High School Biology/Life Science Course Guidance

Introduction

Science is a way of thinking about and investigating the world in which we live, not merely a collection of facts and theories. Learning science is an active process. This learning reflects the intellectual and cultural traditions that characterize the practice of contemporary science. The goal of science education is to provide students with well conceived opportunities to investigate the natural world and to use those explanations to make useful predictions.

High School Life Science courses should be laboratory courses grounded in the New Jersey Core Curriculum Content Standards for Science (NJCCCS). The content of the course should be organized around *Enduring Understandings* including scientific processes, cells, genetics, evolution and natural systems. *Essential Questions* for the Life Science course should be at the heart of the curriculum. The Essential Questions are deliberately open, promote inquiry, and may produce different plausible responses. The purpose of this document is to provide clarification to the NJCCCS and establish a structure for the development of a high school biology/life science course and related assessments. **This document is NOT the definition of the totality of curriculum in life sciences. It is the information that should be *included* in life science courses for all students.** The district curriculum in this area may include additional content.

School districts are welcome to expand upon the expectations defined in this document in order to meet the unique needs of their students. Students should be encouraged to participate in Advance Placement courses or the International Baccalaureate (IB) Diploma Program.

Understanding science is multifaceted. Current research indicates that proficiency in one aspect of science is closely related to proficiency in others. The strands of scientific proficiency are intertwined therefore the debate between science content versus scientific process is mute. The strands of scientific proficiency describe broad enduring understandings for students. They address the knowledge and reasoning skills that students must acquire to be considered proficient in science. They are also a means to that end: they are practices that students need to participate in and become fluent with in order to develop proficiency. (NRC, 2006)

Interpreting the Document

The New Jersey Core Curriculum Content Standards and Cumulative Progress Indicators (CPI) are highlighted with bold text and are further identified by an alpha numeric code.
For Example ***5.5.12 A 1*** refers to:

Standard **5.5**: *Characteristics of Life*

by the end of grade **12**

Strand **A**: *Matter, Energy and Organization in Living Systems*

Cumulative Progress Indicator **1**: *Students will relate the structure of molecules to their function in cellular structure and metabolism.*

Each Strand begins with a brief summary of the *Enduring Understandings* that students should develop as a result of their experiences in a science course. The term *Enduring* U*nderstanding* refers to the big ideas, or the important understandings, that students need to "get inside of" and retain after they've forgotten many of the details. Put differently, the enduring understandings provide a larger purpose for learning the targeted content. They implicitly answer the question:

Why is this topic worth studying? (Wiggins, 2005). Each CPI is further clarified with a narrative of **Areas of Focus** and **Explanatory Bullets, Examples, and Comments**.

The sections titled **Biologically Speaking** represent core scientific terms that should be used in the natural course of instruction. **These are <u>not</u> to be considered vocabulary lists for memorization or designed to be the subject of drills in definition; rather, they represent the vocabulary of scientific inquiry in specific strands of biological inquiry, without which that inquiry cannot be effectively conducted or communicated**.

Finally, this document was produced to further clarify the teaching and learning expectations as defined by the NJCCCS and to signal the content boundaries for the biology/life science EOC test. For all intents and purposes the authors have merged the science standards and the test specifications document to produce this guidance document.

Student who are scientifically proficient:

- Know, use and interpret scientific explanations of the natural world;
- Generate and evaluate scientific evidence and explanations;
- Understand the nature and development of scientific knowledge; and
- Participate productively in scientific practices and discourse. (NRC, 2006)

Life Science (NJCCCS 5.5 and 5.10)**: Essential Questions:**

1. What is the relationship between structure and function in living systems?
2. How are matter and energy transformed and transferred in living systems?
3. How do responses to internal and external stimuli lead to the survival of an organism?
4. Why do organisms have their specific traits?
5. How do natural selection and evolution explain the development of Earth's present species?
6. How do human activities impact the environment and living systems?

Cross Content Integration

Science concepts should also be integrated with concepts and skills from other curriculum areas. Reading, writing, mathematics, and technology should be emphasized as integral to science. Personal relevance of science in students' lives is an important part of helping students to value science and should be emphasized. Developing students' oral and written communication skills in science should be an important part of science. Students should regularly write and discuss their experiments, observations, and inferences.

Providing opportunities for students to gain insights into science-related careers adds to the relevance of science learning. Biology/life sciences provide students with opportunities to investigate careers in genetics, biotechnology, environmental science, and many fields of health care and medicine.

Assessment

Assessment should be an integral part of science instruction. Assessment provides students with feedback on how well they are meeting expectations, teachers with feedback on how well their students are learning; and, school districts with feedback on the effectiveness of their curriculum. This feedback in turn encourages students to improve their understanding of science, stimulates changes in instruction, and guides the professional development of teachers.

Formative and summative assessments should focus on higher-order thinking skills rather than simply checking whether students have memorized certain facts. Assessment should probe for students' understanding, reasoning, and use of that knowledge-the skills that are developed through inquiry.

Assessments might include performances, portfolios, interviews, investigative reports, laboratory investigations, lab reports, or written essays. They need to be developmentally appropriate, set in contexts familiar to students, and as free from bias as possible. Although difficult, such assessments are a critical part of the effective science education. (NRC, 1996)

Biology/Life Science End of Course Test

Effective with the 2007-2008 school year, the department of education is moving to an end-of-course model for assessing science, starting with a biology/life science end-of-course (EOC) assessment to be administered for the first time in May 2008. This assessment replaces the High School Proficiency Assessment (HSPA) Science test.

The biology/life science EOC test will consist of approximately forty-five 1-point multiple choice and three 3-point constructed response items, plus an embedded field-test section containing additional multiple-choice and constructed response items. Students will not know which items are operational and which are field-test items. Student scores will be based on the operational portion only. Score reports will be released to districts in the summer of 2007, following a standard-setting process which will establish cut scores for proficiency.

In association with the biology/ life science EOC test, the department is working with the New Jersey Performance Assessment Alliance (NJPAA) to field-test a performance assessment prompt (approximately 90 minutes) to all students taking the Biology EOC test. The student response to this prompt will be scored and reported by NJPAA under a grant agreement with the NJDOE. Student scores on the prompt will not form part of the student score for the Biology/Life Science EOC test. Sample Student Prompt Booklet, Student Response Booklet, and Teacher Guidelines Booklet are available at:

http://www.nj.gov/education/aps/cccs/science/resources

Achieving proficiency on the May 2008 Biology EOC test is not a graduation requirement.

Performance Level Descriptions

Achievement Level	Performance Level Description
Advanced Proficient	This level signifies superior performance.
Proficient	This level represents solid academic performance for each grade assessed. Students reaching this level have demonstrated competency over challenging subject matter, including subject matter knowledge, application of such knowledge to real-world situations, and analytical skills appropriate to the subject matter.
Partial Proficient	This level denotes partial mastery of prerequisite knowledge and skills that are fundamental for proficient work at each grade.

Composition of the EOC Exam

Enduring Understandings and the *Essential Questions* about biology/life science, arising from standards 5.5 and 5.10, should be the focus of instruction and are therefore the focus of the end of course assessment.

Multiple choice, open ended, and performance assessment items are derived from the intersection of the process and content standards. Thus, test items about photosynthesis, for example may be written so as to embody standard 5.1 (Scientific Process); 5.2 (Science and Society); 5.3 (Mathematical Applications) or 5.4 (Nature and Process of Technology); or indeed a hybrid of two or more process standards. Each content strand identified may be the basis for a variety of items, representing a range of difficulty levels and test item construction approaches, but all aligned to the NJ CCCS.

By consensus and design, standard 5.1, (Scientific Processes) is emphasized in item development. The priority among the process standards is due to its fundamental role in science: the process of rational, empirical investigation of the world in which we live. This prioritization should further signal to the field that scientific investigations should be an integral part of the biology curriculum.

Test construction will align with the process standards in approximately the following proportions:

70% 5.1 (Scientific Processes)

10% 5.2 (Science and Society) and 5.4 (Nature and Process of Technology)

10% 5.3 (Mathematical Applications)

10% Knowledge/Factual Recall

Thus, almost three-quarters of the Areas of Focus will measure student proficiency with understanding and utilizing the scientific processes. All open-ended test items will draw upon the Scientific Process - Habits of Mind/Inquiry skill standards.

Example EOC Test Item

DIRECTIONS FOR QUESTION 48: When responding to the open-ended question that follows, you may use words, tables, diagrams, and/or drawings. Write your answer on page 5 in your answer folder.

48. Adrian has constructed a miniature ecosystem that includes plants and tiny animals in a sealed glass jar. He measures the concentrations of oxygen and carbon dioxide in the air inside the jar periodically.

    After recording an increase in oxygen and a decrease in carbon dioxide, he concludes that there are too many plants for the number of animals in the jar.

- How did the measurements lead him to that conclusion?
- If Adrian places the glass jar in a room that receives less light, how will this help balance the ecosystem in the glass jar?

Scoring Guide for Biology Open-Ended (OE) Questions

The following generic rubric is used as a guide to develop specific scoring guides or rubrics for each of the open-ended (OE) questions that appear on the Biology/ Life Science EOC Assessment. These scoring rubrics provide the criteria for evaluating and scoring student performance and are developed by a committee of scientists and teachers. Rubrics ensure that there is consistency, fairness, and accuracy in scoring open-ended questions.

Generic Rubric

The zero-to-three-point generic scoring rubric below was created to help readers score open-ended responses consistently. In scoring, a reader should accept the use of appropriate labeled diagrams, charts, formulas, and/or symbols that are part of the correct answer even when the question does not specifically request their use.

3-Point Response
The student response is reasonably correct, clear, and satisfactory.

2-Point Response
The student response has minor omissions and/or some incorrect or irrelevant information.

1-Point Response
The student response includes some correct information, but most information included in the response is either incorrect or irrelevant.

0-Point Response
The student attempts the task, but the response is incorrect, irrelevant, or inappropriate.

Instructional Choices

Since 1996, the National Science Education Standards have envisioned student-centered instruction. The New Jersey Core Curriculum Content Standards for Science explicitly reflect a belief that students learn science best by being actively engaged in science. The following table illustrates where emphasis should be placed when selecting instructional strategies. (NRC, 1996)

LESS EMPHASIS ON:	MORE EMPHASIS ON:
Treating all students alike and responding to the group as a whole	Understanding and responding to individual student's interests, strengths, experiences, and needs
Rigidly following curriculum	Selecting and adapting curriculum
Focusing on student acquisition of information	Focusing on student understanding and use of scientific knowledge, ideas, and inquiry process
Presenting scientific knowledge through lecture, text and demonstration	Guiding students in active and extended scientific investigations
Asking for recitation of acquired knowledge	Providing opportunities for scientific discussion and debate among students
Testing students for factual information at the end of the unit or chapter	Continuously assessing student understanding
Maintaining responsibility and authority	Sharing responsibility for learning with students
Supporting competition	Supporting a classroom community with cooperation, shared responsibility and respect
Working alone	Working with teachers to enhance the science program

High School Lab Science Guidance

The New Jersey Department of Education does not provide an operational definition for "lab science." This section is intended to provide a framework for local education agencies to use in the development of lab science courses.

The unique characteristic of science, as a discipline of study, is that it generates theories and laws that must be consistent with observations. Much of the evidence from these observations is collected during laboratory investigations. A school laboratory investigation should be an experience in the laboratory, classroom, or field that provides students with opportunities to interact directly with natural phenomena or with data collected by others using tools, materials, data collection techniques, and models. Throughout the process, students should have opportunities to design investigations, engage in scientific reasoning, manipulate equipment, record data, analyze results, and discuss their findings. These skills and knowledge, fostered by laboratory investigations, are an important part of inquiry—the process of asking questions and conducting experiments as a way to understand the natural world (NSTA, 2004). While reading about science, using computer simulations, and observing teacher demonstrations may be valuable, they are not a substitute for laboratory investigations.

For science to be taught effectively, investigations must be an integral part of the science curriculum. The department recommends that all teachers of science provide instruction with a priority on making observations and gathering evidence, much of which students experience in the lab or the field, to help students develop a deep understanding of science content, as well as an understanding of the nature of science, the attitudes of science, and the skills of scientific reasoning (NRC 2006, p. 127). Furthermore, the department is committed to ensuring that all students—including students with disabilities, students with limited English proficiency, and students who are gifted and talented—have the opportunity to participate in laboratory investigations in a safe environment.

Developmentally-appropriate laboratory investigations are essential for students of all grade and ability levels. They should not be a rote exercise in which students are merely following directions, as though they were reading a cookbook, nor should they be a superfluous afterthought that is only tangentially related to the instructional sequence of content (see Appendix A for an example).

Properly designed laboratory investigations should:

- Have a definite purpose that is communicated clearly to all students;
- Focus on the processes of science as a way to convey content;
- Incorporate ongoing student reflection and discussion; and
- Enable students to develop safe and conscientious lab habits and procedures.

Co-Requisite Content Standards and CPIs for Life Science Courses

STANDARD 5.5 (Characteristics of Life) All students will gain an understanding of the structure, characteristics, and basic needs of organisms and will investigate the diversity of life.	**STANDARD 5.10 (Environmental Studies) All students will develop an understanding of the environment as a system of interdependent components affected by human activity and natural phenomena.**
Strands and Cumulative Progress Indicators *Building upon knowledge and skills gained in preceding grades, by the end of Grade 12, students will:* **5.5.12 A. Matter, Energy, and Organization in Living Systems** 1. Relate the structure of molecules to their function in cellular structure and metabolism. 2. Explain how plants convert light energy to chemical energy. 3. Describe how plants produce substances high in energy content that become the primary source of energy for life. 4. Relate disease in humans and other organisms to infections or intrinsic failures of system. **5.5.12 B. Diversity and Biological Evolution** 1. Explain that through evolution the Earth's present species developed from earlier distinctly different species. 2. Explain how the theory of natural selection accounts for extinction as well as an increase in the proportion of individuals with advantageous characteristics within a species. **5.5.12 C. Reproduction and Heredity** 1. Describe how information is encoded and transmitted in genetic material. 2. Explain how genetic material can be altered by natural and/or artificial means; mutations and new gene combinations may have positive, negative, or no effect on organisms or species. 3. Assess the impact of current and emerging technologies on our understanding of inherited human characteristics.	**Strands and Cumulative Progress Indicators** *Building upon knowledge and skills gained in preceding grades, by the end of Grade 12, students will:* **5.10.12 A. Natural Systems and Interactions** 1. Distinguish naturally occurring process from those believed to have been modified by human interaction or activity. • climate change • ozone production • erosion and deposition • threatened and endangered species **B. Human Interactions and Impact** 1. Assess the impact of human activities on the cycling of matter and the flow of energy through ecosystems. 2. Use scientific, economic, and other data to assess environmental risks and benefits associated with societal activity.

Co-Requisite Content Standards and CPIs for Life Science Courses

STANDARD 5.1 **(Scientific Process)** **All students will develop problem-solving, decision-making and inquiry skills, reflected by formulating usable questions and hypotheses, planning experiments, conducting experiments, conducting systematic observations, interpreting and analyzing data, drawing conclusions, and communicating results.**	**STANDARD 5.2** **(Science and Society)** **All students will develop an understanding of how people of various cultures have contributed to the advancement of science and technology, and how major discoveries and events affect historical events.**	**STANDARD 5.3** **(Mathematical Applications)** **All students will integrate mathematics as a tool for problem-solving in science, and as a means of expressing and/or modeling scientific theories.**	**STANDARD 5.4** **(Nature and Process of Technology)** **All students will understand the interrelationships between science and technology and develop a conceptual understanding of the nature and process of technology.**
Strands and Cumulative Progress Indicators Building upon knowledge and skills gained in preceding grades, by the end of Grade 12, students will: **5.1.12 A. Habits of Mind** 1. When making decisions, evaluate conclusions, weigh evidence, and recognize that arguments may not have equal merit. 2. Assess the risks and benefits associated with alternative solutions. 3. Engage in collaboration, peer review, and accurate reporting of findings. 4. Explore cases that demonstrate the interdisciplinary nature of scientific enterprise. **5.1.12 B. Inquiry and Problem Solving** 1. Select and use the appropriate instrumentation to design and construct investigations. 2. Show that experimental results can lead to new questions and further investigations. **5.1.12 C. Safety** 1. Understand, evaluate and practice safe procedures for conducting science investigations.	**Strands and Cumulative Progress Indicators** Building upon knowledge and skills gained in preceding grades, by the end of Grade 12, students will: **5.2.12 A. Cultural Contributions** 1. Recognize the role of the scientific community in responding to changing social and political conditions and how scientific and technological achievement effect historical events. **5.2.12 B. Historical Perspectives** 1. Examine the lives and contributions of important scientists who affected major breakthroughs in our understanding of the natural and designed world. 2. Discuss significant technological achievements in which science has played an important part as well as technological advances that have contributed directly to the advancement of scientific knowledge. 3. Describe the historical origin of important scientific developments such as atomic theory, genetics, plate tectonics, etc., showing how scientific theories develop, are tested, and can be replaced or modified in light of new information and improved investigative techniques.	**Strands and Cumulative Progress Indicators** Building upon knowledge and skills gained in preceding grades, by the end of Grade 12, students will: **5.3.12 A. Numerical Operations** *Reinforce indicators from previous grade level.* **5.3.12 B. Geometry and Measurement** 1. When performing mathematical operations with measured quantities, express answers to reflect the degree of precision and accuracy of the input data. **5.3.12 C. Patterns and Algebra** 1. Apply mathematical models that describe physical phenomena to predict real world events. **5.3.12 D. Data Analysis and Probability** 1. Construct and interpret graphs of data to represent inverse and non-linear relationships, and statistical distributions.	**Strands and Cumulative Progress Indicators** Building upon knowledge and skills gained in preceding grades, by the end of Grade 12, students will: **5.4.12 A. Science and Technology** 1. Know that scientific inquiry is driven by the desire to understand the natural world and seeks to answer questions that may or may not directly influence humans, while technology is driven by the need to meet human needs and solve human problems. **5.4.12 B. Nature of Technology** 1. Assess the impacts of introducing a new technology in terms of alternative solutions, costs, tradeoffs, risks, benefits and environmental impact. **5.4.12 C. Technological Design** 1. Plan, develop, and implement a proposal to solve an authentic, technological problem.

Scientific Inquiry (5.1.12) All students will develop problem-solving, decision-making and inquiry skills, reflected by formulating usable questions and hypothesis, planning experiments, conducting systematic observations, interpreting and analyzing data, drawing conclusions, and communicating results.

A. Habits of Mind

(5.1.12 A 1) When making decisions, evaluate conclusions, weigh evidence, and recognize that arguments may not have equal merit.

Students should understand that:

- *Scientific explanations must meet certain criteria (e.g., they must be consistent with experimental and observational evidence about nature, make accurate predictions about systems being studied, be logical, respect the rules of evidence, be open to criticism, report methods and procedures, make a commitment to making knowledge public) to be considered valid.*
- *Conceptual principles and knowledge guide scientific inquiries.*

Students should be able to:

- *Exercise sound reasoning in understanding*
- *Make complex choices and decisions*
- *Identify and ask significant questions that clarify various points of view and lead to better solutions*
- *Frame and analyze, and synthesize information in order to solve problems and answer questions*
- *Evaluate information critically and competently and use information accurately and creatively for the issue or problem at hand*
- *Formulate scientific questions about an issue and define experimental procedures for finding answers*
- *Plan and conduct practical tests to solve problems or answer a question, collect and analyze data using appropriate instruments and techniques safely and accurately.*
- *Develop models and explanations to fit evidence obtained from investigations.*

(5.1.12 A 2) Assess the risks and benefits associated with alternative solutions.

Students should understand that:

- *All scientific knowledge is subject to change as new evidence becomes available.*
- *Some scientific ideas are incomplete and opportunity exists in these areas for new advances; theories are continually tested, revised, and occasionally discarded.*
- *From time to time, major shifts occur in the scientific view of how the world works, but usually the changes that take place in the body of scientific knowledge are small modifications of prior knowledge.*

(5.1.12 A 3) Engage in collaboration, peer review, and accurate reporting of findings.

Students should be able to:

- *Demonstrate the ability to work effectively with diverse teams*
- *Demonstrate originality and inventiveness in work.*
- *Act on creative ideas to make a tangible and useful contribution to the domain in which the innovation occurs.*
- *Exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal*
- *Assume shared responsibility for collaborative work*
- *Use technology as a tool to research, organize, evaluate and communicate information, and the possession of a fundamental understanding of the problem at hand*
    - *Select and use appropriate scientific vocabulary to orally share and communicate scientific ideas, plans, results, and conclusions resulting from observations and investigations.*
    - *Create written reports and journals to share and communicate scientific ideas, plans, results, and conclusions resulting from observations and investigations.*
    - *Create multimedia presentations incorporating numeric, symbolic and/or graphic modes of representation to share scientific ideas, plans, results and conclusions.*
    - *Model solutions to a range of problems in science and technology using computer simulation software.*
    - *Use secure electronic networks to share information*

(5.1.12 A 4) Explore cases that demonstrate the interdisciplinary nature of the scientific enterprise.

Students should understand that:

- *Science involves different types of work in many different disciplines (e.g., scientists in different disciplines ask different questions, use different methods of investigation, and accept different types of evidence to support their explanations; many scientific investigations require the contributions of individuals from different disciplines; new disciplines of science, such as geophysics and biochemistry, often emerge at the interface of older disciplines).*

B. Inquiry and Problem Solving

(5.1.12 B 1) Select and use appropriate instrumentation to design and conduct investigations.

Students will be able to:

- *Learn quickly the proper use of new instruments by following instructions in manuals or by taking instructions from an experienced user.*
- *Design and conduct scientific investigations (e.g., formulates testable hypotheses; identifies and clarifies the method, controls, and variables; analyzes, organizes, and displays data; revises methods and explanations; presents results; receives critical response from others).*
- *Select and analyze information from various sources, including electronic and print resources, community resources, and personally collected data to answer questions being investigated.*
- *Collect and use quantitative and quantitative data and information, seek evidence and sources of information to identify flaws such as errors and bias and explain how the evidence gathered supports or refutes an initial hypothesis.*
- *Analyze data and information gathered to clarify problems or issues identifying costs and benefits from a social, cultural, and or environmental perspective*

<u>Students should understand that:</u> (5.1.12 B 1 continued)

- *When conditions of an investigation cannot be controlled, it may be necessary to discern patterns by observing a wide range of natural occurrences.*
- *Technology (e.g., hand tools, measuring instruments, calculators, computers) and mathematics (e.g., measurement, formulas, charts, graphs) are integral in the performance of accurate scientific investigations and communications.*

Tools for use in science classrooms include but are not limited to: internet, sciLinks, online resources, print resources (newspapers, books, magazines), PDA's, web databases (NASA, EPA, NOAA, USGS, etc), observational and measurement tools (microscopes, probes), TV programs (NASA, Discovery, National Geographic), multimedia applications videos, DVD's CD ROMSs) calculators, telecommunications, spreadsheets, word processing.

(5.1.12 B 2) Show that experimental results can lead to new questions and further investigations.

<u>Students should understand that:</u>

- *Investigations and public communication among scientists must meet certain criteria in order to result in new knowledge and methods (e.g., arguments must be logical and demonstrate connections between natural phenomena, investigations, and the historical body of scientific knowledge; the methods and procedures used to obtain evidence must be clearly reported to enhance opportunities for further investigation).*

C. Safety

(5.1.12 C 1) Understand, evaluate and practice safe procedures for conducting science investigations.

<u>Students will be able to:</u>

- *Follow correct procedures for use of scientific apparatus.*
- *Demonstrate appropriate technique in all laboratory situations.*
- *Follow protocol for identifying and reporting safety problems and violations.*

Science, Society and Technology (5.2.12) All students will develop an understanding of how people of various cultures have contributed to the advancement of science and technology, and how major discoveries and events affect historical events.

A. Cultural Contributions

(5.2.12 A 1) Recognize the role of the scientific community in responding to changing social and political conditions and how scientific and technological achievement effect historical events.

Students should understand that:

- *Ethical traditions are associated with the scientific enterprise (e.g., commitment to peer review, truthful reporting about the methods and outcomes of investigations, publication of the results of work) and that scientists who violate these traditions are censored by their peers.*
- *Science and technology are essential social enterprises, but alone they can only indicate what can happen, not what should happen.*

Students should be able to:

- *Identify the reputable and appropriate communities of learners to whom research findings should be reported, compare data, and adapt it as needed.*
- *Use science learned to create a personal action plan on a community issue.*
- *Communicate with interested learners using appropriate web resources and publication media such as journals (print or electronic)*

B. Historical Perspectives

(5.2.12 B 1) Examine the lives and contributions of important scientists who affected major breakthroughs in our understanding of the natural and designed world.

Students should understand that:

- *Throughout history, diverse cultures have developed scientific ideas and solved human problems through technology.*

As students study science they should be aware of the historical perspective that has impacted the development of various scientific theories. It is important for students to know that our body of scientific knowledge continues to grow and develop. It is not expected that students will be able to memorize the specific contributions of individual scientists, but rather they will appreciate the context of their work and how it has impacted what we know about the world in which we live.

(5.2.12 B 2) Discuss significant technological achievements in which science has played an important part as well as technological advances that have contributed directly to the advancement of scientific knowledge.

Students should understand that:

- *Progress in science and invention depend heavily on what else is happening in society, and history often depends on scientific and technological developments*
- *Technology usually affects society more directly than science because it solves practical problems and serves human needs (and may create new problems and needs).*

(5.2.12 B 3) Describe the historical origin of important scientific developments such as atomic theory, genetics, plate tectonics, etc., showing how scientific theories develop, are tested, and can be replaced or modified in light of new information and improved investigative techniques.

Students should understand that:

- *In the short run, new ideas that do not mesh with mainstream ideas in science often encounter vigorous criticism.*
- *From time to time, major shifts occur in the scientific view of how the world works. More often, however, the changes that take place in the body of scientific knowledge are small modifications of prior knowledge. Change and continuity are features of science.*

Mathematical Applications (5.3.12) All students will integrate mathematics as a tool for problem-solving in science, and as a means of expressing and/or modeling scientific theories.

A. Numerical Operations

(5.3.12 A 1) Reinforce indicators from previous grade level*

Students will be able to:

- *Use common prefixes such as milli-, centi-, and kilo-.*
- *Convert within a measurement system (e.g., centimeters to meters).*
- *Use the correct number of significant figures.*
- *Solve simple algebraic expressions.*
- *Use ratio and proportion to solve problems.*

B. Geometry and Measurement

(5.3.12 B 1) When performing mathematical operations with measured quantities, express answers to reflect the degree of precision and accuracy of the input data.

Students will be able to:

- *Measure with accuracy and precision (e.g., length, volume, mass, temperature, time).*
- *Reflect the degree of precision and accuracy of the measurements when performing mathematical operations with measured quantities.*
- *Determine percent error from experimental and accepted values.*
- *Use appropriate metric/standard international (SI) units of measurement for mass (kg); length (m); and time (s).*
- *Use the appropriate temperature scale (Celsius (^{o}C) or Kelvin (K)).*

C. Patterns and Algebra

(5.3.12 C 1) Apply mathematical models that describe physical phenomena to predict real world events.

Students should understand that:

- *Symbolic statements can be manipulated by rules of mathematical logic to produce other statements, of the same relationship, which may show some interesting aspect more clearly.*
- *Any mathematical model, graphic, or algebraic, is limited in how well it can represent the real world works. The usefulness of a mathematical model for predicting may be limited by uncertainties in measurements, by neglect of some important influence, or by requiring too much computation.*
- *Often it is easy to find a mathematical model that fits a phenomena over a small range of conditions (such as temperature or time), but it may not fit well over a wider range.*

D. Data Analysis and Probability

(5.3.12 D 1) Construct and interpret graphs of data to represent inverse and non-linear relationships, and statistical distributions.

<u>Students will understand that:</u>

- *Both percentages and actual counts have to be taken into account in comparing different groups using wither category by itself could be misleading.*
- *The middle of a data distribution may be misleading – when the data are not distributed symmetrically, or when there are extreme high or low values, or when the distribution is not reasonably smooth.*

<u>Students will be able to:</u>

- *Construct and use tables and graphs to interpret data sets.*
- *Use appropriate technology to construct and interpret graphs of data to represent inverse and non-linear relationships, and statistical distributions.*
- *Use appropriate technology to perform basic statistical procedures to analyze the center and spread of data.*

Nature and Process of Technology (5.4.12) All students will understand the interrelationships between science and technology and develop a conceptual understanding of the nature and process of technology.

A. Science and Technology

(5.4.12 A 1) Know that scientific inquiry is driven by the desire to understand the natural world and seeks to answer questions that may or may not directly influence humans, while technology is driven by the need to meet human needs and solve human problems.

Students should understand that:

- *Scientific inquiry is driven by the desire to understand the natural world and seeks to answer questions that may or may not directly influence humans.*
- *Technology is driven by the need to meet human needs and solve human problems*
- *Biotechnology is used in a variety of areas (e.g., agriculture, pharmaceuticals, food and beverage, fuels and energy, the environment, genetic engineering) and requires specific scientific knowledge about the natural system being modified.*

B. Nature of Technology

(5.4.12 B 1) Assess the impacts of introducing a new technology in terms of alternative solutions, costs, tradeoffs, risks, benefits and environmental impact.

Students should understand that:

- *Alternatives, risks, costs, and benefits must be considered when deciding on proposals to introduce new technologies or to curtail existing ones (e.g., Are there alternative ways to achieve the same ends? Who benefits and who suffers? What are the financial and social costs and who bears them? How serious are the risks and who is in jeopardy? What resources will be needed and where will they come from?).*

C. Technological Design

(5.4.12 C 1) Plan, develop, and implement a proposal to solve an authentic, technological problem.

Students should understand that:

- *A design involves different design factors (e.g., ergonomics, maintenance and repair, environmental concerns).*
- *A design involves design principles (e.g., flexibility, proportion, function).*
- *Since there is no such thing as a perfect design, trade-offs of one criterion for another must occur to find an optimized solution.*
- *The scientific principles of energy, work, and power are integral to technological design (e.g., the Second Law of Thermodynamics means that a system cannot be designed which is 100% efficient).*
- *An optimal solution to a design problem is more likely to be found when the process followed is systematic and repetitive.*

Characteristics of Life (5.5.12) All students will gain an understanding of structure, characteristics, and basic needs of organisms and will investigate the diversity of life.

A. Matter, Energy, and Organization in Living Systems

Enduring Understanding: The cell is the basic unit of life. Living cells are composed of elements that form large, complex molecules. The primary source of energy to sustain most life is derived from a conversion of light energy to chemical energy through the process of photosynthesis.

(5.5.12 A 1) Relate the structure of molecules to their function in cellular structure and metabolism.

Areas of Focus	Explanatory Bullets, Examples, and Comments
o All organisms are composed of cells, ranging from just one cell to many cells. About two-thirds of the weight of cells is accounted for by water, which gives cells many of their properties. o In multicellular organisms, specialized cells perform specialized functions. Organs and organ systems are composed of cells and function to serve the needs of cells for food, air, and waste removal. The way in which cells function is similar in all living organisms. o Many functions needed to sustain life are carried out by cells. They grow and divide, thereby producing more cells. Food is used to provide energy for the work that cells do and is also a source of the molecular building blocks from which needed materials are assembled. o Living systems are made of complex molecules (including carbohydrates, fats, proteins, and nucleic acids) that consist mostly of a few elements, especially carbon, hydrogen, oxygen, nitrogen, and phosphorous. o Cellular processes are carried out by many different types of molecules, mostly proteins. The function of each protein molecule depends on its specific sequence of amino acids and the shape of the molecule.	• Water is the single most abundant compound in living things. • The levels of organization in multicellular organisms are individual cells, tissues, organs, and organ systems. • Carbohydrates, like sugars and starches, are composed of carbon, hydrogen, and oxygen. • Lipids are used to store energy but some are important parts of biological membranes, and waterproof coverings. • Proteins contain nitrogen as well as carbon, hydrogen, and oxygen and are used as a structural component of life. • Enzymes are specialized proteins that may control the rate of reactions and regulate cellular activities.

(5.5.12 A 2) Explain how plants convert light energy to chemical energy.	
Areas of Focus	**Explanatory Bullets, Examples, and Comments**
o Plants have the capability through photosynthesis to take energy from light, using carbon dioxide and water to form sugar molecules and oxygen. These sugar molecules can be used to make amino acids and other carbon-containing (organic) molecules and assembled into larger molecules with biological activity (including proteins, DNA, carbohydrates, and fats).	• Plants and some microorganisms containing chloroplasts are able to use light energy from the sun to produce food. • In addition to water and carbon dioxide, photosynthesis requires light and chlorophyll, a molecule found in the chloroplast. The process of photosynthesis includes both the light dependent and light independent reactions.

(5.5.12 A 3) Describe how plants (*and other organisms*) produce substances high in energy content that become the primary source of energy for life.	
Areas of Focus	**Explanatory Bullets, Examples, and Comments**
o The chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. o At each link in an ecosystem, some energy is stored in newly made structures, but much is dissipated into the environment as heat. Continual input of energy from sunlight keeps the process going. Matter and energy are conserved in each change.	• Each step in a food web is called a trophic level. Producers make up the first level. Consumers make up the second, third, or high levels. • An ecological pyramid is a diagram that shows the relative amounts of energy or matter contained within each trophic level. • Only about 10 percent of the energy available within one trophic level is transferred to the organism at the next highest trophic level.

(5.5.12 A 4) Relate disease in humans and other organisms to infections or intrinsic failures of system.	
Areas of Focus	**Explanatory Bullets, Examples, and Comments**
o Mutated genes can cause body parts or systems to work poorly. o Pathogens enter the human body and multiply to create infection. o Some viral diseases destroy critical cells of the immune system, leaving the body unable to deal with multiple infection agents and cancerous cells. o Advances in technology give today's human beings a better chance of staying healthier than their ancestors.	• Changes in DNA (mutations) can occur spontaneously at low rates. Inserting, deleting or substituting DNA segments can alter genes. • An altered gene may be passed on to every cell that develops from it. The resulting change may help, harm, or have little effect on an offspring's success in its environment. • Bacteria are pathogens that produce disease in one or two general ways. Some bacteria damage cells by breaking down the cells for food, while others release toxins (poisons) that travel throughout the body interfering with normal biological activities. • Like bacteria, viruses produce disease by disrupting the body's normal equilibrium. • Antibiotics are compounds that kill bacteria without harming human cells. Antibiotics have no effect on viruses. • Antiviral drugs have been developed to fight certain viral diseases. These drugs inhibit the ability of viruses to invade and multiply inside living cells.

Biologically Speaking

active site, aerobic, anaerobic, autotroph, carbohydrate, cellular respiration, cell theory, chlorophyll, cohesion, dehydration synthesis, deletion, diffusion, enzyme, energy pyramid, equilibrium, heterotroph, hypertonic, hypotonic, indicator, lipid, lock and key, osmosis, pH, photosynthesis, protein, solute, solvent, substrate.

NOTE: *Biologically Speaking* is a list of terms that students and teachers should integrate into their normal daily conversations around science topics. These are **not** vocabulary lists for students to memorize.

B. Diversity and Biological Evolution

Enduring Understanding: Evolution provides the central scientific understanding of the history of the modern living world. Evolutionary processes allow some species to survive through long term Earth changes, while leading to extinction of others. Organisms that inherit characteristics advantageous for survival in their physical environment reproduce and increase the proportion of individuals with similar traits in the species.

(5.5.12 B 1) Explain that through evolution the Earth's present species developed from earlier distinctly different species.	
Areas of Focus	**Explanatory Bullets, Examples, and Comments**
o Scientists consider a variety of evidence in order to classify organisms into three domains and six kingdoms. o Molecular evidence substantiates the anatomical evidence for evolution and provides additional detail about the sequence in which various lines of descent branched. o Modern ideas about evolution (natural selection and common descent) provide a scientific explanation for the history of life on Earth.	• As biologists learned more about the natural world, they realized that a two kingdom (*Plantae* and *Animalia*) classification system did not adequately represent the full diversity of life. • Scientists placed microorganisms and bacteria into their own kingdom, which was named *Protista*. Mushrooms, yeasts, and molds were separated from the *Plantae* and placed into the Kingdom *Fungi*. Finally, the bacteria were placed into the Kingdom *Monera*, due to the absence of an organized nucleus. • The six-kingdom system of classification includes the kingdoms *Eubacteria*, *Archaebacteria*, *Protista*, *Fungi*, *Plantae and Animalia*. • Early systems of classification grouped organisms together based on visible characteristics. • Organisms are now grouped into categories that represent lines of evolutionary decent, or phylogeny. • Similarities in DNA can be used to help determine classification and evolutionary relationship.

(5.5.12 B 2) Explain how the theory of natural selection accounts for extinction as well as an increase in the proportion of individuals with advantageous characteristics within a species.	
Areas of Focus	**Explanatory Bullets, Examples, and Comments**
o Evolution is the consequence of the interactions of (1) the potential for a species to increase its numbers; (2) the genetic variability of offspring due to mutation and recombination of genes; (3) a finite supply of the resources required for life; and (4) the ensuing selection from environmental pressure of those organisms better able to survive and leave offspring.	• Early investigations helped to recognize Earth to be many billions of years old, and that the processes that had changed Earth in the past are the same processes that operate in the present. • The basic theory of theoretical biological evolution is that Earth's present day species developed from earlier, distinctly different species. • Natural selection and its evolutionary consequences provide scientific explanation for the fossil record of ancient forms, as well as the striking molecular similarities observed among diverse species of living things. • Over time, natural selection results in changes in the inherited characteristics of a population. These changes increase a species' fitness in its environment. • The fossil record and the structural and embryological similarities between species, provide evidence that supports the theory of evolution. • Biologists realize that there are two main sources of genetic variation: mutations and the recombination that results from sexual reproduction. • Species are reproductively distinct groups of organisms as a result of being geographically isolated. **Sample Test Item:** Brussels sprouts, cabbage, and cauliflower are all variations of the same species of mustard plant. If they are allowed to crossbreed, they will eventually produce similar looking offspring. What processes created these different variations in the first place? A. sexual selection B. natural selection C. DNA transplants D. selective breeding*

Biologically Speaking
adaptation, adaptive radiation, analogous, convergent evolution, derived characteristic, divergent evolution, domain, evolution, extinction, fossil record, homologous, kingdom, natural selection, phylogeny, punctuated equilibrium, recombination, species, taxon, taxonomy.

C. Reproduction and Heredity

Enduring Understandings:

Information passed from parent to offspring is coded in deoxyribonucleic acid (DNA) molecules. The molecular structure of the DNA molecule is consistent in all living things and similar in members of a species; variance in the sequence of DNA bases in an organism gives it unique characteristics. The information in DNA provides instructions for assembling protein molecules in cells.

There are predictable patterns of inheritance. Asexual reproduction produces offspring that have the same genetic code as the parent and leads to less variation in a species.

Sexual reproduction produces offspring with a mixture of DNA increasing the genetic variation of an organism, and therefore, the species.

(5.5.12 C 1) Describe how information is encoded and transmitted in genetic material.	
Areas of Focus	**Explanatory Bullets, Examples, and Comments**
o Hereditary information is contained in genes, located in the chromosomes of most cells. A human cell contains many thousands of different genes. One or many genes can determine an inherited trait of an individual, and a single gene can influence more than one trait.	• Scientific discoveries identified DNA as the nucleic acid that stores and transmits genetic information from one generation of an organism to another. • Each strand in a DNA ladder is made up of a chain of nucleotides. • The two strands in the DNA ladder are held together by hydrogen bonds between the nitrogen bases adenine and thymine and guanine and cytosine. • During replication, a DNA molecule separates into two strands, and then produces two complimentary strands following the rules of base pairing.

(5.5.12 C 2) Explain how genetic material can be altered by natural and/or artificial means; mutations and new gene combinations may have positive, negative, or no effect on organisms or species.	
Areas of Focus	**Explanatory Bullets, Examples, and Comments**
o Genes are segments of DNA molecules. Inserting, deleting, or substituting DNA segments can alter genes. An altered gene may be passed on to every cell that develops from it. o Sorting and recombination of genes in sexual reproduction results in a great variety of possible gene combinations from the offspring of any two parents. o The passing of traits from one generation to the next follows predictable patterns of inheritance. The patterns can be analyzed through the use of statistical models.	• Changes in DNA (mutations) can occur spontaneously at low rate. Changes that result from mutations may help, harm, or have little effect on an offspring's success in its environment. • In sexually reproducing organisms, only mutations in germ cells (egg and sperm) can be passed on to an organism's offspring. • Most heritable differences are due to gene shuffling that occurs during the production of gametes. • Cross-over that occurs during meiosis further increases the number of different genotypes that can appear in an offspring. • A Punnett square is a diagram used to predict which traits an offspring will have based on the traits found in its parents. • The principle of dominance states that some genes are dominant and some are recessive. • Recessive traits from one parent may be hidden for one or more generations and then appear in future generations. • Some alleles are neither dominant nor recessive. • Codominance is a condition in which two alleles contribute to the phenotype (i.e. I^A I^B). **Sample Test Item:** **The Genetics of Cat Fur** **Trait** – **Inheritance** short hair – dominant long hair – recessive If a long haired cat is mated to a pure-bred short haired cat, what will be the expected appearance of their offspring? A. 100% short-haired* B. 75% short-haired; 25% long-haired C. 50% short-haired; 50% long-haired D. 25% short-haired; 75% long-haired

The Genetics of Cat Fur

Trait	Inheritance
short hair	dominant
long hair	recessive

(5.5.12 C 3) Assess the impact of current and emerging technologies on our understanding of inherited human characteristics.	
Areas of Focus	**Explanatory Bullets, Examples, and Comments**
o Biotechnology allows for the screening and possible treatment of genetic disorders. o Biotechnology allows for determining the degree of relatedness among individuals.	• Our understanding of genetics has led to the improved varieties of plants, animals, and medicines through the application of technology. • New varieties of cultivated plants and domesticated animals have resulted from selected breeding for particular traits. • Genetic engineering has permitted the introduction of deliberate mutations, which may be maintained as new varieties. • The Human Genome Project is an ongoing effort to analyze the human DNA sequence. • Information about the human genome might be used to cure genetic disorders by gene therapy. The technique may replace an absent or faulty gene. • Analyzing DNA sequences may reveal the degree of relatedness among individuals.

Biologically Speaking:

allele, chromatid, cross-over, dihybrid, diploid, F_1 cross, F_2 cross, genotype, haploid, heterozygous, homozygous, incomplete dominance, karyotype, nitrogen base, nucleotide, pedigree, phenotype, replication, recombinant, tetrad, test-cross, transcription, translation

Environmental Studies (5.10.12) All students will develop an understanding of the environment as a system of interdependent components affected by human activity and natural phenomena.

A. Natural Systems and Interactions

Enduring Understanding: Living systems interact with naturally occurring processes in the physical environment. Human intervention can affect the balance of natural cycles within the environment. Scientific data must be considered in the analysis of human decisions which would impact these cycles and alter the living world.

(5.10.12 A1) Distinguish naturally occurring process from those believed to have been modified by human interaction or activity.

- Climate change
- Ozone production
- Erosion and deposition
- Threatened and endangered species

Areas of Focus	Explanatory Bullets, Examples, and Comments
o Human activities and decisions can lead to species becoming threatened or endangered.	• Carbon dioxide, methane, and water vapor trap heat energy and maintain Earth's temperature range. The natural situation in which heat is retained by this layer is called the greenhouse effect. • Conservation efforts focus on protecting entire ecosystems as well as single species. Protecting an ecosystem will ensure that the natural habitats and the interaction of many different species are preserved at the same time.

B. Human Interactions and Impact

(5.10.12 B 1) Assess the impact of human activities on the cycling of matter and the flow of energy through ecosystems.	
Areas of Focus	**Explanatory Bullets, Examples, and Comments**
o Although the interrelationships and interdependence of organisms may generate biological communities in ecosystems that are stable for hundreds or thousands of years, ecosystems may change when climate changes or when one or more new species appear as a result of migration or local evolution.	• The environment is a system of interdependent components. • Human activities impact the cycling of matter and the flow of energy through an ecosystem. • Human activities can reduce biodiversity by altering habitats, hunting species to extinction, and introducing toxic compounds into food webs. • Human activities can affect the quality and the supply of renewable resources such as land, forests, fisheries, air and fresh water. • Humans attempt to maintain balance within an ecosystem through protection, conservation, and the preservation of natural resources. • Sound scientific methods are essential in determining the degree of environmental impact caused by humans.

(5.10.12 B 2) Use scientific, economic, and other data to assess environmental risks and benefits associated with societal activity.	
Areas of Focus	**Explanatory Bullets, Examples, and Comments**
• All organisms cause changes in the environment where they live. Some of these changes are detrimental to the organisms or other organisms, whereas others are beneficial.	• Researchers are gathering data to monitor and evaluate the effects of human activities. • Two areas of interest include the ozone layer and the global climate system. • Researchers are urging people to make wise choices in the use and conservation of resources. ***Sample Test Item:*** *An ecologist obtains a water sample from a possibly polluted river. Which form of pollution could be searched for by examining slides of the water under a compound light microscope?* *A. bacteria** *B. acid rain* *C. heavy metals* *D. dissolved riverbank minerals*

Biologically Speaking:
abiotic, acid rain, biome, biotic, competition, consumer, ecosystem, food web, global warming, habitat, ozone layer, population, producer, succession, water cycle.

Appendix A: Exemplar Lesson: Fossils [1]

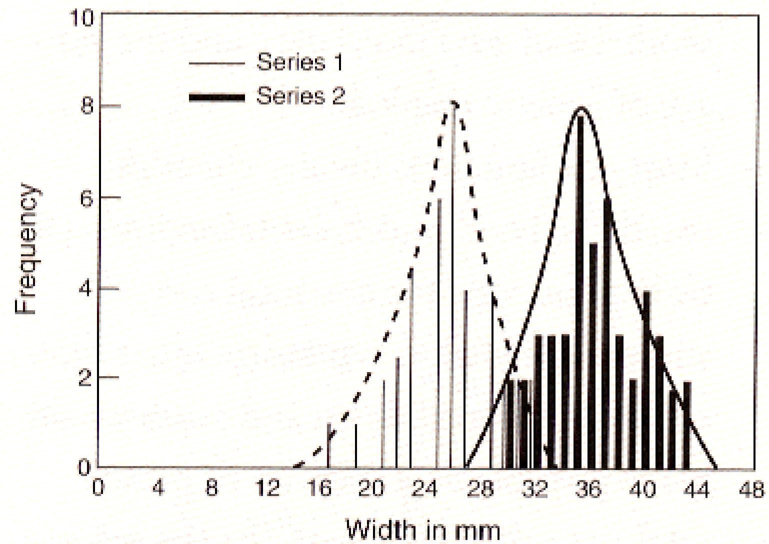
The investigation in this example centers on the use of fossils to develop concepts about variation of characteristics in a population, evolution--including indicators of past environments and changes in those environments, the role of climate in biological adaptation, and use of geological data. High-school students generally exhibit interest in fossils and what the fossils indicate about organisms and their habitats. Fossils can be purchased from scientific supply houses, as well as collected locally in some places. In the investigation described here, the students conduct an inquiry to answer an apparently simple question: Do two slightly different fossils represent an evolutionary trend? In doing the activity, students rely on prior knowledge from life science. They use mathematical knowledge and skill. The focus of the discussion is to explain organized data.

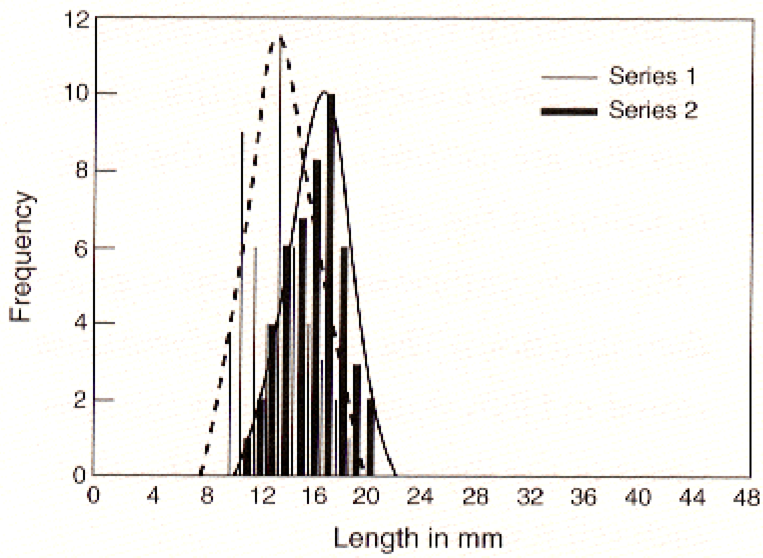
The investigation begins with a task that students originally perceive as easy--describing the characteristics of two brachiopods to see if change has occurred. The student inquiries begin when the teacher, Mr. D., gives each student two similar but slightly different fossils and asks the students if they think an evolutionary trend can be discerned. The openness and ambiguity of the question results in mixed responses. Mr. D. asks for a justification of each answer and gently challenges the students' responses by posing questions such as: "How do you know? How could you support your answer? What evidence would you need? What if these fossils were from the same rock formation? How do you know that the differences are not normal variations in this species? What if the two fossils were from rock formations deposited 10 millions years apart? Can you tell if evolution has or has not occurred by examining only two samples?"

Mr. D. shows students two trays, each with about 100 carefully selected fossil brachio-pods. He asks the students to describe the fossils. After they have had time to examine the fossils, he hears descriptions such as "They look like butterflies," and "They are kind of triangular with a big middle section and ribs." Then he asks if there are any differences between the fossils in the two trays. The students quickly conclude that they cannot really tell any differences based on the general description, so Mr. D. asks how they could tell if the fossil populations were different. From the ensuing discussion, students determine that quantitative description of specific characteristics, such as length, width, and number of ribs are most helpful.

Mr. D. places the students in groups of four and presents them with two trays of brachiopods. They are told to measure, record, and graph some characteristics of the brachiopod populations. The students decide what they want to measure and how to do it. They work for a class period measuring and entering their data on length and width of the brachiopods in the populations in a computer database. When all data are entered, summarized, and graphed, the class results resemble those displayed in the figure.

[1] Example from National Science Education Standards (pp. 182-183)





The students begin examining the graphs showing frequency distribution of the length and width of fossils. As the figure indicates, the results for either dimension show a continuous variation for the two populations. Students observe that regardless of the dimension measured, the mean for the two populations differs.

After the graphs are drawn, Mr. D. asks the students to explain the differences in the populations. The students suggest several general explanations: evolution has not occurred--these are simply different kinds of brachiopods; evolution has occurred--the differences in the means for length and width demonstrate evolutionary change in the populations; evolution has not occurred--the differences are a result of normal variations in the populations.

Mr. D. takes time to provide some background information that the students should consider. He notes that evolution occurs in populations, and changes in a population's environment result in selection for those organisms best fit for the new environment. He continues with a few questions that again challenge the students' thinking: Did the geological evidence indicate the environment changed? How can you be sure that the fossils were not from different environments and deposited within a scale of time that would not explain the degree of evolutionary change? Why would natural selection for differences in length and width of brachiopods occur? What differences in structure and function are represented in the length and width of brachiopods?

The students must use the evidence from their investigations and other reviews of scientific literature to develop scientific explanations for the aforementioned general explanations. They take the next class period to complete this assignment.

After a day's work by the students on background research and preparation, Mr. D. holds a small conference at which the students' papers are presented and discussed. He focuses students on their ability to ask skeptical questions, evaluate the use of evidence, assess the understanding of geological and biological concepts, and review aspects of scientific inquiries. During the discussions, students are directed to address the following questions: What evidence would you look for that might indicate these brachiopods were the same or different species? What constitutes the same or different species? Were the rocks in which the fossils were deposited formed at the same or different times? How similar or different were the environments of deposition of the rocks? What is the effect of sample size on reliability of conclusions?

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