Solar Education for NY
SchoolPower...Naturally

A Photosynthesis Timeline

SPN LESSON #40

TEACHER INFORMATION

LEARNING OUTCOME

After studying the work of scientists that shows science as a social enterprise, students realize that the values of the scientist's society influence the research of that scientist.

LESSON OVERVIEW

This lesson builds upon the SPN lesson #39, *Where Do Plants Get Their Food?* Introducing photosynthesis through an historical approach helps students understand how advances in science are typically incremental. Students perceive that ideas develop and change, and are influenced by available resources and current societal values.

Students examine the conclusions drawn by van Helmont at the completion of his willow tree experiment. A teacher-directed class discussion leads students to understand that van Helmont's work was limited by the thinking of society at the time and the equipment available to him. They see that even though his conclusion was incorrect, his approach to science and his experiment showing that plants do not obtain food from the soil were significant contributions to our understanding of photosynthesis. A brief description of Antoine Lavoisier's work further illustrates the significance of societal influence and of incremental change in science.

Students are next asked to construct a timeline that:
(a) indicates the general time period during which each of the scientists listed did their work;
(b) denotes each scientist's important contribution(s) to the understanding of photosynthesis; and
(c) proportionally represents the time elapsed between the work of one scientist and the next.

GRADE-LEVEL APPROPRIATENESS

This Level III interdisciplinary lesson is intended for use with students in grades 9–10 who are enrolled in a Living Environment course.

MATERIALS

- Internet and/or library for researching the lives of various scientists
- Paper
- Metric ruler

SAFETY

There are no special safety precautions that need to be taken.

TEACHING THE LESSON

- Show a transparency of the photosynthetic process that is much more complex than what high school students should be expected to understand. Use the transparency to stimulate discussion about how we have come to know so much about photosynthesis. Where did our knowledge start?
- Point out that scientists have described about 80 separate but interdependent reactions that are part of the photosynthetic process. Assure students that they will not be studying all 80 of these reactions!
- Ask the following questions:

  (a) How long has the scientific community known about these complex reactions?

  (b) Why is knowledge of the process of photosynthesis important?

  (c) How have scientists come to know so much about the process of photosynthesis?

  (d) Is there still more to be learned about the process?
- Remind students of the 17^{th}-century experiment van Helmont conducted with the willow tree and his conclusion that the weight gained by the plant came from water (in other words, he concluded that plants obtain food from water). This experiment is described in the SPN lesson #39, *Where Do Plants Get Their Food?*

  (a) Ask students, "Was van Helmont wrong?"

  (They will most likely have a problem with the concept that van Helmont conducted an important experiment, one essential to our understanding of photosynthesis, but did not obtain the "correct" answer.)

  (b) Direct students to analyze the experiment and the conclusions van Helmont made. Ask them if, on the basis of the data he collected, he was incorrect.

  (Point out that the prevailing belief at the time was that plants were a combination of fire and earth and that van Helmont's study was designed to refute this belief. Many researchers have chosen to repeat the tree study—as perhaps the students themselves did in the SPN lesson #39, *Where Do Plants Get Their Food?*)

  (c) Discuss how (or perhaps whether) van Helmont's investigation contributed to the science of photosynthesis.
- Next, provide students with some background information on the life and work of Antoine Lavoisier. Explain that he obtained a law degree due to family pressure; however, he loved science and pursued it passionately while working as a public servant. He used his "discovery" of oxygen to overthrow the phlogiston theory. Explain that it was actually Joseph Priestley who discovered the existence of oxygen gas. He shared his information with Lavoisier, who then repeated Priestley's experiments. Lavoisier ultimately named what Priestley called "dephlogisticated air" oxygen. A popular idea at the time was that all flammable materials contain phlogiston, which they thought was a substance without color, odor, taste, or weight that was given off during burning. "Phlogisticated" substances contain phlogiston. When these substances are burned, they are "dephlogisticated." The ash left after the material is burned was believed to be the true material. Making careful measurements, Lavoisier demonstrated that the transmutation of water to earth was not possible and that the sediment observed from boiling

water came from the container, not from water being transformed into earth. He burned phosphorus and sulfur in air, and showed that the products weighed more than the original phosphorus and sulfur and that the weight gained was lost from the air. Thus he established the law of conservation of mass. These discoveries led him to believe that plants get food from water and a little soil, or from the air. You might want to use excerpts from a fictitious news interview of Lavoisier's wife written after he was beheaded during the French Revolution (http://www.woodrow.org/teachers/ci/1992/Lavoisier.html).

- Use the story of Lavoisier and the information about van Helmont to illustrate that science is a social enterprise and scientific understanding does not emerge all at once or fully formed. Help students recognize that each new concept reflects the personal background, time, and place of its discoverer. At this point, students are ready to begin the timeline activity.
- The Photosynthesis Timeline Scoring Guide should be given to students before they begin their research and construct their timeline.
- After students have completed the basic timeline activity, discuss with them what scientists might ask about photosynthesis today and in the future. Ask students what factors might influence the research of these individuals.

ACCEPTABLE RESPONSES FOR DEVELOP YOUR UNDERSTANDING SECTION

The chronological sequence should be ordered as follows, if the general time period during which each scientist worked is considered rather than the specific dates associated with discoveries:

Aristotle (384 – 322 B.C.)

Jan van Helmont (1580 – 1644)

Robert Boyle (1627 – 1691)

Nehemiah Grew (1641 – 1712)

S. Hales (1677 – 1761)

Joseph Priestley (1733 – 1804)

Jan Ingenhousz (1730 – 1799)

Antoine Lavoisier (1743 – 1794)

Julius Robert Mayer (1814 – 1878)

J. v. Sachs (1832 – 1897)

George Washington Carver (1860 – 1943)

Melvin Calvin (1911 – 1997)

Norman Borlaug (1914 –)

- See the References for Background Information section of this activity for each scientist's specific contribution(s) to our understanding of photosynthesis. Web sites for further information are also provided.
- Some additional scientists whom students might add to the timeline include but are not limited to:

  T. W. Engelmann (1843 – 1909) fashioned a gadget out of a modified microscope condenser that allowed him to expose parts of photosynthetically active cells (of the green alga *Spirogyra*) to a

thin ray of light. His aim was to discover which components of the cell functioned as light receptors. To measure the oxygen production, he dispersed the threadlike *Spirogyra* in a bacteria-containing suspension. Whenever parts of the chloroplast were illuminated, the bacteria concentrated in this area (where oxygen was available). The illumination of other parts of the cell resulted in no such aggregations.

F. F. Blackman and G. L. C. Mathgel (1905, University of Cambridge, Great Britain) were among the first to study this topic systematically. They cultivated plants under different but controlled carbon dioxide concentrations, different light intensities, and different temperatures, and they noted the effects of these parameters on the rate of photosynthesis.

C. B. van Niel (1930s, Stanford University) analyzed photosynthesis as it occurs in a number of purple bacteria. He wanted to know if, in addition to carbon dioxide, these bacteria needed hydrogen sulfide for photosynthesis. van Niel was able to determine that photosynthesis is a redox reaction with H_2X as the electron donator (the oxydizable substance). In the case of green plants, it is H_2O. This means that the water, not the carbon dioxide, is broken down.

Information on many other scientists can be found at http://photoscience.la.asu.edu/photosyn/photoweb/default.html#History which has the article "Photosynthesis and the Web 2002," which appeared in *Photosynthesis Research*, the official journal of the International Society of Photosynthesis Research (ISPR).

Activity Analysis

1. Why are advances in understanding the complexity of photosynthesis occurring more rapidly now than in the 1600s?

   Possible answers include but are not limited to: (a) more is known for scientists to build upon; (b) instruments and techniques are available to scientists today that were not available 100 or 200 years ago (commonly held misconceptions from the past have been proven incorrect and therefore no longer bias the thinking of scientists); and (c) societal influences do not seem to hold back photosynthesis research in the same way as in the past.

2. (a) As a result of your research during this activity, state two questions scientists may still have about photosynthesis

   Accept any reasonable answer such as "How does chlorophyll actually convert the light energy into the energy present in food?"

   (b) Describe two ways in which the values of today's society might inhibit further research into photosynthesis.

   Due to a bias toward applied research rather than pure research, society may think photosynthesis research is not (a) as important as other types of research (e.g., AIDS, SARS); (b) worth the time and money; (c) necessary because we already know everything there is to know or at least enough; or (d) significant because people think there is no money to be made.

3. (a) If you were asked to develop a timeline for the development of photovoltaic systems, how might it be similar to your photosynthesis timeline?

   Advances would occur slowly in the beginning and increase in frequency as more is known.

   (b) Explain how leaves and photovoltaic modules are similar in terms of the work that they do.

   Both convert light energy into another form.

ADDITIONAL SUPPORT FOR TEACHERS

SOURCE FOR THIS ADAPTED ACTIVITY

National Science Education Standards, National Academy Press, Washington, DC, 1996.

BACKGROUND INFORMATION and REFERENCES FOR BACKGROUND INFORMATION

Aristotle (384 – 322 B.C.) thought that plants get everything they need from the soil through their roots.
- Botany Online http://www.biologie.uni-hamburg.de/b-online/e01/01a.htm

Robert Boyle (1627 – 1691) carefully experimented with increase in plant biomass in an effort to determine what happened to water taken up by plants.

Melvin Calvin (1911 – 1997) and his team, using the carbon 14 tracer, mapped the complete route that carbon travels through a plant during photosynthesis, starting from its absorption as atmospheric carbon dioxide to its conversion into carbohydrates and other organic compounds. Calvin and his team also showed that chlorophyll uses radiant energy to split water molecules into hydrogen and oxygen.
- University of California at Berkeley
  http://www.berkeley.edu/news/media/releases/97legacy/calvin.html
- Nobel Prize Awarded To Nine Lawrence Berkeley National Lab Scientists
  http://www.lbl.gov/Science-Articles/Archive/nine-nobel-laureates.html

Nehemiah Grew (1641 – 1712) discovered stomata; asked if stomata allowed the exchange of substances between plants and the atmosphere.
- History of Horticulture Purdue University Lecture
  http://www.hort.purdue.edu/newcrop/history/lecture29/lec29.html

S. Hales (1677 – 1761) understood that air and light are necessary for the nutrition of green plants. It was not until the composition of air out of a variety of gases became known that the significance of air and light for plant nutrition was studied.

Jan Ingenhousz (1730 – 1799) knew of Priestley's experiments; spent a summer near London doing over 500 experiments, during which he discovered that light plays a major role in photosynthesis.
-excerpts from *Experiments upon Vegetables, Discovering Their great Power of purifying the Common Air in the Sunshine, and of Injuring it in the Shade and at Night. To Which is Joined, A new Method of examining the accurate Degree of Salubrity of the Atmosphere*
  http://photoscience.la.asu.edu/project-I/ingenhousz_paper1.html
-BBC Homepage History; Historic Figures
  http://www.bbc.co.uk/history/historic_figures/ingenhousz_jan.shtml

Antoine Lavoisier (1743 – 1794) discovered the concept of oxidation; reasoned that plants got food either from water and a little soil, or from the air.
- Webexhibits.org http://webexhibits.org/causesofcolor/7.html

Julius Robert Mayer (1814 – 1878) recognized that plants convert solar energy into chemical energy.
- Webexhibits.org http://webexhibits.org/causesofcolor/7.html
- Nobel Prize Awarded To Nine Lawrence Berkeley National Lab Scientists
  http://www.lbl.gov/Science-Articles/Archive/nine-nobel-laureates.html

Joseph Priestley (1733 – 1804) discovered that plants produce oxygen.
- Woodrow Wilson Leadership Program in Chemistry, The Woodrow Wilson National Fellowship Foundation, CN 5281, Princeton, NJ 08543-5281 http://www.woodrow.org/teachers/chemistry/institutes/1992/Priestley.html
- Useless Information http://home.nycap.rr.com/useless/priestly/priestly.html

J. v. Sachs (1832 – 1897) finally proved that chlorophyll is involved in photosynthesis. In addition, he showed that starch is produced in chloroplasts as a result of the photosynthetic activities.

Jan van Helmont (1580 – 1644) questioned whether plants obtain their food from the soil. Through experimentation he decided that plants obtain food from water rather than soil. He coined the term *gas* and described the properties of carbon dioxide.
- Eric Weisstein's World of Biography http://scienceworld.wolfram.com/biography/Helmont.html

EXTENDED ACTIVITIES

Research and Application

Assign pairs of students to research Norman Borlaug and George Washington Carver. Ask them to decide what these individuals accomplished and find out how they made use of an understanding of the process of photosynthesis. The connection is not as obvious but more of a technological application that requires a basic understanding of plant growth and chemical pathways including photosynthesis.

Norman Borlaug (1914 –) devoted his energies for more than 30 years to the improvement of wheat. He contributed more than any other person to the so-called "Green Revolution." This revolution made it possible to improve living conditions for hundreds of millions of people living in developing countries. Borlaug was awarded the Nobel Peace Prize in 1970 for his work.
- Biographical information and online articles/interviews: http://www.ideachannel.com/Borlaug.htm
- *The Atlantic Monthly* online: http://www.theatlantic.com/issues/97jan/borlaug/borlaug.htm
- *The Atlantic Monthly*; January 1997*; Forgotten Benefactor of Humanity;* Volume 279, No. 1; pages 75–82.

George Washington Carver (1860 – 1943) developed a crop rotation method, which alternated nitrate-producing legumes—such as peanuts and peas—with cotton, which depletes soil of its nutrients. To make use of the extra peanuts produced, Carver developed 325 different uses including cooking oil and printer's ink. He also discovered that sweet potatoes and pecans enriched depleted soils and found almost 20 uses for these crops, including the manufacture of synthetic rubber. (source: Hall of Fame Inventor Profile http://www.invent.org/hall_of_fame/30.html)
- The Faces of Science: African Americans in the Sciences http://www.princeton.edu/~mcbrown/display/carver.html
- Iowa State University e-library http://www.lib.iastate.edu/spcl/gwc/bio.html

Ethical Issues Research

Have students make a list of controversial scientific topics. These might include fetal stem cell research, xenotransplants, cloning, pharming, the development of transgenic organisms, and many others. Have students pick one of these and write an essay that addresses why the topic is controversial and what they (the students) think will be the case 100 years from now. Will scientific research on the topic shut down? What are some of the societal and scientific reasons

for the shutdown? Should scientific research on the topic continue? What are the potential benefits to society? Will future students developing a timeline based on present-day problems associated with researching these areas view current research in the same way we view early research on photosynthesis?

Some students might be interested in the ethics involved in conducting research. They will have noticed that both Priestley and Lavoisier were working on oxygen topics during the same time period. If they search the literature for these two individuals, they will discover that Lavoisier is believed to have taken credit for some of Priestley's work. This kind of human problem can be brought into the present day by students' finding and describing how such problems are currently resolved.

Gender Research

Have students identify the predominant gender of the scientists listed on the photosynthesis studies timeline. Ask them to research how the predominance of males is related to the social conditions that existed relative to the division of labor by gender. You might assign students different centuries and ask them to investigate gender roles and expectations (education, responsibilities) that existed at the time. As a follow-up, ask students to share their findings, list common themes, and discuss whether the factors operating then still influence the role of women in science.

LINKS TO MST LEARNING STANDARDS AND CORE CURRICULA

Standard 1—Analysis, Inquiry, and Design: Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.

Key Idea 1: The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing and creative process.

S1.1: Elaborate on basic scientific and personal explanations of natural phenomena, and develop extended visual models and mathematical formulations to represent one's thinking.

S1.1a: Scientific explanations are built by combining evidence that can be observed with what people already know about the world.

S1.1b: Learning about the historical development of scientific concepts or about individuals who have contributed to scientific knowledge provides a better understanding of scientific inquiry and the relationship between science and society.

S1.1c: Science provides knowledge, but values are also essential to making effective and ethical decisions about the application of scientific knowledge.

S1.2: Hone ideas through reasoning, library research, and discussion with others, including experts.

S1.2a: Inquiry involves asking questions and locating, interpreting, and processing information from a variety of sources.

S1.2b: Inquiry involves making judgments about the reliability of the source and relevance of information.

S1.3: Work toward reconciling competing explanations; clarify points of agreement and disagreement.

S1.3a: Scientific explanations are accepted when they are consistent with experimental and observational evidence and when they lead to accurate predictions.

S1.3b: All scientific explanations are tentative and subject to change or improvement. Each new bit of evidence can create more questions than it answers. This leads to increasingly better understanding of how things work in the living world.

S1.4: Coordinate explanations at different levels of scale, points of focus, and degrees of complexity and specificity, and recognize the need for such alternative representations of the natural world.

S1.4a: Well-accepted theories are ones that are supported by different kinds of scientific investigations often involving the contributions of individuals from different disciplines.

Standard 2—Information Systems: Students will access, generate, process, and transfer information, using appropriate technologies.

Key Idea 1: Information technology is used to retrieve, process, and communicate information as a tool to enhance learning.

- understand the use of the Internet and computer software
- prepare presentations demonstrating a clear sense of audience and purpose
- access, select, collate, and analyze information obtained from a wide variety of sources, including the Internet, library, and/or other print sources

Standard 6—Interconnectedness: Common Themes: Students will understand the relationships and common themes that connect mathematics, science, and technology and will apply the themes to these and other areas of learning.

Key Idea 3: The grouping of magnitudes of size, time, frequency, and pressures or other units of measurement into a series of relative order provides a useful way to deal with the immense range and the changes in scale that affect the behavior and design of systems.

Standard 4

The Living Environment

Key Idea 5: Organisms maintain a dynamic equilibrium that sustains life.

5.1: Explain the basic biochemical processes in living organisms and their importance in maintaining dynamic equilibrium.

5.1a: The energy for life comes primarily from the Sun. Photosynthesis provides a vital connection between the Sun and the energy needs of living systems.

5.3: Relate processes at the system level to the cellular level in order to explain dynamic equilibrium in multicelled organisms.

5.3a: Dynamic equilibrium results from detection of and response to stimuli. Organisms detect and respond to change in a variety of ways both at the cellular level and at the organismal level.

5.3b: Feedback mechanisms have evolved that maintain homeostasis. Examples include the changes in heart rate or respiratory rate in response to increased activity in muscle cells, the maintenance of blood sugar levels by insulin from the pancreas, and the changes in openings in the leaves of plants by guard cells to regulate water loss and gas exchange.

Produced by the Research Foundation of the State University of New York with funding from the New York State Energy Research and Development Authority (NYSERDA)
www.nyserda.org

Should you have questions about this activity or suggestions for improvement, please contact Bill Peruzzi at billperuz@aol.com

(STUDENT HANDOUT SECTION FOLLOWS)

Name _____

Date _____

A Photosynthesis Timeline

Introduction

It has taken hundreds of years and the contributions of many scientists to answer the question, "Where do plants get their food?" It is now known that plants, and some other organisms, use solar energy to combine molecules of carbon dioxide and water into energy-rich organic compounds. Photosynthesis provides a vital connection between the Sun and the energy needs of living organisms.

Because scientific ideas depend on experimental and observational confirmation, scientific knowledge is, in principle, subject to change as new evidence becomes available. Usually, such changes occur as small modifications in existing knowledge. With that in mind, read through the list of scientists below. Each of these individuals contributed to our understanding of the process of photosynthesis. It is your task to develop a timeline for their accomplishments.

Materials

- Internet and/or library for researching the lives of various scientists
- Paper
- Metric ruler

Develop your understanding

1. Below is a list of scientists. On a separate index card or a half sheet of paper, record the name of each scientist.

J. v. Sachs	Nehemiah Grew	Jan van Helmont
Robert Boyle	S. Hales	Melvin Calvin
Joseph Priestley	Jan Ingenhousz	Aristotle
Antoine Lavoisier	Julius Robert Mayer	

2. Research each scientist, using reference books, the Internet, and/or science texts. On the index card or half sheet of paper for each individual, record the following:

   (a) the general time period during which he lived and worked;

   (b) the significant contribution(s) he made to our understanding of photosynthesis; and

   (c) information about factors that may have influenced his research such as equipment available, other scientists working during the same general time frame, and the political environment.

   For example, on the index card for Nehemiah Grew, you might record: Nehemiah Grew (1641 – 1712), born in Coventry, England, was the cofounder of plant anatomy with Marcello Malpighi. He was a practicing physician. His work on plant anatomy

began in 1664. His objective was to compare plant and animal tissues. He approached botany from a medical standpoint. Grew started the study of tissues (histology); his major contribution to science was to relate anatomy (form) and physiology (function).

In terms of photosynthesis, Grew was the first to successfully extract chlorophyll from leaves. He also observed stomata through the microscope and wrote, "Could it be that they allowed the exchange of substances between plants and the atmosphere?" He recorded much of his important work with plants in *Anatomy of Plants* (1682).

No important advances were made that built upon the ideas of Grew and Malpighi for more than a century.

References:

http://www.hort.purdue.edu/newcrop/history/lecture29/lec29.html

Biology: You and Your Environment. Annotated Teacher's Edition by John D. Cunningham. D.C. Heath Company: Lexington, MA, 1976.

3. After collecting information for all of the scientists, arrange the cards in chronological order.
4. Identify two additional scientists (not mentioned in this activity) who made significant contributions to our understanding of photosynthesis. Complete an index card / half sheet for each of them. Include the same kind of information you included for the others.
5. Decide on the best scale to illustrate proportionally the time between each scientist's work. Draw your timeline.
6. Mark the date for each scientist, and record his or her name and major contribution. When the timeline is complete, submit it along with all of your index cards or half sheets.

Activity Analysis

1. Why are advances in understanding the complexity of photosynthesis occurring more rapidly today than in the 1600s?
2. (a) As a result of your research during this activity, what are two questions scientists may still have about photosynthesis?

   (b) Describe two ways in which the values of today's society might inhibit further research into photosynthesis.
3. (a) If you were asked to develop a timeline for the development of photovoltaic systems, how might it be similar to your photosynthesis timeline?

   (b) Explain how leaves and photovoltaic modules are similar in terms of how they function.

Name _____ Date _____
Section _____

Photosynthesis Timeline Scoring Guide					
Critical Thinking Level	**Content**	**Score**			
Knowledge	Identifies facts/events related to photosynthesis for each scientist.	4	3	2	1
Comprehension	Classifies events as important and uses evidence to show why they are significant in understanding the process of photosynthesis.	4	3	2	1
Application	Organizes individuals (events/facts) to show proper sequencing.	4	3	2	1
Synthesis	Prioritizes and creates a timeline of scientists (events/facts).	4	3	2	1
Research Skills	References two or more sources for each scientist.	4	3	2	1
	Researches and incorporates in the timeline the names and contributions of two more scientists who added to our understanding of photosynthesis.	4	3	2	1
Mechanical Skills	Uses appropriate scientific vocabulary and spells correctly.	4	3	2	1
	Total Score =				

Comments: