# MR. TOMPKINS CURIE

## HELP OR HARM? EXPLORING APPLICATIONS OF RESEARCH INTO RADIOACTIVITY

**GRADES 9-12**
with extensions for MIDDLE SCHOOL AND COLLEGE.

## ABOUT THE VIDEO

The video consists of two sections: a) *lecture* and b) *illustrated dream sequence*. The lecture describes much of the life and work of Marie Curie and her husband, Pierre, who were awarded Nobel Prizes for their work early in the 20th century. In Mr. Tompkins' illustrated journey, he comes face-to-face with Mme. Curie in the midst of a World War I battle. Curie is in the process of making rounds to medical facilities where she assists in the treatment of injured soldiers by training surgeons in the use of X-ray machines.

The activities in this guide address the following concepts from the video:

The lecture addresses the following topics from the video:

- **The positive benefits and controversial outcomes of performing scientific research.**
- **Applications of fundamental scientific research in the field of nuclear chemistry and specifically radioactivity**

Other topics addressed in this video include:

- **The structure of the atom**
- **Radioactivity**
- **Isotopes**

## LEARNING OUTCOMES

As a result of this lesson students will be able to:

- **Articulate their understanding of the relationship between science and the needs and values of society.**
- **Communicate and debate the importance of scientific literacy in a technologically advanced society.**
- **Describe the importance and value of examining the limits of scientific knowledge.**
- **Give several examples of scientific research that create ethical challenges for scientists and/or citizens.**
- **Find, evaluate, summarize and communicate sources of technical information.**

## PRIOR KNOWLEDGE AND SKILLS (RECOMMENDED)

Prior to introducing this lesson, students should already know and understand:

- **The history of western civilization from 1850-1950, especially with respect to the industrial revolution and World War I.**
- **The structure of the atom; the atom is composed of protons, electrons and neutrons.**
- **The concept that atoms are the basic building blocks of matter.**
- **The elements as fundamental substances of matter with unique combinations of protons, electrons and neutrons.**
- **Radioactivity, defined as the emission of particles as a result of nuclear instability.protons, electrons and neutrons.**
- **The role of science in society.**

## STUDENT ACTIVITIES

Prior to viewing the video, the class discusses the beneficial, controversial and/or harmful applications of scientific knowledge. Students either brainstorm examples of each or they briefly research contemporary applications of radioactivity. Next, students view all or parts of *The Adventures of Mr. Tompkins: Curie.* The lecture and dream sequence address Marie Curie's research in the field of nuclear chemistry, research that was fundamental to the development of technologies with both beneficial as well as harmful applications. Using nuclear chemistry and the Curie family's contributions to science as the kernel, the class returns to the discussion of the acceptable limits of scientific research and its applications, especially those that arose from the work of the Curies.

## NATIONAL SCIENCE STANDARDS

This guide meets the national science standards for an understanding of:

- **The scientific enterprise**
- **The nature of scientific knowledge and inquiry**

PRE-VIDEO ACTIVITY

# SCIENTIFIC APPLICATIONS Creating Horrors or Solutions?

## TEACHING TIME

**20 minutes**

This activity is designed to elicit students' prior knowledge and understanding of science's role in society and students' initial definitions of acceptable science. Specifically, students discuss beneficial and controversial applications of scientific research. The teacher facilitates a whole class discussion.

## PREPARATION

1. Copy student handouts: *Applications of Science, Pierre Curie Quote.* (Optional): *Class Discussion Rubric.)*

2. Use the Internet to find and select a version of *Duck and Cover,* a film produced by the U.S. Civil Defense Administration in 1951.

One example of the video is posted on YouTube at:
http://www.youtube.com/watch?v=ixy5FBLnh7o

3. (Optional): Arrange to project *Duck and Cover* from a computer to a common viewing screen.

## MATERIALS

- Photocopied student handouts (one per individual)
- Pencil or pen
- Internet access
- (Optional): *Applications of Science* handout, concept map
- (Optional): The ability to project video footage from online sources to a common viewing area.

## TO DO AND TO NOTICE

Open a class discussion about the beneficial and harmful applications of scientific research. Begin by asking one or both of the following questions: "Who has had an X-ray (this year)?" or, "What is your reaction to the word 'radiation'?" Alternatively, you may show *Duck and Cover* to initially engage students in a discussion about the atomic bomb and then segue into a discussion of the many other applications of our knowledge of radioactivity (see "Extensions" on page five of this guide).

Follow the question with a general discussion of X-ray photography or of students' reactions to the word, "radiation". Ask for volunteers to try to explain how X-rays work and why they are of value. *If students do not mention it, be sure to address that when getting an X-ray, we are exposed to a low dose of radiation (that is, particles energetic enough to ionize an atom with which they make contact).*

Next, choose **one** of the following as an in-class or homework assignment. Once students have completed the task, invite volunteers to share and explain the applications of science that they identified as beneficial or harmful.

## GRAPHIC ORGANIZER

Have students complete and share a two-column table that lists beneficial and controversial applications of scientific research.

| HELPFUL | CONTROVERSIAL / HARMFUL |
|---|---|
| smoke detectors | atomic bomb |
| carbon dating | radium-painted watches (now outlawed) |
| nuclear power | nuclear power |
| radioactive tracers | "radon caves" and radon "health mines"for purported health benefits |
| radioactive iodine to treat hyperthyroid | |
| X-ray use to screen airline passengers | X-ray use to screen airline passengers |
| radiation therapy for cancer | radioactive camera lenses (no longer produced) |
| diagnostics such as PET scans | |
| food preservation via irradiation | "dirty bombs" |
| medical X-rays | |
| radiation to sterilize medical equipment | |
| welding joint inspection | |

## STUDENT RESEARCH

Following the initial discussion about X-rays and radiation, provide students with access to the Internet and/or library to identify other applications (beneficial and/or harmful) that arose from scientific research into the nature of the atom and/or radioactivity. For a jumping-off point, see a list of applications in the columns above.

**During or prior to the video, evaluate student knowledge and understanding of the difference between radioactivity and X-rays:**

**Radioactivity** occurs naturally and refers to the particles emitted by atoms in response to nuclear instability.

The term **"X-ray"** refers to electromagnetic radiation created when a high voltage accelerates electrons within a vacuum tube. The electrons collide with a metal target emitting the X-rays. Their discovery is attributed to Wilhelm Roentgen. A possible discussion question is:

*"What are some similarities and differences between radioactivity and X-rays?"*

## INTRODUCING AND WATCHING THE VIDEO

Introduce the characters in the video and explain the context in which the characters meet. Explain that the fictional character, Mr. Tompkins, is a bank clerk who attends science lectures. Following each evening lecture, he dreams about what he learned, meeting famous scientists and asking follow-up questions about their work.

Explain that Dr. Igor Gamow, a real professor, introduces each of the famous scientists, providing the background on their research and a brief biography. In this video, Dr. Gamow lectures on the Curie family and primarily the work and life of Marie Curie. Mr. Tompkins meets Marie Curie as she delivers X-ray equipment to doctors at hospitals near the front line during World War I.

1. Watch the recommended video segments.

2. Pause at the end of each segment to allow students to complete the table in *The Mother of Radioactivity* handout.

3. Support student review of the video segment as appropriate for your classroom situation. You may wish to project an image of the Graphic Organizer table on the screen and model taking notes for the students. (For instructional strategies, see *Modifications: Middle School Level* .)

## DISCUSSION

Return to the pre-video class discussion regarding the acceptable limits of scientific knowledge and its applications, specifically the outcomes of research by the Curies.

Have students refer to their notes, citing examples, as you facilitate a discussion of how the work of the Curie family has been used by others to benefit and/or harm humans and the natural world.

Some possible prompts for discussion include, but are not limited to:

*"What were the positive and negative outcomes of the Curies' research into radioactivity? Was their work within the acceptable limits of scientific research? What* are *the acceptable limits?"*

*"How many people have benefited from our understanding of radioactivity and the structure and power of the atom? What are the benefits?"*

*"How many people do you think have been harmed from the same fundamental knowledge? How were they harmed?"*

*"Do you think that the benefits outweigh the harm?"*

*"Do you think the Curies should feel pride or regret for the applications of the knowledge of radioactivity that they shared with the world?"*

*"If a scientist uncovers a secret of nature, who has the responsibility for how this knowledge is applied?"*

## VIDEO

Review the final minute of the video then distribute the *Pierre Curie's Nobel Lecture Quote* handout (see handout for full text). Ask a volunteer to read it aloud for the class and, as a class, discuss the quote to ensure that students understand Pierre Curie's statement. Ask students to restate Curie's main points in their own words.

## WRITE

Following a discussion of the Curie quote, ask students to answer the following question, supporting their responses with specific examples:

*"Looking back in time, has our understanding of radioactivity benefited or harmed humanity?"*

# ACTIVITIES DURING & AFTER THE VIDEO

**Madame Curie**
**The Mother of Radioactivity**

## TEACHING TIME

**10 minutes: video viewing**

**20-30 minutes: Follow-up discussion and writing assignment (time will vary according to teacher's expectations)**

## PREPARATION

1. Cue the video to the relevant sequences listed below.

2. Photocopy the handout *The Mother of Radioactivity* (one per student).

## MATERIALS

•*The Advs. of Mr. Tompkins: Curie* DVD or streaming Internet video.

• Multimedia equipment for projecting Curie for the whole class to view or for pairs of students to view on individual computer monitors.

• *The Mother of Radioactivity* handout (one per student).

## RELATED VIDEO SEGMENTS

**12:00–18:13**
History of the X-ray, discovery of radioactive elements, radioactivity as a property of matter, and Madame Curie's research that led to her Ph.D. and first Nobel Prize in physics (1903).

**26:07–27:15**
Curie explains her role in World War I and medical applications of early X-ray equipment.

**34:56–38:20**
Curie's exposure to radioactivity and health consequences, applications of research to nuclear medicine, use of radium in common household products and effects of exposure to workers.

**40:05–41:15 (required)**
Pierre Curie quoted on the pros and cons of penetrating the secrets of nature.

## WHAT'S GOING ON?

Scientific research generally has a wide variety of outcomes and applications. The scientific enterprise is concerned with furthering our understanding of the natural world as exemplified by the work of Madame Curie. However, the applications of knowledge can be beneficial (as in the case of an X-ray) or harmful (as in the case of the atomic bomb).

As a society, especially when our beliefs are challenged, we often react emotionally, condemning the scientific enterprise that provides the understanding of nature. This lesson asks students to reflect on the moral or ethical challenges that scientists face when pushing the boundaries of knowledge and separate knowledge acquisition from application.

The 21st century promises breakthroughs in a wide variety of scientific and technical fields, advances that may challenge the beliefs of society. For example, the fields of biotechnology and nanotechnology have begun to blossom. If past patterns repeat, we should anticipate a public debate about acceptable applications of scientific knowledge, the role of scientists and science in our society and the depth to which humans should penetrate the secrets of nature. In an increasingly technological world, individuals will need to develop a level of scientific literacy that allows them to understand and, if they choose, participate in the discussion about the limits and applications of human knowledge and understanding of nature.

## DID YOU KNOW?

**The Uranium Decay Chain Sequence**
In his lecture, Dr. Gamow briefly describes the radioactive decay of uranium. This is often known as either the Radium or Uranium series. The decay sequence from uranium to lead is extensive but may be abbreviated for most purposes to the following:

**U - Th - Ra - Rn - Po - Pb**

The chain begins with naturally occurring *uranium-238* (U) and includes, among others, the elements *thorium* (Th), *radium* (Ra), *radon* (Rn), *polonium* (Po) and *lead* (Pb).

**Deadly Radon**
Radon (Rn) causes cancer. Homebuyers often test for existence and quantity of radon prior to purchasing a home. Radon gas, due to its high density, pools in basements and subbasements requiring mitigation efforts.

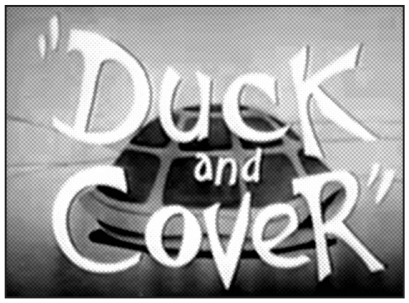
**Nobel Prizes**
Madame Curie received two Nobel Prizes. The first, in 1903, was awarded to her, her husband Pierre Curie and the scientist Henri Becquerel for their work with radiation. The second Nobel Prize was awarded in 1911 for her discovery of radium and polonium. She discovered these two elements in 1898 while seeking the source of radioactivity in several samples of pitchblende from Bohemia.

# EXTENSIONS

### FORMAL DEBATE

The central theme of this lesson, acceptable limits of scientific research and its applications, provides an opportunity for students to perform independent research and hold a formal debate. A debate assessment rubric has been included should the instructor wish to expand the lesson.

### EXTENDED *DUCK AND COVER* DISCUSSION




*Note: In the aftermath of 9/11, this movie may elicit strong feelings in some students. Use your best judgment as to whether it is appropriate.)*

Show and discuss the film *Duck and Cover*. Discuss the benefits and the drawbacks of the ability to harness the power of the atom and the nature of the film. Explain that the U.S. Civil Defense Administration produced this film during the Cold War to prepare United States citizens for a nuclear attack.

**Possible discussion prompts include:**
*"Will ducking and covering protect one from a nuclear explosion?"*

*"What might be the state of the world, the environment, and society after a nuclear explosion (whether from a bomb or from an accident)?"*

*"What might have been some effects of watching this film as a child or an adult when it first appeared in the 1950's? Do you think people led a more confident or more fearful life as a result of viewing the film?"*

### COMPARE & CONTRAST: X-RAYS AND RADIOACTIVITY

Students are commonly confused about the difference between X-rays and radioactivity. You may wish to hold a discussion on this topic.

**Possible questions include:**
*"What's the same and what's different about X-rays and radioactivity?"*
(Answer: The particles are the same, but radioactivity happens on its own.)

*"Who discovered X-rays?"*
(Answer: Wilhelm Roentgen)

*"Marie Curie didn't work with X-rays until twenty years after they were discovered. What did she contribute?*
(Answer: Practical applications)

### MIDDLE SCHOOL MODIFICATIONS

At the middle school level, students need support to develop their listening and note-taking skills. Many students do not know how to identify and record key concepts that they read or hear. Therefore, teachers should model the process of listening for and recording key ideas.

- **After viewing each video segment, lead the class through the process of completing the handout *The Mother of Radioactivity.*** Project an image of the handout on a screen. Call on students to help complete each section of the table. Write their responses on the table, refining and combining the language of several volunteers to create a final response.

### COLLEGE MODIFICATIONS

- **Assign the video (or portions of it) as pre-lecture homework** in order to motivate student curiosity or solicit their questions for the lecture.
- **Assign discussion questions for class discussion within a course management system** or other online class discussion forum.
- **Ask students to write a short essay about the acceptable limits of scientific research for homework.**
- **Use the video and/or discussion questions in lecture to augment lecture topics on *radioactivity, nuclear physics, atomic structure*** and other topics.
- **Additional discussion/essay topics include:**
  - Purposes, potential advantages, dangers, and common myths about nuclear reactors.
  - The current claims regarding cold fusion.
  - The difference between fission and fusion, and in what types of processes each occurs.
  - The public fear relating to radioactivity. Which fears are rational and which are irrational?
  - More discussion questions and relevant homework can be found in:

***Physics and Technology for Future Presidents: An Introduction to the Essential Physics Every World Leader Needs to Know***
(Richard A. Muller, Princeton University Press).

### ASSESSMENT OPTIONS

- Use class discussion and student participation to assess the ability of individuals to comprehend and communicate complex concepts and content.
- Collect and review student work on the handouts for this lesson. Use these documents to evaluate individuals' abilities to brainstorm and take notes. Review student writing samples to evaluate their ability to communicate complex concepts in writing.

# APPLICATIONS OF SCIENTIFIC RESEARCH

NAME_____

DATE_____

**Directions:** Use the two-column table to brainstorm helpful and controversial applications of scientific and/or medical research.

| HELPFUL | CONTROVERSIAL / HARMFUL |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

# PIERRE CURIE'S NOBEL LECTURE QUOTE

**Directions:**
1. In your own words, explain this quote. Specifically, why does Pierre Curie compare himself to Alfred Nobel, creator of the Nobel Prize?

2. Answer the following question: "Looking back in time, has our understanding of radioactivity benefited or harmed humanity?" Support your response with specific examples.

*It can even be thought that radium could become very dangerous in criminal hands, and here the question can be raised whether mankind benefits from knowing the secrets of Nature, whether it is ready to profit from it or whether this knowledge will not be harmful for it. The example of the discoveries of (Alfred) Nobel is characteristic, as powerful explosives have enabled man to do wonderful work. They are also a terrible means of destruction in the hands of great criminals who lead the peoples towards war. I am one of those who believe with Nobel that mankind will derive more good than harm from the new discoveries.*

*Pierre Curie*
*June 6, 1905*
*Stockholm, Sweden.*

# CLASS DISCUSSION RUBRIC*

*NATIONAL LIBRARY OF MEDICINE

NAME_____DATE_____

| STANDARDS | EXCEEDS STANDARD (5 POINTS) | MEETS STANDARD (4 POINTS) | NEEDS IMPROVEMENT (0-3 POINTS) |
|---|---|---|---|
| **Develop and demonstrate critical reading, listening, and viewing strategies.** | Student refers to or cites specific sections or portions of sources and gives thorough explanation of their significance.<br><br>Student fully identifies and evaluates the primary focus, logic, style, and structure of a source. | Student articulates a general concept but cannot identify or cite a source for support.<br><br>Student adequately identifies and evaluates the primary focus, logic, style, and structure of a source. | Student cannot give a reference to support discussion points.<br><br>Student cannot identify and/or evaluate the primary focus, logic, style, and structure of a source. |
| **Construct meaning beyond the literal level-e.g., drawing inferences, confirming and correcting, making comparisons and connections, and drawing conclusions.** | Student responds to questions with full and specific knowledge, and often uses discipline-specific language in his or her response. | Student demonstrates general idea in her or his responses, but without key details or deeper analyses. | Student cannot answer questions about the topic. |
| **Participate as an active member of a reading, listening, and viewing community.** | Student listens attentively and refers to relevant class materials to aid in full participation in the discussion.<br><br>Student records key ideas and revises her or his previous responses based on new findings from the discussion.<br>Student consistently volunteers to share knowledge with class. | Student is attentive but may not refer to class materials during the discussion.<br><br>Student may not record key ideas and information from the discussion.<br><br>Student occasionally volunteers to share knowledge with class. | Student is inattentive and does not have or refer to class materials related to the discussion at hand.<br><br>Student doesn't take notes or revise his or her responses based on the discussion.<br><br>Student never volunteers to share knowledge with class. |

# DEBATE RUBRIC*

*NATIONAL LIBRARY OF MEDICINE

NAME_____DATE_____

| STANDARDS | EXCEEDS STANDARD (5 POINTS) | MEETS STANDARD (4 POINTS) | NEEDS IMPROVEMENT (0-3 POINTS) |
|---|---|---|---|
| **Organization** | Exceptionally complete and clear viewpoints. All viewpoints organized logically and methodically. | Generally complete and/or clear viewpoints. Most viewpoints organized logically and methodically. | Lack of understanding of topic. Difficulty or inability to communicate topic to audience. Provided few or some relevant reasons given in support. |
| **Arguments** | Demonstrated exceptional understanding of topic and ability to communicate it to a lay audience. Provided all of the relevant reasons given support. | Demonstrated effective understanding of topic. Somewhat able to communicate topic to lay audience. Provided most of the relevant reasons given in support. | Lack of understanding of topic. Difficulty or inability to communicate topic to audience. Provided few or some relevant reasons given in support. |
| **Supporting Evidence** | Many appropriate examples and facts given in support of reasons. | Several appropriate examples and/or facts given in support of reason. | Examples or facts given either were inappropriate or lacking. |
| **Rebuttal** | Multiple counter-arguments were made; counter arguments were effective. | Several effective counter-arguments were made. | Few or ineffective counter arguments were made.<br><br>Student never volunteers to share knowledge with class. |
| **Communication Skills** | Displayed appropriate tone of voice, exceptional level of understanding and enthusiasm for topic, and appropriate body language, team or individual appearance appropriate for setting. Demonstrated respect for opposing team. | Displayed some combination but not all of the appropriate communication skills: tone of voice, understanding and enthusiasm, and body language, team or individual appearance appropriate for setting. Demonstrated adequate respect for opposing team. | Presenter lacked all or most of the appropriate communication skills: tone of voice, understanding and enthusiasm, and body language; team or individual appearance inappropriate for setting. Demonstrated little or no respect for opposing team. |

# ADDITIONAL RESOURCES

**ABC's of Nuclear Science**
**Lawrence Berkley National Laboratory**
**Nuclear Science Division**
*Home Page*
http://www.lbl.gov/abc/Basic.html

*Nuclear Science Wall Chart*
http://www.lbl.gov/abc/wallchart/index.html

**HyperPhysics**
http://hyperphysics.phy-astr.gsu.edu/hbase/nuccon.html#c1

**Modern Uses of Radioisotopes**
**Duke University**
http://www.chem.duke.edu/~jds/cruise_chem/nuclear/uses.html

**Non-Destructive Testing Resource Center**
*Uses of Radioactivity/Radiation*
http://www.ndt-ed.org/EducationResources/HighSchool/Radiography/usesradioactivity.htm

**Nobel Prize.Org**
*Biography of Marie Curie*
http://nobelprize.org/nobel_prizes/chemistry/laureates/1911/marie-curie.html

*Radioactive Substances, Especially Radium*
*Nobel Lecture June 6, 1905, by Pierre Curie*
http://nobelprize.org/nobel_prizes/physics/laureates/1903/pierre-curie-lecture.html

**PhET Interactive Simulations**
University of Colorado, Boulder
*Related simulations include:*
*Alpha Decay*
*Beta Decay*
*Simplified MRI*
*Nuclear Fission*