Cell Biology and Cancer

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in collaboration with the
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BSCS
A SCIENCE EDUCATION CURRICULUM STUDY

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Please contact NIH with questions about this supplement at *supplements@science.education.nih.gov*.

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Foreword

This curriculum supplement, from the National Institutes of Health (NIH) Curriculum Supplement Series, brings cutting-edge medical science and basic research discoveries from the laboratories of the NIH into classrooms. As the largest medical research institution in the United States, NIH plays a vital role in the health of all Americans and seeks to foster interest in research, science, and medicine-related careers for future generations. NIH's Office of Science Education (OSE) is dedicated to promoting science education and scientific literacy.

We designed this curriculum supplement to complement existing life science curricula at both the state and local levels and to be consistent with the *National Science Education Standards* (released by the National Academy of Sciences in 1996). It was developed and tested by a team of teachers, scientists, medical experts, and other professionals with relevant subject-area expertise from institutes and medical schools across the country, representatives from the National Cancer Institute, and curriculum design experts from Biological Sciences Curriculum Study (BSCS) and Videodiscovery. The authors incorporated real scientific data and actual case studies into classroom activities. A three-year development process included geographically dispersed field tests by teachers and students. For the 2012 edition, key sections of the supplement were updated, but the Student Lessons remain basically the same.

The structure of this module enables teachers to facilitate learning and stimulate student interest by applying scientific concepts to real-life scenarios. Design elements include a conceptual flow of lessons based on the BSCS 5E Instructional Model (page 9), cutting-edge science content, and built-in assessment tools. Activities promote active and collaborative learning and are inquiry-based to help students develop problem-solving strategies and critical-thinking skills.

Each of our curriculum supplements comes with a complete set of materials for teachers, including extensive background and resource information, detailed lesson plans, masters for student worksheets, and a Web site with videos, interactive activities, updates, and corrections (as needed). The supplements are distributed at no cost to educators across the United States upon request. They may be copied for classroom use but may not be sold.

We welcome your feedback. For a complete list of curriculum supplements and ordering information, or to submit feedback, please visit *http://science.education.nih.gov*.

We appreciate the valuable contributions of the talented staff at Biological Sciences Curriculum Study (BSCS) and Videodiscovery, Inc. We are also grateful to the NIH scientists, advisors, and all other participating professionals for their work and dedication. Finally, we thank the teachers and students who participated in focus groups and field tests to ensure that these materials are both engaging and effective.

I hope you find our series a valuable addition to your classroom and wish you a productive school year.

Bruce A. Fuchs, Ph.D.
National Institutes of Health

About the National Institutes of Health

Founded in 1887, NIH is the federal focal point for health research in the United States. Today, NIH is one of the agencies within the Department of Health and Human Services. Its mission is science in pursuit of fundamental knowledge about the nature and behavior of living systems and the application of that knowledge to extend healthy life and reduce the burdens of illness and disability. NIH works toward meeting the mission by providing leadership, direction, and grant support to programs designed to improve the health of the nation through research.

NIH's education programs contribute to ensuring the continued supply of well-trained basic research and clinical investigators, as well as the myriad professionals in the many allied disciplines who support the research enterprise. These efforts also help educate people about scientific results so that they can make informed decisions about their own—and the public's—health.

This curriculum supplement is one such education effort. It is a collaboration among the National Cancer Institute, the NIH Office of Science Education, Biological Sciences Curriculum Study, and Videodiscovery, Inc.

For more about NIH, visit *http://www.nih.gov.*

About the National Cancer Institute

The National Cancer Institute (NCI), a component of the NIH, is the federal government's principal agency for cancer research and training. The NCI coordinates the National Cancer Program, which conducts and supports research, training, health information dissemination, and other programs with respect to the cause, diagnosis, prevention and treatment of cancer, rehabilitation from cancer, and the continuing care of cancer patients and the families of cancer patients.

The NCI was established under the National Cancer Act of 1937. The National Cancer Act of 1971 broadened the scope and responsibilities of the NCI and created the National Cancer Program. Over the years, the NCI's mandate has come to include dissemination of current cancer information and assessment of the incorporation of state-of-the-art cancer treatments into clinical practice. Today, the NCI's activities include

- supporting and coordinating research projects conducted by universities, hospitals, research foundations, and businesses throughout this country and abroad through research grants and cooperative agreements;
- conducting research in its own laboratories and clinics;
- supporting education and training in all areas of cancer research through training grants, fellowships, and "career awards" for long-time researchers;
- supporting a national network of Cancer Centers, which are hubs of cutting-edge research, high quality cancer care, and outreach and education for both healthcare professionals and the general public;
- collaborating with voluntary organizations and other national and foreign institutions engaged in cancer research and training activities;
- collaborating with partners in industry in a number of areas, including the development of technologies that are revolutionizing cancer research; and
- collecting and disseminating information about cancer.

For more information about the National Cancer Institute, visit its Web site at *http://www.cancer.gov*.

About Biological Sciences Curriculum Study

Headquartered in Colorado Springs, Colorado, BSCS was founded in 1958 as a curriculum study committed to an evidence- and inquiry-based approach to science education. BSCS instructional materials and professional development services are based on current research about teaching and learning for all science classrooms, kindergarten through college.

BSCS's materials are extensively field-tested in diverse settings across the country and evaluated for proven effectiveness. The BSCS 5E Instructional Model and inquiry are hallmarks of its materials, placing students at the center of their learning.

The BSCS mission is to transform science teaching and learning through research and development that strengthens learning environments and inspires a global community of scientifically literate citizens. BSCS is a 501(c)3 nonprofit organization. For more information, please visit *http://www.bscs.org*.

Introduction to *Cell Biology and Cancer*

"Tumors destroy man in a unique and appalling way, as flesh of his own flesh which has somehow been rendered proliferative, rampant, predatory, and ungovernable. . . . Yet, despite more than 70 years of experimental study, they remain the least understood. . . . What can be the why for these happenings?"

—Peyton Rous, in his acceptance lecture for the Nobel Prize in Physiology or Medicine (1966)

Late in 1910, a young scientist at Rockefeller University was preparing to conduct a most improbable experiment. He wanted to know whether one chicken could "catch" cancer from another. At that time, the concept that every cell in the body is derived from another cell was new, and the idea that cancer might involve a disruption of normal cell growth was just taking hold.

Thirty years had passed since Louis Pasteur's influential paper on germ theory dislodged the humoral theory of disease that had prevailed for more than 2,000 years, and the prevailing scientific view of cancer emphasized the role of chemical and physical agents, not infectious ones, as potential causes.

Nevertheless, the 30-year-old Peyton Rous was able to show that cell-free extracts from one chicken were able to cause the formation of the same type of tumor when injected into a second chicken. Rous' tumor extracts had been passed through a filter with pores so small that even bacteria were excluded. This result strongly implicated the newly discovered "filterable agents" known as viruses. Rous was later able to demonstrate that other types of chicken tumors could also be spread by their own, unique "filterable agents," and that each would faithfully produce its original type of tumor (bone, cartilage, blood vessel) when injected into healthy animals.

Unfortunately, the full significance of these data was not to be realized for many decades. One reason was the difficulty of reproducing these results in mammals. But another reason was that scientists could not place Rous' discovery in a proper context. So many different things seemed to be associated with cancer that no one was able to make sense of it all. For example,

- In 1700, the Italian physician Bernardino Ramazzini wrote about the high rate of breast cancer among nuns and speculated that it was related to their celibacy and childlessness. This was the first indication that how one lived might affect the development of cancer.
- In 1775, Percivall Pott, a London physician, suggested that the very high rate of scrotal and nasal cancers among chimney sweeps was a result of their exposure to soot. This was the first indication that exposure to certain chemicals in the environment could be an important factor in cancer.
- In 1886, Hilario de Gouvea, a professor at the Medical School in Rio de Janeiro, Brazil, reported the case of a family with an increased susceptibility to retinoblastoma, a form of cancer that normally occurs in only 1 out of about 20,000 children. This suggested that certain cancers have a hereditary basis.
- The discovery of X-rays in 1895 led to their association with the skin cancer on the hand of a lab technician by 1902. Within a decade, many more physicians and scientists, unaware of the dangers of radiation, developed a variety of cancers.
- In 1907, an epidemiological study found that the meat-eating people from Germany, Ireland, and Scandinavia living in Chicago had higher

rates of cancer than did their Italian and Chinese neighbors, who ate considerably less meat.

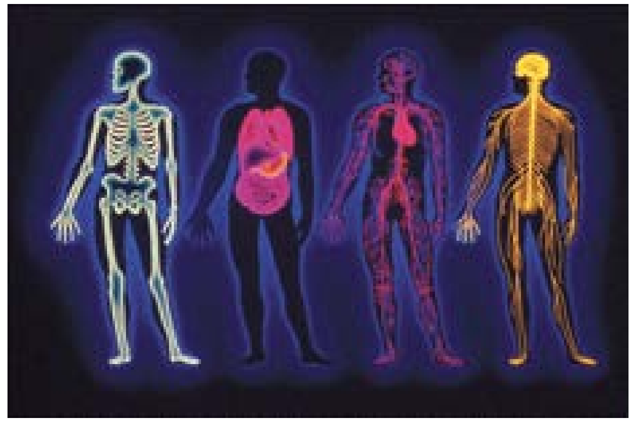
At the time Peyton Rous accepted his Nobel Prize, it was not clear how these, and many other observations, would ever be reconciled. By the early 1970s, however, scientists armed with the new tools of molecular biology were about to revolutionize our understanding of cancer. In fact, just over three decades later, Rous would be astounded to learn of the progress made in answering his question of "why?"

What Are the Objectives of the Module?

Cell Biology and Cancer has two objectives. The first is to introduce students to major concepts related to the development and impact of cancer. Today, we have a picture of cancer that, while still incomplete, is remarkably coherent and precise. Cancer develops when mutations occur in genes that normally operate to control the cell's life cycle of growth, proliferation, and death. These mutations prompt the cell to divide inappropriately. Cancer-causing mutations can be induced by a wide variety of environmental agents and even several known viruses. Such mutations can also be inherited—thus the observation that some families have a higher risk for developing cancer than others. We still have much to learn about cancer, to be sure. However, the clarity and detail of our understanding today speak powerfully of the enormous gains scientists have made since the War on Cancer was launched in 1971. We hope this module will help students catch a bit of the excitement of these gains.

A second objective is to convey to students the relationship between basic biomedical research and the improvement of personal and public health. Cancer-related research has yielded many benefits for humankind. Most directly, it has guided the development of public health policies and medical interventions that today are helping us prevent, treat, and even cure cancer. As illustrations of the progress created by cancer research, note that cancer mortality decreased at a rate of 1.4 percent per year from 1999 to 2008. For the major cancers, the most recent trends show significant declines in death rates for colorectal, lung, prostate, and female breast cancer.

Figure 1. *For people touched by cancer in any body system, modern science offers better treatment and brighter prospects than ever before.*



Cancer incidence rates show a more varied picture: the overall trend for 1999 to 2008 was steady. The major cancers (colorectal, male lung, and prostate cancer) showed significant declines during this period, while female lung cancer rates decreased between 2004 and 2008 and female breast cancer rates declined between 1999 and 2004 but were stable between 2004 and 2008.

It is notable that the combined cancer incidence rates for both sexes had very different trends. For men the rate decreased steadily from 1994 to 2008. For women the rate declined between 1998 and 2006 but remained stable from 2006 to 2008. Recently, incidence rates have actually increased for several cancers, including pancreas and kidney, which are associated with excess weight.

Death rates from all cancers combined have decreased significantly in men and women; from 2004 through 2008, cancer death rates declined about 1.6 percent per year. These decreases, which began in the early 1990s, are driven by declines in the three most common cancers in men (lung, colorectal, and prostate), and declines in the three leading cancers in women (lung, breast, and colorectal). Prostate and breast cancers are the most frequently diagnosed cancers in the United States, but lung cancer accounts for the largest number of cancer deaths.

Research is also pointing the way to new therapies that scientists hope will combat the disease without as many of the devastating side effects of current treatments. For example, much of the current drug development to prevent or fight cancer focuses on targeting specific genes, proteins, and pathways unique to or altered in cancer cells. Although many of these types of drugs are still in various stages of testing and development, several are already approved for use, and enthusiasm about the prospects of controlling cancer at the molecular level continues. Gleevec®, for example, is a small-molecule drug approved by the U.S. Food and Drug Administration (FDA) to treat gastrointestinal stromal tumor (a rare cancer of the gastrointestinal tract) and certain kinds of chronic myeloid leukemia. Gleevec® is also approved for certain kinds of acute lymphoblastic leukemia, chronic eosinophilic leukemia, dermatofibrosarcoma protuberans, myelodysplastic/myeloproliferative disorders, and systemic mastocytosis. It is also being studied in the treatment of other types of cancer.

An enormous amount of progress is also being made in the field of cancer vaccines, which stimulate the immune system to kill existing cancer cells or to recognize and attack pathogens before they can cause disease. Cancer vaccines, which are still largely experimental, are either preventive—intended to prevent cancer from developing in healthy people—or therapeutic—intended to treat existing cancers by strengthening the body's natural defenses against the disease. The FDA has already approved two cancer preventive vaccines. The first is a vaccine against the hepatitis B virus (HBV). Chronic HBV infections can lead to liver cancer. The second vaccine, which is known as Gardasil®, is highly effective in preventing infections by two types of human papilloma virus (HPV) that cause most (70 percent of) cervical cancers in the United States and Western Europe. Cervarix is also approved to prevent infections with the two types of HPV that cause most cervical cancers and some oropharyngeal cancers. The FDA has also approved sipuleucel-T (Provenge®) for the treatment of some men with metastatic prostate cancer.

Cancer research has yielded other benefits as well. In particular, it has vastly improved our understanding of many of the body's most critical cellular and molecular processes. The need to understand cancer has spurred research into the normal cell cycle (the sequence of events by which cells enlarge and divide), mutation, DNA repair, growth factors, cell signaling, and cell aging and death. Research has also led to an improved understanding of cell adhesion and anchorage (the "address" system that keeps normal cells from establishing themselves in inappropriate parts of the body), angiogenesis (the formation of blood vessels), and the role of the immune system in protecting the body from harm caused by abnormal cells as well as from invading microbes and viruses.

This module addresses our progress in understanding the cellular and molecular bases of cancer and considers the impact of what we have learned for individuals and society. We could have addressed many concepts, but with the help of a wide variety of experts in this field, we chose these for your students to explore:

- Cancer is a group of more than 100 diseases that develop across time. It can occur in virtually any of the body's tissues, and both hereditary and environmental factors contribute to its development.
- The growth and differentiation of cells in the body are normally precisely regulated; this regulation is fundamental to the orderly process of development that we observe across the life spans of multicellular organisms. Cancer develops due to the loss of growth control in cells. Loss of control can occur as a result of mutations in genes that are involved in cell-cycle control.
- No single event is enough to turn a cell into a cancerous cell. Instead, it seems that the accumulation of damage to a number of genes ("multiple hits") across time leads to cancer.
- Scientists use systematic and rigorous criteria to evaluate claims about factors that may contribute to cancer development. Consumers can evaluate such claims by applying criteria related to the source, certainty, and reasonableness of the supporting information.

- We can use our understanding of the science of cancer to improve personal and public health. Translating our understanding of science into public policy can raise a variety of issues, such as the degree to which society should govern the health practices of individuals. Such issues often involve a tension between the values of preserving personal and public health and preserving individual freedom and autonomy.

We hope the module's five lessons will carry these concepts to your students effectively. Although the lessons contain much interesting information about various types of cancer, we suggest that you focus your students' attention on the major concepts the module was designed to convey. The concluding steps in each lesson are intended to remind students of those concepts.

Why Teach the Module?

High school biology classes offer an ideal setting for integrating many areas of student interest. In this module, students participate in activities that integrate inquiry science, human health, mathematics, and the interweaving of science, technology, and society. The real-life context of the module's classroom lessons is engaging for students, and the knowledge gained can be applied immediately to students' lives.

What's in It for the Teacher?

Cell Biology and Cancer meets many of the criteria by which teachers and their programs are assessed.

- The module is **standards based** and meets science content, teaching, and assessment standards as expressed in the *National Science Education Standards*. It pays particular attention to the standards that describe what students should know and be able to do with respect to **scientific inquiry**.
- It is an **integrated** module, drawing most heavily from the subjects of science, social science, mathematics, and health.
- It has a Web-based **technology component**.
- It includes built-in **assessment tools**, which are noted in each lesson with an assessment icon.

In addition, the module provides a means for **professional development**. Teachers can engage in new and different teaching practices like those described in this module without completely overhauling their entire program. In *Designing Professional Development for Teachers of Science and Mathematics*, the authors wrote that replacement modules such as this one "offer a window through which teachers get a glimpse of what new teaching strategies look like in action" (Loucks-Horsley et al., 1998). By experiencing a short-term unit, teachers can "change how they think about teaching and embrace new approaches that stimulate students to problem solve, reason, investigate, and construct their own meaning for the content." The use of a supplemental unit such as this one can encourage reflection and discussion and stimulate teachers to improve their practices by focusing on student learning through inquiry.

Implementing the Module

The five lessons in this module are designed to be taught either in sequence, as a supplement to your standard curriculum, or as individual lessons that support or enhance your treatment of specific concepts in biology. The following pages offer general suggestions about using these materials in the classroom; you will find specific suggestions in the support material provided for each lesson.

What Are the Goals of the Module?

Cell Biology and Cancer is designed to help students reach the following major goals associated with biological literacy:

- to understand a set of basic scientific principles related to cancer as a cellular phenomenon,
- to experience the process of inquiry and develop an enhanced understanding of the nature and methods of science, and
- to recognize the role of science in society and the relationship between basic science and personal and public health.

What Are the Science Concepts and How Are They Organized?

We have organized the lessons to form a conceptual whole that moves students from an introduction to cancer (*The Faces of Cancer*), to an investigation of its biological basis (*Cancer and the Cell Cycle* and *Cancer as a Multistep Process*), to a discussion of how people evaluate claims about cancer (*Evaluating Claims About Cancer*), and, finally, to a consideration of how understanding cancer can help people make decisions about issues related to personal and public health (*Acting on Information About Cancer*). Table 1 displays the sequence of major concepts addressed by the five lessons.

Table 1. Conceptual flow of the lessons.

Activity	Learning Stage*	Major Concepts
Lesson 1 *The Faces of Cancer*	Engage	Cancer is a group of more than 100 diseases that develop across time in virtually any of the body's tissues. Both hereditary and environmental factors contribute to its development.
Lesson 2 *Cancer and the Cell Cycle*	Explore/Explain	The growth and differentiation of cells in the body normally are precisely regulated; this regulation is fundamental to the orderly process of development that we observe across the life spans of multicellular organisms. Cancer develops due to the loss of growth control in cells. Loss of control occurs as a result of mutations in genes that are involved in cell-cycle control.
Lesson 3 *Cancer as a Multistep Process*	Explore/Explain	No single event is enough to turn a cell into a cancerous cell. Instead, it seems that the accumulation of damage to a number of genes ("multiple hits") across time leads to cancer.
Lesson 4 *Evaluating Claims About Cancer*	Elaborate	Scientists use systematic and rigorous criteria to evaluate claims about factors associated with cancer. Consumers can evaluate such claims by applying criteria related to the source, certainty, and reasonableness of the supporting information.
Lesson 5 Acting on Information About Cancer	Evaluate	We can use our understanding of the science of cancer to improve personal and public health. Translating our understanding of science into public policy can raise a variety of issues, such as the degree to which society should govern the health practices of individuals. Such issues often involve a tension between the values of preserving personal and public health and preserving individual freedom and autonomy.

Table 2. Correlation between lessons and high school biology topics.

High School Biology Topic	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5
Biology of Cancer	Yes	Yes	Yes	No	No
Cell Cycle and Regulation of Cell Division	No	Yes	Yes	No	No
Mutation	No	Yes	Yes	No	No
Cancer and Personal and Public Health	No	No	No	Yes	Yes

Although we encourage you to use the lessons in the sequence outlined in Table 1, many of the lessons can be taught individually, to replace or enhance a more traditional approach to the same or related content. Table 2 provides recommendations for inserting the lessons into a standard high school curriculum in biology.

How Does the Module Correlate with the *National Science Education Standards*?

Cell Biology and Cancer supports teachers in their efforts to reform science education in the spirit of the National Research Council's 1996 *National Science Education Standards (NSES)*. Table 3 lists the content and teaching standards that this module primarily addresses.

How Does the BSCS 5E Instructional Model Promote Active, Collaborative, Inquiry-Based Learning?

The activities in this module are designed to offer students the opportunity to participate in active, collaborative, and inquiry-based learning in biology. But what do these terms mean? Despite their current popularity, many teachers think of active, collaborative, and inquiry-based learning rather generically. Defining these three key terms specifically will provide a foundation on which we can build a detailed description of the instructional approach that the five lessons in this module advocate and implement.

Conceptually the broadest of the three, **active learning**, means that students are involved "in doing things and thinking about the things they are doing" (Bonwell and Eison, 1991, p. 2). These authors elaborate by listing the following characteristics typically associated with strategies that deserve to be labeled "active":

- Students are involved in more than listening.
- Instructors place less emphasis on transmitting information and more emphasis on developing students' skills.
- Students are involved in higher-order thinking (for example, analysis, synthesis, and evaluation).
- Students are engaged in activities (for example, reading, discussing, and writing).
- Instructors encourage students' exploration of their own understandings, attitudes, and values.

Most teachers endorse the use of active learning. We know intuitively, if not experientially and explicitly, that learning does not occur through a process of passive absorption. But often, we do not realize how active students must be for real learning to occur. Typically, the answer to this question is more active than we might expect.

The lessons in this module were designed with the following assumptions about active learning (BSCS, 1999):

1. An activity promotes active learning to the degree to which all students, not simply a vocal few, are involved in mental processing related to the content.
2. An activity promotes active learning to the degree that it offers extended opportunities for students to become personally engaged with the content.
3. An activity promotes active learning to the degree that it involves students in thinking deeply about content.

The activities also make extensive use of **collaborative learning**. Collaborative and cooperative learning currently enjoy "favorite child" status among the many strategies available to teachers. Teachers are using group approaches

Table 3. Correlation to the National Science Education Standards.
A. The Content Standards

Standard A: As a result of activities in grades 9–12, all students should develop abilities necessary to do scientific inquiry and understandings about scientific inquiry	**Correlation to *Cell Biology and Cancer***
• Identify questions and concepts that guide scientific investigations.	Lessons 2, 3, and 4
• Design and conduct scientific investigations.	Lesson 4
• Use technology and mathematics to improve investigations and communications.	Lesson 3
• Formulate and revise scientific explanations and models using logic and evidence.	Lessons 2, 3, and 4
• Recognize and analyze alternative explanations and models.	Lessons 3
• Communicate and defend a scientific argument.	Lessons 4
• Understanding scientific inquiry.	Lessons 2, 3, and 4
Standard C: As a result of their activities in grades 9–12, all students	**Correlation to *Cell Biology and Cancer***
should develop understanding of the cell:	
• Cells store and use information to guide their functions.	Lesson 2 and 3
• Cell functions are regulated.	
should develop understanding of the molecular basis of heredity:	
• In all organisms, the instructions for specifying the characteristics of the organism are carried in the DNA.	Lesson 2 and 3
• Changes in DNA occur spontaneously at low rates.	
should develop understanding of the interdependence of organisms:	
• Human beings live within the world's ecosystems.	Lesson 5
Standard E: As a result of activities in grades 9–12, all students	**Correlation to *Cell Biology and Cancer***
should develop abilities of technological design and understandings about science and technology:	
• Science often advances with the introduction of new technologies.	Lesson 2
• Creativity, imagination, and a good knowledge base are all required in the work of science and engineering.	Lessons 1–5
Standard F: As a result of activities in grades 9–12, all students should develop understanding of	**Correlation to *Cell Biology and Cancer***
should develop understanding of:	
• personal and community health	Lessons 1, 4, and 5
• natural and human-induced hazards	Lessons 1, 4, and 5
• science and technology in local, national, and global challenges	Lesson 5
Standard G: As a result of activities in grades 9–12, all students	**Correlation to *Cell Biology and Cancer***
should develop understanding of:	
• science as a human endeavor	Lessons 2 and 4
• nature of scientific knowledge	Lessons 2, 3, and 4
• historical perspectives	Lesson 2

Table 3. Correlation to the National Science Education Standards.
B. The Teaching Standards

Standard A: Teachers of science plan an inquiry-based science program for their students. In doing this, teachers	Correlation to *Cell Biology and Cancer*
• develop a framework of yearlong and short-term goals for students.	Each lesson provides short-term objectives for students. Table 1, Conceptual Flow of the Activities and Table 7, Timeline for Teaching the Module, also help teachers plan.
• select science content and adapt and design curriculum to meet the interests, knowledge, understanding, abilities, and experiences of students.	Using the module helps teachers update their curriculum in response to their students' interest in this topic.
• select teaching and assessment strategies that support the development of student understanding and nurture a community of science learners.	The focus on active, collaborative, and inquiry-based learning in the activities helps teachers meet this standard.
Standard B: Teachers of science guide and facilitate learning. In doing this, teachers	**Correlation to *Cell Biology and Cancer***
• focus and support inquiries while interacting with students.	All of the activities in the module encourage and support student inquiry.
• orchestrate discourse among students about scientific ideas.	All of the activities in the module promote discourse among students.
• challenge students to accept and share responsibility for their own learning.	All of the activities in the module challenge students to accept and share responsibility for their learning.
• recognize and respond to student diversity and encourage all students to participate fully in science learning.	Combining the BSCS 5E Instructional Model with active, collaborative learning is an effective way of responding to the diversity of student backgrounds and learning styles.
• encourage and model the skills of scientific inquiry, as well as the curiosity, openness to new ideas and data, and skepticism that characterize science.	Annotations for the teacher that occur throughout the lessons provide many suggestions for how teachers can model these attributes.
Standard C: Teachers of science engage in ongoing assessment of their teaching and of student learning. In doing this, teachers	**Correlation to *Cell Biology and Cancer***
• use multiple methods and systematically gather data about student understanding and ability	Each lesson has a variety of assessment components embedded within its structure. Annotations draw teachers' attention to these opportunities for assessment.
• analyze assessment data to guide teaching	Annotations provide answers to questions that can help teachers analyze student feedback. The annotations also suggest ways for teachers to change their approach to students, based on that feedback.
Standard E: Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning. In doing this, teachers	**Correlation to *Cell Biology and Cancer***
• display and demand respect for the diverse ideas, skills, and experiences of all students	The answers provided in the annotations for teachers model these qualities.
• nurture collaboration among students	All the lessons are designed to be completed by students working in collaborative groups.
• structure and facilitate ongoing formal and informal discussion based on a shared understanding of rules of scientific discourse	All the discussions in the lessons model the rules of scientific discourse.
• model and emphasize the skills, attitudes, and values of scientific inquiry	The annotations for teachers provide many suggestions about how to model these skills, attitudes, and values.

across disciplines, for in- and out-of-class assignments, with large and small classes, and with beginning and advanced students. In fact, you will often find that collaborative activities go hand-in-hand with active learning.

Collaborative and cooperative learning, which have long theoretical and empirical histories, come out of different academic traditions, operate on different premises, and use different strategies. But both approaches share a fundamental commitment to the notion that students learn from and with each other—"learning through joint intellectual effort," according to one expert (Brody, 1995, p. 134). In the interest of brevity, we will leave undiscussed the finer distinctions between the two, offering in this curriculum a mix of strategies that put students together and engage them in tasks that encourage learning together.

Finally, the activities in the module use inquiry-based strategies. All truly inquiry-based activities share the characteristics of active learning. In addition, inquiry-based strategies emphasize discovery: the process of observation, followed by analysis, that leads to explanation, to conclusion, or to the next question. Note that an activity need not involve students in active experimentation to be fundamentally an inquiry experience.

More than active or collaborative learning, inquiry-based strategies attempt to teach students how biologists see the world, how they think about what they see, and how they draw conclusions that are consistent with observations and current knowledge. Such strategies say to the student, in effect, "This is science as a way of knowing."

The BSCS 5E Instructional Model

The lessons in the module were designed using an instructional model to organize and sequence the experiences offered to students. This model, called the BSCS 5E Instructional Model, is based on constructivism, a term that expresses a view of the student as an active agent who "constructs" meaning out of his or her interactions with events (Perkins, 1992). According to this view, rather than passively absorbing information, the student redefines, reorganizes, elaborates, and changes his or her initial understandings through interactions with phenomena, the environment, and other individuals. In short, the student interprets objects and phenomena and then internalizes this interpretation in terms of previous experiences.

A constructivist view of learning recognizes that the development of ideas and the acquisition of lasting understandings take time and experience (Saunders, 1992). In the typical classroom, this means that fewer concepts and subjects can be covered during the school year or, in this case, in five days of instruction. Nevertheless, research suggests that students who are given time and opportunity to thoroughly grasp a small number of important concepts do better on traditional tests than students who are exposed briefly to a large number of ideas (Sizer, 1992; Knapp et al., 1995). In fact, the intensive thinking involved in constructing a thorough understanding of a few major ideas appears to benefit all students, regardless of ability.

Tables 4 and 5 illustrate the key components of the BSCS 5E Instructional Model, so-called because it takes students through five phases of learning that are easily described using five words that begin with the letter "E": Engage, Explore, Explain, Elaborate, and Evaluate.

This instructional model allows students to share common experiences related to cancer, to use and build on prior knowledge, to construct meaning, and to assess continually their understanding of a major concept. It avoids excessive use of lecture because research shows that 10 minutes is near the upper limit of comfortable attention that students give to lecture material, whereas the attention span in an investigative activity is far longer (Project Kaleidoscope, 1991). In the 5E Model, the teacher acts as facilitator and coach much more frequently than he or she acts as the disseminator of information.

The following paragraphs illustrate how the 5Es are implemented across the lessons in this module. They also provide suggestions about effective teaching behaviors that help students experience each phase of the learning cycle.