Health Physics Society
Specialists in Radiation Safety

Radiobiology Lesson Plan

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Objectives:

- Reinforce knowledge of cellular structure
- Demonstrate the low probability of interaction
- Explain the factors contributing to cellular sensitivity
- For older groups—describe mechanisms of cellular injury

Materials:

- Student/teacher text associated with lesson on cell structure
- Large (1.2 m × 1.2 m) felt model of an animal cell
- Projectile that will stick to the model
  - NERF bullets with Velcro®
  - Ping pong balls with Velcro
- Index cards or candy
- Career brochures or career video

Lesson Plan:

Introduce the profession of health physics.

When asked, most individuals have no idea what a health physicist is, although most students infer that health physics is a profession associated with the health care industry. While there are many radiation safety officers and medical physicists associated with health care, a great deal more are associated with an aspect of occupational radiation protection. This part of the discussion should be flexible when you are there as part of a career day. There is usually a great deal of interest in knowing how much a health physicist gets in salary, so be prepared with information on entry-level positions. In addition, be knowledgeable of employers in the area who would hire a health physicist or radiological control technician. There usually isn't a great deal of interest in knowing just how much math and science it takes to be successful in this field, but in your back pocket you might want to know if local or state colleges offer a comparable degree.

The Health Physics Society has prepared brochures and a career video to supplement your discussion. These can be found at hps.org/publicinformation/hpcareers.html.

Ask the students questions to gauge their level of knowledge and comfort with the topic.

- Do you know of anyone who works with radiation and/or radioactive material?
- Do you know of anyone who has undergone radiation treatment for a disease like cancer?
- Have you had an x ray? A bone scan?
- What word comes to mind when someone mentions radiation?

Depending on the age group, I have received answers that cover a broad range. Since I usually am introducing this to students in/around a national laboratory, it is not uncommon to hear "my mom" or "my dad" in answer to the first question. It is also not uncommon to hear about a relative in the context of the second. Most students have undergone at least one x ray. Some words that have been mentioned regarding radiation are "deadly," "Teenage Mutant Ninja Turtles," "Spiderman," "the Hulk," "scary," "bombs and/or weapons," and "reactors" (Fukushima, Three Mile Island, Chernobyl). Unfortunately, I have rarely heard radiation mentioned in a favorable context. Even

with those who are knowledgeable of medical applications, the media images of mutations and public misinformation override their perceptions.

To encourage participation in the discussion, I have used index cards and have had the students write down their answers to those questions at the beginning of the discussion. Students are hesitant to admit their interest out loud, but will often write down what they are thinking. Collect the cards and then summarize or read the answers.

I have found that it works even better to use a bag of candy (make sure you find out ahead of time if there are any food allergies in the class). Reward a student with a piece of candy for offering his or her opinion.

Explain cell structure.

As most students correlate radiation effects to mutations and cancer, using an animal cell model has a greater effect than using a plant cell, which has a hard wall.

When designing your model, talk in advance with the teacher about the best way to mount your model to a wall and include that in your design. Is it to hang like a banner with a rod across the top? Are there hooks and do you need to include eyelets? Are thumbtacks allowed?

The complexity of the model introduced to the students depends upon the grade in which they are enrolled. The model I utilized showed the major structures of the cell, including representations of the nucleus, endoplasmic reticulum, Golgi apparatus, ribosomes, mitochondria, centrioles, lysosomes, vacuoles, and cytoplasm. To prepare my model, I took a large piece of felt (approximately 1.2 m × 1.2 m) as my base. As an animal cell doesn't have a rectangular structure, I used scissors to add some curves. Then I cut out a variety of shapes out of different colors of felt to represent the various cell structures. I attached these with Wonder-Under®, an iron-on product (there are others available). I did not use school glue because it usually bleeds through both layers of felt, leaving a surface that Velcro will not easily stick to. It probably took me about 3 hours to prepare my model from start to finish.

Use the model you created to reinforce the lesson plan and explain cell structure. Have the students identify the various cellular structures represented and the function of each structure. Then move the discussion into speculation as to what would happen to the cell if each part of the cell were damaged. Middle school students will probably have little knowledge of the various repair mechanisms available to a cell, but a high school biology class may know more. I would suggest limiting this discussion to the functionality of the structure, i.e., possible damage to the DNA if the nucleus were damaged or release of materials into the cytoplasm if a lysosome or vacuole were compromised.

Demonstrate the probability of damage.

This is an interactive section. Give each student a projectile, as described in the list of materials. Have each student "aim" his or her projectile at the cell model. Talk about the random nature of interactions—radiation can scatter off of other materials, unlike a laser, which has focus and directionality.

Even though the model is not to scale (the modelled structures will be relatively larger than actual), you should find that the majority of the projectiles interact with the cytoplasm. This is more graphic if you have enough projectiles for everyone in the class. We had about 20 students per class and the most any class got to interact with a structure was about 10%. We then spent some time talking about relative sizes of radioactive particles to the cell structures.

Initiate discussion.

After the interactive demonstration, hold a discussion about radiation effects. The detail of this discussion will be directly related to the time you have to present and the background of the students.

A big part of this discussion is introducing the concept to the students that radiation is one of many "insults" that a cell may endure and, because of that, the cell doesn't necessarily see radiation as unique. Usually, radiation damages the cell through excitation and ionization or free radical production (antioxidants). A good reference to use for this part is the chapter "Biological Effects of Radiation" in *Introduction to Health Physics* by Herman

Cember. The focus is then on the extent that cellular damage is related to the total dose and the dose rate. The other factors (type of radiation, mode of delivery, and other environmental stressors) may be omitted if there are time limitations. Introduce dose as acute versus chronic.

- Acute: an x ray for a broken bone
- Chronic: drinking water, cosmic radiation

If your group has been introduced to cellular reproduction by this time, move into the concept of cellular sensitivity, in particular the law of Bergonie and Tribondeau. In summary, that law states that cellular sensitivity is proportional to reproductive activity and inversely proportional to the degree of cellular differentiation. The chapter "Cellular Radiation Damage" out of *Handbook of Radiobiology* by Kedar Prasad is invaluable as a basis. Ask the students to provide examples of cells that divided rapidly and those that are highly differentiated.

- Examples of rapidly dividing: blood cells, crypt cells
- Examples of highly differentiated: nerve cells

Using the familiarity of the students with radiation cancer treatment and the symptoms they observe, lead the discussion to follow the development of acute radiation effects. I found the students were aware of blood changes (anemia, fatigue, immunodeficiency) and then the nausea and vomiting. Few were knowledgeable of the biological effects on the nervous system. As this group of students was aware (as the result of a previous presentation on nuclear power) of the natural background levels at 0.006 Gy, I was able to compare values.

- Hemopoietic syndrome (2 Gy)
- Gastrointestinal syndrome (10 Gy)
- Central nervous system syndrome (20 Gy)

Delayed radiation effects are generally categorized as cancer, genetic effects, and cataracts. As most of these are caused by direct damage, steer the discussion to what cell structures had to be damaged to cause these. Then relate this to cellular division, discussing when these effects would be exhibited. The success of this lesson plan is directly related to the discussions that you have with the instructor prior to your scheduled presentation, as the primary objective is to supplement the curriculum around cell structure. Teachers are usually bound by the established and approved curriculum and associated text. Support and additional materials can be provided upon request.