Looking Good, Feeling Good: From the Inside Out

Exploring Bone, Muscle, and Skin

under a Contract from the
National Institutes of Health

National Institute of
Arthritis and Musculoskeletal and Skin Diseases

BSCS
Center for Curriculum Development
5415 Mark Dabling Boulevard
Colorado Springs, CO 80918

BSCS Development Team
Rodger W. Bybee, Principal Investigator
Mark V. Bloom, Project Director
Jerry Phillips, Curriculum Developer
Nicole Knapp, Curriculum Developer
Carrie Zander, Project Assistant
Lisa Pence, Project Assistant
Terry Redmond, Project Assistant
Ted Lamb, Evaluator
Barbara Perrin, Production Manager
Diane Gionfriddo, Photo Research
Lisa Rasmussen, Graphic Designer
Stacey Luce, Production Specialist

BSCS Administrative Staff
Carlo Parravano, Chair, Board of Directors
Rodger W. Bybee, Executive Director
Janet Carlson Powell, Associate Director, Chief Science Education Officer
Pamela Van Scotter, Director, Center for Curriculum Development

National Institutes of Health
Elizabeth Stillman (formerly Freedman), Science Writer and Information Specialist, National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS)
Mario Cerritelli, Chief, Career Development Section Office of Science and Technology, NIAMS
Joan McGowan, Director, Musculoskeletal Diseases Branch, NIAMS
Barbara B. Mittleman, Director, Office of Scientific Interchange, NIAMS
Richard Clark, Editor, Office of Communications and Public Liaison, NIAMS
Ray Fleming, Deputy Director, Office of Communications and Public Liaison, NIAMS
Bruce Fuchs, Director, Office of Science Education (OSE)
Lisa Strauss, Project Officer, OSE
Cindy Allen, Editor, OSE

Ai Group
Peter Charczenko, President
Judd Exley, Associate Web Designer/Developer
Anuradha Parthasarathy, Web Programmer/Developer
Matt Esposito, Web Programmer/Developer

SAIC
Bach Nguyen, Project Manager
Steve Larson, Web Director
Doug Green, Project Lead
Dave Nevins, Senior Web Developer
Katie Riley, Web Developer
James Chandler, Web Developer/Usability Specialist
Abdellah Bougrine, Web Developer/Section 508 Specialist
Mary Jo Mallonee, Web Developer/Editor

Advisory Committee
Nicole Cavaliere, Cheyenne Elementary School, Peoria, Arizona
Kenneth Kraemer, National Cancer Institute, Bethesda, Maryland
Daniel Lovell, Cincinnati Children's Hospital Medical Center, Ohio
Susan M. Ott, University of Washington Medical Center, Seattle, Washington
Laura Robbins, Hospital for Special Surgery, New York, New York
Donna Roberts, West Marion School, Foxworth, Mississippi

Writing Team
Louisa Bliss, Gilman Middle School, Gilman, Vermont
Anna Kong, Stone Academy, Chicago, Illinois
Karen Mallin, University of Miami School of Medicine, Florida
Susan M. Ott, University of Washington Medical Center, Seattle, Washington
Kornelis Poelstra, University of Virginia, Charlottesville, Virginia
Laura Tosi, Children's National Medical Center, Washington, D.C.

Field-Test Teachers
Gary Dewey, North Shore Christian Middle School, Michigan
Claireen Espinoza, Taos Day School, New Mexico
Kishla Holland, Lincoln Multicultural Middle School, Washington, D.C.
Larry Hurst, Catlin Gable School, Oregon
Bev Maronn, Harlan Community Middle School, Iowa
Andy Mazzolini, All Saints' Episcopal Day School, Arizona
Rachel Robb, St. Elizabeth Catholic School, Texas
Gabriel Viego, St. Mary of the Angels, Illinois

This material is based on work supported by the National Institutes of Health under Contract No. 263-02-C-0061. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the funding agency.

Copyright © 2005 by BSCS. All rights reserved. You have the permission of BSCS to reproduce items in this module for your classroom use. The copyright on this module, however, does not cover reproduction of these items for any other use. For permissions and other rights under this copyright, please contact BSCS, 5415 Mark Dabling Blvd., Colorado Springs, CO 80918-3842; www.bscs.org; info@bscs.org; (719) 531-5550.

NIH Publication No.: 05-5565

ISBN: 1-929614-21-7

Please contact the NIH Office of Science Education with questions about this supplement at *supplements@science.education.nih.gov.*

Contents

Foreword v

About the National Institutes of Health vii

About the National Institute of Arthritis and Musculoskeletal and Skin Diseases ix

Introduction to *Looking Good, Feeling Good: From the Inside Out* 1
- What Are the Objectives of the Module?
- Why Teach the Module?
- What's in It for the Teacher?

Implementing the Module 3
- What Are the Goals of the Module?
- What Are the Science Concepts and How Are They Connected?
- How Does the Module Correlate with the *National Science Education Standards*?
  - Content Standards: Grades 5–8
  - Teaching Standards
  - Assessment Standards
- How Does the 5E Instructional Model Promote Active, Collaborative, Inquiry-Based Learning?
  - Engage
  - Explore
  - Explain
  - Elaborate
  - Evaluate
- How Does the Module Support Ongoing Assessment?
- How Can Teachers Promote Safety in the Science Classroom?
- How Can Controversial Topics Be Handled in the Classroom?
- Animals as Research Models

Using the Student Lessons. 15
- Format of the Lessons
- Timeline for the Module

Using the Web Site. 17
- Hardware/Software Requirements
- Downloading and Installing Macromedia Flash Player
- Getting the Most out of the Web Site
- Collaborative Groups
- Web Activities for Students with Disabilities

Information about the Musculoskeletal and Skin Systems 21
1 Introduction 21
2 Misconceptions about the Musculoskeletal and Skin Systems 22
3 Characteristics of Living and Nonliving Systems 23

4 Characteristics of Bone, Muscle, and Skin 24
4.1 Bone 25
4.2 Muscle 27
4.3 Skin 30
5 Interactions 32
5.1 Joints 33
5.2 Vitamin D 34
6 Diseases and Disorders 35
6.1 Diseases Affect Bone 35
6.2 Diseases and Injuries Can Affect Muscle Function 36
6.3 There Are a Wide Variety of Disorders of the Skin 37
7 Influences 40

Glossary 43

References 45

Student Lessons
- Lesson 1 — *It's Alive! Or Is It?* 49
- Lesson 2 — *What Makes Bones Strong?* 57
- Lesson 3 — *Anatomy of a Kick* 69
- Lesson 4 — *Use It or Lose It* 89
- Lesson 5 — *Helping the Body Build Strong Bones* 97
- Lesson 6 — *Shining the Light on Skin* 107
- Lesson 7 — *Decisions Today for a Healthy Tomorrow* 123

Masters 129

Foreword

This curriculum supplement, from the *NIH Curriculum Supplement Series*, brings cutting-edge medical science and basic research discoveries from the laboratories of the National Institutes of Health (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. The NIH 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 *National Science Education Standards*.[1] It was developed and tested by a team composed of teachers, scientists, medical experts, and other professionals with relevant subject-area expertise from schools and institutes from across the country, and by NIH scientists and curriculum-design experts from Biological Sciences Curriculum Study (BSCS), Ai Group, and SAIC. The authors incorporated real scientific data and actual case studies into classroom activities. A two-year development process included geographically dispersed field tests by teachers and students.

The structure of this module enables teachers to effectively facilitate learning and stimulate student interest by applying scientific concepts to real-life scenarios. Design elements include a conceptual flow of lessons based on BSCS's 5E Instructional Model of Learning, multisubject integration emphasizing 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 curriculum supplement comes with a complete set of materials for both teachers and students, including printed materials, extensive background and resource information, and a Web site with interactive activities. These supplements are distributed at no cost to teachers across the United States. All materials may be copied for classroom use but may not be sold. We welcome feedback from our users. For a complete list of curriculum supplements, updates, availability, and ordering information, or to submit feedback, please visit our Web site at *http://science.education.nih.gov* or write to

Curriculum Supplement Series
Office of Science Education
National Institutes of Health
6705 Rockledge Drive, Suite 700 MSC 7984
Bethesda, MD 20817-1814

We appreciate the valuable contributions of the talented staff at BSCS, Ai Group, and SAIC. We are also grateful to the NIH scientists, advisers, 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 supplements 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.
Director
Office of Science Education
National Institutes of Health
supplements@science.education.nih.gov

[1] In 1996, the National Academy of Sciences released the *National Science Education Standards*, which outlines what all citizens should understand about science by the time they graduate from high school. The *Standards* encourages teachers to select major science concepts that empower students to use information to solve problems rather than stressing memorization of unrelated information.

About the National Institutes of Health

Begun as the one-room Laboratory of Hygiene in 1887, the National Institutes of Health (NIH) today is one of the world's foremost medical research centers and the federal focal point for health research in the United States.

Mission and Goals

The NIH 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. The goals of the agency are to

- foster fundamental creative discoveries, innovative research strategies, and their applications as a basis for advancing significantly the nation's capacity to protect and improve health;
- develop, maintain, and renew scientific resources—both human and physical—that will ensure the nation's ability to prevent disease;
- expand the knowledge base in medical and associated sciences in order to enhance the nation's economic well-being and ensure a continued high return on the public investment in research; and
- exemplify and promote the highest level of scientific integrity, public accountability, and social responsibility in the conduct of science.

NIH works toward meeting those goals by providing leadership, direction, and grant support to programs designed to improve the health of the nation through research in the

- causes, diagnosis, prevention, and cure of human diseases;
- processes of human growth and development;
- biological effects of environmental contaminants;
- understanding of mental, addictive, and physical disorders; and
- collection, dissemination, and exchange of information in medicine and health, including the development and support of medical libraries and the training of medical librarians and other health information specialists.

Organization

Composed of 27 separate institutes and centers, NIH is one of eight health agencies of the Public Health Service within the U.S. Department of Health and Human Services. NIH encompasses 75 buildings on more than 300 acres in Bethesda, Md., as well as facilities at several other sites in the United States. The NIH budget has grown from about $300 in 1887 to more than $28 billion in 2005.

Research Programs

One of NIH's principal concerns is to invest wisely the tax dollars entrusted to it for the support and conduct of this research. Approximately 82 percent of the investment is made through grants and contracts supporting research and training in more than 2,000 research institutions throughout the United States and abroad. In fact, NIH grantees are located in every state in the country. These grants and contracts make up the NIH Extramural Research Program.

Approximately 10 percent of the budget goes to NIH's Intramural Research Programs, the more than 2,000 projects conducted mainly in its own laboratories. These projects are central to the NIH scientific effort. First-rate intramural scientists collaborate with one another regardless of institute affiliation or scientific discipline and have the intellectual freedom to pursue their research leads in NIH's own laboratories. These explorations range from basic biology to behavioral research, to studies on treatment of major diseases.

Grant-Making Process

The grant-making process begins with an idea that an individual scientist describes in a written application for a research grant. The project might be small, or it might involve millions of dollars. The project might become useful immediately as a diagnostic test or new treatment, or it might involve studies of basic biological processes whose clinical value may not be apparent for many years.

Each research grant application undergoes peer review. A panel of scientific experts, primarily from outside the government, who are active and productive researchers in the biomedical sciences, first evaluates the scientific merit of the application. Then, a national advisory council or board, composed of eminent scientists as well as members of the public who are interested in health issues or the biomedical sciences, determines the project's overall merit and priority in advancing the research agenda of the particular NIH funding institutes.

About 38,500 research and training applications are reviewed annually through the NIH peer-review system. At any given time, NIH supports 35,000 grants in universities, medical schools, and other research and research training institutions, both nationally and internationally.

NIH Nobelists

The roster of people who have conducted NIH research or who have received NIH support over the years includes some of the world's most illustrious scientists and physicians. Among them are 115 winners of Nobel Prizes for achievements as diverse as deciphering the genetic code and identifying the causes of hepatitis.

Five Nobelists made their prize-winning discoveries in NIH laboratories. You can learn more about Nobelists who have received NIH support at *http://www.nih.gov/about/almanac/nobel/index.htm*.

Impact on the Nation's Health

Through its research, NIH has played a major role in making possible many achievements over the past few decades, including

- Mortality from heart disease, the number one killer in the United States, dropped by 36 percent between 1977 and 1999.
- Improved treatments and detection methods increased the relative five-year survival rate for people with cancer to 60 percent.
- With effective medications and psychotherapy, the 19 million Americans who suffer from depression can now look forward to a better, more productive future.
- Vaccines are now available that protect against infectious diseases that once killed and disabled millions of children and adults.
- In 1990, NIH researchers performed the first trial of gene therapy in humans. Scientists are increasingly able to locate, identify, and describe the functions of many of the genes in the human genome. The ultimate goal is to develop screening tools and gene therapies for the general population for cancer and many other diseases.

Science Education

Science education by NIH and its institutes contributes 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 science education effort, a collaboration among three partners: the NIH National Institute of Arthritis and Musculoskeletal and Skin Diseases, the NIH Office of Science Education, and Biological Sciences Curriculum Study.

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

About the National Institute of Arthritis and Musculoskeletal and Skin Diseases

About NIAMS

Since 1985, the National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS) has been funding and conducting biomedical research on bones, joints, muscles, and skin, both healthy and diseased. We are part of the U.S. Department of Health and Human Services' National Institutes of Health, the premier supporter of biomedical research in the United States. Understanding these biological systems; improving quality of life for people with diseases such as arthritis, osteoporosis, muscular dystrophy, and psoriasis; and preventing disease from happening are the driving forces behind what we do.

Almost every household in America is affected in some way by one or more disorders involving muscle, skin, or bone, and people of all ages, racial and ethnic populations, and economic groups feel the impact. In fact, President George W. Bush recognized the importance of bone and muscle disorders, a major part of this curriculum, by designating 2002–2011 as the National Bone and Joint Decade. A broad-based coalition of individuals and groups, including NIAMS, is working to accomplish the mission of the Bone and Joint Decade: to improve the health-related quality of life for people affected by musculoskeletal disorders.

To improve the nation's health requires more than research. We need to ensure that present and future research scientists, health professionals, educators, students, patients, and their families know what we already know about bones, joints, muscles, and skin—and what we are learning. Thus, education and training join research as the three pillars of our mission.

Commitment to Training

NIAMS supports the next generation of scientists in the fields of muscle, skin, and bones through research training opportunities. This next generation can advance understanding of normal muscle, bone, and skin development and function as well as develop new strategies for the detection, prevention, and treatment of associated diseases. This curriculum is one way to inspire young people to pursue scientific careers. NIH provides research training opportunities for individuals interested in pursuing scientific careers, from high school through postgraduate opportunities. Information on NIH-sponsored training opportunities is available at *http://www.training.nih.gov*.

Information Dissemination

NIAMS remains committed to a comprehensive program of information dissemination. Within NIAMS, the Office of Communications and Public Liaison disseminates information to patients, voluntary and professional organizations, healthcare providers, the media, and Congress about NIAMS programs, issues, and accomplishments. We work closely with our many voluntary and professional societies to both learn their needs and views and disseminate our research findings to them. Current knowledge and research advances can be useful to everyone, as people make decisions about healthy living, seeking medical treatment, and evaluating options. NIAMS makes this information available through health education materials, the NIAMS Web site, various news media, and outreach programs. We have also developed a Spanish-language Web site called En Español (In Spanish) as a tool to reach out to the growing Hispanic/Latino population. En

Español is located on the NIAMS homepage. This curriculum supplement is one of many ways NIAMS is reaching out with information and hope. We invite you to find out more by visiting our Web site at *http://www.niams.nih.gov*.

For more information on the Bone and Joint Decade, please visit *http://www.boneandjointdecade.org/us*.

Introduction to *Looking Good, Feeling Good: From the Inside Out–Exploring Bone, Muscle, and Skin*

The middle school years represent a time when young people establish habits and lifestyles that will affect their health for the rest of their lives. At this young age, students are not thinking about their adult years or the fact that they are just an accident away from becoming disabled. They take the workings of their bodies for granted.

This module introduces students to the musculoskeletal and skin systems. The relationships between structures and functions, the interactions between these body systems, and factors that influence the body systems' functions are stressed.

What Are the Objectives of the Module?

Looking Good, Feeling Good: From the Inside Out has four objectives. The first is to help students understand the basic structures that are part of the musculoskeletal and skin systems. These structures are discussed in the context of the systems' myriad functions. While students have some knowledge of the functions of bone, muscle, and skin, most do not appreciate the full range of activities carried out by these systems that are essential for their good health. For example, the abilities of skin to regulate body temperature and of bone to serve as a reservoir for important minerals are often overlooked.

The second objective is to provide students with an opportunity to practice and refine their critical-thinking skills. Such abilities are important not just for scientific pursuits, but for making decisions in everyday life. Our fast-changing world requires today's young people to be lifelong learners. They must be able to evaluate information from a variety of sources and assess its usefulness. They need to analyze information about diet, exercise, and environmental factors that influences the workings of their musculoskeletal and skin systems.

The third objective is to convey to students the purpose of scientific research. Ongoing research affects how we understand the world around us and gives us a foundation for improving our choices about personal health and the health of our community. In this module, students participate in a series of inquiry-based activities that help them construct their own understanding of the musculoskeletal and skin systems. The lessons encourage students to think about the relationships among knowledge, choice, behavior, and human health in this way:

Knowledge (what is known and not known) + Choice = Power

Power + Behavior = Enhanced Human Health

The final objective of the module is to encourage students to think in terms of these relationships now and as they grow older.

Why Teach the Module?

Middle school life science classes offer an ideal setting for integrating many areas of student interest. In this module, students participate in activities that integrate inquiry, biology, human

health, mathematics, and the interweaving of science, technology, and society. The real-life context of the module's classroom lessons is engaging, and the knowledge gained can be applied immediately to students' lives.

What's in It for the Teacher?

Looking Good, Feeling Good: From the Inside Out 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.
- The module has a Web-based **technology component** that includes interactive graphics, animations, and a database.
- The module includes built-in **assessment tools**, which are noted in each of the lessons with an assessment icon.

In addition, the module provides a means for **professional development**. Teachers can engage in new and different teaching practices such as those described in this module without completely overhauling their entire program. In *Designing Professional Development for Teachers of Science and Mathematics*, Susan Loucks-Horsley et al. write that replacement modules such as this one "offer a window through which teachers can get a glimpse of what new teaching strategies look like in action."[31] 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 module can encourage reflection and discussion and stimulate teachers to improve their practices by focusing on student learning through inquiry.

Correlation of *Looking Good, Feeling Good: From the Inside Out* to Middle School Life Science Topics

Topics	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7
Structure and function in living systems	✓	✓	✓				✓
Regulation and behavior		✓	✓	✓	✓	✓	✓
Human health and medicine		✓		✓	✓	✓	✓
Nature of science	✓	✓	✓	✓	✓	✓	✓
Relationship among science, technology, and society						✓	✓

Implementing the Module

The following table correlates topics often included in the middle school life science curriculum with the major concepts presented in this module. This information is presented to help teachers make decisions about incorporating this material into the curriculum. The seven lessons in this module are designed to be taught in sequence over seven to nine days (as a supplement to the standard curriculum) or as individual lessons that support or enhance your treatment of specific concepts in middle school science. The following pages offer general suggestions about using these materials in the classroom. You will find specific suggestions in the procedures provided for each lesson.

What Are the Goals of the Module?

Looking Good, Feeling Good: From the Inside Out is designed to help students achieve the following major goals associated with scientific literacy:

- to understand basic biology associated with the musculoskeletal and skin systems;
- to experience the process of scientific inquiry and develop an enhanced understanding of the nature and methods of science;
- to hone critical-thinking skills; and
- to recognize the role of science in society and the relationship between basic science and human health.

What Are the Science Concepts and How Are They Connected?

The lessons are organized into a conceptual framework that allows students to move from what they already know about the musculoskeletal and skin systems, some of which may be incorrect, to gaining a more complete and accurate perspective on these body systems. Students are engaged in the topic by considering the characteristics of living systems and how cells contribute to each type of body system (*It's Alive! Or Is It?*). Students then explore how the structure of bone relates to its function (*What Makes Bones Strong?*). The interaction of body systems, as between muscle and bone, is explored in a computer-based activity in Lesson 3 (*Anatomy of a Kick*). The next three lessons give students an opportunity to investigate how behaviors (such as exercise) and the environment (such as exposure to sunlight) influence body systems (*Use It or Lose it, Helping the Body Build Strong Bones, and Shining the Light on Skin*). Finally, in Lesson 7, *Decisions Today for a Healthy Tomorrow*, students reflect on what they have learned about each body system. They develop lifestyle recommendations for maintaining healthy body systems. The following table illustrates the scientific content and conceptual flow of the seven lessons.

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

NSES

Looking Good, Feeling Good: From the Inside Out supports teachers in their efforts to reform science education in the spirit of the National Research Council's 1996 *National Science Education Standards* (NSES). The content is explicitly standards based. Each time a standard is addressed in a lesson, an icon appears in the margin and the applicable standard is identified. The following table lists the specific content standards that this module addresses.

Science Content and Conceptual Flow of the Lessons

Lesson and Learning Focus*	Topics Covered and Major Concepts
1: *It's Alive! Or Is It?* ***Engage:*** Students become engaged in the study of the bone, muscle, and skin systems.	***Bone, muscle and skin are living systems.*** • They are composed of one or more cells. • They function according to a genetic blueprint. • They obtain and use energy. • They interact with their environment.
2: *What Makes Bones Strong?* ***Explore/Explain:*** Students consider the structure-function relationships of the body systems with an emphasis on bone.	***The components of bone include cells, minerals, and the protein collagen.*** ***The structure of a bone depends, in part, on minerals and collagen.*** ***The structure of a bone affects its strength.***
3: *Anatomy of a Kick* ***Explore/Explain:*** Students investigate how a series of muscle contractions produce the movements needed to kick a ball.	***Muscle and bone interact to produce movement.*** • Muscles attach to bone on both sides of the joint. • Muscles produce movement by contracting. • Opposing muscles are required to produce movement in opposite directions.
4: *Use It or Lose It* ***Explain/Elaborate:*** Students deepen their understanding of muscles by considering the impact of resistance training on muscle mass.	***Animals can be used as a model system to study muscles.*** ***Muscle mass increases with resistance training.*** ***Muscle mass decreases after resistance training ends.***
5: *Helping the Body Build Strong Bones* ***Explain/Elaborate:*** Students deepen their understanding of bone by considering the effects of diet and exercise on bone-mineral content.	***Diet and weight-bearing exercise are major influences on bone health.*** ***Increased bone-mineral content is associated with stronger, healthier bones.*** ***Different sports produce weight loading on different bones, leading to bone-specific changes in bone-mineral density.***
6: *Shining the Light on Skin* ***Explain/Elaborate:*** Students deepen their understanding of skin by using inexpensive UV monitors to determine levels of sun exposure. The effects of sun-blocking products also are investigated.	***The intensity of sunlight is influenced by the weather, location, and time at which measurements are made.*** ***Items designed to protect us from sun exposure vary in the amount of protection they provide.*** ***To protect their skin from damage, people should follow the shadow rule and seek shade if their shadows are shorter than their heights.***
7: *Decisions Today for a Healthy Tomorrow* ***Evaluate:*** Students reflect on what they learned during the module and use their knowledge to develop lifestyle recommendations for maintaining healthy body systems.	***Bone, muscle, and skin contain living cells.*** ***The structures of bone, muscle, and skin relate to their functions.*** ***Bone, muscle, and skin do not work in isolation but interact with other body systems.*** ***The health of the bone, muscle, and skin systems is influenced by many factors, including behaviors over which we have control.***

*See *How Does the 5E Instructional Model Promote Active, Collaborative, Inquiry-Based Learning?* on page 7.

Content Standards: Grades 5–8

Standard A: As a result of their activities in grades 5–8, all students should develop	**Correlation to *Looking Good, Feeling Good: From the Inside Out***
Abilities necessary to do scientific inquiry	
• Use appropriate tools and techniques to gather, analyze, and interpret data.	Lessons 2, 3, 4, 5, 6
• Develop descriptions, explanations, predictions, and models using evidence.	All lessons
• Think critically and logically to make the relationships between evidence and explanations.	Lessons 2, 3, 4, 5, 6
• Recognize and analyze alternative explanations and predictions.	Lessons 2, 3, 4, 5, 6
• Communicate scientific procedures and explanations.	Lessons 2, 6, 7
• Use mathematics in all aspects of scientific inquiry.	Lessons 4, 5, 6
Understandings about scientific inquiry	
• Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models.	All lessons
• Mathematics is important in all aspects of scientific inquiry.	Lessons 4, 5, 6
Standard C: As a result of their activities in grades 5–8, all students should develop an understanding of	
Structure and function in living systems	
• 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 lessons
• 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 that serve the organism as a whole.	Lessons 2, 3, 4, 5, 6
• The human organism has systems for digestion, respiration, reproduction, circulation, excretion, movement, control and coordination, and for protection from disease.	All lessons
Reproduction and heredity	
• Some traits are inherited and others result from interactions with the environment.	Lessons 1, 4, 5, 6
Regulation and behavior	
• Behavior is one kind of response an organism can make to an internal or environmental stimulus.	Lessons 4, 5, 6

Standard E: As a result of their activities in grades 5–8, all students should develop	
Understandings about science and technology	
• Science and technology are reciprocal. Science helps drive technology. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable.	Lessons 1, 2, 3, 6
Standard F: As a result of their activities in grades 5–8, all students should develop an understanding of	
Personal health	
• Regular exercise is important to the maintenance of and improvement of health. The benefits of physical fitness include maintaining healthy weight, having energy and strength for routine activities, good muscle tone, bone strength, strong heart-lung systems, and improved mental health. Personal exercise, especially developing cardiovascular endurance, is the foundation of physical fitness.	Lessons 3, 4, 5, 7
• The potential for accidents and the existence of hazards impose the need for injury prevention. Safe living involves the development and use of safety precautions and the recognition of risk in personal decisions.	Lessons 4, 5, 6, 7
Standard G: As a result of their activities in grades 5–8, all students should develop an understanding of	
Nature of science	
• Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models.	Lessons 4, 5, 6
• It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists.	Lesson 6

Teaching Standards

The suggested teaching strategies in all the lessons support teachers as they work to meet the teaching standards outlined in the *National Science Education Standards.* This module helps teachers of science plan an inquiry-based science program by providing short-term objectives for students. It also includes planning tools such as the Science Content and Conceptual Flow of the Lessons table and the Suggested Timeline table for teaching the module. Teachers can use this module to update their curriculum in response to their students' interest in this topic. The focus on active, collaborative, and inquiry-based learning in the lessons helps teachers support the development of student understanding and nurture a community of science learners.

The structure of the lessons in this module enables teachers to guide and facilitate learning. All of the activities encourage and support student inquiry, promote discourse among students, and challenge students to accept and share responsibility for their learning. The use of the 5E Instructional Model, combined with active, collaborative learning, allows teachers to respond effectively to the diversity of student backgrounds and learning styles. The module is fully annotated, with suggestions for how teachers can encourage and model the skills of scientific inquiry, as well as foster the curiosity,

skepticism, and openness to new ideas and data that characterize the study of science.

Assessment Standards

Teachers can engage in ongoing assessment of their teaching and of student learning using the variety of assessment components embedded within the module's structure. The assessment tasks are authentic; they are similar to tasks that students will engage in outside the classroom or to practices in which scientists participate. Annotations guide teachers to these opportunities for assessment and provide answers to questions that can help teachers analyze student feedback.

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

Because learning does not occur by way of passive absorption, the lessons in this module promote active learning. Students are involved in more than listening and reading. They are developing skills, analyzing and evaluating evidence, experiencing and discussing, and talking to their peers about their own understanding. Students work collaboratively with others to solve problems and plan investigations. Many students find that they learn better when they work with others in a collaborative environment than when they work alone in a competitive environment. When active, collaborative learning is directed toward scientific inquiry, students succeed in making their own discoveries. They ask questions, observe, analyze, explain, draw conclusions, and ask new questions. These inquiry-based experiences include both those that involve students in direct experimentation and those in which students develop explanations through critical and logical thinking.

The viewpoint that students are active thinkers who construct their own understanding from interactions with phenomena, the environment, and other individuals is based on the theory of **constructivism**. A constructivist view of learning recognizes that students need time to

- express their current thinking;
- interact with objects, organisms, substances, and equipment to develop a range of experiences on which to base their thinking;
- reflect on their thinking by writing and expressing themselves and comparing what they think with what others think; and
- make connections between their learning experiences and the real world.

This module provides a built-in structure for creating a constructivist classroom: the BSCS 5E Instructional Model. The model sequences the learning experiences so that students have the opportunity to construct their understanding of a concept over time. The model leads students through five phases of learning that are easily described using words that begin with the letter E: Engage, Explore, Explain, Elaborate, and Evaluate. The following paragraphs illustrate how the five Es are implemented across the lessons in this module.

Engage

Students come to learning situations with prior knowledge. This knowledge may or may not be congruent with the concepts presented in this module. The Engage lesson provides the opportunity for teachers to find out what students already know or think they know about the topic and concepts to be covered.

The Engage lesson in this module, Lesson 1: *It's Alive! Or Is It?*, is designed to

- pique students' curiosity and generate interest;
- determine students' current understanding about bone, muscle, and skin;
- invite students to raise their own questions about bone, muscle, and skin;
- encourage students to compare their ideas with those of others; and
- enable teachers to assess what students do or do not understand about the stated outcomes of the lesson.

Explore

In the Explore phase of the module, Lesson 2: *What Makes Bones Strong?*, students investigate

which characteristics of bone contribute to its strength. Students model bones of different compositions and analyze data about their strengths. This lesson provides a common set of experiences within which students can begin to construct their understanding. Students

- interact with materials and ideas through classroom and small group discussions;
- consider different ways to solve a problem or frame a question;
- acquire a common set of experiences with their classmates so that they can compare results and ideas;
- observe, describe, record, compare, and share their ideas and experiences; and
- express their developing understanding of the structure-function relationships in bone.

Explain

The Explain phase, Lessons 3 through 6, provides opportunities for students to connect their previous experiences and to begin to make conceptual sense of the main ideas of the module. This stage also allows for the introduction of formal language, scientific terms, and content information that might make students' previous experiences easier to describe and explain. The Explain lessons in this module encourage students to

- explain concepts and ideas (in their own words) about the functions, interactions among, and influences on the bone, muscle, and skin systems;
- listen to and compare the explanations of others with their own;
- become involved in student-to-student discourse in which they explain their thinking to others and debate their ideas;
- revise their ideas;
- record their ideas and current understanding;
- use labels, terminology, and formal language; and
- compare their current thinking with what they previously thought.

Elaborate

In the Elaborate phase, Lessons 5 and 6, students apply or extend previously introduced concepts in new situations and relate their previous experiences to new ones. In the Elaborate lessons in this module, students

- make conceptual connections between new and former experiences, connecting aspects of their experimental analyses with their concepts of bone, muscle, and skin;
- connect ideas, solve problems, and apply their understanding to a new situation;
- use scientific terms and descriptions;
- draw reasonable conclusions from evidence and data;
- add depth to their understanding of concepts and processes; and
- communicate their understanding to others.

Evaluate

The Evaluate lesson is the final stage of the Instructional Model, but it only provides a "snapshot" of what the students understand and how far they have come from where they began. In reality, the evaluation of students' conceptual understanding and ability to use skills begins with the Engage lesson and continues throughout each stage of the instructional model, as described in the following section. Combined with the students' written work and performance of tasks throughout the module, however, the Evaluate lesson can serve as a summative assessment of what students know and can do.

The Evaluate lesson in this module, Lesson 7: *Decisions Today for a Healthy Tomorrow*, provides an opportunity for students to

- demonstrate what they understand about bone, muscle, and skin and how well they can apply their knowledge to making recommendations for maintaining healthy body systems;
- share their current thinking with others;
- assess their own progress by comparing their current understanding with their prior knowledge; and
- ask questions that take them deeper into a concept.

To review the relationship of the 5E Instructional Model to the concepts presented in the module, see the table titled Science Content and Conceptual Flow of the Lessons, on page 4.

When a teacher uses the 5E Instructional Model, he or she engages in practices that are very different from those of a traditional teacher. In response, students also learn in ways that are different from those experienced in a traditional classroom. The tables on page 10 and 11, What the Teacher Does and What the Students Do, outline these differences.

How Does the Module Support Ongoing Assessment?

Because teachers will use this module in a variety of ways and at a variety of points in the curriculum, the most appropriate mechanism for assessing student learning is one that occurs informally at various points within the lessons, rather than just once at the end of the module. Accordingly, integrated within the lessons are specific assessment components. These "embedded" assessment opportunities include one or more of the following strategies:

- performance-based activities, such as creating graphs or participating in a discussion about risk assessment;
- oral presentations to the class, such as reporting experimental results; and
- written assignments, such as answering questions or writing about demonstrations.

These strategies allow the teacher to assess a variety of aspects of the learning process, such as students' prior knowledge and current understanding, problem-solving and critical-thinking skills, level of understanding of new information, communication skills, and ability to synthesize ideas and apply understanding to a new situation.

An assessment icon and an annotation that describes the aspect of learning that teachers can assess appear in the margin beside each step in which embedded assessment occurs.

How Can Teachers Promote Safety in the Science Classroom?

Even simple science demonstrations and investigations can be hazardous unless teachers and students know and follow safety precautions. Teachers are responsible for providing students with active instruction concerning their conduct and safety in the classroom. Posting rules in a classroom is not enough; teachers also need to provide adequate supervision and advance warning if there are dangers involved in the science investigation. By maintaining equipment in proper working order, teachers ensure a safe environment for students.

The following are important ways to implement and maintain a safety program:

- Provide eye protection for students, teachers, and visitors. Require that everyone participating wear regulation goggles in any situation where there might be splashes, spills, or spattering. Teachers should always wear goggles in such situations.
- Know and follow the state and district safety rules and policies. Be sure to fully explain to the students the safety rules they should use in the classroom.
- At the beginning of the school year, establish consequences for students who behave in an unsafe manner. Make these consequences clear to students.
- Do not overlook any violation of a safety practice, no matter how minor. If a rule is broken, take steps to ensure that the infraction will not occur a second time.
- Set a good example by observing all safety practices. This includes wearing eye protection during all investigations when eye protection is required for the students.
- Know and follow waste-disposal regulations.
- Be aware of students who have allergies or other medical conditions that might limit their ability to participate in activities. Consult with the school nurse or school administrator.
- Anticipate potential problems. When planning teacher demonstrations or student investigations, identify potential hazards

What the Teacher Does

Stage	That is *consistent* with the 5E Instructional Model	That is *inconsistent* with the 5E Instructional Model
Engage	• Piques students' curiosity and generates interest • Determines students' current understanding (prior knowledge) of a concept or idea • Invites students to express what they think • Invites students to raise their own questions	• Introduces vocabulary • Explains concepts • Provides definitions and answers • Provides closure • Discourages students' ideas and questions
Explore	• Encourages student-to-student interaction • Observes and listens to the students as they interact • Asks probing questions to help students make sense of their experiences • Provides time for students to puzzle through problems	• Provides answers • Proceeds too rapidly for students to make sense of their experiences • Provides closure • Tells the students that they are wrong • Gives information and facts that solve the problem • Leads the students step-by-step to a solution
Explain	• Encourages students to use their common experiences and data from the Engage and Explore lessons to develop explanations • Asks questions that help students express understanding and explanations • Requests justification (evidence) for students' explanations • Provides time for students to compare their ideas with those of others and perhaps to revise their thinking • Introduces terminology and alternative explanations after students express their ideas	• Neglects to solicit students' explanations • Ignores data and information students gathered from previous lessons • Dismisses students' ideas • Accepts explanations that are not supported by evidence • Introduces unrelated concepts or skills
Elaborate	• Focuses students' attention on conceptual connections between new and former experiences • Encourages students to use what they have learned to explain a new event or idea • Reinforces students' use of scientific terms and descriptions previously introduced • Asks questions that help students draw reasonable conclusions from evidence and data	• Neglects to help students connect new and former experiences • Provides definitive answers • Tells the students that they are wrong • Leads students step-by-step to a solution
Evaluate	• Observes and records as students demonstrate their understanding of the concept(s) and performance of skills • Provides time for students to compare their ideas with those of others and perhaps to revise their thinking • Interviews students as a means of assessing their developing understanding • Encourages students to assess their own progress	• Tests vocabulary words, terms, and isolated facts • Introduces new ideas or concepts • Creates ambiguity • Promotes open-ended discussion unrelated to the concept or skill

What the Students Do

Stage	That is *consistent* with the 5E Instructional Model	That is *inconsistent* with the 5E Instructional Model
Engage	• Become interested in and curious about the concept or topic • Express current understanding of a concept or idea • Raise questions such as, What do I already know about this? What do I want to know about this? How could I find out?	• Ask for the "right" answer • Offer the "right" answer • Insist on answers or explanations • Seek closure
Explore	• "Mess around" with materials and ideas • Conduct investigations in which they observe, describe, and record data • Try different ways to solve a problem or answer a question • Acquire a common set of experiences so they can compare results and ideas • Compare their ideas with those of others	• Let others do the thinking and exploring (passive involvement) • Work quietly with little or no interaction with others (only appropriate when exploring ideas or feelings) • Stop with one solution • Demand or seek closure
Explain	• Explain concepts and ideas in their own words • Base their explanations on evidence acquired during previous investigations • Record their ideas and current understanding • Reflect on and perhaps revise their ideas • Express their ideas using appropriate scientific language • Compare their ideas with what scientists know and understand	• Propose explanations from "thin air" with no relationship to previous experiences • Bring up irrelevant experiences and examples • Accept explanations without justification • Ignore or dismiss other plausible explanations • Propose explanations without evidence to support their ideas
Elaborate	• Make conceptual connections between new and former experiences • Use what they have learned to explain a new object, event, organism, or idea • Use scientific terms and descriptions • Draw reasonable conclusions from evidence and data • Communicate their understanding to others	• Ignore previous information or evidence • Draw conclusions from "thin air" • Use terminology inappropriately and without understanding
Evaluate	• Demonstrate what they understand about the concepts and how well they can implement a skill • Compare their current thinking with that of others and perhaps revise their ideas • Assess their own progress by comparing their current understanding with their prior knowledge • Ask new questions that take them deeper into a concept or topic area	• Disregard evidence or previously accepted explanations in drawing conclusions • Offer only yes-or-no answers or memorized definitions or explanations as answers • Fail to express satisfactory explanations in their own words • Introduce new, irrelevant topics

and safety concerns. Be aware of what might go wrong and what can be done to prevent the worst-case scenario. Before each activity, verbally alert the students to the potential hazards and distribute specific safety instructions as well.
- Supervise students at all times during a hands-on activity.
- Provide sufficient time for students to set up the equipment, perform the investigation, and properly clean up and store the materials after use.
- Never assume that students know or remember safety rules or practices from their previous science classes.

How Can Controversial Topics Be Handled in the Classroom?

Teachers sometimes feel that the discussion of values is inappropriate in the science classroom or that it detracts from the learning of "real" science. The lessons in this module, however, are based upon the conviction that there is much to be gained by involving students in analyzing issues of science, technology, and society. Society expects all citizens to participate in the democratic process, and our educational system must provide opportunities for students to learn to deal with contentious issues with civility, objectivity, and fairness. Likewise, students need to learn that science intersects with life in many ways.

In this module, students are given a variety of opportunities to discuss, interpret, and evaluate basic science and health issues, some in the light of their values and ethics. As students encounter issues about which they feel strongly, some discussions might become controversial. The degree of controversy will depend on many factors, such as how similar the students are with respect to socioeconomic status, perspectives, value systems, and religious preferences. In addition, the language and attitude of the teacher factor into the flow of ideas and the quality of exchange among the students.

The following guidelines may help teachers facilitate discussions that balance factual information with feelings:
- Remain neutral. Neutrality may be the single most important characteristic of a successful discussion facilitator.
- Encourage students to discover as much information about the issue as possible.
- Keep the discussion relevant and moving forward by questioning or posing appropriate problems or hypothetical situations. Encourage everyone to contribute, but do not force reluctant students to enter the discussion.
- Emphasize that everyone must be open to hearing and considering diverse views.
- Use unbiased questioning to help the students critically examine all views presented.
- Allow for the discussion of all feelings and opinions.
- Avoid seeking consensus on all issues. The multifaceted issues that the students discuss result in the presentation of divergent views, and students should learn that this is acceptable.
- Acknowledge all contributions in the same evenhanded manner. If a student seems to be saying something for its shock value, see whether other students recognize the inappropriate comment and invite them to respond.
- Create a sense of freedom in the classroom. Remind students, however, that freedom implies the responsibility to exercise that freedom in ways that generate positive results for all.
- Insist upon a non-hostile environment in the classroom. Remind students to respond to ideas instead of to the individuals presenting those ideas.
- Respect silence. Reflective discussions often are slow. If a teacher breaks the silence, students may allow the teacher to dominate the discussion.

- At the end of the discussion, ask the students to summarize the points that they and their classmates have made. Respect students regardless of their opinion about any controversial issue.

Animals as Research Models

Scientists often use animals in research to learn something about human biology. The animals serve as model systems for the human body. All mammals have a similar physiology, so in many cases, what is true for mice, rats, and goats is also true for humans. For example, in the study described in Lesson 4: *Use It or Lose It*, researchers removed specific muscles from the animal in order to weigh them and determine their mass. Obviously, this could not be done with humans.

When using animal models, scientists first must choose an animal appropriate to their research. Scientists studying genetics often use fruit flies (*Drosophila melanogaster*) because they have a short generation time. However, fruit flies are not a good model to use when investigating aspects of mammalian physiology. In such cases, a mouse or rat is preferred. Researchers can control the environments of the animals in ways that would not be possible with humans. Even the genetics of the animals can be standardized. Using the analogy of identical twins may help students appreciate this. By carefully selecting and breeding mice for many generations, scientists have produced genetically identical strains. All mice from the same strain can be considered identical twins of each other. Male and female mice differ only by those genes involved in determining their sex.

Animal models do have their drawbacks. Some animals are difficult or expensive to maintain. Consequently, many scientists try to develop non-animal models using cell cultures or computer simulations. Unfortunately, such models usually fail to duplicate the complexity of the animal or human body. Medical and scientific research will continue to depend on animal models for the foreseeable future.

Scientists who use animals as research subjects must abide by federal policies. Public Health Service policy dictates specific requirements for animal care and use in research. This policy conforms to the Health Research Extension Act of 1985 (Public Law 99-158) and applies to all research, research training, biological testing, and other activities that involve animals. The principles for using and caring for vertebrate animals in research and testing include the following:

- The transportation, care, and use of animals should be in accordance with the Animal Welfare Act and other applicable federal laws, guidelines, and policies.
- Procedures involving animals should be designed with consideration of their relevance to human or animal health, the advancement of knowledge, or the good of society.
- The animals selected should be of an appropriate species and quality and the minimum number required to obtain valid results. Methods such as mathematical models, computer simulations, and in vitro biological systems should be considered.
- Procedures should minimize discomfort, distress, and pain to the animals.
- Procedures that may cause more than momentary or slight pain should be performed with appropriate sedation, analgesia, or anesthesia.
- Animals that would suffer severe or chronic pain or distress that cannot be relieved should be painlessly killed.
- The living conditions of animals should be appropriate for the species. The housing, feeding, and care of animals must be directed by a veterinarian or a trained, experienced scientist.
- Investigators who work with animals must be appropriately qualified and trained for conducting procedures on living animals.
- Exceptions to any of these principles must be reviewed and approved by an appropriate committee prior to the procedure.

- An Institutional Animal Care and Use Committee (IACUC) oversees all animal use in each institution where animal research is conducted. The IACUC must approve the research plan and species to be used. IACUCs include scientists and nonscientists from outside the institution. Nonscientists are often representatives of humane organizations.

Using the Student Lessons

The heart of this module is the set of seven classroom lessons. These lessons are the vehicles that will carry important concepts related to the bone, muscle, and skin systems to your students. To review the concepts in detail, refer to the table Science Content and Conceptual Flow of the Lessons, on page 000.

Format of the Lessons

As you scan the lessons, you will find that each contains several major features.

At a Glance provides a convenient summary of the lesson.

- The **Overview** provides a short summary of student activities.
- The **Major Concepts** section states the central ideas the lesson is designed to convey.
- **Objectives** lists specific understandings or abilities students should have after completing the lesson.
- **Teacher Background** specifies which portions of the background section titled *Information about the Musculoskeletal and Skin Systems* relate directly to the student lesson. This reading material provides the science content that underlies the key concepts covered in the lesson. The information provided is not intended to form the basis of lectures to students. Instead, it enhances your understanding of the content so that you can more accurately facilitate class discussions, answer student questions, and provide additional examples.

In Advance provides instructions for collecting and preparing the materials required to complete the activities in the lesson.

- **Web-Based Activities** tells you which of the lesson's activities use the *Looking Good, Feeling Good: From the Inside Out* Web site as the basis for instruction.
- **Photocopies** lists the paper copies and transparencies that need to be made from masters, which follow Lesson 7.
- **Materials** lists all the materials other than photocopies needed for each of the activities in the lesson.
- **Preparation** outlines tasks you need to do before you teach the lesson.

Procedure outlines the steps in each activity of the lesson. It provides implementation hints and answers to discussion questions. Within the procedure, annotations, with their easy-to-spot icons, provide additional commentary:

identifies where assessments are embedded in the module's structure. An annotation suggests strategies for assessment.

identifies teaching strategies that address specific science content standards as defined by the National Science Education Standards.

identifies when to use the Web site as part of the teaching strategy. Instructions tell you how to access the Web site and the relevant activity. Information about using the Web site can be found in Using the Web Site (see page 17). A print-based alternative to Web activities is provided in the event that computers with Internet access are not available.

identifies suggestions from field-test teachers for teaching strategies, class management, and module implementation.

identifies a print-based alternative to a Web-based activity to be used when computers are not available.

The **Lesson Organizer** provides a brief summary of the lesson. It outlines procedural steps for each activity and includes icons that denote where in each activity masters, transparencies, and the Web site are used. The lesson organizer is intended to be a memory aid for you to use only after you become familiar with the detailed procedures for the activities. It can be a handy resource during lesson preparation as well as during classroom instruction.

The **Masters** are found after Lesson 7, at the end of the module.

Timeline for the Module

The following timeline outlines the optimal plan for completing the seven lessons in this module. This schedule assumes that you will teach the activities on consecutive school days. If your class requires more time for completing the procedures, for discussion of issues raised in this module, or for completing activities on the Web site, adjust your timeline accordingly

Suggested Timeline

Timeline	Activity
3 weeks ahead	Reserve computers and verify Internet access Download required plug-ins
1 week ahead	Copy masters, make transparencies, gather materials
Day 1 Monday	**Lesson 1** Activity 1: *It's Alive! Or Is It?*
Day 2 Tuesday	**Lesson 2** Activity 1: *What Makes Bones Strong?*
Day 3 Wednesday	**Lesson 3** Activity 1: *Anatomy of a Kick*
Day 4 Thursday	**Lesson 4** Activity 1: *Use It or Lose It*
Day 5 Friday	**Lesson 5** Activity 1: *Got Milk?* Activity 2: *Is All Exercise the Same?*
Day 6 Monday	**Lesson 6** Activity 1: *Measuring Sunlight*
Day 7 Tuesday	**Lesson 6** Activity 2: *Be Prepared!*
Day 8 Wednesday	**Lesson 7** Activity 1: *Decisions Today for a Healthy Tomorrow*

Using the Web Site

The Web site for *Looking Good, Feeling Good: From the Inside Out* is a wonderful tool that can help you organize your use of the module, engage student interest in learning, and orchestrate and individualize instruction. The Web site features animations and an interactive database that complement Lesson 3, *Anatomy of a Kick*, and Lesson 6, *Shining the Light on Skin*. To access the Web site, type the following URL into your browser: *http://science.education.nih.gov/supplements/bone/teacher.* Click on the link to a specific lesson under *Web Portion of Student Activities*. If you do not have computer or Internet access, you can use the print-based alternative provided for each Web activity except for Activity 1 in Lesson 6. Text pertaining only to Web-based activities is lightly shaded.

Hardware/Software Requirements

The Web site can be accessed from Apple Macintosh and IBM-compatible personal computers. Links to download the Macromedia Flash and QuickTime Player plug-ins are provided on the Web site's Getting Started page. *These plug-ins are required for the activities to function properly.* The recommended hardware and software requirements for using the Web site are listed in the table below. Although your computer configuration may differ from those listed, the Web site may still be functional on your computer. The most important items in this list are current browsers and plug-ins; older versions may not work satisfactorily.

Downloading and Installing Macromedia Flash Player

To experience full functionality of the Web site, Macromedia Flash Player, version 6.0 or higher, must be downloaded and installed on the hard drive of each computer that will be used to access the site. The procedure for downloading and installing Macromedia Flash Player is outlined here:

Recommended Hardware/Software Requirements for Using the Web Site*

CPU/processor (PC Intel, Mac)	Pentium III, 600 MHz; or Mac G4
Operating system (DOS/Windows, Mac OS)	Windows 2000 or higher; or Mac OS 9 or newer
System memory (RAM)	256 MB
Screen display	1024 × 768, 16 bit (65K colors)
Browser	Microsoft Internet Explorer 6.0 or Netscape Communicator 7.1 and higher
Browser settings	Fonts, JavaScript, and Java
Free hard-drive space	5 MB
Connection speed	56 kbps modem or high-speed Internet connection
Plug-ins, installed for your Web browser	Macromedia Flash Player (version 6.0 or better); or Apple QuickTime Player (version 6 or better)
Audio	Sound card with speakers
Video	No

* For users of screen-reader software, a multichannel sound card such as Sound Blaster® Live!™ is recommended.

- Open a Web browser.
- Access the main page of the Web site at *http://science.education.nih.gov/supplements/bones/teacher.*
- Click on "Getting Started" toward the top of the page. This will open up a page of information on system requirements for the module.
- Scroll down to the "Recommended Setup" section and click on the "Macromedia Flash" link. This will bring up the Macromedia Flash Player Download Center Web site.
- The Download Center Web site should present you with the option of installing the latest version (highest number) of Macromedia Flash Player. As of August 2005, this should be at least version 8.0.
- Click on the button marked "Download Now." Clicking this button will allow Macromedia's Web site to download and install Flash Player on your computer's hard drive.
- Your Web browser may present you with a security dialog box asking if you would like to install and run Macromedia Flash Player. Click "Yes."
- After a minute or so, you should once again see the Macromedia Download Center Web page on your browser. There will be a box toward the top of the page containing clickable text. The appearance of this box in your browser window indicates that you have successfully downloaded and installed Macromedia Flash Player.

Getting the Most out of the Web Site

Before you use the Web site, or any other piece of instructional software in your classroom, it may be valuable to identify some of the benefits you expect the software to provide. Well-designed instructional multimedia software can

- motivate students by helping them enjoy learning and want to learn more because it enlivens content that students otherwise might find uninteresting,
- offer unique instructional capabilities that allow students to explore topics in greater depth and in ways that are closer to real-life experiences than print-based resources can offer,
- provide teachers with support for experimenting with new instructional approaches that allow students to work independently or in small teams and that give teachers increased credibility among today's technology-literate students, and
- increase teacher productivity by helping teachers with assessment, record keeping, and classroom planning and management.

The ideal use of the Web site requires one computer for each student team. However, if you have only one computer available in the classroom, you can still use the Web site (for example, by using a suitable device for projecting the screen image, or by rotating student teams through the computer station).

Collaborative Groups

Many of the activities in the lessons are designed to be completed by teams of students working together. Although individual students working alone can complete these activities, this strategy will not stimulate the types of student-student interactions that are part of active, collaborative, inquiry-based learning. Therefore, we recommend that you organize collaborative teams of two to four students each, depending on the number of computers available. Students in groups larger than this will have difficulty organizing the student-computer interactions equitably, which can lead to one or two students assuming the primary responsibility for the computer-based work. Although this type of arrangement can be efficient, it means that some students will not have the opportunity to experience the in-depth discovery and analysis that the Web site was designed to stimulate.

We recommend that you keep students in the same collaborative teams for all the activities

in the lessons. This will allow each team to develop a shared experience with the Web site and with the ideas and issues that the activities present. A shared experience will also enhance your students' perceptions of the lessons as a conceptual whole.

If your student-to-computer ratio is greater than four to one, you will need to change the way you teach the module from the instructions in the lessons. For example, if you have only one computer available, you may want students to complete the Web-based work over an extended time period. You can do this several ways. The most practical way is to use your computer as a center along with several other centers at which students complete other activities. In this approach, students rotate through the computer center, eventually completing the Web-based work you have assigned.

A second way to structure the lessons if you have only one computer available is to use a projection system to display the desktop screen for the whole class to view. Giving selected students in the class the opportunity to manipulate the Web activities in response to suggestions from the class can give students some of the same autonomy in their learning they would have gained from working in small teams.

Web Activities for Students with Disabilities

The Office of Science Education (OSE) is committed to providing access to the Curriculum Supplement Series for individuals with disabilities, including members of the public and federal employees. To meet this commitment, we will comply with the requirements of Section 508 of the Rehabilitation Act. Section 508 requires that individuals with disabilities who are members of the public seeking these materials will have access to and use of information and data that are comparable to those provided to members of the public who are not individuals with disabilities. The online versions of this series have been prepared to comply with Section 508.

If you use assistive technology (such as a Braille reader or a screen reader) and the format of any materials on our Web site interferes with your ability to access the information, please let us know. To enable us to respond in a manner most helpful to you, please indicate the nature

Looking Good, Feeling Good: From the Inside Out 508-Compliant Web Activities

Lesson, activity	For students with hearing impairment	For students with sight impairment
Lesson 3, Activity 1: *Anatomy of a Kick*	No special considerations are required.	Students using screen-magnification or screen-reading software can choose an alternate, text-based version of the activity. The content of the two versions of the activity is equivalent. The "Progress Map" at the bottom of each page keeps track of the student's progress. If the student closes the activity and returns to it later, the activity will resume where the student left it. The last page of the activity provides a summary of all the student's answers. The student can use the Progress Map to return to any page and edit his or her responses. The computer the students use must be connected to the Internet. Supervision is recommended.
Lesson 6, Activity 1: *Measuring Sunlight*	No special considerations are required.	The tabular report data entered have been designed to be accessible with a screen reader. No adjustment to the procedure is necessary.

of the problem, the format in which you would like to receive the material, the Web address of the requested material, and your contact information.

Contact us at

Curriculum Supplement Series
Office of Science Education
National Institutes of Health
6705 Rockledge Drive, Suite 700 MSC 7984
Bethesda, MD 20892-7984
supplements@science.education.nih.gov

Information about the Musculoskeletal and Skin Systems

1 Introduction

Adolescents, and many adults, take the health of their bone, muscle, and skin for granted. Only when there is a problem such as a broken bone, a muscle sprain, or a skin blemish (especially before an important event) do people think about these vital body systems. Health problems that affect bone, muscle, and skin are common. In fact, muscle and bone problems have prompted the World Health Organization to declare the years 2000–2010 the Bone and Joint Decade. Thirty-eight nations, including the United States, have endorsed this initiative.[13,14] The goals of the United States Bone and Joint Decade include an increased awareness of the burden of musculoskeletal disorders on society; the use of educational programs to promote prevention of these disorders; continuing research into the prevention, diagnosis, and treatment of musculoskeletal disorders; and improved treatment.

This section provides an introduction to the musculoskeletal and skin systems, including their involvement both in maintenance of good health and their dysfunction in disease. As such, it uses language and concepts not appropriate for middle school students. Our intention is to give you enough background that you will be able to assess your students' understanding of the topic and be equipped to answer their most common questions.

The musculoskeletal and skin systems and their functions are topics that are extremely well suited for middle school students. As stated in the *National Science Education Standards (NSES)*, topics related to human biology are especially relevant to middle school students because students at this point in cognitive development begin to understand the relationship between structure and function.[47] Middle school students are inherently interested in human biology because of the developmental changes they are experiencing. Students can integrate structure-function relationships in the context of human body systems working together.

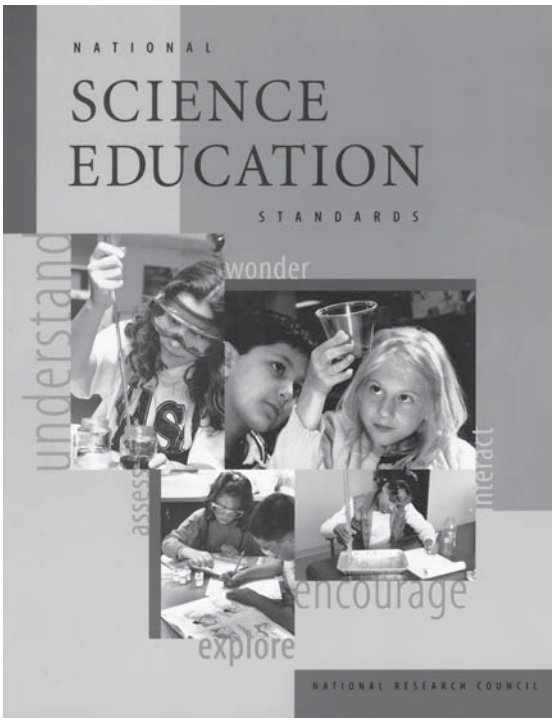


Figure 1. Looking Good, Feeling Good: From the Inside Out *addresses content and personal health standards from the* National Science Education Standards.

In this module, students learn that their bones, muscles, and skin fulfill many roles that enable a person to complete complex voluntary

tasks as well as involuntary actions that are essential to health. The information about the musculoskeletal and skin systems will also help students achieve the content standards related to Life Science, particularly concepts related to the structure and function of living systems. In addition, this module addresses standards related to Science in Personal and Social Perspectives (personal health). The concepts conveyed will also address several of the National Health Education Standards.

2 Misconceptions about the Musculoskeletal and Skin Systems

Adolescents, like many adults, have perceptions about their musculoskeletal and skin systems that are likely to be incorrect or incomplete. Almost every day, people are exposed to material on television or radio or in the newspapers about a new medicine, exercise, treatment, product, or diet that can influence their health. For example, advertisements promote "nutritional supplements" that will build muscle without exercise or dieting. Adolescents hear, see, or read about many over-the-counter treatments for acne—a condition about which they are especially aware because of their age. Many teenagers will try these products in search of help. Teenagers also receive inaccurate information about acne from peers or family members who believe that acne is caused by eating chocolate or other sweets. In addition, pharmaceutical companies often advertise prescription medications that are used to prevent disease. Although these medications can be valuable when used correctly, the advertisements do not give a complete picture.

Generally, science textbooks for middle school students present limited scientific information on the musculoskeletal and skin systems. As part of the presentation on the major body systems, science textbooks include a diagram of each of these systems with the parts labeled and some cursory information about their functions. Too often, however, this information becomes a vocabulary exercise without conveying any real understanding of how these systems work or regulate a vast array of physiological processes.

Some misconceptions about the musculoskeletal and skin systems are the following:

Misconception 1: Muscles are only used for voluntary physical actions like walking, running, or throwing. Skeletal muscles are probably most familiar to middle school students even though other types of muscles, cardiac and smooth, are essential for life functions. The heart muscle is composed of a different type of muscle cell (cardiac muscle cells) and beats to move blood throughout the body. Smooth muscle cells line blood vessels and the intestinal tract to help move blood or food through those passages. The tongue is made up of muscle cells that enable us to speak and is also an important part of the digestive system.

Misconception 2: Your muscles turn to fat if you quit exercising. Misconception 2 is common not only among adolescents but also among adults and reflects a basic misunderstanding of how the body works. If a person stops exercising, his or her muscle cells may decrease in volume and become smaller. At the same time, a person may increase the volume of fat cells in his or her body. This concurrent change may give the impression that muscle is becoming fat, but this is not the case.

Fat cells are different from muscle cells; muscle cells do not turn into fat.

Misconception 3: Bones are not living structures. Adolescents may have conflicting ideas about whether bones are living structures, depending upon the context of the situation they are considering. On the one hand, they may believe that bones are just hard things that hold the body up and have muscles attached to them. On the other hand, teenagers recognize that broken bones heal. Few students have an understanding of how their bones grow during development or recognize that the **bone marrow** is critical for production of both red and white blood cells. Even maintenance of bone structure is a dynamic process; the action of specialized cells called **osteoblasts** to form new bone is counterbalanced by other cells, **osteoclasts**,

which break down bone through resorption. As people age, bone resorption predominates over bone formation.[15]

Misconception 4: Diseases like osteoporosis or arthritis affect only old people, so teenagers do not need to be concerned about them. Although osteoporosis, a disease in which bone density decreases, affects older individuals, scientists now realize that it is important for young people to take care of their bones because this can influence the onset of osteoporosis in later life.[29,52] Exercise, including resistance and high-impact exercise, and good nutrition, including adequate **calcium** intake (1,300 milligrams per day for children ages 9 to 18), are important for optimal bone health.[3,41]

Misconception 5: Acne is caused by eating chocolate or greasy foods. The exact cause of acne is not known. This incomplete understanding has allowed many myths about the causes of acne to become widespread. There is little evidence that diet causes or affects the course of acne. Rather, acne is caused by a number of interacting factors. One important factor is the increase in male hormones (androgens) that accompanies puberty in both boys and girls. Nearly 85 percent of adolescents and young adults develop acne. Since acne seems to run in families, it is thought to have a genetic component as well. Although the causes of acne are unclear, several factors have been shown to exacerbate the disorder. These include changing hormone levels in females (as before their menstrual periods), friction caused by rubbing the skin, irritants such as pollution, squeezing of the lesions, and vigorous scrubbing of the skin.[43]

Misconception 6: Body piercings and tattoos are completely safe. Body modifications involve breaking the skin, and consequently, carry a risk of infection. People with tattoos are nine times more likely to be infected with the hepatitis C virus than are people without tattoos.[35] The American Red Cross prevents people from donating blood for one year after they get a tattoo, body piercing, or acupuncture treatments.[9]

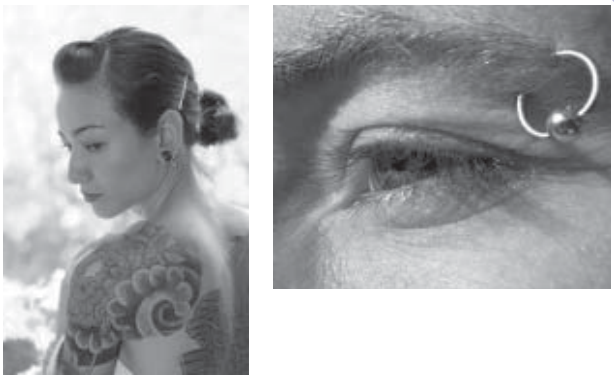


Figure 2. *Tattoos and body piercings involve breaking the skin and therefore carry a risk of infection.*

There are health risks associated with body piercings and tattoos. Anyone considering undergoing these procedures should first research them, be aware of the health risks, find a provider who performs the procedure correctly, and use proper follow-up care.

3 Characteristics of Living and Nonliving Systems

It should be simple to distinguish between living and nonliving systems. After all, even children know that a rock is nonliving and a spider is a living creature. However, defining life is not a trivial task. Life has been defined in many ways for many different purposes, and there is no single definition that works for everyone. The Characteristics of Living Systems table lists some characteristics that are commonly found in definitions of living systems.

Characteristics of Living Systems

Composed of one or more cells
Function according to a genetic blueprint
Obtain and generate energy (that is, have a metabolism)
Interact with their environment

These characteristics were derived with the following in mind:

- they are simple and basic, with very few exceptions;
- they provide conditions sufficient to determine whether something is living or not;
- they are consistent with common usage and when applied to simple examples, allow those examples to be classified in the same way.

Some objects that are clearly nonliving are derived from once-living systems, however. A lump of coal is largely made up of material from plants that lived millions of years ago.

The ability to reproduce is often identified as a characteristic of living systems. This characteristic is not listed separately because bone, muscle, and skin are living systems, but they do not reproduce themselves. The cells of bone reproduce and carry out activities (such as making protein and depositing mineral) that allow bone to grow, repair, and remodel itself. Bone cells do not reproduce and make new bones. In the Characteristics of Living Systems table, reproduction falls under the characteristic "function according to a genetic blueprint."

Although a single-celled organism such as an amoeba is classified as living, the situation in multicellular organisms such as humans is more complicated. As with the amoeba, we can classify a human as living. Indeed, close examination of the human body reveals that it is composed of living cells, cells that were once living, and nonliving substances produced by living cells. These distinctions become important as we investigate the structures and functions of bone, muscle, and skin.

4 Characteristics of Bone, Muscle, and Skin

Human development is a complex process that begins with a fertilized egg cell and eventually gives rise to an adult human composed of over 100 trillion cells.[30] As development proceeds, cells begin to take on specialized roles that remain stable throughout the life of the individual. Cells with the same function may group together in specific ways to form a colony of cells called a **tissue**. An adult human makes use of over 200 different tissues.[60] One or more tissues may work together to form one of the body's **organs**. As the number of cells in the developing human increases, the fate of the individual cells becomes evermore restricted. This process by which a cell becomes committed to a specific function is called **differentiation**.

Just as the human body has different organs that carry out specific functions, the human cell has different organelles that have specialized functions. All human cells share certain characteristics. They

- possess a plasma membrane that separates their inside contents from the outside environment,
- enclose their genetic material inside a membrane-bound organelle called a nucleus,
- generate usable energy within organelles called mitochondria, and
- synthesize proteins using ribosomes.

Despite these similarities, differentiation produces cells that differ in significant ways from one another. The shapes of different cells relate to their functions within the body. For example, nerve cells have many long branches that enable them to communicate with each other and with other cells. Even the presence or absence of a critical organelle, such as the nucleus, can vary by cell type. A mature red blood cell has no nucleus, while a mature skeletal muscle cell has many nuclei derived from cells that have fused together. We shall learn in the following sections how the cells of the musculoskeletal and skin systems have characteristic shapes that relate to their functions and how they combine to form specialized tissues.

4.1 Bone

Bones serve many important functions. They allow us to do things we take for granted, such as stand and sit, walk and run. They do this in concert with muscles, which attach to bones via **tendons**. Our bones provide structural support for the body and help determine our shape. Bones also protect internal organs (the skull protects the brain, and the ribs protect the heart and lungs), and the bone marrow produces red blood cells and the white blood cells of the immune system. Bones are lightweight yet very strong, static in appearance yet very dynamic. How does the structure of bones determine how they function in the body?

Our skeletal system serves as a storage depot for calcium and other physiologically important ions.

Bones have a unique structure. The human skeleton has 206 bones of different sizes and shapes. Bones such as those in the arms and legs are called long bones. Others, such as those in the skull, are called flat bones. Other categories include the short bones (for instance, the carpel bones of wrist) and the irregular bones (for instance, vertebrae). In general, adult human bones are composed of about 70 percent minerals and 30 percent organic matter.[20] The minerals are primarily a crystalline complex of calcium and phosphate called hydroxyapatite, while 90 to 95 percent of the organic matter is the protein collagen. The remainder of the organic matter consists of a gelatinous medium called **ground substance**, which contains extracellular fluid and specialized proteins called **proteoglycans**. How these organic and inorganic materials are put together to form the strong unit we call bone is discussed in section 4.1.3., *Bone Formation*.

Looking at a cross section of a long bone, one sees an inner cavity surrounded by an outer fibrous matrix. The inner cavity contains bone marrow, which consists of fatty tissue and cells that give rise to the red and white blood cells that circulate in the body. The bone matrix contains hydroxyapatite and calcium salts deposited in a network of collagen fibers. On the outside of the bone is a fibrous layer called the periosteum (Figure 3).

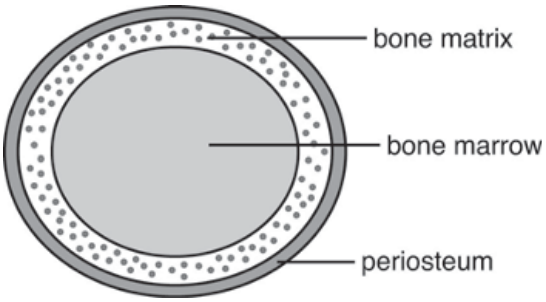


Figure 3. *Cross section of a bone.*

A closer look reveals more details. There are two forms of bone—compact (hard) bone, the solid, hard outside part of bone that is optimized to handle compressive and bending forces, and spongy (cancellous) bone, which is found inside the compact bone and near the ends of the bone. Blood vessels are also present and allow nutrients to be brought to bone cells and waste products to be carried away. Blood vessels and nerves pass through narrow openings, or canals, that run parallel to the surface and along the long axis of the bone.

Bone contains three specialized cell types. The name of each begins with *osteo*, since this is the Greek word for bone. Osteoblasts are cells that form new bone. They are found on the surface of new bone and they have a single nucleus (Figure 4). They are derived from stem cells in the bone marrow. Osteoblasts produce collagen found in bone and the proteoglycans found in ground substance. They are rich in alkaline phosphatase, a phosphate-splitting enzyme required for bone mineralization, a process that osteoblasts control. When osteoblasts have completed making new bone, the cells take on a flattened appearance and line the surface of the bone. Now in a more mature, less active

state, the cells are called bone-lining cells. They still serve important functions, however. For instance, bone-lining cells respond to specific hormones and produce proteins that activate another type of bone cell called the osteoclast.

Osteoclasts are large, multinucleated cells that are capable of movement. They are formed by the fusion of mononuclear cells derived from stem cells in the bone marrow. Unlike osteoblasts, osteoclasts lie in depressions where their function is to dissolve (resorb) bone and help shape it (Figure 4). They begin by attacking the mineral portion of bone and then they degrade the bone proteins.

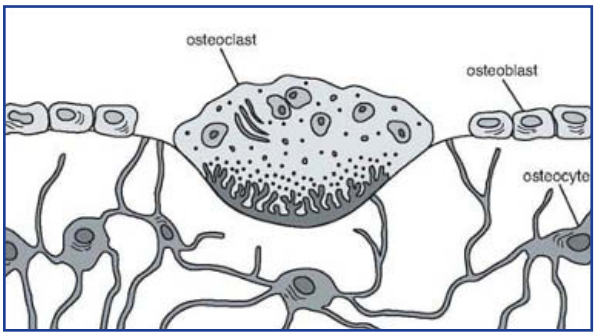


Figure 4. *An osteoclast, osteoblasts, and osteocytes (across the bottom).*

Osteocytes are cells that reside inside bone. They are derived from osteoblasts as new bone is being formed and then become surrounded by the new bone. However, rather than being isolated, osteocytes communicate through long branches that connect these cells to one another. These cells regulate the response of bone to its mechanical environment.[53] Osteocytes sense pressures or cracks in bone and help direct osteoclasts to locations where bone will be remodeled.

Bone formation involves an organic matrix. To understand how bone is formed and why its properties confer such strength, imagine that you have steel rods and cement that you will use to construct a wall or a bridge. Pouring cement around steel rods placed in a suitable frame produces a material (reinforced concrete) that is stronger and more capable of withstanding movement than either steel rods or cement alone. Bone has a similar organization. The steel rods are chains of collagen, which confer resiliency, and the cement is **hydroxyapatite**, which confers strength.

Bone formation begins with synthesis of the organic matrix by osteoblasts. The matrix can be likened to a protein scaffolding. Next, through a mechanism not yet understood, osteoblasts deposit mineral crystals in the spaces between the protein scaffolding. The mineral consists primarily of calcium and phosphorus. Finally, osteoclasts work with osteocytes to shape or remodel the bone by breaking down the proteins and resorbing the minerals. Bone formation is not a strictly linear process, however. Bones are constantly being formed, broken down, and re-formed. Bone is a very dynamic, continually changing tissue. Osteoblasts, osteoclasts, and osteocytes function to maintain a balance between bone deposition and bone resorption that allows bones to grow, repair themselves, and remain strong.

The activity of osteoblasts and osteoclasts is influenced by a number of factors. **Vitamin D** helps the intestine absorb calcium from foods into the bloodstream after digestion. It is also important in regulating phosphate in the body (see also section 5.2, *Vitamin D*).[23] Additionally, when blood-calcium levels are low, the parathyroid glands release parathyroid hormone into the blood. Parathyroid hormone activates the osteoclasts, thereby increasing the rate of bone breakdown. Other factors that regulate the dynamic balance between bone deposition and bone breakdown include growth factors and hormones. Importantly, exercise is an important factor in normal bone growth and development. Also, the composition of bone mineral is not fixed. Other ions, if present, can be incorporated into new or remodeled bone. Fluoride, for example, can be incorporated into bone mineral to form **fluorapatite**, which is harder, less soluble, and more resistant to resorption than is hydroxyapatite.

Bones grow as we grow. This is no surprise. In fact, more bone is formed during the first 20

to 30 years of life than is resorbed, resulting in an increase in bone mass. However, contrary to what some might think, long bones do not grow (or elongate) from the middle, a region called the **diaphysis**. Rather, the bones grow from their ends, regions called the **epiphyses** (singular is epiphysis).

Cartilage is a connective tissue specialized to handle mechanical stress without becoming distorted permanently. It is found in areas where shock-absorbing properties are needed or where smooth movement between bones (that is, at a **joint**) is required. As bones grow, additional cartilage is deposited at the epiphyseal, or growth, plate. This cartilage is the framework on which bone matrix is deposited. Bone growth continues as long as the growth plates are able to produce **chondrocytes** (cartilage-producing cells). The growth plate determines the length and shape of the mature bone and is the weakest part of the growing skeleton. The growth plate can be injured (fractured) during an acute incident, such as a fall, or from overuse, such as during intense sports training.[2] If untreated, some growth plate fractures can lead to permanent damage and can cause bone growth to stop prematurely.[44]

Hormones are responsible for the cessation of growth. At the end of puberty, high levels of estrogen or testosterone cause the chondrocytes to die, and they are replaced by bone. It is during late adolescence that humans achieve their peak bone mass.[33] Over the next 30 or more years, the human adult skeleton is maintained by precisely balanced bone formation and bone resorption.[49] Sometime after humans reach their 60s, bone mass begins to decrease because new bone formation can no longer keep pace with bone resorption.

Adequate calcium intake during teen years, when bone formation is very active, is an important factor in preventing excessive bone resorption later in life.

4.2 Muscle

Muscle is the most abundant tissue in most animals. In vertebrates, such as humans, there are different types of muscle, and each has a unique cellular structure and function. Skeletal muscle enables us to walk, run, lift, or do other physical movements. It enables people to maintain their body posture. Skeletal muscle is also referred to as striated muscle because the arrangement of muscle fibers has a striped (striated) appearance when viewed under a microscope. Smooth muscle is found in the walls of the stomach and intestines, the urinary bladder, the bronchi of the lungs, and the arterial blood vessels. It functions to propel substances along their tracts within the body. Smooth muscle lacks striations and is composed of cells that are spindle shaped. A third type of muscle, cardiac muscle, makes up the heart and pumps blood throughout the body. As the name implies, skeletal muscle is intimately associated with the skeletal system, and for this reason, this module focuses on skeletal muscle and does not discuss cardiac and smooth muscle. Unless otherwise noted, the term *muscle* refers to skeletal muscle from this point on.

During human development, the differentiation of the muscle system is essentially complete just 8 weeks after fertilization. The first cells committed to form muscle in the developing embryo are called **myoblasts**. Some myoblasts divide rapidly, while others migrate to areas where muscle tissue needs to form, such as the developing limb buds. Once myoblasts arrive at their needed location, they stop cell division and begin to fuse together with adjoining myoblasts. The results of this cell fusion create a larger cell with many nuclei that share the same cytoplasm. These multinucleated cells continue to differentiate into a **myotube**, which is the basic structural cell of muscle tissue.

The most essential feature of muscle cells is their ability to generate force by contracting, or shortening—a function unlike that of other types of cells. In skeletal muscle, numerous myotubes bundle together to form a muscle. Within each myotube are thin and thick

filaments. Under the microscope, the regular arrangement of these filaments accounts for the alternating light and dark bands seen in the tissue. The functional unit of the muscle is called the **sarcomere**. Each sarcomere has a dark Z line at each end. By examining the structure of the sarcomere, we can begin to appreciate how a muscle cell is able to contract and exert force on the skeletal system.

When researchers observed muscle contraction under the microscope, they noticed that the sarcomere shortened, that is, the Z lines moved closer together. This observation suggested that muscle contraction proceeds by having thin and thick filaments slide past each other, shortening the sarcomere.

This process is described by the **sliding-filament model** of muscle contraction (Figure 5). According to this model, the lengths of the thin and thick filaments do not change. Rather, the extent to which they overlap changes. As the amount of overlap between the thin and thick filaments increases, the length of the sarcomere decreases. **Thin filaments** are made of a protein called **actin**, and **thick filaments** are made of a protein called **myosin**. The myosin molecule has a long "tail" region with a protruding "head" at one end. The myosin head provides the energy needed to move the filaments past each other by breaking down the high-energy molecule ATP into ADP and inorganic phosphate.

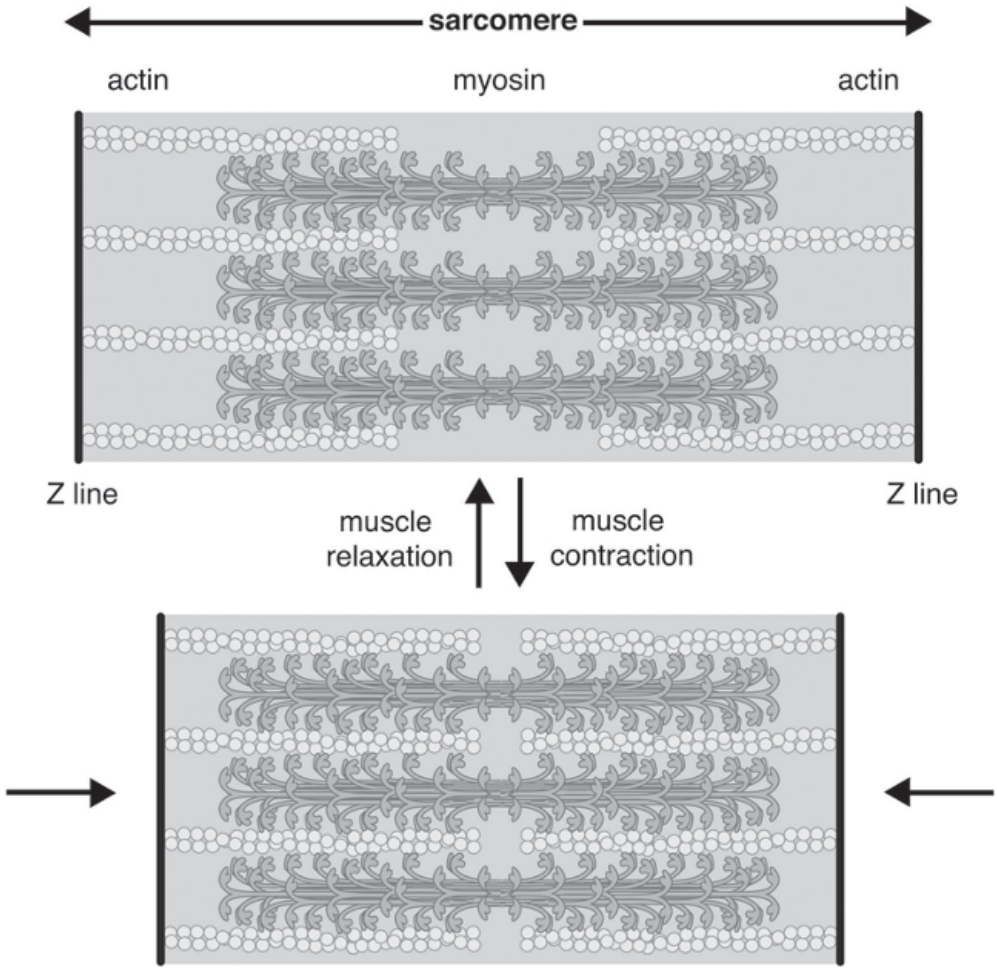


Figure 5. *The sliding-filament model of muscle contraction.*

Muscle contraction is controlled by the nervous system. Nerves that interact with a muscle cell release a neurotransmitter, known as **acetylcholine**. This triggers electrical changes within the muscle cell that lead to the release of calcium ions from the **sarcoplasmic reticulum** (a specialized form of the endoplasmic reticulum). The calcium ions release an inhibitory mechanism and allow the actin and myosin filaments to slide past each other.

The muscle fibers themselves are not all identical. They can be classified as slow-twitch fibers or fast-twitch fibers. At Thanksgiving dinner, we refer to these different types of turkey muscle as dark meat and light meat. The dark meat is composed of muscle that has a large proportion of slow-twitch fibers. The slow-twitch fibers are made of muscle cells that have more mitochondria and therefore more red-colored cytochromes than cells from fast-twitch fibers. Slow-twitch fibers have less sarcoplasmic reticulum as compared with fast-twitch fibers. Slow-twitch fibers contract at a rate about five times longer than fast-twitch fibers. Fast-twitch fibers are specialized for generating rapid, forceful contractions for short-term activities such as jumping or sprinting over a period of a few seconds to about a minute. Some of our muscles, such as those controlling eye movements, are made almost exclusively from fast-twitch fibers. Slow-twitch fibers are specialized for prolonged activity over a period of minutes or hours. The soleus muscle in the lower leg is made up of slow-twitch fibers.

Most of our muscles are composed of a mixture of slow-twitch and fast-twitch fibers, and this mix varies among individuals. The ratio of slow-twitch to fast-twitch fibers for a given muscle is largely genetically determined, though some studies have shown that rigorous training can alter the ratio.[10] This partly explains why some individuals excel at running sprints while others excel at running long distances.[56]

An important point to remember about muscle is that it only contracts and relaxes.

This means that in order to move a limb either up and down or back and forth, a pair of muscles must be involved. Indeed, skeletal muscles work in antagonistic pairs. For example, when a person bends his or her arm, the biceps contract (shorten) and the triceps relax (lengthen). When the arm straightens, the biceps relax and the triceps contract. Contraction is called the concentric phase, whereas the relaxation of the muscle is the eccentric phase. In general, most people think of muscles generating force only as they contract and get shorter. In the case of eccentric contractions, however, the muscles exert force even as they are lengthening. For example, to descend stairs in a controlled way, the quadriceps, or thigh muscle, must contract even as the movement of the knee joint tends to stretch it. Scientists are now recognizing that understanding more about eccentric contractions is important because they are common physiologically, are often associated with muscle soreness and injuries, and may be important in muscle-strengthening activities.[56]

Scientists continue to learn more about the value of regular exercise for maintaining or improving health. Exercise reduces the risk of certain medical conditions including heart disease and obesity and can help reduce complications in other diseases such as diabetes. Exercise is important for children and adolescents as well as for adults. Although in the past, weight (or resistance) training was not recommended for children, the American College of Sports Medicine recently advised that resistance training using nonmaximal weights and the supervision of a trained instructor is safe.[8] In addition to helping build optimal bone mass and reducing the risk of obesity, youth resistance training may decrease the incidence of some sports injuries. The increase in muscular strength that occurs when an adolescent

participates in resistance training appears to be a result of increased neuromuscular activation and coordination rather than muscle growth.[19]

4.3 Skin

Skin is the largest organ of the human body. Skin is in constant contact with the environment and plays several important roles in maintaining our health and well-being. It serves many purposes, including

- providing a barrier to microorganisms and toxins,
- preventing us from drying out,
- helping us to maintain temperature control,
- helping us sense pressure and temperature, and
- providing aesthetic and beauty qualities.

Skin is composed of distinct layers. In humans, a functional skin barrier is acquired by about 8.5 months of prenatal development. Babies born prematurely do not have an effective skin barrier and must be kept alive in sterile incubators until they develop the requisite protection. Skin has three layers—the **epidermis**, the **dermis**, and the **subcutaneous fat layer**. The thickness of the epidermis and dermis is different for skin with or without hair. Glabrous skin (skin without hair) has an epidermal layer that is about 1.5 millimeters (mm) thick and a dermal layer that is about 3 mm thick. Hairy skin has an epidermal layer that is 0.07 mm thick and a dermal layer that is 1 to 2 mm thick. The thickness of the subcutaneous fat layer varies throughout the body and from one individual to another (Figure 6).

The outermost layer of skin, which we can see, is called the epidermis. The epidermis itself also has multiple layers. The outer layer of the epidermis consists largely of dead skin cells, which are being continuously sloughed off. In fact, most of the house dust that you see is actually composed of dead skin cells. This layer of skin does not feel pain because it lacks blood vessels and nerves. The living, multiplying skin cells are found at the bottom of the epidermis, the basal layer.[21]

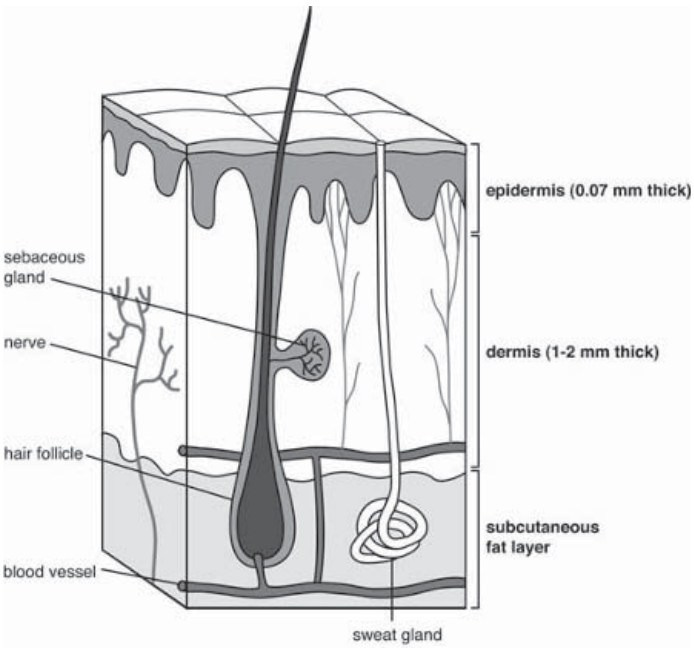


Figure 6. *Skin layers (epidermis, dermis, and subcutaneous fat layer). Not drawn to scale.*

Beneath the epidermis is the dermis, which provides a strong, resilient, and flexible infrastructure for the skin. The main component of the dermis is **collagen**, which accounts for nearly 70 to 75 percent of the skin's dry weight. Collagen is a versatile protein that provides strength.[21,28] It is necessary for healing wounds, but overproduction during healing leads to scars. Stretch marks are caused by collagen fibers that have been stretched to the point of tearing. Another important component of the dermis is elastin, which gives skin its elasticity.[11] Collagen and elastin degenerate with age, causing wrinkles and sagging.

The dermis is supplied with nutrients and oxygen by blood vessels. A recent study suggests that blood vessels are not the only way skin cells get oxygen, however. According to Markus Stücker of Ruhr University, the atmosphere, thought to be unimportant, actually supplies

the top 0.25 to 0.40 mm of skin with oxygen.[54] This corresponds to the entire epidermis and a portion of the dermis below. This finding has implications for doctors treating skin diseases. Healthy skin that is cut off from the air can compensate by obtaining oxygen from the blood, while diseased skin appears unable to do this.

The blood vessels in the dermis hold as much as 25 percent of the body's blood supply at one time. Transdermal drugs take advantage of this vast network of blood vessels. Any substance that penetrates the epidermis and reaches the dermis can enter the bloodstream.[11]

The dermis is also rich in nerves. Sensations transmitted by nerves in the skin include touch, temperature, pain, itching, and pressure.[28] Free nerve endings are scattered throughout the skin and are grouped around the bases of hair. They can register pain and pressure.[21]

The dermis contains **hair follicles, sebaceous glands**, and **sweat glands**. (Hair grows from the bulb at the hair follicle's base, which is in the subcutaneous fat layer.) On one side of the follicle is a sebaceous gland that produces an oily substance that lubricates the hair and epidermis. On the other side of the follicle is the erector pili muscle used to erect the hairs.

There are two types of sweat glands. The **eccrine glands** are located all over the skin surface. They produce a salty liquid that functions as a cooling mechanism when it evaporates from the skin surface. This liquid is somewhat acidic, which helps retard the growth of bacteria that live on the skin. The **apocrine glands** are thought to produce odors that serve as sexual messages. They are located under the armpits and on the genitals. Starting at puberty, these glands begin secreting a mixture of protein and fat. Bacteria can thrive in these environments and are responsible for body odor.

The bottom layer of the skin is the subcutaneous fat layer. This layer consists primarily of fat cells separated by bands of fibrous connective tissue. It provides a reservoir of energy as well as insulation and gives us our shape.[21,28] The subcutaneous fat layer may best be known because of cellulite. Cellulite is the puckered appearance of skin thought to be caused by fibrous bands dividing lobules of fat.[11,28]

Skin cells come in several types. The epidermis is formed by multiple layers of **keratinocytes**. These cells make **keratin**, which is a type of protein that provides the skin with its structural integrity. Keratinocytes make up 90 to 95 percent of the cells in the epidermis.[21,28] The keratinocytes in the outer layer are dead, whereas the keratinocytes in the bottom layer are alive and produce the keratinocytes, which eventually make their way up to the surface of the skin. Keratinocytes also produce hair and nails.

The epidermis also contains **melanocytes**. There is about one melanocyte for every keratinocyte in the skin.[28] Melanocytes are cells that produce a pigment called **melanin**. Melanin is transferred to the cells of the epidermis and hair, giving skin and hair their color. The number of melanocytes in the epidermis is the same for all races, but the amount of melanin produced varies. Melanin absorbs **ultraviolet light** and protects us from sun damage.[21] The melanin shields the DNA of the nucleus in keratinocytes from the mutating effects of the sun.[11, 28]

Tanning is the result of increased production of melanin in response to exposure to ultraviolet light and provides greater sun protection.

Other skin cells include Merkel's cells, Langerhans cells, and fibroblast cells. Merkel's cells are sensory receptors that respond to sensations of pressure and are more numerous in the palms and soles of the feet. Langerhans cells are found in the epidermis and dermis as well as other parts of the body. They monitor immune reactions in the skin and play an important role in reactions to poison ivy and other skin irritants.[28] Fibroblast cells, which produce collagen, are the primary cell type in the dermis.

Skin can reflect an individual's general state of health. Skin can suggest that a person is tired or ill. A skin problem also can reflect the onset of another disease. For example, skin itches may be harbingers of diabetes and kidney disease. Clear skin is an important aspect of sexual attraction in virtually all cultures. From an evolutionary point of view, the association between good health (and fertility) and unblemished skin may be responsible for our attraction to those with clear skin.

Since skin is important to sexual attraction, it is not surprising that some people modify the appearance of their skin to enhance their attractiveness. The most common methods include tanning, piercing, and tattoos. Unfortunately, all of these practices can have negative and potentially serious health consequences. A recent survey of 454 university students revealed that more than half had a body piercing and about one-quarter had a tattoo.[35] Nearly one-fifth reported that they had a medical complication due to the procedure itself or how they cared for the piercing or tattoo afterward.

Figure 7. *Clear skin is a sign of general good health and one aspect of sexual attraction.*

Research into the science of skin is leading to new understandings about how the skin performs its vital functions. For example, studies are shedding light on how skin senses heat,[50] interacts with the immune system in wound repair,[25] and elicits responses to antigens presented at the skin surface.[22] Other studies are concerned with developing new ways for treating people whose skin has been damaged by accident or disease. Each year, there are about 13,000 hospitalizations in the United States that require extensive skin grafting.[58] Unfortunately, the existing skin graft technology has limitations. One company called Stratatech has discovered a rare mutation in a culture of skin cells that allows the cells to grow indefinitely. Tests using animals have shown that skin from this culture can be used successfully to treat wounds. It is hoped that this culture will develop into an off-the-shelf product used by doctors performing skin grafts. Researchers looking at skin stem cells taken from mice have found that they can develop into other types of cells such as nerve, muscle, and fat cells.[55] Their intention is to coax human skin cells to form other cell types that could be used to treat patients with a variety of disorders.

The skin is also being exploited in drug-delivery techniques. Such techniques involve widening the skin's pores using ultrasound waves or an electric shock, or even using a grid of microscopic needles.[12] These approaches offer a number of advantages over traditional means of drug delivery. They can ensure the steady release of a drug over long periods of time and bypass the rapid breakdown that occurs in the digestive system. They are also painless and convenient.

Similar to other organs in the body, bone, muscle, and skin rely on interactions with other body parts to function normally.

5 Interactions

As discussed in previous sections, bone, muscle, and skin are living systems and are active metabolically. They are connected, as are all other organs, by the body's cardiovascular system. This allows bone, muscle, and skin to respond to hormones and growth factors produced by other tissues. As a result, growth and other metabolic activities in bone, muscle, and skin occur in a coordinated manner. The nervous system also allows interactions between bone, muscle, and skin. Consider what occurs when nerves in the skin of fingers contact a hot object—the muscles of the arm quickly contract, and the arm is moved away from the heat.

In this section, we consider two examples of how bone, muscle, and skin interact. First, we consider joints, which involve interactions between bones and muscles, and then we look at interactions among all three systems related to vitamin D.

5.1 Joints

A joint is the place where two bones meet. Because bones are hard, tough structures that resist movement individually, joints form new structures that can move. By joining, or articulating, all the bones of the body, a skeleton of defined shape that is capable of movement is formed.

Joints can be classified in several ways, but for our purposes, joints will be classified by the type of movement they allow. Accordingly, joints can be separated into three main groups: fixed or immovable, slightly movable, and freely movable. Fixed or immovable joints are found between the bones of the skull. The individual bones are joined by dense, fibrous connective tissue, which is why these joints are also called fibrous joints. Fixed joints serve a protective function, although they do allow growth to occur. Teeth are attached to the jaws by fixed joints.

Slightly movable joints are found, for example, between individual vertebra of the vertebral, or spinal, column and where ribs join to the breastbone. In slightly movable joints, the bones are attached to one another by pads or discs of the connective tissue, or cartilage.

Most joints in the human body are freely movable and are characterized by a cavity that contains a fluid, called **synovial fluid**, that provides lubrication. The ends of adjacent bones have complementary shapes, which further reduces friction, and are covered with a layer of smooth, hard cartilage. These joints are completely enclosed by a baglike **ligament** that holds the joint together and prevents the synovial fluid from leaking out.

There are six basic categories of freely movable joints:

- Ball-and-socket joints allow more freedom of movement than any other joint. One bone of the joint has a rounded head that fits into the socket of the other bone. Ball-and-socket joints are found at the hips and shoulders.
- Gliding joints are composed of bones that are almost flat and slide over one another. They offer flexibility in movement direction, although they do not allow great range in movement. The bones of the wrist are connected through gliding joints.
- Hinge joints allow movement up and down, although they do not allow twisting or sliding. One bone, the humerus (bone of the upper arm), for example, fits into the rounded part of another bone, the ulna (the fixed bone of the forearm), thus forming a hinge joint (the elbow).
- Pivot joints allow bones to spin around one another. They are formed when one bone fits into the ring shape of another bone. A pivot joint allows the twisting motion of the elbow (as opposed to the up-and-down motion of the hinge joint). Additionally, a pivot joint is found between the first two vertebrae in the neck, allowing us to provide a negative response by rotating our head left and right.
- Condyloid joints allow movement in many directions, although they do not allow rotation. One bone of the joint is concave

while the other is convex. The lower jaw is attached to the skull through a condyloid joint.

- Saddle joints allow side-to-side movement and limited rotation. The bones of a saddle joint have odd shapes but are completely complementary to one another. The lower finger bones are connected to the bones of the hand through saddle joints.

5.2 Vitamin D

Rickets is a childhood disorder characterized by softening and weakening of the bones. Although the first scientific description of rickets came in the mid-1600s, it was not until about 1920 that the disease was associated with a deficiency of vitamin D. In the 1930s, the chemical structure of vitamin D was established—the vitamin is a fat-soluble steroid. Actually, the term vitamin D does not refer to a single molecule but rather to a family of related molecules. The active form is vitamin D_3, although D_3 itself can be converted in the body into other active molecules. In our discussions, we will use the generic term, vitamin D, to refer to the active substance.

Vitamins are generally defined as required substances that affect metabolic pathways and that the body cannot make, so they must be supplied in the diet. By this definition, vitamin D is technically not a vitamin. True, it is found in foods, particularly animal products, oily fish, and artificially fortified foods (such as milk, margarine, butter, and cereals). However, it can be produced in the body by the action of sunlight or ultraviolet light on a precursor molecule, 7-dehydrocholesterol, which is found in the skin of humans and most other higher animals.

This complex process is summarized in Figure 8. The vitamin D produced in skin enters the bloodstream. It is bound to proteins and transported to sites around the body. Although vitamin D affects numerous metabolic pathways, its primary role is to regulate the absorption and use of calcium and phosphorus in the body. In addition to increasing absorption of calcium and phosphorus in the intestines and kidneys, vitamin D helps maintain blood levels of these two important minerals. It also helps form strong bones by increasing the calcium content of bone. When there is a deficiency of vitamin D, calcium absorption decreases. In response, the body produces a hormone that removes calcium from bone in an attempt to raise blood-calcium levels. This results in weaker bone structure (rickets in children, osteomalacia in adults).

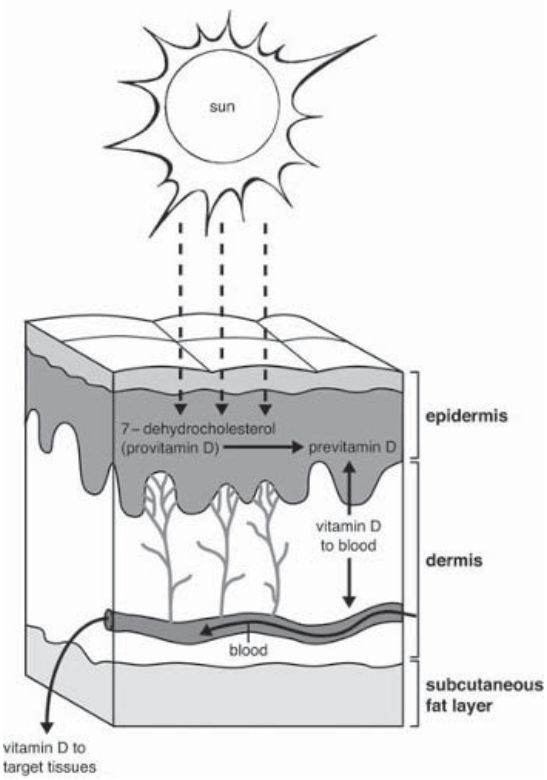


Figure 8. *Vitamin D production. (Not drawn to scale.)*

Vitamin D deficiency may also affect muscles, since calcium is essential for normal nerve impulse transmission and muscle contraction. Calcium deficiency may result in prolonged muscle spasms and muscle pain.

Exposure to the sun is a double-edged sword. On the one hand, excess exposure has adverse effects on the skin and is associated with increased risks of skin cancer. On the other hand, insufficient exposure to the sun may lead to vitamin D deficiency and its attendant bone

and muscle problems. It is possible, however, to both protect against sun-damaged skin and get sufficient exposure to ensure adequate vitamin D synthesis. For example, in summer it takes only 10 to 15 minutes of sunlight on the face and wrists, two to three times a week between 8 a.m. and 4 p.m. to allow the body to make enough vitamin D. Sunscreen, which can block the beneficial effects of sun exposure, should be used to protect the skin at all other times.

Other factors influence vitamin D synthesis, including air pollution, which blocks sunlight; dark pigmentation in the skin; and clothing worn to cover skin. Additionally, vitamin D synthesis may decrease during the winter in geographic locations where the days are shorter, more time is spent indoors, and people dress warmly and cover up well when outdoors.[23, 24]

6 Diseases and Disorders

There are many diseases and disorders of bone, muscle, and skin. However, it is beyond the scope of this section to discuss them all. We provide here brief introductions to diseases and disorders related to lessons in this module and to several that students may ask about.

6.1 Diseases affecting bone

Achondroplasia. Achondroplasia is a genetic disorder of bone growth that affects males and females of all races and occurs in about 1 of every 25,000 births. People with achondroplasia exhibit abnormal body proportions; their arms and legs are very short while their torso is nearly normal in size. In normally proportioned people, cartilage develops into bone during fetal development and childhood. This process is abnormally slow in the growth plates of long bones in people with achondroplasia, resulting in shorter bones in the arms and legs.

Fractures. A bone can fracture, or break, when the pressure on it becomes too great, and the fracture can occur in several different ways. For instance, the bone may break across its width, lengthwise, at an angle, or spirally. The bone may crack rather than break all the way through or, in the case of extreme force, the bone may actually shatter. The broken bone may not damage surrounding tissue or penetrate the skin. On the other hand, it may damage the skin and surrounding tissue and increase the risk of infection to both the skin and the bone. Additionally, fractures may produce significant blood loss since bones have a rich blood supply.

The underlying causes of fractures are varied. Most common are fractures that result from injury. The injury may be acute, such as a fall, or it may occur more slowly over time, such as that resulting from a repetitive activity (for instance, running) that aggravates a susceptible site. Additionally, diseases (such as osteoporosis and cancer), nutritional deficiencies (such as of calcium and vitamin D), and some medications can make bone more susceptible to fracture.

Osteoarthritis. Osteoarthritis, the most common type of arthritis, affects the cartilage that covers the ends of bones in a joint. In osteoarthritis, also called degenerative joint disease, the cartilage breaks down and causes pain, swelling, and loss of motion. In addition, bone spurs may form and bits of bone or cartilage can break off and float inside the joint space.[45]

Scientists do not yet know what causes osteoarthritis. Like most diseases, scientists believe that genetic factors are an important contributing factor. Physicians can treat individuals with osteoarthritis using a number of strategies, including pain management, exercise, rest and joint care, weight control, medications, and nontraditional treatment approaches. Individuals who are concerned about the degeneration of joint cartilage sometimes take various nutritional supplements, most notably chondroitin and glucosamine (natural components of cartilage), to help maintain healthy cartilage and thereby reduce the risk or severity of osteoarthritis. Scientific evidence for the efficacy of these products varies.

Osteoporosis. Osteoporosis is a disease in which bone loss occurs accompanied by a decrease in bone strength. Women are four times more likely to have osteoporosis than men. Three factors contribute to osteoporosis:

- accelerated bone loss at menopause in women or as a consequence of aging in both men and women,
- failure to reach peak bone mass during childhood and adolescence, and
- bone loss that results from other conditions, such as eating disorders or certain medical treatments.[41]

Scientists now believe that the best time for preventing osteoporosis may be during childhood and adolescence, when bones are growing rapidly. In healthy children, adequate intake of calcium and vitamin D and weight-bearing physical activity may be sufficient to prevent osteoporosis.[29]

Figure 9. *Healthy behaviors early in life can help prevent bone disorders such as osteoporosis later in life.*

Treatments for osteoporosis are aimed at altering the imbalance between decreased bone formation and increased resorption.

Some medications inhibit the formation or activity of osteoclasts.[46] Scientists are also investigating therapies that would stimulate bone formation by osteoblasts.[51]

Osteogenesis imperfecta. Osteogenesis imperfecta is also known as brittle bone disease. It affects an estimated 20,000 to 50,000 individuals in the United States.[57] The news media will periodically present a case study of someone with this disease. Because it is usually diagnosed in children, it has, at times, been attributed incorrectly to child abuse. This inherited genetic disease is characterized by bones that break easily. In this disease, collagen is either formed in inadequate amounts or is changed structurally.[48]

There is no cure for this disease. Treatments focus on preventing or controlling the symptoms, maximizing mobility, and developing optimal bone mass and muscle strength.[48] The goal for treatment is to prevent fractures and deformities while allowing the child with the disease to function as independently as possible.

6.2 Diseases and injuries affecting muscle

The ability of muscles to function effectively can be impaired by a number of diseases and injuries. In some diseases, the muscle tissue may not be the primary organ affected but may be impaired as a consequence of a problem at another site in the body.

Amyotrophic lateral sclerosis. Amyotrophic lateral sclerosis (ALS) is also called Lou Gehrig's disease, and it has received media coverage because of the fame of the baseball player, Lou Gehrig. More recently, the book Tuesdays with Morrie (by Mitch Albom, 1997) told the story of a college professor who was afflicted with the disease. Individuals with ALS lose control

of voluntary muscles because the nerves that innervate them are destroyed. As the disease progresses, muscles continue to weaken until they become paralyzed. There is currently no treatment for ALS. Most afflicted people die of respiratory failure because ALS paralyzes the muscles used for breathing.[34]

Muscular dystrophy. Muscular dystrophy is a group of genetic diseases characterized by progressive muscle weakness and loss of muscle tissue. Diagnosis of a specific form of muscular dystrophy is based on the individual's symptoms, the age of onset, and the nature of the genetic transmission. The most common types of muscular dystrophy are due to a deficiency in the muscle protein dystrophin.[36]

Duchenne's muscular dystrophy is the most severe form of the disease. Initially, it affects the muscles of the pelvis, upper arms, and upper legs. Becker's muscular dystrophy is milder than Duchenne's and progresses more slowly. Both Duchenne's and Becker's muscular dystrophy afflict boys almost exclusively.[37] There is currently no cure for any type of muscular dystrophy. Treatments may include physical therapy, medications, assistive devices, and surgery.

Sprains and strains. Ankle sprains are the most common injury, often occurring during sports or recreational activities.[40] A sprain occurs when a ligament, the tissue that connects bones at a joint, stretches or tears. A strain is an injury to either muscle or tendon. The immediate treatment for these injuries is "RICE" (**R**est, **I**ce, **C**ompression, **E**levation).

Tetany. Tetany is condition characterized by muscle spasms (twitching and cramps) brought on when calcium levels in body fluids fall below normal. This can be associated with calcium or vitamin deficiencies, the pathogenic bacterium Clostridium tetani, or with other medical conditions. When calcium levels are below normal, the nervous system becomes more excitable and nerves fire spontaneously. These impulses cause skeletal muscles to contract spasmodically. Tetany can usually be treated with calcium, vitamin D, and diet.

Because skin diseases are so visible to others, affected individuals may feel embarrassed or even ashamed about their conditions.

6.3 Disorders of skin

The psychological effects of skin conditions can be more serious than the conditions themselves. Young children with skin diseases may be subject to teasing, while teenagers, concerned about their physical appearance, may be shunned by their peers. Adults, too, feel the stigma associated with skin disease. They may become more withdrawn and even refuse to seek treatment for their condition, believing (often erroneously) that nothing can be done for them. A recent survey indicated that less than half of the people with a skin disorder seek advice from a doctor, but instead rely on others, such as pharmacists, for information.[32] It is likely that there are significant numbers of people who are misinformed about their conditions and may be relying on treatments that have little value.

Some of the more common skin diseases include

- acne,
- atopic dermatitis (eczema),
- skin cancer,
- alopecia (hair loss), and
- vitiligo.

Many of these diseases can affect individuals of all races and both genders. For example, acne is a problem for both males and females of all races. Other diseases, however, are more prevalent in some populations than others. For example in the United States, **scleroderma** has a higher prevalence among certain Native Americans, and **keloids** occur more frequently in African-American individuals.[42]

The following discussion focuses on those disorders with particular relevance to young people and those relevant to this module.

Acne. Acne is a skin disorder that results when hormones interact with the skin's sebaceous glands. These glands produce an oily substance called sebum. Sebum normally reaches the skin surface through an opening of a hair follicle called a pore. During acne, the pore becomes blocked by the hair, sebum, and the cells that line the follicle. This mixture of oil and cells allows the bacteria that normally live on the skin to grow within the plugged pore. Substances produced by the bacteria attract white blood cells and cause inflammation, characterized by redness, swelling, heat, and pain. Eventually, the wall of the follicle breaks down and its contents spill into the surrounding skin, producing a lesion commonly called a pimple. People with acne usually exhibit a variety of skin lesions that may include whiteheads and blackheads. Whiteheads are plugged follicles that remain below the skin surface and produce a white bump. If a plugged follicle reaches the skin surface, it appears black and is called a blackhead.

Figure 10. *Acne is a common skin disease that can be effectively treated.*

Treatments for acne include oral and topical medications used alone or in combination. Most of these medications retard or halt bacterial growth and reduce inflammation. Severe acne can be treated effectively using isotretinoin (Accutane). This drug usually clears up acne in 15 to 20 weeks and also helps prevent scarring. It can, however, cause birth defects in the developing fetus of a pregnant woman. Therefore, women who take the drug and are of child-bearing age must use two forms of birth control before, during, and after treatment. Another possible side effect of taking Accutane is mental disorders. Some patients taking Accutane have become depressed or developed other serious mental problems. More recently, isotretinoin has been shown to produce detrimental effects on bone.[17]

Alopecia. Alopecia refers to the partial or complete loss of hair, and it may result from genetic factors, normal aging, certain medications, or disease. Male-pattern alopecia is very common. Although the condition is genetic and related to the male sex hormones, its precise cause is unknown. Female-pattern alopecia is also common, although it is usually characterized by thinning of the hair in specific regions of the head rather than complete hair loss as in males. Alopecia areata is a disorder affecting 4 million Americans, 60 percent of them under the age of 20. It causes sudden hair loss on the scalp and other body regions because follicles stop producing hair; bald patches can appear overnight. The precise cause of this disorder is unknown, although it is thought to be an autoimmune disorder. While alopecia areata is not life threatening, and while it can disappear as quickly as it appeared, it can be difficult for children to cope with psychologically.

Atopic dermatitis. Atopic dermatitis, often called eczema, is a chronic skin disease that most often afflicts infants and young children, although it can arise in adults as well. Major symptoms of atopic dermatitis include intense itching, rashes in areas characteristic of the disease, repeatedly occurring symptoms, and a personal or family history of atopic disorders such as hay fever, asthma, and eczema. Symptoms can be made worse by exposure to irritants such as wool or synthetic fibers, poorly fitting clothes that chafe the skin, soaps that dry out the skin, and allergens (substances in plants or animals that trigger an immune reaction).

The cause of atopic dermatitis is not known. Evidence suggests that it is a multifactorial disease, meaning that both genetic and

environmental factors interact to produce the symptoms. Although stress is known to make the condition worse, it is not a cause of the disorder. Atopic dermatitis is not infectious and cannot be passed from one person to another. The disorder seems to be associated with hay fever and asthma. Many children who outgrow atopic dermatitis later develop hay fever and asthma.

Treatment of atopic dermatitis involves healing the skin and keeping it healthy, preventing the onset of symptoms, and treating the symptoms when they arise. An important aspect of treatment is daily skin care, which involves proper bathing and application of lubricants immediately after bathing. When symptoms occur, they may be treated using corticosteroid creams and ointments. Phototherapy with ultraviolet light, sometimes in conjunction with drugs called psoralens, may control the symptoms. Adults with severe forms of the disease may be treated with immunosuppressive drugs such as cyclosporine.

Skin cancer. Skin cancer (including **melanoma** and nonmelanoma skin cancer) is the most common cancer, accounting for more than 40 percent of all cancers. About 1.3 million cases of nonmelanoma skin cancer are diagnosed each year in the United States.[5] Skin cancer is a disease in which cells of the epidermis lose their ability to control their own growth. These cancer cells form tumors that, if left untreated, can spread to other parts of the body and produce serious, often fatal disease.

Cancer can arise in any of the three types of cells found in the epidermis: round cells called **basal cells**; flat, scaly surface cells called **squamous cells**; and melanocytes, which give skin its characteristic color. Basal cell cancer is the most common form. It is usually found in body areas that have been exposed to the sun. It may appear as a small, raised bump with a smooth texture. Another form resembles a scar and is firm to the touch. Basal cell cancers may spread to other tissues around the cancer, but they usually do not spread to other parts of the body. Squamous cell tumors also appear in areas that have been exposed to the sun. They may also appear in areas that have been burned, exposed to chemicals, or subjected to X-ray therapy. Squamous cell tumors often appear as firm, red bumps. They may feel scaly, bleed, or develop a crust. Squamous cell tumors can spread to lymph nodes in the area.
A more serious form of skin cancer is called melanoma (cancer in the melanocytes). Melanoma accounts for about 4 percent of skin cancer cases but causes approximately 79 percent of skin cancer deaths.[6] It usually occurs in adults and may appear as a new mole or as a change in an existing mole. Melanoma can spread cancer to other parts of the body. Early diagnosis of melanoma is critical for effective treatment.

Sun exposure is linked to more than 90 percent of nonmelanoma skin cancers.[39]

Exposure to the sun's radiation has been identified as the primary risk factor for skin cancer. Shorter-wavelength ultraviolet light called **UVB** rays cause tanning and burning in humans. A 1 percent increase in UVB-ray exposure may produce a 2 percent increase in skin cancer incidence. Longer wavelength **UVA** rays penetrate more deeply into the dermis. UVA rays produce an immediate darkening of the skin as it is absorbed by melanin. Exposure to UVA rays can weaken the skin's inner connective tissue, damage the immune system, and possibly lead to cancer.[1] UVA rays can also burn the eyes and result in cataracts. Severe, blistering sunburns, particularly those experienced during childhood or as a teenager, increase an individual's risk of developing melanoma.[7,38] Although proponents of tanning beds argue that they are safe, the mere fact that they expose the skin to ultraviolet radiation means that they contribute to the risk of skin cancer.

Rates of skin cancer are also influenced by the degree of skin pigmentation. Rates are highest for those with the lightest-colored skin. Theoretically, all skin cancer is preventable. It

has been estimated that most people get about 80 percent of their lifetime sun exposure before the age of 18. Therefore, it is prudent to protect children from needless sun exposure. Those at greatest risk for skin cancer (children and those with light skin) should use protective clothing and sunscreens whenever possible.

Figure 11. *UV light used in tanning beds carries similar health risks to sunlight.*

Skin cancers are treated by several different methods, depending on the type of cell involved and to what extent the cancer has progressed. The most common approach is to surgically remove the tumor by cutting, burning, or freezing. Another technique is radiation therapy, which uses X-rays to kill cancer cells and shrink tumors. Chemotherapy uses drugs to kill cancer cells and may be applied topically to the skin or given systemically, in which case it enters the bloodstream and can kill cancer cells in other areas of the body. Biological therapies are now being developed that use the body's immune system to fight the disease.

Vitiligo. Vitiligo is a skin condition resulting from a loss of pigment. Any part of the body may be affected and develop the characteristic white patches of the disorder. Vitiligo affects 1 to 2 percent of the population, and about half of those affected first exhibit the disorder before the age of 20. There appears to be a genetic component to vitiligo, and it is thought to be an autoimmune disorder affecting the pigment-producing cells of the skin. Although the disease can be managed with medications and other treatments, there is no cure for it.

7 Influences

The structure and function of bone, muscle, and skin are subject to many influences. Some influences as well as some of their negative ramifications are presented in the following table.

Bone, Muscle, and Skin Can Be Influenced by Many Things

General Factor	Influenced by	Possible Outcome
Genetics	Gender (for instance, hormones) Behavior (for instance, activity level or nutrition) Genetic predisposition	Obesity, poor muscle tone, poor bone quality Susceptibility to disease
Behavior	Social factors Cultural factors Economic factors Political factors	Concern about appearance Use of products to enhance appearance (for instance, cosmetics and nutritional supplements) Risky behaviors (for instance, tattoos, body piercing, smoking, overexposure to sun)
Environment	Geography (for instance, elevation, latitude, or rural versus urban setting) Pollution	Exposure to UV light Exposure to chemical pollutants

The factor that has the greatest influence on these body systems is genetics. We have no control over this factor, nor do many of us have control over our exposure to environmental pollutants. However, the key for middle school students is to realize that we do have control over many of the large number of factors that influence our bone, muscle, and skin, through the choices we make. For instance, we choose not only how long we will expose ourselves to the sun, but also what protective measures we will use, such as sunscreens and hats. Within cultural, social, and economic limits, we make decisions about the foods we eat and thus determine our intake of key nutrients, such as protein and calcium. We are influenced by peers and the media and make decisions about risky behaviors, such as smoking. We make decisions about exercise, about what we slap (sometimes slop) on our skin, about what we can do to enhance our appearance—all generally done thinking only about now and without concern for any long-term effects on our bone, muscle, and skin.

This curriculum supplement introduces students to three key body systems. It also provides an opportunity to introduce students to decision making and to realizing that decisions made today have consequences in the future.

Glossary

acetylcholine: A neurotransmitter whose release leads to muscle contraction.

actin: A contractile protein found in muscle cells. Together with myosin, actin provides the mechanism for muscle contraction.

apocrine gland: A large sweat gland found in hairy regions of the body. Starting at puberty, apocrine glands secrete a mixture of protein and fat. Bacteria can thrive in these environments and are responsible for body odor. The glands are also thought to send sexual messages through odor. Modified apocrine glands produce mother's milk.

basal cells: Small, round cells located in the lower portion of the skin's epidermis.

bone marrow: A soft tissue found in the center of large bones. Bone marrow produces blood cells.

calcium: A chemical element that plays a vital role in the biochemistry of a cell. Calcium is an important part of a healthy diet. It is stored in the skeleton and released into the bloodstream as needed.

cartilage: An elastic connective tissue. Unlike bone, cartilage does not contain blood vessels and lacks the ability to regenerate.

chondrocyte: A type of cell found in cartilage.

collagen: The primary protein found in connective tissue. It gives skin its elasticity and provides strength to ligaments and tendons.

dermis: The layer of skin found beneath the epidermis. It contains many nerve endings that are responsible for the sense of touch.

diaphysis: The shaft of a long bone.

differentiation: During development, the process by which individual cells in the body take on specialized functions.

eccrine gland: A sweat gland that participates in regulating the temperature of the body. It is found in the skin over most parts of the body.

epidermis: The outermost layer of the skin.

epiphyses: The end portions of long bones where growth occurs.

fluorapatite: A fluorine-containing mineral that contributes strength to bone.

ground substance: Material in which cells of connective tissue are embedded. It is also called matrix.

hair follicle: An infolding of the epidermis that contains the root of an individual hair.

hydroxyapatite: A mineral containing calcium and phosphorous that contributes strength to bone.

joint: A location where bones meet and allow movement about that location.

keloids: An overgrowth of fibrous scar tissue caused by excessive tissue repair at the site of a skin injury.

keratin: The primary structural protein found in hair and nails.

keratinocytes: Cells of the epidermis that synthesize keratin.

ligament: Connective tissue that connects bone to bone.

melanin: A dark pigment produced in the bottom layer of the skin's epidermis. Melanin absorbs ultraviolet light and is largely responsible for the color of the skin.

melanocyte: A type of cell found in the epidermis that produces the pigment melanin.

melanoma: A form of skin cancer that derives from a melanocyte.

myoblast: An immature muscle cell.

myosin: A contractile protein found in muscle cells. Together with actin, myosin provides the mechanism for muscle contraction.

myotube: A mature muscle cell.

organ: A part of the body that performs a specific function. The heart and lungs are examples of organs.

osteoblast: A cell that contributes to the formation of bone.

osteoclast: A cell that contributes to the breakdown and resorption of bone.

osteocyte: A branched cell found in the bone matrix. Osteocytes are derived from osteoblasts. They communicate with other cells and help the bone respond to its environment.

proteoglycans: A class of proteins with a high polysaccharide content.

sarcomere: The structural and functional unit of muscle contraction.

sarcoplasmic reticulum: The form of endoplasmic reticulum found in muscle fibers.

scleroderma: A chronic disorder characterized by hardening and thickening of the skin.

sebaceous gland: A gland that secretes an oily substance into a hair follicle to lubricate hair or skin.

shadow rule: A rule stated as, "short shadow—seek shade." It is a convenient way to assess when protection from the sun is needed.

sliding-filament model: A model that describes how muscle cells contract using filaments made of actin and myosin.

squamous cells: A layer of flat skin cells found in the epidermis.

subcutaneous fat layer: A layer of fat cells beneath the dermis.

sweat gland: Small tubular glands found nearly everywhere in the skin that secrete perspiration through pores in the skin.

synovial fluid: a fluid found in joints that provides lubrication.

tendon: A band of connective tissue that attaches muscle to bone.

thick filament: One of two types of filaments found in myofibrils. It is mainly composed of the protein myosin.

thin filament: One of two types of filaments found in myofibrils. It is mainly composed of the protein actin.

tissue: A population of similar cells that act together to perform one or more specific functions in the body.

ultraviolet light: A portion of the electromagnetic spectrum having wavelengths shorter than visible light but longer than X-rays.

UVA: Long wavelength (320–380 nanometers) ultraviolet light.

UVB: Short wavelength (280–320 nanometers) ultraviolet light.

vitamin D: A fat-soluble vitamin needed for normal growth of bone. Vitamin D is produced when sterols in the body are irradiated by ultraviolet light.

References

1. American Academy of Dermatology. 2003. *Pathophysiology of ultraviolet irradiation.* Retrieved October 23, 2003, from the World Wide Web: *http://www.aad.org/professionals/Residents/MedStudCoreCurr/DCUVIrradiation.htm*

2. American Academy of Orthopaedic Surgeons. 2000. *Growth plate fractures.* Retrieved January 12, 2004, from the World Wide Web: *http://orthoinfo.aaos.org/fact/thr_report.cfm?Thread_ID=244&topcategory=About%20Orthopaedics*

3. American Academy of Orthopaedic Surgeons. 2000. *Osteoporosis prevention starts early.* Retrieved January 12, 2004, from the World Wide Web: *http://orthoinfo.aaos.org/fact/thr_report.cfm?Thread_ID=134&topcategory=Osteoporosis*

4. American Association for the Advancement of Science. 1993. *Benchmarks for Science Literacy.* Washington, DC: AAAS.

5. American Cancer Society. 2001. *How many people get melanoma skin cancer?* Retrieved July 9, 2002, from the World Wide Web: *http://www.cancer.org/docroot/CRI/content/CRI_2_2_1X_How_many_people_get_melanoma_skin_cancer_50.asp?sitearea=*

6. American Cancer Society. 2001. *How many people get nonmelanoma skin cancer?* Retrieved July 9, 2002, from the World Wide Web: *http://www.cancer.org/docroot/CRI/content/CRI_2_2_1X_How_many_people_get_nonmelanoma_skin_cancer_51.asp?sitearea=*

7. American Cancer Society. 2003. *What are the risk factors for melanoma?* Retrieved January 12, 2004, from the World Wide Web: *http://www.cancer.org/docroot/CRI/CRI_2_1x.asp?dt=39*

8. American College of Sports Medicine. 1998. *Youth strength training.* Retrieved June 9, 2002, from the World Wide Web: *www.acsm.org*

9. American Red Cross. 2002. *BPAC statement of tattoos and piercings.* Retrieved July 13, 2002, from the World Wide Web: *http://www.redcross.org/press/biomed/bm_pr/020314bpac.html*

10. Anderson, J.L., Schjerling, and P. Saltin, B. 2000. Muscle, genes and athletic performance. *Scientific American, 283*(3): 49–55.

11. Balin, A.K., and Pratt Balin, L. 1997. *The Life of Skin: What It Hides, What It Reveals, and How It Communicates.* New York: Bantam Books.

12. Bhattacharjee, Y. 2001, July 2. More than the patch: New ways to take medicine by the skin. *The New York Times*, F5.

13. Bone and Joint Decade America. 2002. *Fast facts on the bone and joint decade.* Retrieved June 9, 2002 from the World Wide Web: *http://www.usbjd.org/about/index.cfm?pg=fast.cfm*

14. Bush, G.W. 2002. *National Bone and Joint Decade Proclamation.* Retrieved June 4, 2002, from the World Wide Web: *http://www.whitehouse.gov/news/releases/2002/03/20020325-5.html*

15. Chen, G.K., and Duque, G. 2002. Age-related bone loss: Old bone, new facts. *Gerontology, 48,* 62–71.

16. Creighton, D.L., Morgan, A.L., Bordley, D., and Gunnar Brolinson, P. 2001. *Journal of Applied Physiology*, *90:* 565–570.

17. DiGiovanna, J.J. 2001. Isotretinoin effects on bone. *Journal of the American Academy of Dermatolology, 45*: 176–182.

18. Downham, T. 1998. The shadow rule: A simple method for sun protection. *Southern Medical Journal, 91*: 619–623.

19. Guy, J.A., and Micheli, L.J. 2001. Strength training for children and adolescents. *Journal of the American Academy of Orthopaedic Surgeons*, *9*: 29–36.

20. Guyton, A.C., and Hall, J.E. 1996. *Textbook of Medical Physiology*. Philadelphia: W.B. Saunders Co.

21. Haake, A., Scott, G.A., and Holbrook, K.A. 2001. Structure and function of the skin: Overview of the epidermis and dermis. In R. K. Freinkel and D.T. Woodley (Eds.), *The Biology of Skin*. New York: The Parthenon Publishing Group.

22. Hayday, A., and Viney J.L. 2000. The ins and outs of body surface immunology. *Science, 290*, 127–131.

23. Holick, M. 1996. *Vitamin D and bone health*. Presented at the Nutritional Advances in Human Bone Metabolism Symposium given at the Experimental Biology '95 meeting, April 11, 1995, Atlanta, GA.

24. Holick, M. 2003. Vitamin D: A millennium perspective. *Journal of Cellular Biochemistry, 88*: 296–307.

25. Jameson J., Ugarte, K., Chen, N., Yachi, P., Fuchs, E., Boismenu, R., et al. 2002. A role for skin __ T cells in wound repair. *Science, 296*: 747–749.

26. Johnson, R.L., Rothman, A.L., Xie, J., Goodrich, L.V., Bare, J.W., Binifas, J.M., et al. 2002. Current concepts in pediatric bone disease. *Pediatric Clinics of North America, 49*: 143–173.

27. Lee, S., and Farrar, R.P. 2003. Resistance training induces muscle-specific changes in muscle mass and function in rat [Electronic version]. *Journal of Exercise Physiology, 6*: 80–87. Retrieved December 11, 2003, from the World Wide Web: *http://www.css.edu/users/tboone2/asep/May2003JEPonline.html*

28. Leffell, D.J. 2000. *Total Skin: The Definitive Guide to Whole Skin Care for Life*. New York: Hyperion.

29. Leonard, M.B., and Zemel, B.S. 2002. Current concepts in pediatric bone disease. *Pediatric Clinics of North America*, *49*: 143–173.

30. Lodish, H., Berk, A., Zipursky, L.S., Matsudaira, P., Baltimore, D., and Darnell, J. 2000. *Molecular Cell Biology* (4th ed.). New York: W. H. Freeman.

31. Loucks-Horsley, S., Hewson, P., Love, N., and Stiles, K. 1998. *Designing Professional Development for Teachers of Science and Mathematics*. Thousand Oaks, CA: Corwin Press.

32. Marks, R. 2001. The public health approach to the burden of common skin diseases in the community. *Journal of Dermatology,* 11: 602–605.

33. Matkovic, V., Jelic, T., Wardlaw, G.M., Ilich, J.Z., Goel, P.K., Wright, J.K., et al. 1994. Timing of peak bone mass in Caucasian females and its implication for the prevention of osteoporosis. Inference from a cross-sectional model. *Journal of Clinical Investigation, 93*: 799– 808.

34. Mayo Foundation for Medical Education and Research. 2001. *What is ALS?* Retrieved July 11, 2002, from the World Wide Web: *http://www.mayoclinic.com*

35. Mayo Foundation for Medical Education and Research. 2002. *Body piercing and tattoos: More than skin deep.* Retrieved January 13, 2004, from the World Wide Web: *http://www.mayoclinic.com/invoke.cfm?objectid=3DC17F76-13E3-499B-AE9111954BDFFCA5*

36. Mayo Foundation for Medical Education and Research. 2002. *Muscular dystrophy.* Retrieved January 13, 2004, from the World Wide Web: *http://www.mayoclinic.com*

37. Muscular Dystrophy Association. 2000. *Facts about Duchenne and Becker muscular dystrophies (DMD and BMD).* Retrieved July 10, 2002, from the World Wide Web: *http://www.mdausa.org/publications/fa-dmdbmd-what.html*

38. National Cancer Institute. 2002. *Skin Cancer (PDQ®): Prevention.* Retrieved July 10, 2002, from the World Wide Web: *http://www.nci.nih.gov/CancerInformation/SkinCancer/Patient/*

39. National Institute of Arthritis and Musculoskeletal and Skin Diseases. 1993. *Research in Public and Professional Eeducation for the Prevention and Control of Skin Cancer.* Bethesda, MD: NIAMS.

40. National Institute of Arthritis and Musculoskeletal and Skin Diseases. 1999. *Questions and answers about sprains and strains.* Retrieved June 4, 2002, from the World Wide Web: *http://www.niams.nih.gov/hi/topics/strain_sprain/strain_sprain.htm*

41. National Institute of Arthritis and Musculoskeletal and Skin Diseases. 2000. *Osteoporosis: Progress and promise.* Retrieved June 9, 2002, from the World Wide Web: *http://www.niams.nih.gov/hi/topics/osteoporosis/opbkgr.htm*

42. National Institute of Arthritis and Musculoskeletal and Skin Diseases. 2000. *Strategic Plan. Plan for Reducing Health Disparities.* Retrieved July 13, 2002, from the World Wide Web: *http://www.niams.nih.gov/an/stratplan/strategicplanhd/strategicplanhd.htm*

43. National Institute of Arthritis and Musculoskeletal and Skin Diseases. 2001a. *Health topics: Questions and answers about acne.* Retrieved June 10, 2002, from the World Wide Web: http://www.niams.nih.gov/hi/topics/acne/acne.htm#acne_a

44. National Institute of Arthritis and Musculoskeletal and Skin Diseases. 2001. *Questions and answers about growth plate injuries.* Retrieved June 4, 2002, from the World Wide Web: *http://www.niams.nih.gov/hi/topics/growth_plate/growth.htm*

45. National Institute of Arthritis and Musculoskeletal and Skin Diseases. 2002. *Handout on health: Osteoarthritis.* Retrieved July 1, 2002, from the World Wide Web: *http://www.niams.nih.gov/hi/topics/arthritis/oahandout.htm*

46. National Institutes of Health Osteoporosis and Related Bone Diseases National Resource Center. 2002. *Use of bisphosphonates in metabolic bone diseases.* Retrieved January 13, 2003, from the World Wide Web: *http://www.osteo.org/newfile.asp?doc=p128i&doctitle=Use+of+Bisphosphonates+in+Metabolic+Bone+Diseases&doctype=HTML+Fact+Sheet*

47. National Research Council. 1996. *National Science Education Standards.* Washington, DC: National Academy Press.

48. Osteogenesis Imperfecta Foundation. No date. *Fast facts on osteogenesis imperfecta.* Retrieved July 10, 2002, from the World Wide Web: *http://www.oif.org/site/PageServer?pagename=FastFacts*

49. Parfitt, A.M. 1994. Osteonal and hemi-osteonal remodeling: The spatial and temporal framework for signal traffic in adult human bone. *Journal of Cellular Biochemistry, 55*: 273–286.

50. Peier, A.M., Reeve, A.J., Andersson, D.A., Moqrich, A., Earley, T.J., Hergarden, A.C., et al. 2002. A heat-sensitive TRP channel expressed in keratinocytes. *Science, 296*: 2046–2049.

51. Rodan, G.A., and Martin, T.J. 2000. Therapeutic approaches to bone diseases. *Science, 289*: 1508–1514.

52. Saggese, G., Baroncelli, G.I., and Betelloni, S. 2001. Osteoporosis in children and adolescents: Diagnosis, risk factors, and prevention. *Journal of Pediatric Endocrinology, 14*: 833–859.

53. Skerry T.M., Bitensky L., Chayen, J., and Lanyon, L.E. 1989, October. Early strain-related changes in enzyme activity in osteocytes following bone loading in vivo. *Journal of Bone and Mineral Research, 4*(5): 783–788.

54. Stücker, M. 2002. The cutaneous uptake of oxygen contributes significantly to the oxygen supply of human dermis and epidermis. *Journal of Physiology, 538*: 985–994.

55. Toma, J.G., Akhavan, M., Fernades, K.J.L., Barnabe-Heider, F., Sadikot, D.R., and Miller, M. 2001. Isolation of multipotent adult stem cells from the dermis of mammalian skin. *Nature Cell Biology, 3*: 778–784.

56. University of California Regents. 2000. *Muscle physiology.* Retrieved July 10, 2002, from the World Wide Web: *http://muscle.ucsd.edu*

57. University of Maryland Medicine. 2001. *Osteogenesis imperfecta.* Retrieved July 10, 2002, from the World Wide Web: *http://www.umm.edu/bone/oi.htm*

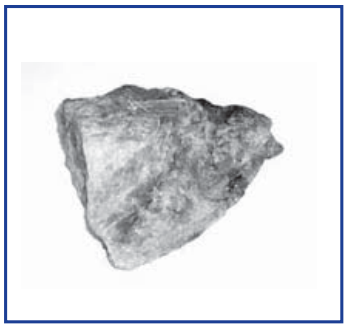
58. University of Wisconsin-Madison. 2000. *Chance discovery of "immortal skin" holds medical promise.* Retrieved June 14, 2003, from the World Wide Web: *http://www.news.wisc.edu/releases/5528.html*

59. Voltek, J.S., Gomez, A.L., Scheett, T.P., Sharman, M.J., French, D.N., Rubin, M.R., et al. 2003. *Journal of the American Dietetic Association, 103(10)*: 1353–1356.

60. Wolpert, L., Beddington, R., Brockes, J., Jessell, T., Lawrence, P., and Meyerowitz, E. 1998. *Principles of Development.* London: Current Biology Ltd.

Lesson 1
Engage

It's Alive! Or Is It?



At a Glance

Overview

Lesson 1 consists of one activity that engages students in the study of bones, muscle, and skin. Through a teacher demonstration and class discussion, students share their prior knowledge about living systems and bone, muscle, and skin. Students then develop a list of characteristics of living things and their own understanding of bone, muscle, and skin as living systems.

Major Concepts

Bone, muscle, and skin are living systems. Some common characteristics of living systems are that they

- are composed of one or more cells,
- function according to a genetic blueprint,
- obtain and use energy, and
- interact with their environment.

Objectives

After completing this lesson, students will be able to

- describe characteristics of living things and
- explain characteristics of bone, muscle, and skin that allow these systems to be classified as living.

Teacher Background

See the following sections in Information about the Musculoskeletal and Skin Systems:

1 *Introduction* (pages 1–2)
3 *Characteristics of Living and Nonliving Systems* (pages 23–24)

In Advance

Activity	Web Component?	Photocopies	Materials
1	No	Master 1.1, *It's Alive! Or Is It?*, 1 copy per student	1 piece of white chalk 1 rubber band 1 piece of heavy paper, wrapping paper, or a report cover 1 chicken breast bone, "wishbone," or other animal bone that is dried and easily broken 1 piece of raw meat of any kind, although red meat may be more easily associated with muscle 1 piece of chicken skin 1 knife 1 pair of scissors

Preparation

Wash the chicken bone, raw meat, and chicken skin. Keep the meat and skin on ice prior to use. Wear plastic or rubber gloves when handling these items to prevent possible bacterial contamination. Cover an area of a front table or workbench with nonabsorbent material to prevent contamination of the work space. Have necessary materials on hand to dispose of meat and chicken skin in accordance with your school's regulations. Just before class, pair the materials as follows: chalk with bone; rubber band with muscle; and paper with skin.

Make photocopies.

Procedure

Note to teachers: In this lesson, students develop a list of characteristics of living systems. Defining life is not a trivial task. Life has been defined in many ways for many different purposes, and there is no single definition that works for everyone. The characteristics that we focus on in this lesson were derived with the following in mind:

- they are simple and basic, with a minimum of exceptions;
- they provide sufficient conditions that enable us to specify whether something is living or not;
- they are consistent with common usage and, when applied to simple examples, allow those examples to be classified in the same way.

Proceed through the lesson at a steady pace. The idea is to elicit students' prior knowledge about living systems and help them appreciate that muscle, skin, and especially bone contain living cells.

1. **Focus student attention on the three pairs of materials on the front table. Begin with the paper and skin. Ask students, "What do these two items have in common?"**

   Allow only two to three minutes to develop this list. Student responses will vary. They may indicate that both skin and paper are flat and flexible. In addition to observable characteristics, try to focus students on functions. Both items can be used as coverings to contain things or as a protective layer for items beneath them.

   Note to teachers: Asking this question requires students to call on their prior knowledge and to engage their thinking. At this point, do not critique student responses. Appropriate teacher comments are short and positive, such as "Good" and "What else?" Other appropriate teacher responses include "Why do you believe that?" or "How do you know that?" Questions such as these allow you to assess current student knowledge about the subject and adjust lessons accordingly. They also provide a springboard to "Let's find out" or "Let's investigate." In general, it is time to move forward when you see that thinking has been engaged.

2. **Ask students, "How are paper and skin different?"**

   Once again, allow only two to three minutes to develop this list. Student responses again will vary. Although they probably will lack details, they may indicate that paper and skin are made of different things. Try to get students to elaborate on this response. They may also indicate that both came from sources that were alive at one time.

3. **Repeat the questions in Steps 1 and 2 for chalk and bone and for the rubber band and meat.**

   Developing lists of similarities and dissimilarities for these two pairs should proceed quickly. For each pair, try to have students come up with at least one response relating to what each item is composed of. Note that it is possible that students may not know that meat is animal muscle. If necessary, tell them that meat is muscle tissue.

4. **Break both the chalk and the bone. Cut both the rubber band and the piece of meat. Cut both the paper and the chicken skin. Ask students, "Can these items repair themselves? Why or why not?"**

   Students will realize that the chalk, rubber band, and paper cannot repair themselves. They also should realize that the bone, meat, and skin cannot repair themselves. Some students, however, may make the leap to bone, muscle, and skin in an intact organism, such as a human, and indicate that these three systems can indeed repair themselves.

5. **Ask students to raise their hands if they have ever broken a bone, injured a muscle, or cut their skin.**

6. **Ask students to lower their hands if their injuries healed.**

   All students should lower their hands unless their injury is very recent or they have a condition that prevents normal healing. Some students may indicate that healing occurred, but it took a long time. All student responses are appropriate for discussions later in this lesson and in subsequent lessons.

   Note to teachers: Some students may raise the issue of scars forming at the site of a previous skin injury. Rather than allow this topic to change the focus of class discussion, simply indicate that scar formation is an indication that the tissue has healed.

7. **Ask students, "Why could the bone, muscle, and skin of your body heal while the broken chicken bone, cut piece of meat, and cut chicken skin could not repair themselves?"**

   While students may understand that there are basic differences between muscle in their body and meat on the table, for instance, they may have trouble expressing what those differences are and why the two function differently. You may have to guide the discussion by asking additional questions:
   - "Can the chicken bone, meat, and skin 'feel' pain or respond to a stimulus, like a pinprick, as bone, muscle, and skin in the body would?"
   - "If your skin were cut, it would bleed—why didn't the chicken skin bleed when cut?"
   - "Can the chicken bone, meat, and skin grow as bone, muscle, and skin in the body do?"

   Try to guide this brief discussion so that students view the bone, muscle, and skin of their bodies as active, changing, and responsive systems that are connected to other body systems, such as nerves and blood vessels.

8. **Divide the class into teams of three or four. Ask each team to make a list of characteristics of living systems.**

   Give teams just five minutes for this task. If students need help getting started, suggest that they think about finishing sentences that begin, "Living systems are made of …" or "Living systems are able to … ."

9. **Ask teams to share the items on their list with the class.**

   Write the responses on the board. Try to summarize the responses like this: living systems
   - are composed of one or more cells;
   - function according to a genetic blueprint (the cells contain DNA);
   - obtain and make energy; and
   - interact with their environment.

   If students respond that living systems can move, for instance, you might indicate that this characteristic is the result of obtaining and making energy and interacting with the environment.

   Note to teachers: The ability to reproduce is a commonly listed characteristic of living systems. In this lesson, that characteristic is not listed separately because bone, although it is a living system, does not reproduce itself. Rather, the cells of bone reproduce and carry out those activities (such as making protein and depositing mineral) that allow bone to grow, repair, and remodel itself. If students mention reproduction as a characteristic of living systems, list this response under "function according to a genetic blueprint (the cells contain DNA)."

10. **Provide each student with one copy of Master 1.1, *It's Alive! Or Is It?* Ask students to fill in the first column, Characteristics of Living Systems, with the summary items you've created from Step 9.**

11. **Ask students to consider the class discussion and complete the table. For instance, if the first item in the characteristics column is "Living systems are made of cells," students should check the "Yes" column if they agree with this statement or the "No" column if they disagree with this statement. They do this for each system—bone, muscle, and skin—for each characteristic of a living system.**

12. **Ask students if they believe that bone, muscle, and skin are living systems. Ask for a show of hands.**

13. **Ask several students to share their thoughts and reasoning with the class.**

14. **Ask students to write an answer to the question at the bottom of Master 1.1, *It's Alive! Or Is It?*, Why do you believe bone, muscle, and skin have been grouped together for study in this module?**

NSES

Content Standard C:
Some traits are inherited and others result from interactions with the environment.

Assessment:
Collect students' copies of Master 1.1. They will help you assess how well each student distinguishes between the living and the nonliving.

15. Ask several students to share their thoughts with the class.

Why bone, muscle, and skin have been grouped for this module may not be obvious to students. Answering this question provides an opportunity for students to reflect on prior knowledge, and it sets the stage for the investigations to follow. Over the course of this module, students will develop the understanding that these systems all have structural functions and they protect the body. Also, these systems simultaneously allow flexibility and strength.

16. Explain to students that they are about to begin their study of bone, muscle, and skin. As they investigate these three systems, they can reflect on their understanding of bone, muscle, and skin as living systems by comparing their new insights with their responses in this lesson.

Lesson 1 Organizer

What the Teacher Does	Procedure Reference
Activity 1: *It's Alive! Or Is It?*	
Focus students' attention on the three pairs of materials: paper and skin, chalk and bone, and rubber band and muscle. • Ask what each pair of items has in common.	Page 51 Step 1
Ask how each pair differs: • Paper and skin • Chalk and bone • Rubber band and meat	Page 51 Steps 2 and 3
Break the chalk and bone. Cut the rubber band and meat. Cut the paper and chicken skin. • Ask if these items can repair themselves.	Page 51 Step 4
Ask students to raise their hands if they have ever broken a bone, injured a muscle or cut their skin. • Instruct students to lower their hands if their injuries healed.	Page 52 Steps 5 and 6
Ask students why their bones, muscle, and skin can heal but the samples on the table cannot.	Page 52 Step 7
Divide the class into teams of three or four. Instruct teams to • make a list of characteristics of living things and • share their list with the rest of the class.	Pages 52–53 Steps 8 and 9 M
Give each student a copy of Master 1.1, *It's Alive! Or Is It?* • Ask students to fill in the column labeled "Characteristics of Living Systems." • Ask students to complete the rest of the table.	Page 53 Steps 10 and 11
Ask students whether they believe that bone, muscle, and skin are living systems. • Ask for a show of hands. • Have several students share their reasoning with the class.	Page 53 Steps 12 and 13
Ask students to write an answer to the question at the bottom of Master 1.1, *It's Alive! Or Is It?* • Have several students share their reasoning with the class.	Pages 53–54 Steps 14 and 15
Explain that they will now investigate bone, muscle, and skin. • They should remember their new insights as the lessons proceed.	Page 54 Step 16

M = Involves copying a master.

What Makes Bones Strong?

Lesson 2
Explore
Explain

At a Glance

Overview

In Lesson 2, students discuss the function of bone, muscle, and skin and then focus their attention on bone. They use pasta and rubber bands to model how minerals and collagen contribute to bone strength. Results of the modeling activity are used to make predictions about what will happen when chicken bones have their mineral and collagen content reduced. The lesson concludes with students evaluating a bathtub model for its relationship to the dynamic nature of bone in the body.

Major Concepts

- The components of bone include cells, minerals, and the protein collagen.
- The structure of a bone depends, in part, on minerals and collagen.
- The structure of a bone affects its strength.

Objectives

After completing this lesson, students will be able to

- recognize that there is a relationship between the structure and function of bone and
- describe how minerals and collagen affect the strength of bone.

Teacher Background

See the following sections in Information about the Musculoskeletal and Skin Systems:

4 Characteristics of Bone, Muscle, and Skin (pages 24–32)
6.1 Diseases affecting bone (pages 35–36)

In Advance

Activity	Web Component?	Photocopies	Materials
1	No	Master 2.1, *Bone Structure*, 1 transparency Master 2.2, *Testing the Pasta Model*, 1 copy per team of 3 Master 2.3, *Bone in Balance*, 1 copy per student and 1 transparency	angel-hair pasta (50 pieces per team of 3) rubber bands (10 if using tiny bands meant for braces or 5 if using small regular bands, per team of 3) large paper clips (2 per team of 3) ruler weights (about 200 grams each, 2 per team of 3) 1 balance 3 to 6 chicken bones per class 100 mL white vinegar 100 mL bleach 3 containers that hold at least 100 mL, with lids water

Note to teachers: The smaller bones of the chicken wing work well when soaked in vinegar, while the larger bones of the leg work well when soaked in bleach (see the Preparation section). Standard 5/8-inch washers work well as weights for this lesson. They are easily hooked on a partially unfolded paper clip, and six of them weigh about 200 grams. An alternative to pushing desks together to support the pasta is to use two stacks of books and suspend the pasta between them.

Preparation

For each class you teach, you will need one or two bones from each treatment group. About three days before class, place one or two clean, dry chicken bones into each of the following:

- 100 mL water (control)
- 100 mL white vinegar (undiluted)
- 100 mL bleach (undiluted)

Cover each container and leave undisturbed. An overnight treatment with bleach should be enough to produce bones that are brittle and break easily. After removing the bones from the bleach, soak them in several changes of water. Use a quart of water per change. A two-day treatment with vinegar should be enough to produce flexible wing bones. Be sure to keep the vinegar-treated bones wet. If allowed to dry, the bones will lose their flexibility and regain their hardness. Be careful not to spill the bleach or vinegar on your skin or clothing.

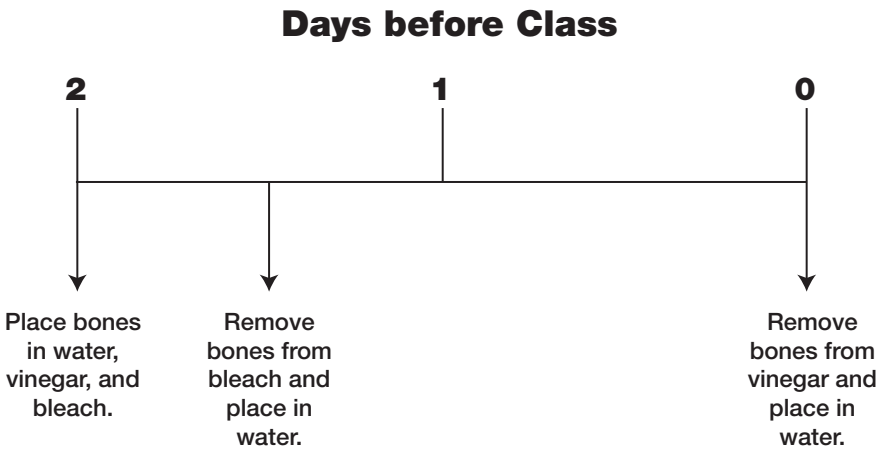


Figure 2.2. *Timeline for bone preparation.*

Count out 40 pieces of angel-hair pasta, divide them into two groups of 20 strands, and bundle each group using small rubber bands, as seen in the Figure 2.2. You can use one of these groups at Step 10 and again at Step 22. The second group should be soaked in water for two minutes before Step 23. You can place this bundle in water when you reach Step 19 or 20.

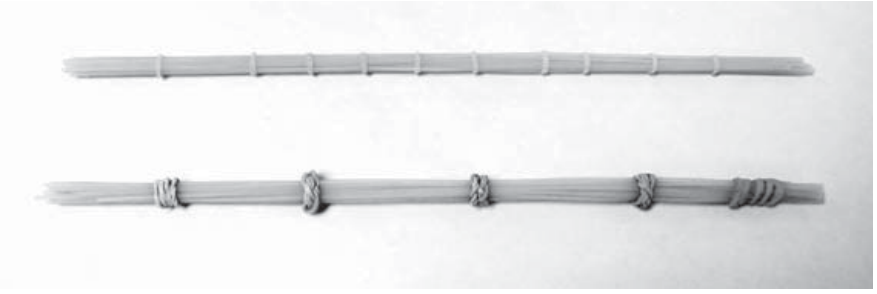


Figure 2.3. *Bundled pasta.*

Prepare photocopies and transparencies.

Procedure

1. **Begin by asking the class, "What does skin do for us?"**

   Focus the discussion on skin as a protective barrier. If not mentioned, bring out other functions such as "holding us together" and heat regulation through sweating.

2. **Ask the class, "What does muscle do for us?"**

   Students may say that muscle allows us to move and gives us strength. Emphasize that the primary function of muscle is to interact with the skeleton to produce movement.

3. **Ask the class, "What does bone do for us?"**

   Focus the discussion on the ability of bone to provide strength, support, and protection for the body. Other functions include storing minerals and containing bone marrow.

4. **Explain to the class that in each case (skin, muscle, and bone), the functions of the body system are related to its unique structure. Explain that in this activity, students will examine the relationship between structure and function in bone.**

5. **Remind the class that they learned in Lesson 1 that bone is a living tissue. Ask, "What is bone made of?"**

   Using what they learned in Lesson 1, students should respond that bone is made of cells. Some students may also recognize that bone contains calcium. If students do not mention calcium, remind them of the phrase, "Milk builds strong bones." Ask them why they think milk builds strong bones. Bring out the idea that calcium in milk helps build strong bones.

NSES

Content Standard C: Specialized functions in multicellular organisms.

6. **Explain that in addition to cells, bone contains minerals and a protein called collagen that is found outside the cells. Ask the class if they know what minerals and collagen are.**

   Students likely will not have a good understanding of minerals and collagen. For the purpose of this lesson, bring out the idea that minerals are chemicals important to our health. Explain that the minerals most important to the health of bone are calcium and phosphorus. These minerals provide bone with strength. Collagen is a protein that also contributes to bone strength.

7. **Display a transparency of Master 2.1, *Bone Structure*. Explain to students the following:**
   - **Bone contains collagen and minerals, which form the hard structure of bone.**
   - **Bone cells make collagen and send it outside the cells, where the collagen molecules are linked into bundles; the cells then deposit minerals around the collagen.**
   - **There are two forms of bone: compact bone and spongy bone.**
   - **The outside of bone is compact bone, which makes the bone strong.**
   - **The inside of bone is spongy bone. Spongy bone provides structure to the bone. It also allows bone to slightly compress when placed under stress and return to its original shape when the stress is removed.**

   The master shows a section of bone from the hip joint. The inset on the left is a microscopic view of spongy bone showing the collagen-

mineral framework. The inset on the upper right shows individual collagen molecules that have been linked together to form a bundle. The calcium-containing mineral is deposited around the collagen molecules (the mineral is not shown in this inset).

You can make an analogy to reinforced concrete. Imagine that you have steel rods and cement that you will use to construct a wall or a bridge. Pouring cement around steel rods placed in a suitable frame produces a material (reinforced concrete) that is stronger and more capable of withstanding movement than either steel rods or cement alone. Bone has a similar organization. The steel rods are chains of collagen, which confer resiliency, and the cement is crystals of mineral containing calcium and phosphorus, which confer strength.

8. **Ask students to predict which is stronger, a group of protein molecules that are not linked together and have mineral around them or a similar number of protein molecules that are linked together and have mineral around them.**

   This can be done quickly with a show of hands.

9. **Explain that scientists often use models to gain information about biological systems and that students will use a model to study bone strength.**

10. **Once again, display the transparency of Master 2.1, *Bone Structure*. Hold up a bundle of pasta held together with rubber bands (see Figure 2.3). Explain that it represents bone.**

11. **Ask students to relate the pasta model of bone to the images on Master 2.1:**

    - **What do the pieces of pasta represent?**

    The pasta represents the collagen and minerals in bone.

    - **What do the rubber bands represent?**

    The rubber bands represent the links that bundle the protein molecules together.

12. **Divide the class into teams of three. Give each team**
    - **50 pieces angel-hair of pasta**
    - **Rubber bands: 10 (if using tiny bands intended for braces) or 5 (if using small regular bands)**
    - **A ruler**
    - **Two large paper clips**
    - **Two weights such as several large washers (about 200 grams each)**

NSES

Content Standard A: Different kinds of questions suggest different kinds of scientific investigations… some involve making modules.

Note to teachers: This modeling activity is intended to be performed by each team of students. If you do not have the time or materials for this approach, then perform the modeling as a class demonstration. If you perform a demonstration, be sure to ask students what they think will happen before you perform each test. Make sure that students explain their reasoning. Also, some students may think that this activity is trivial and obvious. Make the point that it is not enough in science to believe we know the answer to a question. Rather, it is essential to investigate and obtain the evidence on which conclusions are based.

13. **Explain that students are to compare the strength of bone with minerals and bundled collagen (pasta bundled with rubber bands) to bone with minerals and unbundled collagen (loose pasta strands).**

Tip from the field test: You may want to explain that the pasta model being tested here is similar to models that engineers construct to assess the strength of different bridge and building designs.

14. **Give each team one copy of Master 2.2, *Testing the Pasta Model*, and ask teams to perform strength tests on their models (bundled pasta and unbundled pasta).**

Explain that the master provides instructions for carrying out the tests to determine the relative strengths of the two models. The instructions suggest pushing two desks close together to provide support for the pasta. Alternatively, students can use stacks of books as shown in Figure 2.3. Circulate among the teams and make sure they are performing the tests correctly. Give teams about 15 minutes to complete their tests.

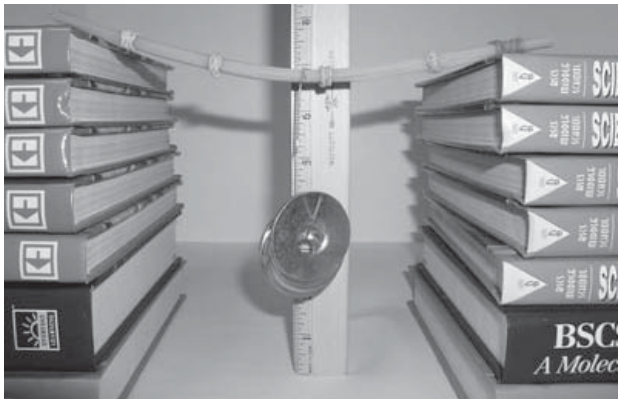


Figure 2.4. *Testing the strength of bundled pasta.*

15. **After teams have completed their tests, ask for volunteers to report their findings.**

    Students will report that the bundled sample of pasta bent less than the unbundled pasta.

16. **Ask, "What do the results of your tests say about the contributions of bundled collagen to the strength of bone?"**

    Student responses will vary. Students should understand that the presence of the rubber bands strengthened the pasta and caused it to bend less than unbundled pasta when put under stress. They also should be able to relate this to bone by concluding that linking the collagen together leads to stronger bones.

NS ES

Content Standard A: Use appropriate tools and techniques to gather, analyze, and interpret data.

17. **Show students the bone that was soaked in bleach. Explain that this bone was soaked in bleach to remove the bone's collagen but not the mineral. Ask students to predict how removing the collagen will affect the strength of the bone.**

    Students likely will respond that the bone will not be as strong with the collagen removed.

18. **Show the class the chicken bone that was soaked in water. Demonstrate (or have a student come up and demonstrate) that the bone is hard and not flexible by holding it at each end and trying to bend it.**

    Do not use so much force that the bone breaks. Explain that this bone has not had either collagen or mineral removed. It is the control being used to study the effect of removing collagen from bone.

    Note to teachers: Remember to place a bundle of pasta in water. It should soak for about two minutes before you perform Step 23.

19. **Demonstrate (or have a student come up and demonstrate) that the bleach-treated bone is brittle and cracks easily compared with the water-treated (control) bone.**

20. **Ask students if this result met their expectations.**

    Some students will feel that the demonstration shows that the bone has less strength and confirmed their expectation (especially if it breaks!). Bring out during the discussion the fact that this bone has less collagen than normal. Note that this demonstration complements the modeling that students have done. Both the model and the chicken bones show that low levels of collagen (the bleach-treated bone) or defective collagen (no bundling; the unbundled pasta) result in bone that is less strong than normal.

21. **Ask students to predict how removing calcium will affect the strength of bone.**

    Students likely will respond that removing calcium will weaken bones.

22. **Show students a bundle of pasta that has not been soaked in water. Ask students how they could use this pasta to model the removal of calcium from bone.**

    If necessary, remind students that the pasta strands represent calcium around collagen molecules. If no students suggest it, mention that you have soaked a bundle of pasta in water to model the removal of calcium from bone.

23. **Place both the unsoaked and soaked bundles of pasta between desks as described on Master 2.2, *Testing the Pasta Model*. Begin placing weights on both bundles. Ask students to observe what happens.**

    The soaked pasta is not capable of supporting much weight compared with the unsoaked control pasta.

24. **Show students a bone that was soaked in vinegar. Explain that this bone was soaked in vinegar to remove some of its calcium. Ask students to predict, based on the modeling demonstration just performed, what effect removing calcium will have on the bone's strength.**

    Students will answer that the bone soaked in vinegar will not be as strong as the control bone soaked in water.

25. **As before, demonstrate (or have a student come up and demonstrate) that the bone is more flexible and somewhat rubbery.**

    Tip from the field test: You can soak a wishbone in vinegar and it will become flexible enough to tie into a knot!

26. **Ask students if this result met their expectations.**

    Some students will feel that the demonstration shows that the bone has less strength and confirmed their expectation. Other students may feel that because the bone bends and does not break, it did not meet their expectation. To these students, point out that the collagen is still present and accounts for the strength observed. If necessary, remind them again of the reinforced concrete analogy. The steel rods are still present but the concrete is partially removed.

27. **Explain that during this lesson, students have been collecting information about bone in the same way that scientists do—by removing the object for study (bone) from the body and subjecting it to testing and observation.**

    It is important for students to realize that although studying bone outside the body is helpful, it cannot tell us everything we want to know about bone. For example, a different sort of model must be used to investigate how bone behaves when inside the body.

28. **Ask students to think back to the skin system. Explain that the body is continually making new skin cells. Ask, "Why is this necessary?"**

    Student answers will vary. Bring out during the discussion the fact that skin cells are continually dying and that they must be replaced.

29. **Explain that a similar situation exists within bones: old bone material is actively destroyed and is replaced by new bone material.**

30. **Write the word "homeostasis" on the board. Explain that scientists use this term to describe a process in the body that is maintained in a balance.**

    You may need to explain that balance means keeping the level of something constant, that is, replacing a body material that is lost with an equal amount of new material.

31. **Ask students why is it important that replacing old skin with new, or old bone with new, be kept in balance.**

    Students' responses will vary. Make sure that they realize that if more new material is made than old is removed, too much material (skin or bone) accumulates. Likewise, if more old material is removed than new material is made, a lack of material (skin or bone) results.

32. **Display an overhead transparency of Master 2.3, *Bone in Balance*. Explain that**
    - **bone contains cells called osteoblasts, which make collagen and deposit calcium around the collagen;**
    - **bone contains other cells called osteoclasts, which remove collagen and calcium from bone; and**
    - **the activities of osteoblasts and osteoclasts are balanced to maintain healthy bones.**

Do not emphasize memorizing the names of these two bone cells. Rather, mention these cells and what they do to reinforce the notion that bone contains cells and is a living tissue.

33. **Continue by explaining that scientists often use a bathtub model to represent processes in the body that are kept in balance. Indicate that the water in this diagram represents the calcium and collagen in bone. The faucet represents osteoblasts, which make collagen, move it outside the cells, and deposit minerals around the collagen. The drain represents the osteoclasts, which remove calcium and collagen from bone.**

34. **Give each student one copy of Master 2.3, *Bone in Balance*, which they will use for a brief homework assignment. Instruct students to write a short paragraph that explains how the bathtub represents bone as a living tissue. Challenge them to consider what changes in the level of "water" in the bathtub mean.**

Assessment:
Collect students' copies of master 2.3. They will help you assess how well each students understands homostasis.

A major point of the bathtub model is that bone is dynamic (ever changing). The body maintains the calcium and collagen (the water) at a constant level in healthy bone. The level of calcium and collagen (the water) may be viewed in two ways in this model. In one, changes in the level, either up or down, can represent changes leading to poor bone health if the changes are the result of imbalance between osteoblast and osteoclast activities. Viewed a second way, changes in the level of calcium and collagen, either up or down, can be used to represent the different amounts of bone associated with humans of different ages. Viewed this way, the level may be higher or lower at different ages, but the level remains in balance because osteoblast and osteoclast activities are balanced. Students will not understand how and why these changes in bone content occur. The influence of diet and exercise on bone health will be investigated in Lesson 5, *Helping the Body Build Strong Bones.*

Lesson 2 Organizer

What the Teacher Does	Procedure Reference
Activity 1: *What Makes Bones Strong*?	
Ask the class, • "What does skin do for us?" • "What does muscle do for us?" • "What does bone do for us?"	Pages 59–60 Steps 1–3
Explain that • the function of each body system relates to its structure and • students will study the relationship of structure and function in bone.	Page 60 Step 4
Remind students that bone is a living system. • Ask, "What is bone made of?"	Page 60 Step 5
Explain that bone contains minerals and a protein called collagen.	Page 60 Step 6
Display a transparency of Master 2.1, *Bone Structure*. Explain the important aspects of the diagram.	Pages 60–61 Step 7 T
Have students predict whether proteins linked together are stronger or weaker than unlinked proteins.	Page 61 Step 8
Explain that scientists use models to study biological systems. • Display a transparency of Master 2.1, *Bone Structure*. • Show the pasta model of bone. • Ask students to relate the pasta model to the bone diagrams.	Page 61 Steps 9–11 T
Divide the class into teams of three. Give each team the materials needed to construct and test its pasta model. • Give each team a copy of Master 2.2, *Testing the Pasta Model*. • Instruct teams to compare the strength of the bundled and unbundled pasta.	Pages 61–62 Steps 12–14 M
Ask for volunteers to report their findings. • Ask "What do the results of your tests say about the contribution of bundled collagen to the strength of bone?"	Page 63 Steps 15 and 16
Show students a chicken bone that was soaked in bleach. • Explain that this treatment removed some collagen. • Ask how this will affect bone strength.	Page 63 Step 17

Show students a chicken bone that was soaked in water. • Demonstrate that this bone is hard and inflexible. • Demonstrate that the bone soaked in bleach is brittle. • Ask if this result is surprising.	Page 63 Steps 18–20
Ask students to predict how removing calcium will affect bone strength.	Page 64 Step 21
Show students a bundle of pasta. Ask how they could use this pasta to model the removal of calcium from bone.	Page 64 Step 22
Compare the strength of pasta that has been soaked in water with pasta that has not been soaked in water.	Page 64 Step 23
Show students a chicken bone that was soaked in vinegar. • Explain that this treatment removed some calcium. • Ask how this will affect bone strength. • Demonstrate that this bone is rubbery. • Ask if the result was surprising.	Page 64 Steps 24–26
Explain that they have been collecting information the same way as scientists do: by removing the object for study (bone) from the body.	Page 65 Step 27
Ask students to think back to the skin system. • Ask why the body must always make new skin cells. • Relate this to the situation with bone.	Page 65 Steps 28 and 29
Write "homeostasis" on the board and provide its definition. • Ask why it is important that replacing old cells with new ones be kept in balance.	Page 65 Steps 30 and 31
Display a transparency of Master 2.3, *Bone in Balance*, and explain its important aspects.	Pages 65–66 Steps 32–33 T
Give each student a copy of Master 2.3, *Bone in Balance*, and for homework, ask students to write a short paragraph that explains how the bathtub represents bone as a living tissue.	Page 66 Step 34 M

T = Involves making a transparency. M = Involves copying a master.

Anatomy of a Kick

Lesson 3
Explore
Explain

At a Glance

Overview

Lesson 3 consists of a single activity in which students investigate the opposing actions of muscles. In the Web version of the activity, students view an animation of a character running up to and then kicking a soccer ball. They then determine the order in which six muscle groups work to execute the kick. In the print version of the activity, students watch a classmate demonstrate a kicking motion and then determine the order in which the same six muscle groups contract. Students learn that muscles produce movement by contracting and that opposing muscles are required to move a limb in opposing directions.

Major Concepts

- Muscles attach to bone on both sides of the joint.
- Muscles produce movement by contracting.
- Opposing muscles are required to produce movement in opposite directions.

Objectives

After completing this lesson, students will be able to

- explain that muscles are attached to bones,
- explain that muscles produce movement by contracting, and
- explain that opposing muscles or groups of muscles produce movement in opposite directions.

Teacher Background

See the following sections in Information about the Musculoskeletal and Skin Systems:

4.2 Muscle (pages 27–30)
5.1 Joints (pages 33–34)

In Advance

Activity	Web Component?	Photocopies	Materials
1	Yes	Master 3.1, *Muscles*, 1 transparency Master 3.2, *Anatomy of a Kick Results*, 1 copy per team of 3 Master 3.3, *Relax! I'm Contracting*, 1 copy per team of 3 and 1 transparency Master 3.4, *Muscle Group Sequence*, 1 copy per team of 3 and 1 transparency (for print version only)	None except photocopies and transparencies

Preparation

Reserve the required number of computers (one computer for each student team of three). To save time, have browsers open to this URL: *http://science.education.nih.gov/supplements/bone/student.*

Prepare photocopies and transparencies.

Procedure

For classrooms using the *Web-based version* of this activity:

Note to teachers: The following procedure describes how to conduct the Web-based version of this activity, the preferred form of instruction. Instructions for conducting the alternative print-based version follow on page 78.

1. **Ask students to hold their right arms straight out in front of them with the palm facing up. Then ask them to flex that arm —that is, they should bring the extended hand upward toward their heads while bending their elbow.**

2. **Ask students to use their left hands to feel what the muscles of their right upper arm are doing.**

   Students should examine both the biceps and triceps. Some students may not know the names of these muscles. Point out to students that the biceps is on the top (or front) of the upper arm and the triceps is on the bottom (or back) of the upper arm.

3. **Ask students to extend their right arms back to the starting position and continue to feel what the biceps and triceps of their right upper arms are doing.**

4. **Ask students to describe what they feel happening to the muscles of their right upper arms.**

   Students generally can feel the biceps of the right arm shorten (contract) and become less soft and more firm as the arm is flexed. At this point, the triceps is relaxed. As the arm is extended, particularly if it is held straight out or straight down, students can feel the biceps stretch and become relaxed while the triceps becomes more firm (it is difficult to feel the triceps contract).

5. **Ask students the following questions:**
   - "Which muscle allows you to flex your arm?" or "Where on your arm is the muscle that allows you to flex your arm?"
   - "Which muscle allows you to extend your arm?" or "Where on your arm is the muscle that allows you to extend your arm?"

   Students should recognize that the biceps flexes the arm while the triceps extends it. Some students might believe erroneously that the biceps pulls (contracts) to flex the arm and then pushes to extend it. However, they should have learned from their own muscles that the biceps is very relaxed and the triceps begins to tighten when the arm is extended.

   - "Why do you need both biceps and triceps to move the lower arm up and down at the elbow?"

   Students should conclude that muscles act by contracting (shortening). Help them realize that muscles work in opposing pairs to produce opposite (for instance, push-pull) movements.

   Note to teachers: The major objectives of this lesson are to stress that muscles produce movement when they contract and that they are arranged in opposing pairs. You should not get distracted with details of anatomy. Questions may come up, however, about how muscles attach to bone. You may wish to explain that
   - where two bones meet is called a joint (for example, the elbow is a joint);
   - special connective tissue called tendons attaches muscles to bone; and
   - ligaments are another type of connective tissue. They connect bone to bone; that is, ligaments hold the bones of a joint together.

   Students will probably understand that the biceps and triceps should each connect the upper arm to the lower arm. Although the anatomy

is more complex than students need to understand, the biceps originates in two places, the collarbone and the upper arm bone (humerus) and then attaches to the radius of the lower arm. The triceps also originates in the collarbone and the humerus and then attaches to the ulna of the lower arm.

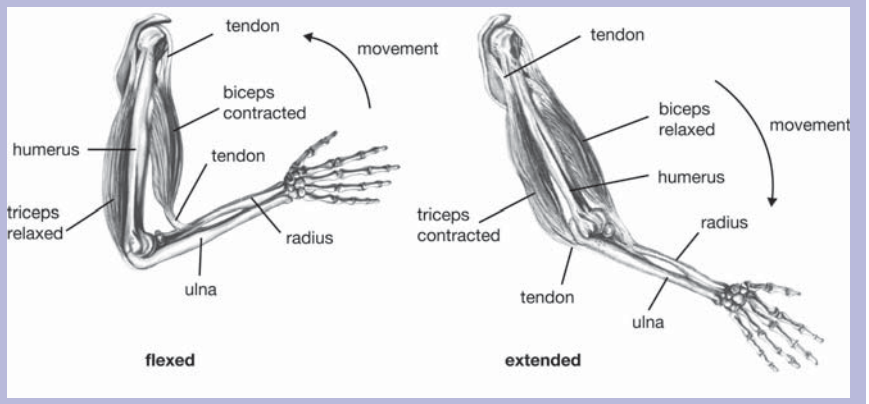


Figure 3.2. *Right arm, palm down.*

6. **Explain to students that moving the arm about the elbow is a simple motion involving two muscle groups. Show the transparency of Master 3.1, *Muscles*, and explain that more complicated movements, such as running, involve more than two muscle groups.**

   Point out to students that the human body has more than 660 skeletal muscles, which includes 56 total in both legs.

7. **Explain that students will next investigate six muscle groups involved in kicking a soccer ball. To simplify the situation, they will be able to see the muscle groups represented as colored bands. They will also see how the muscle groups connect the bones of the hip, leg, and foot.**

   By noting specific points of attachment of the muscle groups, students can assess the movement that contraction of a muscle group produces about joints at the hip, knee, and ankle.

8. **Organize students into teams of three.**

   Give each team one copy of Master 3.2, *Anatomy of a Kick Results*.

   Explain that they will use this handout to record the locations and movements produced by the six muscle groups involved in the activity.

   Direct students to their computer stations.

9. **Ensure that students' browsers are open to the URL *http://science.education.nih.gov/supplements/bone/student* and ask students to click on the "Lesson 3—Anatomy of a Kick" link.**

   After the opening animation plays, the activity screen is divided into three sections:
   - In the upper left area, users can watch an animation of a character kicking a ball. Two views are provided. One shows the character with its complete muscle system. The other shows a skeleton with colored bands representing the six different muscle groups. A slider is provided so that the user can control the progress of the animation and even stop motion so that the movement of the leg and foot can be studied in detail.
   - In the upper right area, the leg bones are depicted with colored bands of muscle attached to them. These bands represent larger groups of muscles and make it easier for students to see how the muscles attach to the bones around a joint. Users may select front, back, and side views to visualize the attachment locations of the muscle groups. When students click on the letter representing a muscle group, the movement produced by that muscle group is shown.
   - The bottom portion of the screen features six boxes where students enter the sequence of muscle contractions necessary to kick the ball. To help students begin, the first muscle group used is already filled in. The figure to the left of the boxes shows the lower leg pulled back as the character begins its kick. The muscle group responsible for pulling the lower leg back is "D," and that letter is entered in the first box.

10. **Instruct teams to begin by investigating how each of the six muscle groups attaches to the skeleton. They also should observe the movements produced by each muscle group. Students should fill out Master 3.2, *Anatomy of a Kick Results*, as they investigate.**

    Students should do the following:
    - View the leg in the upper right-hand panel from all three views: front, back, and side. This helps them understand where each muscle group attaches to the bones of the hip, leg, and foot.
    - Click on each muscle group to observe the movement it produces. By clicking on a muscle group, students see movement around a joint (hip, knee, or ankle) that is in only one direction. This emphasizes that muscles only contract to produce movement in one direction.

Content Standard A:
Think Critically and logically to make the relationship between evidence and explanations.

11. Instruct students to view the animations of the figure kicking the ball in the upper left-hand panel.

These animations show the leg movements used to kick a ball. Students can play the animations at normal speed or use the slider to control the animation manually.

12. After students investigate the activity of the six muscle groups and observe the kicking motion, they should determine the sequence in which the six muscle groups function to allow the character to kick the soccer ball. Students should enter their sequences in the boxes at the bottom of the screen. They can test their sequences by clicking on the "Test" button.

The first muscle group to contract (D) is already entered on the screen. Students enter muscle groups functioning second through sixth during the kick. If the sequence entered is correct, an animation of the character kicking the ball plays. If a sequence entered is not correct, the boxes are cleared from the first incorrect box to the end. The contraction of muscle groups A and F occurs almost simultaneously during the kick. For this reason, students can either enter AF or FA within the sequence and be considered correct. Therefore, the correct sequences are D B F A C E and D B A F C E.

Tip from the field test
If students would like a larger view of the animations, they can right click with their mouse and use the zoom feature.

Assessment:
Collect Master 3.2 to assess students' understanding.

13. Reconvene the class. Ask students, "What did you learn about muscles from this activity?" Collect Master 3.2.

Student responses will vary. Bring out in the discussion that muscles attached to bones on both sides of a joint produce movement about the joint. Students should also recognize that by being arranged in opposing pairs, muscles, which can only contract, move bones back and forth.

14. Ask students, "Why does the body need so many skeletal muscles?"

Answers will vary. Focus student thinking on the many movements the human body is capable of performing. For example, the hand and fingers are capable of a wide variety of different movements.

15. **Explain that students are now going to apply their knowledge of muscle function to an analysis of how muscles move bones in the arms. Display a transparency of Master 3.3, *Relax! I'm Contracting*.**

    Master 3.3 depicts a human skeleton in three panels. In the first panel, the skeleton has its arms extending straight out from the body. The second panel depicts movement about each elbow and wrist joint. In the third panel, the arms have returned to their original positions. In Panel A, eight muscles are shown. Each muscle attaches on either side of a joint and is identified by a number.

16. **Ask students to compare the positions of the arms among the figures in the three panels. What movements have occurred to change the arm positions from Panel A to Panel B? From Panel B to Panel C?**

    Students should mention the following:
    - In going from Panel A to Panel B, there has been movement about the elbow and wrist joints.
    - In going from Panel B to Panel C, there also has been movement about the elbow and wrist joints, but this time in reverse of that moving from Panel A to Panel B.

17. **Give each student one copy of Master 3.3, *Relax! I'm Contracting*. Instruct students to**
    - consider the movements needed to go from Panel A to Panel B;
    - indicate in the left-hand table whether each of the eight labeled muscles was relaxing or contracting;
    - consider the movements needed to go from Panel B to Panel C; and
    - indicate in the right-hand table whether each of the eight labeled muscles was relaxing or contracting.

    Give students about five minutes to complete the task. The correct responses are shown in Figure 3.3.

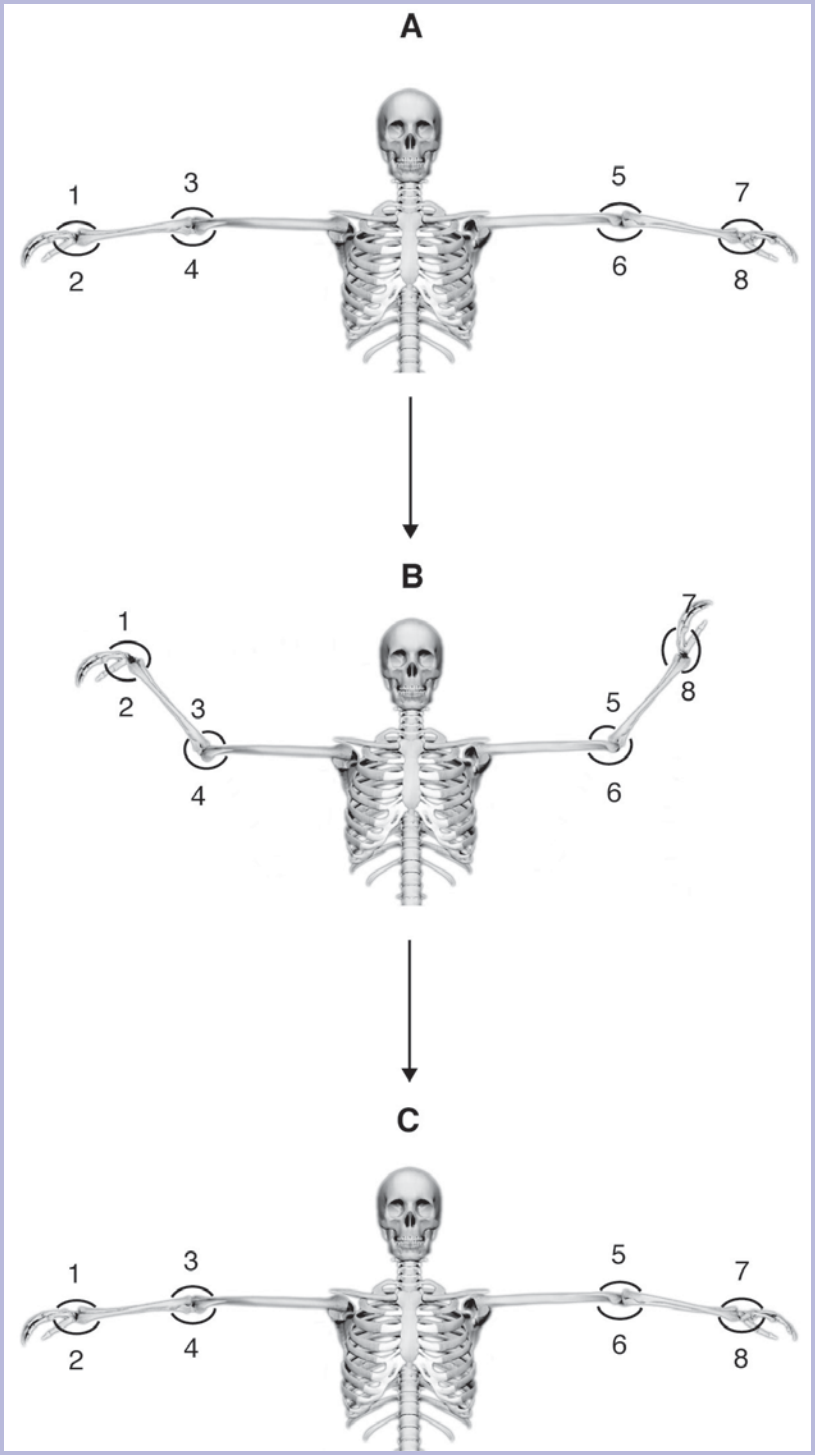


Figure 3.3. *Muscle movement about joints.*

Movement from Panel A to Panel B

1	Relaxing
2	Contracting
3	Contracting
4	Relaxing
5	Contracting
6	Relaxing
7	Contracting
8	Relaxing

Movement from Panel B to Panel C

Muscle	Contracting or Relaxing?
1	Contracting
2	Relaxing
3	Relaxing
4	Contracting
5	Relaxing
6	Contracting
7	Relaxing
8	Contracting

18. Ask students which muscles were relaxing and which were contracting. Write their responses on the transparency.

If a student makes a mistake, ask the class if they agree. Guide the discussion to bring out the correct muscle movements.

19. Ask students if they can relate the pattern of relaxing and contracting muscles when they compare the results between the two tables.

Students should notice that as movement goes from Panel A to Panel B, the pattern of muscle contraction is the opposite of that going from Panel B to Panel C. This is because the movement depicted in the panels goes from a starting position to a new position and then back to the original position.

20. Conclude the lesson by asking students to write a sentence or two describing how muscles cause our arms or legs to move. Instruct them to include the ideas of contraction and opposing pairs in their description.

The following is an example of what a student might write: "Opposing pairs of muscles contract to cause movement in opposite directions."

Assessment:
Assign Step 20 as homework and use it as an assessment of student learning.

Alternate print version for those classes without access to the Internet:

1. **Ask students to hold their right arms straight out in front of them with the palm facing up. Then ask them to flex that arm—that is, they should bring the extended hand upward toward their heads while bending their elbow.**

2. **Ask students to use their left hands to feel what the muscles of their right upper arms are doing.**

   Students should examine both the biceps and triceps. Some students may not know the names of these muscles. Point out to students that the biceps is on the top (or front) of the upper arm and the triceps is on the bottom (or back) of the upper arm.

3. **Ask students to extend their right arms back to the starting position and continue to feel what the biceps and triceps of their right upper arms are doing.**

4. **Ask students to describe what they feel happening to the muscles of their right upper arms.**

   Students generally can feel the biceps of the right arm shorten (contract) and become less soft and more firm as the arm is flexed. At this point, the triceps is relaxed. As the arm is extended, particularly if it is held straight out or straight down, students can feel the biceps stretch and become relaxed while the triceps becomes more firm (it is difficult to feel the triceps contract).

5. **Ask students the following questions:**
   - "Which muscle allows you to flex your arm?" or "Where on your arm is the muscle that allows you to flex your arm?"
   - "Which muscle allows you to extend your arm?" or "Where on your arm is the muscle that allows you to extend your arm?"

   Students should recognize that the biceps flexes the arm while the triceps extends it. Some students might believe erroneously that the biceps pulls (contracts) to flex the arm and then pushes to extend it. However, they should have learned from their own muscles that the biceps is very relaxed and the triceps begins to tighten when the arm is extended.

   - "Why do you need both biceps and triceps to move the lower arm up and down at the elbow?"

Students should conclude that muscles act by contracting (shortening). Help them realize that muscles work in opposing pairs to produce opposite (for instance, push-pull) movements.

Note to teachers: The major objectives of this lesson are to stress that muscles produce movement when they contract and that they are arranged in opposing pairs. You should not get distracted with details of anatomy. Questions may come up, however, about how muscles attach to bone. You may wish to explain that

- where two bones meet is called a joint (for example, the elbow is a joint);
- special connective tissue called tendons attaches muscles to bone; and
- ligaments are another type of connective tissue. They connect bone to bone; that is, ligaments hold the bones of a joint together.

Students will probably understand that the biceps and triceps each connect the upper arm to the lower arm. Although the anatomy is more complex than students need to understand, the biceps originates in two places, the collarbone and the upper arm bone (humerus) and then attaches to the radius of the lower arm. The triceps also originates in the collarbone and the humerus and then attaches to the ulna of the lower arm.

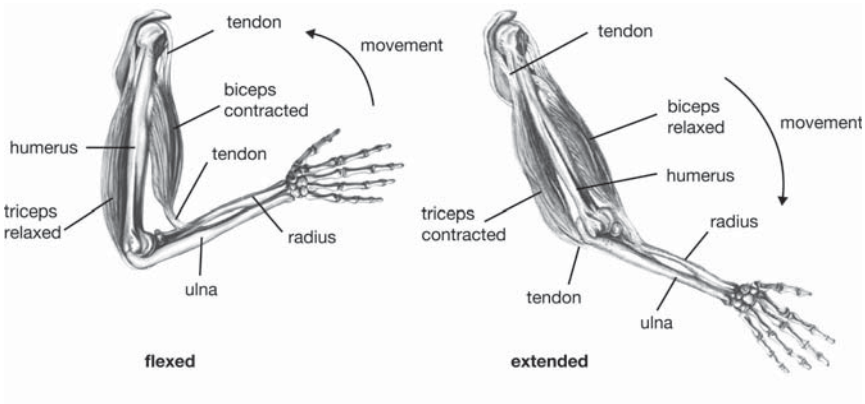


Figure 3.4. *Right arm, palm down.*

6. **Explain to students that moving the arm about the elbow is a simple motion involving two muscle groups. Show the transparency of Master 3.1, *Muscles*, and explain that more complicated movements, such as running, involve more than two muscle groups.**

   Point out to students that the human body has more than 660 skeletal muscles, which includes 56 total in both legs.

7. **Explain that they will next investigate the more complicated movements associated with kicking a soccer ball. Ask for one student to come to the front of the room and demonstrate how he or she would kick an imaginary ball lying on the ground.**

8. **As the student kicks, ask the class to point out muscles that produce the kicking motion.**
   - For each muscle that students point out, have them explain where they think that the muscle attaches to the leg bones.
   - Ask what happens when that muscle contracts.
   - As necessary, have the student repeat that part of the kick featuring the muscle under discussion.

   Keep this discussion relatively brief. Do not try to discuss all the muscles involved. The next step will address six muscle groups involved in kicking a ball. Guide the discussion so that muscles connecting the hip to the upper leg, the upper leg to the lower leg, and the lower leg to the foot are discussed.

9. **Display a transparency of Master 3.4, *Muscle Group Sequence*. Explain that this transparency depicts six muscle groups needed for kicking a ball. The muscle groups are represented as shaded bands attached to the skeleton.**
   - Go over each muscle group, pointing out where it attaches to the skeleton.
   - For each muscle group, ask the students, "What will happen when this muscle contracts?"

   As the movements produced by muscle contractions are discussed, they can be drawn on the transparency as arrows indicating the direction of movement. By noting specific points of attachment of the muscle groups, students can assess the movement that contraction of a muscle group produces about the hip joint, knee, or ankle.

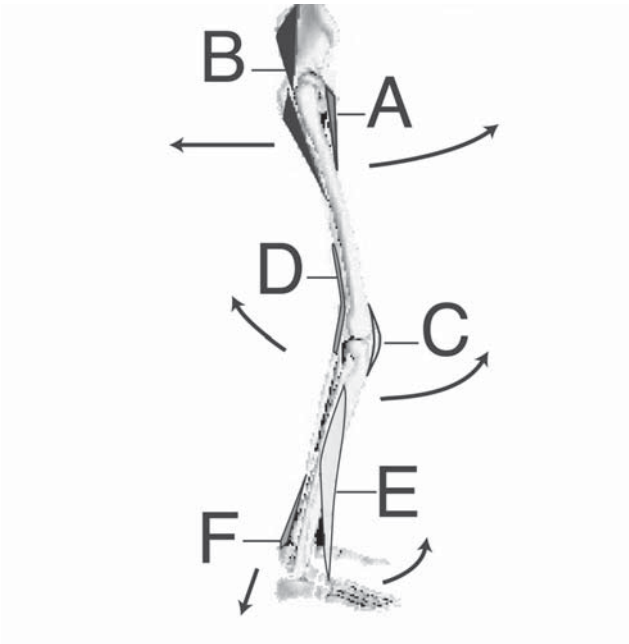


Figure 3.5. *The six muscle groups.*

Note to teachers: The kicking motion will vary depending on how individual students kick. See also the annotation for Step 12 below.

Content Standard A: Think critically and logically to make the relationship between evidence and explanations.

10. **Organize students into teams of three. Give each team one copy of Master 3.4, *Muscle Group Sequence*.**

11. **One member of each team should demonstrate the kicking motion as necessary. Instruct teams to review**
    - **how each of the six muscle groups attaches to the skeleton and**
    - **the movements produced by each muscle group.**

12. **After teams observe the kicking motion and review the movements produced by the six muscle groups, they should determine the sequence in which the six muscle groups function to produce the kicking motion. Students should write down their sequences in the table on Master 3.4, *Muscle Group Sequence*.**

    Because students will not necessarily demonstrate the same kicking motion, there is no single, correct sequence in which the six muscle groups will function to produce the kicking motion. For instance, some students may pull their leg back (D) before bending the leg at the knee (C), while others may reverse that order. There also may be variation in the point at which the foot is extended and flexed. It is important only that students present a reasonable sequence of muscle action that demonstrates muscles contracting in an order consistent with the kick investigated by their group.

Assessment:
Collect copies of Master 3.4 to assess students' understanding.

13. **After teams have determined their sequences, reconvene the class. Ask for volunteers to demonstrate their kicks, report their sequences of muscle contractions, and explain their reasoning. Collect copies of Master 3.4.**

    Student responses will vary. Bring out in the discussion that muscles attached to bones on both sides of a joint produce movement about the joint. Students should also recognize that by being arranged in opposing pairs, muscles, which can only contract, move bones back and forth.

14. **Ask students, "Why does the body need so many skeletal muscles?"**

    Answers will vary. Focus student thinking on the many movements the human body is capable of performing. For example, the hand and fingers are capable of a wide variety of different movements.

15. **Explain that students are now going to apply their knowledge of muscle function to an analysis of how muscles move bones in the arms. Display a transparency of Master 3.3, *Relax! I'm Contracting.***

    Master 3.3 depicts a human skeleton in three panels. In the first panel, the skeleton has its arms extending straight out from the body. The second panel depicts movement about each elbow and wrist joint. In the third panel, the arms have returned to their original positions. In Panel A, eight muscles are shown. Each muscle attaches on either side of a joint and is identified by a number.

16. **Ask students to compare the positions of the arms among the figures in the three panels. What movements have occurred to change the arm positions from Panel A to Panel B? From Panel B to Panel C?**

    Students should mention the following:
    - In going from Panel A to Panel B, there has been movement about the elbow and wrist joints.
    - In going from Panel B to Panel C, there also has been movement about the elbow and wrist joints, but this time in reverse of that moving from panel A to panel B.

17. **Give each student one copy of Master 3.3, *Relax! I'm Contracting*. Instruct students to**
    - **consider the movements needed to go from Panel A to Panel B;**
    - **indicate in the left-hand table whether each of the eight labeled muscles was relaxing or contracting;**
    - **consider the movements needed to go from Panel B to Panel C; and**
    - **indicate in the table on the right-hand whether each of the eight labeled muscles was relaxing or contracting.**

Give students about five minutes to complete the task. The correct responses are shown in Figure 3.6.

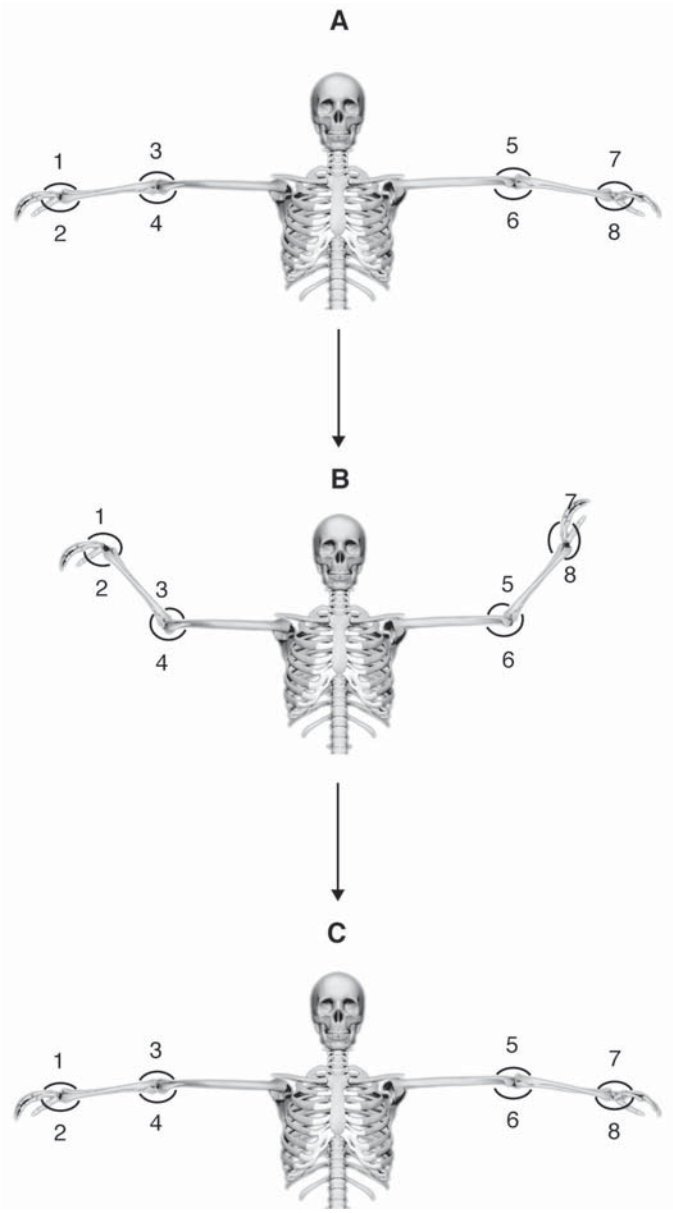


Figure 3.6. *Muscle movements about joints.*

Movement from Panel A to Panel B

1	Relaxing
2	Contracting
3	Contracting
4	Relaxing
5	Contracting
6	Relaxing
7	Contracting
8	Relaxing

Movement from Panel B to Panel C

Muscle	Contracting or Relaxing?
1	Contracting
2	Relaxing
3	Relaxing
4	Contracting
5	Relaxing
6	Contracting
7	Relaxing
8	Contracting

18. Ask students which muscles were relaxing and which were contracting. Write their responses on the transparency.

If a student makes a mistake, ask the class if they agree. Guide the discussion to bring out the correct muscle movements.

19. Ask students if they can relate the pattern of relaxing and contracting muscles when they compare the results between the two tables.

Students should notice that as movement goes from Panel A to Panel B, the pattern of muscle contraction is the opposite of that going from Panel B to Panel C. This is because the movement depicted in the panels goes from a starting position to a new position and then back to the original position.

20. Conclude the lesson by asking students to write a sentence or two describing how muscles cause our arms or legs to move. Instruct them to include the ideas of *contraction* and *opposing pairs* in their descriptions.

The following is an example of what a student might write: "Opposing pairs of muscles contract to cause movement in opposite directions."

Assessment:
Assign Step 20 as homework, and use it as an assessment of student learning.

Lesson 3 Organizer: Web Version

What the Teacher Does	Procedure Reference
Activity 1: *Anatomy of a Kick*	
Have students hold out their right arms and flex them. They use their left hands to feel the muscles of the right arm. • Ask students what the muscles in their arms are doing during the flex action.	Pages 70–71 Steps 1–4
Ask students, • "Which muscle allows you flex your arm?" • "Which muscle allows you to extend your arm?" • "Why do you need both biceps and triceps to move the lower arm up and down at the elbow?"	Pages 70–71 Step 5
Explain that moving the arm about the elbow involves two different muscle groups. Display a transparency of Master 3.1, *Muscles*, and explain that more complicated movements such as running involve more than two muscle groups.	Page 72 Step 6 T
Explain that students will now investigate how six different muscle groups contribute to the kicking of a soccer ball.	Page 72 Step 7
Divide the class into teams of three. • Give each team a copy of Master 3.2, *Anatomy of a Kick Results*. • Explain that they will use it to record the locations and movements produced by the different muscle groups in the activity. • Direct the teams to their computer stations.	Pages 73–73 Step 8 M
Instruct teams to go to the module's Web site and click on the link to "Lesson 3—*Anatomy of a Kick*."	Page 73 Step 9
Instruct teams to • investigate how each of the six muscle groups attaches to the skeleton; • observe the movements produced by each muscle group; • record their conclusions on Master 3.2, *Anatomy of a Kick Results*; and • view the animations of the figure kicking the ball in the upper left-hand panel.	Pages 73–74 Steps 10 and 11

After students complete the analysis, instruct them to enter at the bottom of the screen the sequence of muscle group contractions needed to kick the ball. • After entering their sequences, they should click on the "Test" button to see if the sequence is correct.	Page 74 Step 12
Reconvene the class. Ask students, • "What did you learn about muscles from the lesson?" • "Why does the body need so many skeletal muscles?"	Page 74 Steps 13–14
Explain that students will now apply their muscle knowledge to movement of the arms. Display a transparency of Master 3.3, *Relax! I'm Contracting*.	Page 75 Step 15
Instruct students to compare the positions of the arms among the figures in the three panels. Ask, • "What movements have occurred to change the arm positions from Panel A to Panel B?" • "From Panel B to Panel C?"	Page 75 Step 16
Give each student one copy of Master 3.3, *Relax! I'm Contracting*. Instruct students to • consider the movements needed to go from Panel A to Panel B and from Panel B to Panel C and • indicate whether each labeled muscle was relaxing or contracting in each case.	Pages 75–76 Step 17
Ask students which muscles were relaxing and which were contracting. Write their responses on the transparency.	Page 77 Step 18
Ask students to relate the pattern of muscle contractions when they compare the results in the two tables.	Page 77 Step 19
Conclude the lesson by asking students to write one or two sentences describing how muscles cause arms or legs to move. They must use "*contraction*" and "*opposing pairs*" in their descriptions.	Page 77 Step 20

T = Involves making a transparency. WWW = Involves using the Internet.

M = Involves copying a master.

Lesson 3 Organizer: Print Version

What the Teacher Does	Procedure Reference
Activity 1: *Anatomy of a Kick*	
Have students hold out their right arms and flex them. They use their left hands to feel the muscles of the right arm. • Ask students what the muscles in their arms are doing during the flex action.	Page 78 Steps 1–4
Ask students, • "Which muscle allows you flex your arm?" • "Which muscle allows you to extend your arm?" • "Why do you need both biceps and triceps to move the lower arm up and down at the elbow?"	Pages 78–79 Step 5
Explain that moving the arm about the elbow involves two different muscle groups. Display a transparency of Master 3.1, *Muscles* and explain that more complicated movements such as running involve more than two muscle groups.	Page 79 Step 6 T
Explain that students will now investigate the more complicated movements associated with kicking a soccer ball. Ask one student to demonstrate kicking an imaginary ball. Ask students to describe the muscles needed to kick the ball. • For each muscle, describe where it attaches. • Ask, "What happens when it contracts?"	Page 80 Steps 7 and 8
Display a transparency of Master 3.4, *Muscle Group Sequence*. Explain that it depicts six muscle groups needed to kick a ball. • Point out where each muscle group attaches to the skeleton. • For each muscle group, ask, "What will happen when this muscle contracts?"	Pages 80–81 Step 9 T
Divide the class into teams of three. Give each team one copy of Master 3.4, *Muscle Group Sequence*.	Page 81 Step 10 M
Instruct a member of each team to demonstrate the kicking motion. Ask teams to review • how each muscle group attaches to the skeleton and • the movements produced by each muscle group.	Page 81 Step 11
After students complete the analysis, instruct them to enter the sequence of muscle group contractions needed to kick the ball on Master 3.4, *Muscle Group Sequence*.	Page 81 Step 12

Reconvene the class. Ask for volunteers to • demonstrate their kicks, • report their sequences of muscle contractions, and • explain their reasoning.	Page 82 Step 13 **T**
Ask students, "Why does the body need so many skeletal muscles?" Explain that they will now apply their muscle knowledge to movement of the arms. Display a transparency of Master 3.3, *Relax! I'm Contracting.*	Page 82 Steps 14 and 15
Ask students to compare the positions of the arms among the figures in the three panels. Ask, • "What movements have occurred to change the arm positions from Panel A to Panel B?" • "From Panel B to Panel C?"	Page 82 Step 16
Give each student one copy of Master 3.3, *Relax! I'm Contracting*. Instruct students to • consider the movements needed to go from Panel A to Panel B and from Panel B to Panel C and • indicate whether each labeled muscle was relaxing or contracting in each case.	Pages 83–84 Step 17 **M**
Ask students which muscles were relaxing and which were contracting. Write their responses on the transparency.	Page 84 Step 18
Ask students to relate the pattern of muscle contractions when they compare the results in the two tables.	Page 84 Step 19
Conclude the lesson by asking students to write one or two sentences describing how muscles cause arms or legs to move. They must use "contraction" and "opposing pairs" in their descriptions.	Page 84 Step 20

T = Involves making a transparency. **M** = Involves copying a master.

Use It or Lose It

Lesson 4
Explore
Explain

At a Glance

Overview

Lesson 4 introduces students to one behavior influencing muscle: resistance training. Students look at data from a laboratory study of the effects of resistance training on the muscle mass of rats. Students learn that laboratory animals, such as rats, are used as model systems in research. Students graph data that show an increase in muscle mass in response to resistance training and a decrease after training stops. Through analysis of data and class discussion, students learn that resistance training is an important influence on muscle mass.

Major Concepts

- Animals can be used as a model system to study muscles.
- Muscle mass increases with resistance training ("use it").
- Muscle mass decreases when resistance training ends ("lose it").

Objectives

After completing this lesson, students will be able to

- describe how resistance training influences muscle,
- recognize that animals such as rats are used as model systems in research, and
- use mathematics to organize and present data.

Teacher Background

See the following sections in Information about the Musculoskeletal and Skin Systems:

2 *Misconceptions about the Musculoskeletal and Skin Systems* (pages 22–23)
4.2 *Muscle* (pages 27–30)
7 *Influences* (page 40)

In Advance

Activity	Web Component?	Photocopies	Materials
1	No	Master 4.1, *Rat Resistance Training Study*, 1 copy per team of 2 Master 4.2, *Muscle Data*, 1 transparency Master 4.3, *Graph Template*, 1 copy per team of 2 Masters 4.4a and b, *Resistance Training Study Worksheet and Graph Template*, 1 copy per team of 2	None except photocopies and transparencies

Preparation

Prepare photocopies and transparencies.

Note to teachers: The study described in this activity is based on actual research by S. Lee and R.P. Farrar (see References section, number 21). The data we used are authentic, although in some cases, numbers were rounded off to make them easier to work with.

Procedure

1. **Ask students what the statement "use it or lose it" means. Then ask whether they think this statement is true.**

   Many students will recognize that the statement refers to using muscles and that if you do not regularly use your muscles, your muscles will get smaller; that is, you will lose muscle. Students are likely to think that the statement is true. Some students may have experienced (directly or indirectly through a sibling or friend) getting bigger muscles while training for a sport and then noticing the muscles "shrink" once the athletic season is over. Other students will have had experience with lose it from a limb being immobilized in a cast. After the cast is removed, the limb appears smaller (that is, has less muscle mass) than before the accident.

2. **Ask students how they could test this statement.**

   To test use it, students might suggest measuring arm or leg size before beginning an exercise program and again after exercising for a specified length of time. To test lose it, students might suggest measuring arm or leg size of an athlete during his or her athletic season and then again after the season has ended and training has stopped, or before and after a cast is placed on a limb.
   Encourage students to think about the limitations of their proposed

tests. For example, is measuring an arm or leg an accurate measure of muscle size or mass (arms and legs contain fat, skin, and blood vessels in addition to muscle)? Students should also consider the variables that they might need to control, such as weight gain or loss and the type and duration of exercise.

3. **Divide students into teams of two and explain that they will look at the results of a study that investigated the effect of resistance training on rat muscle systems.**

4. **Distribute one copy of Master 4.1, *Rat Resistance Training Study*, to each team. Instruct students to read the description of the research study.**

   Circulate and ensure that students understand the description of the study and what resistance training and stopping training are. You might ask students to explain what they think the study investigated. Encourage students to think about examples of resistance training that they or people they know take part in and examples of stopping training, such as football players stopping weight lifting after the season is over.

   Note to teachers: To measure muscle mass, rats were euthanized, and the flexor hallucis longus muscle was removed and its mass was measured. Only one control group was used in this study because scientists in earlier studies, as well as this one, confirmed that the size of the animals does not change significantly during the 16 weeks of this type of experiment. Using one control group also reduces the number of animals that need to be euthanized.

5. **In this study, the experimental subjects are laboratory rats. We are interested in how muscles work in humans. Ask students to propose reasons why scientists use laboratory animals in research instead of people.**

   Scientists use animals in research to learn something about human biology. The animals serve as model systems for the human body. See the section Animals as Research Models in Implementing the Module on pages 13–14.

   Some students may object to working with laboratory animals. Refer to the advice given in How Can Controversial Topics Be Handled in the Classroom? on page 12. You may want to provide some examples of the many beneficial outcomes from experimentation involving laboratory animals. The benefits include the discovery of the causes of, the prevention of, and effective treatments for many infectious diseases, as well as the development and perfection of surgical techniques. For example, Louis Pasteur used rabbits and guinea pigs to identify the bacteria that cause anthrax and to develop a

NSES

Content Standard G:
It is part of scientific inquiry to evaluate the results of scientific investigation.

vaccine against this disease. Successful open-heart surgery and organ transplants are based on years of animal experimentation. Using animals in research studies of the musculoskeletal system has potential benefits for, among other things, improved rehabilitation following injury or disease.

6. **Refocus attention on the study description. Ask students to identify which groups in the study represent use it and which groups represent lose it. Then ask students to predict how muscle mass will compare for the control and each training group. (Will it increase, decrease, or stay the same?)**

   Group 1 represents use it and Groups 2 and 3 represent lose it. Accept all student responses at this point; they will discuss the use it or lose it statement in more detail at the end of this lesson.

   Students are likely to predict that the muscle mass of rats from Groups 1, 2, and 3 that experienced resistance training will be larger than the muscle mass of the control rats. Many students may be unsure about the effect of stopping training on the muscle mass of rats and may think that Groups 1, 2, and 3 will have similar muscle masses.

7. **Display a transparency of Master 4.2, *Muscle Data*. Cover the data from Groups 2 and 3. Allow students to only see the control group and Group 1 data.**

8. **Give each team one copy of Master 4.3, *Graph Template*. Instruct the teams to plot on the graph template the data from the control group and Group 1. Students should plot the data for this activity as a bar graph.**

   Encourage students to divide up the work of plotting the data. One student can plot the control and Group 1 data in this step. The other student can plot the Groups 2 and 3 data in the next step.

9. **Ask students to predict where the bars for Groups 2 and 3 will be on their graph. Then show students the remaining data on Master 4.2 and instruct them to plot Group 2 and Group 3 data on the graph template.**

Student graphs should look similar to Figure 4.2.

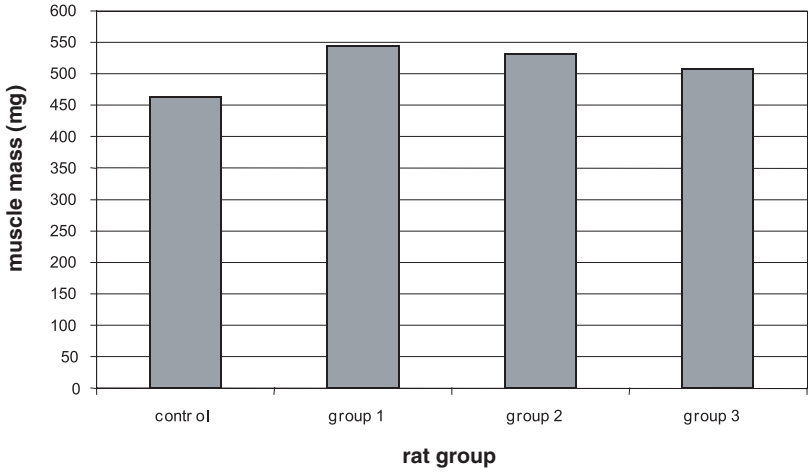


Figure 4.2. *Average mass of flexor hallucis longus (FHL) muscle for study groups.*

10. Give each team one copy of Master 4.4, *Resistance Training Study Worksheet and Graph Template*.

11. Instruct teams to complete the worksheet and plot the values on the graph.

Continue to display a transparency of Master 4.2, *Muscle Data*, to provide students with the data they will need to complete the worksheet and graph. Students may not understand why it is important to plot the data again as a percentage of muscle mass increase. Explain that the percentages are useful for making comparisons. Student graphs should look similar to Figure 4.3.

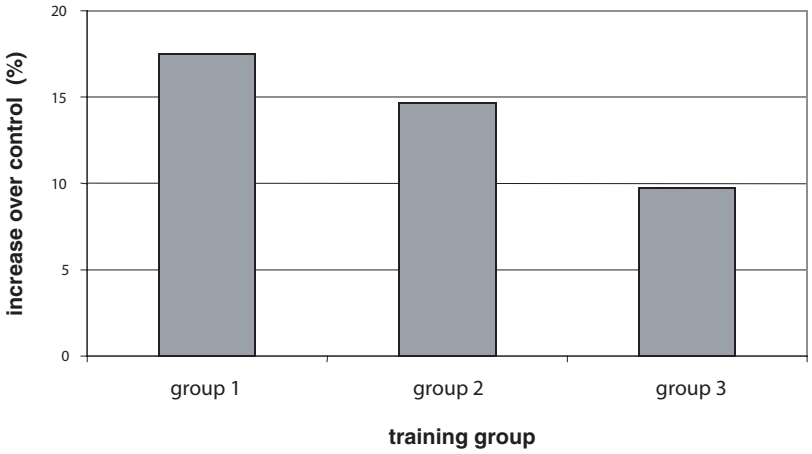


Figure 4.3. *Percent muscle mass increase of training groups over control group.*

12. **Ask students if they think rats were a good model system in the study presented in this lesson. Encourage students to explain their responses.**

    Students are likely to respond that the rats in the study were a good model system. Students recognize that if they lift weights, their muscles will get bigger, and in this study the leg muscle of the trained rats also got bigger. Explain to students that this study is also a good model system because the training program of the rats is similar to how people train with weights. Like the training program in this rat study, human training programs usually involve training two to three times per week while gradually increasing the weight. Also explain to students that the increase in rat leg muscle mass is similar to the increase of muscle mass of humans in a resistance training program.

13. **Facilitate a class discussion of the students' predictions about what use it or lose it means compared with the data from the study.**

    Most students probably recognize that training would increase the muscle mass. However, many students may be surprised by how much muscle mass decreased in the groups that stopped training.

    Teacher note: Students may believe that the numbers of muscle cells in the rats are changing during the study. Actually, the gain of muscle mass seen after resistance training and muscle mass loss after training stops is due to changes in the sizes of the muscle cells, not their numbers.

14. **Instruct students to individually write a short summary (two to four sentences) about what use it or lose it means to them after completing this lesson. Remind students to use what they learned from the resistance training study and the class discussions.**

    The following is an example of what a student might write: "Use it or lose it means that to maintain your muscles, you must use them by exercising or training. If you stop exercising or training, your muscle mass will decrease and you will lose muscle."

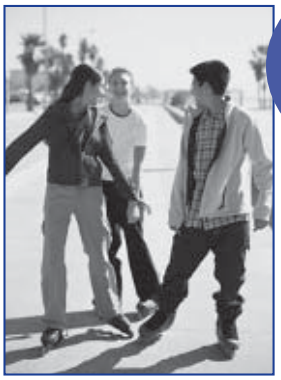
Assessment:
Assign Step 14 as homework and use it as an assessment of student learning for the lesson.

Lesson 4 Organizer

What the Teacher Does	Procedure Reference
Activity 1: *Use It or Lose It*	
Ask the students what the statement "use it or lose it" means. • Do they think it is true? • How could they test it?	Pages 90–91 Steps 1 and 2
Divide the class into teams of two. Explain that they will examine the results of a study that investigated the effect of resistance training on rats.	Page 91 Step 3
Give each team one copy of Master 4.1, *Rat Resistance Training Study*, and instruct students to read it.	Page 91 Step 4 **M**
Ask the teams why the study uses rats instead of humans.	Pages 91–92 Step 5
Ask the teams which groups represent use it and which groups represent lose it. • Instruct teams to predict how the muscle mass will compare for the control group and each training group.	Page 92 Step 6
Display a transparency of Master 4.2, *Muscle Data*. Cover the data from Groups 2 and 3 so that only data from the control group and Group 1 are visible.	Page 92 Step 7 **T**
Give each team one copy of Master 4.3, *Graph Template*. Instruct the teams to plot the data from the control group and Group 1 as a bar graph.	Page 92 Step 8 **M**
Ask students to predict where on the graph data from Groups 2 and 3 will appear. • Reveal the remaining data on the transparency of Master 4.2, *Muscle Data*. • Instruct teams to plot the data on Master 4.3, *Graph Template*.	Page 92 Step 9
Give each team one copy of Master 4.4, *Resistance Training Worksheet and Graph Template*. • Instruct teams to complete the worksheet and plot the values on the graph.	Page 93 Steps 10 and 11 **M**
Ask the students if they think rats were a good model for this study. They should explain their reasoning.	Page 94 Step 12
Facilitate a class discussion about the students' predictions regarding use it or lose it. Relate it to data from the study.	Page 94 Step 13
Instruct students to individually write a short summary of what use it or lose it means to them now.	Page 94 Step 14

M = Involves copying a master. **T** = Involves making a transparency.

Helping the Body Build Strong Bones



Lesson 5
Explain
Elaborate

At a Glance

Overview

In Lesson 5, students analyze two experiments that deal with the effect of diet and weight-bearing activities on bone mineral content. In the first experiment, students make predictions about the effects of milk and a weight-bearing activity (resistance training) on strength and bone-mineral content. They analyze actual data to test their predictions. In the second experiment, students consider how playing different sports with different weight-loading levels affects bone-mineral content.

Major Concepts

- Diet and weight-bearing activities are major influences on bone health.
- Increased bone-mineral content is associated with stronger, healthier bones.
- Different sports produce weight loading on different bones, leading to bone-specific changes in bone-mineral density.

Objectives

After completing this lesson, students will be able to

- explain the importance of diet and weight-bearing activities to the strength and health of their bones;
- analyze data tables to make evidence-based conclusions;
- explain the relationship between minerals, especially calcium, and bone strength; and
- explain that different types of weight-bearing activities produce different effects on the skeleton.

Teacher Background

See the following sections in Information about the Musculoskeletal and Skin Systems:

2 *Misconceptions about the Musculoskeletal and Skin Systems* (page 22)
4.1 *Bone* (pages 25–227)
5.2 *Vitamin D* (pages 34–35)
6.1 *Diseases affecting bone* (pages 35–36)
7 *Influences* (page 40)

In Advance

Activity	Web Component?	Photocopies	Materials
1	No	Master 5.1, *Description of Milk Study*, 1 transparency Master 5.2, *Data from Milk Study*, 1 copy per team of 2	None except photocopies and transparencies
2	No	Master 5.3, *Description of Sports Study*, 1 transparency Master 5.4, *Data from Sports Study*, 1 copy per team of 2	None except photocopies and transparencies

Preparation

Prepare photocopies and transparencies.

Procedure

Note to teachers: The study described in this activity is based on actual research by J.S. Voltek et al. (see References section, number 59). The data we use are authentic, although in some cases, numbers were rounded off to make them easier to work with.

Activity 1: *Got Milk?*

1. **Begin the activity by reminding the class of what they learned in Lesson 2: *What Makes Bones Strong:***
   - **Minerals and collagen affect the strength of bone.**
   - **As shown in the bathtub model, bone is a dynamic system that gains and loses material in response to environmental factors such as growth, stress, and diet.**

   Ask the class, "On the basis of what you have learned about bone, what can you do to increase the strength and health of your bones?"

   Write their responses on the board. Student responses will vary. Some will mention changing diet. Others may mention exercise. Make sure these two responses are on your list.

2. **Explain that students will investigate how diet and different physical activities influence bone. Ask the class, "How can we tell if a bone is healthy or if it is strong?"**

   Students may mention that bone strength can be measured by having people perform fitness tests. To such a response, point out

that these tests are largely measuring muscle, not bone, strength. If students respond that the bone itself can be subjected to a chemical analysis, mention the problem of having to remove it from the person being studied!

3. **Explain that scientists use specialized X-rays to estimate the amount of minerals in bones without harming the person being studied. X-rays of bones being studied are compared with X-rays of bones that have known amounts of minerals in them.**

   Teacher note: The specialized X-rays referred to here are called bone mineral density (BMD) scans. The most widely used method of BMD scan is dual X-ray absorptiometry (DEXA scan). DEXA scans use two different X-ray beams. Bone mineral density scans provide quantitative information about bone that cannot be obtained from standard X-rays.

4. **Explain to students that they are going to read about a study that investigates the influence of diet and physical activity on the health of bone. Place a transparency of Master 5.1, *Description of Milk Study*, on an overhead and read it aloud to the class. Ask students whether they have any questions about how the experiment was performed.**

   The important points for students to understand are that teenagers in both groups experienced the same resistance training (bench pressing) and that those in the group that drank juice did not receive the extra minerals, especially calcium, which were consumed by those in the milk group.

5. **Ask the class to predict the results of the experiment. Write their predictions on the board.**

   Student responses will vary. Some may predict that teenagers in the milk group will display greater strength and have more minerals in their bones than teenagers in the juice group. At this time, accept all answers.

6. **Divide the class into teams of two. Give each team one copy of Master 5.2, *Data from Milk Study*. Explain that they have a few minutes to look it over and write down what conclusions they can make from the data.**

   Give the teams about five minutes to write down their conclusions. Students should notice that the amount of weight that study participants bench-pressed increased for both the juice group and the milk group. They should also notice that although the bone minerals increased in both groups, bone minerals increased more for the milk group than the juice group.

NSES

Content Standard E: Technology is essential to science because it provides intruments and techniques that enable observations of objects and phenomena that are otherwise unobservable.

Note to teachers: Students may notice that in Week 6, the bench-pressed weight is slightly greater for the milk group than the juice group. Explain that you would expect the average bench-pressed weight to be similar but not necessarily the same for the juice group and milk group because of variation among individuals in this study. Emphasize how similar the values are, considering that each group had 15 teenagers who might respond differently to resistance training.

7. **Remind the class of their predictions written on the board. Ask, "Were your predictions supported by the data? Why or why not?"**

   Some of the predictions will have been supported by the data, while others will not.

8. **Ask the class, "On the basis of the data from this study, what conclusions can you make about the effects of drinking milk on strength and the mineral content of bone?"**

   Student responses will vary. The discussion should bring out two main conclusions: 1) both groups of teenagers showed the same increase in strength (as measured by the amount of weight they could bench-press), and 2) the milk group's increase in bone minerals was twice that of the juice group.

   Some students may respond that since both the juice and milk groups showed the same increase in strength, calcium and other minerals found in milk are not important. Point out that the study measured bone mineral content as well as strength and that the milk group showed a greater increase in bone-mineral content. If bone-mineral content goes up, then bones are stronger and less likely to break. Healthy bones with greater bone-mineral content may also help protect against disease and fractures later in life.

   Tip from the field test: Some students may realize that milk contains protein as well as calcium, neither of which is present in orange juice. Explain that more studies would have to be done to determine whether the greater increase in bone-mineral content for milk drinkers compared with juice drinkers resulted from the calcium or protein in the milk. Use this as an opportunity to point out the tentative nature of science. Scientists must use results from many studies to establish the influences on bone-mineral content.

Activity 2: *Is All Exercise the Same?*

Note to teachers: The study described in this activity is based on actual research: D.L. Creighton et al. (see References section, number 16). The study includes estimates of bone-mineral density obtained by analyzing X-ray films. Because these measurements are made on two-dimensional pieces of film, the data are expressed in units of mass (grams) per area (cm^2) and not per volume (cm^3), as is expected for a density measurement. In this activity, we refer to bone-mineral content and not to bone-mineral density.

Content Standard F: Regular exercise is important to the maintainence of and improvement of health.

1. **Ask students to recall the data presented in the previous activity. Ask the class, "How would resistance training alone affect bone minerals?"**

   Students should recognize that resistance training increases bone minerals, because the data in the previous study showed increases in bone minerals for those in the juice group as well as for those in the milk group.

2. **Ask the class, "Do you think different kinds of physical activities affect bone minerals differently?" Explain to students that they will examine the results of a study that compares the influence of different physical activities on bone mineral content.**

3. **Have the students assemble in teams of two, as in the previous activity. Give each team one copy of Master 5.3, *Description of Sports Study*. Have a student read it aloud to the class. Ask whether they have any questions about how the study was performed.**

   Answer any questions about how the study was performed. It is important to stress that students in the various groups were similar to each other except for their exercise habits.

4. **Instruct teams to discuss the study and place the different groups in order of increasing bone-mineral content.**

   Students should write in the spaces provided on Master 5.3, *Description of Sports Study*. The group with the highest level of bone minerals should be labeled "1," while the group with the lowest level of bone minerals should be labeled "4."

5. **Ask for volunteers to report their rankings and to explain why they put the groups in the order that they did.**

   Most students will conclude correctly that the control group (those who exercise very little) has the lowest level of bone minerals.

Students will probably not agree, however, on which sports produce the highest level of bone minerals. At this time, do not reveal the correct sequence. Students will confirm or refute their predictions in the next steps.

6. **Give each team one copy of Master 5.4, *Data from Sports Study.* Allow the teams five minutes to review the data and reorder the groups, if desired.**

   Teacher note: Students may ask why the study only provided bone-mineral content for the spine and hip and not bones in other parts of the body such as the leg or arm. Explain that the spine and hip are the most common areas tested for bone-mineral content because they generally have the most bone loss and are more likely to fracture when weakened by low mineral content.

7. **After teams have completed their task, ask whether any teams have reordered their groups. Ask them to explain why.**

   The data allow the teams to generate this order:
   1. basketball and volleyball (highest)
   2. soccer and running short-distance track
   3. swimming
   4. control (lowest)

   Students should explain that they reordered their groups based on the bone-mineral content data given in Master 5.4. These data showed that for both spine and hip measurements, the basketball and volleyball group had the highest bone-mineral content, followed by soccer and short-distance track, followed by swimming. The control group, which did not exercise, had the lowest bone-mineral content.

8. **Ask teams to discuss where in the list they would rank the bone-mineral content of an astronaut who had spent time in space and then returned to Earth. They should record their prediction on Master 5.3, *Description of Sports Study.***

   Make it clear that you are referring to an astronaut who has spent time in space and had his or her bone minerals measured after returning to Earth. Encourage students to think about what might be different for an astronaut in space as compared to someone on Earth.

9. **Ask teams to share their predictions with the class and explain how they decided where to rank the astronaut.**

   Student answers will vary. Students are likely to rank the astronaut near swimming (3) and the control group (4) because astronauts cannot be as active as an individual playing basketball or soccer.

Students might also rank the astronaut near 3 or 4 because they recognize that astronauts are in a weightless environment and thus are unable to do activities that put weight on their bones.

10. **Explain to the class that the astronaut would be ranked 5, with bone-mineral content less than the control group because astronauts lose minerals from their bones while in space. Ask students why they think this happens.**

    Make sure students understand that astronauts lose minerals from their bones even if they exercise in space (such as ride a stationary bike). Students should recognize that astronauts are in a weightless (gravity-less) environment. Guide the discussion to bring out the importance of putting stress on bone and that weight is necessary to put stress on bone. In a weightless environment, astronauts put very little stress on their bones.

11. **Remind the class that placing bone under stress from physical activity leads to minerals being added to bone. Weight-bearing activities put bone under more stress than nonweight-bearing activities.**

    Make sure students understand that weight-bearing activities include any activity in which feet and legs carry a person's weight or any activity that involves carrying, lifting, or pushing a heavy object. Therefore, walking and jumping are considered weight-bearing activities.

12. **Instruct students to revisit the data from the sports study. Facilitate a class discussion of whether any or all of the sports would be considered a weight-bearing activity. Include astronauts in your discussion.**

    Make sure students understand that basketball, volleyball, soccer, and short-distance track are weight-bearing activities. In both groups, the sports involve carrying a person's weight while running and jumping. Swimming is not a weight-bearing activity because water supports the body. Students should recognize that astronauts are unable to do weight-bearing activities because they are in a weightless environment.

13. **Explain to the class that osteoporosis is a disease characterized by low bone- mineral content and an increased risk for fractures (breaks). The disease usually affects people later in life. This study suggests that increasing bone-mineral content by playing sports while young may help lessen the effects of osteoporosis when older. Ask the class, "What type of physical activity (not a sport) do you think would lead to the greatest gains in bone-mineral content?"**

On the basis of the study discussed in this activity, students should recognize that weight-bearing forms of exercise lead to gains in bone-mineral content. They may suggest running. You might suggest that students think about how basketball and volleyball differ from soccer and short-distance running. Remind them that the basketball and volleyball group had the highest bone-mineral content. Students might recognize that basketball and volleyball involve more jumping than soccer. If necessary, remind the class that placing the bones under high levels of stress helps to increase the amount of minerals in bone. Jumping has been found to be an especially effective form of exercise in this regard. As a result, jumping exercises are being recommended as a part of physical education programs in schools.

Assessment:
Assign Step 14 as homework and use it as an assessment of student learning for the lesson.

14. **To conclude the activity, instruct students to write a brief explanation of why the bone-mineral contents of astronauts and each of the groups from the sports study are different.**

As each sport is discussed, make sure that students explain why the bone-mineral content differs between groups. Look for explanations that point out that bones under weight-bearing stress, as from gravity and physical activity, will have increased mineral content.

- Astronauts—Astronauts can exercise in space, but very little stress is placed on their bones because of the weightless environment. Because their bones are not placed under stress, they lose bone minerals while in space.
- Control group—Students in the control group exercised very little. This lack of exercise accounts for these students having the second-lowest bone-mineral content of the five categories in this activity.
- Swimming—An environment such as water supports the body and partly relieves the stress from gravity. Therefore, swimming is not called a weight-bearing exercise and does little to increase bone-mineral content.
- Soccer and running short-distance track—Training for these sports involves running and jumping, mostly on grass or a soft track. Soccer and running are weight-bearing sports and lead to increased bone-mineral content in the spine and hip.
- Basketball and volleyball—Training for these sports involves running, jumping, and cutting (changing directions sharply and suddenly) on hard surfaces. Basketball and volleyball are also weight-bearing sports. However, they place greater stress on the bones than soccer and running short distances. This leads to higher bone-mineral contents.

Lesson 5 Organizer

What the Teacher Does	Procedure Reference
Activity 1: *Got Milk?*	
Remind the students of what they learned in Lesson 2, *What Makes Bones Strong;* • Minerals and collagen affect bone strength. • Bone is a dynamic system that responds to the environment. Ask students, "On the basis of what you have learned about bone, what can you do to increase the strength of your bones?"	Page 98 Step 1
Explain that students will investigate how diet and different types of exercise influence bones. • Ask, "How can we tell if a bone is healthy or strong?" • Explain that a special type of X-ray can be used to estimate the mineral content of bone.	Pages 98–99 Steps 2 and 3
Explain that students will read about a study that investigates the influences of diet and physical activity on the health of bone. • Display a transparency of Master 5.1, *Description of Milk Study*. • Read it aloud.	Page 99 Step 4 T
Ask students to predict the results of the experiment. Write their predictions on the board.	Page 99 Step 5
Divide the class into teams of two. Give each team one copy of Master 5.2, *Data from Milk Study*. • Instruct teams to review the data and write down their conclusions.	Pages 99–100 Step 6 M
Remind the students of their earlier predictions: • Ask, "Were your predictions supported by the data? Why or why not?" • Ask, "On the basis of data from this study, what conclusions can you make about the effects of drinking milk on strength and the mineral content of bone?"	Page 100 Steps 7 and 8
Activity 2: *Is All Exercise the Same?*	
Remind the students of the data presented in the previous activity: • Ask, "How would resistance training alone affect bone minerals?" • Ask, "Do you think different kinds of physical activities affect bone minerals differently?" • Explain that students will examine the results of a study that investigates this question.	Page 101 Steps 1 and 2
Divide the class into teams of two. • Give each team one copy of Master 5.3, *Description of Sports Study*. • Read it aloud.	Page 101 Step 3 M

Instruct teams to discuss the study and place the groups in order of increasing bone-mineral content. Ask for volunteers to report their rankings and explain their reasoning.	Pages 101–102 Steps 4 and 5 M
Give each team one copy of Master 5.4, *Data from Sports Study*. Allow teams to review the data and reorder their groups as desired. If any teams have reordered their groups, ask them to explain why.	Page 102 Steps 6 and 7
Ask teams where they would rank the bone-mineral content of an astronaut who had spent considerable time in space and then returned to Earth. • They should record their prediction on Master 5.3, *Description of Sports Study*. • Ask teams to share their predictions and reasoning.	Pages 102–103 Steps 8 and 9
Explain that the astronaut would have less bone-mineral content than the control group. Ask students why this would be. Remind students that • placing bones under stress from physical activity leads to higher bone mineral content and • weight-bearing activities put bones under more stress than nonweight-bearing activities.	Page 103 Steps 10 and 11
Instruct students to revisit the data from the sports study. Facilitate a discussion about which activities can be considered weight bearing.	Page 103 Step 12
Describe the disease osteoporosis to the students. Ask, "What type of physical activity (not a sport) do you think would lead to the greatest gains in bone-mineral content?"	Pages 103–104 Step 13
As a homework assignment, instruct students to write a brief explanation of why the bone-mineral contents of astronauts and each of the groups from the sports study are different.	Page 104 Step 14

T = Involves making a transparency. M = Involves copying a master.

Lesson 6
Explain
Elaborate

Shining the Light on Skin

At a Glance

Overview

Lesson 6 has two activities and will take two days to complete. In the first activity, students investigate the relationships between certain environmental factors and levels of exposure to sunlight. Students form hypotheses related to how variables such as location, time of year, time of day, and the weather influence the intensity of sunlight. They test their hypotheses using student- and teacher-generated results in an online database. In the second activity, students design and carry out experiments that test the effectiveness of various items intended to provide protection from the sun.

Major Concepts

- The intensity of sunlight is influenced by the weather, location, and time at which measurements are made.
- Items designed to protect us from sun exposure vary in the amount of protection they provide.
- To protect their skin from damage, people should follow the shadow rule and seek shade if their shadows have a length less than their height (that is, short shadow, seek shade).

Objectives

After completing this lesson, students will be able to

- use the shadow rule and SunCheck Timers to measure relative amounts of sunlight exposure,
- formulate a testable question about exposure to sunlight and conduct an investigation,
- analyze and interpret data tables, and
- assess the effectiveness of various types of sun protection.

Teacher Background

Consult the following sections in Information about the Musculoskeletal and Skin Systems:
4.3 Skin (pages 30–32)
5.2 Vitamin D (pages 34–35)
6.3 Disorders of skin (pages 37–40)

Additional information about skin cancer can be found at *http://cancer.gov/cancerinfo/types/Skin/* and *http://www.mskcc.org/mskcc/html/420.cfm*. General information about skin and skin problems can be found at *http://www.aad.org/*.

In Advance

Activity	Web Component?	Photocopies	Materials
1	Yes	Master 6.1, *Calculating the Shadow Ratio*, 1 transparency	SunCheck Timers (3 per class) Meter stick (1 per class) Object to cast shadow 2 large sheets of paper
2	No	Master 6.1, *Calculating the Shadow Ratio*, 1 copy per team of 3 or 4 (optional)	SunCheck Timers 2 or 3 kinds of sunscreen 2 or 3 kinds of sunglasses T-shirts of different colors Other materials depending on student investigations (see Preparation)

Note to teachers: The fraction of sunlight that causes damage to the skin is called ultraviolet (UV) light. These activities require students to use disposable UV monitors to measure different levels of exposure to sunlight. The specific products recommended for this activity are sold as SunCheck Monitors and Timers. These products have three different UV-sensitive panels. Each panel is protected by a cover that you peel off before use. The three panels are designed to represent three types of skin sensitivity to UV light: normal, sensitive, and supersensitive. Exposure to sunlight causes the panels to turn from white to blue. When the color of the panel matches that of the reference panel, then

the wearer is assumed to have been exposed to enough UV light for that day. In this lesson, we don't regard the SunCheck products as tools that assess "safe" levels of sun exposure. Instead, they are simply used as inexpensive monitors of UV-light exposure.

To use the SunCheck Monitor or Timer,

- peel off the protective cover from one of the monitor's supersensitive panel,
- expose the timer to sunlight, and
- note the time needed for the color to change in the panel.

SunCheck Monitors and Timers are available from a number of suppliers, including

- *http://www.suncheck.com* and
- *http://www.sunclothingetc.com*.

Preparation

Purchase SunCheck Timers for use in both activities. (Throughout the lesson, the two SunCheck products are collectively called SunCheck Timers.) The timers cost between $0.50 and $1.00 each, depending on the supplier and the quantity purchased. To make sure that SunCheck Timers are available for this lesson, remember to order them well in advance.

Activity 1: *Measuring Sunlight*

Note to teachers: In Activity 1, students use data obtained from SunCheck Timers to explore different factors that influence exposure to UV light. At the same time, students will encounter data about shadow ratios, where

$$\text{shadow ratio} = \frac{\text{length of shadow}}{\text{height of object casting the shadow}}$$

Before beginning this lesson, determine how much time is required for the supersensitive panel on a SunCheck Timer to match its reference color. To do this, take the SunCheck Timer outside (not indoors or behind glass), peel off the protective cover from the supersensitive panel, and place the timer in a location that is exposed to sunlight. You might want to tape the timer in place to prevent the wind from moving it. Ensure that the timer will remain in the sun for the entire exposure and that the location will not become shady. Write down the time the exposure begins and the time when the supersensitive panel matches its reference color. Also determine the shadow ratio when you first expose the timer. Measure the height of an object and the length of its shadow. A meter stick is handy for this task. Record the shadow ratio as the shadow length divided by the object height (see Master 6.1, *Calculating the Shadow Ratio*). You will need this information for the database used in Activity 1. The time it takes for the supersensitive panel to match its reference color can be less than 30 minutes during warmer months or an hour or more during winter months.

You will also need to collect data (shadow ratios and corresponding times of exposure using SunCheck Timers) at three different times of day. Begin taking measurements when the shadow is longer and will be getting shorter or when the shadow is very short and will be getting longer. For example, you could collect data at 8 a.m., 10 a.m., and 12 p.m., or 12 p.m., 2 p.m., and 4 p.m. These data could be collected on a weekend or by student volunteers during the week.

After you have three shadow ratios and three corresponding times for the supersensitive panel to match its reference color, go to the Web site *http://science.education.nih.gov/suplements/bone/student*. Click on "Teacher Database Administration."

- Enter the user name "sunadmin" and password "admin" (all in lowercase letters) and then click "Submit."
- On the data entry page, enter the time for the supersensitive panel to match its reference color and the shadow ratio you calculated for one of your observations. You will need to make separate entries for the three data points you collected.
- Enter your school's latitude and elevation, date that your measurement was made, the time of day when the timer was first exposed to sunlight, and weather conditions. For the latitude entry, refer to the latitude map and enter the latitude closest to your location. If your location is equally distant from two latitudes, enter the higher one.
- Click on "Done," which will take you back to the Web site home page.
- You can enter additional data at any time by returning to the Teacher Database Administration page.

The database includes only times corresponding to the supersensitive panel. The factors that influence these times also work in the same way to influence times for the other two panels. We suggest using the times for only the supersensitive panel because they are the shortest and therefore the easiest to measure. Depending on conditions, the exposure time needed for the normal panel to match its reference can exceed four hours. Using the sensitive and normal panels is optional, but only times corresponding to the supersensitive panel should be entered in the database.

Activity 2: *Be Prepared!*

Have an adequate number of SunCheck Timers and meter sticks on hand. Also have available two or three sunscreens with different SPFs, two or three different types of sunglasses, and some different articles of clothing, such as T-shirts of different colors. To make this easier, you can ask student volunteers to bring these items to class before the lesson.

Prepare photocopies and transparencies.

Activity 1: *Measuring Sunlight*

Procedure

Note to teachers: This lesson discusses the benefits and risks associated with exposure to sunlight. For the most part, we're referring to the ultraviolet part of the light spectrum. If your students are familiar with the light spectrum, you may want to speak of UV light rather than sunlight.

1. **Begin the activity by asking the class, "Is sunlight good for your health?"**

   Student responses will vary. Some may feel that sunlight is good for health because they associate it with an active lifestyle. You may follow up such a response by asking, "Are people who spend a lot of time outdoors healthy because of exposure to the sun or because they get lots of exercise?" Some students may mention that sunlight is needed to help the body produce vitamin D. Other students may respond that sunlight is bad for one's health because it can lead to sunburn, skin damage, and increased risk for getting skin cancer.

2. **Explain to students that UV light, which is one part of sunlight, can cause sun damage that increases the risk for getting skin cancer. However, UV light is also needed to allow the body to produce vitamin D. People with too little vitamin D can suffer from a disease called rickets. Only 10 to 15 minutes of sunlight on the face and wrists, two to three times a week between 8 a.m. and 4 p.m. in the summer are adequate for the body to make enough vitamin D.**

   Students should understand that a healthy relationship with sunlight involves a balance between its health benefits and risks. Students may focus on how they would like their skin to look in order for them to "fit in" rather than how to keep their skin and bodies healthy. Explain to students that the National Institutes of Health (NIH) recommends that "the best skin color is the one you were born with."

   Note to teachers: Some students may believe that dark-skinned individuals do not get sunburned and are not at risk for skin cancer. However, dark-skinned individuals do get sunburned and may be at a significant risk for sun-induced skin cancer. Recent research has demonstrated that complex factors, such as skin type, genetics, and melanin distribution, may be as important as race and skin color in determining skin-cancer risk.

   In dark-skinned individuals, melanin production is continuous. In light-skinned individuals, exposure to UV light stimulates the

NSES

Content Standard F: Safe living involves the development and use of safety precautions and the recognition of risk in personal decisions.

production of melanin. Melanin absorbs UV light and provides some protection against the damaging effects of UV light. The skin becomes darker (it tans) as melanin levels increase to protect the skin from UV exposure. A suntan or sunburn actually represents cellular damage from UV exposure. Importantly, UV light causes damage to DNA. The UV light used in tanning booths is no different and increases the risk for getting skin cancer and premature aging of the skin.

3. **Ask students whether they think the amount of UV light is the same during the summer as during the winter. Then ask students, "What factors influence how much UV light you get?"**

   Student responses will vary. Make sure that the following are mentioned:
   - time of year,
   - time of day,
   - weather conditions,
   - latitude,
   - elevation, and
   - reflections off water, sand, or snow.

4. **Ask students, "How could you measure the amount of UV light?"**

   Students are unlikely to be familiar with techniques for measuring UV light. A few students might be familiar with products that change color in response to UV light, the UV index, or UV meters.

5. **Explain to students that you have already used two strategies for measuring UV light. One is the shadow ratio. Display a transparency of Master 6.1, *Calculating the Shadow Ratio*. Explain that the shadow ratio provides an indication of UV light intensity. The shadow ratio is calculated as the length of the shadow, divided by the height of the object casting the shadow.**

Content Standard A: Mathematics is important in all aspects of scientific inquiry.

6. **Write "Time of Day," "Shadow Ratio," and "SunCheck Time" on a large sheet of paper. On the sheet, record the time of day when you collected data and the shadow ratios that you entered in the database. Share the information with the class.**

   You will add the SunCheck times to the paper in Step 8. The paper should look similar to the following:

Time of Day	Shadow Ratio	SunCheck Time

Figure 6.2. *Data collection setup.*

7. **Explain to students that you also measured UV light using a SunCheck Timer. Take out a SunCheck Timer and pass it around the room as you explain how it works.**

Tip from the field test: The SunCheck Timers' three panels are designated "supersensitive," "sensitive," and "normal." These refer not to skin types but to different sensitivities to the sun. In this activity, the SunCheck Timers are simply used as inexpensive UV monitors. Despite what the packaging materials may say, students should not think of them as tools for assessing safe levels of UV exposure. Refer to the teacher note after Step 2.

8. **Explain that you have already determined how long the supersensitive panel on a SunCheck Timer can be exposed to sunlight before the supersensitive panel matches the reference color. Write the times you obtained under "SunCheck Time" on the large sheet of paper.**

   Display the paper with the shadow ratios and times for the SunCheck Timers. Students will use this information in Activity 2: *Be Prepared!*

9. **Explain that you have recorded the times and the shadow ratios in a database that includes the same information measured under other conditions. Inform students that they will use the database to develop a question about sunlight exposure, answer it by using the data in the database, and provide a short written summary of their findings.**

10. **Divide students into teams of two or three. Direct each team to a computer and instruct them to proceed to** *http://science.education.nih.gov/supplements/bone/student* **and click on "Lesson 6—Shining the Light on Skin."**

11. **Explain to students that each team should ask at least one question that can be answered using the information in the database.**

    Students have a number of options for generating average exposure times in the database, such as average exposure times for specific
    - latitude ranges,
    - elevation ranges,

- months,
- times of day,
- weather conditions, and
- combinations of these variables.

The database allows students to formulate and test many different questions by comparing average exposure times for various environments. For example, questions that can be tested by using information in the database include the following:

- Are exposure times longer for schools at higher latitudes?
- Are exposure times shorter for schools at higher elevations?
- Are exposure times longer during winter months and shorter during spring months?
- Are exposure times shortest during the middle of the day?
- Are exposure times shorter on clear days?

Students are limited by their imaginations, but their questions must be answerable using the available data.

12. After teams pose their questions, they should to establish a hypothesis.

At the middle school level, converting the question to a statement is an acceptable method for establishing a hypothesis. For the example question, "Are times longer during winter months and shorter during spring months?" a hypothesis can be, "Times during winter months are longer than times during spring months." Students could then test this hypothesis by comparing the average time during December with the average time during April. The alternative hypothesis, "Times during winter months are similar to times during spring months," is equally acceptable.

A hypothesis is a statement that predicts an outcome. Hypotheses are testable. The statement is tentative because empirical evidence has not yet been obtained to support or contradict it. However, it is a reasonable statement, because it is based on prior knowledge about the phenomenon. For example, some students may have experienced that the sun is less direct during winter compared with spring. For these students, a reasonable hypothesis would be the first one suggested. Other students may live at lower latitudes and may experience similar amounts of sunlight during different months of the year. For these students, the second hypothesis is a reasonable one.

The validity of either hypothesis is tested using data. The data will either support or not support the hypothesis. Many students think that a good hypothesis is one that the data support. In fact, neither hypothesis (one that the data support or one that the data fail to support) is better. The important point is that students will have

engaged in an authentic scientific activity. They will have formulated a hypothesis and used data to determine whether the hypothesis is supported or not supported. Using empirical evidence to draw conclusions about phenomena is a key feature of scientific inquiry.

13. **On the "Generate Report" page, teams must enter their hypotheses (only one hypothesis at a time) and select the variables they need to generate a report or reports that will allow them to test their hypotheses. After they have selected their variables, they should click on "Generate Report."**

    To test a hypothesis, such as times are shorter during winter than during summer, a student has to generate two different reports, one for the winter and a second for the summer, and compare them. If possible, allow students to print their reports. Otherwise, instruct students to record the results of their reports on a piece of paper. If time allows, encourage students to ask additional questions and produce the reports necessary to answer those questions.

    Note to teachers: The database will not accept an entry if a hypothesis is not entered. Testing some hypotheses will require that students generate more than one report.

    Note to teachers: The following information is provided to assist you in answering students' questions:

- The angle of the sun relative to Earth's surface varies with the time of day. When the sun is at its highest point in the sky, the angle is such that sunlight travels the shortest distance through the atmosphere. As a result, less UV light is absorbed by the atmosphere and less is deflected when the sun is high in the sky. Of course, the changing angle of the sun in the sky is the basis of the shadow rule.
- In temperate climates, UV light can vary in intensity up to 25-fold between winter and summer. Nearer the Equator, UV levels vary much less during the year, since the sun is always relatively high in the sky in the middle of the day.
- The greater the distance from the tropics, the lower the intensity of UV light. For instance, the average annual exposure of a person in Hawaii is about four times greater than that of a person living near the border between the United States and Canada. This results from the greater distance the UV light travels through Earth's atmosphere at higher latitudes.
- The intensity of UV light increases about 4 to 5 percent for every 1,000 feet of increase in altitude. The higher the altitude, the shorter the distance UV light has to travel through the atmosphere.
- Many people know firsthand that UV light has a significant effect on skin on a cloudy summer day, even though the temperature may feel cool. This is because the water in clouds absorbs heat much better than UV light. Pollution, like clouds, absorbs only a small amount of UV light passing through it. Wind has no effect on the intensity of UV light.

- Some surfaces reflect UV light better than others. Grass reflects little UV light (only about 3 percent), while a white, sandy beach or rippling water reflects much more (25 and 20 percent, respectively). Fresh snow can reflect up to 85 percent of UV light, which, together with higher altitudes, can account for severe effects on the skin, even in winter.

14. **After teams have posed hypotheses and generated reports to test their hypotheses, they should write a short summary of their findings.**

    The reports should indicate whether the data supported or did not support the hypothesis and what evidence was used to form a conclusion.

15. **Ask for volunteers to report their findings, including why their team chose their hypothesis or hypotheses.**

    Make sure that students are testing hypotheses that can be investigated using available data.

16. **If a team is not sure that the data support the hypothesis, ask why and consider what additional data could help address the hypothesis.**

    Even if the team has written an appropriate hypothesis, there may be too few entries in the database to reach a firm conclusion.

17. **As time permits, ask other teams to report their findings. Try to elicit different hypotheses.**

18. **Facilitate a class discussion of the relationship between the shadow ratio and the length of time for a supersensitive panel to match its reference color. Ask for several teams to share the shadow ratios and times they collected in their reports. Record their results on a large sheet of paper.**

    Group the shadow ratios and times for location with similar latitudes and altitudes. Students should notice that the shadow ratio is smaller when the times are shorter. Keep the results posted in the classroom. Students may refer to these results during Activity 2.

19. **Instruct students to write two or three sentences describing what influences the amount of UV light to which they are exposed.**

    Students should explain that latitude, elevation, time of year, time of day, and weather conditions can all affect the amount of UV light.

Assessment: Step 19 can be assigned individually as homework and used as an assessment for this activity.

Activity 2: *Be Prepared!*

1. **Ask the class, "How could you protect yourself from too much sun exposure?" Write their responses on the board.**

   If students are uncertain how to respond, suggest that they consider different types of environments such as in and out of the shade or in and out of the water. If not mentioned by a student, bring up the topic of products designed to protect us from sunlight, such as sunscreens, sunglasses, and different types and colors of clothing.

2. **Divide the class into teams of three or four. Instruct the teams to ask a question about protection from sun exposure that can be answered using two or three SunCheck Timers.**

   To ensure that the class addresses a variety of questions, you may want to refer to the questions written on the board and have different teams volunteer to answer different questions.

   Note to teachers: The SunCheck Timers will work when underwater or when covered with sunscreen.

3. **After the teams have decided on a question, ask them to establish a hypothesis as they did in the previous activity.**

4. **Instruct teams to design an investigation that can test the hypothesis using the materials you provide. Ask each team to bring its design to you for approval.**

   Note to teachers: Make sure that the teams understand that a proper investigation should include a control where the timer is exposed to sunlight without protection. If necessary, take one question as an example and, in front of the class, go over how to design the investigation for that question. Teams should record the question, the hypothesis, and the design of the investigation on a piece of paper. They can refer to this while they conduct their investigations and again when they write a report of the investigation.

5. **Once you have approved each team's design, remind students that the shadow ratio can be used to assess the intensity of UV light. Display the paper from Activity 1, Step 8, showing the time of day, shadow ratios, and SunCheck times. Ask teams to predict what the shadow ratio will be for their investigations.**

   Students should use the data you collected to make their predictions.

NSES

Content Standard F:
Scientists formulate and test their explanations of natureusing observations, experiments, and theoretical and mathematical models.

6. **Ask teams to predict what the time for each their SunCheck Timers will be in their investigations.**

   Students should predict that the control timer will have a time similar to the results you obtained. Timers with sun protection such as shade, clothing, or sunscreen should have longer times. For example, students might predict that a SunCheck Timer placed next to the water will have a shorter time than the control.

7. **Distribute the SunCheck Timers and materials needed to complete the investigations. Instruct the teams to go outside and begin their investigations. Students should determine the shadow ratio when they first expose their SunCheck Timers.**

   If necessary, distribute copies of Master 6.1, *Calculating the Shadow Ratio*, to each team to help them determine the shadow ratio. Students should write down the time required for the panel that corresponds to supersensitive skin to match its reference color. The time needed to complete the investigations likely will go beyond class time. The time required to reach the maximum safe sun exposure does not have to correspond with your class schedule. If long times are being measured, students from other classes may check the timers. Another option is to have a student expose the timers over the weekend and record the times.

   Note to teachers: To conserve the SunCheck Timers, you can use just one as a control for all experiments performed at the same time.

8. **Instruct the teams to write reports of their investigations on a single sheet of paper. Their reports should include:**
   - **the question they asked,**
   - **the hypothesis,**
   - **the prediction for the shadow ratios and times for each SunCheck Timer,**
   - **a description of the experimental design,**
   - **the results obtained (shadow ratios and times for each SunCheck Timer used),**
   - **the answer to the question, and**
   - **recommendations for behaviors that will protect skin from excessive exposure to sunlight.**

9. **Have a member of each team take about two minutes to summarize the findings for the class.**

   If any teams were not able to answer their questions, ask them what additional data they would need to do so. If teams draw conclusions that go beyond their data, guide the discussion to bring this out.

10. **Ask a few of the teams to compare their predictions with the shadow ratios and times they obtained in their investigations. They should explain why they think their predictions did or did not match their results.**

11. **Ask students whether they think the shadow ratio is a good indicator of how much UV light they are getting. Explain that the shadow ratio is based on the shadow rule. The shadow rule states, "short shadow, seek shade." Encourage students to use this rule as a guide for when to protect themselves from the sun and minimize the risks of sun exposure.**

    The shadow rule is an easy way for anyone to minimize the risks of sun exposure by staying out of the sun when UV light is more intense. Students will not usually have a SunCheck Timer with them but they can notice how long their shadow is compared with their height.

    Note to teachers: More information about the shadow rule is available in an article by T. Downham (see the Reference section, number 18).

12. **To conclude the lesson, instruct students to write a short paragraph describing the shadow rule and how it can be used to decide when to protect themselves from sun exposure. They should also describe different ways to protect themselves from excessive sun exposure.**

    Students should explain that the shadow rule directs them to seek shade when they have a short shadow. They should understand that shadows indicate how much UV light is present. They should also explain that when shadows are short, people should protect their skin from the sun by seeking shade or using products such as sunscreen, sunglasses, hats, and other articles of clothing.

Assessment:
Step 12 can be assigned as homework and used as an assessment of students' understanding of this lesson.

Lesson 6 Organizer

What the Teacher Does	Procedure Reference
Activity 1: *Measuring Sunlight*	
Ask students, "Is sunlight good for your health?"	Page 111 Step 1
Explain the following information about UV light, which is one part of sunlight: • UV light can cause sun damage that increases the risk for getting skin cancer. • UV light is needed for the body to produce vitamin D. • Too little vitamin D can cause a disease called rickets. • Only 10 to 15 minutes' of sunlight on the face and wrists, two to three times a week between 8 a.m. and 4 p.m. in the summer are adequate for the body to make enough vitamin D.	Pages 111-112 Step 2
Ask students whether they think the amount of UV light is the same during the summer and the winter. Ask students, • "What factors influence how much UV light you get?" • "How could you measure the amount of UV light?"	Page 112 Step 3 and 4
Display a transparency of Master 6.1, *Calculating the Shadow Ratio*. • Explain that the shadow ratio provides an indication of UV-light intensity.	Page 112 Step 5
Write "Time of Day," "Shadow Ratio," and "SunCheck Time" on a large sheet of paper. Record on the paper • the time of day when you collected data for the database and • the shadow ratios you calculated and entered into the database.	Pages 112–113 Step 6
Pass around a SunCheck Timer and explain how it works. • Explain that you have already determined how long the supersensitive panel can be exposed to sunlight before the panel matches the reference color. • Write the times you obtained on the large sheet of paper.	Page 113 Steps 7 and 8
Explain that you have entered the shadow ratios and the times for the supersensitive panel into a database and that they will use the database to develop a question about sunlight exposure. • Divide students into teams of two or three. • Instruct teams to go to the supplement Web site and click on the "Lesson 6—Shining the Light on Skin" link.	Page 113 Steps 9 and 10

Instruct each team to ask at least one question that can be answered using the information in the database. • After teams pose their questions, they should enter their hypotheses on the "Generate Report" page and select the variables that will allow them to test their hypotheses. • After they have selected variables, they should click on "Generate Report."	Pages 114–115 Steps 11–13
Instruct teams to write a summary of their findings.	Page 116 Step 14
Ask for volunteers to report their findings and explain whether the data supported their hypothesis. • Make sure students are testing hypotheses that can be investigated using the available data. • If a team is not sure that the data support its hypothesis, ask the team to consider what additional data could help address the hypothesis. • As time permits, ask other students to report their findings to elicit different hypotheses.	Page 116 Step 15–17
Facilitate a class discussion of the relationship between the shadow ratio and the length of time for a supersensitive panel to match its reference color. • Ask several teams to share the shadow ratios and times of day they collected in their reports. • Record the teams' results on a large sheet of paper.	Pages 116–117 Step 18
As a homework assignment, ask students to write two or three sentences describing what influences the amount of UV light to which they are exposed.	Page 117 Step 19
Activity 2: *Be Prepared!*	
Ask the class, "How you could protect yourself from too much sun exposure?"	Page 117 Step 1
Divide the class into teams of three or four. • Instruct teams to ask a question about sun exposure that can be answered using two or three SunCheck Timers.	Page 117 Step 2
Ask each team to establish a hypothesis based on its question. • Instruct teams to design an investigation that can test their hypotheses. • Ask each team to bring its design to you for approval.	Page 117 Steps 3 and 4
Once you have approved each team's design, remind students that the shadow ratio can be used to assess the intensity of UV light. • Display the paper from Activity 1, Step 8, showing the time of day, shadow ratios, and SunCheck times. • Ask teams to predict the shadow ratio for their investigation.	Page 118 Step 5

Ask students to predict what the time for each of their SunCheck Timers will be.	Page 118 Step 6
Distribute SunCheck Timers and materials needed to complete the investigations. • Instruct teams to begin their investigations. • Students should determine the shadow ratios when they first expose their SunCheck Timers.	Page 118 Step 7
Instruct teams to write reports of their investigations on a single sheet of paper. • Ask a member of each team to take two minutes to summarize its findings for the class.	Pages 118–119 Steps 8 and 9
Ask a few teams to compare their predictions with the shadow ratios and times they obtained in their investigations.	Page 119 Step 10
Ask students whether they think the shadow ratio is a good indicator of how much UV light they are getting. Explain that • the shadow ratio is based on the shadow rule and • the shadow rule states, "short shadow, seek shade."	Page 119 Step 11
As a homework assignment, ask students to write a short paragraph describing • the shadow rule and how it can be used to decide when to protect themselves from sun exposure and • different ways to protect themselves from excessive sun exposure.	Page 119 Step 12

T = Involves making a transparency. www = Involves using the internet.

Lesson 7
Evaluate

Decisions Today for a Healthy Tomorrow

At a Glance

Overview

In Lesson 7, students are asked to reflect on what they have learned about bone, muscle, and skin and communicate that to classmates who have not been exposed to the module. The students are asked to develop lifestyle recommendations for maintaining healthy body systems. This final lesson offers students an opportunity to pull together what they have learned during the module and apply it to their personal lives.

Major Concepts

- Bone, muscle, and skin contain living cells.
- The structures of bone, muscle, and skin relate to their functions.
- The bone, muscle, and skin systems do not work in isolation but interact with other body systems.
- The health of the bone, muscle, and skin systems is influenced by many factors including behaviors over which we have control.

Objectives

After completing this lesson, students will be able to

- describe that the bone, muscle, and skin systems are made of living cells;
- describe the function of bone, muscle, and skin systems;
- explain how bone and muscle interact to produce movement; and
- explain how lifestyle choices can influence the health of the bone, muscle, and skin systems.

Teacher Background

See the following sections in Information about the Musculoskeletal and Skin Systems:

1 *Introduction* (page 21)
2 *Misconceptions about the Musculoskeletal and Skin Systems* (pages 22–23)
3 *Characteristics of Living and Nonliving Systems* (pages 23–24)
4 *Characteristics of Bone, Muscle, and Skin* (pages 24–25)
4.1 *Bone* (pages 25–27)
4.2 *Muscle* (pages 27–30)
4.3 *Skin* (pages 30–32)

5.2 *Vitamin D* (pages 34–35)
6.1 *Diseases affect bone* (pages 35–36)
6.2 *Diseases and injuries can affect muscle function* (pages 36–37)
6.3 *Disorders of the skin* (pages 37–40)
7 *Influences* (page 40)

In Advance

Activity	Web Component?	Photocopies	Materials
1	No	Master 7.1, *Outline for Health Recommendations*, 1 copy per student and 1 transparency	None except photocopies and transparencies

Preparation

Prepare photocopies and transparencies.

Procedure

Content Standard F: Personal exercise, especially developing cardiovascular endurance, is the foundation of physical fitness.

1. **Explain to students that they are going to reflect on what they have learned about the bone, muscle, and skin systems. Their objective is to communicate their new knowledge to classmates who have not had the benefit of being exposed to this module.**

   At a minimum, students will write answers to the questions posed in the next step. Ideally, students will take things a step further and incorporate their answers into a presentation. Presentations can take the form of posters, brochures, songs, or scripts for radio or television commercials.

2. **Give each student one copy of Master 7.1, *Outline for Health Recommendations*. Explain that students are to provide short answers to the questions on the outline. Give the students about 20 minutes to complete their answers.**

   These answers will be discussed and developed into the information that will be used to create the poster. Student responses should be brief yet include the major concepts presented during the module. Sample answers to the questions are provided in the following table:

Sample Answers to Master 7.1, *Outline for Health Recommendations*

Question	Bone	Muscle	Skin
What is it made of?	Bone is composed of cells (some that make new bone and others that remove bone), minerals, and collagen.	Muscle is composed of cells that contract to produce the movement of bones.	Skin is composed of cells that protect against damage from the sun and cells that help regulate temperature.
What does it do?	Bone provides structural support for the body. It also stores minerals, such as calcium, for use elsewhere in the body.	Muscle contractions produce movement of the limbs and other body parts.	Skin provides a protective barrier against the environment.
How does it work?	Bone material is added or removed in response to signals from the environment, such as stress.	Muscles can only move by contracting. This means that muscles work in opposing pairs to move a limb in more than one direction.	Skin cells provide a physical barrier and absorb UV light.
How do our behaviors affect it?	Exercise leads to an increase in bone mass and strength. Diets deficient in minerals produce weaker bones.	Exercise causes muscles to grow and become stronger, while inactivity causes muscles to lose size and strength.	Excessive exposure to UV light, including sunlight and tanning booths, increases the risk of skin cancer.
How do we keep it healthy?	We can eat a healthy diet and maintain an appropriate exercise program.	We can maintain an appropriate exercise program.	We can seek shade, wear appropriate clothing, and use sunblocks to reduce the risk of skin cancer.

3. **After students have prepared their answers, assemble them into teams of three. Instruct the teammates to share their answers and make any desired changes to their answers.**

   Give teams about 10 minutes to discuss their responses.

4. **Reconvene the class and display a transparency of Master 7.1, *Outline for Health Recommendations*. Read each question on the transparency and ask for volunteers to provide their responses.**

   As students give responses, list them on the board (not on the transparency).

5. **After students' responses for each question are listed on the board, discuss each question to generate the best answer. Write these answers on the transparency.**

6. **To conclude the lesson, give students a homework assignment. Ask that each student use the information in his or her outline of health recommendations to prepare a presentation to be given to other students who have not been exposed to this module. The formats of their presentations are limited only by their imaginations—for example, they could take the form of posters, brochures, songs, or scripts for radio or television commercials.**

   Students' recommendations will vary. Be sure that they include the major concepts brought out during the module, such as the following:
   - Exercise and a diet rich in minerals help build and maintain strong bones.
   - Exercise and a balanced diet help build and maintain strong muscles.
   - Seeking shade, routine use of protective clothing, and applying sunscreens reduce the risk of skin cancer.

Assessment:
The homework assignment in Step 6 can be used as an evaluation of student learning.

Lesson 7 Organizer

What the Teacher Does	Procedure Reference
Activity 1: *Decisions Today for a Healthy Tomorrow*	
Explain to students that they will summarize what they have learned about bone, muscle, and skin in a presentation that communicates their new knowledge to classmates who have not been exposed to this module.	Page 124 Step 1
Give each student one copy of Master 7.1, *Outline for Health Recommendations*: • Instruct students to answer the questions on the master.	Pages 124-125 Step 2 M
Divide the class into teams of three students. Instruct teammates to share their answers and make changes as desired.	Page 126 Step 3 T
Reconvene the class and display a transparency of Master 7.1, *Outline for Health Recommendations*: • Read each question aloud and ask for volunteers to give their answers. • Write their answers on the board.	Page 126 Step 4
Discuss the answers to each question. Write the best answer for each question on the transparency of Master 7.1, *Outline for Health Recommendations*.	Page 126 Step 5
As a homework assignment, ask students to use what they have learned during this module to create a presentation that includes recommendations about maintaining healthy bones, muscles, and skin.	Page 126 Step 6

T = Involves making a transparency. M = Involves copying a master.

Masters

Lesson 1, *It's Alive! Or Is It?*
Master 1.1, *It's Alive! Or Is It?* . . . . . .student copies

Lesson 2, *What Makes Bones Strong?*
Master 2.1, *Bone Structure* . . . . . .transparency
Master 2.2, *Testing the Pasta Model* . . . . . .team copies
Master 2.3, *Bone in Balance* . . . . . .student copies and transparency

Lesson 3, *Anatomy of a Kick*
Master 3.1, *Muscles*. . . . . .transparency
Master 3.2, *Anatomy of Kick Results*. . . . . .team copies
Master 3.3, *Relax! I'm Contracting* . . . . . team copies and transparency
Master 3.4, *Muscle Group Sequence* . . . . . team copies and transparency

Lesson 4, *Use It or Lose It*
Master 4.1, *Rat Resistance Training Study*. . . . . .team copies
Master 4.2, *Muscle Data* . . . . . .transparency
Master 4.3, *Graph Template* . . . . . .team copies
Master 4.4, *Resistance Training Study Worksheet and Graph Template* . . . . . .team copies

Lesson 5, *Helping the Body Build Strong Bones*
Master 5.1, *Description of Milk Study* . . . . . .transparency
Master 5.2, *Data from Milk Study*. . . . . .team copies
Master 5.3, *Description of Sports Study* . . . . . .transparency
Master 5.4, *Data from Sports Study* . . . . . .team copies

Lesson 6, *Shining the Light on Skin*
Master 6.1, *Calculating the Shadow Ratio*. . . . . transparency (team copies optional)

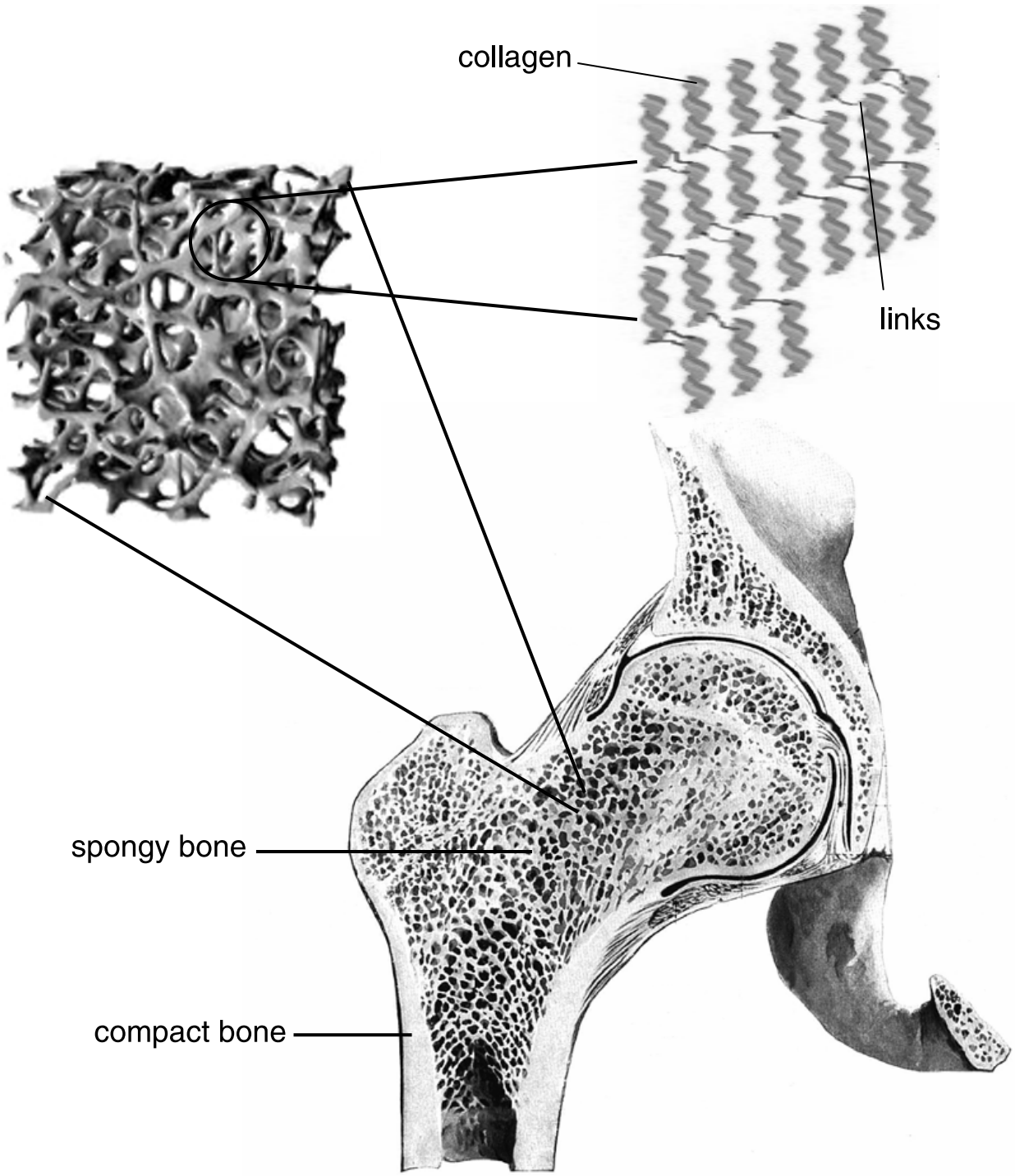
Lesson 7, *Today for a Healthy Tomorrow*
Master 7.1, *Outline for Health Recommendations* . . . . . student copies and transparency

It's Alive! Or Is It?

Properties of living systems	Bone		Muscle		Skin	
	Yes	No	Yes	No	Yes	No

Why do you believe bone, muscle, and skin have been grouped together for study in this module?

Bone Structure



Testing the Pasta Model

1. Use your ruler to move two desks or tables (of the same height) 20 centimeters apart.

2. Sort out two groups of pasta, each containing 20 pieces.

3. Use rubber bands to bundle one group of pasta; leave the other group unbundled.

4. Bend two paper clips and attach weights to them. Each paper clip should hold about 200 grams.

5. Place the bundled pasta between two desks so that each end rests on about the same amount of desk.

6. Carefully hang one of the paper clips with weights from the center portion of the pasta.

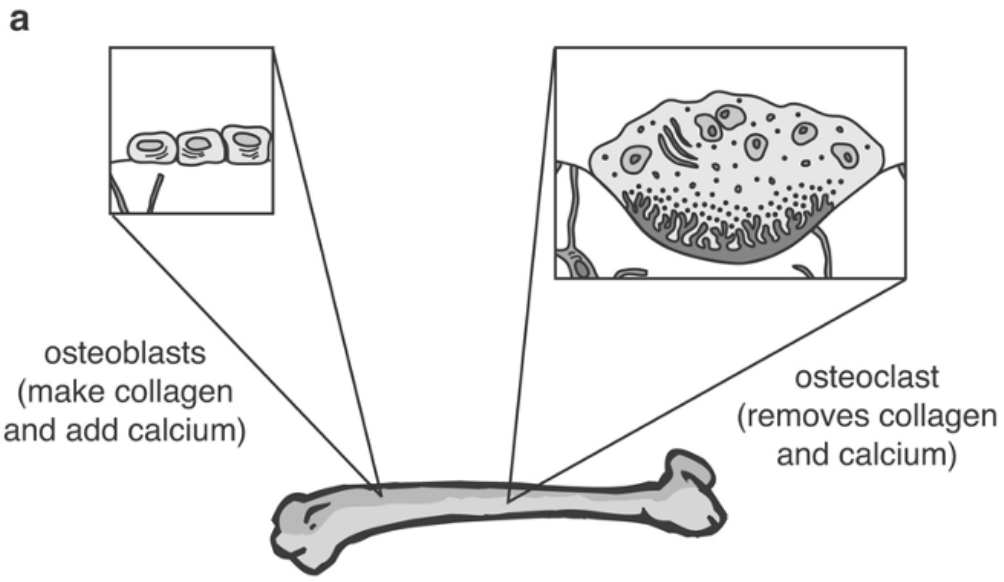
7. Use a ruler to measure the distance from the desks to the lowest portion of the sagging pasta. Record the measurement on a piece of paper.

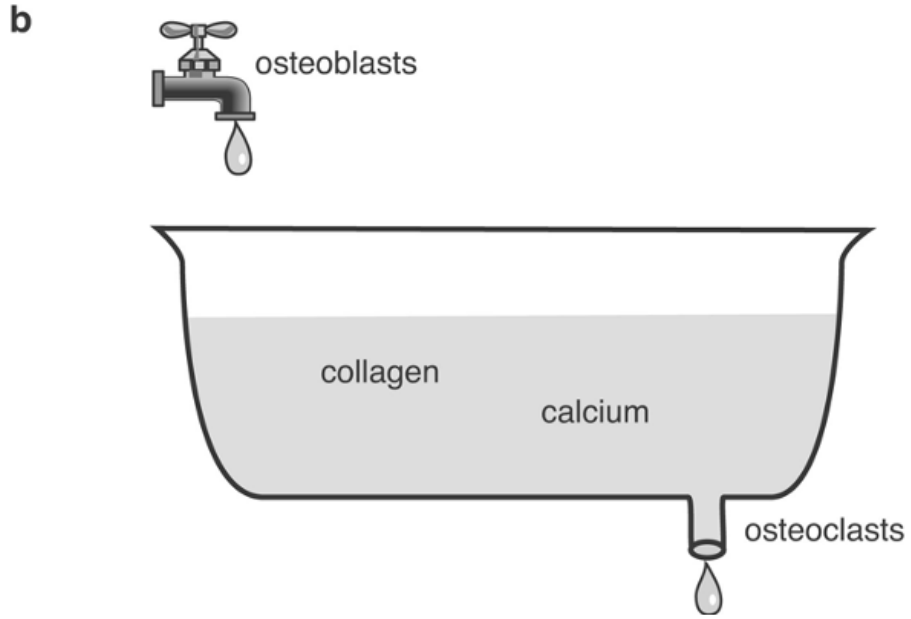
8. Remove the bundled pasta and place the 25 pieces of unbundled pasta between the desks as before.

9. Carefully hang one of the paper clips with weights from the center portion of the pasta.

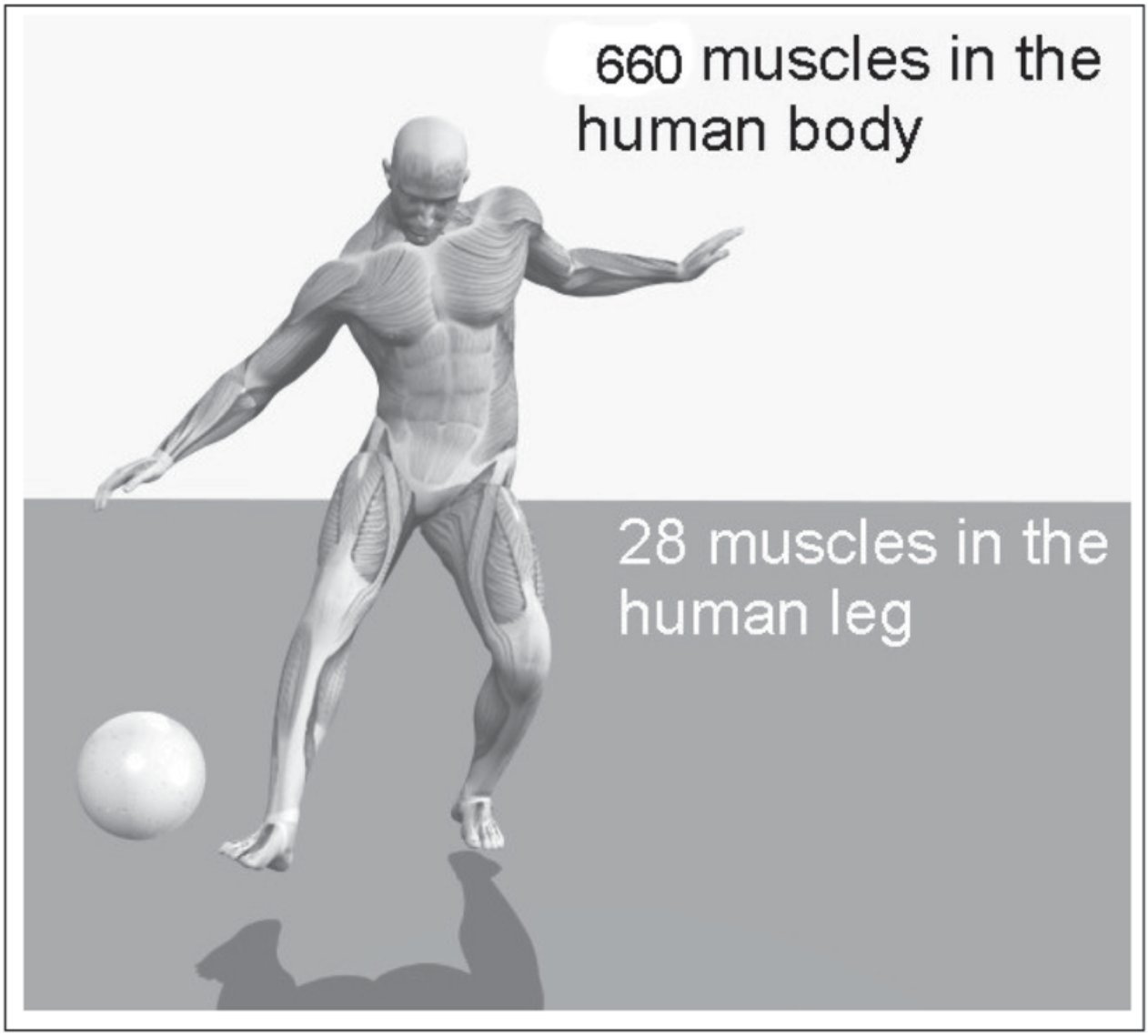
10. Use a ruler to measure the distance from the desks to the lowest portion of the sagging pasta. Record the measurement on a piece of paper.

Bone in Balance

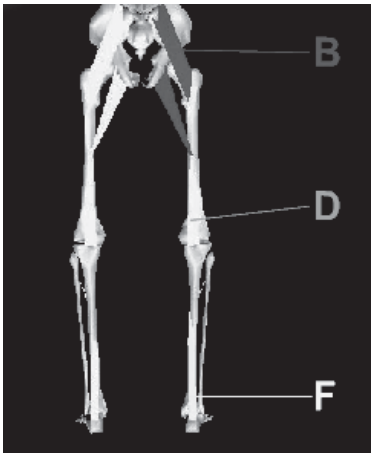


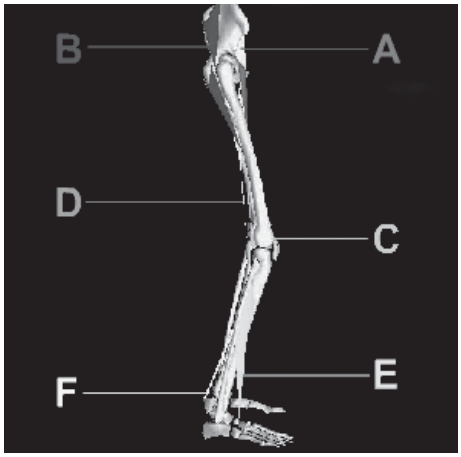


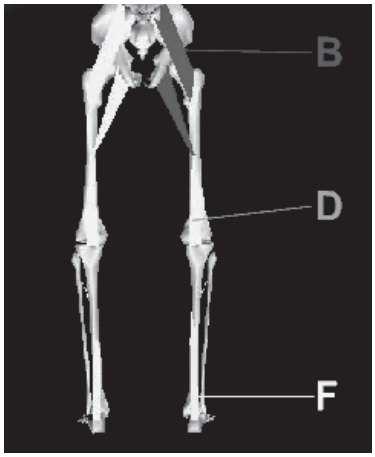
Muscles



Anatomy of a Kick Results







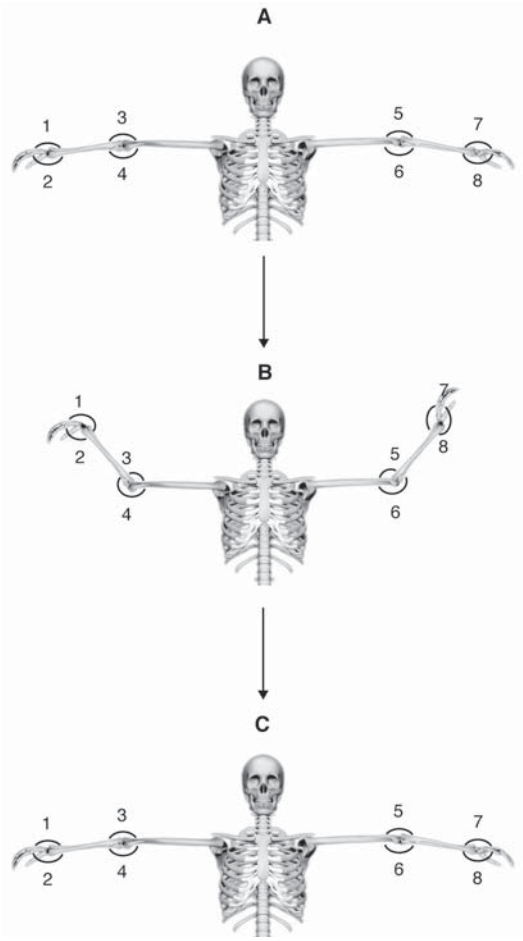
1. Fill in the table and answer the question below to show what you have learned about muscles. In the "Muscle Group" column on the right, write the order in which the muscle groups function to produce the kicking motion you are investigating.

Muscles Matter!

Attachment (From where to where)	Movement (Which body part moves how)	Muscle Group (Identified by letter)
		1.
		2.
		3.
		4.
		5.
		6.

2. Which muscle groups work in opposing pairs?

Relax! I'm Contracting



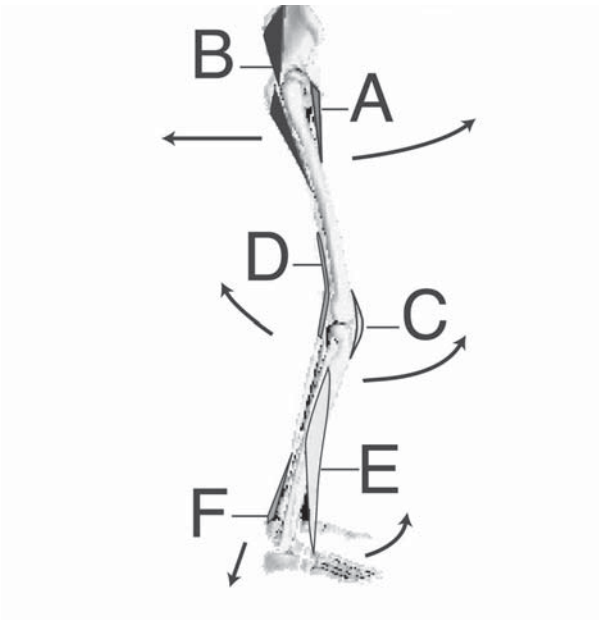
Movement from Panel A to Panel B

Muscle	Contracting or Relaxing?
1	
2	
3	
4	
5	
6	
7	
8	

Movement from Panel B to Panel C

Muscle	Contracting or Relaxing?
1	
2	
3	
4	
5	
6	
7	
8	

Muscle Group Sequence

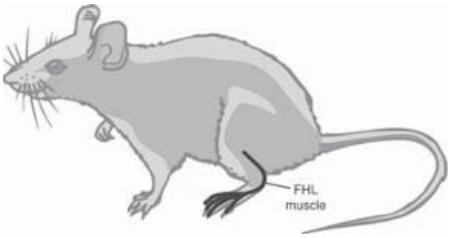


1. Write the order in which the muscle groups function to produce the kicking motion you are investigating.

Muscle group (identified by letter)
1.
2.
3.
4.
5.
6.

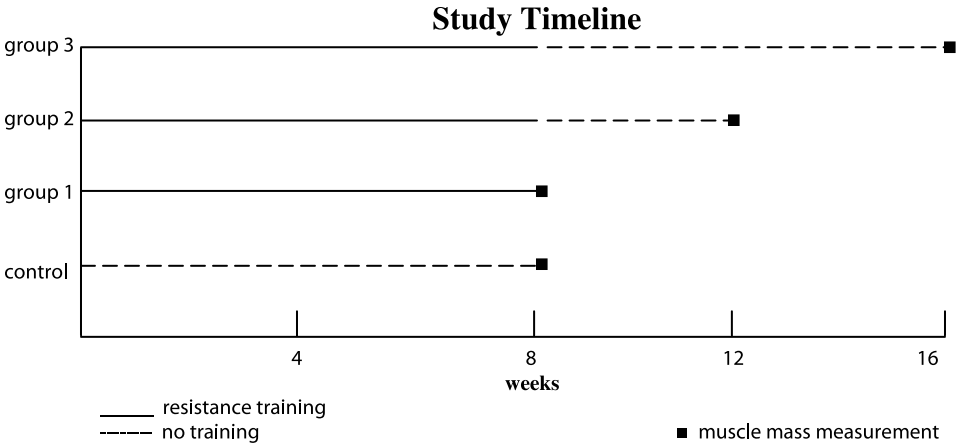
2. Which muscle groups work in opposing pairs?

Rat Resistance Training Study



This study investigates the effect of performing resistance training and stopping training on the muscle mass of rats. Resistance training is exercise that causes your muscles to pull and push against a force. In this study, the resistance training involved rats carrying weights up a ladder.

Rats were divided into two groups. Five rats in the control group did no training for 8 weeks and then had their muscle mass measured. Fifteen rats performed resistance training for 8 weeks. The resistance training consisted of rats climbing a ladder with weights attached to their tails. Training was conducted twice a day every 3 days. Weight was increased gradually during the 8 weeks of training. After the 8 weeks of training, five of the rats, called group 1, had their muscle mass measured. Another five rats became group 2 and received no training for 4 weeks, and then had their muscle mass measured. The remaining five rats became group 3 and received no training for 8 weeks, and then had their muscle mass measured.



At the times indicated on the chart, the mass of one leg muscle of the rats was measured. This muscle is known as the flexor hallucis longus (FHL). The FHL is located on the back of the lower leg and across the bottom of the foot. This muscle flexes the foot and toes in rats.

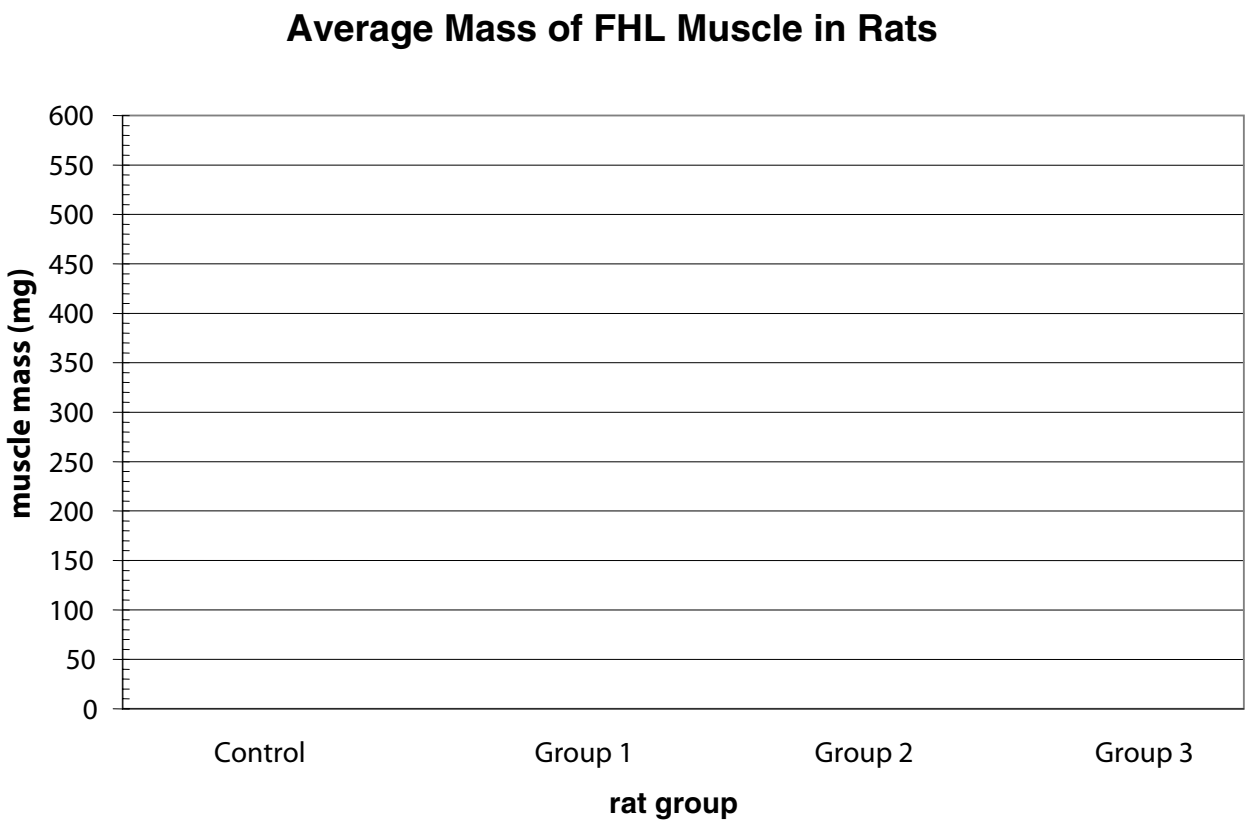
1. Plot the average mass of the FHL muscle for each rat group (from Master 4.2, *Muscle Data*) on Master 4.3, *Graph Template.*
2. Follow the instructions on the worksheet (Master 4.4a, *Resistance Training Study Worksheet and Graph Template*) and calculate the increase in muscle mass for each of the training groups.
3. Plot the increase in muscle mass on the second graph template (Master 4.4b).

Muscle Data

Average Mass of FHL Muscle in Rats

Rat group	Average muscle mass (mg)
Control group	463
Group 1 8 weeks of resistance training	544
Group 2 8 weeks of resistance training, then 4 weeks of no training	531
Group 3 8 weeks of resistance training, then 8 weeks of no training	508

Graph Template



Resistance Training Study Worksheet and Graph Template

1. Use this formula and the example below to calculate the change in muscle mass* as a percentage for each training group as compared with the Control Group.

2. Plot the values from the last column on the graph template.

$$\text{\% muscle mass increase} = \frac{\text{Training Group Mass (G)} - \text{Control Group Mass (C)}}{\text{Control Group Mass (C)}} \times 100\%$$

Example:
Training Group mass (G) = 600
Control Group mass (C) = 463

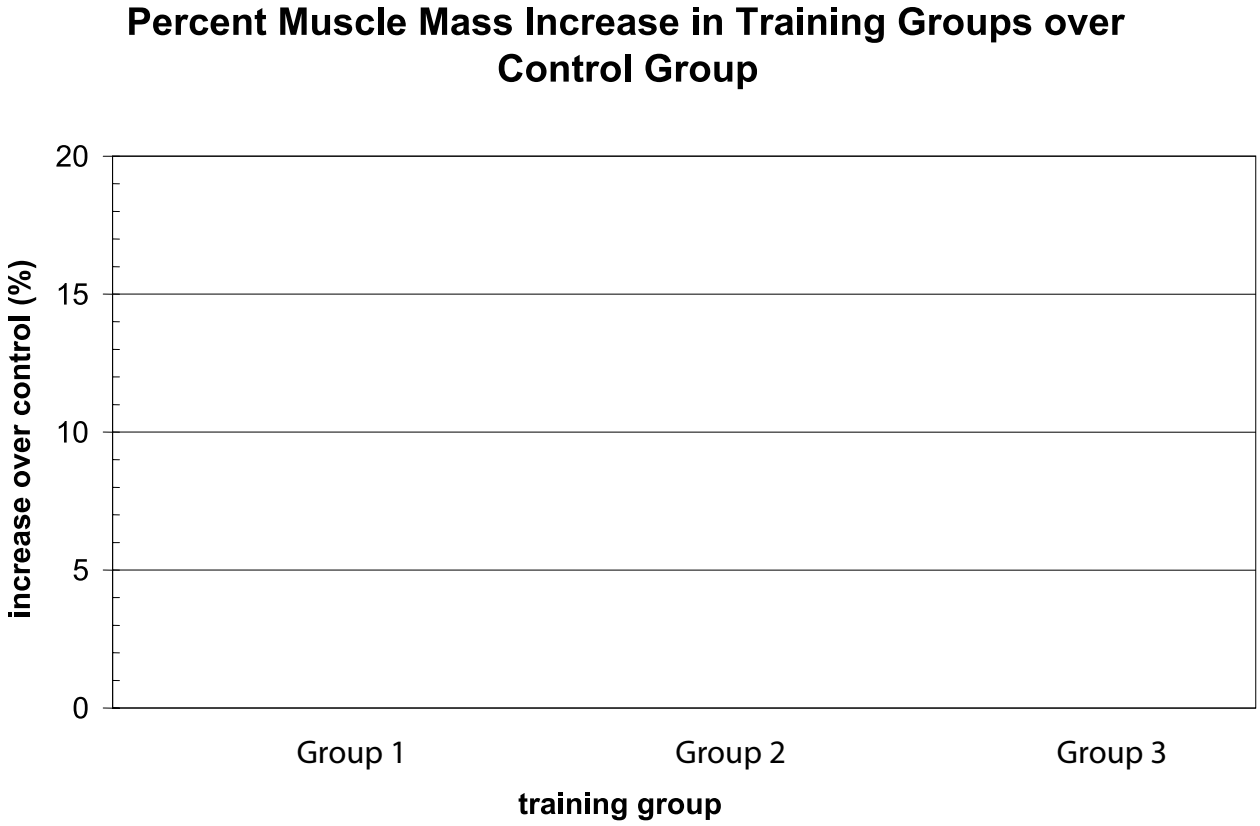
$$\text{\% muscle mass increase} = \frac{600-463}{463} \times 100\% = 30\%$$

600 – 463 = 137
137 ÷ 463 = 0.30
0.30 × 100% = 30%

Training Group (G)	**G – C**	**÷ C**	**× 100% = % muscle mass increase**
Group 1	___ **– 463 =**	___ **÷ 463 =**	___ **× 100 =** ___
Group 2	___ **– 463 =**	___ **÷ 463 =**	___ **× 100 =** ___
Group 3	___ **– 463 =**	___ **÷ 463 =**	___ **× 100 =** ___

*All units in milligrams.

Resistance Training Study Worksheet and Graph Template



Description of Milk Study

This study examines how drinking milk affects the results of physical exercise. Thirty healthy teenagers were divided into two groups. One group drank three servings of milk each day, while the second group drank three servings of orange juice each day. The orange juice did not contain extra calcium. Both groups of teenagers then participated in a 12-week program of resistance training. Resistance training is exercise that causes your muscles to pull and push against a force. Examples of resistance training include weight lifting, push-ups, pull-ups, or using exercise machines. During and after the training, the teenagers from both groups had their strength tested (how much weight they could bench press). They also were X-rayed to estimate the amount of minerals in their bones.

Data from Milk Study

Juice Group

	Week 0	Week 6	Week 12
Bench press (kg)	49	53	60
Percent increase in bone minerals	0.00	0.54	1.26

Milk Group

	Week 0	Week 6	Week 12
Bench press (kg)	49	54	60
Percent increase in bone minerals	0.00	1.42	2.48

Description of Sports Study

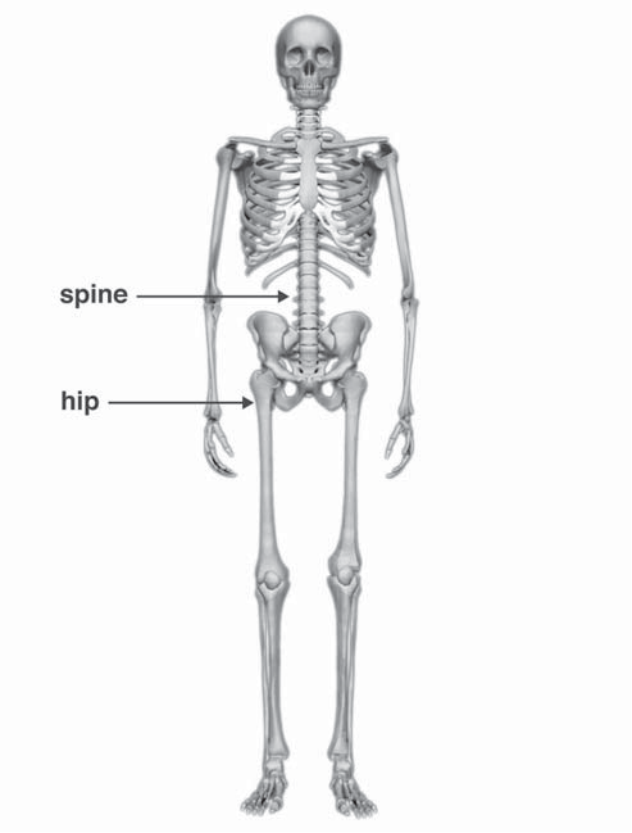
This study examines the effects of playing different sports on the mineral content of bone.

A total of 41 college students participated in the study. They were divided into four groups:

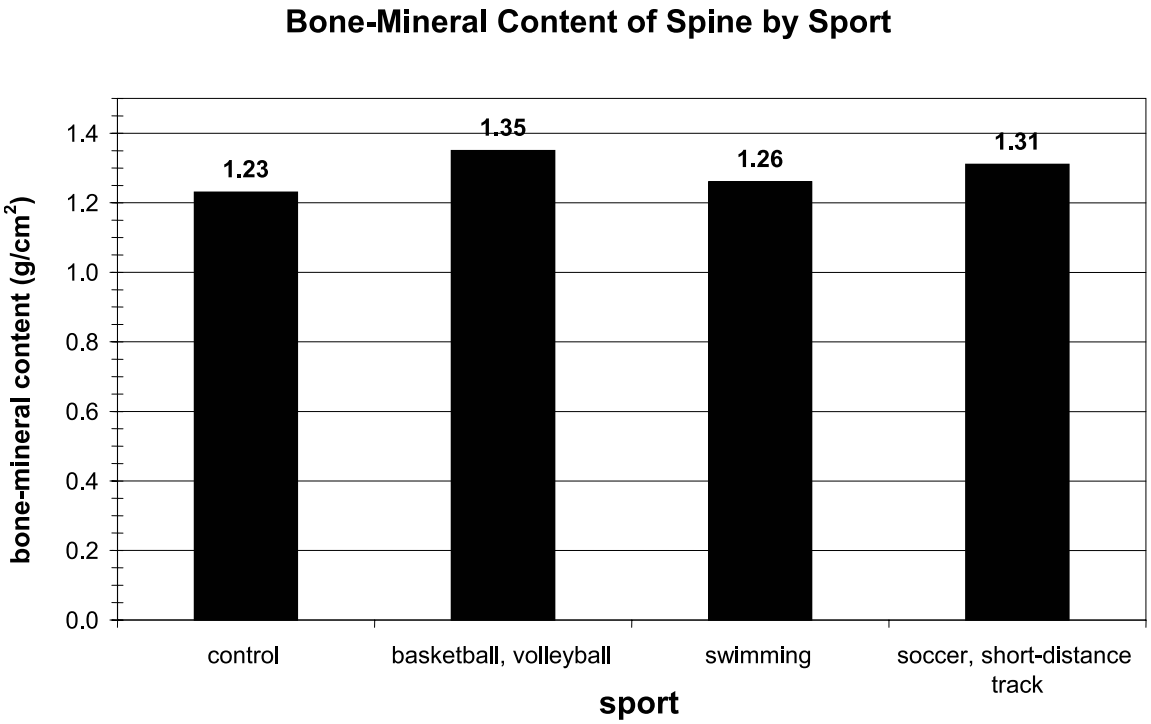
____ Control group: students who get very little exercise
____ Group 1: students who play basketball or volleyball
____ Group 2: students who swim
____ Group 3: students who play soccer or run short-distance track

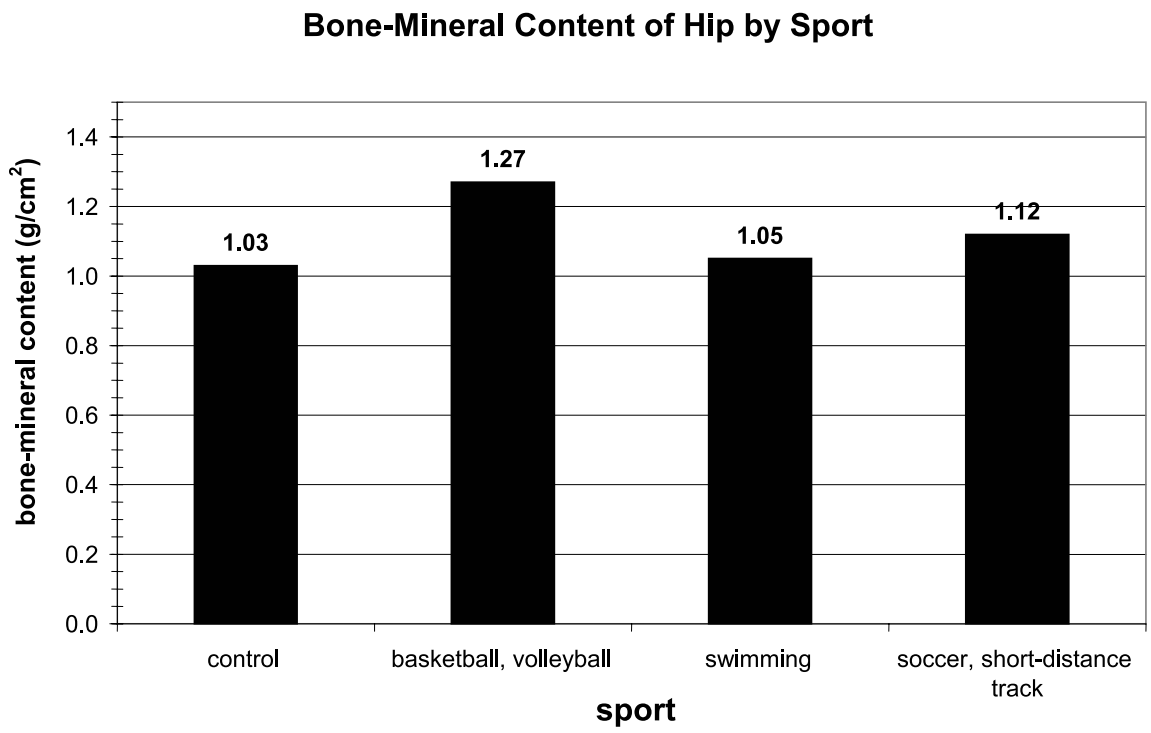
After completing their playing season, students were X-rayed to estimate the amount of minerals in their bones. Bone-mineral measurements were made at two locations: the spine and the hip (see the following).

Use your knowledge of exercise and bone to rank the four different groups in the study with respect to their bone-mineral content. The group with the highest level of bone minerals should be labeled "1," while the group with the lowest level of bone minerals should be labeled "4." Write your rankings in the spaces next to the group descriptions above.

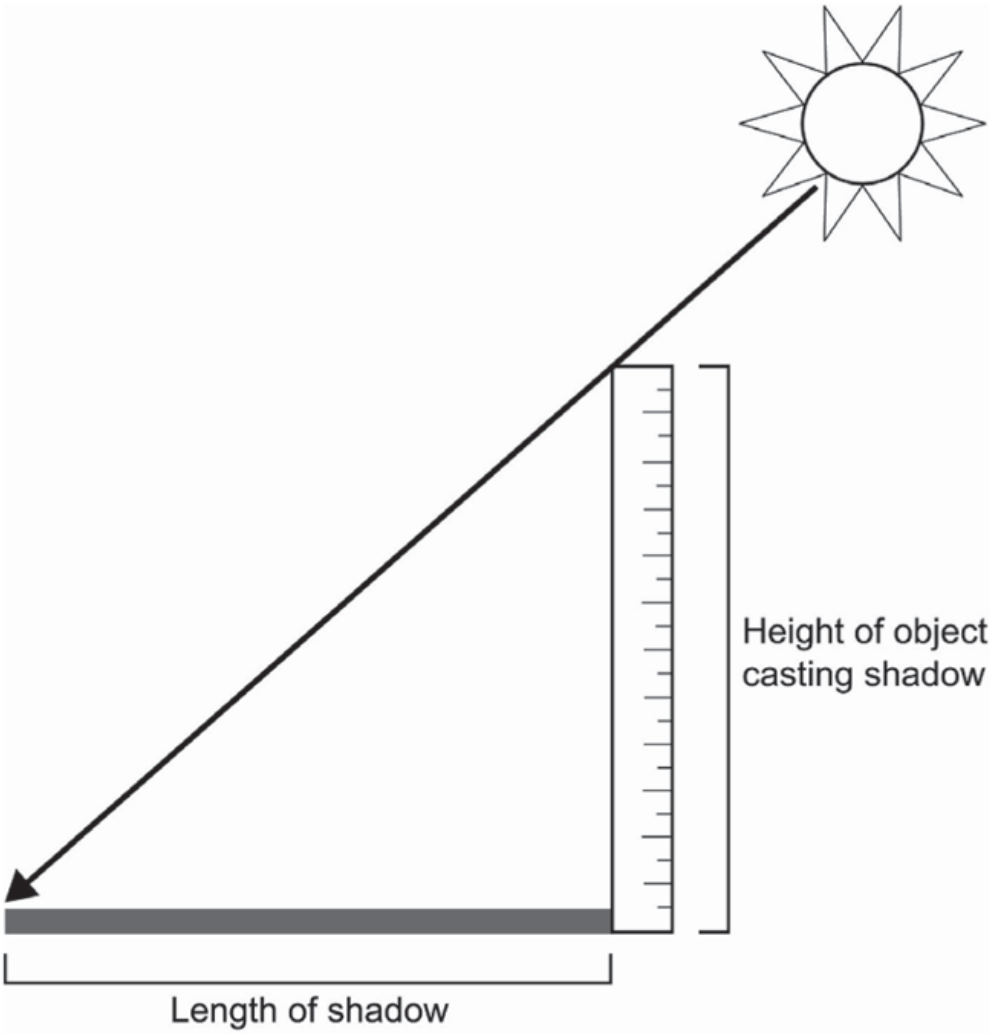


Data from Sports Study





Calculating the Shadow Ratio



$$\textbf{Shadow ratio} = \frac{\text{Length of shadow}}{\text{Height of object casting shadow}}$$

Outline for Health Recommendations

Question	Bone	Muscle	Skin
What is it made of?			
What does it do?			
How does it work?			
How do our behaviors affect it?			
How do we keep it healthy?			