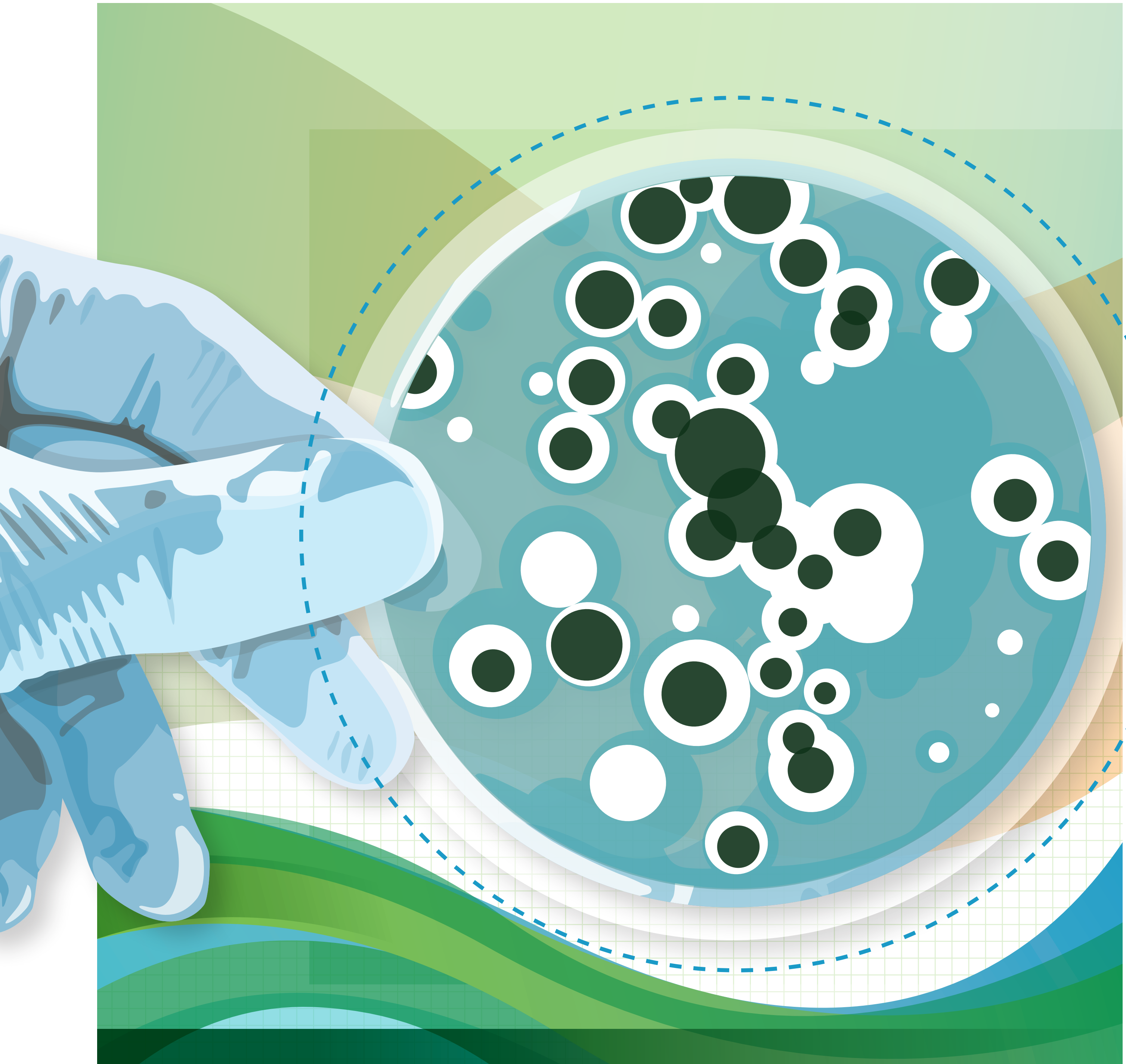

The Social Nature of Scientific Research

Grades 7-12 | First Edition

NWABR.ORG
Northwest Association for Biomedical Research

The Social Nature of Scientific Research

Practices and Processes

NWABR.ORG
Northwest Association for Biomedical Research

This curriculum is available on the NWABR website, http://nwabr.org

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Credits

AUTHORS AND CONTRIBUTORS

Renee Agatsuma, MSEd
Former Faculty, Garfield High School, Seattle, WA

Myra Arnone, MAT, NBCT
Faculty, Redmond High School, Redmond, WA

Dawn Brown, MEd
Science Teacher, Truman Career Academy, Federal Way, WA

Jeanne Ting Chowning, MS
Northwest Association for Biomedical Research, Seattle, WA

Elise Cooksley, MS, NBCT
Faculty, Two Rivers High School, North Bend, WA

Paula Fraser, MLS
Bellevue, WA

Joan Griswold, MIT
Northwest Association for Biomedical Research, Seattle, WA

Rosetta Eun Ryong Lee
Faculty, Seattle Girls School, Seattle, WA

Jodie Spitze, NBCT
Faculty, Kent-Meridian High School, Kent, WA

EXPERT REVIEWERS

Jeremy J. Belarmino
University of Illinois, Urbana-Champaign
Education Policy, Organization, and Leadership

Jeanne L. Brunner, MEd
Educational Psychology
University of Illinois at Urbana-Champaign

Kelly Edwards, PhD
Associate Professor, Department of Medical History & Ethics
Director, ELSI/Outreach Core, Center for Ecogenetics and Environmental Health
University of Washington
Seattle, WA

Barbara Waxman, PhD
Paragon Educational Network
Seattle, WA

PROJECT MANAGEMENT, EDITING, AND CURRICULUM PRODUCTION

Kristen Bergsman, MEd
Laughing Crow Curriculum LLC

COVER DESIGN

Cover produced by Laughing Crow Curriculum LLC
Designed by Clayton DeFrate Design

GRAPHIC DESIGN

Clayton DeFrate Design

COPYEDITING

Polly Freeman, MA

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COLLABORATIONS TO UNDERSTAND RESEARCH ETHICS (CURE) LEADERSHIP TEAM

Jeanne Ting Chowning, MS
Principal Investigator, CURE
Director of Education
Northwest Association for Biomedical Research

Susan Adler
Co-Principal Investigator, CURE
Executive Director
Northwest Association for Biomedical Research

Joan Griswold, MIT
Curriculum Design Lead
Northwest Association for Biomedical Research

CURE FIELD TEST TEACHERS

Judy Chambers
Faculty, Highline High School, Burien, WA

Mary Glodowski, NBCT, PAEMST
Science Teacher, Meadowdale High School, Lynnwood, WA

Kristi Martinez, MIT
Faculty, Eastlake High School, Sammamish, WA

Tim Renz
Faculty, Foster High School, Tukwila, WA

Dawn Tessandore
Faculty, Highline High School, Burien, WA

Jodie Spitze, NBCT
Faculty, Kent-Meridian High School, Kent, WA

Dianne Thompson
Faculty, Kent-Meridian High School, Kent, WA

CURE ADVISORY BOARD

Bill Cameron, PhD
Associate Professor, Department of Behavioral Neuroscience
Oregon Health and Science University

Carolyn Cohen, MEd
Cohen Research & Evaluation

Susanna Cunningham, PhD
Professor, Department of Biobehavioral Nursing
& Health Systems
University of Washington

Nora Disis, PhD
Director, Center for Translational Medicine in Women's Health
Institute for Translational Health Sciences
University of Washington

Kelly Edwards, PhD
Associate Professor, Department of Medical History & Ethics
Director, ELSI/Outreach Core, Center for Ecogenetics and
Environmental Health
University of Washington

Judy Fenyk-Melody, DVM, DACLAM
Director, Preclinical
Amgen

Joan Griswold, MIT
Curriculum Design Lead
Northwest Association for Biomedical Research

José Lopez, MD
Executive Vice President for Research
Puget Sound Blood Center

Dana Riley Black, PhD
Director, Center for Inquiry Science
Institute for Systems Biology

Louisa Stark, PhD
Director, Genetic Science Learning Center
Eccles Institute of Human Genetics
University of Utah

Beverly Torok-Storb, PhD
Senior Scientist, Fred Hutchinson Cancer Research

Reitha Weeks, PhD
Program Manager, Science Outreach
Northwest Association for Biomedical Research

Elaine Woo
Science Program Manager, Seattle Public Schools

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The Social Nature of Scientific Research

CURRICULUM OVERVIEW

Is science self-correcting over time? Do the processes involved in biomedical research—collaboration, communication, skepticism, peer review—lead to a valuable and objective way of learning about the world?

This curriculum introduces students to ways in which scientific research is conducted, how social forces influence scientific priorities, and how basic scientific research may, or may not, support medical applications for human health. Throughout the unit, students are asked to consider their roles and responsibilities as scientifically literate citizens.

RESEARCH ETHICS SERIES ENDURING UNDERSTANDINGS

- The biomedical research process is complex and dynamic, requiring information and tools of reasoning.
- The biomedical research process is driven by potential benefits to people and animals.
- The biomedical research process has evolved as scientists and other members of society have reflected on acceptable practices. It continues to do so as our knowledge expands.
- The biomedical research process requires active participation by scientists, consumers, clinicians, citizens, and research participants.

The Social Nature of Scientific Research curriculum is part of NWABR's Research Ethics Series, which also includes *The Science and Ethics of Animal Research* and *The Science and Ethics of Humans in Research* (see page 8).

INSTRUCTIONAL COMPONENTS

Elements: The curriculum consists of a formative assessment, five sequential lessons, a summative assessment, and supplementary classroom tools supporting student media review and analysis.

The media review and analysis support tools can be used throughout the unit or school year to help students become more comfortable with formulating and criticizing arguments.

Time:

Element	Approximate Time Required
Formative Assessment	1 class period of 55 minutes
Lesson One	5 class periods of 55 minutes each
Lesson Two	1 class period of 55 minutes
Lesson Three	1-2 class periods of 55 minutes each
Lessons Four and *Five*	1 class period each
Summative Assessment	1 class period to begin; additional time depends on how much in-class time is given for completing the assignment.
Supplementary media review and analysis support tools (in *Appendix*)	As needed; can be used independently throughout the school year.

Targeted Audiences: Grades 7–12

Systems Thinking

Science is a human enterprise conducted in a social context; science and its technological applications clearly have interconnected ethical implications. This curriculum seeks to integrate elements of the research endeavor and impact student learning in the following ways:

- Students learn to look at the interconnections between parts in a system rather than looking at qualities of separate objects.
- Students see a "web" of interconnection between a set of events, rather than thinking linearly about the events.
- Students understand that a whole system may have different properties than the parts of the system.

Fostering a Safe Classroom Environment

It is especially important to foster a safe classroom atmosphere when students must consider and discuss possibly controversial issues. The ethical issues addressed throughout this curriculum may involve conflicting moral choices. Please review or create classroom discussion ground rules ("norms") before beginning the unit (see *Appendix*, *Creating Discussion Ground Rules*).

THE SOCIAL NATURE OF SCIENTIFIC RESEARCH

Essential Questions

1. How is scientific research different from other ways of discovery and learning about the world?
2. How does the ethical conduct of scientific research lead to a process that promotes accountability, integrity, and intellectual honesty?
3. How are scientific research, society, and culture shaped and influenced by each other?
4. How does scientific research develop and change in response to new evidence, knowledge, and the application of new tools?
5. What is my role and responsibility as a scientifically literate citizen?

LESSON OVERVIEW

The ***5 E Learning Cycle Model***, as publicized through its use in the BSCS (Biological Sciences Curriculum Study) science program, incorporates five phases of learning: engagement, exploration, explanation, elaboration, and evaluation. The lessons in this curriculum follow the 5 E Model to guide students through this powerful cycle of learning. In the lesson plan descriptions provided below, notes indicate which stage of the 5 E Learning Cycle Model aligns with each lesson plan.

Formative Assessment: Identifying Misconceptions

"Engage"

The Formative Assessment is an "engage" activity in which students consider whether they agree or disagree with statements about the social nature of scientific research. Students first talk in pairs, then "vote with their feet" by standing along a continuum that best represents their position on the statement. This serves to take students' prior knowledge into account for the remainder of the unit, and uncovers potential misconceptions about the social nature of scientific research.

Graphic Organizer

"Explain"

The *Unit Graphic Organizer* helps students consolidate concepts and show relationships between subsystems of scientific research they will learn about in this unit. This organizer will be revisited at the end of each lesson.

Lesson One: Gummy Bear Lab Meeting

"Explore & Explain"

In this lesson, students participate in a scenario-based lab activity designed to help them define qualities that result in reliable and meaningful scientific research. By having students conduct an investigation that gives highly variable results within and between lab teams, students learn the importance of making ***strong arguments*** in science as they use evidence and reasoning to support their claims. They also **communicate**, **collaborate**, and **skeptically evaluate** each other's claims. Other aspects of scientific practice that the lesson illustrates include the importance of repeated trials, replicable methods, and integrity and honesty in data collection. After a class discussion of the checks and balances in place to ensure good science, teams repeat the lab activity with a protocol that they decide upon collaboratively. Lastly, students prepare to "submit their results for publication" and learn about the ***peer review*** process.

Lesson Two: *“Stupidity” in Science—A text-based discussion*

“Elaborate”
Students participate in a text-based discussion of the article “The importance of stupidity in scientific research” by Martin Schwartz. Using evidence found in the text, students consider how success is defined in scientific research and discuss how scientific pursuits may require persistence despite setbacks and a tolerance for ***not knowing*** much of the time. Students then relate their experiences of ***not knowing*** during the gummy bear lab from the previous lesson to the social nature of scientific research. This type of text-based discussion is a ***Socratic Seminar***.

Lesson Three: Science through the Centuries

“Explore & Explain”
In this lesson, students participate in an historical activity demonstrating how current research builds on prior understanding, and how scientific priorities are influenced by the social and health concerns of the time. This is a “jigsaw” activity, in which students are first divided into four different time period groups (1700s, 1800s, 1900s, and 2000s) to discuss social concerns and medical technology of the time. Each time period is seen through the eyes of four individual characters: a ***citizen***, a ***medical practitioner***, a ***person with Type I Diabetes***, and a ***scientist***. The students then regroup by character roles to compare themes over time. Lastly, students are introduced to ***translational research*** and see that, in many cases, basic research and the resulting application to human health are many decades apart.

Lesson Four: The Process of Scientific Research

“Explain”
Students arrange sets of cards to show their understanding of the process of biomedical research. Students see how basic research may lead to studies involving both animals and humans and may culminate in the availability of new treatments and medications. They then apply their understanding of the overall progression of biomedical research to early chromosomal studies and the story of Gleevec, a drug approved by the Food and Drug Administration (FDA) in 2001 to treat chronic myelogenous leukemia. Lastly, students consider the ethical guidelines that scientists follow in every stage of research. This lesson includes instructions on how to arrange the cards using a ***foldable***.

Lesson Five: Who Should Decide?

“Elaborate & Evaluate”
In this lesson, students participate in a Structured Academic Controversy around the question, “Should citizens determine funding for scientific research?” The general public can often see the importance of human research and clinical trials, but they may not be able to see the value of ***basic research***, especially when the budgets are tight. The National Science Foundation (NSF) distributes funds for basic research, and because the outcomes of the research are not always directly applicable to a health treatment or cure, questions can be raised about a study’s usefulness. Students explore both sides of this issue before examining their own personal views.

Summative Assessment: Case Study

“Evaluate”
Students apply the concepts they have learned during the unit to a case study or other chosen material from the class. From their completed graphic organizers, students choose three concepts to evaluate and explain how the concept contributes to the process of scientific research. Students also communicate the importance of being scientifically literate in their roles as science students, members of society, users of medications, and potential voters and taxpayers.

Appendix and Supplementary Tools

The two supplementary student handouts in this section can be used independently or together any time during the school year. The *Media Review and Analysis* handout can be used to support students in analyzing media for purpose, perspective, assumptions, claims, and impact. This handout can be used in any subject and for most types of media. An optional section on ***scientific process*** can be used for students analyzing scientific articles. Students are further supported in thoughtful analysis by using a handout entitled *My Evolution of Thought*, which helps students identify their attitude toward a subject before and after analysis. These tools help students explore the importance of being scientifically literate about the social nature of scientific research in a world influenced by mass media.

RESEARCH ETHICS SERIES

The Social Nature of Scientific Research is part of the following curricular set:

The Social Nature of Scientific Research

- How is scientific research different from other ways of discovery and learning about the world?
- How does the ethical conduct of scientific research lead to a process that promotes accountability, integrity, and intellectual honesty?
- How are scientific research and society shaped and influenced by each other?
- How does scientific research develop and change in response to new evidence, knowledge, and the application of new tools?
- What is my role and responsibility in being a scientifically literate citizen?

The Science and Ethics of Animal Research

- Why do scientists use animals in research?
- How does the history of animal research influence current views and policies?
- How do ethical considerations influence the use of animals in research?
- How can my actions reflect my position on the use of animals in research?

The Science and Ethics of Humans in Research

- How does the history of research with human participants influence attitudes, policies, and current practice?
- Why do scientists involve humans in research? How do scientists recruit, engage, and partner with study participants?
- What is the process used to make decisions regarding humans in research, and how are costs and benefits evaluated?
- How does the process of carrying out ethical trials involving humans influence the time needed to develop new cures and treatments?
- How can my actions reflect my position on research involving humans?

Each unit is designed to be used independently or as part of a larger curricular set.
All three units are available from http://nwabr.org.

CORRELATION TO NATIONAL LEARNING STANDARDS

National Standards Alignment: Science (Grades 5–12)

	Formative Assessment	**Lesson One:** Gummy Bear Lab Meeting	**Lesson Two:** "Stupidity" in Scientific Research	**Lesson Three:** Science through the Centuries	**Lesson Four:** Process of Research	**Lesson Five:** Who Should Decide?
Science as Inquiry						
Abilities necessary to do scientific inquiry.		•	•			
Understandings about scientific inquiry.	•	•	•	•	•	•
Science and Technology						
Abilities of technological design.	•			•	•	
Understandings about science and technology.	•			•	•	•
Science in Personal and Social Perspectives						
Personal and community health.				•	•	•
Science and technology in society.	•	•	•	•	•	•
Risks and benefits.	•		•	•	•	•
History and Nature of Science						
Science as human endeavor.	•	•	•	•	•	•
Nature of scientific knowledge.	•	•	•	•	•	•
Historical perspectives.	•			•	•	

Source: National Research Council. 1996. *National Science Education Standards*. Washington, D.C.: National Academies Press.

Common Core State Standards

For English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects

	Lessons 1–5
Comprehension and Collaboration, Grades 9–10	
1. Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.	•
a. Come to discussions prepared, having read and researched material under study; explicitly draw on that preparation by referring to evidence from texts and other research on the topic or issue to stimulate a thoughtful, well-reasoned exchange of ideas.	•
b. Work with peers to set rules for collegial discussions and decision-making (e.g., informal consensus, taking votes on key issues, presentation of alternate views), clear goals and deadlines, and individual roles as needed.	•
c. Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.	•
d. Respond thoughtfully to diverse perspectives, summarize points of agreement and disagreement, and, when warranted, qualify or justify their own views and understanding and make new connections in light of the evidence and reasoning presented.	•

Source: National Governors Association Center for Best Practices, Council of Chief State School Officers. 2010. *Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects*. Washington, D.C.: National Governors Association Center for Best Practices, Council of Chief State School Officers.

Framework for K–12 Science Education

	Formative Assessment	Lesson One: Gummy Bear Lab Meeting	Lesson Two: "Stupidity" in Scientific Research	Lesson Three: Science through the Centuries	Lesson Four: Process of Research	Lesson Five: Who Should Decide?
Scientific Practices						
1. Asking questions.	•	•	•	•		•
2. Developing and using models.		•			•	•
3. Planning and carrying out investigations.		•				
4. Analyzing and interpreting data.	•	•		•	•	•
5. Using mathematics, information and computer technology, and computational thinking.		•				•
6. Constructing explanations.	•	•	•	•	•	•
7. Engaging in argument from evidence.		•	•	•		•
8. Obtaining, evaluating, and communicating Information.	•	•	•	•	•	•
Crosscutting Concepts						
Patterns.		•	•	•	•	
Cause and effect: mechanisms and explanation.	•	•	•	•	•	•
Systems and system models.	•	•	•	•	•	•
Core Ideas: Life Sciences						
LS 1: From molecules to organisms: structures and processes.		•		•	•	
LS 2: Ecosystems: interactions, energy, and dynamics. D: Social interactions and group behaviors.	•			•	•	•
LS 3: Heredity: inheritance and variation of traits.				•	•	

Source: Committee on Conceptual Framework for the New K–12 Science Education Standards, National Research Council. 2011. *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: National Academies Press.

Formative Assessment
and Unit Graphic Organizer

INTRODUCTION

The Formative Assessment is an "engage" activity in which students consider whether they agree or disagree with statements about the social nature of scientific research. Students first talk in pairs, then "vote with their feet" by standing along a continuum that best represents their position on the statement. This serves to take students' prior knowledge into account for the remainder of the unit, and uncovers potential misconceptions about the social nature of scientific research.

The *Unit Graphic Organizer* introduced in this lesson helps students organize concepts and show relationships between subsystems of scientific research they will learn about in this unit. This organizer will be revisited at the end of each lesson.

CLASS TIME

This assessment should take about one class period of 55 minutes.

KEY CONCEPTS

- Science is a process by which scientists strive for objectivity when engaging with and learning about the natural world.
- Science is nevertheless a human endeavor and, as such, is tempered by human subjectivity.

LEARNING OBJECTIVES

Students will know:

- Science is a process and way of thinking rather than a set of facts to memorize.
- Science is a process that includes repetition, evaluation, and critique.

Students will be able to:

- Assess a statement and write a justification.

MATERIALS

Materials	Quantity
Student Handout—*Formative Assessment: Statements about the Social Nature of Scientific Research* [**Note:** Alternatively, you may project the *Formative Assessment* and ask students to write the answers in their notebooks.]	1 per student
Teacher Resource—*Guide to Statements about the Social Nature of Scientific Research*	1
Two signs: "Strongly Agree" and "Strongly Disagree"	2 signs
Student Handout—*Unit Graphic Organizer*	1 per student
Possible Answers to *Unit Graphic Organizer*	1

NOTE TO THE TEACHER

The National Research Council (NRC) has done extensive work compiling research findings about the cognitive and developmental aspects of learning. Their research has shown that students learn science best when certain principles are followed. These are a deliberate acknowledgement of and connection to prior knowledge, a connection between what they are learning and "big ideas," and a meta-cognitive reflection on the learning accomplished (NRC, 2005). Basically, students need to know what they thought before a concept was introduced, what they are being taught ***and*** why, followed by time for reflection back on what they learned and ***how their thinking changed***. Without this reflection, many students will revert to their prior knowledge even after direct instruction and activities. Sometimes students will remember the information long enough to take a test on it before reverting back to prior knowledge (NRC, 2005).

It is important to acknowledge that students don't come to us as empty vessels waiting for knowledge to be poured in; they have prior knowledge and misconceptions that they may have gained through their life experiences. This naïve knowledge is not something students "let go of" easily, even with direct instruction, but it is something that is completely logical within a student's experiences and not something that should be mocked by the teacher (NRC, 2005). For example, many students think that variation within a species comes from the environment rather than a result of sexual reproduction (Driver et al, 2007). As teachers, we need to deliberately ask questions that challenge students to acknowledge and confront their prior knowledge and/or misconceptions so that they can reflect on them, and move beyond them. These misconceptions can contribute to a student's inability to understand deeper content thoroughly. For example, many students have difficulty understanding the relative sizes of atoms, cell, molecules, and organelles (Driver et al, 2007). Without this understanding, how could we expect them to understand "higher content learning" like diffusion or cell communication? There are many resources that cite research done on common misconceptions held by children and adults. These resources are listed in the ***Sources*** section below. It is important to acknowledge misconceptions so that we can help our students progress beyond them.

The following misconceptions are relevant to this curriculum specifically, and/or to the nature of science in general.

Common Misconceptions about the Nature of Scientific Research

- Science is about facts that need to be memorized rather than a way of thinking or a process.
- Scientists need to use the "scientific method" in a specific order that requires a controlled experiment.
- Science doesn't change, and we already know all there is to know.
- Science is a way to "prove" or produce a desired outcome or invention, rather than a way to explore or build knowledge.
- Experiments can be used to "prove" or "disprove" a theory once and for all.
- It is important to be correct in your hypotheses—and doing so makes you a better scientist.
- Science that does not come to a firm conclusion is not useful.
- Scientists are completely **objective** and don't bring biases, moral values, motives, or preconceptions into their work, and therefore can be trusted more than others.
- Science and technology are the same thing and play the same role in scientific research.

Common Misconceptions about Data/Evidence in Science

- Students may consider correlation the same thing as causation.
- Students may not understand the need for multiple trials, especially when designing their own experiments, unless they are explicitly asked.
- Students may not understand the difference between a result in which the manipulated variable had no effect on the responding variable and the result in which it had the opposite effect than predicted.
- Students might not understand the need for controlling variables in an experiment.
- Students may not understand that scientists can legitimately hold different explanations for the same set of observations.
- Students will often accept arguments based on inadequate sample sizes, accept causality, and accept conclusions based on statistically insignificant differences.
- Students may not clearly understand which types of measurements to take in an investigation and when to take them.
- Students may have difficulty understanding the differences between models and experiments.

TEACHER PREPARATION

- Make copies of the *Formative Assessment* and blank *Unit Graphic Organizer*.
- Create two signs; one sign should read "Strongly Agree" and the other "Strongly Disagree." Attach the signs to a wall to create a continuum, allowing enough room for students to stand between the two signs to indicate a moderate stance.

PROCEDURE

Part I: Formative Assessment

1. Pass out the *Formative Assessment: Statements about the Social Nature of Scientific Research* to each student. Alternatively, you may project the *Formative Assessment* and ask students to write the answers in their notebooks.
2. Individually, have students decide whether they agree or disagree with each statement.
3. After taking a stance on each statement, have students turn to a neighbor to discuss their positions.
4. Students should then fill in the "Explain Your Answer" section of the handout.
5. After allowing some time for one-on-one discussion, tell students that they will "vote with their feet" by standing along a continuum from ***strongly agree*** to ***strongly disagree*** to show their stance for each statement. Point out the signs you have attached to the wall to create a continuum.
6. Read the first statement and have students stand at the point along the wall that represents their stance. Elicit student ideas, and have students share what they think and why.

   [Note: If a student is voicing a lone position and standing alone, it may add a helpful balance for the teacher to physically stand next to that student.]
7. Continue the procedure with the remaining six statements.

   [**Note:** As a formative assessment, the goal is not for students to come to the "right" answer, but to generate discussion on these issues and give the teacher a sense of student thoughts before they participate in the curricular unit. Teachers can lead the discussion using the Teacher Resource—*Guide to the Statements about the Social Nature of Scientific Research*.]
8. In closing, talk with students about their thoughts on the social nature of scientific research before and after participating in the activity.

Part II: Unit Graphic Organizer

9. If you haven't already, pass out one blank copy of the *Unit Graphic Organizer* to each student.
10. Tell students that they will use the graphic organizer to tie together important concepts throughout the unit. They will revisit the graphic organizer after each lesson.

ADAPTATION

Alternatively, you may project the *Formative Assessment* and ask students to write the answers in their notebooks.

GLOSSARY

Objective: Not influenced by personal feelings or opinions when considering or representing facts.

Subjective: Based on or influenced by personal feelings, tastes, or opinions.

RESOURCES

While not specifically focused on the social nature of scientific research, there are a number of valuable resources that help students explore the nature of science in general.

Science Knowledge Survey
Use this survey to help address students' misconceptions about science.
http://www.indiana.edu/~ensiweb/lessons/sci.tst.html

Can You Believe It? Mini-booklet
This mini-booklet helps students weigh the validity of scientific information by asking seven critical questions about media claims.
http://www.exploratorium.edu/evidence/assets/seven_questions/Can_You_Believe_It.pdf

Seven Warning Signs of Bogus Science
The importance of peer review, scientific collaboration, transparency and data collection is emphasized in this web resource.
http://www.webexhibits.org/bogus/index.html

Project 2061: Science for all Americans
This book from the American Association for the Advancement of Science (AAAS) has a number of helpful chapters on this topic, including "The Nature of Science" (Chapter 1) and "Habits of Mind" (Chapter 12).
http://www.project2061.org/publications/sfaa/online/sfaatoc.htm

SOURCES

Abd-El-Khalick, F. (2012). Examining the sources for our understandings about science: Enduring conflations and critical issues in research on nature of science in science education. *International Journal of Science Education*, *34*(3), 353–374.

American Association for the Advancement of Science (2009). *Benchmarks for scientific literacy: The research base*. Retrieved from http://www.project2061.org/publications/bsl/online/index.php?chapter=15&section=C&band=1#11c

Driver, R., Squires, A., Rushworth, P., and Wood-Robinson, V. (2007). *Making sense of secondary science: Research into children's ideas*. New York, NY: RoutledgeFalmer.

Evolution and the Nature of Science Institutes. (2011). Nature of Science Lessons. Retrieved from http://www.indiana.edu/~ensiweb/natsc.fs.html

Keeley, P. (2005). *Science curriculum topic study*. Thousand Oaks, CA: Corwin Press.

National Research Council. (2005). *How students learn science in the classroom*. Washington, DC: National Academies Press.

University of California Museum of Paleontology. (2011). Misconceptions about science. *Understanding science*. Retrieved from http://undsci.berkeley.edu/teaching/misconceptions.php#b1

STUDENT HANDOUT – FORMATIVE ASSESSMENT

Statements about the Social Nature of Scientific Research

Name____ Date_______________ Period_______________

Instructions:
Write "A" for Agree (or you lean that way) and "D" for Disagree (or you lean that way) in the space before each statement. When you are finished, talk your ideas over with another student and then write an explanation for your answers.

_____ 1. Scientists' opinions, biases, and personal beliefs influence their research.
Explain your answer:

_____ 2. A scientific idea is not valid in the scientific community until it has stood up to the scrutiny and critique of other scientists.
Explain your answer:

_____ 3. Scientists can look at the same set of data and come up with different valid interpretations.
Explain your answer:

_____ 4. Scientists will critically assess and evaluate each other's work, even if they agree with the results of that work.
Explain your answer:

_____ 5. A good scientist is one who gets the results he or she was expecting.
Explain your answer:

_____ 6. Science is universal and is not affected by the culture in which it is practiced.
Explain your answer:

_____ 7. Scientists usually stick to the "scientific method" which is used to test a hypothesis by controlling and manipulating variables.
Explain your answer:

_____ 8. Science is able to prove or disprove theories, facts, and laws, once and for all.
Explain your answer:

HANDOUT

Guide to Statements about the Social Nature of Scientific Research

Instructions:
Write "A" for Agree (or you lean that way) and "D" for Disagree (or you lean that way) in the space before each statement.

A 1. Scientists' opinions, biases, and personal beliefs influence their research.

Agree: *Science is a human endeavor and, as such, is not fully objective. There are a number of features found in biomedical research that provide checks and balances within the system. Some of these features are: running multiple trials, using placebos, double-blinding a study, working collaboratively, peer review, and scientists reproducing each other's work. Opinions and personal beliefs, however, can still influence what science gets done, what is studied, and what gets funded.*

A 2. A scientific idea is not valid in the scientific community until it has stood up to the scrutiny and critique of other scientists.

Agree: *Science is a collaborative process, and is not done in isolation over the long term. Scientists rely on others not only to guide them in the type of work they do, but also to share ideas and improve the scientific approach.*

A 3. Scientists can look at the same set of data and come up with different valid interpretations.

Agree: *Scientists aren't a homogenous group. They can have differing opinions and views on data. It is in talking through these different ideas and challenging each other that scientists can come up with more valid conclusions based on the data. In the end "nature wins;" in other words, though there may be valid conclusions about data that are contradictory, we assume that there are stable features of nature that can be discovered through science.*

A 4. Scientists will critically assess and evaluate each other's work, even if they agree with the results of that work.

Agree: *Scientists are critical of each other's work; this is the process of peer review. There is a misconception in some of the popular media that climate scientists or evolutionary scientists, for example, conspire to put out a unified message, while ignoring conflicting evidence.*

D 5. A good scientist is one who gets the results he or she was expecting.

Disagree: *Getting expected results has nothing to do with being a good or poor scientist. Being a good scientist entails refining methods and experimental designs, continuing to ask testable questions and understanding why an experiment did not go as anticipated. In fact, scientists can sometimes learn more from unexpected results than from expected results. (Students often consider expected results to be the sign of a "successful" experiment, and unexpected results to be the sign of a "failed" experiment.)*

D 6. Science is universal and is not affected by the culture in which it is practiced.

Disagree: *This is an active area of discussion among scientists and philosophers. Currently, most people recognize that science reflects the norms and social/political values of the culture in which it is practiced. This is one reason that feedback and input from a heterogeneous scientific community is important to the scientific process.*

D 7. Scientists usually stick to the "scientific method" which is used to test a hypothesis by controlling and manipulating variables.

Disagree: *There is no single "scientific method." The recipe-like steps often taught in school may describe how experiments are carried out, but science uses a number of approaches to explore and find meaning in the natural world. Other approaches include observational and descriptive studies, epidemiological studies, correlational studies—even serendipity plays a part in scientific discovery.*

D 8. Science is able to prove or disprove theories, facts, and laws, once and for all.

Disagree: *Although much scientific knowledge is reliable and durable and has not changed over time, scientific knowledge, by nature, cannot be absolute or certain. Scientific ideas can change in light of new evidence, new ways of thinking, and new technology—it is subject to skepticism. Even a scientific law that is supported by much empirical evidence cannot be proven to be upheld in every circumstance under every condition. Science is able to describe patterns and provide useful generalizations about predicting how things work under specific circumstances, but scientific knowledge is always subject to change.*

STUDENT HANDOUT
Unit Graphic Organizer

Name________________________________ Date______________ Period______________

Throughout this unit we will explore scientific research as a system of interconnected processes:

SUBSYSTEMS OF SCIENTIFIC RESEARCH

Being a Scientifically Literate Citizen

Translational Research

Role of Science and Society

Research Process

Possible Answers for Unit Graphic Organizer

Throughout this unit we will explore scientific research as a system of interconnected processes:

SUBSYSTEMS OF SCIENTIFIC RESEARCH

Research Process

- Communication
- Collaboration
- Skepticism
- Peer review
- Publication
- Repeatable trials
- Integrity
- Persistence despite setbacks

Role of Science and Society

- Citizens and social needs influence research directions
- Society funds the research it values
- Media influences societal views of science

Translational Research

- Basic science
- Discovery of new ideas
- Animal trials
- Human trials
- New cures and treatments
- Ethical guidelines

Being a Scientifically Literate Citizen

Understanding practices and processes as a:

- Student
- Member of society
- Consumer of medications and treatments
- Tax payer
- Voter

[**Note:** This graphic works well as a four-part foldable, if you are familiar with this technique. More information is available at: www.dinah.com/conceptmaps/conceptmaps.php.]

LESSON 1:

Gummy Bear Lab Meeting:

Social Practices in a Scientific Community

INTRODUCTION

In this lesson, students participate in a scenario-based lab activity designed to help them define qualities that result in reliable and meaningful scientific research. By having students conduct an investigation that gives highly variable results within and between lab teams, students learn the importance of making ***strong arguments*** in science as they use evidence and reasoning to support their claims. They also **communicate**, **collaborate**, and **skeptically evaluate** each other's claims. Other aspects of scientific practice that the lesson illustrates include the importance of **repeatable trials**, replicable methods, and **integrity** and honesty in data collection. After a class discussion of the checks and balances in place to ensure good science, teams repeat the lab activity with a protocol that they decide upon collaboratively. Lastly, students prepare to "submit their results for publication" and learn about the **peer review** process.

CLASS TIME

Five class periods of 55 minutes each allows students to complete the lab and engage in the collaborative process (see ***Suggested Timing*** section for more information).

KEY CONCEPTS

- Social interactions are a key part of the process of science. Scientists often discuss and refine their methods in **collaboration** with others; they also communicate their results to the research community for evaluation through the peer review process.
- The peer review process helps make science more "objective" as scientists critique and/or try to repeat the findings of others. These checks and balances within the scientific research process help lead to quality research and confidence in results.
- **Skepticism** is valued in science; scientists actively question the methods and findings of others and do not accept claims that are not backed with strong evidence and support.
- Engaging in scientific research can be a messy endeavor, requiring personal characteristics such as persistence and a tolerance for ambiguity.

Vocabulary words used in each lesson are in **bold**. Definitions can be found at the end of each lesson and in the *Master Glossary* in the *Appendix*.

LEARNING OBJECTIVES

Student will know:

- **Communication**, collaboration, and skepticism are essential to the scientific research process.
- It is important to back claims with evidence and reasoning, and to use evidence and reasoning to evaluate the claims of others.

Students will be able to:

- Actively participate in a class discussion evaluating the varied methods and results of approaches used by class members.
- Make claims and support them with evidence and reasoning.
- Critically and respectfully evaluate the claims of others.
- Revise methods in light of group discussion.

MATERIALS

Materials	Quantity
Student Handout 1.1—*Gummy Bear Lab Protocol*	1 per student
Student Handout 1.2—*Lab Meeting Data Sheet*	1 per student
Student Handout 1.3—*Lesson Assessment*	1 per student
Teacher Resource 1.1—*Class Frequency Distribution Table*. Two copies are needed for recording class data from each of the two protocols.	2
Teacher Resource 1.2—*Journal of Applied Polymer Confections Acceptance Letter*	1
Access to water and paper towels, plus an assortment of lab materials such as metric rulers, scales, graduated cylinders, beakers, scalpels, and clamp stands	1 set per student group
Gummy bears [**Note:** Our field test teachers had success with Black Forest brand bears, as they tend to retain their shape better when left in water]	Minimum of 2 per student

SUGGESTED TIMING

Day	Activities
Day One	Introduce lab. Students develop and carry out protocol. Bears soak in water overnight.
Day Two	Students analyze data. Students prepare to present.
Day Three	Lab meeting, including presentations. May include discussion of new protocol.
Day Four	Determination of new protocol. Students carry out new protocol. Bears soak in water overnight.
Day Five	Students analyze and share new data. Discussion of peer review. Closure.

TEACHER PREPARATION

- Make copies as described in the *Materials* section.
- Set up each lab station with an assortment of lab equipment and a number of gummy bears to choose from. Make sure there is a minimum of eight gummy bears per lab station.

NOTES TO THE TEACHER

This lesson requires an investment of time. Though it may be tempting to merge two days into one, the discussion ***processes*** take time and should not be rushed. Allowing students enough time to work together through a common problem at their own pace with minimal teacher input is key to the success of the lesson.

The protocol for this lab provides guidelines so that students will be able to share data gathered in a uniform way. Make sure students know that there is no one "scientific method" that all scientists use to discover new information. Scientists use a number of practices and approaches to explore and find meaning in the natural world. Other approaches include observational and descriptive studies, epidemiological studies, correlational studies—even serendipity plays a part in scientific discovery.

The wide range of results between and among lab teams may lead to student frustration and a sense of confusion during the lab. This is an expected part of scientific research when there is no "answer in the back of the book." Help students work through their frustration by communicating with each other and working together to come up with the best plan for improving their lab protocol.

Students may be confused and frustrated as they try to fit this activity into a traditional "scientific method" format. However, this activity is focused on a particular ***practice*** in science (optimizing a procedure through communication and cycles of collaborative feedback). Students may try to establish a "control" – if they wish to do that, allow them to. The discussion afterwards can focus on whether or not a control provides useful information in this case.

You know your students best. If students will likely be uncomfortable with the open-ended nature of the lab and the idea of critiquing their classmates, we recommend beginning the unit with *Lesson Two: "Stupidity" in Science: A Text-based Discussion*. This lesson speaks to the importance of not having all the answers in science, and sets up a discussion method based on evidence that students might find helpful during the lab meeting. This discussion strategy also provides students with practice making evidence-based claims.

PROCEDURE

In this lesson, students are given a scenario in which they are scientists working for a principal investigator (PI) on a research problem involving **diffusion** of water into gummy bears. Gummy bears are made of gelatin and sugar. Gelatin is a **polymer** that forms large three-dimensional matrices that give structural support to jellies and jams. Students conduct the lab twice with a classroom discussion in between.

Day One: Introduction to the Lab—Collaboration

1. Begin the lesson by asking students: "Have you ever had a problem that when you talked to several other people about it, you came up with a better solution than if you just thought about it yourself?"

2. After discussing some student examples, note that collaboration and communication are key aspects of the social part of science. Explain that students will be doing a lab activity that highlights these concepts. The lab will also demonstrate how skepticism is important in science.

3. With student input, create working definitions of communication, collaboration, and skepticism:
   - **Communication:** Sharing information with others.
   - **Collaboration:** Working together with others toward a goal.
   - **Skepticism:** Evaluating information critically and looking for evidence and reasoning behind claims.

4. Tell students that over the next five days, their classroom is going to become a scientific community, and they are going to become "polymer scientists." Share with them that there is currently a lot of controversy in the polymer research community about the type of polymer and how much it increases in volume when left in water.

[**Note:** You may want to expand on the definition and chemical characteristics of polymers if appropriate. For this lab, students only need to know that a polymer is a large thread-like molecule made of repeating units.]

5. Relate the expanding of polymers in water to important research on creating absorbent materials that might soak up chemical spills or hold water in soil. Liquid-absorbing polymers may also be used in soft contact lenses, dressings for burns, or in tissue engineering. New research is also being done on polymers as a potential drug-delivery molecule.

6. Explain that one way scientists communicate is by sharing their findings with others in journals. If the class obtains good, careful results, their findings will be "published" in the *Journal of Applied Polymer Confections* (a make-believe journal). Publishing in a journal allows a scientist's work to be viewed skeptically by other scientists which can advance the field of polymer science. If scientific ideas withstand repeated scrutiny and testing, they become increasingly accepted within the community.

7. Tell students that you are the "Principal Investigator" (PI) in charge of the lab group (class) investigating the characteristics of polymers. They are scientists studying polymer science. They will be working in teams conducting basic research to be used as the foundation for future research.

8. Explain to students that past research with gummy bears has shown that the size of a gummy bear increases between 200 and 600 percent when soaked in water. It is thought that this is due to water molecules entering the polymer matrix.

9. Tell students that the class will need to obtain a precise answer to the question:

   How much does the volume of a gummy bear increase after soaking in water?

   To answer the question, students will need to focus on the ***best method*** of obtaining the most consistent data. During the upcoming lab meeting, when students share and discuss their results, students will need to make a strong argument for the measurement method they used based on their evidence (the percent change in volume of their gummy bears).

[**Optional:** If your students need extra motivation, suggest that the whole class get extra participation points if class results are carefully obtained and their work is "published." Results have to be accurate and consistent to be published.]

10. Organize students into teams of four. Each team should meet at a lab station, where an assortment of gummy bears and laboratory equipment will be available to them.

11. Tell students that each team will work independently without input from the teacher or other lab teams.

12. Hand out copies of Student Handout 1.1—*Gummy Bear Lab Protocol*, one per student. Allow time for students to record observations, discuss method of measurement, and complete the protocol.

13. Let beakers sit undisturbed overnight.

Day Two: Communication

14. **Communication:** Tell students that they need to prepare for a "lab meeting," where they will discuss their results as a class. Ask students what the goal of a "lab meeting" might be. Possible answers might include:
    - To compare findings.
    - To analyze each other's work.
    - To figure out what to do next.
15. Tell students that it is time to communicate to each other what they've found in order to determine the best method of obtaining data to be used in future trials. Students have been collaborating in their teams so far, and now they are preparing to collaborate with the larger lab group.
16. Each lab group will need to collect the beakers containing the gummy bears that soaked overnight. Next, challenge students to complete the ***Day Two Protocol*** on Student Handout 1.1—*Gummy Bear Lab Protocol*.
17. To prepare for the lab meeting, each group should prepare to communicate to other groups what happened to their gummy bears and how well their method of measurement worked. Students should work with their group members to write the answers to the following questions in their lab notebooks:
    - What was your method?
    - What can you conclude about the effectiveness of your method of measurement? (***Claim***)
    - What did you find to be the percentage increase of gummy bears soaked in water?
    - How do the data and your experiences support your conclusion and why? (***Evidence*** and ***reasoning***)
    - What worked with your method? What did not?
18. One person from each group should record the group data on one copy of Teacher Resource 1.1—*Class Frequency Distribution Table*. Percentage changes for each bear should be rounded to the nearest 50 before recording.

[**Note:** It is helpful to give each team a different colored marker to enter their data on the class data table. The colors will show concentrations of data.]

19. As students are preparing to share their data in the lab meeting, teachers may wish to model ways to communicate about data and methods. For example, "Our method was to measure the volume before and after by measuring length x width x height, using the highest point on the bear as the height. From the results of our trial, we think bears increase 300%. In our graph you can see that one bear increased 500%, but all our other bears were closer to 300%. One source of error is that a chunk of our yellow bear broke off when we tried to measure it."
20. Ask students to share responsibility for presenting among their group members. Each student should share one or more of the points outlined in *Step #17*.

Day Three: The Lab Meeting—Collaboration and Skepticism

21. **Collaboration:** In your role as PI, explain that today you will be convening a ***lab meeting*** for the scientists to share their initial data, review the methods of other teams, and give critical feedback in order to redesign the existing protocol for the next set of trials. Tell students there will be a short question and answer period following each informal presentation so that the other teams can assess the quality and validity of the conclusions drawn from the team's data.
22. Revisit any class norms developed earlier about respectful listening and critiquing ideas rather than people. Stress for students that they are working collaboratively as part of the PI's lab group, not competitively between lab teams.
23. **Skepticism:** Explain that students should be skeptical of each team's work and ask for clarification or explanations in a civil way. Emphasize that the point is not to accuse one another of shoddy work, but to challenge them to think critically about methods that result in the most reliable data. Model for students what would be an appropriate critical, skeptical question ("Why did you choose that method of measurement?") and an inappropriate one ("Why did you do it in such an obviously wrong way?")

> "Skepticism is the agent of reason against organized irrationalism—and is therefore one of the keys to human social and civic decency."
>
> ~Stephen Jay Gould

24. **Courage:** Tell students that full and honest participation in a lab meeting may also require courage on their part. It takes courage to:

- Put out their ideas for criticism.
- Critique the views of others and speak up.
- Give up a cherished idea and not take it personally.

25. Distribute copies of Student Handout 1.2—*Lab Meeting Data Sheet*, one per student, for students to take notes on during the lab meeting, or ask them to take notes in their notebooks.

26. Have the first team present their work. Choose a confident and resilient team that is comfortable serving as a model for the lab meeting, where their results will be questioned and challenged by the class.

27. After the first team presents, have students consider whether the team used a "scientific" approach. Derive the ideas that scientific approaches are precise (not vague) and have a solid design (for example, confounding variables are controlled), and that scientific answers are well-supported with evidence.

28. Open the class up to other questions from students. If spontaneous questions from the class do not address the topics below, you may need to provide some facilitation. For example, you can ask each lab team to come up with a question for the first presenting team.

29. As students ask questions, it may be helpful to write them on the board, grouped by topic. Leave these questions up on the board during the rest of the presentations.

Measurement method
How did you measure? How did you make sure each member of your team measured the same way? Did you check each other's measurements to make sure you were consistent?

Claims, Evidence, Reasoning
What did you conclude about your method of measurement? Can you explain how your data or experiences support your claim?

Overall Approach
What would you do differently next time? What were possible sources of error? Should the whole class use your approach if we were to do this again? Why or why not?

Data
What do your data show? Did you check each other's math when calculating percent size change?

30. Repeat this process for the remaining teams, allowing questions to be student-driven. Teachers can facilitate the lab meeting by helping students recognize areas in which questioning may be productive.

[**Note:** It is natural that the focus of a presentation is on the presenters. A good lab meeting, however, relies heavily on good questions from the student listeners. As a challenge to the class, have them write down the ***best question posed*** at the end of Student Handout 1.2—*Lab Meeting Data Sheet*.]

31. Once all teams have presented, lead the class in a discussion about the overall quality of the investigation.

    a. Do you feel you can confidently determine the percent change in volume that occurs in gummy bears soaked in water using the conclusions presented? Why or why not? (*Challenge them if they say yes!*)

    b. Which measurement method appeared to give the most consistent results? Does this mean it results in the most valid data? How would you be able to test the validity of the data? (*Replication*)

32. *Questions #c-e* are optional, if time allows.

    c. Which team appears to have the most consistent data? Does this mean they have the most valid data? How would you be able to test the validity of their conclusions? (*Replication*)

    d. What characteristics of good scientific design might be missing from the protocols? What changes need to be made?

    e. What variables were controlled for? (*Amount of water, size of beaker, etc.*) What was the treatment?

33. Explain to students that scientists commonly engage in these types of discussions to improve techniques and solve problems. The problem they should be able to discover with this initial investigation is that the irregular shape of the gummy bear makes it difficult to measure accurately and consistently across trials.

34. Ask students to think about possible ***sources of error*** in this trial and how to remedy those. They may also point out the small ***sample size*** makes variability in the data more significant. Lead them to the idea that in the next trial, the class could pool all its data to make a larger sample size.

Day Four: Collaborative Redesign

35. Facilitate a student-led brainstorming session about ways to modify the existing protocol to get better measurements. Allow for a variety of creative solutions. Tell students that as their PI, you would like to see them improve the protocol for this investigation to get more accurate and consistent results across all teams to publish your lab's findings. Stress that in authentic scientific research (unlike experiments often done in schools), procedures and/or experiments are often repeated.

36. Record students' suggested methods on the board or ask a student to do so. Facilitate a discussion of their pros and cons. Ask for clarification when necessary, but allow students to control the overall research design as much as possible.

37. Have the class agree on one method that all teams will use for a second round of the investigation. Guide them through this by recording their ideas on the board for all to see. Make sure to allow adequate time for this discussion; a high tolerance for long pauses and plenty of "think time" is helpful.

38. Students should record the new protocol they will use in their journals or on a sheet of paper they can attach to Student Handout 1.1—*Gummy Bear Lab Protocol*.

39. Give students time to complete the new protocol.

40. Provide closure by asking students: How did the lab meeting tie back to the ideas of communication, collaboration, and skepticism? What about courage?

41. Let the beakers sit undisturbed overnight.

Day Five: Peer Review and Integrity

42. Students should collect the beakers that soaked overnight and make/record their final measurements.

43. One person from each team should record their results (rounded to the nearest 50) on a second copy of Teacher Resource 1.1—*Class Frequency Distribution Table*. Again, it may be helpful for each lab group to use a unique pen color.

44. Display the *Class Frequency Distribution Table* for all to see. Have students ask questions of each other and discuss the quality of results. Make sure to address whether any teams ran into problems with the new protocol or deviated from the new protocol. It is not necessary to have each individual group present at this time; instead focus on the whole-class discussion.

45. Ask students if they think this data and their conclusions are strong enough to be published and read by other scientists. Explain to them that this is called peer review and is part of the checks and balances that make scientists accountable for the quality of their work. Explain that scientists submit papers (much like a lab report) to scientific journals. The editors and other scientists review the work to see if it is worthy of publication.

46. Tell students that peer review can happen on a number of levels. For example:

- ***Small-scale peer review*** happens when members of a team or lab group question and critique each other's work internally. Students have just participated in this type of peer review during the lab meeting, and may be familiar with this from peer-review experiences in other classes.
- ***Large-scale peer review*** happens when a team or lab group shares their ideas and findings with the broader scientific community. This provides a way for claims and evidence to be rigorously examined by others who are knowledgeable in a field. Scientific findings that have been accepted over time by the scientific community move knowledge forward and help make science more "objective." Submitting papers to a peer-reviewed journal is one example of this type of peer review. However, future findings might cause scientists to revisit their understandings, and thus scientific knowledge ultimately remains tentative even when a large body of evidence supports it.

47. Explain that while the practices of peer review and publication lead to a way of knowing about the world that can be very reliable, the pressure on scientists to publish in a peer-reviewed journal can be intense. Hence the saying, "*Publish or Perish*."

48. Ask the class, "Did any teams leave out information when you presented to the class?" For example, did teams report on bears that broke? Did teams report on whether or not they blotted the bears before measuring? Ask if, in general, there were places where data could be ignored, fabricated, or falsified. How would students feel if their careers depended on the publication of this data?

49. Ask students how integrity and honesty in data collection impact the classroom results. In a collaborative environment, one person's dishonesty can have an effect on everybody in the lab, especially if the group's work will be published with shared authorship. For many reasons, it is important that all information (like data, how it was analyzed, results, graphs, conclusions, and explanations of how the study was done) be made available to anyone wishing to see it. Making the steps and actions taken during the lab easily understood and clear to others is called **transparency**.

[**Note:** Of the more than 2,000 papers that were retracted from scientific journals between 1977 and 2010, two-thirds were retracted due to scientific misconduct, which includes plagiarism as well as knowingly and intentionally falsifying data.]

50. Tell students that scientific research can lead to data and facts that are reliable and durable, so many people consider "science" to be very objective, or leading towards "truth." The ***process*** of scientific research, however, is a human endeavor and open to subjectivity. For example, cultural elements influence how science is conducted, how science is communicated, and what science gets funded.

51. Collect the *Student Handouts* and/or lab notebooks and tell students that as the PI, you will use their work to write a (fictitious) paper for submission to the *Journal of Applied Polymer Confections*.

52. Before submitting the "paper" to the journal, ask the students, "Who should get credit for the work?" and "In what order should names be listed on the submitted paper?" Tell students that these are very important questions in the scientific community. In most publications, the order in which the authors are listed denotes the relative contribution of each person. In some cases, relative contribution is made apparent through font size, how the name is listed, or through side notes. Different scientific journals have different established norms for publication.

53. Tell students you have sent off their work in a paper called "The Effect of Hydration on a Gelatin Polymer Confection." You have (remarkably quickly) received a letter from the editors of the *Journal of Applied Polymer Confections*. (To maintain the imagined scenario, teachers may choose to wait a few days to "receive" the letter from the journal.) The editors have sent your paper to a number of other scientists in the field of polymer confections for peer review. Based on the peer review, the editors have accepted the work, but the reviewers request modifications. Their critique includes these issues:

   - Sample size is too small for data to be significant.
   - A stronger connection to the social impacts and applications to future research should be made.
   - Explore how different colors, brands, and formulations of gummy bears (gelatin vs. vegetarian pectin types) are affected by hydration.

54. Explain that this type of critique is common and that science is always expanding and questioning what is known. Explain that the process of having one's work published in a highly-regarded journal is very competitive. For example, the journal *Science* accepts less than 8% of the articles submitted.

55. Review with the class the process they completed and how this models the same process that scientists complete: collaboration within investigations, repeatable procedures, multiple trials, peer review, revision of procedures, and publication of results. This provides a segue to *Lesson Two*, in which students explore the qualities that make a successful scientist using a text-based discussion.

56. Lastly, show students the simulated letter, Teacher Resource 1.2—*Journal of Applied Polymer Confections Acceptance Letter*, stating that their paper has been accepted with revisions.

Closure

57. Ask students, "Was this lab really about gummy bears? Why or why not?" Lead students to the idea that the processes they took part in are important in all fields of science, from physics to bioengineering. In school, students are often asked to ***master*** prior knowledge. In this lab, they were involved in the process of ***creating*** new claims and discussing/critiquing the claims of others, which are essential parts of the scientific process. Tell students that not all scientific activities are "experiments"; there are many types of scientific practices such as observation/measurement that are also important.

58. Ask students whether the lab meeting is like any other types of discussions they have had.

59. Have students retrieve their *Unit Graphic Organizer* handouts and look at the first column titled "Research Process." Ask students, "What are the structures, systems, or ways of thought that lead to reliable results in research?" Students should brainstorm and write down phrases such as:

   - Working collaboratively.
   - Communicating with each other and the wider scientific community.
   - Demonstrating skepticism.
   - Performing multiple, repeatable trials.
   - Process of peer review and publishing.
   - Being persistent despite setbacks.
   - Working and reporting with integrity.
   - Being comfortable with ambiguity.

60. In addition, draw students' attention to the last column, "*Being a Scientifically Literate Citizen*." Ask students how their understanding of the research process impacts them as students. Discuss their responsibility to be scientifically literate in their role as a ***student*** and add that word to the graphic organizer.

Assessment

61. Instruct students to choose two characteristics of scientific research the class explored during this lab (i.e., communication, collaboration, skepticism, integrity, courage, peer review). For each one:

a. ***Define*** the concept (what does the word mean?)

b. ***Identify*** its importance (how and why is it necessary?)

c. ***Give an example*** of what it looks like in the science classroom (for example, in the gummy bear lab or in another activity).

d. ***Give an example*** of what it looks like in the greater scientific community.

This assessment is similar to the end-of-unit *Summative Assessment* and will familiarize students with the process. A rubric for this is also included at the end of this lesson. In addition, teachers may choose to have students complete a formal lab write up for this lesson, or write a brief paper outlining their methods and results to submit for publication in the *Journal of Applied Polymer Confections*. These may be assigned as homework.

62. If time permits, also revisit the Formative Assessment—*Statements about the Social Nature of Scientific Research* and discuss how students' ideas about science have changed—or not. Ask students to provide examples and reasons for their answers, referring to specific activities that took place throughout the lesson.

HOMEWORK

Students can choose one of the short stories found in *The Scientist* magazine's "Top Science Scandals of 2011" and "Top Science Scandals of 2012" and explain how the story illustrates a ***lack*** of integrity, collaboration, skepticism, peer review, or other foundations of good scientific research. The stories can be found here:

- http://the-scientist.com/2011/12/19/top-science-scandals-of-2011/#disqus_thread
- http://www.the-scientist.com/?articles.view/articleNo/33695/title/Top-Science-Scandals-of-2012/

EXTENSION

Students can conduct additional research online related to water retention in polymers. This research is connected to "ecospheres" and other products that improve the capacity of soil to hold water.

GLOSSARY

Collaboration: Working together to create something, solve a problem, or answer a question.

Communication: Sharing information with others.

Diffusion: The passive movement of molecules from an area of high concentration to an area of lower concentration.

Integrity: Honesty and truthfulness in one's research; avoiding cheating and plagiarism.

Peer review: The evaluation of scientific work or findings by others working in the same scientific field.

Polymer: A molecule or compound made up of several repeating units.

Repeatable trials: A feature of a valid scientific experiment, meaning it can be performed multiple times and produce the same or similar results.

Skepticism: A doubting or questioning attitude or state of mind.

Transparency: The quality of a scientific experiment or other process that allows others to easily see what actions have been performed.

SOURCES

University of California Museum of Paleontology. (2013). "Scrutinizing science: Peer review." *Understanding Science*. Retrieved from http://undsci.berkeley.edu/article/0_0_0/howscienceworks_16

Group of Gummy Bears Photograph. Thomas Rosenau/Wikimedia Commons.

Jelly Beans Photograph. Gcardinal from Norway/Wikimedia Commons.

STUDENT HANDOUT 1.1

Gummy Bear Lab Protocol

Name____ Date_______________ Period_______________

Communication, Collaboration, and Skepticism

GB Discovery Laboratory

Improving the quality of life with polymers

Welcome to your new job as a scientist for GB Discovery Laboratory. We are dedicated to designing polymer solutions to problems in biology and medicine. **Polymers** are large thread-like molecules made of smaller repeating chemical subunits. The specialty of your department is quantifying the effectiveness of liquid-absorbing polymers. Your department has previously studied and published their experimental findings on liquid-absorbing polymers used in soft contact lenses, dressings for burns, tissue engineering, and oil spill containment.

As members of the scientific community, we value and expect your full participation in our department lab meetings. Working with others is critical to improving the quality of science done by our group. Our lab meetings will focus on:

- **Communication** – sharing your information with others.
- **Collaboration** – working together with others toward a goal.
- **Skepticism** – evaluating information critically and looking for evidence and reasoning behind claims.

Your department has been divided into lab teams to investigate the ability of gummy bear polymers to hold water. Our goal is to determine the best procedure for measuring changes in gummy bear volume. Your team will design a plan, conduct an experiment, and then share your findings with the entire department during our next lab meeting. Following our own internal **peer review**, GB Discovery Laboratory plans to submit your findings for publication in the *Journal of Applied Polymer Confections* for broader peer review by the scientific community.

Day One Protocol

1. In your lab notebook, record your descriptive observations about the gummy bear, including color and shape.

2. Record the question: *How much does the volume of a gummy bear increase after soaking in water?*

3. Collaborate with your lab team to determine a way to measure the volume of the gummy bears. [**Note:** There are many ways possible.]

4. Once you have agreed on a method, record your planned procedure.

5. Construct a data table to record the volume data of each team member's gummy bear. Be sure to have a column for "Initial volume before soaking" and "Volume after 24 hours" (or however long you soaked your bears).

6. Measure your bear using the team method, record the measurement in your data table, and communicate your findings so each team member includes all bear volume data in their table.

7. Soak the bears overnight in a beaker of water.

HANDOUT

Day Two Protocol

8. Gently remove gummy bears from the beakers and pat them dry. Be very careful because the candy is now extremely breakable.

9. Using the same method your team used before soaking, measure the volume of the bears and record the data in your table.

10. Calculate the percent change for each measurement for each bear using the formula provided below. Share your answer with your team members.

$$\text{Percent change} = \frac{\text{FINAL} - \text{INITIAL}}{\text{INITIAL}} \times 100$$

FINAL = VOLUME *after* 24 hrs
INITIAL = VOLUME *before* soaking

11. Your teacher will have a *Class Frequency Distribution Table*. Choose one member of your team to record your data on the table in the color assigned to your team. You will need to round the percentage change for each bear to the nearest 50 before recording your data.

12. Answer the following questions in your lab notebook:
- What was your method?
- What can you conclude about the effectiveness of your method of measurement? (***Claim***)
- What did you find to be the percentage increase of gummy bears soaked in water?
- How do the data or your experiences support your conclusion and why? (***Evidence and reasoning***)
- What worked with your method? What did not?

13. Collaborate with your team to divide the previous questions among your team members and be prepared to communicate the answers to the class.

14. Throw the bears away in the trash and clean out your beakers. Follow your teacher's instructions on putting away the lab equipment.

HANDOUT

STUDENT HANDOUT 1.2

Lab Meeting Data Sheet

Name____ Date______________ Period______________

Lab Team	Percent Change of Bear Volume(s)	Clarifying Questions, Responses, and Notes

Challenge: Write down the ***best question*** asked by a student listening to team presentations.

HANDOUT

STUDENT HANDOUT 1.3

Lesson Assessment

Name____ Date________________ Period________________

Gummy Bear Lab Meeting: Social Practices in a Scientific Community

Instructions:
Choose two characteristics of scientific research that we explored during this lab.
(i.e., communication, collaboration, skepticism, integrity, courage, peer review). For each one:

a. ***Define*** the concept (what does the word mean?)

b. ***Identify*** its importance (how and why is it necessary?)

c. ***Give an example*** of what it looks like in the science classroom.

d. ***Give an example*** of what it looks like in the greater scientific community.

Rubric:

Exemplary	Proficient	Partially Proficient	Developing
Student is able to ***define two concepts, identify their importance, and give examples of their applications***			
Student defines concepts and clearly articulates their meaning.	Student clearly defines concepts.	Student partially defines concept(s).	Student defines concept(s) poorly.
Student identifies the importance of each concept, addressing both how and why each is necessary.	Student identifies the importance of each concept.	Student only partially identifies the importance of each concept.	Student discusses the importance of each concept briefly or not at all.
Student demonstrates thoughtfulness and insight in connecting each concept both to the classroom and to the scientific community.	Student connects each concept both to the classroom and to the scientific community.	Student only partially connects each concept both to the classroom and to the scientific community.	Student connects each concept both to the classroom and to the scientific community briefly or not at all.
Student addresses more than one concept.	Student addresses more than one concept.	Student only addresses one concept.	Student only addresses one concept.
Student expertly uses vocabulary and examples to explain concepts and their applications.	Student uses vocabulary and examples to explain concepts and their applications.	Student uses vocabulary and examples to explain concepts and their applications but the examples may lack clarity and/or contain minor errors in understanding.	Student examples may lack clarity and/or contain major errors in understanding.

TEACHER RESOURCE 1.1

Class Frequency Distribution Table

RESOURCE

Instructions:
Round the percentage change in volume for each bear to the nearest 50. Place an X in the appropriate column, using your team's color, if instructed to do so. Make sure all of the X's are the same size.

Circle One: Protocol 1 Protocol 2

Number of Bears

200	250	300	350	400	450	500	550	600	650	700	750	800

Percent Change in Volume

Journal of Applied Polymer Confections Acceptance Letter

Journal of
Applied Polymer Confections

JAPC-C-12-033299
The effect of hydration on the volume of a gelatin polymer confection

Dear Authors,

Thank you for submitting your revised manuscript to the *Journal of Applied Polymer Confections* for review. After careful consideration and peer review, we feel that your manuscript is ***suitable for publication with revisions***.

Please address the following critiques from the reviewers:

From Reviewer #1:

- Sample size is too small for data to be significant.
- A stronger connection should be made to the social impacts and applications to future research.

From Reviewer #2:

- Explore how different colors, brands, and formulations of gummy bears (gelatin vs. vegetarian pectin types) are affected by hydration.

Please submit your modifications to the manuscript and responses to the critiques within 60 days.
If you choose not to proceed with publication, please notify us.

Yours sincerely,

Leena L. Pranikay, Ph.D.
Academic Editor

Journal of Applied Polymer Confections

HANDOUT

LESSON 2:
"Stupidity" in Science: A Text-based Discussion

INTRODUCTION

In this lesson, students participate in a text-based discussion of the article "The importance of stupidity in scientific research" by Martin Schwartz. Using evidence found in the text, students consider how success is defined in scientific research. They also discuss how scientific pursuits may require persistence despite setbacks and a tolerance for ***not knowing*** much of the time. Students then relate their experiences of ***not knowing*** during the gummy bear lab from *Lesson One* to the social nature of scientific research. This type of text-based discussion is known as a ***Socratic Seminar***.

CLASS TIME

One class period of 55 minutes.

KEY CONCEPTS

- Scientists actively seek out what they do not know or understand in order to learn and understand new concepts. This type of discovery and learning about the world may be different from other ways of gathering information.

LEARNING OBJECTIVES

Students will know:

- Scientific research requires the scientist to actively seek out what he or she does not know or understand in order to learn/discover new concepts (**"productive stupidity"**).

Students will be able to:

- Demonstrate their understanding of how scientists accept uncertainty by participating in a text-based class discussion.
- Move the discussion forward by referring to evidence from the text.

MATERIALS

Materials	Quantity
Student Handout 1.1—*Guided Reading Questions*	1 per student
Student Handout 2.2—*Post-Discussion Reflection*	1 per student
Optional: Student Handout 2.3—*Discussion Partner Evaluation*	1 per student
"The importance of stupidity in scientific research" article by Martin Schwartz. [**Note:** This can be freely downloaded from the *Journal of Cell Science* website: http://jcs.biologists.org/content/121/11/1771.full.pdf. The article is also available through PubMed with the following PMID: 18492790.]	1 per student

NOTE TO THE TEACHER

A ***Socratic Seminar*** is a high-level text-based discussion. Teacher resources for this type of discussion can be found in the *Appendix* and in the NWABR *Ethics Primer* found at http://nwabr.org.

Students often misunderstand the term "scientific research." Instead of understanding it as a process requiring persistence in the face of setbacks and a tolerance for ambiguity, "research" is sometimes thought to be the same thing as doing a "research paper" on some topic.

It is helpful for students to sit in a circle for this type of discussion. If students don't know each other's names, name plates or name tags are recommended. If the class is large, teachers may choose a ***fishbowl variation***, in which the students are divided into two groups and sit in two concentric circles facing the center. One half of the class is in the inside circle, facing each other and discussing the text, while the remainder sit in the outer circle observing and listening. Members of the outer circle can take notes or use an evaluation form (see Student Handout 2.3—*Discussion Partner Evaluation*) to track the overall conversation. Some teachers reserve an empty "hot seat" in the inner circle for those in the outer circle who really want to jump in to make a contribution and then leave. The groups switch halfway through the discussion to allow the outer group a chance to discuss the text.

TEACHER PREPARATION

- Make copies of *Student Handouts*, one per student.
- Download "The importance of stupidity in scientific research" article. Number each paragraph, 1–8, so that students can easily refer to passages during the class discussion. Make copies of the article, one per student.

PROCEDURE

1. Assign as homework, or read together in class the article "The importance of stupidity in scientific research" by Martin Schwartz.
2. Hand out copies of Student Handout 2.1—*Guided Reading Questions*, one per student. Tell students to answer the questions after they complete the reading.
3. You may ask students to use some reading strategies to help them better understand the article. These strategies could include:
   - Reading the article through twice: the first time provides a general overview and the second time is more detail-oriented.
   - Defining any unknown vocabulary for students, such as **undergraduate**, **graduate**, and **PhD student**. (Do not define the terms **absolute stupidity** or **relative stupidity**, as the students will focus on this during the discussion.)
   - Asking students to mark up their article using the following symbols:

     ? for something the student does not understand.

     ! to signify a good point made by the author.

     ***** to signify a point with which the student disagrees.

     A fully marked article can then be used as an "entrance ticket" to the discussion.
4. Arrange the classroom for the discussion (see *Note to the Teacher* section above for more information).
5. Tell the class they will be having a class discussion using ideas covered by the reading to better understand the way scientists approach their work. The purpose of the discussion is not to complete the reading guide but to ***achieve a deeper understanding*** about the ideas and values expressed by the author. They can use the guided questions for note-taking or reference, but active participation in the discussion should be their main focus.
6. Begin the discussion by reviewing the group discussion norms. If you have not previously set classroom norms for whole group discussions, information for doing so can be found in the *Appendix*.

   Some classroom norms particularly important for a Socratic Seminar include:
   - Don't raise hands.
   - Listen carefully.
   - Address one another respectfully.
   - Base any opinions on the text.
7. Direct students to the numbered paragraphs. Explain that they need to base their opinions and questions on the text and be sure to refer to the paragraph number so that the rest of the class can see where the idea/question came from. Pulling evidence from the text is an important part of this type of discussion.
8. Explain that since this is a whole group discussion, students should not feel they need to raise hands and be called upon. Encourage them to listen carefully to one another's ideas and comment during natural breaks in the conversation.
9. Begin by posing the question:

   "Why does the author think that stupidity is important in science?"

   Encourage a variety of students to comment on this question, referring to the text as they share their ideas.
10. Follow up this initial question using the suggested questions below, or come up with your own. However, make sure to ask those questions in **bold** since the ideas discussed in answering them will be built upon in later lessons:
    - Why was the realization of the author's ignorance infinitely "liberating"?
    - What does the author mean by productive stupidity? How is it different from other types?
    - Is "stupidity" the best word?
    - **What qualities make a successful scientist?**
    - **How do you think success is defined in science?**
    - Do you think "stupidity" is important in science?

- Does creativity play a role in science?
- **How did you experience "stupidity" in the gummy bear lab?**
- **How is the science described by the author similar or different from how science is taught in schools?**
- Allow students to pose their own questions, if desired.

"Thoroughly conscious ignorance is the prelude to every real advance in society."

~James Clerk Maxwell, 1831-1879

"In an honest search for knowledge you quite often have to abide by ignorance for an indefinite period."

~Erwin Schrödinger, 1948

11. Debrief the discussion by asking students if they have any other ideas they would like to share about the text. Point out for students that creativity plays a role in science. For example, when the author realized that Taube could not solve the research problem, he felt liberated to solve it himself. In other words, he could not solve the problem because he was looking for the "right" method when no such method existed. It was only when the author was free to develop his own method that he could solve his research problem. This is the very essence of creativity in science.
12. Ask students how they thought the discussion went and whether the class met the goal of the discussion (to better understand the ideas presented by the author).
13. Relate the discussion to the lab meeting from the gummy bear activity in *Lesson One*. Both are collaborative endeavors that rely on evidence to analyze and critique something. In the case of the gummy bear lab meeting, students were critiquing each other's data and methods. In the case of the reading, students were critiquing Martin Schwartz's ideas about scientific research. Did these things feel the same or different? In what ways? Is it harder to critique a friend or acquaintance than a stranger?
14. Hand out copies of Student Handout 2.2—*Post-Discussion Reflection*, one per student. This handout can be used as an "exit ticket" or can be completed as homework.

Closure

15. Have students retrieve their *Unit Graphic Organizer* handouts and look at the first column titled "Research Process." Ask students if they would like to add anything to this based on today's discussion. Students may also put an exclamation point or star next to phrases that have been reinforced through this lesson, such as "tolerance of ambiguity" or "persistence despite setbacks."

HOMEWORK

Student Handout 2.2—*Post-Discussion Reflection* can be assigned as homework.

GLOSSARY

Absolute stupidity: A complete lack of knowledge or understanding of a given topic.

Graduate student: A person who has earned a college degree and is pursuing additional education, such as a master's degree or PhD.

PhD student: A person pursuing a doctorate degree, the highest degree awarded for graduate study.

Productively stupid/Productive stupidity: The attribute of realizing how little one knows in order to develop good questions.

Relative stupidity: Willful indifference to becoming informed or enlightened, especially in relation to others who make the effort to read, learn, or think about important material.

Undergraduate student: A person studying at a university or college after high school with the goal of earning a bachelor's degree. This is usually a four-year degree.

SOURCES

Schwartz, M. (2008). The importance of stupidity in scientific research. *Journal of Cell Science. 121 (Pt 11):* 1771. Retrieved from http://jcs.biologists.org/content/121/11/1771.full.pdf

STUDENT HANDOUT 2.1
Guided Reading Questions

Name____ Date________________ Period________________

“The importance of stupidity in scientific research” by Martin Schwartz

1. Why did the author’s friend drop out of graduate school?

2. Why do people like subjects they are good at? How does doing well on an assignment or test make you feel?

3. What realization did the author have after being told Nobel Prize winner Henry Taube didn’t know the answer to a question?

4. What is the difference between “productive stupidity” and “relative stupidity”?

5. How did making mistakes and feeling “stupid” impact you during the gummy bear lab?

6. Write your own question:

HANDOUT

STUDENT HANDOUT 2.2

Post-Discussion Reflection

Name____ Date________________ Period________________

1. Do you feel like you understand the article better than you did before the discussion? Explain.

2. Is “stupidity” the best word for the ideas the author is sharing in his article? What other words could you use to describe his ideas?

3. What qualities make a successful scientist? How is success defined in science?

4. Why are mistakes and feeling stupid important to scientific research?

HANDOUT

5. How was our discussion similar to our gummy bear lab meeting in which we critiqued each other’s data and methods?

STUDENT HANDOUT 2.3
Discussion Partner Evaluation

Name____ Date_______________ Period_______________

Name of person you are observing _________________________________

1. Record a check mark for each time your partner contributed in a meaningful way.

2. On a scale of 1 – 5, with 5 being the highest, how well did your partner do at the following?

_____ **Analysis and Reasoning**

Did your partner....

- Cite reasons and evidence for his statements with support from the text?
- Demonstrate that she had given thoughtful consideration to the topic?
- Provide relevant and insightful comments?
- Demonstrate organized thinking?
- Move the discussion to a deeper level?

Notes/Comments:

_____ **Discussion Skills**

Did your partner....

- Speak loudly and clearly?
- Stay on topic?
- Talk directly to other students rather than the teacher?
- Stay focused on the discussion?
- Invite other people into the discussion?
- Share air time equally with others (didn't talk more than was fair to others)?

Notes/Comments:

_____ **Civility**

Did your partner....

- Listen to others respectfully?
- Enter the discussion in in a polite manner?
- Avoid inappropriate language (slang, swearing)?
- Question others in a civil manner?

Notes/Comments:

HANDOUT

HANDOUT

LESSON 3:
Science through the Centuries

INTRODUCTION

In this lesson, students participate in an historical activity demonstrating how current research builds on prior understanding, and how scientific priorities are influenced by the social and health concerns of the time. This is a "jigsaw" activity in which students are first divided into four different time period groups (1700s, 1800s, 1900s, and 2000s) to discuss social concerns and medical technology of the time. Each time period is seen through the eyes of four individual characters: a ***citizen***, a ***medical practitioner***, a ***person with Type I Diabetes***, and a ***scientist***. The students then regroup by character roles to compare themes over time. Lastly, students are introduced to **translational research** and see that, in many cases, basic research and the resulting application to human health are many decades apart.

CLASS TIME

Two class periods of 55 minutes each.

KEY CONCEPTS

- Scientific and educational priorities are influenced by the social and health concerns of the time.
- The history of science shows that curiosity-driven basic research paves the way for heath treatments and medical advances, even though there may be decades between the basic research and its resulting application to human health.
- Translational research is the process of connecting **basic research** ("bench" science) to **applied research** ("bedside" science).
- **Serendipity**—making fortunate discoveries by accident—plays a part in the scientific process.

LEARNING OBJECTIVES

Students will know:

- Social concerns influence scientific research.
- Scientific advancements build off prior knowledge gained over time.

Students will be able to:

- Explain how basic research leads to cures and treatments through translational research.
- Give examples of how serendipity plays a part in science.

MATERIALS

Materials	Quantity
Student Handout 3.1—*Science through the Centuries*	1 per student
Possible Answers to Student Handout 3.1—*Science through the Centuries*	1
Student Handout 3.2—*Homework: Ask your Elders*	1 per student
Teacher Resource 3.1—*Science through the Centuries Cards* (see *Teacher Preparation*) 1 copy is needed for a class with up to 16 students; 2 copies are needed for a class with up to 32 students	1 or 2 copies
Computer with PowerPoint and overhead projection	1
Science through the Centuries Slide Set found at http://nwabr.org.	1
Optional: Ball of yarn	1

SUGGESTED TIMING

Day	Activities
Day One	Students meet in time period groups. Students jigsaw into character groups and present.
Day Two	Continue presentations, if needed. Class discussion on future trends. Introduction of translational research. Closure.

The timing for this lesson is flexible. It is suggested that students complete the jigsaw portion on Day One, and discuss future trends on Day Two.

NOTE TO THE TEACHER

A common student misconception is that medicines, cures, and treatments can be discovered and made available in a relatively short time frame.

Students may think that science is marching on towards "truth." Although this lesson shows a rather linear progression of scientific thought, make sure that students know that scientific knowledge, in any given era, can be changed and replaced in the following era.

TEACHER PREPARATION

- Make copies of Student Handout 3.1—*Science through the Centuries* and Student Handout 3.2—*Homework: Ask your Elders*, one per student.
- To show the PowerPoint slide set, prepare the computer and projection unit. Download the *Science through the Centuries Slide Set*.
- Copy the cards found on Teacher Resource 3.1—*Science through the Centuries Cards*. It is helpful, but not necessary, to copy each century onto a different color paper. Make one copy for a class with up to 16 students or two copies for a class with up to 32 students. Cut up the cards.

PROCEDURE – DAY ONE

Part I: Time Period Groupings

1. Tell students that they will be participating in an activity that explores how social concerns have influenced scientific knowledge and research over the last few centuries. Students will also map connections between current scientific discoveries and scientific knowledge from years past.
2. Divide the class into four or eight groups. Each group will represent a different century: the 1700s, 1800s, 1900s, and 2000s. Assign a century to each group. For larger classes, two groups can represent the same time period.

   [**Note:** Divide the class into four groups for a class up with up to 16 students. For a class with up to 32 students, divide into eight groups.]
3. Tell students that they will be looking at four representative people, or characters, from each time period (a ***citizen***, a ***medical practitioner***, a ***scientist***, and a ***person with diabetes***). Through these people, four themes will be explored. These themes are:
   - *Who pays for education? Who is educated during this time period? How is scientific research funded?*
   - *Which diseases are prevalent during this time? How is science addressing those diseases?*
   - *How do scientific discoveries build off previous work?*
   - *How is the specific disease example of diabetes identified and treated during this time period?*
4. For each group, hand out the *Science through the Centuries* cards, found on Teacher Resource 3.1, corresponding to the correct century.
5. Make sure that students know that, though the cards may represent real people or historical figures and are historically accurate, the first person statements were fictionalized.
6. Allow time for students to read the information on their group's cards and discuss it with their group members.
7. The first batch of slides in the *Science through the Centuries Slide Set* contains select pictures from each time period. Share these slides with students.

   Optional: If time permits, have each time period group research everyday aspects of life from their time period. What does a typical house look like? What amenities are included (i.e., electricity or plumbing)? What do people wear?
8. Have each student in the group choose a character to represent (the ***citizen***, the ***medical practitioner***, the ***scientist***, or the ***person with diabetes***) for the next section.

Part II: Character Groupings

9. Reorganize groups so that all of the ***citizens*** across all time periods are in one group, all the ***medical practitioners*** are in one group, all the ***scientists*** are in one group, and all the ***people with diabetes*** are in one group. For larger classes, teachers can have two groups for each character.

10. Pass out copies of Student Handout 3.1—*Science through the Centuries*, one per student.

11. Tell students that each character group will focus on a theme:

- **Citizens:** Who pays for ***education***? Who is educated during this time period? How is scientific research funded?
- **Medical Practitioners:** Which ***diseases*** are prevalent during this time? How is science addressing those diseases?
- **Scientists:** How do scientific ***discoveries*** build off previous work?
- **Person with Diabetes:** How is diabetes identified and ***treated*** during this time period?

12. Allow time for students to share each individual's biographical information within their character group. Students should share in chronological order. As each character shares, the other students in the group should fill out the row representing the character on Student Handout 3.1—*Science through the Centuries*.

13. After the characters have shared, have each group identify any ***trends over time*** they observe. These trends can be written down in the space provided on the handout.

Part III: Class Sharing and Interconnections

14. Select one student representing the ***citizen*** from each time period to come to the front of the room and summarize the information on his or her card. Students should present in chronological order. The second batch of slides in the *Science through the Centuries Slide Set* contains the information from the cards.

15. Students not presenting should fill out the corresponding section of Student Handout 3.1—*Science through the Centuries* either individually or as a class. Suggested answers and discussion prompts can be found on Possible Answers to Student Handout 3.1—*Science through the Centuries*.

16. After the ***citizens*** have presented, invite the ***medical practitioners*** to present in the same way. Repeat the sequence with the ***scientists*** and then ***people with diabetes***.

17. **Optional:** When all sixteen characters have presented, have them stand in a circle facing each other. Hand a ball of yarn to the student representing Aubrey Mathwig and ask the question: "Who is Aubrey connected to?" or "Whose work has helped Aubrey?"

   Aubrey should explain why/how she is connected to one other person in the circle and toss the yarn to that person while holding on to her end. (*She is connected to a number of people. For example, she is connected to all the people with diabetes who came before her and paved the way for research; she is connected to the medical practitioner of her time; she has benefitted from work done by Jonas Salk, Louis Pasteur, and others.*)

   The person she tosses the yarn to (Jonas Salk, for example) should hold on to a piece of the yarn and then pass the ball of yarn on to someone else he is connected to, such as Louis Pasteur. With some creativity, all the people in the circle can eventually be linked by the yarn, creating an interconnected web. This web represents how citizens' needs can drive scientific research, how research can spur new medical practices, how medical practices can benefit citizens and patients, and how patients value new discoveries (such as insulin).

18. Students may return to their seats.

PROCEDURE – DAY TWO

Part IV: What Does the Future Hold?

[Note: Field test teachers report that this discussion may take a lot of time. Please dedicate as much (or as little) time to this section as you have available, leaving enough class time for instruction about translational research and for closure.]

19. Ask students, "What do you think the future holds?" or "What trends from the past may predict future directions?" If students have a difficult time envisioning the future, a corollary question is, "How do films and television shows portray the future? What are some of the social and scientific trends other people envision?"

   Some possible future ***social/educational*** trends include:

   - Life expectancy is predicted to increase for both men and women.
   - Health care advances may become too expensive for much of the global population.
   - Climate changes may stress national economies and cause more people to move from rural areas, increasing the size of cities.
   - Education will likely be more technology based, though funding is always going to be a challenge. If not addressed, educational disparities may increase based on disparate access to resources globally.

Some possible ***scientific*** and ***health-related*** trends include:

- An aging population means an increase in chronic disease.
- Cancer cases are expected to double in most countries during the next 25 years, but earlier detection and treatment may allow people to live with cancer for long periods of time.
- As the genetic component of disease becomes known, health care will become more personalized and increasingly rely on genetic tests and genetic counseling.
- DNA microchips containing a person's full genome might become a common part of an individual's medical file. These chips can help assess individual risks for developing different cancers as well as heart disease, diabetes, and other diseases.
- Medical research may increasingly rely on large databases containing the genomes of different populations.
- Medical sensors located under the skin may continually monitor the health of an individual and communicate wirelessly with databases and health care professionals.
- Stem cells might be used to create genetically identical replacement organs for transplant patients, reducing the risk of rejection.
- And many more!

20. Explain that the path of scientific advancement is full of missteps, dead ends, and errors. Yet, over time, it has the capacity to correct itself. With this in mind, ask students what they think we believe today that future generations will consider misguided.

Part V: Translational Research

21. Tell students that scientists conducting curiosity-driven research into the fundamental nature of science often set the foundation for discoveries that lead to actual cures or treatments for disease in later years. In many cases, the ***basic research and the application to human health were many decades apart***.

22. Tell students that scientific research is sometimes put into two categories:

- **Basic research** furthers general scientific understanding of how the natural world works. This is quite often academic research.
- **Applied research** relates to human health care applications in the form of treatments or cures of human diseases. This is often done by for-profit companies.

The process of connecting basic research to applied medicine or treatment is called **translational research**. This is sometimes described as "From Bench to Bedside"—from the scientist's laboratory bench to the physician's bedside care of a patient.

> "…the concerted effort to discover new drugs without supporting basic research is like 'trying to construct a skyscraper without fully understanding the properties of bricks and cement.'"
>
> ~A. Jogalekar, PhD

Part VI: Serendipity and Collaboration

23. Define for students the word **serendipity**: making fortunate discoveries by accident, as when people discover valuable things they were not actually looking for. Ask students for examples of serendipity in science. (Two examples can be found in the *Note to Teacher* section at the end of this lesson.) One of the most famous examples of serendipity in science is Alexander Fleming's "accidental" discovery that penicillin mold kills bacteria.

24. **Collaboration and Revision**: Highlight the ways in which scientists have built upon and revised each other's work even if it is not explicitly described in the cards. Point out that health treatments and cures do not occur independently from other scientific research but may owe their success to years, if not decades, of prior work by other scientists. Science is a collaborative endeavor, even over time.

Closure

25. Return with students to the 1700s and read for them this quote from a satirist of the time who described Robert Hooke as:

"…a Sot, that has spent £2000 in Microscopes, to find out the nature of Eels in Vinegar, Mites in Cheese, and the Blue of Plums which he has subtly found out to be living creatures."

Without an understanding that Hooke's early work would directly (and indirectly) contribute to Pasteur's germ theory, Fleming's discovery of antibiotics, and many other scientific advancements, basic research at the time may seem unconnected to subsequent important cures and treatments.

26. Share with students this quote attributed to Isaac Newton and ask how it pertains to today's lesson:

"If I have seen further, it is by standing on the shoulders of giants."

27. Have students retrieve their *Unit Graphic Organizer* handouts and look at the second column, titled "Role of Science and Society." Ask students, "What are the structures, systems, or ways in which society influences what science is done or how it is paid for?" Students should brainstorm and write down phrases such as:

- Social needs (i.e., diseases of the time) influence research directions.
- Society funds education and research it values.

28. Ask students if they have anything to add to other columns. Suggest that students add "serendipity" to the "Research Process" column. To the "Translational Research" column, they may add:

- Basic science may lead to new cures and treatments.

29. Lastly, look at the last column, "Being a Scientifically Literate Citizen." Ask students how their understanding of the role of science and society impacts them as members of society. Discuss their responsibility to be scientifically literate in their role as a ***members of society*** and add those words to the graphic organizer.

HOMEWORK

Student Handout 3.2—*Homework: Ask Your Elders* can be assigned as homework. In this activity, students interview a person in their mid-fifties or older to learn about changes in medical care and/or treatments during that person's lifetime.

EXTENSION

Students can explore an interactive, historical timeline of medical discoveries created by the New England Journal of Medicine.

History of Medical Discoveries
http://www.nejm.org/doi/full/10.1056/NEJMp1114819

NOTE TO THE TEACHER

There are many examples of ***serendipity*** in science—here are two:

"At the Johns Hopkins Hospital in 1947, two allergists gave a new antihistamine, Dramamine, to a patient suffering from hives. Some weeks later, she was pleased to report to her doctors that the car sickness she had suffered from all her life had disappeared. Drs. Leslie Gay and Paul Carliner tested the drug on other patients who suffered from travel sickness, and all were completely freed of discomfort, provided the drug was taken just before beginning the potentially nauseating journey. A large-scale clinical trial involving a troopship with more than 1,300 soldiers crossing the rough North Atlantic for twelve days (Operation Seasickness) decidedly proved the drug's value in preventing and relieving motion sickness. Dramamine is still used today, available over the counter."

From: Meyers, M. A. (2007). *Happy accidents: Serendipity in modern medical breakthroughs*. New York, NY: Arcade Publishing.

"The long-awaited breakthrough [in learning how to freeze and thaw tissues] was a lucky accident. In 1947, a British scientist named Christopher Polge was searching for ways to freeze, store, and revive chicken sperm, a potential boon to farmers. Polge tried immersing the fowl gametes in a fructose solution, which didn't work very well—until one day, mysteriously, it did. Analysis of the curiously effective solution revealed that its label had somehow been switched. The bottle actually contained glycerol, not fructose. Glycerol seemed to be such an effective cryoprotectant that it's still employed in biobanks for preserving blood cells and fluids like saliva and urine. "

From: Silberman, S. (2010, May 24). Libraries of flesh: The sorry state of human tissue storage. *Wired Magazine*. Retrieved from http://www.wired.com/magazine/2010/05/ff_biobanks/all/

GLOSSARY

Applied research: Research that relates to human health care in the form of treatments or cures of human diseases. Applied research is often conducted by for-profit companies.

Basic research: Research that furthers general scientific understanding of how the natural world works. This is often academic research.

Serendipity: The phenomenon of making fortunate discoveries by accident, or discovering valuable things while looking for something else.

Translational research: The process of connecting basic research to applied medicine or treatment; sometimes described as "From Bench to Bedside."

SOURCES

Campbell, D. (2009, June 24). Possible cure found for Crohn's disease. *The Guardian*. Retrieved from http://www.guardian.co.uk/society/2009/jun/24/crohns-disease-cure

Cox, L. (2009, December 14). We will live longer in 2050, study predicts. *ABC News*. Retrieved from http://abcnews.go.com/Health/ActiveAging/humans-live-longer-2050-scientists-predict/story?id=9330511

Davis, L. (2009). Ten science stories that changed our decade. Retrieved from http://io9.com/5430073/ten-science-stories-that-changed-our-decade

Defeat Diabetes Foundation, Inc. (2013, April 5). History of Diabetes in Timeline. Retrieved from http://www.defeatdiabetes.org/about_diabetes/text.asp?id=Diabetes_Timeline

Forsyth, K., Brooks, A., Hodges, L., Carrico, J., and Hilton, J. Causes of death. From a presentation to PHI 350 (Death, Dying and the Quality of Life), University of Kentucky. Retrieved from http://www.uky.edu/Classes/PHI/350/cod.htm

Gee, E.M. (2013). Life expectancy. In *Encyclopedia of death and dying*. Retrieved from http://www.deathreference.com/Ke-Ma/Life-Expectancy.html

A. Jogalekar (2011, July 8). Lost in translation [Web log comment]. Retrieved from http://www.scilogs.eu/en/blog/lindaunobel/2011-07-08/lost-in-translation

Kirby, M. (2002). Fifty years of diabetes management in primary care. *British Journal of Diabetes and Vascular Disease, 2* (6), 457-461. Retrieved from https://secure.sherbornegibbs.com/bjdvd/pdf/1101.pdf

Lambert, T. (2012). A history of medicine. In *Everyday life through the ages*. Retrieved from http://www.localhistories.org/everyday.html

Lowy, S. Douglas R. Lowy: Advancing the field of cancer research. Retrieved from https://www.amherst.edu/campaign/amherstlives/amherstlives/douglas_lowy

Riley, J. C. (2005). Estimates of regional and global life expectancy, 1800–2001. *Population and Development Review*, *31*: 537–543. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1728-4457.2005.00083.x/pdf

Sanders, L.J. (2002). From Thebes to Toronto and the 21st century: An incredible journey. *Diabetes Spectrum*, *15* (1), 56-60. Retrieved from http://spectrum.diabetesjournals.org/content/15/1/56.full

Sattley, M. (2008). The history of diabetes. Retrieved from http://www.diabeteshealth.com/read/2008/12/17/715/the-history-of-diabetes/

Scotsman.com (2011, May 7). Revolutionary cell transplant ends mother's 32-year battle with diabetes. Retrieved from http://www.scotsman.com/news/Revolutionary-cell-transplant-ends-mother39s.6796545.jp

Smith, B. and Smith, K. Discovery of cells and the development of cell theory. Retrieved from http://www.smithlifescience.com/celltheory.htm

United Nations, Department of Economic and Social Affairs, Population Division (2011). [Graph with estimated and projected world population 1950-2100]. *World Population Prospects: The 2010 Revision, New York*. Retrieved from http://esa.un.org/wpp/Analytical-Figures/htm/fig_1.htm

University of Washington School of Medicine. Tumor Vaccine Group Directory. Retrieved from http://depts.washington.edu/tumorvac/directory/principal-invesitagors/disis-mary-l-nora

Waggoner, B. (2001, January 20). Robert Hooke (1635-1703). Retrieved from http://www.ucmp.berkeley.edu/history/hooke.html

World Health Organization. (2011). *The top 10 causes of death* (Media Centre Fact Sheet #310). Retrieved from http://www.who.int/mediacentre/factsheets/fs310/en/index.html

1700-1900 The miracle of life and death appears smaller.. and smaller. In *Access Excellence*. Retrieved from http://www.accessexcellence.org/RC/AB/BC/1750-1900.php

A history of education in America. In *AllSands*. Retrieved from http://www.allsands.com/potluck4/educationhistor_zlr_gn.htm

History of Diabetes – My Big Fat Greek Wedding? Retrieved from http://www.diabeteswellbeing.com/history-diabetes.html

NNDB Mapper. Retrieved from http://www.nndb.com

STUDENT HANDOUT 3.1

Science through the Centuries

Name____ Date_____________ Period_____________

	1700s	1800s	1900s	2000s
CITIZEN Who pays for education? Who is educated?	Mary Walker	Samuel Christian	Pearl McKinley	Andrew Hayes
Summary: Trend over time				

	1700s	1800s	1900s	2000s
MEDICAL PRACTITIONER Which diseases are prevalent? What do doctors think causes them?	Isaac Dawson	Joseph Lister	Alexander Fleming	Douglas Lowy
Summary: Trend over time				

HANDOUT

	1700s	1800s	1900s	2000s
SCIENTIST How do scientists build on prior work?	Robert Hooke	Louis Pasteur	Jonas Salk	Nora Disis
Summary: Trend over time				

	1700s	1800s	1900s	2000s
PERSON with DIABETES How is diabetes identified and treated?	Elizabeth Snell	Mary Roberts	James Walker	Aubrey Mathwig
Summary: Trend over time				

HANDOUT

STUDENT HANDOUT 3.2

Homework: Ask Your Elders

Name____ Date____________ Period____________

Instructions: Find a person in their mid-fifties or older to interview. This can be a relative, neighbor, friend, or acquaintance. Tell the person you are interviewing that you will be asking questions about changes she has seen in medical care or medical treatment in her lifetime.

1. Did you or a family member have a memorable illness when you were young? What was it, and how was it treated?

2. Where there any diseases that "everyone got" or seemed very prevalent? What were they, and how where they treated?

3. Describe a typical visit to the doctor's office. How often did you go? Did you see one doctor or many doctors? How "trusted" was your doctor?

4. Describe a typical visit to the doctor's office today. Do these visits differ from those in your youth?

HANDOUT

5. What types of treatments or cures were common for different diseases in your youth?

6. Do you have any other thoughts on this subject? [**Students:** Please take notes on any discussion on a separate piece of paper and attach it to this handout.]

HANDOUT

Science through the Centuries

	1700s	1800s	1900s	2000s
CITIZEN Who pays for education? Who is educated?	Mary Walker Most education is privately funded. Wealthy landowners and aristocracy pay for the education of their children. The average male, most often farmers, may have some basic reading and writing skills. The church is the intellectual driver of the time and most schooling is religious in nature. Science may be the hobby of wealthy gentlemen who have time to dedicate to exploring their interests.	Samuel Christian Education is still privately funded and the wealthy are the educated class. The idea of "public" education (freely available to the population and paid for through public tax money) is gaining ground as more people move to cities, but it is still not widely available. Boys are better educated than girls, especially at higher levels of education.	Pearl McKinley By the end of the 1900s, tax-payer supported public school education through high school is provided in most developed countries. While private universities still exist and thrive, state universities and government loans allow most people, not just the wealthy, to afford higher education. Future scientists don't have to be from wealthy families to pursue a science education. Military service can also provide education and medical training.	Andrew Hayes Public education for boys and girls through high school is provided in most developed countries. Higher education may be accessible through public universities and government loan programs. Increasing numbers of women are highly educated and involved in research.
Summary: Trend over time	Education becomes more and more accessible to the common person as public schools, funded by taxpayers, become available. Society supports an educated citizenry.			

RESOURCE

	1700s	1800s	1900s	2000s
MEDICAL PRACTITIONER Which diseases are prevalent? What do doctors think causes them?	Isaac Dawson Infectious diseases such as smallpox, cholera, scarlet fever, bubonic plague, and others. Without a clear understanding of the root cause of disease (i.e., microbes are the cause of infection), actual cures are elusive. The well-established theory of the time that disease is caused by an imbalance of the four humors in the body leads to many treatments that may seem bizarre or ill-conceived to us now.	Joseph Lister Infectious disease is a major cause of death during this time period, and scientists are responding to the need for cures and treatments. Major scientific discoveries (cell theory, germ theory, antiseptics, and vaccines) build on prior research to improve human health.	Alexander Fleming Infectious diseases become less of a concern (thanks to new vaccines and treatments) and more attention is paid to chronic diseases such as heart and respiratory disease and cancer during this time. As scientists better understand the role of DNA and genetics, the focus of research shifts to the chronic diseases that affect more and more people. Infectious diseases are still a global problem, and emerging conditions like HIV/AIDS create a need for research in these areas.	Douglas Lowy With cancer and other chronic diseases claiming so many lives during this time, scientific research focuses on these conditions. As the population ages, scientists also look at diseases common to older people (osteoporosis, heart disease, Alzheimer's, etc.). Molecular biology and stem cell research are both important research fields. Infectious diseases are still a global problem; many researchers work in that area.
Summary: Trend over time	Fewer people die from infectious diseases and more people begin to die from to chronic diseases in developed countries. (This section also shows how the prevalent theories of the time influence diagnosis and treatment. For example, physicians who believe illness is caused by an imbalance in the four humors would not acknowledge the existence of germs as the cause of illness.) Scientific research priorities shift to reflect needs.			

RESOURCE

	1700s	1800s	1900s	2000s
SCIENTIST How do scientists build on prior work?	Robert Hooke Robert Hooke depended on the new technology of grinding lenses to view things with a microscope. Though not mentioned in the lesson, Hooke also reviewed the work of Leeuwenhoek, the Dutch microscope maker.	Louis Pasteur Louis Pasteur relied on microscopes for his studies of germs and vaccines. He was building on the technological work of Robert Hooke and others.	Jonas Salk Jonas Salk continued to build on the vaccine research done by Louis Pasteur. The microscope was indispensable.	Nora Disis As she works on a vaccine for a chronic disease, Nora Disis is building on the findings of Pasteur, Salk and others. Microscopy is still an essential technology.
Summary: Trend over time	Though a scientist may not know how his research will be applied in the future, new scientific knowledge and technological developments often propel the research process forward.			

	1700s	1800s	1900s	2000s
PERSON with DIABETES How is diabetes identified and treated?	Elizabeth Snell The disease may or may not have been diagnosed as "diabetes," a disease for which there was a name but no meaningful treatment. In 1674, an English doctor named Thomas Willis observed patients with diabetes. He described their urine as "wonderfully sweet, as if it were imbued with honey or sugar." It is unknown how much medical care a rural farmer in the 1700s might have received; without a name, cause, cure, or treatment, diabetes may have been one of the many causes of premature death at that time.	Mary Roberts Diabetes could be diagnosed. In this case, the patient had access to medical care, but without knowing the underlying cause of the condition, treatment was generally unsuccessful.	James Walker The link between insulin and diabetes is established, and treatments, though rudimentary, address the mechanisms of diabetes. Effects of the disease can be serious, but for the first time diabetes may not be deadly.	Aubrey Mathwig With an understanding of diabetes and a known treatment, diabetes is no longer fatal, if treated. Blood glucose testing and insulin delivery mechanisms are improving over time. Researchers are still very active in this area, however, trying to find out why and how the pancreas stops producing enough insulin or the body can't use the insulin produced. Some diabetics now wear an insulin pump, rather than injecting themselves daily. Future treatments include stem cell transplants, pancreas transplants, or pancreatic cell transplantation.
Summary: Trend over time	As the medical/research community learned more about the underlying cause of diabetes, targeted treatments could be developed. The life expectancy of people with diabetes has increased.			

RESOURCE

Science through the Centuries Cards

CITIZEN OF THE 1700s

My name is **Mary Walker** and I am a typical citizen of the 1700s. I am 16 years old. I have two older sisters, a younger brother, and two siblings who died as babies. Most people are farmers, and many boys go to school, at least for a few years. I was taught some at home, but many of my friends don't know how to read or write. If my brother wants more school, he'll have to go into the ministry because the church supports most education. This isn't likely, though, because somebody will have to take over the family farm.

MEDICAL PRACTITIONER OF THE 1700s

My name is **Isaac Dawson** and I practice medicine. Many people in our community (about one in three) die as infants or toddlers. If you live to be a teenager, you have a good chance of living to be as old as 50 or 60. Most of my patients die of smallpox, cholera, bubonic plague, scarlet fever, or tuberculosis. I believe that illness is caused by bad air or an imbalance of blood, phlegm, yellow bile, and black bile in the body. I use treatments that have been around for thousands of years, such as herbs, suction cups, and "bleeding" to cure disease.

SCIENTIST OF THE 1700s

My name is **Robert Hooke**. I was educated at home in England by my father, a churchman, and sent away to school at the age of 13. I am an old man now, but I've seen lots of scientific advancements. Our lens grinding techniques are now good enough to make two important research tools: telescopes and microscopes. Using a microscope, I was able to see very small things such as plant "cells." The public doesn't always understand my work, though, and I have been publicly ridiculed for spending so much money on microscopes just to see "mites in cheese." I think this is important work that may change science and medicine!

PERSON WITH DIABETES IN THE 1700s

My name is **Elizabeth Snell** and I am 27 years old. My husband is a farmer. I've had eight children, though only four are living now – one boy and three girls. One baby died before he was a week old, and I lost two children to smallpox when it spread through our village this year. My second son, though, that was the strangest thing. William was always hungry and we could hardly get enough food to feed him, but he stayed so skinny. He complained all the time of being tired and one day couldn't get out of bed. Maybe his body had too much black bile, I don't know. One evening we couldn't wake him up and by morning he was gone.

CITIZEN OF THE 1800s

My name is **Samuel Christian** and I am a typical citizen of the 1800s. I am an old man at the age of 52. I am a farmer, but our family's land was not big enough to support everybody, so my younger brothers and their families moved to the city years ago to work in a factory. They are making a living, but I hear that they all live crammed together in one small apartment. I can read and write some, but it's mostly the landowners and wealthy people who are truly "educated" since they are the only people who can afford it. I've heard that free public elementary education might be available for all American children soon—now that more people are moving to cities, some people think that free education will create good citizens, unite society, and prevent crime and poverty.

MEDICAL PRACTITIONER OF THE 1800s

My name is **Joseph Lister**, and I am a well-educated surgeon. Most people of this time die from diseases such as smallpox, cholera, scarlet fever, or tuberculosis. As a surgeon, I see a lot of women and babies die from infections after childbirth. I have heard of Louis Pasteur's work with "germs" and think they could be the cause of infection, not chemical changes due to "bad air" as most people think. Right now, many of the surgeons I work with don't even wash their tools or hands between surgeries. I'm now working on an antiseptic to kill germs on surgical tools, which may reduce infections from operations. Thanks to microscopes, one of my colleagues has discovered that both tuberculosis and cholera are caused by small living things—bacteria.

[**Note:** The popular antiseptic mouthwash *Listerine* is named after Joseph Lister.]

SCIENTIST OF THE 1800s

My name is **Louis Pasteur** and I am the son of a French tanner. My wife and I had five children, but three of them died of typhoid. After that heartache, I have dedicated my life to curing disease, and I would like to thank my university, which often gave me financial support for my studies. Many people still think that disease is caused by bad air, but I have proven that disease is caused by microscopic organisms. I'm calling them "germs." I think these germs are also responsible for spoiling milk and beer. I'm now working on a vaccination for rabies and for anthrax, which kill many domestic animals. Without microscopes and people like **Robert Hooke** who pioneered them, I wouldn't be able to do this work.

[**Note:** The process of pasteurizing milk is named after Louis Pasteur.]

PERSON WITH DIABETES IN THE 1800s

Hello, I am **Mary Roberts** and I am 14 years old. My father is a banker. My mother mostly entertains, but lately she hasn't even been doing that. That's because my eight year old sister got sick. The doctor came a couple of months ago and he said she has the diabetes. Since then, they have tried giving her opium and bleeding her with leeches. Now, the doctor won't let my mother feed her hardly anything – just some broth and black coffee. I'm not allowed to go in her room any more but I peeked in this morning. She doesn't look good! Her eyes are closed and she is real skinny.

CITIZEN OF THE 1900s

My name is **Pearl McKinley** and I am a citizen of the 1900s. I'm 96 now and I've seen a lot of changes! I grew up on a small family farm, but now most people rely on manufacturing jobs. Think of all the things that have been invented in my lifetime: television, credit cards, cell phones, dishwashers, contact lenses, ball point pens, frozen pizza, cars, microwave ovens, CDs, computers, fast food…the list goes on and on. When I was born, only about six percent of the population graduated from high school. Now, about 85 percent do! More and more people go to college now, too. Every child in the U.S. can get a free education now, at least through high school, because public schools are supported by the government.

MEDICAL PRACTITIONER OF THE 1900s

My name is **Alexander Fleming** and I am a medical doctor. It's not uncommon now for people to live until their mid-70s or later, at least in developed countries. During World War I, I saw how easily deep wounds became infected, even though we used sterilization techniques developed by **Joseph Lister** and others. After the war, I began looking for antibacterial agents that would lead to a treatment. After accidentally leaving bacteria cultures to mold, I noticed that the colonies closest to the mold had been destroyed. This led to the discovery of penicillin which has become an early antibiotic and eventually led to treatments for scarlet fever, cholera, tuberculosis, bubonic plague, and other diseases. I, Alexander Fleming, will die of a heart attack as will many others. Chronic diseases involving the heart and respiratory systems will take their toll as people live longer. Cancer will also affect people all over the world.

SCIENTIST OF THE 1900s

My name is **Jonas Salk**. and I was born to immigrants who were determined that I would have a good education. I went to public schools and was the first in my family to go to college. I attended a college in New York for students from working class, immigrant families, then on to medical school. During work on a project funded by a foundation (known as the March of Dimes), my research team and I developed the first effective vaccine against polio. Other researchers developed vaccines for smallpox, measles, mumps, rubella, and many other diseases reducing deaths and disfigurement drastically during this time period. We are all building on the early vaccine work of **Louis Pasteur** and others.

PERSON WITH DIABETES IN THE 1900s

My name is **James Walker**. I am 25 years old. I was diagnosed with diabetes when I was 16 years old, in 1948. Doctors now know that diabetes is caused by a lack of insulin, so I watch what I eat and use insulin to control my blood sugar, which is really difficult. I have to give myself insulin shots several times a day; then the needle and syringe need to be washed and sterilized in boiling water. It's a big needle, too! I even have to sharpen it regularly. The only way to really know my blood sugar levels is to go to the hospital. Once I got a sore on my foot that turned into an ulcer, and I didn't even know it! The doctor said if I had waited any longer to see him I might have lost my foot. At least I'm not allergic to the insulin I use; I've read about some people who are.

CITIZEN OF THE 2000s

My name is **Andrew Hayes** and I am a typical citizen of the 2000s. In the U.S. now, most workers provide some sort of service like health care, education, business, or retail. In developing countries, many people farm, though other types of jobs are becoming more common as developed countries move industries overseas. In the U.S., most people graduate from government-supported public high school, and the majority go on to college or trade school, too, though they may have to pay for part or all of it. Online education is becoming more popular and people now get a lot of their information through technology.

MEDICAL PRACTITIONER OF THE 2000s

My name is **Dr. Douglas Lowy**. Our global life expectancy is about 67 years, though it is not uncommon for people in developed countries to live into their nineties. After studying art history and French and getting my medical degree, I began a career in basic science research at the National Cancer Institute (NCI). My work eventually led to two vaccines for cervical cancer. I am familiar with the work of **Dr. Nora Disis**, who is also working with cancer vaccines. All my work is federally funded through the NCI. As people are living longer, chronic diseases are the source of many health issues. Worldwide, the top health-related causes of death are heart disease and stroke, respiratory infections, pulmonary disease, diarrheal disease, and HIV/AIDS. Diabetes is the ninth cause of death globally. More health concerns are related to diet and access to healthy foods and clean water.

SCIENTIST OF THE 2000s

My name is **Dr. Nora Disis** and I am a medical doctor and researcher interested in women's health, specifically breast and ovarian cancer. I discovered a tumor antigen which led me to develop cancer vaccines. In the past, vaccines made by famous researchers like **Jonas Salk** (1900s) fought infectious diseases like smallpox and polio, so my work using vaccines against cancer is pretty new! I work with the Tumor Vaccine Group in Seattle and rely on research grants from the U.S. government along with many other funding sources.

PERSON WITH DIABETES IN THE 2000s

My name is **Aubrey Mathwig**. I am 25 years old and have Type I Diabetes. I was diagnosed a few years ago when I was drinking two gallons of water every day but was extremely thirsty at all hours. I also was losing weight rapidly and was exhausted all the time. Things in my life have changed since then. First, I have to monitor my blood sugar throughout the day, every day, which can get tedious. I also have to give myself a shot of insulin each time before I eat, and once before bed. I have to be prepared at all times by traveling with insulin, needles, etc., along with a fast-acting carbohydrate in case my blood sugar gets low. Even with this disease, my future is bright as long as I consistently keep on top of my blood sugar levels and take good care of myself.

LESSON 4:
The Process of Scientific Research

INTRODUCTION

In this lesson, students arrange sets of cards to show their understanding of the process of biomedical research. Students see how **basic research** may lead to studies involving both animals and humans and may culminate in the availability of new treatments and medications. Students then apply their understanding of the overall progression of biomedical research to early **chromosomal** studies and the story of Gleevec, a drug approved by the Food and Drug Administration (FDA) in 2001 to treat **chronic myelogenous leukemia** (CML). Lastly, students consider the ethical guidelines that scientists follow in every stage of research. This lesson includes instructions on how to arrange the cards using a ***foldable***, if desired.

CLASS TIME

One class period of 55 minutes.

KEY CONCEPTS

- Many years of basic research may or may not lead to new treatments and medications.
- Beginning with a known medication and working backwards to its origin does not give appropriate weight to knowledge gained from the false starts, dead ends, and blind alleys along the path.
- Ethical guidelines inform every stage of biomedical research.
- New technologies drive scientific discovery.

LEARNING OBJECTIVES

Students will know:

- The biomedical research process resulting in new drugs and treatments involves modeling, ***in vitro*** work, the use of animals, and human trials.
- Drug development can be a slow process, often requiring years of basic research and technological advancements.

Students will be able to:

- Create a flowchart using cards summarizing the process of biomedical research for drug development.

MATERIALS

Materials	Quantity
Student Handout 4.1—*Card Set #1: Translational Research Process*	1 set per group
Student Handout 4.2—*Card Set #2: The Story of Gleevec*	1 set per group
Student Handout 4.3—*Card Set #3: Ethical Guidelines*	1 set per group
Scissors	At least 1 per group
3 x 5 index cards (if not making a foldable)	4 per group
Teacher Resource 4.1—*Notes for Card Set #1: Translational Research Process*	1
Teacher Resource 4.2—*Ordered Card Set #2: The Story of Gleevec*	1
Teacher Resource 4.3—*Making a Foldable*	1
Computer with PowerPoint and overhead projection	1
The Process of Scientific Research Slide Set, found at http://nwabr.org.	1

NOTE TO THE TEACHER

The story of Gleevec is particularly interesting because it was the first drug designed to target and disrupt a specific **enzyme** found in patients with **chronic myelogenous leukemia** (**CML**). CML is a relatively rare type of leukemia, and one of the few cancers that can be linked to a single **oncogene**. The making of Gleevec is wonderfully intertwined with a fifty-year history of chromosomal research and discovery.

The oncogene responsible for the vast majority of CML cases is caused by a **translocation** between **chromosomes** 9 and 22. Scientists first described the resulting abnormal chromosome in 1960 and called it the ***Philadelphia chromosome***. Years later, using progressively better technology, the genetic impact of the translocation was shown to be the Abelson tyrosine kinase gene (*Abl*) of chromosome 9 becoming fused with the break point cluster gene (*Bcr*) of chromosome 22. The resulting Bcr-Abl combination makes an abnormal enzyme (a kinase) that stimulates cancer-causing cells to overproduce.

When the Bcr-Abl enzyme was identified as the cause of CML, researchers worked backwards to find a drug that would disable Bcr-Abl. Picturing Bcr-Abl as the lock, researchers designed and synthesized over 400 molecular keys to fit the lock. The successful key was the molecule STI571 (named Imatinib), marketed by Novartis as Gleevec.

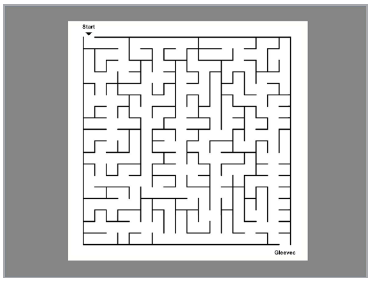
TEACHER PREPARATION

- Make copies of *Student Handouts*. You will need one copy of each handout (three total card sets) for each student group.
- Decide whether you want students to reuse the card sets or make them into foldables. If you would like to ***reuse the card sets*** for multiple classes, students may arrange the cards on the table and use index cards as labels (which will be further described in the Procedure section). If you do not need to reuse the cards, students may arrange the cards into a ***foldable*** (see Teacher Resource 4.3—*Making a Foldable*). Additional materials include two pieces of blank paper for each group, tape, and glue.
- For showing the PowerPoint slide set, prepare the computer and projection unit. Download *The Process of Scientific Research Slide Set*.

PROCEDURE

Introduction

1. Show students a picture of a complicated maze (found in *The Process of Scientific Research Slide Set*) with many openings. Ask students, "What is the easiest way to find the path of the maze?" Point out that there are many dead ends, false starts, and an element of trial and error. Once you've found the path, however, it is easy to retrace the steps back out.



2. Ask students to name any medicine, treatment, therapy, and/or device that improves human health and function. Tell students that considering these things is like starting at the center of a maze—the path to get to any of these products of biomedical research is often unclear. The end product may have been years in the making, with many wrong turns along the way, and may have relied on research from surprising resources.
3. Also point out to students that, in many cases, there is no center of the maze to be found—there is no one linear path that always leads towards success. Furthermore, any of these products in use right now can be improved upon and changed in the face of new evidence and research.
4. Tell students that today's lesson will focus on the process of biomedical research by exploring the route one medicine—Gleevec—took to reach the market. Gleevec is used to treat a form of **leukemia** called chronic myelogenous leukemia (CML).

Part I: Card Set #1—The Process of Translational Research

5. Ask students, "How do you think drugs, treatments, or medical devices are developed?"
6. Have each student spend a few moments drawing a "Drug Development Process Flow Chart" of how they think a drug is developed before it is marketed to the public. Explain that they will compare this initial flow chart to a second one they will generate during the lesson. Tell them not to be discouraged if they are having difficulty, but to make their best attempt.

7. Ask students to consider some questions when developing their flow charts:

   a. Where do scientists find new drugs?

   b. How do they determine that the new drugs will work and are safe in humans?

   c. What, if any, regulations and policies guide the process?

8. Elicit answers from students and write them on the board.

9. Teachers wishing to frame this activity using a foldable should follow the directions on Teacher Resource 4.3—*Making a Foldable*.

10. Divide the class into groups of two to four students each. Hand out copies of Student Handout 4.1—*Card Set #1: Translational Research Process*, one per group. The cards are not in order on the handout. Ask students to cut out the cards.

11. Have students put the cards in order—from the beginning to the end of the process as best they can. Tell students that multiple cards may go at the same "level."

12. When each group is finished arranging the cards, have a "Gallery Walk" to allow the students to see if other groups arrived at the same order.

13. As a class, discuss the basic order of cards using the original order found on Teacher Resource 4.1—*Notes for Card Set #1: Translational Research Process*.

    [**Note:** The first five cards, representing basic research, can go in different orders since the process is cyclical. Students should be able to justify the order they chose.]

14. Keeping the cards arranged in order, have students classify the cards into four categories ***Basic Research***, ***Animal Research***, ***Humans in Research***, and ***New Treatments***.

15. Write each category name on a 3x5 index card and place the card in the correct position next to the arranged cards. Alternatively, students can label these categories on the foldable.

16. Tell students that the three cards in the ***Humans in Research*** section showing increasing numbers of human volunteers represent the **clinical trials phases**. These can be labeled ***Phase I***, ***Phase II***, and ***Phase III***.

17. ***Do not*** have students clear the ***Translational Research*** process cards. They will be adding to the set in *Part II*.

Part II: Card Set #2—The Story of Gleevec

[**Note:** A graphic showing the Philadelphia chromosome and blood cell development can be found at: http://www.cancer.gov/cancertopics/pdq/treatment/CML/Patient.]

18. Now that students have the general framework for the order of biomedical research, tell them that they will receive a second set of cards detailing the drug discovery process for a specific drug.

    The drug they will be exploring is ***Gleevec***. Gleevec is made and marketed by the pharmaceutical company Novartis to treat chronic myelogenous leukemia (CML). CML is a relatively rare cancer of the blood. Prior to Gleevec, fewer than half of patients with CML lived seven years. With Gleevec, nearly 90% are alive seven years later.

19. Pass out Student Handout 4.2—*Card Set #2: The Story of Gleevec* and ask students to cut out the cards. These cards give the history of chromosomal research and the discovery of Gleevec. Dates for some milestone discoveries are in parentheses on some of the cards to help students put them in order.

20. With *Card Set #1* still in place, have students arrange the cards from *Set #2* in chronological order (the dates of milestone events on some cards will help students do this). Make sure that students are tying the Gleevec cards back to the process cards from *Card Set #1*. The correct order for the cards can be found on Teacher Resource 4.2—*Ordered Card Set #2: The Story of Gleevec*.

21. When students have finished arranging *Card Set #2*, ask them:

    a. In which category (***Basic Research***, ***Animal Research***, ***Humans in Research***, and ***New Treatments***) are most of the Gleevec cards? Why?

    b. Which category represents the longest period of time? Why?

    c. In what way do new technologies drive scientific discovery?

22. Remind students of the maze analogy from the beginning of the class. Reiterate that we are tracing backwards from the beginning, knowing the path that worked. This activity does not show all the false starts, dead ends, and blind alleys that were part of the journey.

23. Tell students that *Card Set #1* represents the standard, conventional order for the development for drugs and treatments—in some ways it is an "idealized" model. The development of Gleevec differs from this model in some important ways:

    a. CML is considered an **orphan disease** because it is rare. Drugs to treat orphan diseases undergo a shorter clinical trial phase.

    b. In **Phase I trials**, the drug was given to people with CML, not healthy volunteers.

24. Students may also be interested in knowing that the cost of Gleevec can run between $40,000 and $90,000 a year and must be taken for the rest of the patient's life.

Part III: Card Set #3—Ethical Guidelines

25. Tell students that research at every level follows ethical guidelines and legal regulations. Point out that the two cards from *Card Set #1* marked with stop signs symbolize federal involvement through the Food and Drug Administration (FDA).

26. Ask students, "When doing basic research, what should the rules be?" Encourage students to think about the processes they used when conducting their gummy bear lab in *Lesson One*, such as peer review, collaboration, using repeatable trials and multiple trials, and not falsifying data. These are all aspects of ethical research.

27. Ask students, "When doing research with animals, what should the rules be?" Encourage students to recognize the importance of treating animals humanely by enhancing animal welfare and ensuring the best conditions possible, using as few animals as possible, using the least developed organisms possible, and replacing living organisms with cell/tissue cultures or computer models when possible.

    [**Note:** Additional support for talking with students about animal research can be found in the curriculum, *The Science and Ethics of Animal Research*, available from NWABR's website at: http://nwabr.org/curriculum/animals-research. A poster detailing the **3Rs of animal research** is also available to download.]

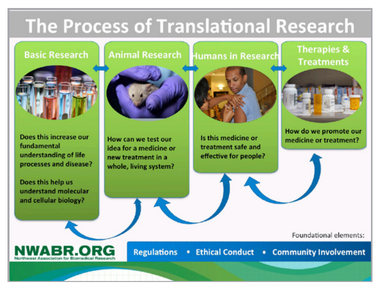
28. Ask students, "When doing research with humans, what should the rules be?" Encourage students to consider the importance of asking people their permission through an informed consent process, treating participants with respect, being fair in selecting participants, and considering the potential harms and benefits of research with humans.

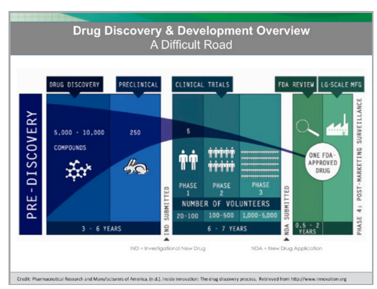
    [**Note:** A more in-depth look at humans in research can be found in the curriculum, *The Science and Ethics of Humans in Research*, available from NWABR's website at: http://nwabr.org/curriculum/humans-research.]

29. Hand out copies of Student Handout 4.3—*Card Set #3: Ethical Oversight*, one per group. Students should cut out the cards and add them to their research process and Gleevec card sets. Alternately, students can write the information about the ethical guidelines on the back of the index card representing the correct category. If using the foldable, students should turn their paper over and glue the cards on to the back.

Closure

30. Show students the accompanying PowerPoint slides: "The Process of Translational Research" and "Drug Discovery & Development Overview: A Difficult Road." Clarify any questions about the process.





31. Ask students to write down one question or comment about the slide, "Drug Discovery & Development Overview: A Difficult Road" to share with the class. Elicit responses from a few students, and then ask if anybody has anything to add to the discussion. Make sure that somebody points out the number of compounds that are considered for every one drug that makes it to the market.

32. Lastly, have students retrieve their *Unit Graphic Organizer* handouts and look at the third column, titled "Translational Research." Ask students, "What is the process through

which new drugs and treatments are made available to treat disease?" Students should write down the steps in the process:

Basic Research ➔ New Discoveries ➔ Animal Research ➔ Humans in Research ➔ New Treatments.

Point out that ethical guidelines exist at every level. Although the arrows point to the right and show a simplified progression, the process is multidirectional, complex, and may end up in a blind alley or dead end at any point.

33. In addition, draw students' attention to the last column, "Being a Scientifically Literate Citizen." Ask students how their understanding of **translational research** impacts them as consumers and/or users of medications and treatments. Discuss their responsibility to be scientifically literate in their role as ***consumers*** and add that word to the graphic organizer.

HOMEWORK

Teachers may assign either the Peter Nowell or Jane Brody article mentioned in the *Extension* section as homework.

EXTENSION

- To further study chromosomes, CellServ sells a kit that allow students to prepare a chromosome spread using human cells. The kits are made using HeLa cells, which links nicely to a case study about HeLa cells found in *Lesson One* of NWABR's *The Science and Ethics of Humans in Research* curriculum. Kits are available to purchase at:

  CellServ
  http://www.cellserv.org/Kits/Kit4.html

- A number of articles and retrospectives have been written about the impact of the discovery of the Philadelphia chromosome. The following articles are accessible for upper-level students and freely downloadable:

  "Discovery of the Philadelphia chromosome" by Peter Nowell, one of the original researchers http://www.jci.org/articles/view/31771.

  "Living with a formerly fatal blood cancer"
  http://www.nytimes.com/2010/01/19/health/19brod.html?_r=1

- Fox Chase Cancer Center held a 50th anniversary symposium on the Philadelphia chromosome. Many of the associated materials can be found here:

  Philadelphia Chromosome: 50th Anniversary Symposium
  http://pubweb.fccc.edu/philadelphiachromosome/history.html

GLOSSARY

Applied research: Research that relates to human health care in the form of treatments or cures of human diseases. Applied research is often conducted by for-profit companies.

Basic research: Research that furthers general scientific understanding of how the natural world works. This is often academic research.

Belmont Principles inform and guide researchers working with human participants. They are:

- ***Respect for Persons:*** Respect for individuals and their ***autonomy***; obtain informed consent.
- ***Maximize Benefits/Minimize Harms:*** This stresses "doing good" and "doing no harm" by minimizing potential harm(s) and maximizing potential benefit(s) to the subject as well as potential benefit to society.
- ***Justice:*** Be fair in distributing the benefits and burdens of research.

Chromosome: A strand of DNA and associated proteins that contains genetic information.

Clinical trials phases: Clinical trials are conducted in three or four phases. Each phase has a different purpose to help researchers answer different questions. Following is an overview of each phase:

- **Phase I**—An experimental drug or treatment is tried on a small group of people (fewer than 100). The purpose is to evaluate its safety, potential dosage, and identify any side effects.
- **Phase II**—The experimental drug or treatment is administered to a larger group of people (several hundred) to further assess safety, and to address issues such as optimal dosing and frequency of dose administration.
- **Phase III**—The experimental drug or treatment is administered to large groups of people (several thousand) to determine its effectiveness, further monitor safety, and compare it with standard or equivalent treatments.

- **Phase IV**—After a drug is licensed by the FDA, researchers track its safety, seeking more information about its risks, benefits, and best use in "real-world" settings.

CML: Chronic Myelogenous Leukemia. A specific form of cancer that affects white blood cells.

Enzyme: A protein or molecule that speeds up a chemical reaction in a living cell.

***In vitro*:** "In glass," referring to an experiment done in a test tube or an artificial, non-living system.

Leukemia: Any cancer that affects normal production of blood cells.

Oncogene: A gene that contributes to the production of a cancer; usually a mutated form of a normal gene.

Orphan disease: In the U.S. an orphan disease, or rare disease, affects fewer than 1 in 1,500 people. They are mostly genetic conditions passed on from parent to child.

Translational research: The process of connecting basic research to applied medicine or treatment; sometimes described as "From Bench to Bedside."

Translocation: Movement of a fragment of one chromosome to a different chromosome.

3 Rs of animal research:

- **Replacement:** Replacing conscious, living vertebrates with cell or tissue cultures, computer models, simulation models, and/or less developed animal species.
- **Reduction:** Using the fewest number of animals possible in a research project to gain valid results.
- **Refinement:** Using any technique or procedure that minimizes distress or enriches the life of an animal used in research.

SOURCES

Brody, J. E. (2010, January 18). Living with a formerly fatal blood cancer. *The New York Times*. Retrieved from http://www.nytimes.com/2010/01/19/health/19brod.html?_r=1

Clinical Trial Image (Man Receiving a H1N1 Vaccine Injection). Courtesy U.S. Navy, # 091119-N-1825E-253. U.S. Navy photo by Mass Communication Specialist 2nd Class Joseph Ebalo/Released. http://www.navy.mil/view_image.asp?id=78844

Computer Modeling Image (Researcher with 3-D Model of Protein). Courtesy of Wellcome Images. Mol. Biophysics, Oxford Univ., Wellcome Images, #B000388. http://wellcomeimages.org

Drug Containers Image. Courtesy of Microsoft Clipart. http://office.microsoft.com/en-us/images/results.aspx?qu=00402126&ex=2

Drug Discovery & Development: Understanding the R&D Process. Retrieved from http://www.innovation.org

Imatinib. (2012, June 4). In *Wikipedia*, *The Free Encyclopedia*. Retrieved from http://en.wikipedia.org/w/index.php?title=Imatinib&oldid=495877778

In vitro Image of Hand Holding Petri Dish. Courtesy of Wikimedia Commons, Umberto Salvagnin. http://commons.wikimedia.org/wiki/File:Cell_culture.jpg#file

In vitro Image of Test Tubes. Courtesy of Microsoft Clipart. http://office.microsoft.com/en-us/images/results.aspx?qu=research&ex=1&AxInstalled=copy&Download=MP900406576&ext=JPG&c=0#ai:MP900406576|mt:2|

Li, J. J. (2006). *Laughing gas, Viagra, and Lipitor: The human stories behind the drugs we use*. New York, NY: Oxford University Press.

Maze Image. Courtesy of Wikimedia Commons, Nandhp. http://commons.wikimedia.org/wiki/File:Prim_Maze.svg

Microscope Image. Courtesy of Microsoft Clipart. http://office.microsoft.com/en-us/images/results.aspx?qu=microscope&ex=2#ai:MP900305708|mt:2

Nowell, P. C. (2007). Discovery of the Philadelphia chromosome: A personal perspective. *The Journal of Clinical Investigation*, *117* (8) 2033-2035. Retried from http://www.jci.org/articles/view/31771

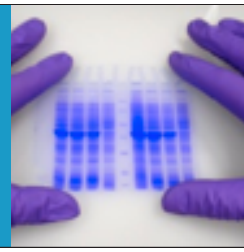
Researcher Holding a Mouse Image. Courtesy of Wellcome Images. http://wellcomeimages.org/indexplus/image/C0018221.html

Card Set #1: Translational Research Process

Name______________________________ Date______________ Period______________

Instructions: Cut out the cards and put them in chronological order.

The Food and Administration (FDA) requires information on the results of animal studies, manufacturing information, and procedures for upcoming clinical trials before humans can be used in drug research.

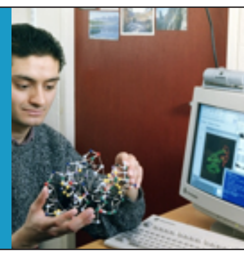


New and improved technologies drive the process of scientific discovery.

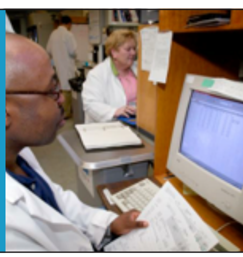
Drug given to a larger number (100-300) of volunteers with the disease to see how effective the drug is in treating the disease and to look for side effects.

Drug tested *in vitro* on target molecules to determine effectiveness.

The Food and Drug Administration (FDA) requires that research results are reviewed and approved before releasing the drug to the market.



Computer modeling shows possible interactions of the drug with the body.



Computers are used to design possible candidate drugs that will “fit” with a target, such as an enzyme involved in a known disease pathway.

Drug given to larger numbers (1,000-3,000) of volunteers with the disease to confirm its effectiveness and to continue to look for risks and side effects from longer use.

Final product approved for market.

Drug tested *in vitro* on cells or tissues to determine effectiveness.

Drug given to small number (20-80) of healthy volunteers to evaluate safety and identify side effects.

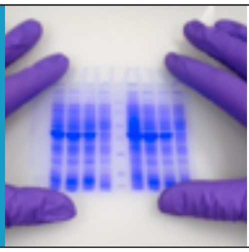
Drug tested in animal models.

HANDOUT

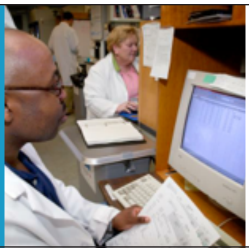
TEACHER RESOURCE 4.1

Notes for Card Set #1: Translational Research Process

These cards are in the correct order (see ***Teacher Notes***).



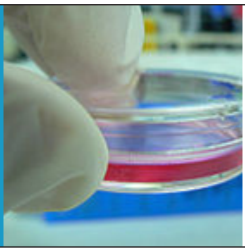
New and improved technologies drive the process of scientific discovery.



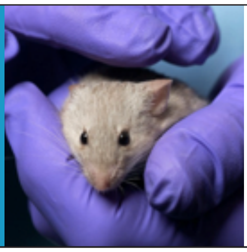
Computers are used to design possible candidate drugs that will "fit" with a target, such as an enzyme involved in a known disease pathway.

Computer modeling shows possible interactions of the drug with the body.

Drug tested *in vitro* on target molecules to determine effectiveness.



Drug tested *in vitro* on cells or tissues to determine effectiveness.



Drug tested in animal models.

BASIC RESEARCH

ANIMAL RESEARCH

Teacher Notes:

This card set: The process of connecting basic research to ***applied research*** is called ***translational research***. This is sometimes described as "From Bench to Bedside"—from the scientist's laboratory bench to the physician's bedside care of a patient.

The group of five cards on this page represent scientific discovery through ***basic research***. Basic research (sometimes called bench science) furthers general scientific understanding of how the natural world works. This is often academic research.

While these five cards are shown in generally the 'correct' order, they can be arranged in different orders as this is a cyclical process that informs and changes itself over time.

These cards are in the correct order (see ***Teacher Notes***).

The Food and Administration (FDA) requires information on the results of animal studies, manufacturing information, and procedures for upcoming clinical trials before humans can be used in drug research.

Drug given to small number (20-80) of healthy volunteers to evaluate safety and identify side effects.

Drug given to a larger number (100-300) of volunteers with the disease to see how effective the drug is in treating the disease and to look for side effects.

Drug given to larger numbers (1,000-3,000) of volunteers with the disease to confirm its effectiveness and to continue to look for risks and side effects from longer use.

The Food and Drug Administration (FDA) requires that research results are reviewed and approved before releasing the drug to the market.

Final product approved for market.

HUMANS IN RESEARCH

NEW TREATMENTS

Teacher Notes:

Applied research is when knowledge gained from ***basic research*** is used to improve human or animal health with treatments or cures for diseases. This is often done by for-profit companies.

RESOURCE

STUDENT HANDOUT 4.2

Card Set #2: The Story of Gleevec

Name________________________________ Date______________ Period______________

Instructions: Cut out the cards and put them in order of events.

After more than 400 *in vitro* tests using different shapes of molecules, one molecule is found to inactivate the BA enzyme. This will later be named Gleevec.	Phase I clinical trials begin with the drug. In this case, the drug was given to people with CML, not healthy volunteers. The study found that one daily pill was sufficient.
Phase III clinical trials begin.	Animal trials begin with the drug. The molecule is well-tolerated in rodents. Later studies show the drug to be very effective in animals with CML.
The drug is approved for market in 2001. It is named Gleevec in the U.S. Post-marketing research finds it to be safe and effective for treatment of ten different cancers.	Thanks to new ***gene mapping*** techniques, scientists learn that the translocation in the Philadelphia chromosome puts two genes, B and A, next to each other. (1984)
Phase II clinical trials are successful in showing the drug to be effective. (1999)	A chromosomal abnormality called the Philadelphia chromosome is found after new air drying techniques for cell preparation allow chromosomes to be seen more clearly. People with CML are found to have this abnormality.
The gene combination is found to make an abnormal BA ***enzyme*** that triggers cells to divide uncontrollably. This is the genetic cause of CML.	Scientists have a specific target: to inactivate the BA enzyme. They design and test hundreds of molecules *in vitro* to find one that shuts down BA. (1990-1992)
Advances in cell culture techniques allow scientists to study human leukemia cells. (1955)	The Philadelphia chromosome is found to result from chromosomes 9 and 22 trading genetic information in a ***chromosomal translocation***.

HANDOUT

HANDOUT

Ordered Card Set #2: The Story of Gleevec

This card set is in the correct order with dates included.

Advances in cell culture techniques allow scientists to study human leukemia cells. (1955)

A chromosomal abnormality called the Philadelphia chromosome is found after new air drying techniques for cell preparation allow chromosomes to be seen more clearly. People with CML are found to have this abnormality. (1960)

The Philadelphia chromosome is found to result from chromosomes 9 and 22 trading genetic information in a ***chromosomal translocation***. (1972)

Thanks to new ***gene mapping*** techniques, scientists learn that the translocation in the Philadelphia chromosome puts two genes, B and A, next to each other. (1984)

The gene combination is found to make an abnormal BA ***enzyme*** that triggers cells to divide uncontrollably. This is the genetic cause of CML. (1987)

Scientists have a specific target: to inactivate the BA enzyme. They design and test hundreds of molecules *in vitro* to find one that shuts down BA. (1990-1992)

After more than 400 *in vitro* tests using different shapes of molecules, one molecule is found to inactivate the BA enzyme. This will later be named Gleevec. (1992)

Animal trials begin with the drug. The molecule is well-tolerated in rodents. (1992)

Later studies show the drug to be very effective in animals with CML.

Phase I clinical trials begin with the drug. In this case, the drug was given to people with CML, not healthy volunteers. The study found that one daily pill was sufficient. (1998)

Phase II clinical trials are successful in showing the drug to be effective. (1999)

Phase III clinical trials begin.

The drug is approved for market in 2001. It is named Gleevec in the U.S.

Post-marketing research finds it to be safe and effective for treatment of ten different cancers.

STUDENT HANDOUT 4.3

Card Set #3: Ethical Guidelines

Name____ Date______________ Period______________

Ethical Guidelines Supporting Basic Research

Scientists and researchers at every level are trained in the ethical conduct of research which entails the use of and need for:

collaboration, peer review, multiple trials, repeatable trials,
skepticism, persistence despite setbacks, transparency,
rules against falsifying data

Ethical Guidelines Supporting Research with Animals

People working with animals follow **The 3 Rs** as ethical guidelines when working with animals:

- **Replacement:** Replacing conscious, living vertebrates with cell or tissue cultures, computer models, simulation models, and/or less developed animal species to the extent possible.
- **Reduction:** Using the fewest number of animals possible in a research project to gain valid results.
- **Refinement:** Using any technique or procedure that minimizes distress or enriches the life of an animal used in research.

Any institution that involves animals in research must also have an ***Institutional Animal Care and Use Committee (IACUC)***. This committee evaluates and oversees all aspects of the animal care and use program for that research facility.

Ethical Guidelines Supporting Humans in Research

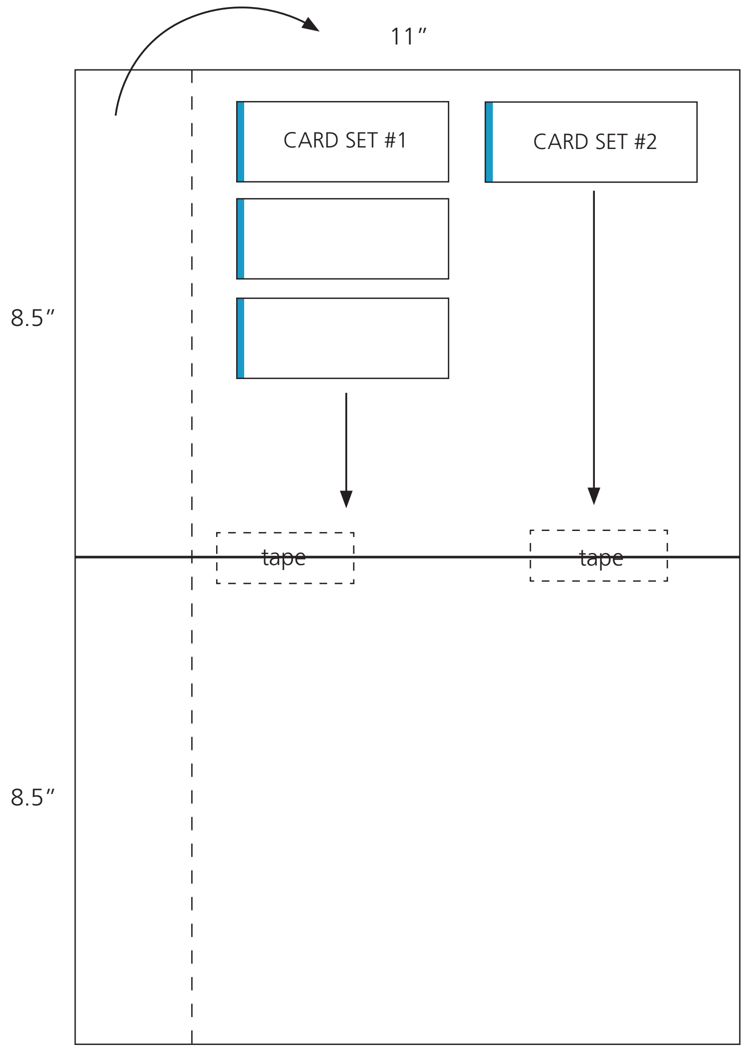
The **Belmont Principles** inform and guide researchers working with human participants. They are:

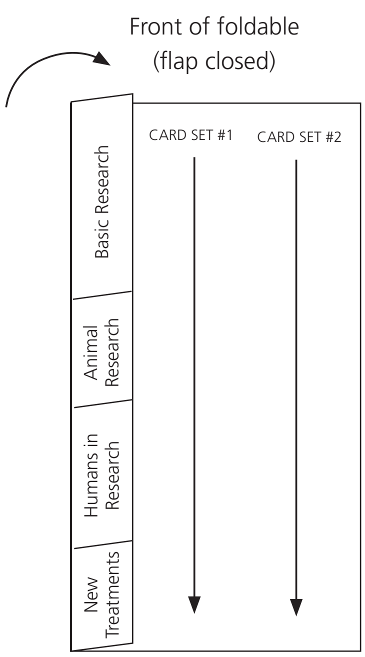
- **Respect for Persons:** Respect for individuals and their ***autonomy***; obtain informed consent.
- **Maximize Benefits/Minimize Harms:** This stresses "doing good" and "doing no harm" by minimizing all potential harm(s) and maximizing potential benefit(s) to the subject as well as potential benefit to society.
- **Justice:** Be fair in distributing the benefits and burdens of research.

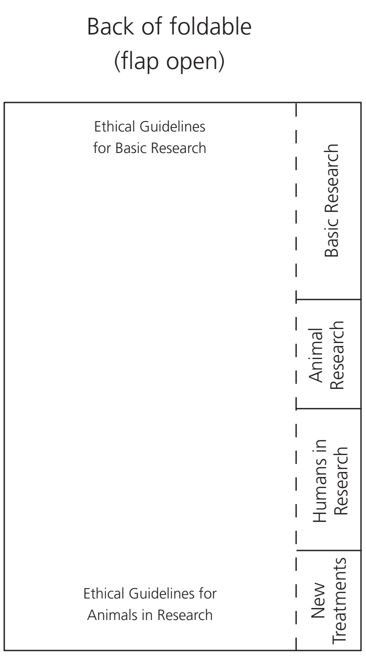
Research involving human participants must also be reviewed, monitored, and approved by an ***Institutional Review Board (IRB)***. IRBs are sometimes called "ethics committees."

Making a Foldable

1. Tape two 8.5 x 11″ sheets of paper together along the long end.
2. Fold the left margin in about 1.5″ along the dotted line. Reopen it.
3. To the right of the fold, arrange *Card Set #1: Translational Research Process*. Tape/glue these in place when finished.
4. Fold the left margin in. On both sides of the flap, write BASIC RESEARCH, ANIMAL RESEARCH, HUMANS IN RESEARCH, and NEW TREATMENTS in the appropriate places (see below).
5. Arrange *Card Set #2: The Story of Gleevec* to the right of *Card Set #1*. Make sure the cards fall into the correct categories labeled in *#4*. Tape/glue in place.
6. Turn the foldable over and open the flap. Write in or glue the ethical guidelines (*Card Set #3*) that underlie each stage of biomedical research.







LESSON 5:
Who Should Decide Basic Science Funding?
A Structured Academic Controversy

INTRODUCTION

In this lesson, students participate in a *Structured Academic Controversy* around the question, "Should citizens determine funding for scientific research?" The general public can often see the importance of human research and clinical trials, but they may not be able to see the value of ***basic research***, especially when budgets are tight. The National Science Foundation (NSF) distributes funds for basic research, and because the research is not always directly applicable to a health treatment or cure, questions can be raised about its usefulness. There have been debates about the applicability of some of the research funded by the NSF, in which it was implied that these studies were a waste of taxpayer money. This led to a suggestion by a U.S. Representative that American citizens should be able to help decide which research projects get funded by the NSF. Students explore both sides of this issue before examining their own views.

CLASS TIME

One class period of 55 minutes.

KEY CONCEPTS

- The usefulness of basic science research is not always obvious to the general public.
- The amount of taxpayer money spent on basic scientific research can be debated to make sure that it is spent wisely.
- The scientific research community uses peer review to help determine what projects should be funded.

LEARNING OBJECTIVES

Students will know:

- Basic science research can be useful in the future for ***translational research*** but may not be seen as useful by the general public.
- The amount of money spent on scientific research is not a huge part of the federal budget.
- It is important to be skeptical of information, especially if it has gone through many filters.

Students will be able to:

- Look at two sides of a controversy and decide how money should be spent.

MATERIALS

Materials	Quantity
Student Handout 5.1—*Structured Academic Controversy Worksheet*	1 per student
Possible Answers to Student Handout 5.1—*Structured Academic Controversy*	1
Student Handout 5.2a—*FOR: Citizens Should Have Input*	2 per group
Student Handout 5.2b—*AGAINST: Citizens Should NOT Have Input*	2 per group
Student Handout 5.3—*Homework: Your Own Stand on Science Funding*	1 per student
Teacher Resource 5.1—*The Federal Budget: How Do We Spend our Money?*	1
Computer with PowerPoint and overhead projection	1
Basic Science Funding Slide Set found at http://nwabr.org	1

NOTE TO THE TEACHER

The National Science Foundation (NSF) provides funding for about 20% of the basic scientific research conducted by colleges and universities through grants and awards (NSF, 2010 April). The NSF has a budget of about $6.9 billion, which may seem like a lot, but is actually only about 0.2% of the total $37 trillion U.S. budget. The NSF uses an extensive review process, asking at least three experts in the relevant field to help determine which projects should be funded (NSF, 2010 May). This research is also evaluated on its intellectual merit as well as its societal applicability (NSF, 2010 May). NSF primarily funds basic science research, which can be seen by some as useless or frivolous because its benefit to society is not always obvious. This is especially a problem in tough financial times with a huge federal deficit. Some Congressional leaders have questioned certain NSF projects that seem to have limited applicability to society, and have asked that the American people have more direct oversight of funding decisions.

TEACHER PREPARATION

- Make copies of *Student Handouts*.
- For showing the PowerPoint slide set, prepare the computer and projection unit. Download the *Basic Science Funding Slide Set*.

PROCEDURE

Part I: What Do You Think…

1. Write these questions on the board or show the corresponding slide from the *Basic Science Funding Slide Set:*
   - "Who do you think should have a say in what scientific research gets funded in the United States?" (*Examples could include: Expert scientists in the field, the state, or federal government; the researchers themselves; voters; an online survey of random people; a university or research institution; etc.*)
   - "About what percentage of the federal budget do you think the U.S. government spends on basic science research?"

   [**Note:** The actual percentage of the federal budget spent on basic research will be revealed to students after the activity. Please ***do not*** share the number with them now.]
2. Solicit student responses to the questions.
3. Continue with the Structured Academic Controversy as described in ***Part II***.

Part II: Structured Academic Controversy

[**Note:** *Structured Academic Controversy* is a text-based, small group deliberation model in which students explore both sides of an issue before examining their own personal views. Active listening is an important part of the process.]

4. Tell students that they will be exploring the following ethical question: ***"Should citizens determine funding for scientific research?"*** Students will be presenting either FOR or AGAINST viewpoints assigned to them, and not relying on their personal opinions.

   [**Note:** The *Basic Science Funding Slide Set* can be used to show students the steps in the *Structured Academic Controversy*.]
5. Divide the class into groups of four students each for the *Structured Academic Controversy*. Each group should have two students who are FOR and two students who are AGAINST citizens helping decide funding questions. Students may sit down with their groups at desks.
6. Explain the framework of a *Structured Academic Controversy*. The basic framework is:
   - Two students represent the FOR position; two represent the AGAINST position.
   - Each pair reads background for their position and prepares their argument.
   - The FOR pair presents while the AGAINST pair listens.
   - The AGAINST pair paraphrases the FOR pair's arguments and asks clarifying questions only.
   - The AGAINST pair presents while the FOR pair listens.
   - The FOR pair paraphrases the AGAINST pair's arguments and asks clarifying questions only.
   - Students drop their assigned roles and discuss their personal positions.
   - Students clarify areas of agreement and disagreement.
7. Remind students of the classroom norms. For example, students should speak one at a time, hear all sides equally, listen well enough to respond, and back up their opinions with clear reasons.
8. Pass out copies of Student Handout 5.1—*Structured Academic Controversy Worksheet*, one per student. Pass out copies of Student Handout 5.2a—*FOR: Citizens Should Have Input* to two members of each group. Pass out copies of Student Handout 5.2b—*AGAINST: Citizens Should NOT Have Input* to the other two members of each group.

9. Tell students that each pair should read the background information supporting their position and fill out the ***Relevant Facts*** section of the worksheet (see Student Handout 5.1).

10. Challenge each pair to plan a presentation of their position and arguments. Students should focus on the ***three most important arguments*** that best support their position.

11. ***One side presents, the other side listens and repeats***. One side presents their important arguments to the other side. The other side needs to listen carefully, take notes, and then paraphrase the arguments back to be sure that they understand them, asking clarifying questions as necessary. Emphasize that there is no discussion at this point. The presenters should be satisfied that their position has been heard and understood.

12. ***The pairs switch*** presentation roles and the process is repeated.

13. ***Students drop their roles***. Students proceed as their individual selves, using information from their experiences as well as the background readings.

14. Share with students the following prompt: "See if you can clarify areas of agreement and disagreement. Feel free to change your mind."

15. Help students finish Student Handout 5.1—*Structured Academic Controversy Worksheet*. Students might have difficulty coming up with possible solutions. See Teacher Resource 5.2— *Possible Answers to Structured Academic Controversy Worksheet* if you think they need help finding compromise.

16. Show students the answer to the question: "About what percentage of the federal budget do you think the U.S. government spends on basic science research?"

    The budget of the National Science Foundation is about $7 billion out of $3.7 trillion, or about 0.2%. The federal budget is 3.7 trillion. Show the math for students:

    First, 3.7 trillion = 3,700 billion. Then,

$$\frac{7 \text{ billion}}{3{,}700 \text{ billion}} = .19\% \sim .2\%$$

17. Using the classroom projection system, display Teacher Resource 5.1—*The Federal Budget: How Do We Spend Our Money?* This image is also included in the *Basic Science Funding Slide Set*. This image displays the federal budget as a pie graph. Note that the top right budget is the entire federal budget of which 37% is **discretionary** spending, which gets debated by Congress every year. The pie graph on the bottom left shows how the discretionary budget is spent.

18. Point out to students that the ***entire Science/ Environment/Energy*** budget is 6% of 37% of the total budget, or about 2.2% of the total budget.

    [**Note:** This discussion is ***not*** intended to be a budget or debt crisis debate. It is just supposed to provide context for the amount of money being debated relative to the total federal budget. The titles on the pie chart are not nuanced enough to convey exactly how money is spent. For example, military spending includes the Pentagon, Department of Defense, wars, veterans' benefits, health care for soldiers, etc. Education expenditures include higher education and K-12 education. Budget talks can be sensitive and bring up passions, especially at a time of financial uncertainty.]

19. Give students a few minutes (or talk as a class) to present the facts in the case (they may be able to pull this out of the readings, but you can also talk about it). Important facts from 2011 are:

    - The National Science Foundation Budget is $6.9 billion.
    - This represents about 0.2% of the federal budget.
    - The federal deficit (the difference between the budget and revenue) is $14 trillion.
    - The NSF funds 20% of basic research.
    - Some people have questioned funding with taxpayer money studies they believed had limited benefit to society.
    - Some have called for more citizen oversight of the National Science Foundation and its grant process to reduce this perceived waste.

Closure

20. Gather student attention back from the small groups, and ask for students to share some ***common ground*** reached in the argument.

21. Solicit student ideas about ***how*** and ***why*** funding decisions should be made for basic scientific research.

22. Talk to students about the way basic research is characterized as it goes through different filters—in this case the filters were the NSF grant proposal abstract, a senator and a representative (or their staff) reading those proposals, and the media picking up the study. A further way this information could be disseminated is through blogs and personal websites. How did the message about the nature of the research change as it went through those successive filters?

23. Tell students that this story illustrates the need to be skeptical and think about the possible biases or "context left out" that might be important to consider when they hear information that has been filtered through multiple sources.

24. Have students retrieve their *Unit Graphic Organizer* handouts and add new information to the organizer. Under "Role of Science and Society" they may add:
    - Media influences societal views of science.
    - Society funds research and education it values.

25. Finally, look at the last column, "Being a Scientifically Literate Citizen." Ask students to think about the role that politics plays in science; how does this impact them as members of society, potential taxpayers, and voters? Discuss their responsibility to be scientifically literate in their role as a ***taxpayer*** and ***voter*** and add those words to the *Unit Graphic Organizer*.

HOMEWORK

Student Handout 5.3—*Homework: Your Own Stand on Science Funding* can be assigned as homework. The handout asks students to reveal their own opinions on science funding.

ADAPTATION

- If the reading level of the article may be an issue for some students, divide the class in half and have a strong reader from the group read the arguments aloud while the others take notes.
- Representative Adrian Smith was the one who called for citizens to be able to oversee NSF funding. You may want to share this video with students who may have difficulty with the article.

Representative Adrian Smith's YouCut Citizen Review (1:46 minutes)
http://www.youtube.com/watch?v=LSYTS-nRt4o

EXTENSION

- Another subject for a *Structured Academic Controversy* could be the cost of Gleevec (see Lesson Four). Gleevec costs between $40,000 and $90,000 a year. The question could be: *"Should Novartis be able to charge so much for their medication?"*
- There are many news stories that highlight some of the controversial studies. Students could explore these studies in more depth:

A Report from Senator Coburn's Office on Spending at the National Science Foundation
http://www.coburn.senate.gov/public//index.cfm?a=Files.Serve&File_id=94c088f1-9629-4eaf-adce-e51331fc0601

Robot Folding Laundry
http://www.wired.com/gadgetlab/2010/04/towel-folding-robot-could-fix-laundry-woes/

Gender and Babies
http://www.livescience.com/14323-genderless-baby-gender-anxiety.html

Shrimp on a Treadmill
http://www.livescience.com/4221-scientists-put-shrimp-treadmill.html

Story of a 2013 Bill that Would Replace Peer Review at the NSF with a Set of Funding Criteria Chosen by Congress
http://news.sciencemag.org/scienceinsider/2013/04/us-lawmaker-proposes-new-criteri-1.html?ref=hp

GLOSSARY

Discretionary: Available to be used as needed or desired; discretionary spending refers to the fraction of the budget that Congress can spend as it chooses each year.

SOURCES

Cantor, Eric. (n.d.) Eric Cantor Majority Leader You Cut Citizen Review. Retrieved from http://majorityleader.gov/youcut/review.htm

Coburn, T. (2011). *The National Science Foundation: Under the microscope*. Washington, DC: U.S. Government Printing Office.

Congressional Budget Office. (2011). *Reducing the deficit: Spending and revenue options*. Washington, DC: U.S. Government Printing Office.

Congressman Adrian Smith launches the first YouCut Citizen Review. Video retrieved from http://www.youtube.com/watch?v=LSYTS-nRt4o

National Science Foundation. About the National Science Foundation. *National Science Foundation: Where Discoveries Begin*. Retrieved from http://www.nsf.gov/about/

National Science Foundation. How we work. *National Science Foundation: Where Discoveries Begin*. Retrieved from http://www.nsf.gov/about/how.jsp

Office of Management and Budget (2011). *Fiscal year budget of the U.S. Government*. Washington, DC: U.S. Government Printing Office.

Pappas, S. (2011, May 26). Scientists cry foul over report criticizing National Science Foundation. *Live Science*. Retrieved from http://www.livescience.com/14353-coburn-nsf-funding-misleading.html

STUDENT HANDOUT 5.1

Structured Academic Controversy Worksheet

Name____ Date_______________ Period_______________

This Issue: ***Should citizens determine funding for scientific research?***

Team Members **FOR**:

1. ____

2. ____

Team Members **AGAINST**:

1. ____

2. ____

Relevant facts:

Questions remaining:

HANDOUT

Main argument(s) FOR:	Main argument(s) AGAINST:
1. 2. 3	1. 2. 3.

List possible solutions (refer to the facts, remaining questions, and main arguments FOR and AGAINST):
Areas of agreement and disagreement:
Circle areas of agreement, above, to highlight common ground reached.

HANDOUT

Structured Academic Controversy Worksheet

This Issue: ***Should citizens determine funding for scientific research?***

Relevant facts:

- *The National Science Foundation (NSF) Budget is $6.9 billion.*
- *This represents about 0.2% of the federal budget, which is $37 trillion.*
- *The federal deficit (the difference between the budget and revenue) is $14 trillion.*
- *The NSF funds 20% of basic research in colleges and universities.*
- *In May 2011, Senator Colburn questioned studies that he believed had limited benefit to society and were therefore a waste of taxpayer money.*
- *Sometimes it may be hard for the average American to understand the relevance of basic research in science.*
- *There has been a call for more citizen oversight of the NSF and its grant process to reduce this perceived waste.*

Main argument(s) FOR:

1. *There is a $14 trillion dollar budget deficit, which means that we need to be very cautious about funding "scientific" projects (e.g., art projects or studies about avatars) that represent frivolous or silly projects.*
2. *If we avoid funding these projects that have questionable benefit to society, we will be able to provide more funding for more relevant studies, like bar coding, the internet, or cloud computing, that have a clear benefit to society.*
3. *Citizens should be able to flag the questionable studies for further review. This doesn't mean the studies will stop—it just means there will be further oversight. What are the scientists trying to hide when they don't want oversight?*
4. *Our tax money helps fund these projects, so we should have a say in how that money is distributed, especially if the government wants to be transparent about how it is spending its money.*
5. *Not even all of the NSF reviewers thought that the work was transformative—they obviously need to be able to speak up more.*

Main argument(s) AGAINST:

1. *The NSF has an extensive review process by experts in the field for every project that is funded. In this review process, the project's intellectual and societal impacts are evaluated.*
2. *Experts in one particular field are best positioned to evaluate studies, since they know the nuances and ins and outs of that particular study and can see how it will be relevant.*
3. *Much basic science research did not seem relevant at the time (e.g., laser, looking at cells under a microscope) but has proven to benefit society later on. You don't want to stifle science.*
4. *To remain competitive in the future, we need to continue to fund these projects that have been extensively reviewed, and only represent a fraction of a percent of the federal budget.*
5. *If the people who had criticized the work had actually talked to the researchers, the researchers could have told them the relevance of their projects. There is only so much you can put in an abstract on the NSF site, especially when you are submitting a proposal to experts in the field who understand background that the general public may not have.*

List possible solutions (many solutions are possible here):

1. *Keep the approval process as it is—there are enough checks and balances in the extensive peer review process the NSF undergoes to make sure that only relevant projects are funded.*
2. *Provide an extra step in the NSF review process that allows any citizen or concerned party (for example, a government representative) to review the proposals and vote on/bring up projects that waste taxpayer money. This would be done* ***before*** *money is given out.*
3. *Allow citizens to flag studies that concern them after reading the proposals on the NSF site so that they could be further reviewed by specific non-partisan experts if there are too many flags. Funding could be pulled if the research was determined not to be "transformative."*
4. *Add an additional oversight committee as an extra step in the review process, with a place for concerned citizens, relevant government representatives, and scientists in the field who will further review the projects. It should* **not** *just be scientists that review these projects. This does not mean that there won't be funding, it just means that there will be more oversight.*
5. *A group from the NSF, in a transparent process, should develop a document that clearly states their position on transformative science research and lays out more clearly the connections between basic science and societal impacts. This document should be used in the review process by all the reviewers, and should be open to citizen comment.*

Circle areas of agreement, above, to highlight common ground reached.

This depends on student conversations. If they have a hard time, have them think about either extreme (NO oversight to CONSTANT oversight) and then work toward the middle.

HANDOUT

STUDENT HANDOUT 5.2a

FOR: Citizens Should Have Input

Name____ Date________________ Period________________

The United States federal budget is complicated—Congress needs to prioritize spending and keep our government going. In tight budget times, all expenses need to be justified, and waste should be reduced. In April 2011, Senator Coburn of Oklahoma produced a report questioning some National Science Foundation (NSF) spending. NSF is the primary federal entity through which basic science research is funded with taxpayer money. Some people consider basic research to be a misuse of taxpayer funds, especially in tight budget times when we have a $14 trillion budget deficit.

Senator Coburn is a practicing physician and cancer survivor who has an understanding of and appreciation for the benefits of science research. He says that scientific research can, "…transform and improve our lives, advance our understanding of the world, and create meaningful new jobs" (Coburn, 2011). In his report, he recognizes that America needs to remain a leader in math and science, but expresses concern that some of the money invested in NSF research is wasted or misused.

Although the NSF has made significant contributions to science, a significant amount of money goes to research that many of us would consider wasteful, frivolous, or even fraudulent, according to the report. The NSF could contribute much more if its resources were better managed and if the studies that are chosen and funded were better supervised. This report identifies over $3 billion in potentially mismanaged funds at NSF, which has a yearly budget of $6.9 billion. This includes money spent on questionable studies, funds given out for research but not used, unnecessary overspending, and a lack of accountability in communicating study results.

Some of the dubious research questions NSF has funded include: how to ride a bike, whether boys like to play with trucks and girls with dolls, how rumors get started, how much housework a husband creates for his wife, and the best time to buy a ticket to a sold out sporting event. Most people would agree that NSF funds would be better spent on identifying more efficient, renewable fuels or fighting drug-resistant bacteria. NSF already has a peer-review process that checks for quality but this process does not effectively screen for worthwhile studies.

After this report was published, Representative Adrian Smith suggested that citizens who ultimately pay for research should have input into which studies the NSF funds. He proposed that citizens review the database of NSF proposals and flag questionable studies. These would then be investigated to determine whether the study had scientific value using guidelines suggested by Senator Coburn. Majority Leader Eric Cantor has launched a website, The *YouCut* Citizen Review of Government, where citizens can report misspending by government agencies. Citizens can search the NSF and report questionable grants that have been previously awarded. In these tough economic times, everyone is hurting, and we must be even more cautious about what is spent so that we are not funding something at the whim of a researcher. This way there will be more money available to worthwhile studies that will more directly benefit our society. Legitimate scientists should support this proposal since they will have more opportunity to get the funding they might have missed out on when unworthy studies get funded.

STUDENT HANDOUT 5.2b

AGAINST: Citizens Should NOT Have Input

Name____ Date_______________ Period_______________

The United States budget is complicated, and we always want to cut waste, but the amount of money spent on science is tiny compared to other areas. For example, the National Science Foundation (NSF) budget is $6.9 billion, which is much smaller than other departmental budgets including the Department of Homeland Security ($43.6 billion) and the Transportation Security Agency ($8.2 billion). Aside from arguments about the total budget of the NSF, citizens are not qualified to see the value of these basic science studies. There are many basic science studies done in the past that would not have seemed valuable to people at the time, but later resulted in amazing advancements. For example, the laser was developed in the 1950s after years of basic science research. When the laser was developed, it had no practical application. Some could argue that it was just physicists "playing with different forms of light," but without this basic research, we would not have CDs, DVDs, the laser printer, laser surgery, etc. Citizens at the time may not have seen the potential value of the laser, as it did not have any applications at the time.

The following is from an article from *Live Science*, a scientific news aggregation website and blog:

> Although a new report by Senator Coburn identifies major contributions of NSF projects and describes the NSF's rigorous analysis of grant proposals, it is critical of some of the projects.
>
> Scientists whose work is criticized in the report say that their research was oversimplified or misrepresented. In some cases a small project which is part of a larger research program is looked at in isolation. For example, the report describes one research project as an experiment to determine whether "boys like trucks and girls like dolls." In fact, Gerianne Alexander, the researcher involved, said the research project is more complicated. This piece of the study is used to evaluate behavior changes resulting from a surge in testosterone levels in infancy. This may potentially help us understand and treat disorders such as autism and ADHD. Another project ridiculed for putting "shrimp on a treadmill" was part of a study on environmental stress in marine animals. In another study, described as teaching robots to fold laundry, the goal was to determine how to make robots that can "interact with complex objects." This has potential for helping the elderly and disabled live more independent lives.

Researchers who were contacted for this article acknowledge the importance of assessing the value of a scientific study but are not convinced that involving the public is the way to do so. Hibbing, one of the researchers discussed in Senator Coburn's study, said, "…it was a 'dangerous' idea to base research funding decisions on a cursory review of findings given that it can be difficult to tell from the early stages of research which avenues will be important."

Discovery in science is not always clear. There are a number of studies that may not be easily understood by reading the abstract submitted to the NSF. In NSF's own words, "in addition to funding research in the traditional academic areas, the agency also supports 'high-risk, high pay-off' ideas, novel [original] collaborations, and numerous projects that may seem like science fiction today, but which the public will take for granted tomorrow" (NSF, 2010 April).

Normal citizens, and even scientists who are out of their field, don't have enough expertise to accurately judge both the intellectual and societal impact of project proposals. Just as you would want a chef judging the work of other chefs, you want an expert in the field judging the scientists' work.

STUDENT HANDOUT 5.3

Homework: Your Own Stand On Science Funding

Name____ Date_______________ Period_______________

1. Were you surprised at the federal budget and how much money the U.S. spends on science research compared to other parts of the budget? Explain.

2. Do you think that the government should fund scientific research at its current levels? Or should spending on research be expanded? Reduced? Explain.

3. Earlier lessons have shown how basic research may eventually lead to studies involving animals and human subjects with the aim of creating a medicine, therapy, or medical device that improves health (the Translational Research Cycle). Think about how you would prioritize each step along the way. Do you think that basic science research, which may or may not even lead to advances in human health, should be more or less a priority than other parts of the Translational Research Cycle? Explain.

HANDOUT

4. Who do you think should be deciding how much money should be spent on basic science research? Explain.

5. Do you think that it is important to be skeptical when you hear science stories (or any stories) in the news? Explain how you saw this in the *Activity*.

6. Do you think it is important to look at the original research papers before you make a decision about the strength of science research? Why or why not?

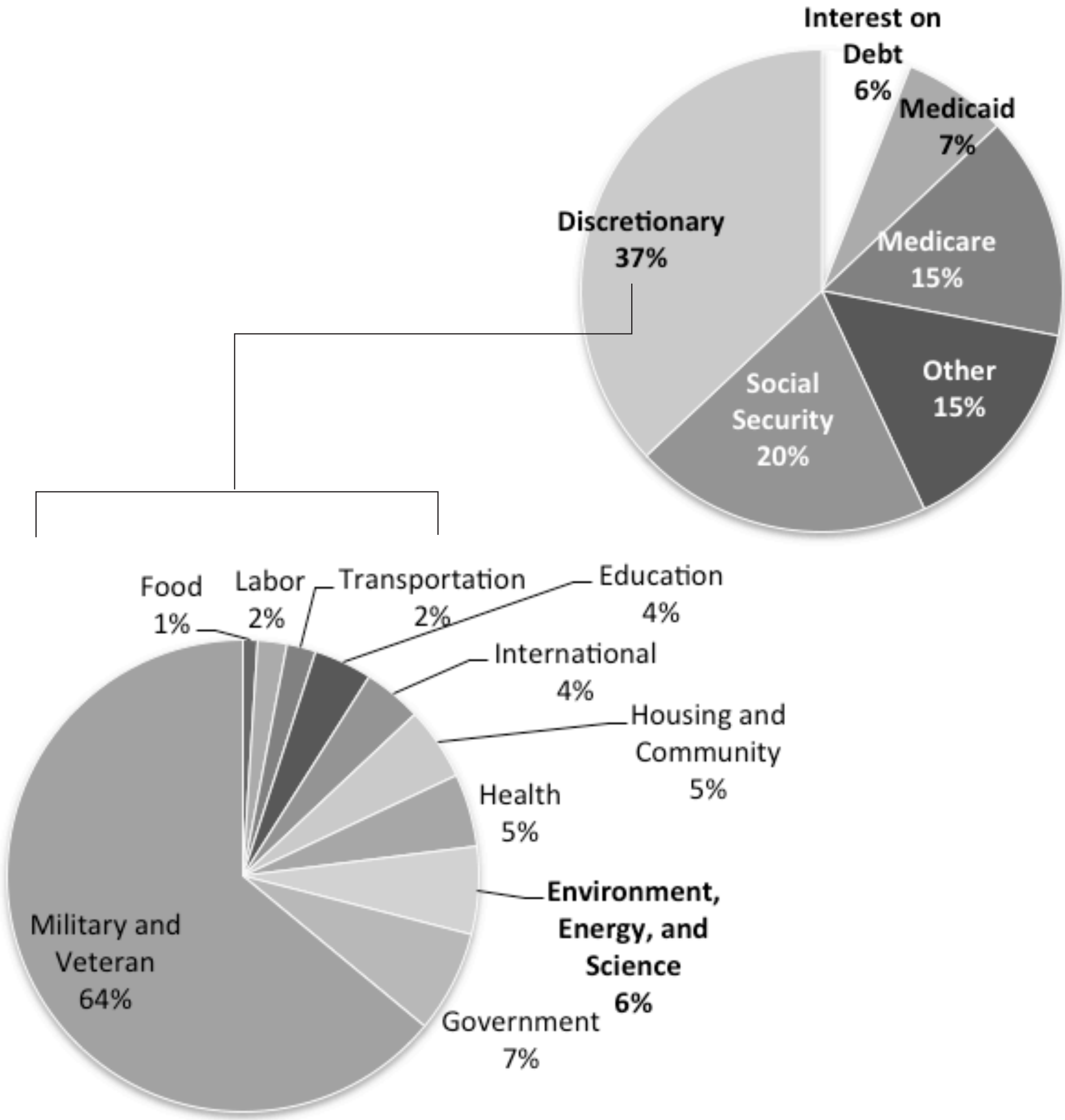
7. What sort of action can you take on this issue personally, especially when you are talking with friends or family and you hear stories in the news or read articles on blogs or websites?

HANDOUT

The Federal Budget: How Do We Spend Our Money?

The $6.9 billion that the federal government uses to fund the National Science Foundation (NSF) seems like a lot of money, but how does it compare to the rest of the federal budget? To compare expenditures, the relative amounts of money spent also need to be compared. The federal budget is around $3.7 trillion. The budget is broken up into mandatory spending, which is about 2/3 of the total budget, and discretionary spending, which Congress reviews every year and can increase or decrease depending on national priorities.

United States Federal Budget



U.S. Discretionary Spending

Source: Congressional Budget Office. (2011). *Reducing the deficit: Spending and revenue options*. Washington, DC: U.S. Government Printing Office.

RESOURCE

Summative Assessment

INTRODUCTION

Students apply the concepts they have learned during the unit to a case study or other chosen material from the class. From their completed graphic organizers, students choose three concepts to evaluate and explain how the concept contributes to the process of scientific research. Students also communicate the importance of being scientifically literate in their roles as science students, members of society, users of medications, and potential voters and taxpayers.

CLASS TIME

One class period of 55 minutes to begin; it may be continued as homework, if desired.

KEY CONCEPTS

- The process of scientific research requires active participation from scientists, consumers, and citizens.
- A scientifically literate person has a clear understanding of the social nature of scientific research, including the practices and processes involved.
- The ethical conduct of scientific research leads to a process that promotes accountability, integrity, and intellectual honesty.

LEARNING OBJECTIVES

Students will be able to:

- Demonstrate their ability to identify and apply their roles and responsibilities as scientifically literate citizens in multiple venues.
- Define three concepts, identify the importance of each, and give examples of their applications.

MATERIALS

Materials	Quantity
Student Handout—*Case Study: Searching for a Cause*	1 per student
Optional: Student Handout—*Case Study Supplementary Information*	1 per student
Student Handout—*Summative Assessment*	1 per student
Completed *Unit Graphic Organizer* from the *Formative Assessment* activity	1 per student
Teacher Resource—*Summative Graphic Organizer*	1
Teacher Resource—*Scoring Rubric for Summative Assessment*	1

Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity.

~National Academy of Sciences

NOTE TO THE TEACHER

Use the *Summative Assessment* to assess student understanding of concepts presented in the lessons in this curriculum. Use Teacher Resource—*Scoring Rubric for Summative Assessment* to score student responses.

TEACHER PREPARATION

- Make copies of *Student Handouts*, one per student.

PROCEDURE

1. As the assessment requires a completed *Unit Graphic Organizer* (from the *Formative Assessment*), make sure that students have written in the necessary ideas and concepts for each column. A completed copy can be found on Teacher Resource—*Summative Graphic Organizer*.
2. Pass out copies of Student Handout—*Case Study: Searching for a Cause*, one per student. Allow time for students to read the case study.
3. For teachers or students wanting more depth, pass out the supplementary information found on Student Handout—*Case Study Supplementary Information*.
4. Pass out copies of Student Handout—*Summative Assessment*, one per student. Follow the instructions on the handout.
5. Students should be encouraged to present the information in a way that best suits them, such as an essay, a PowerPoint presentation, a Prezi, or a speech. You may allow students to choose their own medium, or you may choose the format that you want students to use.

GLOSSARY

Advocacy group: An interest group working on behalf of a particular cause.

Blinded study: A study in which researchers do not know which samples are from patients with a disease (in this case, CFS) and which samples are controls from healthy individuals.

Hypochondriac: A person who is convinced he or she is ill, or will become ill, even though there is no disease.

Lobby: To attempt to influence public officials and legislators to promote a specific cause.

Randomization (randomized): The process of assigning study participants to two or more alternative treatments by chance, such as by flipping a coin or rolling a dice.

Replicate: To reproduce or duplicate; to achieve the same study results by following the same study protocol.

Retract: To formally take back or withdraw a statement as invalid.

Retrovirus: Any of a group of viruses that store genetic information as RNA, not DNA. HIV is an example of a retrovirus.

Study design: A strategic approach to carrying out medical research, often involving "blinding" researchers and participants, randomizing samples, and using placebos (fake "sugar pills") when applicable.

SOURCES

Callaway, E. (2012). The scientist who put the nail in XMRV's coffin. *Nature*. Retrieved from http://www.nature.com/news/the-scientist-who-put-the-nail-in-xmrv-s-coffin-1.11444

Center for Disease Control and Prevention, *CFS case definition*. Retrieved from http://www.cdc.gov/cfs/case-definition/index.html

Cohen, J., and Enserink, M. (2011). False positive. *Science 333*, 1694-1701.

Marcus, A. D. (2011). Scientist who led XMRV research team let go. *Wall Street Journal Health blog*. Retrieved from http://blogs.wsj.com/health/2011/10/03/scientist-who-led-xmrv-research-team-let-go/

Case Study: Searching for a Cause

Name____ Date______________ Period______________

Something was wrong. I was sleeping for hours but waking up exhausted. I had fevers, muscle aches, and headaches—I felt like I had the flu, but it just wouldn't go away. This went on for weeks, which turned to months, then years. My forgetfulness, irritability, and fatigue were causing problems at home, at school, and at work. The doctors I visited were concerned, but test after test could not confirm a diagnosis. Some doctors treated me like I was a **hypochondriac**, or like my symptoms were all in my head.

After years of suffering, I was finally diagnosed with Chronic Fatigue Syndrome (CFS). I was relieved to have a name to put with my symptoms, and it helped to be able to give my friends and family the name of ***something***. Unfortunately, nobody knows what causes CFS and there are no specific tests to diagnose the condition. Worse, some in the medical community still don't recognize CFS as a "real" medical condition and refuse to treat it. Looking for support and direction, I joined a patient **advocacy group** of people suffering with CFS, their families, and caregivers. Together, we are trying to change attitudes about CFS and **lobby** for increased funding for research.

There can be no cure for CFS without first finding a cause. In 2009, we had some exciting news: Judy Mikovits from the Whittemore Peterson Institute (WPI) published an article in the respected journal *Science* showing that a **retrovirus** was found in blood samples of the majority of the CFS patients she examined. Mikovits and her Nevada-based team had collaborated with three other partners in the U.S. to publish the study. The study findings were exciting to both the scientific and CFS communities.

While the publication in *Science* seemed promising and was considered a "game changer" by advocacy groups, other scientists became skeptical when reviewing the data. Even the peer-review process for publication brought up a number of concerns, such as the possibility of patient samples being contaminated by the retrovirus. This, along with other reservations, was addressed by Mikovits and her co-authors before publication. Nevertheless, after publication a research group from London wrote to *Science* addressing what they considered to be flaws in the paper. Among other things, they pointed out flaws in the study design: Mikovits and her team had not **randomized** and **blinded** patient and control samples. In addition, all of the CFS patients were from Nevada and all of the healthy controls were from elsewhere; perhaps there was an environmental explanation.

With these concerns aired, a number of research teams attempted to **replicate** the data. That's when my hopes for a link between the retrovirus and CFS started to fade. The British team reported that they could not find the retrovirus in ***any*** of their CFS patients. Two more negative reports followed, then others. Amidst the accusations and criticisms, however, Judy Mikovits would not back away from her claim. She was steadfast in defense of the work and the methods she and her team used to get their results. When asked to voluntarily **retract** her paper from *Science*, she refused. As a person with CFS, I didn't know what to think. Judy Mikovits had worked tirelessly for so long to find a cause of CFS and it seemed to me she was being harassed by the scientific establishment. It was hard to watch my patient advocacy group—a group so hungry for progress—torn apart by the conflicting reports.

The U.S. government-funded National Institutes of Health (NIH) stepped into the debate during this time, contributing $2.3 million to fund a study to test 150 samples from CFS patients. A solid **study design** was decided upon and the samples were sent to multiple labs throughout the U.S. After waiting impatiently, we were discouraged to read that the study results showed there is no evidence to support the link between the retrovirus and chronic fatigue syndrome. Even before the results were released, the journal *Science* fully **retracted** Judy Mikovits's article from 2009.

I wish I could say the story ended there, but it doesn't. Judy Mikovits was ordered to turn over lab materials to another scientist at the institute and refused. She was fired from her job as research director at WPI. She was then accused of stealing notebooks from the institute, was arrested, and even jailed for a short time. She still stands by her work, however. While an outsider now among scientists, she is a hero for many in the CFS community.

Some people think this whole saga shows what is wrong with science—in this case, poor **study design**, contamination in the lab, refusing to share data, strong personalities, and lots of money leading to conflicting evidence and a confusing message. But I also see how it shows that science ***is*** working. It shows how collaboration, communication, and skepticism play out. It shows how citizen groups and social forces influence science. It shows the need for new cures and treatments and how basic science gets the ball rolling. It also puts a human face on the research endeavor for me—scientists are people invested in their work. In the end I have to hope that this process will, eventually, find a cause and then a cure for CFS. Because I still wake up in the morning exhausted.

This summary is based on a true story. Please see the ***Sources*** section of the lesson plan for source information.

Case Study Glossary

Advocacy group: An interest group working on behalf of a particular cause.

Blinded study: A study in which researchers do not know which samples are from patients with a disease (in this case, CFS) and which samples are controls from healthy individuals.

Hypochondriac: A person who is convinced he or she is ill, or will become ill, even though there is no disease.

Lobby: To attempt to influence public officials and legislators to promote a specific cause.

Randomization (randomized): The process of assigning study participants to two or more alternative treatments by chance, such as by flipping a coin or rolling a dice.

Replicate: To reproduce or duplicate; to achieve the same study results by following the same study protocol.

Retract: To formally take back or withdraw a statement as invalid.

Retrovirus: Any of a group of viruses that store genetic information as RNA, not DNA. HIV is an example of a retrovirus.

Study design: A strategic approach to carrying out medical research, often involving "blinding" researchers and participants, randomizing samples and using placebos (fake "sugar pills") when applicable.

STUDENT HANDOUT
Case Study Supplementary Information

Name____ Date_____________ Period_____________

Optional supplementary case study information:

- The retrovirus reported by Mikovits and her partners is a mouse retrovirus called XMRV. This stands for Xenotropic murine leukemia virus-related virus.
- Over the years, many different viruses have been evaluated as the cause of CFS. The scientific community had considered, and dismissed, Epstein-Barr virus, Adenovirus, HTLV I and II, plus others as the cause of CFS. The hopes of people with CFS and their families have been raised and dashed many times already. This string of disappointments has made many people cautious.
- In their letter to the journal *Science*, the British team noted that it was odd that so many CFS patients were infected with the identical virus, since CFS is such an ill-defined syndrome with so many types of people affected.
- The institution where Judy Mikovits worked, Whittemore Peterson Institute for Neuro-Immune Disease (WPI), was founded by the Whittemore family after the diagnosis of their 12-year-old daughter with CFS.
- A test to detect XMRV in a patient's blood was produced, and a commercial lab offering the test opened in Nevada with financial support from the Whittemore family. The cost of the test is about $500. This drew some criticism, as the people behind the institute supporting the XMRV-CFS link were also the people to benefit from a costly test for the retrovirus.
- Some people with CFS who tested positive using the XMRV test proceeded to use anti-retroviral drugs already FDA-approved for HIV and AIDS patients.

Summative Assessment

Name____ Date_______________ Period_______________

Throughout this unit we have explored the practices and processes of scientific research. We have seen the interconnection between the research process, the relationship between science and society, translational research, and what it means to be a scientifically literate citizen.

Using your completed graphic organizer as your guide, choose ***three concepts*** from the graphic organizer to expand upon. Choose one element from the "Research Process" section (first column), one from the "Role of Science and Society" section (second column), and one from the "Translational Research" section (third column). For each of your chosen concepts:

a. ***Define*** the concept (what does the word mean?)

b. ***Identify*** its importance (how and why is it necessary?)

c. ***Give a real-world example*** of how it is applied (or, inversely, a real-world example of repercussions if it is not applied correctly).

You may use the assessment case study, "Searching for a Cause," or any other materials you have used or learned during this unit to help you with the assessment (see below).

The closing of your assessment should address ***the importance of being a scientifically literate citizen*** (fourth column of the graphic organizer). How does what you've learned apply to your role as a science student, a member of society, a user of medications and treatments, a potential taxpayer, and a future voter?

Complete answers should be supported with examples from classroom discussions, activities, and readings, as well as specific examples of actions you can take to demonstrate the need for scientific literacy. Use the attached scoring rubric to guide you in completing this assignment.

You may choose to show what you know through an essay, a PowerPoint presentation, a speech, a Prezi, or other medium (or your teacher will choose the assessment format).

Other possible sources of information include:

Brody, J. E. (2010 January 18). Living with a formerly fatal blood cancer. *The New York Times*. Retrieved from http://www.nytimes.com/2010/01/19/health/19brod.html?_r=1

Nowell, P. C. (2007). Discovery of the Philadelphia chromosome: A personal perspective. *The Journal of Clinical Investigation 117* (8) 2033-35. Retrieved from http://www.jci.org/articles/view/31771

Summative Graphic Organizer

SUBSYSTEMS OF SCIENTIFIC RESEARCH

Research Process	Role of Science and Society	Translational Research	Being a Scientifically Literate Citizen
Communication Collaboration Skepticism Peer review Publication Repeatable trials Integrity Persistence despite setbacks	Citizens and social needs influence research directions Society funds the research it values Media influences societal views of science	Basic science Discovery of new ideas Animal trials Human trials New cures and treatments Ethical guidelines	Understanding practices and processes as a: Student Member of society Consumer of medications and treatments Tax payer Voter

Scoring Rubric for Summative Assessment

Exemplary	Proficient	Partially proficient	Developing
Using the graphic organizer, student is able to ***define four concepts, identify their importance, and give examples of their applications***.			
Concepts are ***well-defined***. Student accurately uses vocabulary and has ***numerous examples*** to explain the importance of the concepts and their applications in an authentic, clear, and easily understood manner.	Concepts are ***well-defined***. Student accurately uses vocabulary and ***some examples*** to explain these concepts and their applications in an authentic, clear, and easily understood manner.	Concepts are ***partially*** defined. Student accurately uses vocabulary and examples to explain these concepts and their applications but is lacking authenticity, clarity, and/or contains ***minor errors*** in understanding.	Concepts are ***poorly*** defined. Student uses vocabulary and examples to explain these concepts and their applications but is lacking authenticity, clarity, and contains ***major errors*** in understanding.
Student is able to ***apply and interpret his role*** as a scientifically literate citizen by identifying and explaining how his actions in multiple settings will reflect his knowledge of the process of scientific research.			
Explanation shows a ***deep understanding***, is authentic, clear, and easily understood, and accurately uses images, anecdotes, and/or analogies.	Explanation is authentic, clear, and ***easily understood*** and accurately uses images, anecdotes, and/or analogies.	Explanation uses images, anecdotes, and/or analogies, but is ***lacking*** authenticity and/or clarity. Contains ***minor errors*** in understanding.	Explanation uses images, anecdotes, and/or analogies, but is ***lacking*** authenticity and/or clarity. Contains ***major errors*** in understanding.

RESOURCE

APPENDIX

TABLE OF CONTENTS

MASTER GLOSSARY

Absolute stupidity: A complete lack of knowledge or understanding of a given topic.

Advocacy group: An interest group working on behalf of a particular cause.

Applied research: Research that relates to human health care in the form of treatments or cures of human diseases. Applied research is often conducted by for-profit companies.

Basic research: Research that furthers general scientific understanding of how the natural world works. This is often academic research.

Belmont Principles: These Principles inform and guide researchers working with human participants. They are:

- ***Respect for Persons:*** Respect for individuals and their ***autonomy***; obtain informed consent.
- ***Maximize Benefits/Minimize Harms:*** This stresses "doing good" and "doing no harm" by minimizing all potential harm(s) and maximizing potential benefit(s) to the subject as well as potential benefit to society.
- ***Justice:*** Be fair in distributing the benefits and burdens of research.

Blinded study: A study in which researchers do not know which samples are from patients with a disease (in this case, CFS) and which samples are controls from healthy individuals.

Chromosome: A strand of DNA and associated proteins that contains genetic information.

Clinical trials phases: Clinical trials are conducted in three or four phases. Each phase has a different purpose to help researchers answer different questions. Following is an overview of each phase:

- **Phase I**—An experimental drug or treatment is tried on a small group of people (fewer than 100). The purpose is to evaluate its safety, potential dosage, and identify any side effects.
- **Phase II**—The experimental drug or treatment is administered to a larger group of people (several hundred) to further assess safety, and to address issues such as optimal dosing and frequency of dose administration.
- **Phase III**—The experimental drug or treatment is administered to large groups of people (several thousand) to determine its effectiveness, further monitor safety, and compare it with standard or equivalent treatments.
- **Phase IV**—After a drug is licensed by the FDA, researchers track its safety, seeking more information about its risks, benefits, and best use in "real-world" settings.

CML: Chronic Myelogenous Leukemia. A specific form of cancer that affects white blood cells.

Collaboration: Working together to create something, solve a problem, or answer a question.

Communication: Sharing information with others.

Diffusion: The passive movement of molecules from an area of high concentration to an area of lower concentration.

Discretionary: Available to be used as needed or desired; discretionary spending refers to the fraction of the budget that Congress can spend as it chooses each year.

Enzyme: A protein or molecule that speeds up a chemical reaction in a living cell.

Graduate student: A person who has earned a college degree and is pursuing additional education, such as a master's degree or PhD.

Hypochondriac: A person who is convinced he or she is ill, or will become ill, even though there is no disease.

Integrity: Honesty and truthfulness in one's research; avoiding cheating and plagiarism.

In vitro: "In glass," referring to an experiment done in a test tube or an artificial, non-living system.

Leukemia: Any cancer that affects normal production of blood cells.

Lobby: To attempt to influence public officials and legislators to promote a specific cause.

Objective: Not influenced by personal feelings or opinions when considering or representing facts.

Oncogene: A gene that contributes to the production of a cancer; usually a mutated form of a normal gene.

Orphan disease: In the U.S. an orphan disease, or rare disease, affects fewer than 1 in 1,500 people. They are mostly genetic conditions passed on from parent to child.

Peer review: The evaluation of scientific work or findings by others working in the same scientific field.

PhD student: A person pursuing a doctorate degree, the highest degree awarded for graduate study.

Polymer: A molecule or compound made up of several repeating units.

Productively stupid/Productive stupidity: The attribute of realizing how little one knows in order to develop good questions.

Randomization (randomized): The process of assigning study participants to two or more alternative treatments by chance, such as by flipping a coin or rolling a dice.

Relative stupidity: Willful indifference to becoming informed or enlightened, especially in relation to others who make the effort to read, learn, or think about important material.

Repeatable trials: A feature of a valid scientific experiment, meaning it can be performed multiple times and produce the same or similar results.

Replicate: To reproduce or duplicate; to achieve the same study results by following the same study protocol.

Retract: To formally take back or withdraw a statement as invalid.

Retrovirus: Any of a group of viruses that store genetic information as RNA, not DNA. HIV is an example of a retrovirus.

Skepticism: A doubting or questioning attitude or state of mind.

Serendipity: The phenomenon of making fortunate discoveries by accident, or discovering valuable things while looking for something else.

Study design: A strategic approach to carrying out medical research, often involving "blinding" researchers and participants, randomizing samples, and using placebos (fake "sugar pills") when applicable.

Subjective: Based on or influenced by personal feelings, tastes, or opinions.

Translational research: The process of connecting basic research to applied medicine or treatment; sometimes described as "From Bench to Bedside."

Translocation: Movement of a fragment of one chromosome to a different chromosome.

Transparency: The quality of a scientific experiment or other process that allows others to easily see what actions have been performed.

Undergraduate student: A person studying at a university or college after high school with the goal of earning a bachelor's degree. This is usually a four-year degree.

3 Rs of animal research:

- **Replacement:** Replacing conscious, living vertebrates with cell or tissue cultures, computer models, simulation models, and/or less developed animal species.
- **Reduction:** Using the fewest number of animals possible in a research project to gain valid results.
- **Refinement:** Using any technique or procedure that minimizes distress or enriches the life of an animal used in research.

CRITICAL ANALYSIS TOOLS

INTRODUCTION

This section contains two supplementary student handouts that support students in the review and analysis of resources. They can be used at any time during this unit or during the school year, independently or together. Some teachers suggest that students review and analyze articles before beginning *The Social Nature of Scientific Research* to become more comfortable with formulating and criticizing arguments.

Student Handout—*Media Review and Analysis* can be used to support students in analyzing media for purpose, perspective, assumptions, claims, and impact. This handout can be used in any subject and for most types of media. An optional section on ***scientific process*** can be used for students analyzing scientific articles. Students are further supported in thoughtful analysis by using Student Handout—*My Evolution of Thought*, which helps students identify their attitude toward a subject before and after analysis. These tools help students explore the importance of scientific literacy in a world impacted by mass media.

KEY CONCEPTS

- It is important to understand an author's purpose, perspective, assumptions, and claims to fully analyze and evaluate an article.
- Science is a human endeavor and, as such, can be done poorly and can be misused. Science is subject to bias, and unconfirmed claims can be presented as "scientific fact."
- When done well, science is critically assessed by the community, where findings can be strengthened and/or errors, oversights, and fraud exposed.

LEARNING OBJECTIVES

Students will be able to:

- Use critical thinking tools to analyze and evaluate science stories in the media
- Question information, conclusions, and points of view.

Some common student misconceptions include:

- If a science story is presented in a media source, it must be factual.
- All sources with titles of MD or PhD are trustworthy.
- Most media sources are equally credible.
- Stories about science are not biased because they are based on fact.

PROCEDURE

1. These student handouts can be used in a variety of ways, as best determined by the teacher. One or both handouts could be used to help students evaluate:
   - Newspaper articles
   - Articles from popular magazines
   - Scientific journal articles
   - TED talks
   - Claims found in dietary supplement advertisements
   - Claims found in cosmetic advertisements
   - A series of articles supporting or refuting one topic (i.e., global warming)
   - Websites or written information from advocacy groups
   - Pro/con videos on a subject found on YouTube or other multimedia source
2. Using discretion, it can be helpful to print out selected reader/viewer comments from the media source used. These comments can be cut out and given to individual students. Working in teams or as a class, students can work to identify facts that may be missing, alternate viewpoints on the issue, faulty claims, social significance, and perspective. Readers often have a hard time recognizing "what is missing" until it is pointed out by other readers. Of course, the reader comments themselves can be evaluated and analyzed as well.

STUDENT RESOURCES

Many teachers ask students to analyze newspaper or magazine articles or current events. The following resources support student analysis or provide student-accessible science articles.

- NWABR's ***Consumer Awareness*** curriculum contains a lesson in which students discuss the importance of sources of information and talk about the criteria for evaluating scientific papers. Students also identify information sources to refute or support the science behind advertising claims for cosmetic products. *Lesson Four* of the Consumer Awareness curriculum can be found under the *Teacher Tab* at http://nwabr.org.
- An interesting short video set on the use of animals to help cure breast cancer can be found here:

  Jen's Story—The original video (1:00 minute)
  http://www.youtube.com/watch?v=NT4lLIDsjGA

  Jen's Real Story—The parody (1:29 minutes)
  http://www.youtube.com/watch?v=lcyshYXdtRI
- Student-accessible science article can be found at:

  LiveScience
  http://www.livescience.com

  ScienceDaily
  http://www.sciencedaily.com

TEACHER RESOURCES

This lesson is rooted in the concepts and tools of critical thinking. The Foundation for Critical Thinking has distilled the concepts of critical thinking into a very useful 20-page pocket guide, *The Miniature Guide to Critical Thinking: Concepts and Tools*, available at:

The Critical Thinking Community
http://www.Criticalthinking.org

The ENSI (Evolution and the Nature of Science Institute) website has a wealth of helpful information on the nature of science.

ENSI—What is the Nature of Science?
http://www.indiana.edu/~ensiweb/nos.html

STUDENT HANDOUT
Media Review and Analysis

Name____ Date______________ Period______________

BASIC INFORMATION
Article Name
Author(s)
Source (book title, website address, magazine name, etc.)
Location (page number, issue, etc.)
Date Accessed

BASIC ANALYSIS
1. What claims were made in the source?
2. What ***scientific*** facts/concepts does the author use to support this claim? 3. What is the significance and relevance of these facts/concepts?
4. What ***social*** facts/concepts does the author use to support this claim? 5. What is the significance and relevance of these facts/concepts?
6. What inferences (explanations based on observation) does the author make to support this claim?
7. What assumptions (thoughts/ideas we take for granted and do not question) does the author make to support this claim?

PERSPECTIVE

8. What points of view are presented in this source? Does this present any concerns about the validity of the article's claims? Why or why not?

9. What points of view are ***not*** presented in this source? Does this present any concerns about the validity of the article's claims? Why or why not?

10. Who is the intended audience for this source? Does this present any concerns about the validity of the article's claims? Why or why not?

APPLICATION TO SOCIETY

11. Do the claims presented in this source have ***social*** value (do they impact you, your family, your community, etc.)? Why or why not?

12. Do the claims presented in this source have ***scientific*** value (can they lead to more research or discoveries)? Why or why not?

13. What consequences are likely to follow if people read this and take it seriously?

14. What consequences are likely to follow if people read this and ***do not*** take it seriously?

HANDOUT

SCIENTIFIC PROCESS *(Only complete if this source refers to scientific research or advancement)*

15. What process was used to collect the data that were used to support the claims made in this source? (If the process is unclear, explain what that means for the validity and/or reliability of the claims presented.)
16. Are there any problems and/or concerns with the process used to collect the data that are presented? Why are these problems and/or concerns?
17. How were the data analyzed? Does this fit with accepted scientific practice concerning the treatment of data?
18. Does the process presented minimize risks and increase benefit in an ethically justifiable manner? Why or why not?
19. Was this research reviewed by multiple third parties? What does this mean for the validity and reliability of the claims presented in the source?
20. If this research included human subjects, did researchers get informed consent? How well informed were the subjects?

FINAL ANALYSIS

21. Is this a valid and reliable source for your use?
22. Why or why not? (Be specific using the analysis you performed above!)

HANDOUT

My Evolution of Thought

Name____ Date_______________ Period_______________

ARTICLE REVIEW

1. This article is about __________________________. ***Before*** reading the article, answer the following questions:
   a. What do you know about this topic?

   b. What are your current thoughts and/or feelings about it?

   c. How do you think science is involved?

   d. What point or claims do you think this article will make?

   e. Why do you think that? (Be specific!)

2. Read the article through once without making notes or highlights. Simply read it and then answer the following questions:
   a. What are your initial thoughts and feelings about the subject of this article?

   b. Why do you think and feel that? (Be specific!)

3. Read the article through a second time, this time using the following technique:

   a. Underline any part that identifies or discusses the scientific process used in the research.

   b. Circle any part that identifies the author's point of view or opinions.

   c. Box any part that identifies potential ethical considerations and write a quick two or three word note to help you remember why this concerns you

CREATING DISCUSSION GROUND RULES

INTRODUCTION

The study of ethics involves considering moral choices and dilemmas about which reasonable people may disagree. Since a wide range of positions is likely to be found among students in most classrooms, it is especially important to foster a safe classroom atmosphere by creating some discussion ground rules. These ground rules are often referred to as "norms." An agreed-upon set of ground rules should be in place before beginning the *Social Nature of Scientific Research* curriculum.

LEARNING OBJECTIVES

Students will be able to:

- Create and agree to classroom discussion norms.

PROCEDURE

1. Ask the students, "What can we do to make this a safe and comfortable group for discussing issues that might be controversial or difficult? What ground rules should we set up?"
2. Allow students some quiet reflection time, and then gather ideas from the group in a brainstorming session. One method is to ask students to generate a list of ground rules in small groups and then ask each group to share one rule until all have been listed. Clarify and consolidate the ground rules as necessary.
3. Post norms where they can be seen by all and revisit them often. If a discussion gets overly contentious at any time, it is helpful to stop and refer to the ground rules as a class to determine whether they have been upheld.
4. Some possible student ground rules/norms could include:
   - A bioethics discussion is not a competition or a debate with a winner and a loser.
   - Everyone will respect the different viewpoints expressed.
   - If conflicts arise during discussion, they must be resolved in a manner that retains everyone's dignity.
   - Everyone has an equal voice.
   - Interruptions are not allowed and no one person is allowed to dominate the discussion.
   - All are responsible for following and enforcing the rules.
   - Critique ideas, not people.
   - Assume good intent.

SOCRATIC SEMINAR BACKGROUND

BACKGROUND ON THE SOCRATIC SEMINAR

In a Socratic Seminar discussion, the participants carry the burden of responsibility for the quality of the discussion. Good discussions occur when participants study the text closely in advance, listen actively, share their ideas and questions in response to the ideas and questions of others, and search for evidence in the text to support their ideas. The discussion is not about right answers; it is not a debate. Students are encouraged to think out loud and to exchange ideas openly while examining ideas in a rigorous, thoughtful manner.

In a Socratic Seminar, there are several basic elements:

- A text containing important and powerful ideas (it could be an article, film clip, etc.) that is shared with all participants. It is helpful to number the paragraphs in a text so that participants can easily refer to passages.
- A distinctive classroom environment; seating students in a circle and using name cards helps facilitate discussion. The students should have a clear understanding of the discussion norms, which should be prominently posted.
- An opening question that requires interpretation of the text and is genuine (one where there is not an easy, predetermined answer). For example, "What is the most important passage?" or "What is the author driving at in the text?" Recommended questions can be found in the *Procedure* section of the lesson plan

PROCEDURE

Before the Socratic Seminar

1. Introduce the seminar and its purpose: to facilitate a deeper understanding of the ideas and values in the text through shared discussion.
2. Have students read the article(s). It is important that every student reads the text, since the quality of the discussion depends on contributions from each participant. It may be helpful to allow time in class for students to read the article(s).
3. In addition to the classroom discussion norms you may have already set, it is important to include the following norms:
   - Don't raise hands.
   - Listen carefully.
   - Address one another respectfully.
   - Base any opinions on the text.

During the Socratic Seminar Fishbowl Discussion

4. To create the discussion groups, divide the class in half and form two circles (an inner circle and an outer circle). The inner circle is engaged in the discussion, and the students in the outer circle are listening to the inner circle discussion. Students in the outer circle take notes and write down ideas or comments on what they hear in the inner circle discussion. After approximately 10 minutes (or another appropriate time period), the circles flip so that students in the inner circle and outer circle trade places.
5. To begin the discussion, the teacher/facilitator may pose the guiding question(s) or the participants may agree upon questions to begin the discussion.

   Sample questions to serve as the key question or to interpret the text:

   - What is the main idea or underlying value in the text?
   - What is the author's purpose or perspective?
   - What are the ethical concerns raised by the text?
   - What does (a particular phrase) mean?
   - What is the most important word/sentence/paragraph?

Sample questions to move the discussion along:

- Who has a different perspective?
- Who has not yet had a chance to speak?
- Where do you find evidence for that in the text?
- Can you clarify what you mean by that?
- How does that relate to what (someone else) said?
- Is there something in the text that is unclear to you?
- Has anyone changed her mind?

Sample questions to bring the discussion back to students in closing:

- How do the ideas in the text relate to our lives? What do they mean for us personally?
- Why is this material important?
- Is it right that…? Do you agree with the author?

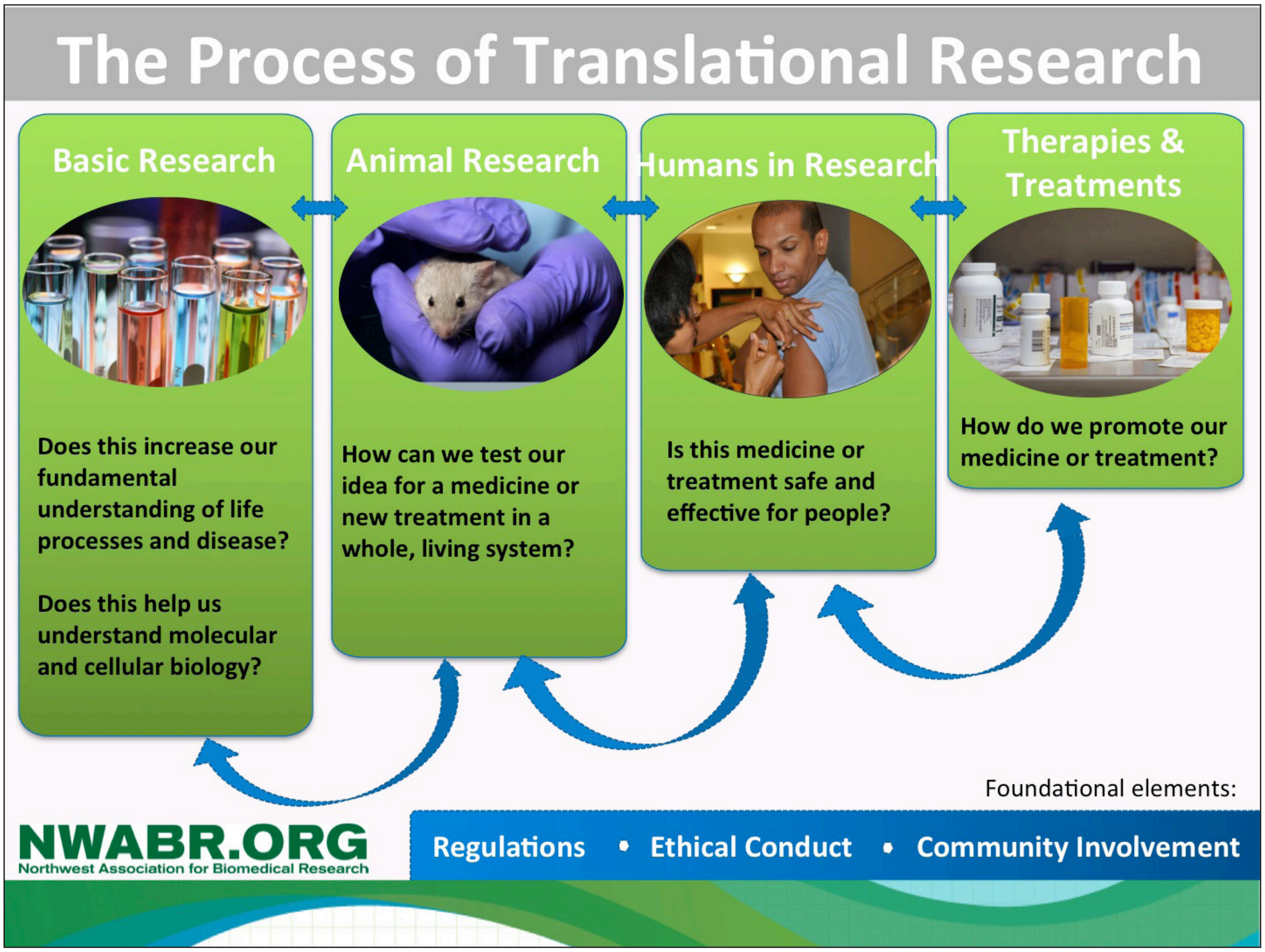
6. The teacher can choose to facilitate the discussion by asking clarifying questions, summarizing comments, and highlighting understandings and misunderstandings. Teachers can restate the opening question if the conversation gets off track, or ask for different ideas if it stalls.
7. Later in the discussion, questions that refer to the experiences of the students and their own judgments can also be used. For example, "Is it right that….?" or "Do you agree with the author?" or "Has anyone changed his mind?" These do not require reference to the text to be answered.

After the Seminar

8. Ask everyone questions such as: "Do you feel like you understand the text(s) at a deeper level?" and "What was one thing you noticed about the seminar?"
9. Share your experience as a facilitator.

CREDIT

Based on materials shared by: Walter Parker, PhD, University of Washington; Paula Fraser, Bellevue PRISM program, Bellevue, WA; Jodie Spitze and Dianne Massey, Kent Meridian High School, Kent, WA. We also gratefully acknowledge the influence of the Coalition of Essential Schools and the National Paideia Center.


The Process of Translational Research
Basic Research
Animal Research
Humans in Research
Therapies & Treatments
Does this increase our fundamental understanding of life processes and disease?
Does this help us understand molecular and cellular biology?
How can we test our idea for a medicine or new treatment in a whole, living system?
Is this medicine or treatment safe and effective for people?
How do we promote our medicine or treatment?
Foundational elements:
NWABR.ORG
Northwest Association for Biomedical Research
Regulations • Ethical Conduct • Community Involvement