Curriculum Units by Fellows of the National Initiative
2019 Volume IV: Energy Sciences

Demystifying Radiation

Curriculum Unit 19.04.09, published September 2019
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Introduction

"If we hear enough lies than we no longer recognize the truth at all."[1] Valery Legasov, *Chernobyl*

In HBO's recent miniseries *Chernobyl*, nuclear scientist Valery Legasov contemplates his role and decisions immediately after the explosion of their nuclear reactor. Amid a cloud of fear, nationalism, and willful ignorance, the manager, partners, and government officials of the Chernobyl nuclear plant endangered and exacerbated the situation that led to the meltdown, and subsequent radioactive fallout. Directors of the show painted a grim image of a population suffering from severe radiation sickness and burns, bodies disintegrating from the inside-out. Viewers watched in stunned empathy as both young and old faced the realization that their level of radiation exposure guaranteed a reduction of their life by decades. This picture and those of the Fukushima Daiichi Accident in 2011 imprinted an unforgettable vision that has forever impacted public opinion towards nuclear energy. Without much information, the general population formed a negative opinion about nuclear energy and radiation. Most view radiation as it related to nuclear accidents, but very few are aware how ubiquitous radiation exposure is in our daily lives and that it is useful and beneficial in many ways.

This curriculum unit for 11th and 12th grade Anatomy and Physiology high school students will attempt to balance and perhaps sway people's opinion regarding nuclear energy and radiation. It will provide readers with a fundamental understanding of radiation, radioactive decay, its sources (natural or man-made), and discuss both the benefits and consequences of radiation exposure.

Rationale

The students of Mt. Pleasant high school live on the east foothills of San Jose, CA. On average San Jose receives 257 days of sunny weather. During summer vacation, the temperature fluctuates between 57 ℉ to 82 ℉ throughout the day.[2] With more than 8 months of sunshine many high school students seek jobs in the local water park. Students flock to Raging Waters where they can work to earn a wage to assist their parents with their own income or simply provide the necessities for themselves. With the ever-rising price of housing in San Jose, students eagerly seek to become the next lifeguard or water-slide operator in the dry heat of the summer months. At the opening of school, students return to school having toiled and baked for weeks, sporting their freshly tanned and taut skin. What my students do not realize as they earn a minimum wage is the cost they are paying each time they forget to wear or reapply sunblock. For many, radiation has already done its damage.

Over the course of three weeks, Anatomy and Physiology students will understand the impact of the sun's energy on their skin and on their DNA. They will contrast the radiation from the sun to nuclear radiation. As the unit progresses, students will learn that radiation, for all its faults, benefits us all. By completing this unit, student will articulate why and how radiation is everywhere!

Content Objectives

In their past Chemistry classes, students in Physiology have learned that energy can be absorbed, stored, and released in chemical bonds. In Human Physiology, we often do not give much time and focus on the uses of energy beyond the breaking of food in the digestive system to gain energy. In fact, there are other forms of energy Physiology students will be exposed to during the year. These are chemical energy, mechanical energy, radiant energy, and electrical energy. Mechanical energy focuses on energy utilized in muscle systems. Electrical energy is found in nerve cells and muscles cells which provides the energy to stimulate muscles and fuels nerve pathways. All these different energy forms are important for Physiology students to understand. This unit will, instead, focus on energies associated with ultraviolet (UV), alpha, beta, and gamma radiation. I will provide a background of each type of radiation and discuss the sources for each along with the benefits and consequences of its use.

Content Background

Radiation Fundamentals

Everything is radioactive! Everyone is exposed to radiation! Exposure to radiation is as natural as being under the sun. In fact, the sun is the source of radiant energy. Radiant energy is emitted and transmitted in waves rather than through matter. We know these waves to be a part of the Electromagnetic Spectrum (EMS). (See Figure 1 – Electromagnetic Spectrum.) EMS shows the correlation between wavelength, frequency, and energy. As we move past the visible light spectrum, wavelength, the distance between the crest of each wave, decreases as the frequency, or rate at which the wave passes over time, increases. Using the formula we can calculate the amount of energy associated with each type of wave. Energy can be calculated knowing h = Planck's constant 6.33 x 10^{34} Js and f = frequency (Hz). Or, energy can be calculated with the wavelength (and the speed of light in a vacuum c = 3 x 10^{8} m/s.[3]

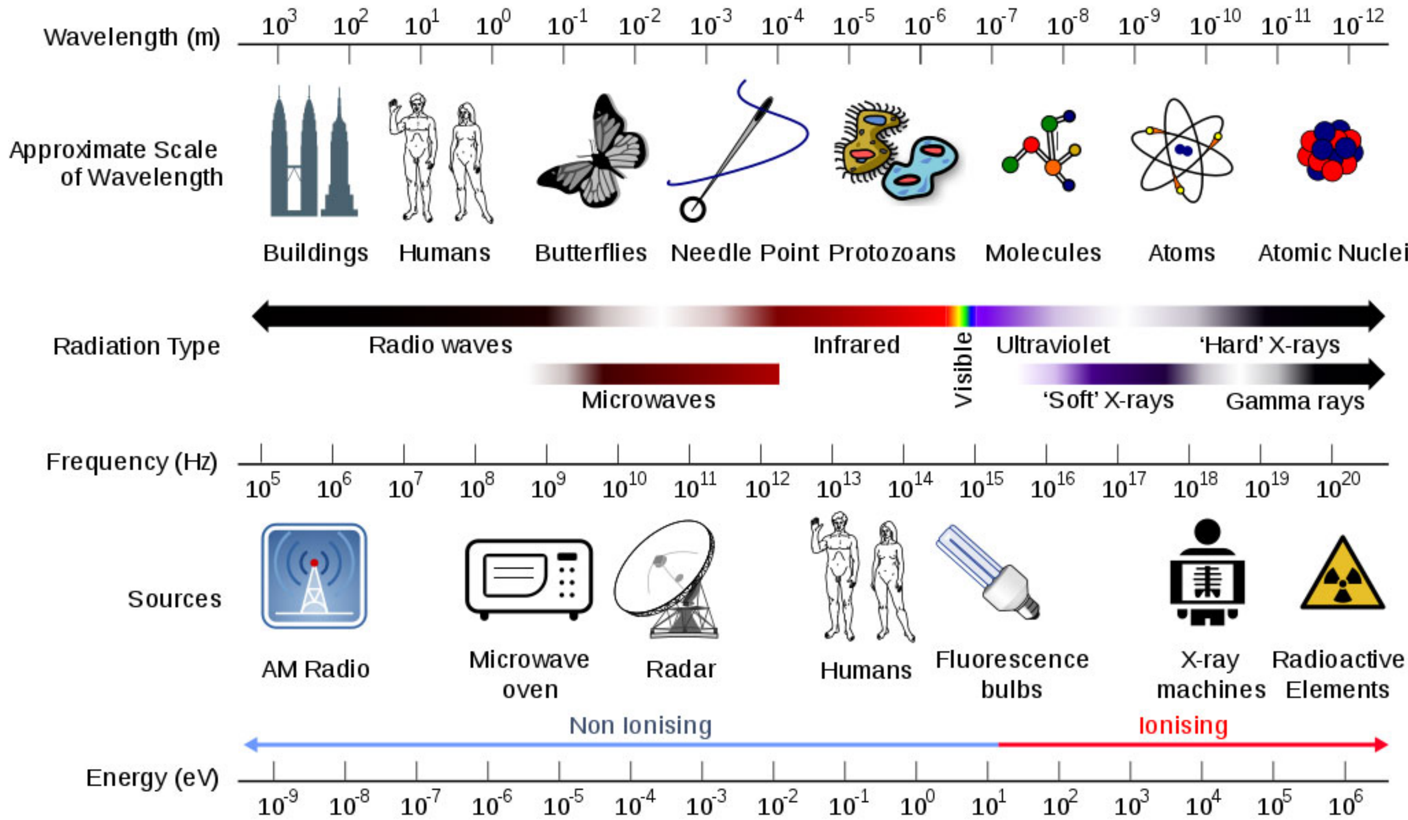

Figure 1. Electromagnetic Spectrum showing wavelengths, frequency, radiation types, and energies associated.[4]

This unit will primarily focus on ultraviolet radiation, X-rays, and gamma rays which are all types of ionizing radiation whose wavelengths are shorter than 400 nm. To begin understanding why there are some types of radiation that are more harmful than others, a review of atomic particles is necessary. Many students will recall the atom. The atom is a unit of matter. The three atomic particles are positively charged protons, neutral neutrons, and negatively charged electrons. Within the nucleus of an atom are protons and neutrons. Because protons are positively charged, they tend to repel (push) each other away; thus, neutrons hold protons together. Atoms vary in the number of neutrons and protons they have. This variance in neutrons and protons creates different elements. Because atoms are high energy, they at times lose or change the number of protons and neutrons that they have. This change in the atom is known as radioactive decay. For example, uranium loses 2 of its protons to become the lighter thorium with 90 protons. This decay matters because each time an atom decays, it creates radiation.[5]

There are three types of radiation produced by radioactive decay: alpha, beta, and gamma radiation. Each are created from an atom trying to balance itself out (having enough neutrons to hold the protons together). Unstable nuclei undergo radioactive decay when a nucleus absorbs another particle or loses a particle. This shift in an atom where there are more protons than neutrons or vice versa creates radioactivity. (See Figure 2-Radioactive Decay.) In alpha radiation, clusters of 2 protons and 2 neutrons are expelled from an atom. This particle is completely harmless outside of the human body, but harmful within the body because it could lead to radiation sickness and other radiation related disorders. Beta particles are released when radioactive atoms expel negatively charged electrons. Unlike alpha particles, these are very light and fast moving. The third type, gamma radiation, is like light rays, but different from alpha and beta particles since gamma radiation has no mass and has no charge. Gamma rays are emissions of photons (a particle of light or electromagnetic radiation). Each particle has its own level of harmfulness to the human body which will be discussed later in the unit.

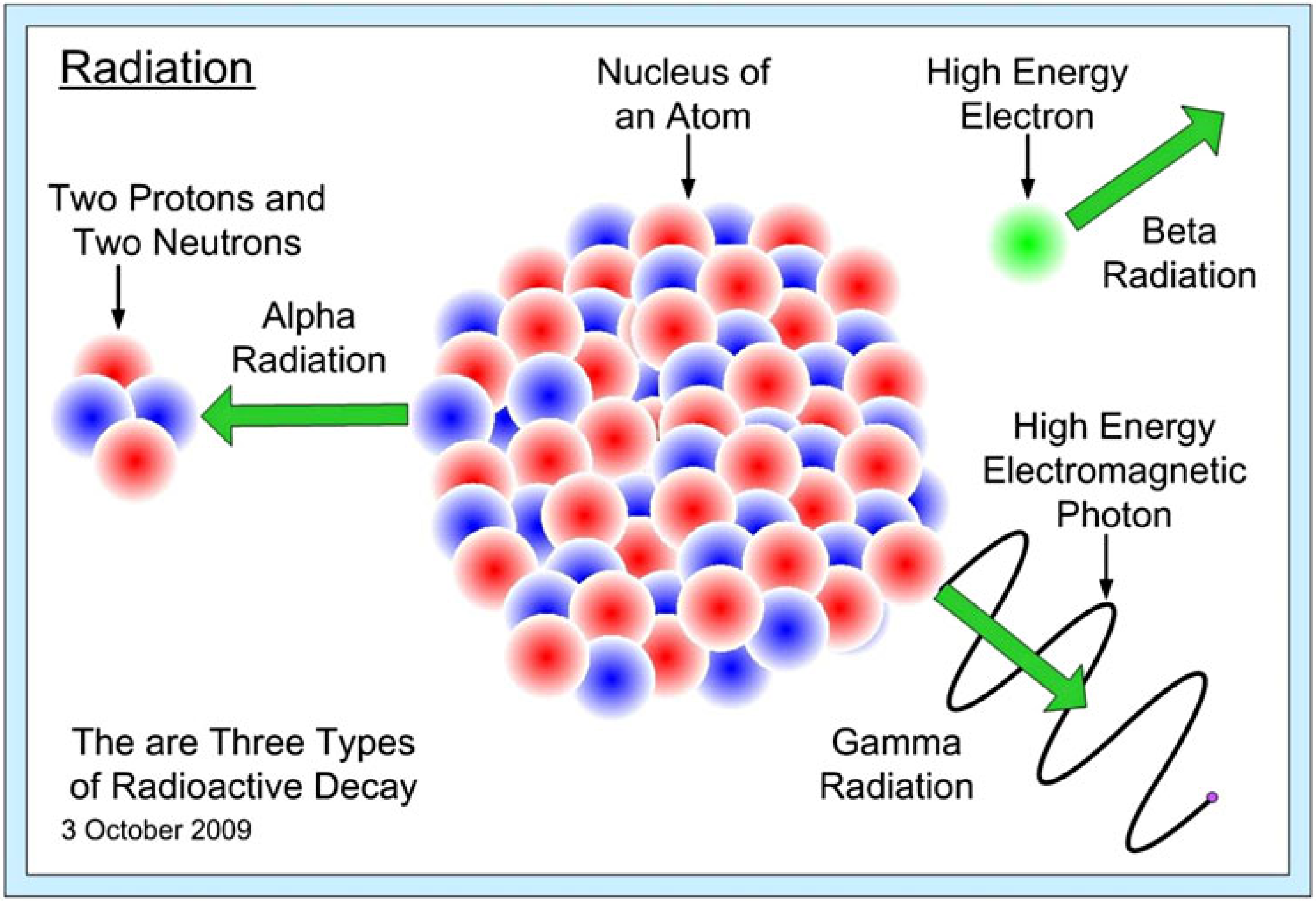

Figure 2. Radioactive decay showing alpha, beta, and gamma radiation.[6]

When measuring radiation there are four components: Radioactivity, Exposure, Absorbed dose, and Dose equivalent. Radioactivity is the amount of ionizing radiation released during over time. This is measured in curie (Ci). Exposure is the amount traveling through air. This is measured in roentgen (R). Absorbed dose is the amount that is absorbed by a person or an object and it is measured in radiation absorbed dose (rad). Dose equivalent measures the combined absorbed radiation and the effect of the radiation on the human body. This measurement is expressed as roentgen equivalent man (rem) and 100 rem equals 1 Sievert (Sv). Thus 1 R (exposure) = 1 rad (absorbed dose) = 1 rem or 1000 mrem (dose equivalent).[7] To put things in perspective, 1 mrem is equivalent to 1 year of living next to a nuclear power plant or 1 flight coast to coast. When discussing exposure to radiation, it would take a very high dose of radiation to cause radiation sickness or death. In fact, it would take about 2,500 mrems to cause radiation sickness. According to an article in *MIT Tech News*, the limit of acceptable exposure is 3000 mrems for adults, while children under 18 should be limited to under 500 mrems. The average American citizen is exposed to 620 mrem each year, well below the acceptable exposure limit.[8]

Sources of Radiation

Natural Radiation

We are all radioactive. Atoms in our bodies decay; we eat food, inhale particles, drink water, and interact with other humans and animals who are all emitting radioactive particles. Gale and Lax in *Radiation* proclaim, "Sleep next to someone and your bedmate will get a dose of Potassium-40 radiation from you" and vice versa.[9] According to the U.S. Environmental Protective Agency, background radiation includes radiation from the ground and soil, water, and even other humans.[10] Radiation from radon, is particularly prevalent with 37% of all natural radiation sources coming from radon.[11] Radon-222 is so prevalent that most people have ingested it or inhaled it from air, water, or soil. Rn-222, in fact, is attributed to 21,000 lung cancer deaths each year.[12]

Ultraviolet Radiation

One type of radiation that my students are particularly interested in studying is ultraviolet radiation. Beyond the visible spectrum is the ultraviolet spectrum. Wavelengths ranging from 10 to 400 nm include three types of UV (A, B, C). Because of the earth's atmospheric composition, most UV rays emitted by the sun are absorbed by the ozone layer. UV-C rays never make it past our ozone layer, while UV-B and UV-A rays do. The more harmful of the two are UV-B rays which have the potential of harming DNA structures. Fortunately, only 5% of UV-B strikes the earth's surface.[13] Most of the damage done to people's skin is caused by UV-B radiation.

UV-B rays cause suntans through the stimulation of melanocytes to produce melanin. The cells associated with melanin production, melanocytes, are not unique to the skin. They are found in the brain, the heart, and mucous membranes of the GI tract. Because melanin does not stay in the skin forever it is passed to keratinocytes, cells with a short life span of 4 to 5 days. UV-B exposure causes damage to the DNA of melanocytes. If the DNA is damaged, it may alter the cell's ability to regulate division causing uncontrolled cell growth. Uncontrolled cell growth could potentially cause cancers, like melanoma. According to the World Health Organization it estimates 65,000 melanoma related deaths occur each year. Though the best way to protect the skin from UV-B rays is simply to cover the exposed skin with long sleeves, UV protective sunscreen can provide some level of protection if used properly.[14] However, sunscreen does not completely block out UV, it merely allows the user to stay exposed longer than not having any protection. The combination of chemicals like zinc oxide reduce penetration of UV rays. A sun protective factor (SPF) label of 20 means the sunscreen can absorb 95% of the harmful UV. Sunblock wearers should still recognize that 5% of UV rays pass the skin which may cause sunburn or premature again over time.

But, how do UV rays damage the skin? First, students need to recall the structure of DNA. DNA is composed of four bases which include combinations of adenine, cytosine, guanine, and thymine. Alone, UV-A cannot damage DNA directly but can cause free radicals which may harm DNA indirectly along with other fats and proteins. UV-B rays on the other hand affect the bonded thymine bases by altering their chemical bonds. Exposure to UV-B creates thymine dimers. When dimers of thymine are formed it creates a kink or bend in the normal structure of DNA which alters the DNA message. This change could lead to mutations, shifts in the DNA code which could lead to improper coding, cancer, or cell death.[15]

Besides creating thymine dimers, DNA bonds can be altered by exposure to higher energy UV. Referring to Figure 3, bonds forming the DNA bases are made of bonds between carbon (C), nitrogen (N), oxygen (O), and hydrogen (H). Respectively, the bond between H and O has 467 kJ of energy, while the bond between N and H has 391 kJ of energy. (See Table 1.) According to the electromagnetic spectrum, UV-C rays can have energy values greater than 427 kJ which would be strong enough to break the bonds in adenine, thymine, guanine, and cytosine. Even if a person were only exposed to UV-A rays, like the kind that penetrates the skin, it has enough energy (299-373 kJ) to break C-C bonds (347 kJ), C-N bonds (305 KJ), C-O bonds (358 kJ). As the graphic (Figure 3) shows many of the bonds holding together the DNA structure can be damaged by UV radiation.[16]

The bottom line is simple, UV radiation's energy has the potential to affect DNA because the chemical bonds holding the bases, to create the DNA ladder are not that strong. This of course is essential to DNA's ability to replicate but it is also the reason why DNA is susceptible to damage from high energy radiation. Fortunately, the skin's DNA has a variety of methods to protect itself from damaging UV radiation.

Despite UV's reputation to cause sunburns, break collagen fibers that cause premature aging, and damage DNA, UV rays can be beneficial. For example, UV-B synthesizes vitamin D which is necessary for bone remodeling. It also prevents Rickets which is a deficiency in vitamin D causing bones to soften. Another benefit of UV radiation occurs in psoriasis patients whose skin produces silvery, flaky, scaly patches. Treatments with a dye called psoralen and UV-A rays kills the DNA of cells with psoriasis allowing healthier skin cells to proliferate.[17]

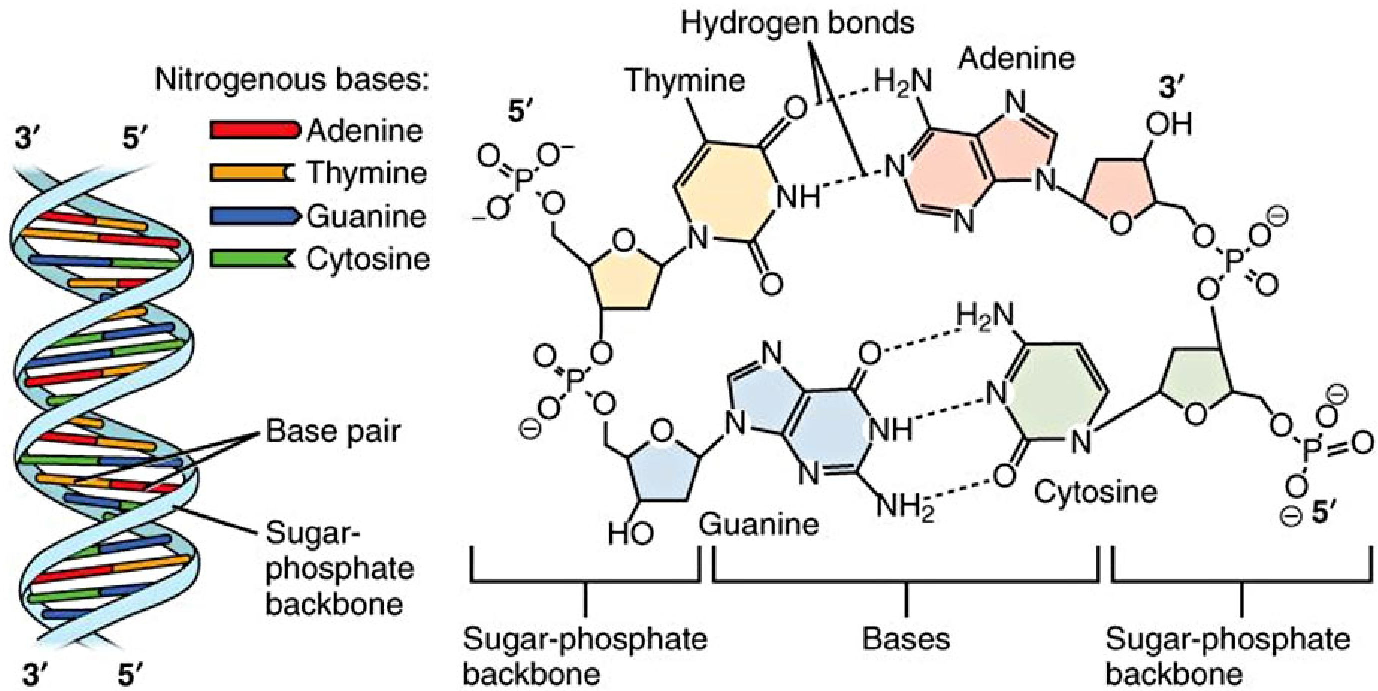

Figure 3. DNA Structure showing chemical bonds between DNA base pairs.[18]

Type of Bonds in DNA	Energy Content in kJ/mol	Broken or Damaged by
Oxygen - Hydrogen	467	UV-C rays (>427 kJ/mol)
Carbon - Hydrogen	413	UV-B rays (373-427 kJ/mol)
Nitrogen - Hydrogen	391	UV-B rays (373-427 kJ/mol)
Carbon - Oxygen	358 (single bond)	UV-A rays (299-373 kJ/mol)
Carbon - Nitrogen	305 (single bond)	UV-A rays (299-373 kJ/mol)
Carbon - Carbon	347 (single bond)	UV-A rays (299-373 kJ/mol)

Table 1. Bond and UV energies,[19] information compiled and modified from Clutch Prep Chemistry and Gary Brudvig's YNI Energy Science seminar 2019.

Man-Made Radiation

My students may be cognizant that sunblock is necessary to maintain healthy skin. But, sunblock is not a priority in their lives. They are more concerned about one thing – power. Power to fuel and charge their cellular devices. Each day, students enter my classroom and inevitably one of them will ask if they can charge their phones, not being remotely concerned where the electricity to power their phones comes from. Granted, living in California with its 8 months of sunny weather means we have plenty of power from the solar sources, but what they do not realize is that 9% of California's power consumption comes from nuclear energy.[20]

Nuclear Energy

How is nuclear energy generated? Nuclear energy is generated during nuclear fission. In nuclear fission, neutrons bombard the element uranium (U), which is a heavy metal that is mined. The crashing of a neutron into the nucleus of a uranium atom causes a splitting of the atom, a breaking of the attractive force between protons and neutrons in the nucleus, which in turn releases energy. This energy, as heat, warms up the surrounding water where uranium rods are submerged. The water warms creating steam, and powers turbines to produce electricity.[21] The fuel used in nuclear reactors comes from enriching uranium. (See Figure 4.) Uranium as an element is mixed with other minerals, sulfuric acid, and oxygen to form uranium oxide. In powder form, this material is not very radioactive and needs further processing to enrich the U-235 relative to the more abundant U-238. The mixture of U-238 and U-235 needs to be mixed with fluorine to obtain uranium hexafluoride (UF_6), which is a gas. The once the powdery uranium oxide material is converted to a gas, UF_6 is centrifuged thousands of times to separate U-238 from U-235 the desired type of uranium to make uranium pellets. Once the enrichment process produces a lot of U-235, the gas is combined with calcium in order to create uranium pellets. Pellets are used as fuel in reactors and the spent U-235 is turned into plutonium (Pu). All throughout this production of nuclear fuel, radioactive rays and particles are created and released when atoms break apart.[22]

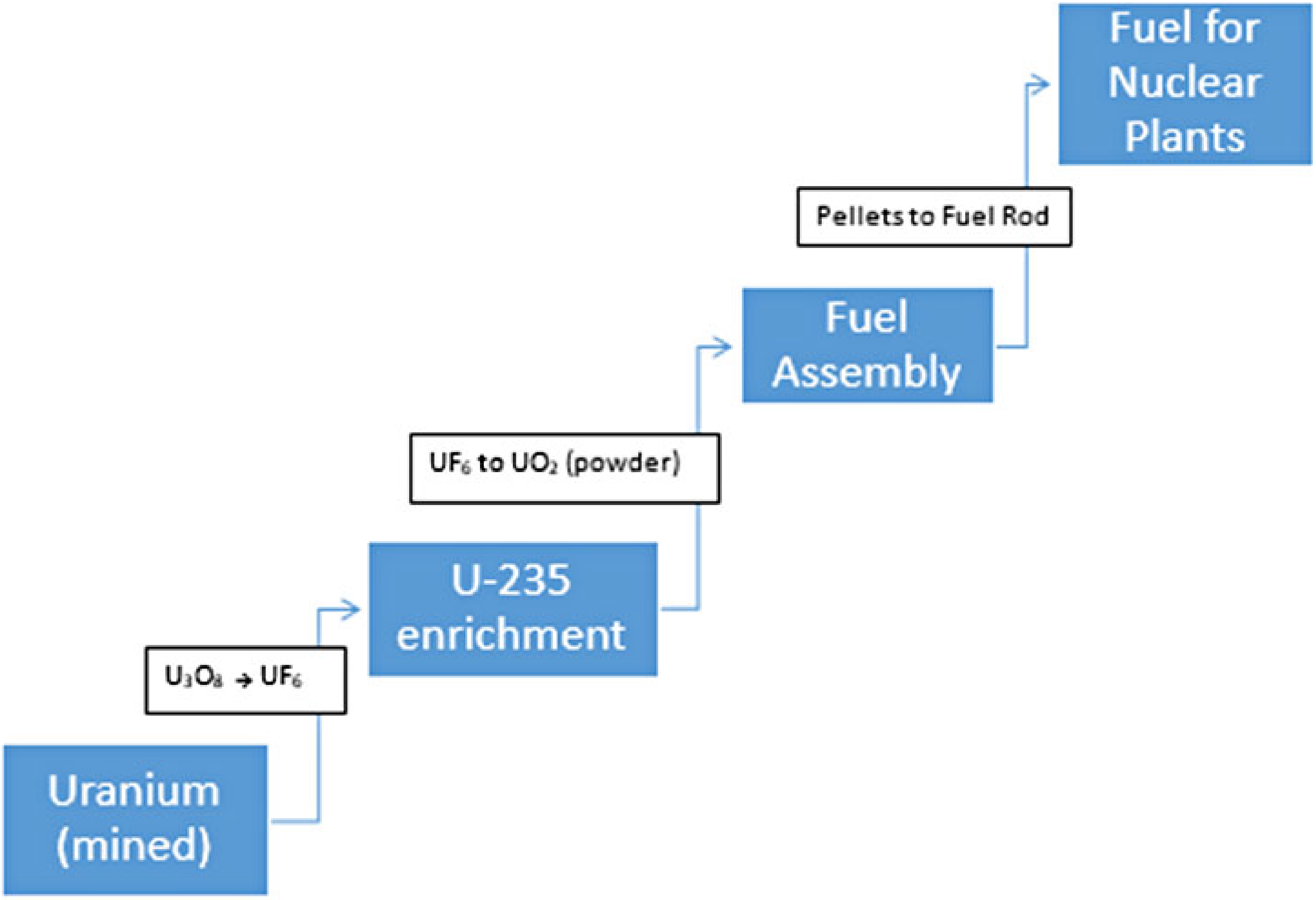

Figure 4. Processes involved in production of nuclear fuel.

Despite potential for supplying and providing the world with over 2500 TWh of electricity, nuclear energy is disfavored in many countries. There are very few reactors building built, with France as the only country that is committed to increasing its nuclear use.[23] The fear of course stems from the disasters at Chernobyl in 1986 and Fukishima Daiichi in 2011. The general population does not see how safe nuclear reactors are since most media only publicize instances when reactors fail. Granted, the high energy contained in nuclear reactors and its potential to cause radiation sickness, radiation related cancers in some, and birth defects in pregnant mothers are alarming. But, we also must balance nuclear disaster image with those of people being hurt during natural gas explosions, cancers related to coal mining and fracking, and exposure to toxic waste materials during the production of supposed clean energy sources. As with most new development, there is a consequence that must be faced or a cost that must be paid. With regards to nuclear energy, the benefits might outweigh the few instances in which people were injured, became ill, or killed.

Radiation in Medicine

Nuclear fuel and nuclear weapons are not the only uses of radioactive materials. Today, the field of medicine has expanded the use of radioactive and nuclear materials to diagnose and treat patients. This unit will discuss the use of X-rays, a high energy electromagnetic wave, and radionuclides (radioisotopes) in medicine.

Most people will at some point be exposed to radiation in a dental or medical office in the form of X-rays. X-rays are high energy photons (light energy) that are invisible to humans since they do not fall within the visible light spectrum of 380 to 740 nanometers. Because X-rays are high energy, they can penetrate the skin but cannot penetrate bones. The shadow that is cast by bones creates an image on an X-ray film. This shadow does not occur when soft tissue like skin and muscles are exposed to X-rays. Bones appear white because of a mineral called hydroxyapatite. Hydroxyapatite combines calcium phosphate and calcium carbonate ($Ca_5(PO_4)_3(OH)$).[24]

The Nobel Prize of 1979 was awarded to Godfrey Hounsfield and Allan Cormack who further developed the use of X-ray technology that became the computer axial tomography (CAT or CT scan). Through a series of 175 to 200 X-ray scans, a full three-dimensional view of a patient's body can be visualized, giving physicians a powerful diagnostic tool. Similar to mammograms, the benefits of exposing the body to far greater ionizing radiation outweighs the bad and "the decision to recommend any medical screening procedure…is based on a delicate balance of estimating potential benefit and risk."[25] The benefit of exposing a patient to higher dose of radiation in CT scans is that CT's produce a highly detailed image of a small cross section of the body. When combining the cross sections, doctors can get a more comprehensive view of the body or a specific organ system to assist in their diagnoses.[26]

Though X-rays and CT scans have allowed doctors to diagnose medical problems for over 100 years, more inventive use of radiation has accelerated our ability to detect and diagnose disease with the use of nuclear medicine. Though the term, nuclear, brings pause and hesitation to patients, radioactive injections and radiotherapy are important tools in today's medicine. Radiotracers, allows doctors to diagnose heart disease, gastrointestinal issues, endocrine dysfunction, and even neurological abnormalities. For example, if a patient noticed they were losing weight but had not changed their diet or exercise, a doctor might want to confirm if the patient has hyperthyroidism. This condition causes the thyroid gland to over produce its hormone thyroxine which might be one cause of unintentional weight loss.[27]

According to Gale and Lax in Radiation, "[Radiation Therapy] is like a nuclear weapon where the antibody is the targeting missile & radionuclide is the nuclear warhead."[28] Radiation Therapy (RT) is given to patients in several small doses over the course of days or weeks. This mode of treatment allows normal cells to recover from the high dose of radiation while killing off the targeted cancerous cells. RT is being used to eradicate cancerous cells, prevent reoccurrence of cancer cells, and reduce the size of a cancerous mass. Like other therapies, the effectivity and damage are dependent on an organs' sensitivity to radiation. Organs like bone marrow, gastrointestinal tract, and skin are highly susceptible and sensitive whereas the brain, kidney tolerate higher levels of radiation.[29]

The world is filled with harmful substances. Radiation is just one of many substances that is potentially harmful and could damage the human body. It is important to not let one source inform our decisions about radiation. The information and exaggerations we hear in the news must be mitigated with fact based on science and research. Admittedly, nuclear energy can pose hazards if nuclear reactors are not well managed, but, most people will never encounter radiation from a nuclear facility. It is more likely that radiation exposure will come medical sources, the food that we eat, and the sun. Since we cannot avoid radiation nor its benefits, each of us can be proactive by monitoring our own radiation exposure levels. Websites like the Environmental Protection Agency offer radiation calculators which allow users to input multiple variables like elevation, proximity to nuclear facilities, occupation, and medical procedures to calculate radiation exposure levels per year. In doing so, the public can inform themselves about their actions that increase or decrease their exposure levels. More importantly, the public may come to realize the truth, that nuclear power plants and radiation are not our enemy. We can easily implement methods to control our exposure to avoid radiation sickness. There is far too much good that radiation has allowed humans which simply outweighs the costs.

Classroom Strategies

My Physiology class is a hub of busy students, activities, conversation, and movement. At times, I wonder if the controlled chaos I call a high school Anatomy and Physiology classroom is productive. Then, I am reminded that it's not how neat your classroom space is that matters when it comes to learning. Riley and Terada, in a January 2019 Edutopia article assert that when it comes to learning, "relationships matter deeply, learning happens when the brain feels safe and supported."[30] In establishing environments where this is the norm "no child is a lost cause." Because my students want to be in my classroom during school hours and beyond, I know the lessons, labs, demonstrations, activities, projects I have created and crafted have fostered a welcoming, challenging, and engaging space for my students.

Having multiple hands-on activities is one strategy to engage students. Another strategy is to promote meaningful connection, communication and social skill through kinesthetic activities. One type of kinesthetic activity described in the section Classroom Activities involves modeling radioactive decay through movement. Students participating in the activity will need to read the background material on alpha, beta, and gamma particles and decide on the movement that will best show the concept. Kinesthetic activities like this allows students to engage in the problem and cooperate with their peers in a more meaningful and structured manner.

Finally, a direct case method will be incorporated through the unit.[31] In order to do this, different medical conditions will be introduced to the class through mock case files. Through the profiles in their mock-case files, students diagnose their patients based on a series of symptoms and descriptions revealed over the course of several class periods. In this manner, students must problem solve, analyze, connect, make claims, and defend their assertions to their peers. In this way, the teacher becomes more of a facilitator rather than a lecturer, assisting students as they progress through their case profiles.

It is important to note that these strategies need not occur separately, rather kinesthetic and hands-on learning should drive students understanding as they compile information for their case file.

Classroom Activities

Lesson 1: Introduction to UV Radiation

An introductory activity to demonstrate the presence of radiation will be to use ultraviolet sensitive beads in multiple small group activities. In this activity, students will need to be provided with a background on the visible light spectrum vs. ultraviolet spectrum. One method to complete this activity is to provide stations with materials and objectives for the station. Students would in turn create their own procedure to test their hypothesis. Another method would be to provide students procedures and ask them to collect specific data for the activity. For the purpose of this unit, I will have my students create their own mini-experiments and thereby create their own procedure.

Station 1: Essential Question: How do varying degrees of sunlight affect UV exposure?

Materials: UV beads, containers for beads, pencil, paper, access to outside

Student Goal: Draft a hypothesis based on the essential question, create a protocol to test the hypothesis and have another pair/ trio test the protocol to receive feedback.

Guiding Questions: What type of data will be collected? How will students use the materials? Is there a way to collect quantitative data? What are the variables in the experiment?

Station 2: Essential Question: How does distance from a UV source affect exposure?

Materials: UV beads, container for beads, rulers, meter sticks, pencil, paper, UV flashlight, safety googles or sunglasses with UV protection

Student Goal: Draft a hypothesis based on the essential question, create a protocol to test the hypothesis and have another pair/trio test the protocol to receive feedback.

Guiding questions: What variable(s) are being tested? How will students use the materials? Will the data collected be qualitative or quantitative?

Station 3: Essential Questions: Are all sunscreens with the SPF equal in their effectivity?

Materials: UV beads, baggies, 2-4 same SPF level sunscreen of different brands, pencil, and paper

Student Goal: Draft a hypothesis based on the essential question, create a protocol to test the hypothesis and have another pair/trio test the protocol to receive feedback.

Guiding questions: What factors besides application might affect the effectivity of the sunscreen? Consider different conditions that might be simulated by the experiment (ex. sweating)?

After trios or small groups have spent about half a class period drafting their protocols for each station, they will pair with another group of students to perform the experiment and to collect data. The activity will conclude with a whole class discussion on their findings.

Lesson 2: Half-Life Activity using Straws

Once students have been provided with a background of radioactive decay and particles, students will participate in a hands-on-activity on half-life. Student goals for the activity include: relating half-life and radioactive decay, creating line graphs with gathered data. This activity is modified from one available on ANS Center for Nuclear Science and Technology Information.[32] The activity will involve students graphing the number of radioactive particles (straws) remaining with each instance of decay.

Protocol for Radioactive Decay with Straws:

1. Cut a straw into 1 cm sections until each student has 20 1 cm segments representing radioactive particles (RP) within a nucleus.
2. Using a small covered Tupperware bowl or other container place the 20 RP inside.

3. Have each student shake the bowl which will represent one instance of decay. For this activity, one shake of the bowl will represent 5 years.
4. Without disrupting the other RP, remove the straws that are showing its opening while leaving the straws on its side in the bowl.
5. After the removal of stabilized radioactive particles (straws showing the opening), students will count the number particles remaining (straws on its side) and record that number on a data table.
6. Students will repeat steps 3 to 5 until the straws have completely decayed.
7. Using the data table they have completed for each trial, individual students will complete a graph showing the number of radioactive particles remaining vs. time (5 years per instance of decay).
8. As students are completing their graphs, the class data should be collected and a class graph will be generated. The graphs will show the relationship between the class total of remaining radioactive particles in each trial and decay. It should be expected the student graph should be similar to the class result.

Following the activity students will be able to predict the number of RP remaining in the nucleus at any given point based on the graph. Furthermore, students communicate how knowing the half-life is useful in the field of archaeology or forensic science.

Lesson 3: Mock Committee Hearing

As a culminating activity, students will participate in a mock Environmental Protection Agency meeting. In this hearing, student groups will need to convince the EPA whether current levels of radiation exposure are safe or whether it is necessary to increase measures of protection against radioactive exposure. Prior to this activity students have already completed lecture, discussion, direct case activities, web-based assignments, and labs to build their foundational knowledge for the hearing. In preparation for this hearing, students will be given different roles and will be given multiple class days to prepare their argument.

Day 1: Assignment

Students will be given roles to play during the hearing. Each student pair/trio must prepare a 5 minute presentation which may include a presentation, poster, or demonstration to support their opinion. Students will be encouraged to use data, graphs, pictures, and eye-witness testimonies to utilize in their testimonies.

Roles for Student(s):

Pro-environment

Pro-nuclear energy

Con-environment

Con-nuclear energy

Medical Doctor (Radiation Specialist)

Corporate Representative for Medical Tech Industry

Local Residents near Fukushima and Chernobyl

Nuclear Power Plant Worker

Economist specializing in Energy

EPA officials

Media Specialist for EPA

Day 2 & 3:

During the class period, students assigned to the roles will be given time to build their argument, gather resources from the internet, their textbook, and class lectures. Students will be asked to complete a work in progress log documenting what they intended to accomplish, what they accomplished, and what questions or issues still need to be addressed after the class period has ended. In this manner, I will be able to give them feedback before the start of the next class as well provide resources.

Day 4:

The class will complete a run-through of each students' argument. Students will be asked to say their speech to another student in order to gather feedback to improve their argument.

Day 5:

Class hearing. The classroom will be organized so that the EPA officials will be seated facing the front of the room, while the eyewitness stand will be the front classroom table. The session will begin by EPA officials stating the purpose of the session and providing ground rules/ time limits. Each eyewitness will have 5 minutes to complete their argument, followed by EPA officials asking clarifying questions. At the end of the class period, media specialist will provide a summary of the day's events and major arguments stated by each eyewitness. At the conclusion of the hearing, EPA officials will decide whether to further limit acceptable radiation levels or to place more stringent requirements on industry. EPA officials will also provide their recommendations and commendations to each eyewitness. To conclude, media specialist will share the final summary for the hearing with the public.

Classroom Resources

"Calculate Your Radiation Dose." EPA. July 10, 2018. Accessed July 14, 2019. https://www.epa.gov/radiation/calculate-your-radiation-dose.

EPA website that allows users to calculate their radiation dose average per year. Takes

into account medical sources of radiation, proximity to power plants, and geography.

Engdahl, Sylvia. *Energy Alternatives*. Farmington Hills, MI: Greenhaven Press, a Part of Gale, Cengage Learning, 2015.

Book would be useful to give students specific articles before a debate.

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OpenStax CNX. Accessed July 14, 2019. https://cnx.org/contents/14fb4ad7-39a1-4eee-ab6e-3ef2482e3e22.

Rice University's Anatomy and Physiology resource book.

OpenStax CNX. Accessed July 15, 2019. http://cnx.org/contents/GFy_h8cu@10.53:rZudN6XP@2/Introduction.

Image for DNA bonds used from this site. Image is freely available for reuse.

"Alpha,beta,gamma,radiation,radiation - Free Photo from Needpix.com." Alpha,beta,gamma,radiation,radiation - Free Photo from Needpix.com. Accessed July 15, 2019. https://www.needpix.com/photo/1315702/alpha-beta-gamma-radiation-radiation-free-pictures-free-photos-free-images-royalty-free.

Image used to show alpha, beta, gamma radiation

Brenner, Michaela, and Vincent J. Hearing. "The Protective Role of Melanin against UV Damage in Human Skin." Photochemistry and Photobiology. 2008. Accessed July 12, 2019. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2671032/.

Science Journal describing in detail how melanin works to protect the skin and act as a

natural sunscreen.

"Calculate Your Radiation Dose." EPA. July 10, 2018. Accessed July 14, 2019. https://www.epa.gov/radiation/calculate-your-radiation-dose.

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Appendix A

California schools use the Next Generation Science Standards to inform and guide their instruction. This unit for Physiology crosses both into Physical and Life Science standards. Four of the NGSS standards are annotated here though there are more standards that this unit addresses.

Science and Engineering Practices: Obtaining, Evaluating, and Communicating Information

HS-PS4-4 Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. 3[2]

Disciplinary Core Ideas: Wave Properties

HS-PS4A- 1 The wavelength and frequency of a wave are related to one another by the speed of travel of the wave which depends on the type of wave and the medium through which it passes. 3[2]

Students will fulfill this standard by reviewing different sources (web-based, articles, journals, and videos) to decide how the EM waves affect their daily lives. They will look at photons at different frequencies, describe the energy associated with radiation types, and assess whether the harm to human tissue.

Disciplinary Core Ideas: Wave Properties

HS- PS4B- 4 Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. 3[2]

Through classroom hands-on activities students will understand the difference between UV, X-ray, and gamma rays and will be able to articulate after each activity how they may damage cells.

Crosscutting Concepts to Engineering and Technology

HS-PS4-5 Information Technologies and Instrumentation Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.3[2]

Student research and mock-EPA hearing activity will show students' knowledge regarding new and emerging medical technologies. Students should be able to address the necessity of some level of radiation exposure for the sake of medical progress.