



Scientist Mentor Idea #4

DEMONSTRATING BASIC TOXICOLOGY IN A K-12 CLASSROOM

NO SAFETY WARNING NEEDED HERE! These demonstrations CAN be done at home and in the classroom, using readily available items. Some require minimal advance work by the teacher. Students are, and should be, impressed with the magnificent collection of state-of-the-art, 21st century technology and other tools available to toxicologists--like molecular probes, gene chips, and transgenic animals. Tell them about these, of course, but if you want to demonstrate some key ideas and be sure they understand--and leave behind a grateful teacher who can replicate these activities--**KEEP IT SIMPLE!**

1♦ Demonstrating Principals of Dose/Response

Dose makes the poison and route of exposure¹ Ask the class whether any chemicals are completely safe. Ask about water. Ask them about water in the lungs. Tell them that a technical term exists for this concept, route of exposure. Discuss the importance of route of exposure. Ask if it is possible to drink too much water or chew too much gum. Make overheads of the first page of each of these publications:

Goldberg, L.D. and Ditchek, N.T. Chewing Gum Diarrhea. *Digestive Diseases* **23**(6): 568, 1978.

Klonoff, D.C. and Jurow, A.H. Acute Water Intoxication as a Complication of Urine Drug Testing in the Workplace. *Journal of the American Medical Association* **265**(1):84-85, 1991.

Discuss that while it is unlikely that any of them would ever drink too much water or eat too much gum, theoretically it is possible. For older students, you could also mention that a soldier in basic training has been known to be "over hydrated" and die of a heart attack. Even people hiking for recreation in hot climates have become seriously ill from *too much* water consumption, resulting in an electrolyte imbalance. Expand on the "dose makes the poison" concept. This discussion works for ages as young as 8.

The greater the dose the greater the effect. The smaller the size the greater the effect.²

Definitions

Dose is the amount of exposure to an agent.

Response is the reaction to the dose.

For example, eating one green apple may be just fine, but eating five green apples at one time may produce a very undesirable response!

Materials Required

Four large glasses (wine glasses work very well)

One small glass

Food color (blue is best, in container to dispense drops)

One pitcher of water

The Greater the Dose, the Greater the Effect.

Effects of Amount



Effects of Size on Response



The Smaller the Size, the Greater the Effect.

Demonstrating importance of amount of the dose (first figure) Fill three large glasses with water, approximately $\frac{3}{4}$ full. This represents the approximate fraction of water in a person. Asking the class how much water is in a person makes for a fun discussion. Put one drop of food color in the first glass, three in the second glass, and then 6 to 9 in the last glass. Ask the class to count with you and how many they would like to have in the last glass. Stir with a pencil or pen and discuss the change in color as a response to increased dose of food color in each glass. Discuss how some chemicals, like caffeine, distribute throughout total body water.

Demonstrating importance of size (second figure) Fill one large glass and the small glass with approximately $\frac{3}{4}$ water. The small glass represents a small child in contrast to the adult size glass. Put one drop of food color in each glass. The small glass will be much darker and usually look like the high dose glass from the first demonstration. Discuss the importance of size (i.e., weight) on dose, using different examples depending on sophistication of the group. A small child who drinks one can of caffeinated soda will have a very different response than an adult because of the difference in the dose.

Discussion For exposure to a chemical agent, dose is usually expressed relative to body weight. This is because for a fixed amount of toxic agent, the dose--and likewise the effect--depends directly on weight. We know, for example, that one shot of alcohol would have a very big effect on a child weighing 10 lbs and a much smaller effect on an adult weighing 200 lbs. To take this into account, dose is measured in units of milligrams of toxicant per kilogram of body weight, abbreviated mg/kg. If someone consumed 100 mg of caffeine, approximately the amount in a cup of coffee or two cans of caffeinated soda, and if they weighed 70 kg (about 155 lbs), the dose would be 100 mg/70 kg of body weight or 1.4 mg/kg. On the other hand, if a child weighing only 10 kg (about 22 lbs) consumed the same 100 mg of caffeine, the dose would 10 mg/kg, seven times as large because the body weight is one seventh. Thus, size and amount of exposure determine the dose and are critical factors in toxicology. This principle can be an extremely important factor in home lead or pesticide exposures, where the dose a child receives is far greater than what the adult experiences due to the small size of the child. Sensitivity may also differ depending on age (size).

2• Air Exposure Sampling Experiment³ Before your visit, work with the teacher to instruct each student how to attach a 'calibrated' piece of fresh sticky (Scotch) tape to a small flat board and place it in an area one might expect particulate air pollutants (in a room with a wood burning fireplace, wherever smokers in the family typically sit, in front of their house or school near the street, etc.) and in an area where the air is perceived as 'clean'. Leave for varying periods of time (e.g., 1-7 days). 'Windstrips' (sticky tape or fly paper) can be hung as an alternative. Have the teacher instruct students to bring their air samplers to class the day of your visit, clearly labeled and ready to evaluate with you. Using magnifying glasses, or microscopes if the class or you have handy, everyone should be able to identify which areas are really 'clean' or 'polluted' and how exposure time affects total exposure. Some findings might surprise them and you. Once you have their attention, group discussion following from that can be tailored to be especially appropriate for general science, environmental science, chemistry, biology or health classes. Teachers of 6th-8th grade science classes report that this works well with their students, but one can imagine trying it with other grades. If air pollution is your specialty, be prepared to explain everything you know in lay terms!

3• Reading Labels: We Are What We Eat^{1,4} One of the ways we are exposed to chemicals in our environment is by eating or drinking them. How much do we know about what we ingest? Awareness and knowledge are critical if we are to improve nutrition to minimize our risk of adverse health effects. An effective way to begin this exercise is to unpack a shopping bag filled with foods, drinks, toothpaste, and other grocery items people often ingest that you are prepared to discuss. Ask students what kinds of chemicals might have been added during growing, manufacturing, or

packaging? What is "organic" food? What does the term "organic" mean for chemists? Do these two meanings differ? How? Are "organic" foods still "full of chemicals"? What is *all* food made of? How do we measure what is in food? Can "natural" chemicals be toxic, or is it only human-made chemicals that we should worry about? Give examples. What environmental laws influence food safety and quality? Basic concepts of nutritional needs could be added to the discussion. If you are able to conduct this exercise over more than one class period, ask students to keep a log of what they eat for a specified period of time and also devote some time to investigating foods they like with respect to issues you have discussed. Fundamental goals of this activity are to develop curiosity in items people often take for granted, and to develop and share strategies for improving knowledge (reading product labels, browsing newspapers, watching newscasts, and searching the Web).

Bring a tube of toothpaste and read the warning label on the tube about contacting the poison control center. Most people are shocked. Ask whether fluoride is good or bad for you. Ask the class if they can guess what the chief reason was for rejecting draft candidates in both World War I and II. Ask the class if they know any 16 to 19 yr olds. Ask how many of them are wearing dentures or have false teeth. In fact, in WWI and II, the chief reason for rejecting draft candidates was a lack of at least six opposing teeth (see <http://www.cdc.gov/epo/mmwr/preview/mmwrhtml/mm4841a1.htm>). The impact of fluoridated water has been so dramatic that the Centers for Disease Control lists it as one of the 10 great health achievements of the 20th century. Despite this, serious opposition exists against fluoridated water, and attacks by these groups usually ignore the concept of dose. As a result, less than 60% of the U.S. water supply is fluoridated. This discussion can be adapted for people ranging from 80 yrs old to 8 years of age, and possibly younger. Be sure to emphasize the benefits of fluoride and reemphasize this, particularly with younger students, so that they go home understanding that it is okay to use fluoridated toothpaste and drink fluoridated water. Fluoride is an ideal compound for communicating "the dose makes the poison".

As you read labels together and consider their implications, depending on the class level the discussion can lead to an almost endless selection of topics. How to read multisyllabic words (English class), basic toxicology principles (chemistry or biology class), how medicines and other products are tested for safety and why toxicologists and other scientists use animal models (health classes). This exercise could even be tailored to offer a new perspective on ethics (social science) or factoring in the costs of development and testing in the final cost of products (math or economics), or a separate unit on the history of toxicity testing. K-3 teachers have even reported success at teaching younger children how to look for key words and symbols on labels signaling clearly not to eat certain things.

4• Creating Your Own Bag of Professional Props⁵ Look around your office or lab for things that you use in your work, are portable, may be unusual to students, fit into a small suitcase or backpack, and help explain what you do. Lab coat, goggles and lab ware, photographs, preserved specimens, vials or other containers of non-hazardous chemicals (see note about this below), particularly interesting data output--even a thick document produced for a client or government agency--anything to help the students understand what you do and recognize that you are making an effort to share this with them. Some schools prohibit children from carrying medications with them. Others may have other policies about bringing any chemical substances onto campus, so try not to inadvertently encourage violating any school policies. A final note of caution: Passing items around the class can be disruptive. Unless you have identical objects for each child, it is usually good practice to keep attention focused on you as you interact with them.

Credits: Ideas contributed by SOT members ¹David Cragin, Ph.D., ²Steven Gilbert, Ph.D., ⁴Elaine Faustman, Ph.D. and Ann de Peyster, Ph.D. ³Adapted from most successful ideas offered by middle and high school teachers participating in the SOT's "Paracelsus Goes to School" K-12 teacher workshops from 1996-2000, supported by the National Institute of Environmental Health Sciences. ⁵Inspired by Toxin-a-Box™ and a presentation by Beverly Shelton at the 2000 annual meeting of AALAS. Scientist Mentor Ideas are a creation of the K-12 Education Subcommittee of the Society of Toxicology's Education Committee.