the quality of individual exercises and the centrality of what each measures.

TOPICS IN LIFE SCIENCES

	9	13	17
Cellular and Molecular Biology			
Cellular theory of life		●	●
Methods for studying cells		●	●
Plant and animal cells		●	●
Cell structure and function		●	●
Life as a chemical process		●	●
Structure and function of basic groups of biochemical compounds		●	●

	9	13	17
Enzymes, hormones, and vitamins as regulators of life processes		●	●
Structure and function of RNA and DNA		●	●
Translation of genetic information from genes to protein formation			●
Energy Transformations			
Importance of energy to life	●	●	●
Food as the source of biological energy	●	●	●
Major energy reactions in living things, photosynthesis and cellular metabolism		●	●
Biological energy as the making and breaking of chemical bonds			●
Structure and Function of Organisms (Protists, Plants, Animals)			
Living and nonliving things	●	●	●
Interdependences within living things—organisms as systems	●	●	●
Hierarchy of structure and function (from molecules to ecosystems)	●	●	●
Equilibrium in living things (homeostasis)		●	●
Structural features of plants	●	●	●
Structural features of animals	●	●	●
Structure and function of body systems (microorganisms, plants, animals, human)	●	●	●
Good health practices	●	●	●
Germ theory of disease	●	●	●
Diversity of Organisms (Classification)			
Major divisions of biology—botany, zoology, etc.	●	●	●

	9	13	17
Categories of living things—kingdom, phylum, etc.		●	●
Classification schemes—structural and/or evolutionary relationships		●	●
Taxonomy of major groups (microorganisms, protists, plants, animals)			●

Genetics and Development

	9	13	17
Reproduction as the fundamental biological process that provides for the continuance of life	●	●	●
Inherited characteristics as the endowments of every living organism that comes into the world	●	●	●
Relationship between inherited traits and physical appearance	●	●	●
Relationship between proteins and inherited traits			●
Gene theory of heredity (chromosomes, genes, DNA)		●	●
Strategies of reproduction—asexual and sexual	●	●	●
The process of meiosis in the life cycle of sexual reproducers			●
Elements of Mendelian genetics		●	●
Inheritance of human traits	●	●	●
Inheritance of human hereditary diseases		●	●
Plant and animal life cycles	●	●	●
Human life cycle	●	●	●
Growth and repair as fundamental activities of living things	●	●	●
Cell division as the essential mechanism of growth and development		●	●
Contemporary issues—genetic engineering, new reproductive technologies (e.g. IVF), genetic counseling, etc.		●	●

Evolution	9	13	17
Evolution of the earth and of life as the result of natural forces	•	•	•
Structural and functional changes in living things as responses to changes in physical environments	•	•	•
Adaptation as the chief means of survival in living things	•	•	•
Origins of new types of organisms through variations in previously living organisms		•	•
Progression from simple to complex organisms on an evolutionary continuum		•	•
Extinction as an important part of evolution		•	•
Historical perspectives (Darwin, Lamarck, etc.)			•
Evidences for evolution (fossils, geological records, comparative studies, etc.)		•	•
Nature of scientific proof as applied to evolution		•	•
Theories related to the origin of life		•	•
Theories of mechanisms that bring about evolutionary changes (natural selection, plate tectonics, etc.)		•	•
Adaptive advantages of biological symmetry (radial, spherical, bilateral)			•
Ecology			
Interdependencies in living systems (populations, communities, ecosystems, biomes)	•	•	•
Energy flow through food chains (decomposers, producers, consumers)	•	•	•
Balanced ecosystems and long-term stability	•	•	•
Environments of living things as continuously changing	•	•	•

	9	13	17
Essential requirements for life—food, certain temperature conditions, moisture, light and oxygen	•	•	•
Biogeochemical cycles (carbon dioxide-oxygen, nitrogen, etc.)		•	•
Competition	•	•	•
Importance of conservation and the protection of the environment (wildlife, natural resources, wilderness)	•	•	•
Importance to humans of microorganisms, plants, and animals	•	•	•
Protective adaptations (mimicry, protective coloration, etc.)	•	•	•
Prey-predator relationships	•	•	•
Latitude and altitude effects on life (life zones)		•	•
Effects of human activities on the environment	•	•	•
Social issues related to the environment (water crisis, pollution, etc.)	•	•	•
World population		•	•

Behavior

	9	13	17
Response of living things to stimuli	•	•	•
Basis of behavior (genetic, physical)		•	•
Animal behavior as a form of adaptation		•	•
Modes of animal behavior (communication, territoriality, social behavior, migratory behavior, innate behavior, learning, navigation)	•	•	•
Animal models and human behavior			•

TOPICS IN PHYSICS

	9	13	17
Mechanics			
Distance, force, energy	●	●	●
Levers, simple machines	●	●	●
Mass, volume, density		●	●
Time, speed, relative motion		●	●
Free-fall, constant acceleration		●	●
Principle of inertia, action-reaction	●	●	●
Weight and mass difference, vectors		●	●
Newton's laws, law of gravitation			●
Conservation of matter	●	●	●
Conservation of energy, work, and energy relation		●	●
Momentum, impulse, and conservation of momentum			●
Rotation, torque, angular momentum			●
Heat and Thermodynamics			
Phases of matter, heating, and cooling	●	●	●
Temperature and temperature scales	●	●	●
Phase changes, energy relations		●	●
Chemical bonds, latent heat, thermal coefficient			●
Calorimetry, first law of thermodynamics		●	●
Heat engines, entropy, second law of thermodynamics			●
Pressure, volume, and temperature relations		●	●
Gas laws, kinetic molecular theory			●

Waves and Optics	9	13	17
Vibration, transmission, and types of waves		•	•
Wavelength, frequency, amplitude, speed		•	•
Reflection, refraction, diffraction, and superposition		•	•
Snell's law, interference patterns, standing waves			•
Sound and air	•	•	•
Sound production, music		•	•
White light and colors, shadows	•	•	•
Lenses, mirrors		•	•
Images, ray diagrams, lens equations			•
Particle vs. wave models for light			•
Doppler effect, redshift			•
Electricity and Magnetism			
Electric materials, attraction and repulsion	•	•	•
Charge, protons, electrons		•	•
Coulomb's law, fields, potential difference			•
Electricity at home	•	•	•
Batteries, current, resistance, simple circuits		•	•
Ohm's law, electrical power, electrical devices			•
Magnetic materials, Earth's magnetism, compass	•	•	•
Oersted's discovery, electromagnetism		•	•
Magnetic field, currents in magnetic fields			•
Electric motors, generators, AC/DC			•
Generating, sending, and using electric power			•
Semiconductors, transistors, and amplification			•

Modern Physics	9	13	17
Atomic structure, the four-force universe		●	●
Bohr atom, quantized orbits			●
Photons, explanation of atomic spectra			●
Radioactive materials, effects of radioactivity	●	●	●
Half-life, radioactive decay, nuclear plants, $E = mc^2$		●	●
Fission, fusion, "binding energy" curve			●
Special relativity—basic principles			●
High energy particles			●
Cosmology—evidence of an expanding universe			●

TOPICS IN CHEMISTRY

Structure of Matter	9	13	17
Concept of elementary particles (atoms and molecules)	●	●	●
Elements and compounds	●	●	●
Electron shells, subshells, and orbitals			●
Radioactivity		●	●
Matter and energy		●	●
Ionic and covalent bonding			●
Polar and nonpolar molecules			●
Macromolecules			●

Periodic Classification	9	13	17
Relationship between electronic structure and periodic classification			●
Metals and nonmetals	●	●	●

	9	13	17
Families of elements		●	●
Noble gases			●
Transition elements			●
Ionization potentials			●
Relative electronegativities			●
Atomic radii (size of atoms)			●

States of Matter and Nature of Solutions

	9	13	17
Physical properties of solids, liquids, and gases (examples: ice, water, water vapor); effectives of temperature, pressure, volume	●	●	●
Energy changes in changes of state	●	●	●
Kinetic and potential energy; temperature dependence of kinetic energy		●	●
Method of expressing concentration of solutions		●	●
Colligative properties of solutions			●
Relationships between solubility and structure			●
Electrical conductivity		●	●

Reactions of Matter

	9	13	17
Changes in properties of matter by chemical reactions	●	●	●
Decomposition		●	●
Combination (burning, rusting, etc.)	●	●	●
Energy of reactions			●
Oxidation-reduction; basic concepts			●
Acids and bases		●	●
Reversible reactions			●

Stoichiometry	9	13	17
Laws of conservation of mass	●	●	●
Laws of chemical combination		●	●
Atomic and molecular weights		●	●
The mole concept			●
Chemical equations; concepts and calculations			●
Percent composition and formulas of compounds			●
Mass-gas volume relationships			●
Volume-volume relationships in gaseous reactions			●
Energy relationships in chemical reactions			●

TOPICS IN EARTH AND SPACE SCIENCES

Earth's History	9	13	17
The rock record	●	●	●
The fossil record	●	●	●
Plate tectonics		●	●
Materials of the Earth			
Earth chemistry		●	●
Rocks	●	●	●
Minerals	●	●	●
Natural resources	●	●	●
Water	●	●	●
Air	●	●	●

	9	13	17
Agents and Processes of Change in Earth's Surface			
Weathering	•	•	•
Erosion	•	•	•
Crustal movements	•	•	•
Glaciers	•	•	•
Water	•	•	•
Winds	•	•	•
Volcanism, earthquakes	•	•	•
The Earth's Atmosphere and Weather			
Air and its movements	•	•	•
Water cycles	•	•	•
Climate, seasons	•	•	•
Weather	•	•	•
Describing and Measuring Time and Location			
Earth's rotation and revolution	•	•	•
Latitude and longitude		•	•
Time and date	•	•	•
Earth's dimensions		•	•
The Oceans			
Ocean water and its movements	•	•	•
The ocean floor	•	•	•

The Solar System, Galaxies, and the Universe	9	13	17
Design of the universe		•	•
Stars and galaxies		•	•
The solar system	•	•	•
The Sun	•	•	•
The Earth's Moon	•	•	•
Space exploration	•	•	•

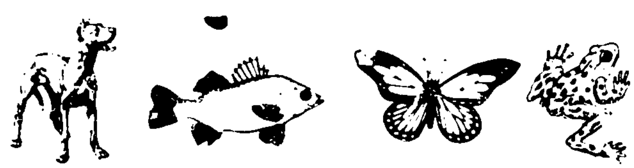
APPENDIX B

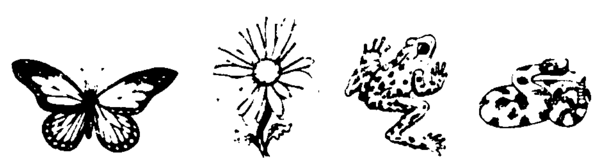
The exercises that follow illustrate the classification of exercises into the various cells of the three-dimensional matrix designed as the framework for the science assessment.

Each exercise is classified into one of six content areas (Life Sciences, Physics, Chemistry, Earth and Space Sciences, History of Science, or Nature of Science); into one of four contexts (Scientific, Personal, Societal, or Technological) and into one of three levels of cognition (Knows, Uses, or Integrates). It is understood that occasionally an exercise will cross discipline or context lines.

1. In which set of living things below do all four things get their food in a similar way?

(A) 

(B) 

(C) 

(D) 

This exercise for 9-year-olds is classified as *Life Science—Scientific—Integrates.* (It is an example of a question that would be classified as *integrates* for 9-year-olds but not for older students.)

2. In the western part of the U.S., poisoned bait is sometimes used to kill coyotes that are attacking sheep. Some people protest this practice. Which of the following is probably NOT a concern of these protesters?

   (A) Other animals, including some endangered species, could be killed by eating the poisoned bait.

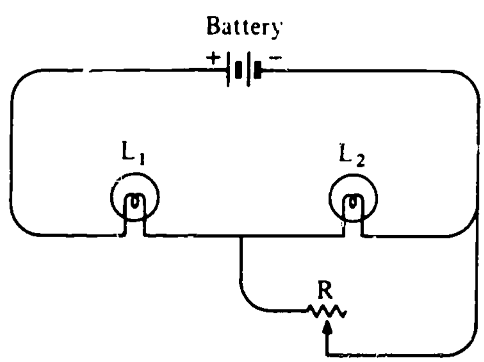
   (B) Eliminating the coyote from the food web may result in increased numbers of mice and rabbits.

   (C) The pelts of coyotes killed by this method will not be of any value

   (D) The wheat crop produced in the area may suffer as a result of an increase in first-level consumers.

   This exercise is classified as *Life Sciences—Societal—Uses*, suitable for 17-year-olds, and possibly for students at age 13.

3.



Light bulbs 1 and 2 and a variable resistor R are connected to a battery as shown above. The resistance of R in this circuit may be increased or decreased.

If the resistance of R in the diagram above is increased, how will the brightness of light bulb 1 be affected?

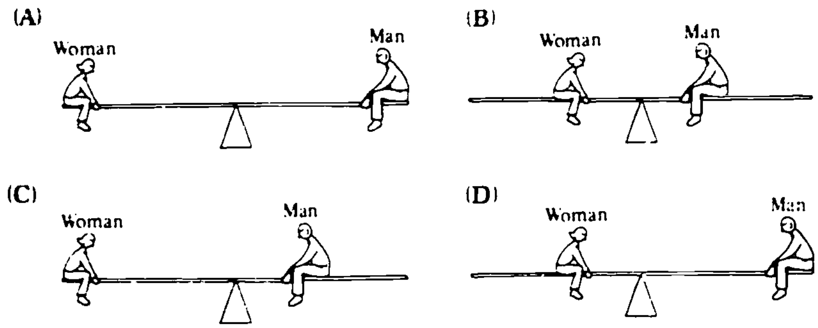
(A) It will increase.

(B) It will decrease.

(C) It will remain the same.

This exercise is classified as *Physics—Scientific—Uses*, suitable for 17-year-olds.

4. A 100-pound woman and a 200-pound man are seated on a seesaw. In which of the following pictures would the seesaw be balanced?



This is an exercise suitable for 9-year-olds, and classified as *Physics —Scientific—Uses.*

5. Which of the following technological advances contributed most to increasing our knowledge of the thickness of the Earth's crust?

(A) The diamond tipped drill bit

(B) The orbiting space telescope

(C) The recording seismograph

(D) Laser surveying techniques

This is a straight recall exercise suitable for age 13 or 17. It is classified *Earth and Space Sciences—Technological—Knows.*

6. The idea that increasing concentrations of carbon dioxide in the atmosphere will result in an increase in the worldwide average atmospheric temperature is based on which of the following facts about carbon dioxide?

(A) It is used by plants in photosynthesis.

(B) It is necessary for precipitation (rain) to occur.

(C) It is produced by the respiration of plants and animals.

(D) It is a better absorber of infrared than of ultraviolet radiation.

This exercise is suitable for 17-year-olds. It is classified as *Earth and Space Sciences—Societal—Uses.*

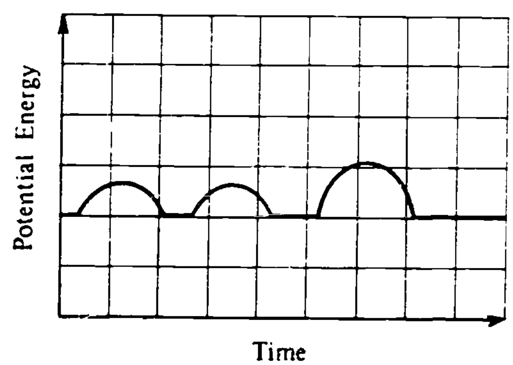
This is an example of an exercise that crosses both discipline and context lines. There are elements of both life sciences and chemistry in the exercise, as well as earth and space sciences. Although one could also argue that the exercise is scientific, the NAEP staff judged that the societal implications in the question were predominant.

7. The urine of a healthy human has a pH of 7.35 to 7.45. Acidosis is a condition in which there is an abnormal increase of hydrogen ions. Urine at which of the following pH readings indicates a state of acidosis?

(A) 6.85 (B) 7.40 (C) 7.65 (D) 7.95

This exercise is classified as *Chemistry—Personal—Uses.* It is suitable for 17-year-olds.

8.



The teacher tells the class, "This graph was made from watching an animal move." Then she asks the students to suggest what kind of animal was observed. Pat thinks a frog was watched as it hopped. Jean thinks the animal was a kangaroo. Which of the following would be most helpful in determining which of the two hypotheses was more likely to be correct?

(A) Knowing how much time is represented by each of the flat portions of the graph

(B) Knowing how much energy is represented by the space between two adjacent horizontal lines

(C) Determining whether the curved sections of the graph are parabolic

(D) Regraphing the data to increase its spread

This exercise is classified as *Nature of Science—Scientific—Integrates.* It is suitable for both 13- and 17-year-olds.

9. By following the history of the natural sciences, we can see that practically every scientific discovery and idea is built on earlier discoveries and ideas. Based on this information, what is the most likely historical order of the following developments?
   1. Fabricius describes the one-way valves in the veins that let blood flow only toward the heart.
   2. Vesalius dissects human cadavers and shows how to use dissections to study human anatomy.
   3. Harvey announces his theory that blood circulates in the body, going from the heart into the arteries, then into the veins and back to the heart.

   (A) 1, 3, 2

   (B) 2, 1, 3

   (C) 2, 3, 1

   (D) 3, 1, 2

   This is a *History of Science—Scientific—Integrates* exercise appropriate for 17-year-olds. Although many History of Science exercises will be in the *Knows* category, this exercise has been included to illustrate that it is possible to assess more than straightforward recall of facts in the history area.

10. Studies have shown that people who smoke cigarettes have a greater likelihood of contracting several diseases. The cause-and-effect relationship between smoking and poor health is which of the following?

    (A) An observation

    (B) An inference

    (C) A law

    (D) A model

    This is a *Nature of Science—Scientific—Knows* exercise that is appropriate for ages 13 and 17.

APPENDIX C

Participants in the Development of the 1985-86 National Assessment of Science

The National Assessment appreciates the efforts of all the individuals who contributed to the development of the 1985-86 science assessment. Many people, including university professors, research scientists, classroom teachers, school administrators and curriculum specialists, as well as parents and other interested lay persons, participated in reviewing successive drafts of these objectives. In addition, more than 30 classroom teachers across the country wrote exercises for the assessment. NAEP could not have developed these objectives and the assessment based on them without the substantial involvement of these people.

Special thanks are due to the members of the Science Learning Area Committee who developed the framework and specifications for the assessment, were responsive to the series of reviews, and spent long hours reviewing and revising exercises. Assisting them were Richard DeVore and Hessy Taft, science examiners at Educational Testing Service, and Marion Epstein, science coordinator for NAEP.

The National Assessment extends its deep appreciation to all participants.

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