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LESSON:

The Scientific Method: Adding Up to a Lot of Good

Summary: Students read a summary of research results showing the potential for neurological damage when certain combinations of food additives are consumed. Students then identify the criticisms of the study and the next steps for research. Short Lesson—This lesson will take 20–30 minutes to implement.

EHP Article: "Adding Up to No Good?"
EHP Student Edition, July 2006, p. A218
http://www.ehponline.org/docs/2006/114-4/forum.html#addi

Objectives: By the end of this lesson, students should be able to:

1. describe how the peer-review process contributes to science;
2. describe how some chemicals work synergistically to produce a health effect; and
3. provide examples of new research that could answer questions raised by the study discussed in the article.

Class Time: 20–30 minutes

Grade Level: 9–12

Subjects Addressed: General Science, Health, Biology, Environmental Science

Prepping the Lesson (15 minutes)

INSTRUCTIONS:

1. Download the entire July 2006 *EHP Student Edition* at http://www.ehponline.org/science-ed/, or download just the article "Adding Up to No Good?" at http://www.ehponline.org/docs/2006/114-4/forum.html#addi.
2. Review the Background Information, Instructions, and Student Instructions.
3. Make copies of the article and Student Instructions.

MATERIALS (per student):

- 1 copy of the *EHP Student Edition*, July 2006, or 1 copy of "Adding Up to No Good?" preferably in color
- 1 copy of the Student Instructions

VOCABULARY:

- *in vivo*
- neurite
- neurotoxicity
- peer-review process
- scientific method
- synergistic

BACKGROUND INFORMATION:

The article provides enough background information to complete the lesson. One of the criticisms of the study cited in this article is that it is *in vitro*, which means it looks at the effects of a chemical on specific cells in a petri dish (in this case neurites), rather than *in vivo*, which refers to studies that use the whole, live animal. *In vitro* studies are an excellent preliminary screening tool. They can be performed relatively quickly and inexpensively and can be controlled very well. *In vitro* studies can also easily be repeated many times to increase confidence in the results. *In vivo* studies, on the other hand, take into account metabolic processes that could alter the chemicals in some way (e.g., decreasing the amount of a specific chemical that actually makes it to the blood stream, creating metabolites that are toxic, etc.).

Typically the results of a combination of *in vitro* and *in vivo* studies are used to make "applied" generalizations about the potential toxicity of a substance or combination of substances. However, with the increasing application of the "precautionary principle" (see the Background Section of the lesson "Depleted Uranium and the Brain," *EHP Student Edition*, March 2005), significant results from *in vitro* screening tools would shift the burden of proof of no adverse affect to the manufacturer.

One question that would be worth discussing with the students after they have completed the assignment is "Does the fact that only specific chemical combinations—e.g., Brilliant Blue paired with L-glutamate—cause negative effects help or hurt the believability of the study?" Students could answer either way, but they should be asked to explain their logic. In many respects this result lends credibility to the study because they were able to measure something so specific. If any and all combinations of Brilliant Blue, L-glutamate, Quinoline Yellow, and aspartame killed the neurites, that would lead to the conclusion that either the scientists had a methodology problem or the effect was caused by one chemical alone.

RESOURCES:

Environmental Health Perspectives, Environews by Topic page, http://ehp.niehs.nih.gov. Choose Chemical Exposures, Food Safety

Scientific method, Wikipedia, http://en.wikipedia.org/wiki/Portal:Scientific_method

Implementing the Lesson

INSTRUCTIONS:

1. Distribute copies of the article "Adding Up to No Good?" and the Student Instructions. Depending on the students' level of experience with the scientific method, you may need to provide a brief introduction to the process in addition to what is provided in the Student Instructions. This lesson will primarily focus on the peer-review and next-steps portion of the scientific method.
2. Students can turn in their work when completed, or you could discuss their answers as a class. You may want to ask the students, "Does the fact that only specific chemical combinations— e.g., Brilliant Blue paired with L-glutamate—cause negative effects help or hurt the believability of the study?" as described in the Background Information section.

NOTES & HELPFUL HINTS:

- Extended discussions could ask the students about additional information they would find helpful to better understand the food additive study. For example, did the study look at food colorings alone, as well as in the paired combinations?

Aligning with Standards

SKILLS USED OR DEVELOPED:

- Communication (note-taking, oral, written—including summarization)
- Comprehension (listening, reading)
- Critical thinking and response
- Experimentation (design)

SPECIFIC CONTENT ADDRESSED:

- Peer review
- Scientific method
- Synergistic relationship
- Neurotoxicity

NATIONAL SCIENCE EDUCATION STANDARDS MET:

Science Content Standards

Unifying Concepts and Processes Standard

- Evidence, models, and explanation
- Change, constancy, and measurement

Science As Inquiry Standard

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Life Science Standard

- The cell

Science in Personal and Social Perspectives Standard
- Personal and community health
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

History and Nature of Science Standard
- Science as a human endeavor
- Nature of scientific knowledge

Assessing the Lesson

Step 2: Read the article "Adding Up to No Good?" Then answer the following questions related to the article and the scientific method.

a) The following questions relate to the food additive study that was originally published in the March 2006 issue of *Toxicological Sciences* and briefly described in the article "Adding Up to No Good?"

What question did the study try to answer?

Do low-concentration mixtures of Quinoline Yellow, Brilliant Blue, L-glutamate, and aspartame affect the growth of neurites from mouse NB2a neuroblastoma cells?

If students provide a broader question such as "Do Quinoline Yellow, Brilliant Blue, L-glutamate, and aspartame cause negative health effects?" ask them to refine the question making it more specific to the study. Explain that such a broad question can relate to many different studies such as effects on kidney or liver cells, growth or behavior of mice, or cancer in humans.

What were the results? Discuss when effects were seen and when they were not seen. Also, using general terms, describe the amounts of the chemicals used in the study (i.e., according to the authors, did they reflect "real life" exposures?).

Quinoline Yellow and aspartame together stunted neurite cell growth, as did Brilliant Blue paired with L-glutamate. These effects were seen at concentrations that could be obtained through normal eating behaviors. No effects were seen with other combinations of the chemicals (e.g., Brilliant Blue paired with aspartame).

Why are these results potentially meaningful?

Because if children eat these food chemical combinations they may experience neurotoxicity or brain damage.

b) Now think about the news article, "Adding Up to No Good?" The article highlights one criticism of the study. Using your own words, describe the criticism.

Scientists at the United Kingdom Food Standards Agency state that other studies show that MSG and aspartame are not absorbed 100% when ingested. As a result, they believe real levels of aspartame and L-glutamate in the body will not reach as high as the concentrations used in the study.

c) List questions related to this study that are still unanswered and need further research.

Students may offer numerous ideas for additional studies. Make sure the answer is clearly described, is a natural extension of the research discussed here, and will answer some aspect of the uncertainties discussed in the article. For example, follow-up studies could have humans, mice, or rats ingest food with aspartame and L-glutamate, and the amounts of each substance in the blood could be measured. These *in vivo* (or whole-animal) studies could also try to measure neurological effects of the combinations (this would likely not be done with humans because of the potential for harm).

Authors and Reviewers

Author: Stefani D. Hines, Community Environmental Health Program, University of New Mexico.

Reviewers: Susan Booker, Erin Dooley, Liam O'Fallon, Lisa Pitman, Wendy Stephan, Kimberly Thigpen Tart, Heather Valli

Give us your feedback! Send comments about this lesson to ehpscienceed@niehs.nih.gov.

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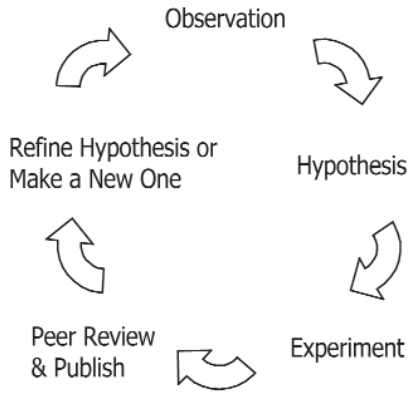
STUDENT INSTRUCTIONS:

The Scientific Method: Adding Up to a Lot of Good

Step 1: The scientific method is a process where new knowledge is obtained based on physical evidence. You can think of the scientific method as a cycle that begins with the very natural human act of making observations and generating questions about those observations. Next, a hypothesis (a testable explanation of those observations) is created and then tested through an experiment. Depending on how well an experiment is designed, the experiment may or may not provide answers or insight into the hypothesis or process being studied. This is why scientists conduct many different experiments on the same or similar topics or phenomena. Some of these experiments simply repeat previous experiments; others modify an experiment slightly, but when combined the individual experiments come together to create a body of knowledge on a specific topic.

In your science classes you have probably done lab activities or experiments where you followed a set of instructions (a "protocol"), recorded the data, obtained a result, and then wrote the procedure, data, and interpretation of the results in a lab notebook. These actions are all very real and valuable parts of the scientific method, but there is more! Science depends on researchers sharing their work with other people in the field. This is called publishing. When scientific work is published it contributes to the greater knowledge. The process of publishing includes peer review, where other scientists in the field read the study and provide critiques, highlighting the strengths and the weaknesses of the experiment. These critiques make the scientific process stronger and more reliable. Critiques also drive new experiments based on the previous results. The scientific method is a never-ending cycle (Figure 1).

Figure 1: The Scientific Method



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a) The following questions relate to the food additive study that was originally published in the March 2006 issue of *Toxicological Sciences* and briefly described in the article "Adding Up to No Good?"

What question did the study try to answer?

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What were the results? Discuss when effects were seen and when they were not seen. Also, using general terms, describe the amounts of the chemicals used in the study (i.e., according to the authors, did they reflect "real life" exposures?).

Why are these results potentially meaningful?

b) Now think about the news article, "Adding Up to No Good?" The article highlights one criticism of the study. Using your own words, describe the criticism.

c) List questions related to this study that are still unanswered and need further research.