Annenberg/CPB
Professional Development Course Guide

Essential Science for Teachers

Life Science

An eight-part professional development course for K–6 science teachers

Produced by the Harvard-Smithsonian Center for Astrophysics

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About the Course

Course Overview

From aardvarks to zebras, the living world provides diverse opportunities for learning in the natural sciences. Children are wonderful observers of their surroundings and are fascinated by even the most common living things. This is especially true when they are encouraged to look at life in ways that scientists do, to ask their own questions, and to shape their own answers.

The challenge is making sure that their understandings are scientifically accurate. To do this requires teachers to have their own sound understandings of core science concepts. ***Essential Science for Teachers: Life Science*** is a content course designed to help K–6 teachers enhance their understandings of "big ideas" in the life sciences. The main goal of this course is to provide teachers with learning opportunities that will directly inform their own classroom practice.

Essential Science for Teachers: Life Science is one in a series of three video-, print-, and Web-based science courses for elementary school teachers. These courses will help teachers better understand the science concepts that underlie the content they teach. Other courses include *Earth and Space Science* and *Physical Science*.

Life Science is composed of eight three-hour sessions, each with a one-hour video program addressing a topic area in the life sciences that is likely to be part of any elementary school science curriculum. Posing the question "What is life?," the course begins by defining life and by considering how life forms are classified. Animal and plant life cycles then become the focus for investigating the continuity of life. Next, diversity within the living world provides the context for exploring the basics of biological evolution. Finally, large-scale biological processes are introduced by looking at how energy and matter enter and move through the living world. Video examples, colorful graphics, lively animations, demonstrations, models, and other visual strategies are used as learning tools to bring meaning to the content being addressed.

Life Science also focuses on the ideas that children bring to the classroom about these topics. Each video program features content segments intertwined with interviews of children that uncover their ideas about the relevant concepts. The video content is supplemented in print and Web materials by a bibliography that suggests readings from the research literature. Each program also highlights an elementary school classroom where a teacher and her students explore the topic using exemplary curriculum materials. A curriculum spokesperson is interviewed to provide insight into the importance of the topic at the elementary school level. Finally, connections are made to the natural world through interviews with one or more scientists who apply relevant concepts to real examples.

By exploring topics that range from the molecules of life to the complexities of an entire ecosystem, *Life Science* strives to provide participants not only with enhanced content understandings, but also with understandings of how this content connects to the elementary school classroom.

Session Descriptions

Session 1. What Is Life?

What distinguishes living things from dead and nonliving things? No single characteristic is enough to define what is meant by "life." In this session, five characteristics are introduced as unifying themes in the living world.

Session 2. Classifying Living Things

How can we make sense of the living world? During this session, a systematic approach to biological classification is introduced as a starting point for understanding the nature of the remarkable diversity of life on Earth.

About the Course, cont'd.

Session 3. Animal Life Cycles

One characteristic of all life forms is a life cycle—from reproduction in one generation to reproduction in the next. This session introduces life cycles by focusing on continuity of life in the animal kingdom. In addition to considering what aspects of life cycles can be observed directly, the underlying role of DNA as the hereditary material is explored.

Session 4. Plant Life Cycles

What is a plant? One distinguishing feature of members of the plant kingdom is their life cycle. In this session, flowering plants serve as examples for studying the plant life cycle by considering the roles of seeds, flowers, and fruits. A comparison to animal life cycles reveals some surprising similarities and intriguing differences.

Session 5. Variation, Adaptation, and Natural Selection

What causes variation within a population of living things? How can variation in one generation influence the next generation? In this session, variation in a population will be examined as the "raw material" upon which natural selection acts.

Session 6. Evolution and the Tree of Life

Why are there so many different kinds of living things? Comparing species that exist today reveals a lot about their relationships to one another and provides evidence of common origins. This session explores the theory of evolution: change in species over time.

Session 7. Energy Flow in Communities

Communities are populations of organisms that live and interact together. The structure of a community is defined by food web interactions. The process of energy flow is the focus of this session as the interactions between producers, consumers, and decomposers are examined.

Session 8. Material Cycles in Ecosystems

Studying an ecosystem involves looking at interactions between living things as well as the nonliving environment that surrounds them. Life depends upon the nonliving world for habitat, as well as energy and materials. In this session, material cycles will be explored as critical processes that sustain life in an ecosystem.

About the Course, cont'd.

Featured Classrooms

Session 1. Louis Marshall Elementary School (P.S. 276), Brooklyn, New York

LauraJo Kelly's second graders explore the characteristics of organisms that are "living," "dead," and "never living." The class then uses their working definitions to define a mystery material, the "green stuff."

Session 2. Oliver Wendell Holmes Elementary School, Dorchester, Massachusetts

Stephanie Selznick's first-grade class compares and contrasts the features of various plants and animals as a way of arriving at the five basic needs of both plants and animals.

Session 3. Glennon Heights Elementary School, Lakewood, Colorado

Mary Bitterlich's third graders model the life cycle of a beetle on paper plates, before placing their plates side by side to illustrate successive generations of a beetle population.

Session 4. Glennon Heights Elementary School, Lakewood, Colorado

Sally Flokiewicz has her third graders predict the next step in the life cycle of a flowering plant. The students draw their predictions and mount them on poster board.

Session 5. William Diamond Middle School, Lexington, Massachusetts

Kathleen Vandiver introduces her sixth-grade class to the concept of sample size by having them measure and graph the heights of their Fast Plants. The class then compares the average height of all the plants versus the average of a smaller sample size.

Session 6. Alice B. Beal Elementary School, Springfield, Massachusetts

Gail Modugno's fifth-grade class compares and contrasts different animal skeletons. The class looks at the features of the skeletons and tries to predict what kind of animals they belonged to and what habitats those animals lived in.

Session 7. Glade Elementary School, Walkersville, Maryland

Melissa Minnick's fifth-grade class labels the organisms in their terrariums as "producers," "decomposers," or "consumers," before each student is asked to write his or her own definition of each term.

Session 8. Fox Hill Elementary School, Burlington, Massachusetts

MaryAnn Bernstein's third graders talk about what they already know about decomposers before working on two activities designed to highlight the decomposer's role in a food web.

Course Components

On-Site Activities

Essential Science for Teachers: Life Science consists of eight sessions[1], each of which includes group activities and discussions as well as an hour-long video program.

Weekly sessions, which should be scheduled for approximately three hours, may be scheduled around live broadcasts, in which case you will want to begin at least 60 minutes before the scheduled broadcast. You may prefer to pre-record the programs on videocassette and schedule the sessions at a time that is more convenient for all participants and that would allow you to stop and restart the video as you discuss it.

This guide provides activities and discussion topics for pre- and post-viewing investigations that complement each of the eight one-hour video programs.

Getting Ready (Site Investigation)

In preparation for watching the program, you will engage in 60 minutes of investigation through discussion and activity.

Watch the Video

Then you will watch the 60-minute video, which includes classroom footage, commentary, science demonstrations, and more.

Going Further (Site Investigation)

Wrap up the session with an additional 60 minutes of investigation through discussion and activity.

Between Sessions

Homework Assignments

Each session will contain the following homework activities. All participants should complete the assignments marked with *—the Reading Assignment, the Problem Set, the Ongoing Concept Mapping, and Preparing for the Next Session. Participants taking the course for graduate credit must complete all of the listed assignments, including those described in the Graduate Course Requirements section.

Note: Required Hours for Graduate Credit: If you are taking this course for graduate credit, the complete set of homework activities has been designed to fulfill the additional three hours required per session. The time taken to complete each assignment will vary among individuals, so no time estimates have been given. Each assignment will result in some form of evidence of learning. This evidence may be useful in building a portfolio for course assessment purposes.

Reading Assignment*

The reading assignment will help you to draw connections between the session topics and research on children's ideas. The readings in this course have originated from research done by the Leeds National Curriculum Science Support Project. Each session will highlight part of this larger body of research and will also include a group discussion related to the reading. The readings can be found in the Appendix.

[1] See the Graduate Course Requirements section for suggestions for scheduling the eight programs into an intensive 15-week course.

Course Components, cont'd.

Life Science Problem Set*
Each session will be accompanied by a problem set that will reinforce content learning by asking questions that apply or extend life science concepts addressed in the video. Possible answers for the problem set will be provided at the end of the session materials. It should be emphasized that many questions have a variety of answers—answers that vary depending on the understandings of the person answering the question. The intent is not to give you "right answers," but to allow you to compare yours with more advanced learners in life science.

Ongoing Concept Mapping*
Within each session, several fundamental concepts are explored. Creating a set of concept maps will provide you with an opportunity to reflect on your understandings of these concepts and their connections to one another as well as to see how the content in each session relates to that of other sessions. A more detailed explanation of concept mapping is included in Session 1.

Guided Journal Entry
As you proceed through this course, one way of building and connecting understandings is to reflect upon your learning as you go. In each session, one or more questions will be suggested to guide a journal entry. At the end of the course, these entries should help you see how your ideas have progressed.

Guided Channel-TalkLife Posting
Although this is a course designed to help enhance your understandings of life science concepts, the intention is for you to use this knowledge to inform your teaching. Often, a community of learners who are also teachers can collaborate to support one another in transforming content knowledge into successful classroom action. In each session, one or more questions will be suggested to guide a discussion on the course discussion list, Channel-TalkLife, to facilitate this type of collaboration among participants. See directions for joining the discussion board below.

Textbook Reading Suggestions
We strongly recommend that you acquire a college-level biology text to refer to in this course. Reading topics will be listed in each session, and can be located in most textbooks in the Table of Contents or Index.

Preparing for the Next Session*
This section will get you thinking about upcoming topics and remind you to bring materials needed for the next session's activities.

Ongoing Activities
The following are activities that you should work on between sessions for the duration of the course:

Bottle Biology
Each video features a section titled Bottle Biology, which is a Web site-based activity that provides ongoing, hands-on opportunities to explore topics being addressed in each session. You can select and build any of four bottle systems and do suggested activities, track progress with our systems, and discuss your experiences with colleagues. Bottle Biology is also designed to be a useful resource in K–6 classrooms.

Course Web Site: www.learner.org/channel/courses/essential/life
Go online for additional activities—including the Bottle Biology project—plus resources and discussion through Channel-TalkLife (see below).

Channel-TalkLife
You can communicate with other course participants throughout the country on the course's email discussion list. To subscribe to Channel-TalkLife, visit http://www.learner.org/mailman/listinfo/channel-talklife.

Graduate Course Requirements

The *Essential Science for Teachers: Life Science* professional development course is designed to be a three-credit graduate-level course for teachers. For more information about how to obtain graduate credit, go to www.learner.org/channel/chnnl_workshops.html.

To be eligible for graduate credit, participants must complete the following projects in addition to all of the regular course activities and assignments. Homework assignments should take approximately three hours per week to complete.

Annotated Bibliography

Prepare an annotated bibliography of a minimum of 25 resources, which can include articles given as reading assignments. Readings can relate to life science content, conceptual change, constructivism, or inquiry teaching and learning. Each entry in the bibliography should include the bibliographical information on the resource, a summary of the content in the reading, and notes on ideas you find helpful or interesting.

Action Research Project

Action research is an effective method of professional development that seeks to improve teaching practices, expand a teacher's knowledge base, and improve the quality of student learning. Your action research project should address new understandings that developed through this course, and how they relate to your classroom practice. As part of your project, maintain a research diary that documents your experiences as you implement new practices in your classroom. Your diary might contain research data, explanatory comments, information on students gathered from classroom interactions or interviews, written reflections, ideas and insights, and/or recommendations for improving practice.

The second component of the project is a final paper, minimally 10 pages in length, double spaced, using a 10- or 12-point font, that summarizes your findings, reflects on the research process, outlines your professional development during your research, and makes recommendations for improving future practice. Additional readings to support your action research are recommended.

Refer to the Appendix for the Action Research Guide, which provides week-by-week directions for conducting your project as well as a list of recommended readings on the action research process.

Portfolio

Create a portfolio evidencing your work for the course. The portfolio might be divided into the following sections: action research diary and final paper; journal, which includes guided entries and reflective entries; annotated bibliography; and homework assignments. Additional sections may be added at your discretion.

Biology Text

It is *strongly* recommended that you acquire a college-level biology text. Suggested readings will be listed for life science topics being addressed in each session.

Graduate Course Requirements, cont'd.

Course Assessment

The successful participant will:

- Attend and actively participate in all class sessions
- Come prepared to class sessions, having completed all reading and homework assignments
- Assemble a course portfolio with all required components present
- Create journal entries that demonstrate an in-depth understanding of relevant concepts and processes, reflect on new learnings, and communicate ideas clearly
- Prepare an action research diary that exhibits well-organized thoughts and insightful interpretations and extensions
- Write an action research final paper that meets length and organization requirements and evidences growth in developing research skills
- Compile an annotated bibliography that contains a minimum of 25 resources with the required bibliographical information, summaries, and comments

Scheduling Course Sessions

Below are recommended options for scheduling credit and non-credit class meetings, based on how participants are viewing the video programs. Because of the amount and kinds of work associated with a graduate-level course, it is recommended that participation in the course for credit be over a 15-week period. “Work weeks” are scheduled to allow participants time to work on their assignments required for graduate credit.

Option One: Viewing the Programs Recorded on Tape or on Learner.org’s Video on Demand (VoD) (for Graduate Credit)	
Week 1	View Program 1 and complete assignments
Week 2	View Program 2 and complete assignments
Week 3	Work Week
Week 4	View Program 3 and complete assignments
Week 5	View Program 4 and complete assignments
Week 6	Work Week
Week 7	View Program 5 and complete assignments
Week 8	View Program 6 and complete assignments
Week 9	Work Week
Week 10	View Program 7 and complete assignments
Week 11	View Program 8 and complete assignments
Weeks 12–15	Complete long-term coursework: assemble portfolio components, action research project and paper, and annotated bibliography

Option Two: Viewing the Programs Live in Real Time on the Annenberg/CPB Channel (for Graduate Credit)	
Week 1	View Program 1 and complete assignments
Week 2	View Program 2 and complete assignments
Week 3	View Program 3 and complete assignments
Week 4	View Program 4 and complete assignments
Week 5	View Program 5 and complete assignments
Week 6	View Program 6 and complete assignments
Week 7	View Program 7 and complete assignments
Week 8	View Program 8 and complete assignments
Weeks 9–15	Complete long-term coursework: assemble portfolio components, action research project and paper, and annotated bibliography

Scheduling Course Sessions, cont'd.

Option Three: **Viewing the Programs Recorded on Tape or Live in Real Time (Not for Graduate Credit)**	
Week 1	View Program 1 and complete assignments
Week 2	View Program 2 and complete assignments
Week 3	View Program 3 and complete assignments
Week 4	View Program 4 and complete assignments
Week 5	View Program 5 and complete assignments
Week 6	View Program 6 and complete assignments
Week 7	View Program 7 and complete assignments
Week 8	View Program 8 and complete assignments

About the Site Investigations

Helpful Hints

Included in the materials for each session you will find detailed instructions for the content of your Getting Ready and Going Further activities (Site Investigations). The following hints are intended to help you and your colleagues get the most out of these pre- and post-video discussions.

Designate a Facilitator

Each week, one person should be responsible for facilitating the Site Investigations (or you might select two people—one to facilitate Getting Ready, the other to facilitate Going Further). We recommend that participants rotate the role of facilitator on a weekly basis.

Review the Site Investigations and Bring the Necessary Materials

Be sure to read over the Getting Ready and Going Further sections of your materials before arriving at each session. The Site Investigations will be the most productive if you and your colleagues come to the sessions prepared for the discussions. A few of the Site Investigations require materials (see Individual Session Materials on the following pages). The facilitator should be responsible for bringing these when necessary.

Keep an Eye on the Time

Sixty minutes go by very quickly, and it is easy to lose track of the time. You should keep an eye on the clock so that you are able to get through everything before the course video begins. (Sites that are watching the course on videotape will have more flexibility if their Site Investigation runs longer than expected.)

Record Your Discussions

We recommend that someone take notes during each site discussion, or, even better, that you make an audiotape recording of the discussions each week. These notes and/or audiotape can serve as make-up materials in case anyone misses a session.

About the Site Investigations, cont'd.

Share Your Discussions on the Internet

The Site Investigations are merely a starting point. We encourage you to continue your discussions with participants from other sites on Channel-TalkLife, the course email discussion list.

Materials

Facilitators should bring the listed materials to the course sessions.

General Materials

During each session, different activities may require various supplies for writing, displaying, and conducting activities. These may be provided at your location, or you may wish to bring a set of supplies for the course.

- Writing/drawing paper (8.5 X 11)
- Newsprint paper (18 X 24)
- Kraft paper (rolls)
- Chalk or dry-erase markers
- Colored pencils, markers, or crayons
- Sticky notes, various colors
- String or yarn
- Scissors
- Paper towels
- Paper plates
- Cutting knives

Specialized Materials

Life Science is designed to require few specialized materials. The following is a list of items that are not required but may enhance session activities:

- Hand lenses
- Metric rulers
- Dissection microscope
- Compound microscope

Individual Session Materials

Session 1. What Is Life?

Pick one set of items and bring the items to Session 1. These items will be classified as living, dead, and non-living. Try to bring all the items on the list—substitute similar items only if necessary. You may also add to the list if you wish—you will need one item per pair of participants in this session.

Set A	Set B	Set C
Hamster or other animal	Goldfish or other fish	Snail or worm
Dead insect	Dried flowers	Skin or peel of a fruit
Spoon	Stuffed animal	Rock
Seashell	Pinecone	Feather
Egg	Seeds	Quartz or other crystal
Sand	Salt or sugar grains	Dried peas
Potato	Ear of corn	Alfalfa sprouts
Package of yeast	Moldy piece of bread	Mushroom
Bottle cork	Dirt	Piece of paper

About the Site Investigations, cont'd.

Session 2. Classifying Living Things

- Specimens of living things (to supplement the group's collection)

At this session, participants will be bringing in collections of specimens that represent a variety of different life forms. The specimens may be living things, whole or parts of dead things, or nonliving representations (e.g., pictures, models, etc.). It may be helpful for you to supplement the collection to try to make it as diverse as possible. Here are some suggestions: microbes (photos, models, specimens on glass slides, in pond water or soil, etc.), molds, mushrooms, algae, mosses, ferns, sponges, corals, worms, insects, spiders, snails, clams, sea stars, sea urchins, fish, amphibians, reptiles, birds, mammals, etc.).

You will be saving this collection for future use—with the exception of living things that need special care. At the end of Session 2, participants will select from the animals in the collection as part of For "Getting Ready" for Session 3.

Session 3. Animal Life Cycles

- Specimen collection

Session 3 explores animal life cycles by starting with some of the animal specimens from the group's collection. At the end of the session, collect the specimens and return them to the collection for future use. Also, save the group's life cycle pattern diagram for the next session.

Also at the end of the session, allow participants to choose at least one flowering plant from the collection. You will do this in the For "Getting Ready" section of Session 4. You may wish to supplement the collection with a variety of flowering plants if there aren't many already available.

Session 4. Plant Life Cycles

- Specimen collection
- Animal life cycle pattern diagram (generated by the group in Session 3)
- Large lima bean seeds soaked overnight in water (1 per participant)
- A variety of other seeds soaked overnight (1 per pair)
- Different types of large, showy flowers (2 per pair)
- Different types of fruit (2 per pair)
- Cutting knives (1 per pair)
- Toothpicks (1 per participant)

Session 4 explores plant life cycles by starting with specimens of flowers from the group's collection. At the end of the session, collect the specimens and return them to the collection for future use.

The materials listed above will be part of activities that involve investigating how seeds, flowers, and fruit play a role in the life cycle of a typical plant—a flowering plant. Try to obtain a variety of seeds, flowers, and fruits so that comparisons can be made.

Session 5. Variation, Adaptation, and Natural Selection

- Specimen collection

For Session 5, participants will be bringing in three to five examples of one type of plant or animal specimen. At the end of the session, collect the specimens and return them to the collection for future use.

For Session 6, participants will be choosing a vertebrate animal for the purposes of doing activities. They may choose from the specimen collection if they wish.

About the Site Investigations, cont'd.

Session 6. Evolution and the Tree of Life

- Specimen collection
- String

For Session 7, participants will be making a community poster using pictures or drawings of the different populations of organisms each considers important to a community. They may choose from the specimen collection if they wish.

Session 7. Energy Flow in Communities

No materials need to be brought by the facilitator. Collect the community posters from the group after this session.

Session 8. Material Cycles in Ecosystems

- Community posters from Session 7
- Track Your Understanding answers from Session 1

About the Contributors

Course Developer

Sue Mattson, Ph.D.

Dr. Sue Mattson received a B.A. in biology from the University of California at Berkeley, followed by a master's in biology and Ph.D. in science education from Florida State University. Dr. Mattson's dissertation focused on the dynamics involved as biologists and science educators worked together to develop a biology course for prospective elementary teachers. In addition to teaching biology at the high school, community college, and university levels, her experiences include curriculum development in the sciences and professional development for teachers. Dr. Mattson has taught science methods courses for early childhood and elementary education majors and served as an instructor in a Web site-based distance learning course for practicing elementary teachers seeking master's or specialist's degrees in science and/or math education. She has worked previously with the Harvard-Smithsonian Center for Astrophysics in the following series: *Case Studies in Science Education, The Next Move: Steps Toward Change in Elementary Math and Science,* and *Looking at Learning…Again, Part I.*

Onscreen Guides

Eleanor Abrams, Ph.D. Dr. Eleanor Abrams is an associate professor at the University of New Hampshire. She is a member of the Department of Education and the interdisciplinary Natural Resources doctoral program. She earned her B.S. in wildlife biology and botany and her doctoral degree in science education from Louisiana State University (1994). Her research focuses on how students learn content and the scientific process through project-based and technology-enriched curricula. Dr. Abrams has developed environmental curriculum where students work, often with scientists, on authentic research projects. One such project is the GLOBE program (Global Learning and Observation to Benefit the Environment) where K–12 students monitor the environmental health of their local area and send the results to other schools and scientists via the World Wide Web.

Linda Grisham, Ph.D. Dr. Linda Grisham received a B.A. in biochemistry from the University of Chicago, followed by a Ph.D. in pharmacology from Stanford University. She has a deep commitment to science and math teacher preparation, particularly for those who teach in underserved communities. She has worked over the years as a research scientist (University of California, Santa Barbara and Brandeis University), science educator, curriculum developer, financial planner, community activist, and radio commentator. Now at Lesley University in Cambridge, Massachusetts, she has a joint appointment in the School of Undergraduate Studies, Natural Science Program and the School of Education and teaches undergraduate and graduate level courses (physics, chemistry, modeling complex systems, pharmacology, and science education). Current projects include the co-creation/implementation of a fully online master's degree program, Science in Education Program for K–8 teachers with TERC, Inc., a science- and math-focused think tank. She is also a founding member of the Institute for African-American E-Culture.

Paul Williams, Ph.D. Dr. Paul Williams has been a professor in the Department of Plant Pathology at the University of Wisconsin–Madison since 1962. He attended the University of British Columbia as an undergraduate and received his Ph.D. from the University of Wisconsin–Madison. Through his research addressing the diseases of cabbages in the state of Wisconsin was born the idea of developing a rapid cycling plant (Fast Plants) as a model for research with a wide range of biological and educational applications. He received a Guggenheim Fellowship in 1978, was made a Fellow of the American Phytopathological Society in 1979 and served as its president in 1989, and received the Eriksson Gold Medal of the Royal Swedish Academy of Science in 1981. He served as director of the Center for Biology Education on the Madison campus from 1989–1995 and was named Atwood Distinguished Professor in the College of Agricultural and Life Sciences at the University of Wisconsin–Madison in 1995. He became a Fellow of the American Association for the Advancement of Science in 1996 and received an honorary D.Sc. from the University of British Columbia in 2001.

About the Contributors, cont'd.

Douglas Zook, Ph.D. Dr. Douglas Zook is an associate professor of science education and biology at Boston University. He also directs the Master of Arts in Teaching program in science education. He is the co-founder and director of the Microcosmos Professional Development Program for Science Teachers and serves as president of the International Symbiosis Society. Dr. Zook received his Ph.D. from Clark University and did extensive post-doctoral symbiosis research at the University of Tuebingen as a Fulbright Scholar. Dr. Zook teaches a science methods course for students who intend to become biology instructors. He also currently teaches a graduate symbiosis course and an undergraduate global ecology course.

Curriculum Developers

Sessions 1 and 7

Herbert D. Thier, Ed.D., SCIS 3+, Lawrence Hall of Science Dr. Herbert D. Thier is currently an academic administrator emeritus at the Lawrence Hall of Science, University of California, Berkeley. Dr. Thier received his B.A. in physics and biology from the State University of New York, Albany in 1953 and his M.A. in school administration in1954. He received his Ed.D. in curriculum and administration from New York University in 1962. Since 1963, he has been leading instructional materials development and teacher enhancement projects in science at the Lawrence Hall of Science. In 1975, he received (with M. Linn), the JRST Research in Science Teaching Award of the National Association for Research in Science Teaching. Dr. Thier received the Distinguished Service to Science Education Award of the National Science Teachers Association in 1994 and the Distinguished Service to Science Education Award of the Connecticut Science Supervisors Association in 1996.

Session 2

Sally Goetz Shuler, Science and Technology for Children, National Science Resource Center Sally Goetz Shuler is the executive director of the National Science Resources Center (NSRC), which is sponsored by the Smithsonian Institution and The National Academies. The mission of the NSRC is to improve the teaching and learning of science in the nation's schools. In addition to managing the NSRC's professional development and outreach activities, Ms. Shuler oversees the development, dissemination, and evaluation of curriculum and other teaching tools for students, including the NSRC's comprehensive science curriculum programs for K–8 students, Science and Technology (STC) and Science and Technology Concepts for Middle School Students (STC/MS). Ms. Shuler has over three decades of experience working to improve K–12 science education at the local, national, and international levels. At the classroom level, she has 10 years of experience as a high school biology, Earth science, and mathematics teacher in both private and public schools. She has also been a science instructor for adult education in Fairfax County, Virginia. At the district level, she served for five years as the K–12 science resource specialist for the Fairfax County Public Schools, the nation's 10th largest school district. Ms. Shuler has an M.S. in environmental health sciences from George Washington University, and a B.A. from Edinboro State University, with majors in biology and geology.

Session 3

Dr. Rodger Bybee, Science T.R.A.C.S. (Teaching Relevant Activities for Concepts and Skills), Biological Sciences Curriculum Study (BSCS) Dr. Rodger W. Bybee is executive director of the Biological Sciences Curriculum Study (BSCS), a non-profit organization in Colorado Springs, Colorado that develops curriculum materials, provides professional development for the science-education community, and conducts research and evaluation on curriculum reform. Prior to joining BSCS, he was executive director of the National Research Council's Center for Science, Mathematics, and Engineering Education (CSMEE), in Washington, D.C. Between 1992 and 1995, he was associate director of BSCS. From 1972 to 1985, he was professor of education at Carleton College in Northfield, Minnesota. He has been active in education for more than 30 years, having taught science at the elementary, secondary, and college levels.

Session 4

Nancy M. Landes, Ph.D., Science T.R.A.C.S., Biological Sciences Curriculum Study Dr. Nancy M. Landes currently serves as the director of the BSCS Center for Professional Development. She began her professional career as a classroom teacher, grades 4 and 5, and completed a master of arts in curriculum and instruction and a Ph.D. in science education at Michigan State University. She joined BSCS in 1983. Since joining, Dr. Landes has served as the project director of two major curriculum development projects—Science for Life and Living: Integrating Science, Technology, and Health and BSCS Science T.R.A.C.S., both in elementary science

About the Contributors, cont'd.

education. In her role as the director of the Center for Professional Development at BSCS, Dr. Landes is the co-principal investigator of the SCI Center, an NSF-funded high school implementation and dissemination center. She has worked with NSTA to develop inquiry-based professional development materials and strategies within NSTA's Building a Presence for Science program. Dr. Landes is particularly interested in helping teachers make the connections between curriculum implementation, professional development, and student learning and in establishing the conditions that make possible the successful implementation of meaningful instructional materials and strategies in science classrooms.

Session 5

Paul Williams, Ph.D., Exploring With Wisconsin Fast Plants, University of Wisconsin Listed above.

Session 6

Karen Worth, Insights, Education Development Center, Inc. Karen Worth has extensive experience in early childhood and elementary science education. She worked as a curriculum and staff developer for both the Elementary Science Study (ESS) and the African Primary Science Program at the Education Development Center in the 1960s. More recently, she was the principal investigator for the development of the Insights Curriculum. She also was principal investigator for a system-wide science education reform effort in Cleveland, Ohio and works as a consultant and advisor to many urban systemic reform efforts across the country. She chaired the Working Group on Science Teaching Standards for the National Science Education Standards effort of the National Academy of Science and is currently co-principal investigator of the NSF-funded K–12 Science Curriculum Dissemination Center at EDC and the Toolkit for Early Childhood Science Education. She has also been a member of the Wheelock College faculty for over 30 years where she teaches early childhood and elementary education courses at the graduate level. She began her career in education as a teacher of young children in New York City and Boston and continues to work closely with teachers and children in classrooms.

Session 8

Tina A. Grotzer, Ed.D., The Understandings of Consequence Project, Project Zero

Dr. Tina A. Grotzer is a research associate at Project Zero at the Harvard Graduate School of Education. Her research focuses on topics at the intersection of cognition, development, and educational practice, such as the learnability of intelligence and how children develop causal models for complex science concepts. She works with students and teachers in several school systems on an ongoing basis, linking theory and practice such that they inform one another. She has studied cognitive development both as a teacher and as a researcher. Tina is co-principal investigator on the Understandings of Consequence Project, funded by the National Science Foundation (NSF). The project identified ways in which student explanations of scientific concepts have different forms of causality at the core than those of scientists. Dr. Grotzer and her colleagues have developed a set of curriculum modules designed to teach the causal forms implicit in the scientific explanations. She received her Ed.D. in 1993 and Ed.M. in 1985 from Harvard University and her A.B. in developmental psychology from Vassar College in 1981.

Scientists

Session 1

Gary Ruvkun, Ph.D. Dr. Gary Ruvkun has been a professor of genetics at the Harvard Medical School since 1985. Dr. Ruvkun received his Ph.D. in biophysics from Harvard University in 1982. His major research interests include neuroendocrine control of metabolism and aging, temporal patterning during development, regulatory RNAs, genomics, neuroendocrine regulation of molting, regulation of fat deposition, microbial diversity, and life on Mars. Over his career, Dr. Ruvkun has authored or co-authored over 90 scientific papers and has maintained a lab and active teaching schedule at the Harvard Medical School. He has received myriad honors for his work including, most recently, the 2001 National Institute of Health Merit Award.

Session 2

Colleen M. Cavanaugh, Ph.D. Dr. Colleen M. Cavanaugh is the Edward C. Jeffrey Professor of Biology in the Department of Organismic and Evolutionary Biology at Harvard University. She received both an M.A. and Ph.D. from Harvard University in 1981 and 1985, respectively. Dr. Cavanaugh's continuing research interests include prokaryote-eukaryote symbiosis, including its physiology, biochemistry, ecology, evolution, the co-evolution of host and symbiont, and the physiology, molecular biology, ecology, and evolution of autotrophs and methanotrophs, as well as microbial cycling of inorganic and organic compounds. In addition to her teaching responsibilities at Harvard, Dr. Cavanaugh is a visiting investigator at the Woods Hole Oceanographic Institution, and has 10 deep-sea research cruises worldwide and 12 deep-sea dives on the submersible Alvin to her credit. She is the author or co-author of approximately 50 peer-reviewed scientific papers.

Session 3

Sigal Klipstein, Ph.D. Dr. Sigal Klipstein is a fellow in the Department of Obstetrics, Gynecology, and Reproductive Biology at the Beth Israel Deaconess Medical Center in Boston. She has received two fellowships, one in medical ethics at Harvard Medical School, and the other in Reproductive Endocrinology and Infertility at Boston IVF and the Beth Israel Deaconess Medical Center. Dr. Klipstein has lectured in both gynecology and medical ethics at the Harvard Medical School, and has authored or co-authored over 10 original articles. She is a member of the New England Fertility Society, the American Society of Reproductive Medicine, and the Society of Reproductive Endocrinology and Infertility.

Session 4

Judith Sumner, Ph.D. Dr. Judith Sumner is a botanist who specializes in flowering plants, specifically their evolution, morphology, anatomy, and adaptations. She has taught extensively both at the college level and at botanical gardens. She served as education director at Garden in the Woods (New England Wild Flower Society) until she accepted her present position at Assumption College in Worcester, where she is a member of the natural sciences faculty. Dr. Sumner has published monographic studies in the *American Journal of Botany, Pollen et Spores,* and *Allertonia.* She monographed two families for recently published volumes of *Flora Vitiensis Nova*. Her first book, *The Natural History of Medicinal Plants,* was published in October 2000; her second, *Domestic Botany: The Natural History of Household Plants,* is due out in 2004.

Dan Scheirer, Ph.D. Dr. Dan Scheirer is an associate professor of biology and also directs the Electron Microscopy and Imaging Center at Northeastern. A plant biologist, Dr. Scheirer's research has focused on studying patterns of plant cell development with diverse plants ranging from algae and mosses to flowering plants, including the plant model organism, *Arabidopsis thaliana*. Dr. Scheirer is also a forensic botanist, and applies plant cell and molecular biology to the resolution of legal questions. A passionate teacher and classroom innovator, Dr. Scheirer teaches an introductory biology course as well as higher-level courses in plant biology, plant development, and electron microscopy. He has authored more than 50 scientific publications as well as essays for college texts and student study guides.

Dan Cousins Dan Cousins is the head grower at Wilson Farms in Lexington, Massachusetts, where he oversees the operation of a one-acre, fully computerized and automated greenhouse. He earned his B.S. in Botany at the University of Texas. After graduating, he worked for five years in Texas as a commercial grower before being hired to serve as a grower at Cornell University. While at Cornell, he also taught a course on interior plantscaping.

Session 5

Georgia Dunston, Ph.D. Dr. Georgia Dunston is professor and chair of the Department of Microbiology at Howard University College of Medicine, and founding director of the newly formed National Human Genome Center (NHGC) at Howard University. Her research on human genome variation in disease susceptibility has been the vanguard of current efforts at Howard University to build national and international research collaborations focusing on the genetics of diseases common in African Americans and other African Diaspora populations. Dr. Dunston is program director of the coordinating center for the Africa America Diabetes Mellitus Study, an international collaboration to study the genetics of type 2 diabetes in ancestral populations of African Americans, and the coordinating center for the African American Hereditary Prostate Cancer Study Network, a national cooperative formed to map and characterize genes for prostate cancer in African Americans. The NHGC is instrumental in bringing multicultural perspectives and resources to an understanding of knowledge gained from the Human Genome Project and research on human genome variation.

Robert Murray, Ph.D. Dr. Robert Murray serves as professor of pediatrics and medicine and chief of the Division of Medical Genetics in the Department of Pediatrics and Child Health in the College of Medicine at Howard Medical School. In addition, he is graduate professor and chairman of the Graduate Department of Genetics and Human Genetics which offers both M.S. and Ph.D. through the Graduate School of Arts and Sciences, also at Howard University. He has authored or co-authored more than 80 publications including four books; most recently, *The Human Genome Project and the Future of Health Care*. Dr. Murray is a fellow of the American Association for the Advancement of Science, a fellow and member of the board of directors of the Hastings Center, a fellow of the Institute of Medicine, National Academy of Sciences, and a former member of its governing council. He has been a member of the Mammalian Genetics Study Section of the Division of Research Grants, NIH, the National Advisory General Medical Sciences Council of NIGMS, NIH, and the Bioethics Advisory Committee to the Secretary of DHEW 1979–1981. He is a member of the American Board of Internal Medicine and the American Board of Medical Genetics.

Session 6

James Hanken, Ph.D. Dr. James Hanken is the director of Harvard University's Museum of Comparative Zoology, where he also serves as the curator of Herpatology. Additionally, he serves as Alexander Agassiz Professor of Zoology in the Department of Organismic and Evolutionary Biology. Dr. Hanken earned his Ph.D. at Berkeley and then worked on the faculty of Colorado State University for 16 years before coming to Harvard in 1999. His research interests include evolutionary biology, especially development, morphology, and systematics, and he works principally with amphibians. Dr. Hanken oversees research efforts in Sri Lanka, Africa, and South America, and is currently engaged in his own fieldwork in Central America, where he is interested in describing new species of salamander. In addition to his work as a biologist, Dr. Hanken as received awards for his nature and scientific photography.

Douglas Causey, Ph.D. Dr. Douglas Causey is senior biologist at the Museum of Comparative Zoology, Harvard University, and serves as the chief ornithologist in the museum. He has authored more than 120 articles and books on natural history, biodiversity, and ornithology, and is actively engaged in research and public education. His research is focused on the co-evolution and natural history of avian viruses, tropical biodiversity, and environmental security and sustainability. He has active research programs in the United States, throughout the Arctic, and Central and South America. At present, he is undertaking a broad-scale survey of birds and avian disease pathogens along migration pathways ranging from Arctic Siberia and Alaska to both coasts of Costa Rica. He has been working for the past decade on various issues relating to national and international environmental policy, and has published several recent articles on environmental security and the conservation of forests and biodiversity.

Session 7

Aaron M. Ellison, Ph.D. Dr. Aaron M. Ellison is senior research fellow in organismic and evolutionary biology at the Harvard Forest, and adjunct professor in the graduate program in organismic and evolutionary biology at the University of Massachusetts at Amherst. He received a B.A. in 1982 from Yale University, and a Ph.D. from Brown University in 1986. In 1992, during his tenure as the Marjorie Fisher Professor of Environmental Studies at Mount Holyoke College, Dr. Ellison received the National Science Foundation's Presidential Faculty Fellow award for "demonstrated excellence and continued promise both in scientific and engineering research and in teaching future generations of students to extend and apply human knowledge." His research foci include: food web dynamics, community ecology of wetlands and forests, evolutionary ecology of carnivorous plants, and the application of Bayesian inference to ecological research and environmental decision-making.

Marianne Farrington, Ph.D. Dr. Marianne Farrington is the associate director of the Edgerton Research Laboratory at the New England Aquarium in Boston, Massachusetts. Dr. Farrington earned a Ph.D. in Biochemistry at Pennsylvania State University in 1987, before going on to Northeastern University to complete her post-doctorate work. In 1991, she joined the New England Aquarium's Edgerton Research Laboratory. She began a course of work that led to the analysis of juvenile groundfish bycatch survival in Northwest Atlantic Fisheries. While at the Aquarium, Dr. Farrington also taught human genetics, biochemistry, molecular biology of the cell, as well as introductory biology courses through Northeastern University's division for returning adults, University College.

Sanat Majumder, Ph.D. Dr. Sanat Majumder is a professor emeritus of biology, at Westfield State College. While active, Dr. Majumder taught a variety of courses, including environmental biology; population, food, and nutrition; and plant physiology. In addition to teaching at Westfield State College, Dr. Majumder taught at Smith College and St. Louis University. As a post-doctoral fellow, Dr. Majumder's research in radiation biology took him to Brookhaven National Laboratory and the University of Hawaii in Honolulu. Dr. Majumder has published a book, *The Drama of Man and Nature,* as well as nearly 30 scientific papers. A native of India, Dr. Majumder currently resides in Northampton, Massachusetts.

About the Contributors, cont'd.

Les Kaufman, Ph.D. Dr. Les Kaufman is an associate professor of biology at Boston University. He also is a fellow at the Harvard University Museum of Comparative Zoology and a research scholar at the New England Aquarium. Dr. Kaufman earned his Ph.D. at John Hopkins in theoretical ecology and evolutionary biology in 1980. His research is in evolutionary ecology and applied research in marine conservation biology, where his focus is on various fish ecologies. In 1997, Dr. Kaufman started a research and graduate training effort to encourage a switch from classical fisheries to ecosystem-based marine resource management. The project is active in New England, East Africa, Florida, California, and the tropical Pacific and Atlantic Oceans, and is also engaged with the New England Fishery Management Council and the California Department of Fish and Game.

Session 8

Adrien Finzi, Ph.D. Dr. Adrien Finzi is an assistant professor in Boston University biology department. Dr. Finzi earned his Ph.D. in 1996 at the University of Connecticut. His research interests include forest ecology, terrestrial biogeochemistry, and global change biology. Currently, his focus is in terrestrial biogeochemistry and global change biology. Specifically, he is investigating the effect of free-air CO2 enrichment on carbon-storage and nutrient cycling in a southern pine-hardwood forest. Dr. Finzi is author or co-author on more than 10 scientific papers.

Charles Tyler In 1989, Charles Tyler started work at the Professional Services Group, Inc. as an operations specialist on the Boston Harbor Project (BHP), where he contributed to operational planning and operational review and input to the conceptual and detailed design of the 1.27 billion-gallon-per-day wastewater facility on Deer Island. After working for over five years with the construction management firm on the BHP, he "jumped the fence" and joined the Massachusetts Water Resources Authority as a project manager in the process group, a group of specialists who focused on punchlisting and construction turnover, and start-up of the newly constructed facilities on Deer Island. Mr. Tyler, who began his career in wastewater operations in 1977, now works on operations and maintenance with technical and process issues in Deer Island's effort to keep the huge facility operating optimally.

Nicky Sheats, Ph.D. Dr. Nicky Sheats received his Ph.D. in the Department of Earth and Planetary Sciences at Harvard University in 2000, where his field of study was biological oceanography with a focus in stable isotope biogeochemistry. His doctoral dissertation focused on determining if sewage nitrogen was being incorporated into the food webs of the Delaware River Estuary and Massachusetts Bay. Currently Dr. Sheats is researching urban air pollution as a post-doctoral fellow at the Earth Institute at Columbia University.

Instructional Materials Appearing in the Course

SCIS 3+
Science Curriculum Improvement Study
Lawrence Hall of Science

SCIS 3+ consists of 13 units and spans from kindergarten through sixth grade.

The concepts developed in each unit of SCIS 3+ are elaborated upon throughout the program. Students acquire a strong background for building scientific literacy that enables them to make intelligent decisions about their environment and the world in which they live.

Completely activity-based, the SCIS 3+ approach is based upon current research as to how children learn. The original program, SCIS, integrated the learning theories of Jean Piaget. Using the Learning Cycle strategy, students are led to discover concepts through their investigations with a wide variety of manipulative materials and live organisms.

SCIS 3+ is a revision of the work of the Science Curriculum Improvement Study, which was developed at the Physics Department and the Lawrence Hall of Science of the University of California at Berkeley with the support of the National Science Foundation. Development of SCIS 3+ was supported and copyrighted by Delta Education. For more information, contact:

Delta Education, Inc.
phone: 1-800-258-1302
http://www.delta-education.com/teachers/science/scis.html

Science and Technology for Children (STC) Curriculum
National Science Resources Center

Science and Technology for Children is an innovative, hands-on science program for children in grades one through six developed by the National Science Resources Center (NSRC). The 24 units of the STC program are designed to provide students with stimulating experiences in the life, Earth, and physical sciences and technology while simultaneously developing their critical-thinking and problem-solving skills.

The STC units provide children with the opportunity to learn age-appropriate concepts and skills and to acquire scientific attitudes and habits of mind. In the primary grades, children begin their study of science by observing, measuring, and identifying properties. Then they move on through a progression of experiences that culminate in grade six with the design of controlled experiments. For more information, contact:

Carolina Biological Supply Company
1-800-334-5551
http://www.carolina.com/

BSCS Science T.R.A.C.S.
Biological Sciences Curriculum Study

BSCS's Science T.R.A.C.S. (Teaching Relevant Activities for Concepts and Skills) engages young learners in science and technology through active, inquiry-oriented experiences guided by the National Science Education Standards and the Benchmarks for Science Literacy.

Through investigations into the weather, the Sun, the Moon, the stars, plants and animals, electrical systems, ecosystems, and much more, students not only develop an awareness of the world around them, but also an understanding of how that world works. Students also learn to work together as reliable members of a scientific team—a great way to make sure everybody in the group is involved and successful.

With BSCS Science T.R.A.C.S., students are partners with their teachers in the assessment process. Within each lesson, students check their own understanding individually or with their team. For more information, contact:

Kendall/Hunt Publishing
1-800-542-6657
http://www.kendallhunt.com/

Exploring With Wisconsin Fast Plants
University of Wisconsin

Exploring With Wisconsin Fast Plants is a resource manual targeted for middle school and elementary teachers, but widely used as a source of ideas for high school and college levels. Exploring With Wisconsin Fast Plants includes complete growing information and dozens of classroom activities. Nine sections assist teachers in aligning with American Association for the Advancement of Science Benchmarks and National Research Council National Standards for Science. For more information, contact:

Kendall/Hunt Publishing Company
1-800-542-6657
http://www.kendallhunt.com/

Instructional Materials Appearing in the Course, cont'd.

Insights
Education Development Center, Inc.

Insights is an elementary hands-on inquiry science program designed to develop children's understanding of key concepts and to improve students' abilities to think creatively and critically. Insights also encourages problem solving and integrates science with the rest of the curriculum.

The Insights curriculum is made up of 17 modules, each of which contains 12 to 20 "learning experiences" (hands-on, inquiry activities) in which teachers guide students as they explore new concepts. Throughout the modules, six major science themes are represented: systems, change, structure and function, diversity, cause and effect, and energy.

Originally funded by a grant from the National Science Foundation, the Insights program was developed by science education specialists at Education Development Center, Inc. For more information, contact:

Kendall/Hunt Publishing Company
1-800-542-6657
http://www.kendallhunt.com/

The Understandings of Consequence Project
Project Zero

The Understandings of Consequence Project, part of Project Zero at the Harvard Graduate School of Education, aims to help students learn difficult science concepts by engaging them in how scientists think about the underlying causality. Students have limited knowledge of the nature of causality so they often distort information that they are learning to fit with a simpler causal model. With funding from the National Science Foundation, the project has developed a series of curriculum modules that present ways of thinking about cause and effect that students need to master in order to develop deep understandings of scientific concepts. Each unit identifies the difficulties that students tend to have in that topic and offers activities to address the difficulties. For more information, contact:

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Understandings of Consequence Project
Project Zero, Harvard Graduate School of Education
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http://pzweb.harvard.edu/ucp/

(Note: The Understandings of Consequence Project was developed with funding from the National Science Foundation (Grant No. REC-9725502 and REC-0106988). All opinions, findings, conclusions or recommendations expressed therein are those of the authors and do not necessarily reflect the views of the National Science Foundation.)

Standards

National Science Education Standards

National Research Council (NRC)

http://bob.nap.edu/readingroom/books/nses/html

Life Science Content Standards: K–4

http://bob.nap.edu/readingroom/books/nses/html/6c.html

The Characteristics of Organisms

- Organisms have basic needs. For example, animals need air, water, and food; plants require air, water, nutrients, and light. Organisms can survive only in environments in which their needs can be met. The world has many different environments, and distinct environments support the life of different types of organisms.
- Each plant or animal has different structures that serve different functions in growth, survival, and reproduction. For example, humans have distinct body structures for walking, holding, seeing, and talking.
- The behavior of individual organisms is influenced by internal cues (such as hunger) and by external cues (such as a change in the environment). Humans and other organisms have senses that help them detect internal and external cues.

Life Cycles of Organisms

- Plants and animals have life cycles that include being born, developing into adults, reproducing, and eventually dying. The details of this life cycle are different for different organisms.
- Plants and animals closely resemble their parents.
- Many characteristics of an organism are inherited from the parents of the organism, but other characteristics result from an individual's interactions with the environment. Inherited characteristics include the color of flowers and the number of limbs of an animal. Other features, such as the ability to ride a bicycle, are learned through interactions with the environment and cannot be passed on to the next generation.

Organisms and Their Environments

- All animals depend on plants. Some animals eat plants for food. Other animals eat animals that eat the plants.
- An organism's patterns of behavior are related to the nature of that organism's environment, including the kinds and numbers of other organisms present, the availability of food and resources, and the physical characteristics of the environment. When the environment changes, some plants and animals survive and reproduce, and others die or move to new locations.

Life Science Content Standards: 5–8

http://bob.nap.edu/readingroom/books/nses/html/6d.html

Structure and Function in Living Organisms

- Living systems at all levels of organization demonstrate the complementary nature of structure and function. Important levels of organization for structure and function include cells, organs, tissues, organ systems, whole organisms, and ecosystems.
- All organisms are composed of cells—the fundamental unit of life. Most organisms are single cells; other organisms, including humans, are multicellular.
- Cells carry on the many functions needed to sustain life. They grow and divide, thereby producing more cells. This requires that they take in nutrients, which they use to provide energy for the work that cells do and to make the materials that a cell or an organism needs.

Standards, cont'd.

- Specialized cells perform specialized functions in multicellular organisms. Groups of specialized cells cooperate to form a tissue, such as a muscle. Different tissues are in turn grouped together to form larger functional units, called organs. Each type of cell, tissue, and organ has a distinct structure and set of functions that serve the organism as a whole.

Reproduction and Heredity

- Reproduction is a characteristic of all living systems; because no individual organism lives forever, reproduction is essential to the continuation of every species. Some organisms reproduce asexually. Other organisms reproduce sexually.
- In many species, including humans, females produce eggs and males produce sperm. Plants also reproduce sexually—the egg and sperm are produced in the flowers of flowering plants. An egg and sperm unite to begin development of a new individual. That new individual receives genetic information from its mother (via the egg) and its father (via the sperm). Sexually produced offspring never are identical to either of their parents.
- Every organism requires a set of instructions for specifying its traits. Heredity is the passage of these instructions from one generation to another.
- Hereditary information is contained in genes, located in the chromosomes of each cell. Each gene carries a single unit of information. An inherited trait of an individual can be determined by one or by many genes, and a single gene can influence more than one trait. A human cell contains many thousands of different genes.
- The characteristics of an organism can be described in terms of a combination of traits. Some traits are inherited and others result from interactions with the environment.

Regulation and Behavior

- All organisms must be able to obtain and use resources, grow, reproduce, and maintain stable internal conditions while living in a constantly changing external environment.

Populations and Ecosystems

- A population consists of all individuals of a species that occur together at a given place and time. All populations living together and the physical factors with which they interact compose an ecosystem.
- Populations of organisms can be categorized by the function they serve in an ecosystem. Plants and some micro-organisms are producers—they make their own food. All animals, including humans, are consumers, which obtain food by eating other organisms. Decomposers, primarily bacteria and fungi, are consumers that use waste materials and dead organisms for food. Food webs identify the relationships among producers, consumers, and decomposers in an ecosystem.
- For ecosystems, the major source of energy is sunlight. Energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis. That energy then passes from organism to organism in food webs.

Diversity and Adaptation of Organisms

- Millions of species of animals, plants, and microorganisms are alive today. Although different species might look dissimilar, the unity among organisms becomes apparent from an analysis of internal structures, the similarity of their chemical processes, and the evidence of common ancestry.
- Biological evolution accounts for the diversity of species developed through gradual processes over many generations. Species acquire many of their unique characteristics through biological adaptation, which involves the selection of naturally occurring variations in populations. Biological adaptations include changes in structures, behaviors, or physiology that enhance survival and reproductive success in a particular environment.

Standards, cont'd.

- Extinction of a species occurs when the environment changes and the adaptive characteristics of a species are insufficient to allow its survival. Fossils indicate that many organisms that lived long ago are extinct. Extinction of species is common; most of the species that have lived on the Earth no longer exist.

Life Science Content Standards: 9–12

http://bob.nap.edu/readingroom/books/nses/html/6e.html

The Cell

- Cells have particular structures that underlie their functions. Every cell is surrounded by a membrane that separates it from the outside world. Inside the cell is a concentrated mixture of thousands of different molecules that form a variety of specialized structures that carry out such cell functions as energy production, transport of molecules, waste disposal, synthesis of new molecules, and the storage of genetic material.
- Cells store and use information to guide their functions. The genetic information stored in DNA is used to direct the synthesis of the thousands of proteins that each cell requires.
- Plant cells contain chloroplasts, the site of photosynthesis. Plants and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy-rich organic compounds and release oxygen to the environment. This process of photosynthesis provides a vital connection between the Sun and the energy needs of living systems.
- Cells can differentiate, and complex multicellular organisms are formed as a highly organized arrangement of differentiated cells. In the development of these multicellular organisms, the progeny from a single cell form an embryo in which the cells multiply and differentiate to form the many specialized cells, tissues, and organs that comprise the final organism. This differentiation is regulated through the expression of different genes.

The Molecular Basis of Heredity

- In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA, a large polymer formed from subunits of four kinds (A, G, C, and T). The chemical and structural properties of DNA explain how the genetic information that underlies heredity is both encoded in genes (as a string of molecular "letters") and replicated (by a templating mechanism). Each DNA molecule in a cell forms a single chromosome.
- Most of the cells in a human contain two copies of each of 22 different chromosomes. In addition, there is a pair of chromosomes that determines sex: a female contains two X chromosomes and a male contains one X and one Y chromosome. Transmission of genetic information to offspring occurs through egg and sperm cells that contain only one representative from each chromosome pair. An egg and a sperm unite to form a new individual. The fact that the human body is formed from cells that contain two copies of each chromosome—and therefore two copies of each gene—explains many features of human heredity, such as how variations that are hidden in one generation can be expressed in the next.
- Changes in DNA (mutations) occur spontaneously at low rates. Some of these changes make no difference to the organism, whereas others can change cells and organisms. Only mutations in germ cells can create the variation that changes an organism's offspring.

Biological Evolution

- Species evolve over time. 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 by the environment of those offspring better able to survive and leave offspring.
- The great diversity of organisms is the result of more than 3.5 billion years of evolution that has filled every available niche with life forms.

Standards, cont'd.

- Natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms, as well as for the striking molecular similarities observed among the diverse species of living organisms.
- The millions of different species of plants, animals, and microorganisms that live on Earth today are related by descent from common ancestors.
- Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities which reflect their evolutionary relationships. Species is the most fundamental unit of classification.

The Interdependence of Organisms

- The atoms and molecules on the Earth cycle among the living and nonliving components of the biosphere.
- Energy flows through ecosystems in one direction, from photosynthetic organisms to herbivores to carnivores and decomposers.
- Organisms both cooperate and compete in ecosystems. The interrelationships and interdependencies of these organisms may generate ecosystems that are stable for hundreds or thousands of years.
- Human beings live within the world's ecosystems. Increasingly, humans modify ecosystems as a result of population growth, technology, and consumption. Human destruction of habitats through direct harvesting, pollution, atmospheric changes, and other factors is threatening current global stability, and if not addressed, ecosystems will be irreversibly affected.

Matter, Energy, and Organization in Living Systems

- All matter tends toward more disorganized states. Living systems require a continuous input of energy to maintain their chemical and physical organizations. With death, and the cessation of energy input, living systems rapidly disintegrate.
- The energy for life primarily derives from the Sun. Plants capture energy by absorbing light and using it to form strong (covalent) chemical bonds between the atoms of carbon-containing (organic) molecules. These molecules can be used to assemble larger molecules with biological activity (including proteins, DNA, sugars, and fats). In addition, the energy stored in bonds between the atoms (chemical energy) can be used as sources of energy for life processes.
- The complexity and organization of organisms accommodates the need for obtaining, transforming, transporting, releasing, and eliminating the matter and energy used to sustain the organism.

Benchmarks

Project 2061 Benchmarks

American Association for the Advancement of Science (AAAS)

The Living Environment

http://www.project2061.org/tools/benchol/ch5/ch5.htm

A. Diversity of Life

By the end of the second grade, students should know that:

- Some animals and plants are alike in the way they look and in the things they do, and others are very different from one another.
- Plants and animals have features that help them live in different environments.
- Stories sometimes give plants and animals attributes they really do not have.

By the end of the fifth grade, students should know that:

- A great variety of kinds of living things can be sorted into groups in many ways using various features to decide which things belong to which group.
- Features used for grouping depend on the purpose of the grouping.

By the end of the eighth grade, students should know that:

- One of the most general distinctions among organisms is between plants, which use sunlight to make their own food, and animals, which consume energy-rich foods. Some kinds of organisms, many of them microscopic, cannot be neatly classified as either plants or animals.
- Animals and plants have a great variety of body plans and internal structures that contribute to their being able to make or find food and reproduce.
- Similarities among organisms are found in internal anatomical features, which can be used to infer the degree of relatedness among organisms. In classifying organisms, biologists consider details of internal and external structures to be more important than behavior or general appearance.
- For sexually reproducing organisms, a species comprises all organisms that can mate with one another to produce fertile offspring.
- All organisms, including the human species, are part of and depend on two main interconnected global food webs. One includes microscopic ocean plants, the animals that feed on them, and finally the animals that feed on those animals. The other web includes land plants, the animals that feed on them, and so forth. The cycles continue indefinitely because organisms decompose after death to return food material to the environment.

By the end of the 12th grade, students should know that:

- The variation of organisms within a species increases the likelihood that at least some members of the species will survive under changed environmental conditions, and a great diversity of species increases the chance that at least some living things will survive in the face of large changes in the environment.
- The degree of kinship between organisms or species can be estimated from the similarity of their DNA sequences, which often closely matches their classification based on anatomical similarities.

B. Heredity

By the end of the second grade, students should know that:

- There is variation among individuals of one kind within a population.
- Offspring are very much, but not exactly, like their parents and like one another.

Benchmarks, cont'd.

By the end of the fifth grade, students should know that:

- Some likenesses between children and parents, such as eye color in human beings, or fruit or flower color in plants, are inherited. Other likenesses, such as people's table manners or carpentry skills, are learned.
- For offspring to resemble their parents, there must be a reliable way to transfer information from one generation to the next.

By the end of the eighth grade, students should know that:

- In some kinds of organisms, all the genes come from a single parent, whereas in organisms that have sexes, typically half of the genes come from each parent.
- In sexual reproduction, a single specialized cell from a female merges with a specialized cell from a male. As the fertilized egg, carrying genetic information from each parent, multiplies to form the complete organism with about a trillion cells, the same genetic information is copied in each cell.
- New varieties of cultivated plants and domestic animals have resulted from selective breeding for particular traits.

By the end of the 12th grade, students should know that:

- Some new gene combinations make little difference, some can produce organisms with new and perhaps enhanced capabilities, and some can be deleterious.
- The information passed from parents to offspring is coded in DNA molecules.
- 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. The resulting features may help, harm, or have little or no effect on the offspring's success in its environment.
- Gene mutations can be caused by such things as radiation and chemicals. When they occur in sex cells, the mutations can be passed on to offspring; if they occur in other cells, they can be passed on to descendant cells only. The experiences an organism has during its lifetime can affect its offspring only if the genes in its own sex cells are changed by the experience.
- The many body cells in an individual can be very different from one another, even though they are all descended from a single cell and thus have essentially identical genetic instructions. Different parts of the instructions are used in different types of cells, influenced by the cell's environment and past history.

C. Cells

By the end of the second grade, students should know that:

- Magnifiers help people see things they could not see without them.
- Most living things need water, food, and air.

By the end of the fifth grade, students should know that:

- Some living things consist of a single cell. Like familiar organisms, they need food, water, and air; a way to dispose of waste; and an environment they can live in.
- Microscopes make it possible to see that living things are made mostly of cells. Some organisms are made of a collection of similar cells that benefit from cooperating. Some organisms' cells vary greatly in appearance and perform very different roles in the organism.

By the end of the eighth grade, students should know that:

- All living things are composed of cells, from just one to many millions, whose details usually are visible only through a microscope. Different body tissues and organs are made up of different kinds of cells. The cells in similar tissues and organs in other animals are similar to those in human beings but differ somewhat from cells found in plants.
- Cells repeatedly divide to make more cells for growth and repair. Various organs and tissues function to serve the needs of cells for food, air, and waste removal.

Benchmarks, cont'd.

- Within cells, many of the basic functions of organisms—such as extracting energy from food and getting rid of waste—are carried out. The way in which cells function is similar in all living organisms.
- About two-thirds of the weight of cells is accounted for by water, which gives cells many of their properties.

By the end of the 12th grade, students should know that:

- Every cell is covered by a membrane that controls what can enter and leave the cell. In all but quite primitive cells, a complex network of proteins provides organization and shape and, for animal cells, movement.
- Within every cell are specialized parts for the transport of materials, energy transfer, protein building, waste disposal, information feedback, and even movement. In addition, most cells in multicellular organisms perform some special functions that others do not.
- The genetic information encoded in DNA molecules provides instructions for assembling protein molecules. The code used is virtually the same for all life forms. Before a cell divides, the instructions are duplicated so that each of the two new cells gets all the necessary information for carrying on.
- A living cell is composed of a small number of chemical elements mainly carbon, hydrogen, nitrogen, oxygen, phosphorous, and sulfur. Carbon atoms can easily bond to several other carbon atoms in chains and rings to form large and complex molecules.

D. Interdependence of Life

By the end of the second grade, students should know that:

- Animals eat plants or other animals for food and may also use plants (or even other animals) for shelter and nesting.
- Living things are found almost everywhere in the world. There are somewhat different kinds in different places.

By the end of the fifth grade, students should know that:

- For any particular environment, some kinds of plants and animals survive well, some survive less well, and some cannot survive at all.
- Insects and various other organisms depend on dead plant and animal material for food.
- Organisms interact with one another in various ways besides providing food. Many plants depend on animals for carrying their pollen to other plants or for dispersing their seeds.
- Changes in an organism's habitat are sometimes beneficial to it and sometimes harmful.

By the end of the eighth grade, students should know that:

- In all environments—freshwater, marine, forest, desert, grassland, mountain, and others—organisms with similar needs may compete with one another for resources, including food, space, water, air, and shelter. In any particular environment, the growth and survival of organisms depend on the physical conditions.
- Two types of organisms may interact with one another in several ways: They may be in a producer/consumer, predator/prey, or parasite/host relationship. Or one organism may scavenge or decompose another. Relationships may be competitive or mutually beneficial. Some species have become so adapted to each other that neither could survive without the other.

By the end of the 12th grade, students should know that:

- Human beings are part of the Earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems.

E. The Flow of Matter and Energy

By the end of the second grade, students should know that:

- Plants and animals both need to take in water, and animals need to take in food. In addition, plants need light.

- Many materials can be recycled and used again, sometimes in different forms.

By the end of the fifth grade, students should know that:

- Almost all kinds of animals' food can be traced back to plants.
- Some source of "energy" is needed for all organisms to stay alive and grow.
- Over the whole Earth, organisms are growing, dying, and decaying, and new organisms are being produced by the old ones.

By the end of the eighth grade, students should know that:

- Food provides molecules that serve as fuel and building material for all organisms. Plants use the energy in light to make sugars out of carbon dioxide and water. This food can be used immediately for fuel or materials or it may be stored for later use. Organisms that eat plants break down the plant structures to produce the materials and energy they need to survive. Then they are consumed by other organisms.
- Over a long time, matter is transferred from one organism to another repeatedly and between organisms and their physical environment. As in all material systems, the total amount of matter remains constant, even though its form and location change.
- Energy can change from one form to another in living things. Animals get energy from oxidizing their food, releasing some of its energy as heat. Almost all food energy comes originally from sunlight.

By the end of the 12th grade, students should know that:

- The amount of life any environment can support is limited by the available energy, water, oxygen, and minerals, and by the ability of ecosystems to recycle the residue of dead organic materials. Human activities and technology can change the flow and reduce the fertility of the land.
- The chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. At each link in a food web, 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.

F. Evolution of Life

By the end of the second grade, students should know that:

- Different plants and animals have external features that help them thrive in different kinds of places.
- Some kinds of organisms that once lived on Earth have completely disappeared, although they were something like others that are alive today.

By the end of the fifth grade, students should know that:

- Individuals of the same kind differ in their characteristics, and sometimes the differences give individuals an advantage in surviving and reproducing.
- Fossils can be compared to one another and to living organisms according to their similarities and differences. Some organisms that lived long ago are similar to existing organisms, but some are quite different.

By the end of the eighth grade, students should know that:

- Small differences between parents and offspring can accumulate (through selective breeding) in successive generations so that descendants are very different from their ancestors.
- Individual organisms with certain traits are more likely than others to survive and have offspring. Changes in environmental conditions can affect the survival of individual organisms and entire species.

Benchmarks, cont'd.

By the end of the 12th grade, students should know that:

- The basic idea of biological evolution is that the Earth's present-day species developed from earlier, distinctly different species.
- Molecular evidence substantiates the anatomical evidence for evolution and provides additional detail about the sequence in which various lines of descent branched off from one another.
- Natural selection provides the following mechanism for evolution: Some variation in heritable characteristics exists within every species, some of these characteristics give individuals an advantage over others in surviving and reproducing, and the advantaged offspring, in turn, are more likely than others to survive and reproduce. The proportion of individuals that have advantageous characteristics will increase.
- Heritable characteristics can be observed at molecular and whole-organism levels—in structure, chemistry, or behavior. These characteristics strongly influence what capabilities an organism will have and how it will react, and therefore influence how likely it is to survive and reproduce.
- New heritable characteristics can result from new combinations of existing genes or from mutations of genes in reproductive cells. Changes in other cells of an organism cannot be passed on to the next generation.
- Natural selection leads to organisms that are well suited for survival in particular environments. Chance alone can result in the persistence of some heritable characteristics having no survival or reproductive advantage or disadvantage for the organism. When an environment changes, the survival value of some inherited characteristics may change.
- The theory of natural selection provides a scientific explanation for the history of life on Earth as depicted in the fossil record and in the similarities evident within the diversity of existing organisms.
- Life on Earth is thought to have begun as simple, one-celled organisms about four billion years ago. During the first two billion years, only single-cell microorganisms existed, but once cells with nuclei developed about a billion years ago, increasingly complex multicellular organisms evolved.
- Evolution builds on what already exists, so the more variety there is, the more there can be in the future. But evolution does not necessitate long-term progress in some set direction. Evolutionary changes appear to be like the growth of a bush: Some branches survive from the beginning with little or no change, many die out altogether, and others branch repeatedly, sometimes giving rise to more complex organisms.