

A MISSION TO MARS

# An Encounter with Radiation

A Unit for High School Biology, Chemistry, and Physics

## The Story

Senmiao (Mimi) Zhan

Elizabeth A. Godin

Rochelle D. Schwartz-Bloom

Duke University Medical Center



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The year is 2040. 71 years after the Apollo 11 has landed on the moon, the United States has finally made technological advancement for the first ever manned mission to Mars. This mission is very crucial to help people determine the livability of Mars. A group of astronauts have applied to participate in this important mission. However, they must go through a series of physical tests before they could be selected to go through a 20-month training to obtain the essential skills needed to travel to Mars.

Traveling to Mars is not an easy task. There are many challenges this human mission must overcome. One of the challenges is the physical harm of exposure to high-energy cosmic rays and other ionizing radiation might pose to the astronauts. Some people have a certain genomic profile that contains a mutation in a gene called *p53* that makes them more susceptible to radiation-induced damage. Astronauts with such a genomic profile will be counseled about the special risks of going on this mission. During the training session, the astronauts who are physically qualified will learn about what kind of radiation will penetrate the spaceship and how exposure to the radiation might affect them.

Luna and Orion both are young astronauts who have applied to the program. The two of them have very different lifestyles and grew up in different environments. Luna is a healthy eater and runs regularly. Orion, on the other hand, likes to eat fried food even though he is still fit. They both have 20/20 vision and are qualified for the mission in terms of their height, blood pressure and education. The genomic test is the only thing left for both Luna and Orion before they become crew members of this Mars mission.

In order to construct Luna and Orion's genomic profile, both of them were sent a kit by NASA to collect their DNA. The kit had the words "Buccal Swab" written on it and contained a pair of latex gloves, a small plastic tube, a long cotton swab, a return envelope, and a set of instructions. The collection process was pretty simple. All they had to do was swab the inside of their cheek with the cotton swab and then put the cotton tip inside the plastic tube (**Figure 1**). After the two had returned their buccal samples to NASA, they were called to go to the local medical center for a consultation with a genetic counselor.

At the genetic counselor's office, Luna and Orion were both excited

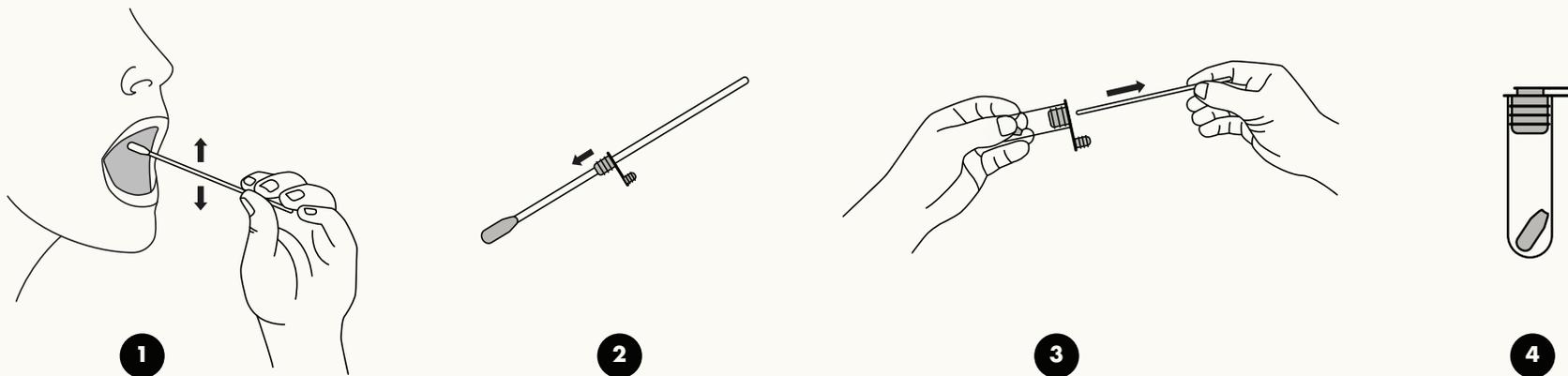


Figure 1. Collecting a buccal swab for a DNA analysis.

to hear their results. First, they were asked to fill out a questionnaire regarding their family medical history. Luna's father was diagnosed with pancreatic cancer several months ago, and her paternal grandfather died of colon cancer a couple of years ago. After filling out the forms, the counselor started to inform Luna and Orion about how the genetic testing was done. The test was only for common mutations in the tumor suppressor *p53* gene, which encodes the tumor suppressor *p53* protein that normally helps cells to die when they are damaged, a process called apoptosis. Some people carry a mutated *p53* gene that makes them more susceptible to getting cancer when they are exposed to a carcinogen.

It turns out that Luna tested positive for a *p53* mutation. The counselor explains that having a *p53* mutation can increase the risk of developing cancer, especially after exposure to carcinogens, or substances in the environment such as tobacco, alcohol, and a lot of high fat foods.

More importantly, exposure to ionizing radiation, such as that encountered by astronauts in outer space, would greatly increase one's chance of developing cancer—regardless of whether (s)he has a mutation in their *p53* gene. And back here on earth, exposure to ultraviolet (UV) radiation from the sun (or tanning beds!) increases our risk of skin cancer. Luckily for many people, we have a protective mechanism against UV-induced skin cancer. We get some protection from a brown pigment in our skin called melanin, which increases when we are exposed to UV light, to help block the harmful radiation from penetrating the skin. Another protective strategy is the use of sunscreen—and sunblock is even better!

Now that you know a little background about *p53* and radiation, your mission is to assess how radiation exposure to astronauts in space impacts their risk of developing cancer. You are especially interested in how to minimize the risk.

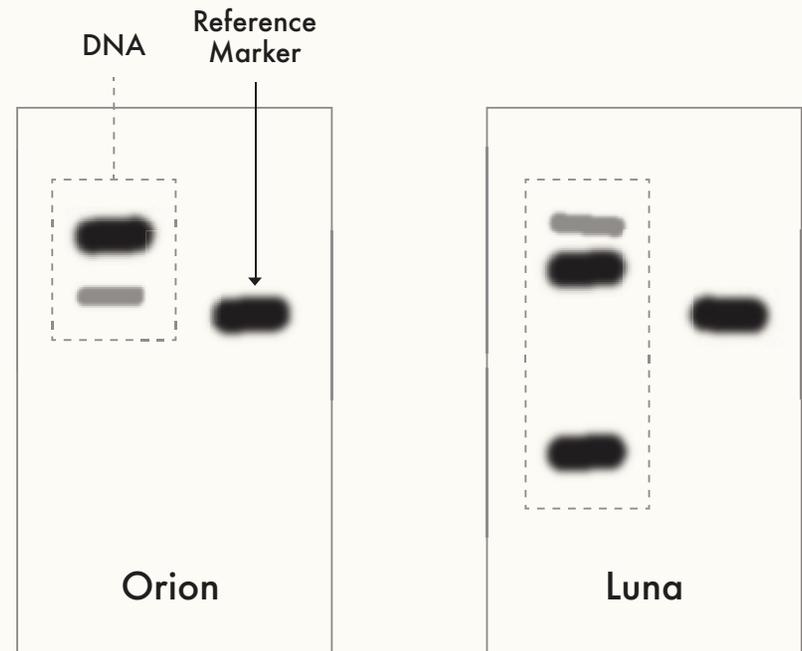


Figure 2. The genetic counselor shows this diagram to Luna and Orion to explain that they were able to detect differences in Luna's genomic profile.

# Mission Questions

1. What is radiation? Which one(s) of the following is (are) radiation?
  - a. X-ray
  - b. Infrared
  - c. Ultraviolet
  - d. Radio waves
  - e. Visible light waves
  - f. Gamma-ray
2. How is radiation measured? What units do scientists use to measure radiation?
3. How does frequency and wavelength differ among the types of radiation above?
4. What kind of radiation will the astronauts encounter while still in the earth's atmosphere? How will it differ as they approach Mars?
5. What is the relationship between genes and proteins? Draw a picture to help explain the relationship, include the following terms in your picture: DNA, mRNA, Ribosome, tRNA, Nucleus, Cytoplasm, Transcription, Translation, Protein.
6. What is a *p53* gene? What is a *p53* protein? What function does it have in a cell?
7. How does the astronaut's genomic profile increase or decrease his/her risk for cancer? Should the astronaut be excluded from space travel if (s)he has a *p53* mutation? Why or why not?
8. How will exposure to radiation affect an astronaut's *p53* gene? And *p53* protein?
9. How could radiation exposure increase the risk of cancer, for example of the lung?
10. How does ultraviolet (UV) radiation affect life on earth? What are the benefits of UV radiation and what are the harms? What are some illnesses associated with too much UV exposure?
11. What are the active ingredients in sunscreen? What are the roles of these chemicals?

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## What is Radiation?

Radiation is a specific type of heat transfer. Let's review some things about heat transfer. In physics, we define heat as a form of energy that is transferred among different substances. Generally, there are three different ways that heat can be transferred (**Figure 1**). Convection is the transfer of heat through gas or liquids. One example would be the hot water vapor that rises when you boil water. Conduction is the transfer of heat between bodies of matter. Heat flows from a body of matter at a higher temperature to a body of matter at a lower temperature. Conduction is the main mechanism that heats up a pot sitting on a hot burner, where heat transfers from the burner to the pot. A third form of heat transfer is radiation, which describes the movement of energetic particles or waves through space or through substances. Radiation is commonly differentiated into two separate categories: ionizing and non-ionizing radiation.

Ionizing radiation carries enough energy to remove electrons from an atom or molecule, thus producing charged particles. Remember that each element on the periodic table has a certain number of protons, which are positively charged. Each element has the same amount of electrons floating on the outer cloud—these are negatively charged to make the net charge of the element approximately neutral (**Figure 2**). Ions form when the element either gains or loses electrons, thus causing the particle to be charged. Examples of ionizing radiation include far UV, X-Ray and Gamma Rays (**Figure 3**).

Non-ionizing radiation is the term given to radiation in

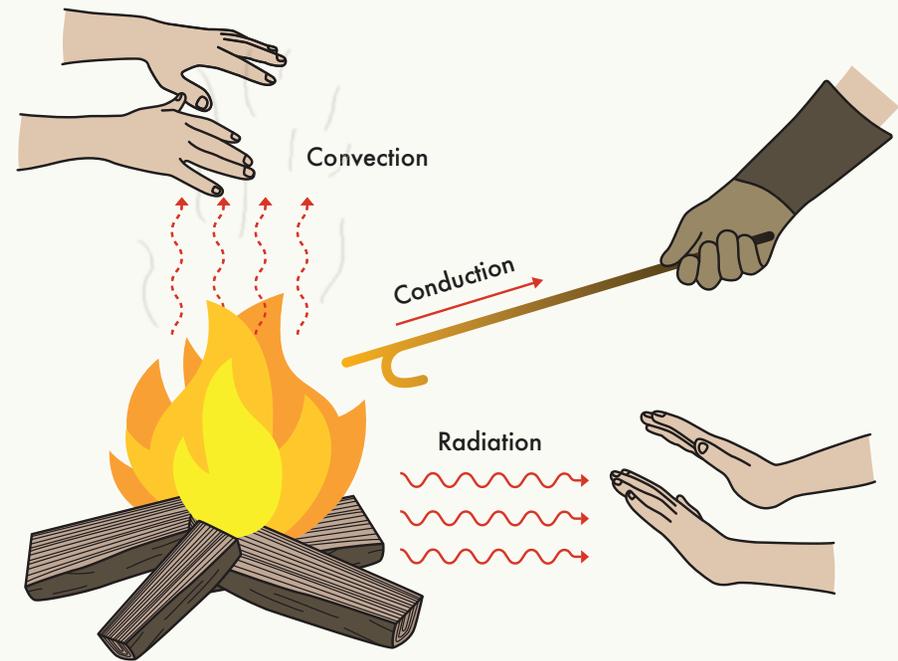


Figure 1. Three types of heat transfer: convection, conduction, and radiation.

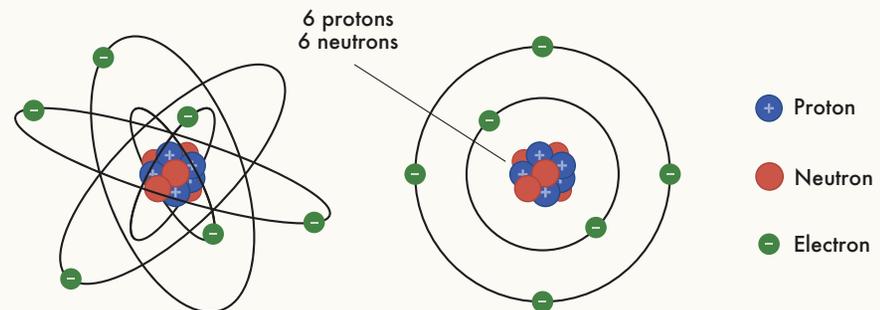


Figure 2. The various parts of a Carbon atom - atoms contain protons and neutrons that are centrally located in the atomic nucleus, while electrons "float" around in the atomic cloud.

one part of the electromagnetic spectrum that does not carry enough energy to ionize particles. Radio waves, microwaves, infrared, visible light, and near ultraviolet (UV) are all examples of electromagnetic radiation. The various types of radiation are differentiated by their wavelength ( $\lambda$ ) and frequency ( $f$ ), which have an inverse relationship (**Figure 3**).

Wavelength is the distance between the same phases of each wave and frequency is the number of times the wave “peaks” (a complete oscillation) in a given amount of time (e.g., per second) (**Figure 4**). So, 100 kHz, means there are  $100 \times 10^3$  oscillations every second (kilo =  $1000 = 10^3$ ).

Waves with shorter wavelength tend to travel faster, or, have high frequency. These waves contain higher energy than their counter parts, which have longer wavelengths and therefore lower frequency. Since radio waves have the longest wavelength and travel the slowest, they also contain the least amount of energy. On the other hand, UV, X-ray, and Gamma rays contain very high energy—atoms can get transferred to molecules in living cells, causing a lot of damage. By the way, the product of the wavelength (in meters) x the frequency (Hz) is actually equal to the speed of light ( $\sim 3 \times 10^8$  meters/sec).

If you’d like to know more about the electromagnetic spectrum, go to the NASA website at:

[http://missionscience.nasa.gov/ems/O1\\_intro.html](http://missionscience.nasa.gov/ems/O1_intro.html)

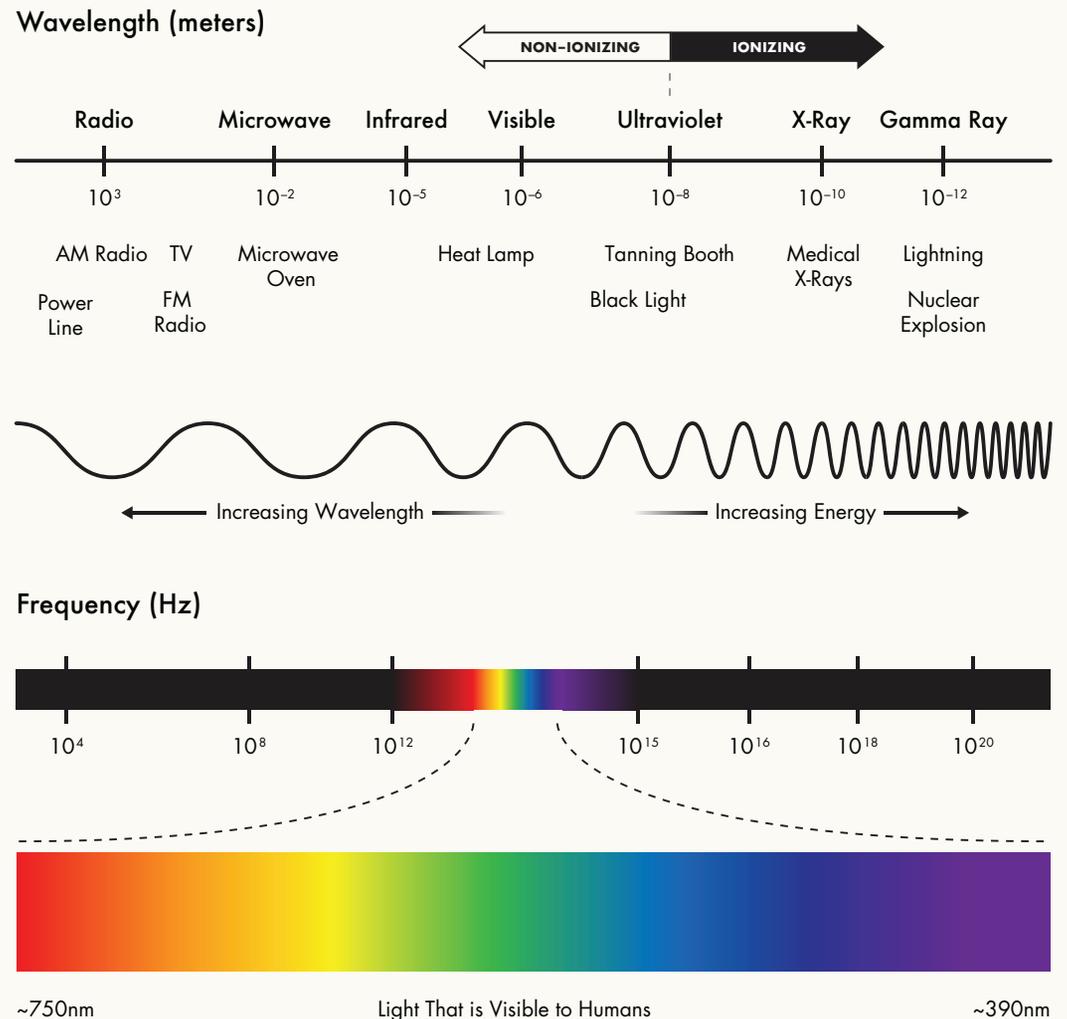


Figure 3. The Electromagnetic spectrum illustrating the range of frequencies of all radiation. Ionizing radiation is radiation with high frequencies (Far UV, X-Ray, and Gamma Ray).

## Background Radiation

People are constantly exposed to radiation on earth. Background radiation is the ionizing radiation that is constantly present in the natural environment, and comes from various natural and artificial sources. Natural sources include radioactive substances in the earth's crust, cosmic rays from outer space that constantly bombard the earth, and very small amounts of radioactivity in the body acquired mainly through water and food. Although natural sources of background radiation make up the majority of the ionizing radiation to which people are exposed, there are artificial sources such as medical x-rays, nuclear weapon tests, nuclear power stations, and scientific research materials that account for a fraction of the background radiation. **Figure 5** shows a breakdown of background radiation.

## Cosmic Rays

Cosmic rays make up about 8% of our background radiation. They are composed of both primary energetic particles that originate in outer space and secondary particles that are generated by the interaction of primary particles with the atmosphere. Primary energetic particles usually consist of particles that are familiar to us, such as protons, atomic nuclei, or electrons. There are, however, trace amounts of other matter that are not discussed here. The effects of cosmic rays are partially shielded by the magnetic field of the Earth, which means that the intensity of cosmic rays is much larger outside the Earth's atmosphere and magnetic field. This could also mean that the amount of radiation you

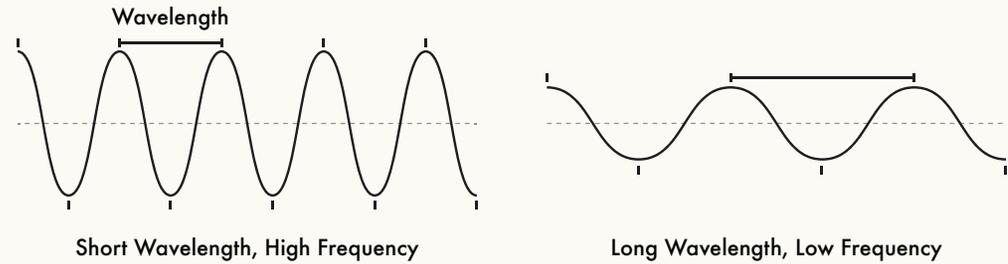


Figure 4. The relationship between wavelength and frequency is inverse.

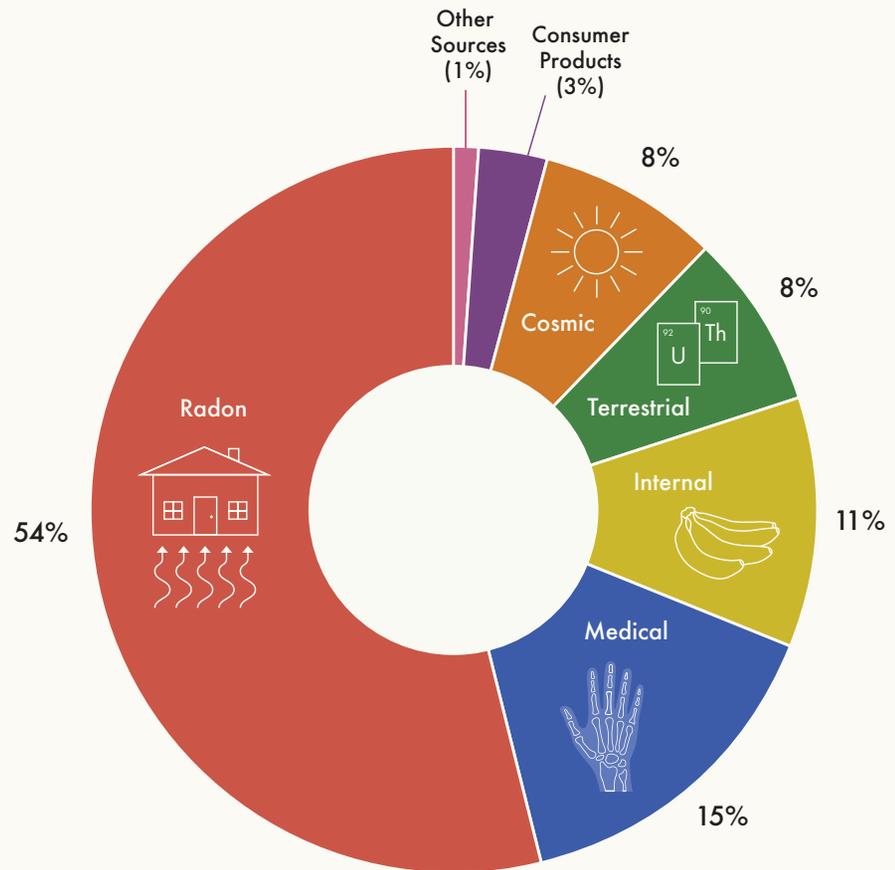


Figure 5. The chart demonstrates the distribution of various types of background radiation we are exposed to on earth.

are exposed to can partially depend on how close you approach the upper part of the atmosphere. When astronauts have to travel outside of the earth's atmosphere, the effect of cosmic radiation becomes a hazard. Space gear has to be designed specifically to combat such high energy radiation.

## How Does Radiation Actually Cause Cellular Damage?

Radiation causes damage to the human body in several ways. One of the most interesting types of damage is radiation's ability to cause cancer. Basically, radiation transfers electrons to cellular molecules such as DNA, which promotes the development of mutations, or changes in the structure of DNA. The DNA mutations then trigger uncontrollable cell growth and division, causing tumors to form. In order to understand how this happens, it is useful to review briefly the basic concepts of DNA.

### A Brief Review of DNA

DNA (deoxyribonucleic acid) is the building block of our genes and chromosomes. DNA is found in every cell within the body and it carries the recipe for building all proteins that cells use to function properly. DNA is made up of molecules, called nucleotides that form the structure of DNA. Each nucleic acid is composed of a nitrogenous base, a five-carbon sugar, and a phosphate group (**Figure 6, left**). There are four nitrogenous bases present in DNA – adenine and guanine (purines) and cytosine and thymine (pyrimidines). There are over 3 billion of these nucleotides in each cell, and they are

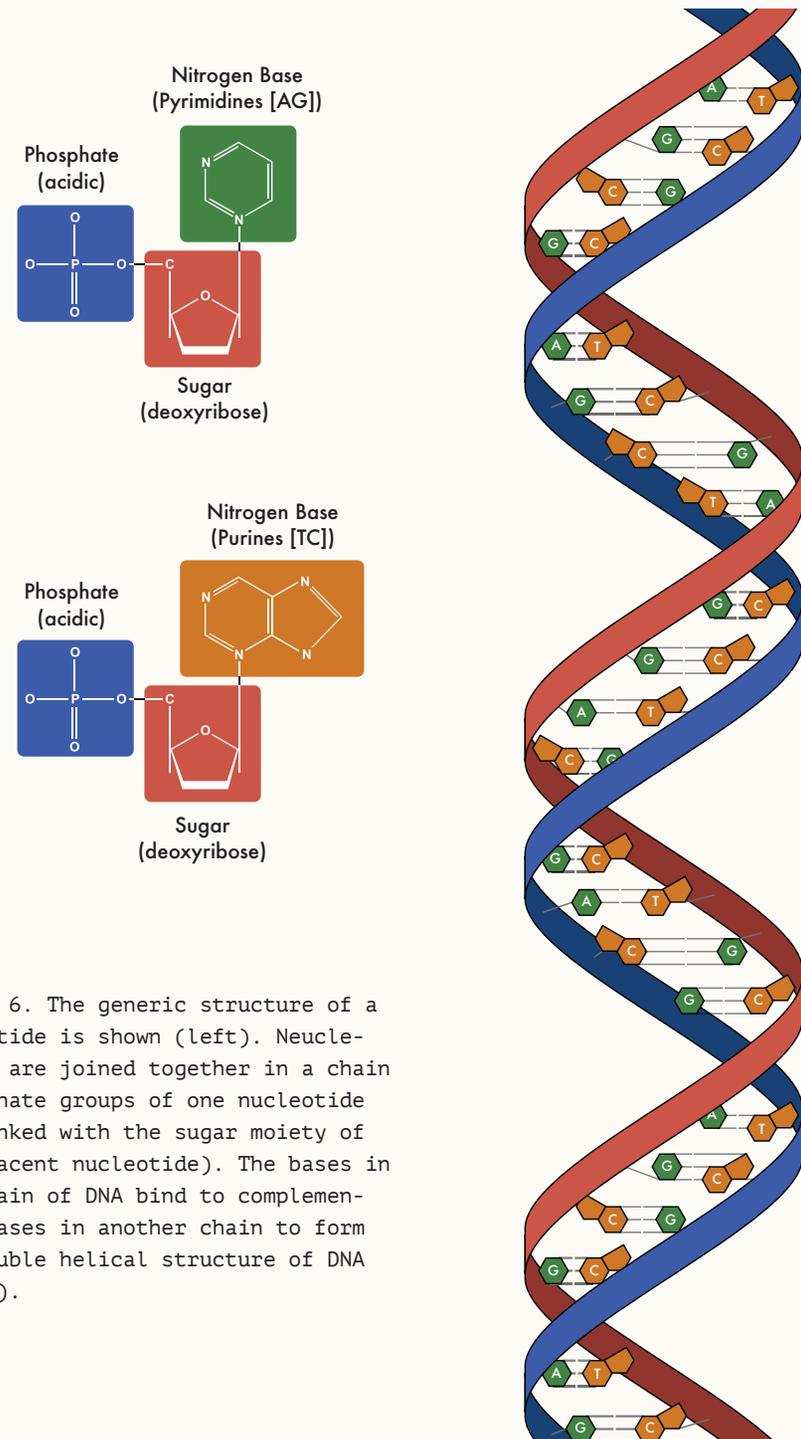


Figure 6. The generic structure of a nucleotide is shown (left). Nucleotides are joined together in a chain (phosphate groups of one nucleotide are linked with the sugar moiety of an adjacent nucleotide). The bases in one chain of DNA bind to complementary bases in another chain to form the double helical structure of DNA (right).

tightly wound and packaged to form 23 pairs of chromosomes that reside in each cell's nucleus. The DNA nucleotides are arranged in a very specific order that contain the "recipe" for each protein to be made.

Think of nucleotides like letters in the alphabet. When letters are arranged in a certain way they form words that make sense to a reader. This is the same concept for DNA. The nucleotides are arranged in an order that makes sense to the cell. The "words", which are composed of strings of DNA nucleotides, are called genes. Each gene instructs the synthesis of a particular protein in the cell, with a specific function. So if the order of the nucleotides is changed, then the function of the gene could change, leading to a problem with the resulting protein.

Every cell's DNA in a person is identical, although the pattern of genes that are normally "on" or "off" in a cell determines what the ultimate function of that cell will be. And surprisingly, each person's DNA is 99.9% identical to every other human in this world, regardless of their nationality or ethnicity. This 0.1% sequence difference in each person is what makes each person unique.

Many cells in the body are constantly dividing and replicating (or reproducing an exact copy). Each time a cell replicates the DNA replicates as well (**Figure 7**). Replication of DNA is a critical process of cell replication. Because DNA carries the recipe for making all protein components of the cell, damage to the cell's DNA could change the entire function of the cell and may also cause problems in cell replication. For example, a cell containing damaged DNA could be replicated indefinitely, producing new copies with damaged DNA.

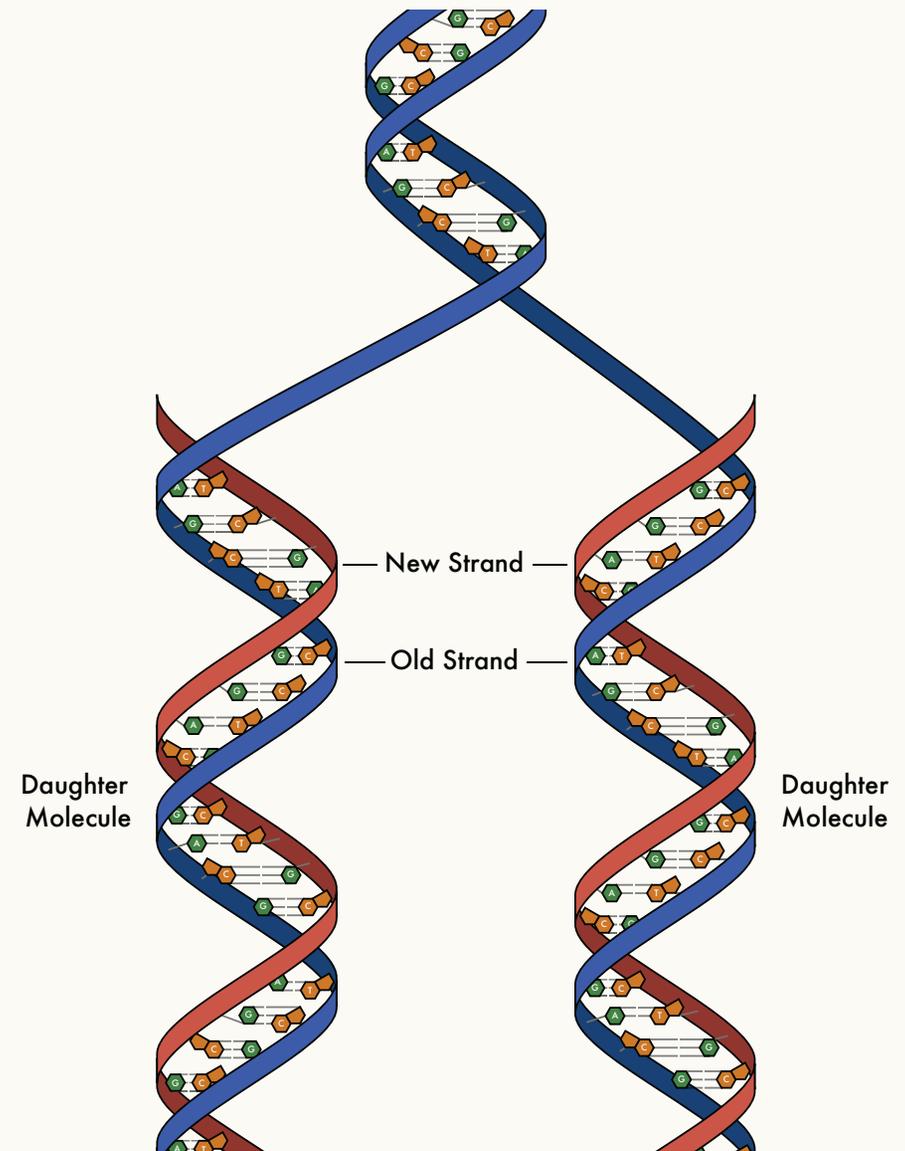


Figure 7. DNA replication. Each of the original strands of DNA is replicated to form an identical copy. One copy of the DNA is found in the newly created cell nucleus and one copy remains in the original cell nucleus.

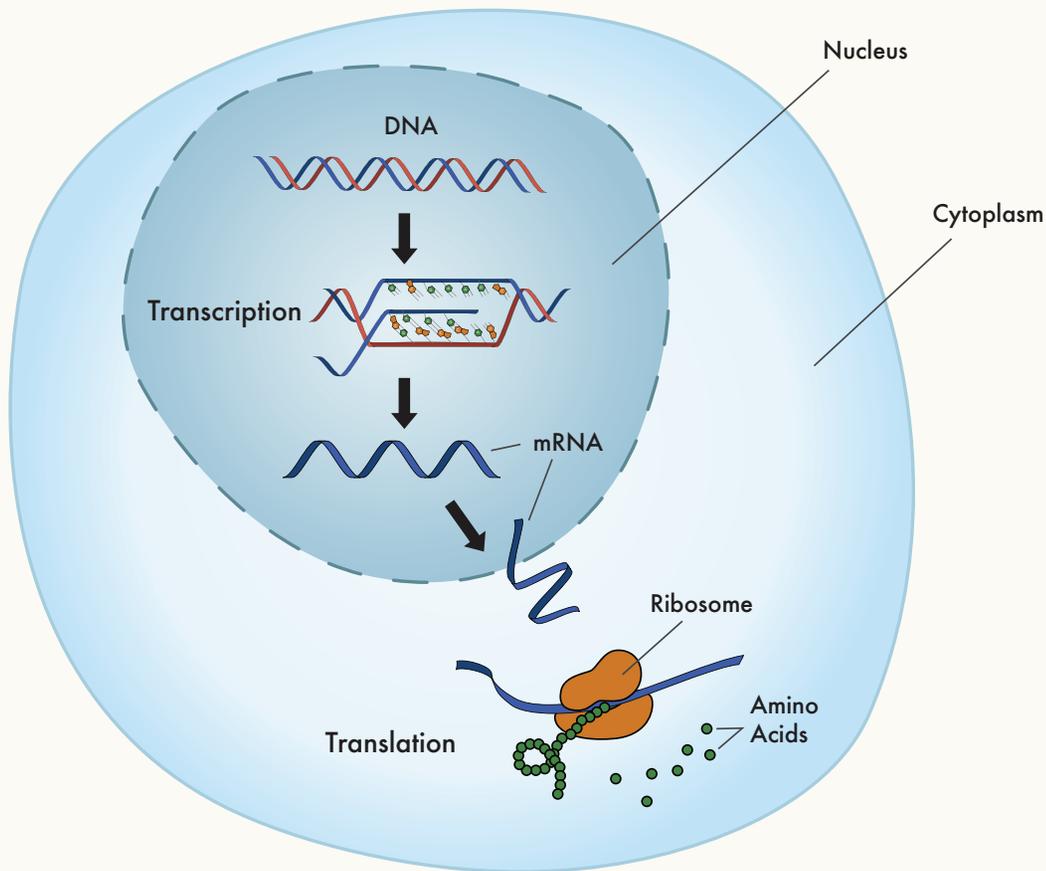


Figure 8. The process of protein synthesis is shown.

## A Brief Review of Protein Synthesis

Once the daughter cells receive the new copy of DNA, the DNA can do its job to initiate protein synthesis (**Figure 8**). First, it is transcribed to messenger RNA inside the nucleus, which is the key step in “turning on or off” the gene’s function. The mRNA then leaves the nucleus through pores in the nuclear membrane, entering the cytoplasm. Once in the cytoplasm the mRNA is translated with the help of transfer RNA (tRNA) to build a protein. The ribosomes in the cytoplasm act as a “shuttle bus system” to travel along the mRNA, picking up tRNA that is bound to a specific amino acid as it goes along. The 3 letter mRNA code tells the tRNA which amino acid to bring over to the mRNA. Each tRNA then releases its amino acid to form a string, and eventually, when the mRNA code says “stop”, the amino acid chain is released, and it folds up into a protein.

## Cells Protect Themselves from Damage to Their DNA

The cell has many mechanisms to ensure that each DNA molecule replicates to form an identical copy. In addition, cells contain certain proteins (“spell-checkers” and “proof-readers”) that make sure that there are no “spelling” errors, or mutations in the nucleotide sequence before DNA replication.

Sometimes a mistake happens (meaning a mutation does occur) and the cells produce proteins that “instruct” the cell to actually commit suicide. This form of cell death is called apoptosis, and it is often the cell’s

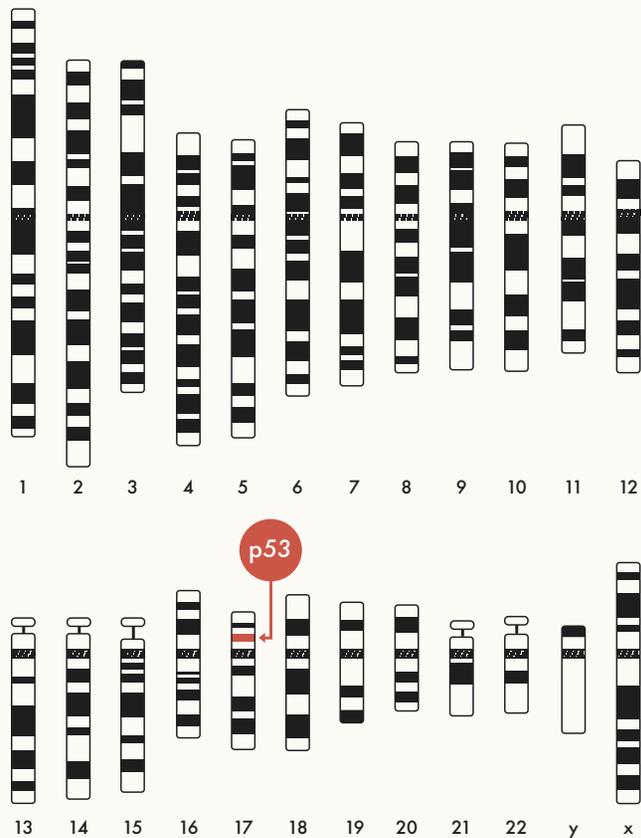


Figure 9. Humans have 23 pairs of chromosomes (22 + 1 pair of sex chromosomes). The figure above is an illustration of the human chromosomes, indicating the chromosomal location (#17) of the *p53* gene that encodes the p53 protein.

last resort for making sure that the DNA mutations do not get replicated.

The p53 protein is an example of a protein that instructs cells to undergo apoptosis when spelling errors or mutations in the DNA occur (**Figures 9 and 10, top**). So p53 comes to the cells' defense—it promotes apoptosis of cells with damaged DNA, thereby eliminating cells that might go on to develop into cancerous cells. In this sense, p53 is considered a “tumor suppressor” protein. Under normal conditions, tumor suppressors slow down cell division, repair DNA mistakes, or tell cells when to undergo apoptosis. These proteins act as the “brakes” in the cell cycle.

Despite the help from a protective protein like p53, problems can arise. For example, sometimes a mutation can occur in the region of DNA that is responsible for making the “spell-checker” or “proofreader” proteins. In fact, mutations can occur in the *p53* gene (**Figure 10, bottom**). Remember that one of the jobs of the p53 protein is to instruct cells to die when mutations are present. So if the *p53* gene now has a mutation, the p53 protein can't do its job to get rid of cells with mutations. Instead, the cells with damaged DNA keep dividing and produce copies of the mutated DNA in the newborn cells. The cycle goes on to produce cancer. Just think of it as releasing the brakes in a speeding car. Once the gene is mutated, the brakes won't work anymore to slow down cell growth!

Another type of gene that is often mutated to promote cancer is an oncogene. Oncogenes have the potential to cause cancer, but only when they get mutated. Once mutated, oncogenes promote (or allow) uncontrolled cell growth, which leads to cancer. Think of them as the accelerator or the “gas pedal”.

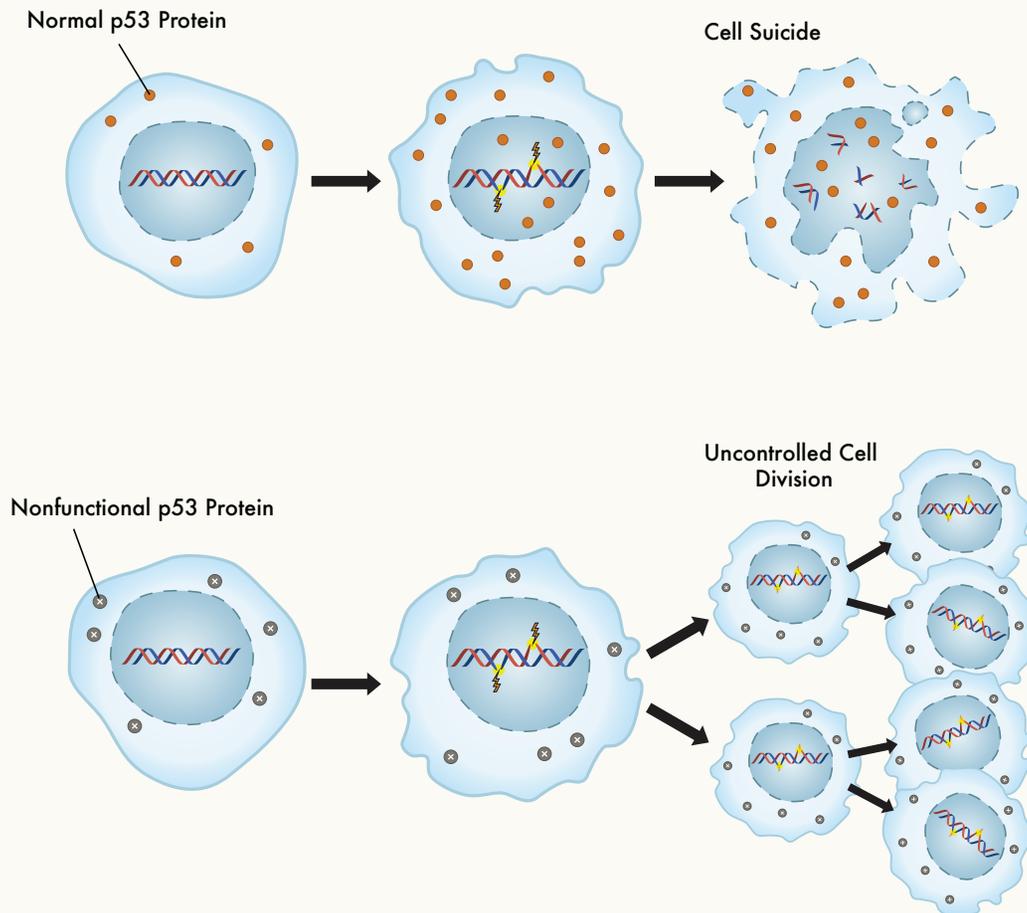


Figure 10. The p53 protein directs suicide of cell with DNA damage. Normally the p53 protein helps the cell destroy itself (cell suicide, or apoptosis) when its DNA becomes damaged (top row). This prevents the cell from going on to divide. But if the *p53* gene has a mutation, then the p53 protein doesn't work properly to help the cell commit suicide. Instead, the cells with damaged DNA go on to divide uncontrollably, leading to the development of tumors (bottom row).

## What is Cancer?

Cancer is defined as an abnormal growth of cells in the body that leads to the formation of a large mass of tissue, called a tumor. Normally, all cells in the body undergo a process of growth and division at some point in time. However, cancer begins when something happens inside the cell that causes it to divide uncontrollably.

Healthy cells contain specific proteins that signal the cell to stop dividing and growing when no longer necessary. But sometimes, the “stop” signals get corrupted, leading to uncontrolled cell growth and division. The disruption of the stop signals can be caused by genetic, or inherited, defects in the cell's DNA, or by external dangers such as radiation or environmental toxins, such as pollutants or chemicals, both of which can cause damage to the cell's DNA. Each of these factors can lead to cancer.

## How Does Cancer Spread?

Early in the development of cancer, the abnormal growth of cells begins in one particular location in the body (usually where the cells with DNA damage are located) and produces a tumor. As the tumor grows, tumor cells can break away and enter the bloodstream (metastasis), where they are then free to travel to any part of the body and continue their rapid and uncontrolled cell growth. People with metastatic cancer often have a lower chance of survival because the cancer has already spread throughout the body. Once cancer begins infecting other regions of the body, it becomes very

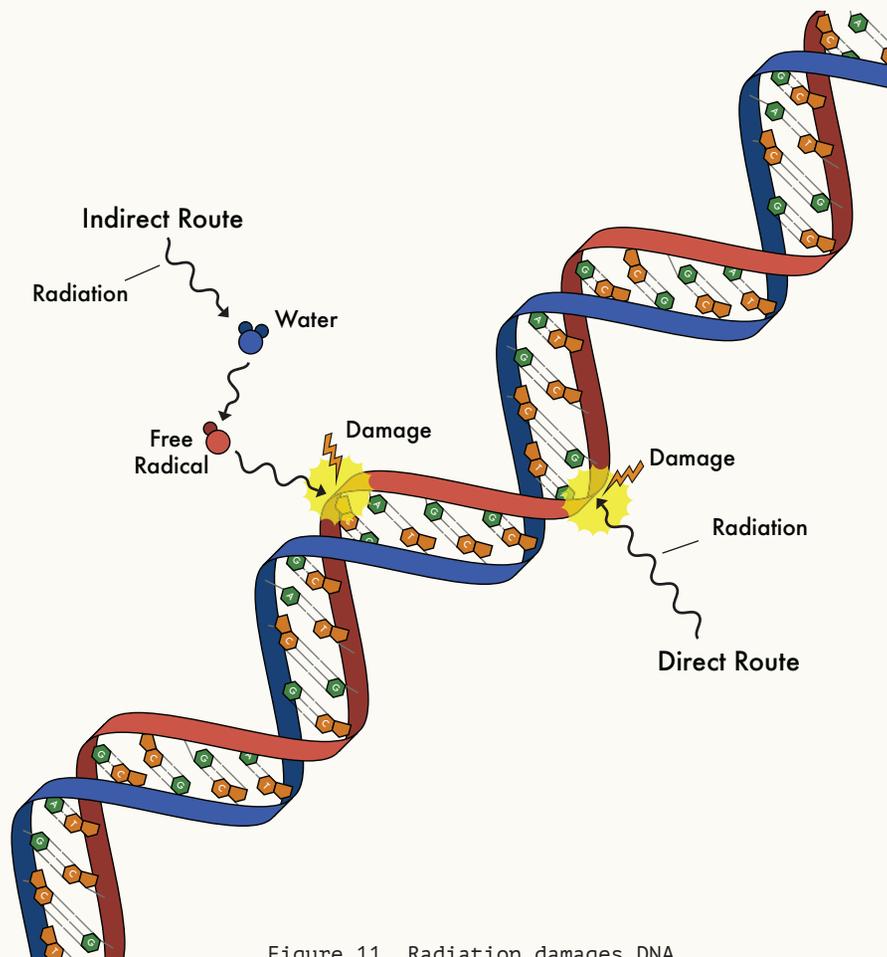


Figure 11. Radiation damages DNA.

difficult to completely destroy all of the cancer cells.

As cancer cells reproduce, they begin to deprive normal healthy cells of nutrients, minerals, and chemicals that are essential to their survival. If the normal cells can't survive, then the function of the organ to which they belong declines, which can lead to illness in the patient.

Unfortunately, for many cancer patients, the cancer cells can eventually overtake the normal cells in the body causing death in people who would otherwise still have many years of life left.

### Why Do Most Cancers Take So Long to Develop?

Most cancers take years to develop and often occur in people as they get older. This long process is mainly due to the cell's protective mechanisms to keep cancer from developing. However, as cells age, the chance of accumulating harmful mutations increases and cancer cells can start to grow. Once the cells become cancerous, it can take years of continuous dividing for the cancer cells to produce a human tumor that is large enough to cause illness or migrate to other tissues. However, the long "incubation" period doesn't mean that nothing is happening. Every time a person is exposed to a certain level of radiation, there is the potential for a mutation to develop in their DNA. As discussed above, the cell's protective mechanisms try to get rid of cells with damaged DNA. But as more mutations occur in the DNA, the higher the chance that some of the damaged cells will escape this fate, and then replicate the mutated DNA.

### Radiation Damage to DNA

Radiation can damage the cellular DNA and its ability to replicate correctly. Ionizing radiation such as that created by cosmic rays can damage the DNA in different ways. One way is to damage the nucleotides or the sugar moieties. Electrons from the high energy rays are

transferred to the oxygen or nitrogen atoms in the DNA nucleotides for example, causing the formation of a mutation—or to be more exact, the wrong base pair to be formed during replication. Another possibility is that the high energy electrons actually cause breaks in the DNA strands. Usually, in cells with DNA damage, the cell would either repair the DNA or execute cell death (apoptosis). If the mutations are not eliminated through the repair system, the cells begin to divide and produce more copies of the damaged DNA (**Figures 11 and 12**).

A third way that ionizing radiation causes DNA damage is indirectly by increasing the amount of reactive oxygen species in a cell. Reactive oxygen species are chemically reactive, charged molecules that damage many parts of the cell, including the DNA. Although reactive oxygen species are formed naturally in the body, our body has repair mechanisms (such as p53) that can account for these errors. However, when reactive oxygen species increase and there are mutations in p53 genes,

the combination is highly likely to lead to uncontrollable cell growth and cancer.

## Radiation Toxicity

Other than the damage to DNA, exposure to large amounts of radiation can also cause other serious harms. Radiation poisoning, also known as acute radiation syndrome (ARS) is a disease caused by exposure to high amounts of ionizing radiation. The first symptoms of this syndrome can be nausea, vomiting, and diarrhea. The person usually feels healthy for a short time and becomes seriously ill afterwards. There can also be skin damage and hair loss. Most people who do not recover from ARS will die within several months of exposure. Destruction to a person's bone marrow that results in various infections and internal bleeding is usually the cause of death. Nuclear reactor accidents that release high amounts of ionizing radiation cause ARS.

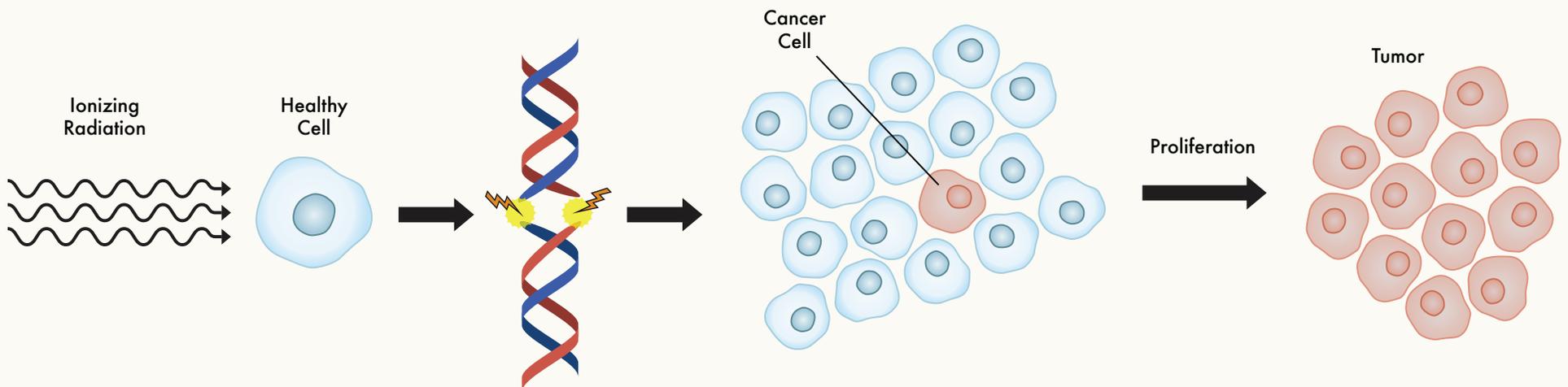


Figure 12. Ionizing radiation can cause DNA strand breaks, leading to uncontrollable cell growth and tumor formation.

## Protection Against Radiation

There are several factors that are involved in protection against radiation exposure. They include: 1) the amount of time exposed, 2) the distance between the victim and the source of radiation, and 3) shielding materials.

The relationship between exposure time and the amount of damage is directly proportional. The longer one is exposed to the radiation, the more dosage of radiation one will receive. Therefore, minimizing the exposure time will greatly reduce the dosage of radiation the body receives. However, when radioactive materials are inside the body (either through swallowing or absorption), one has to wait until they decay or until one's body eliminates the material. When that happens, the concept of half-life controls the time of exposure.

Increasing the distance between the victim and the source of radiation can also act as a protection. This relationship can be calculated with a little bit of math called the Inverse Square Law. The Inverse Square Law basically states that the intensity or strength of the radiation is inversely proportional to the square of the distance from the source. Using the equation:

$$I = \frac{P}{A} = \frac{P}{4\pi r^2}$$

where  $I$  is the intensity of the radiation,  $P$  is the total power of the radiation,  $A$  is the area (of a sphere) of radiation, and  $r$  is the radius of a circle or distance from the source.

For example, the exposure of an individual sitting 4 feet from a radiation source will be  $\frac{1}{4}$  the exposure of an individual sitting 2 feet from the same source. To determine the ratio of exposure with the same intensity ( $I$ ) and power of radiation ( $P$ ), just divide the area ( $A$ ) of one individual from the area of the second individual:

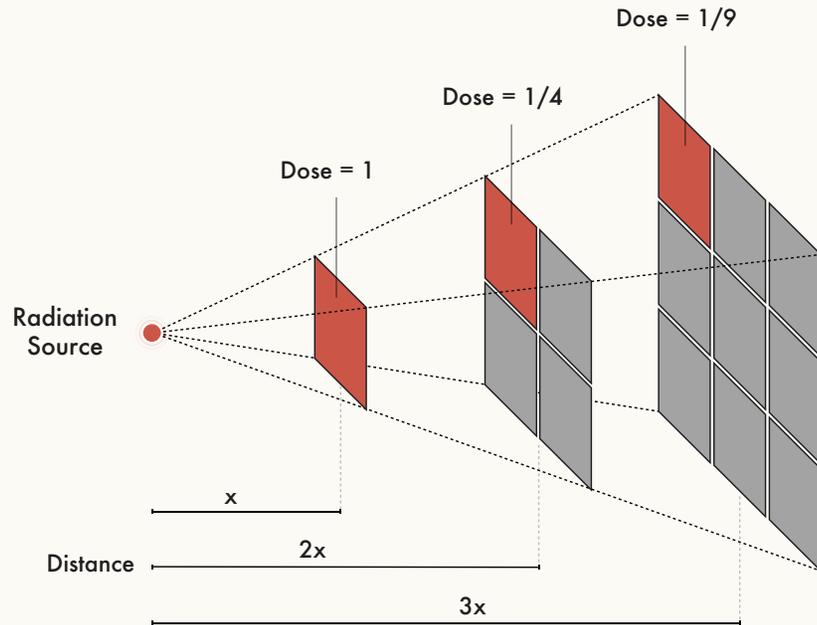


Figure 13. Increased distance will reduce the energy of the radiation.

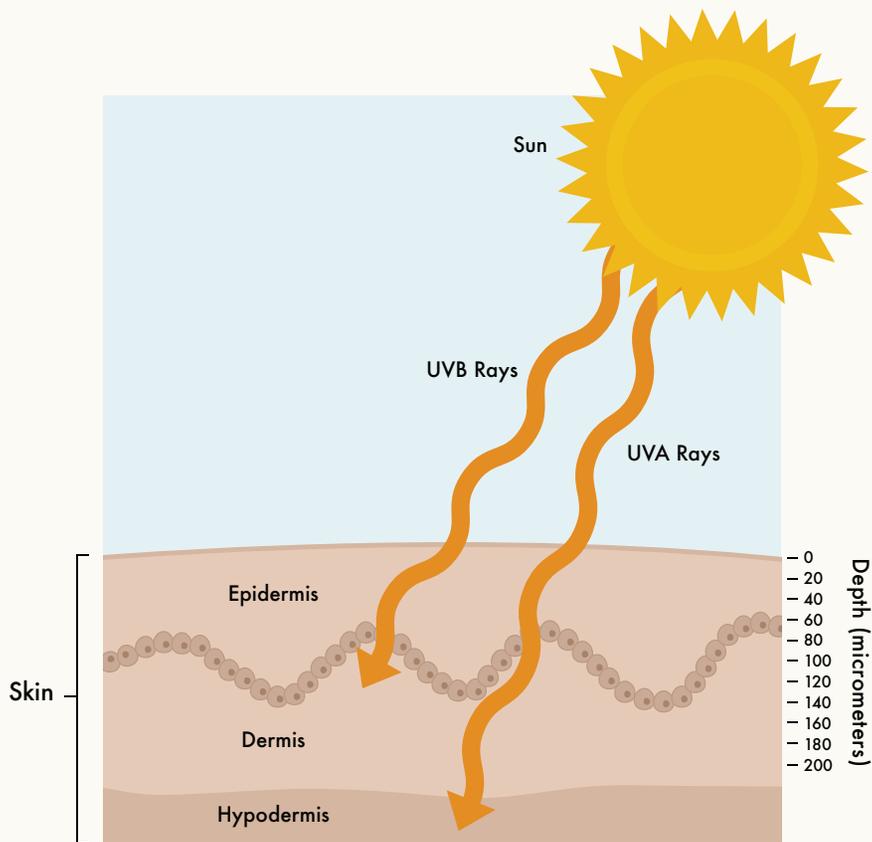


Figure 14. Both UVA and UVB can penetrate deep into the skin and cause cancer.

So, this means that when the distance increases by only 2 feet, the radiation is spread out over four times as much area, so the dose is only one fourth as much (**Figure 13**). Also, it is likely that the radiation will lose energy as distance increases thus reducing the intensity even further.

Another way to protect against radiation is using shields. Radiation shielding can be accomplished with various materials that will absorb radiation between a person and the source of the radiation. One type of very effective shielding material is called Graded-Z shielding. Graded-Z shielding is composed of a laminate of several materials with different Z values (Z values are used to indicate atomic numbers.) This type of material has been shown to reduce electron penetration over 60%. The most common Graded-Z material involves a gradient from high-Z (usually tantalum) through lower-Z elements such as tin, steel, and copper, usually ending with aluminum. Sometimes even lighter materials such as polypropylene or boron carbide are used.

## UV Radiation and Skin Cancer

Although the earth's ozone layer can block out most of the UV radiation from the sun, the small amount that penetrates through the atmosphere can still cause damage to people. UV radiation is actually a spectrum of light that can be further subdivided. The natural source of UV, which is the sun, emits UVA, UVB, and UVC, which all have different wavelength ranges. There are also human-made sources of UV light such as UV fluorescent lamps and "black lights", which are lamps that emit long-wave UV radiation and a very limited amount of visible light. When we are outside in the sunlight, especially in the summer when it is more intense, we use sunscreens to protect ourselves from sunburn. Sunburn and some types of skin cancer can be caused by overexposure to UVB radiation. Although UVC has a shorter wavelength and thus higher energy, it is mostly filtered out by the earth's

atmosphere. Both UVB and UVC can cause direct damage to DNA. UVA, on the other hand, does not cause direct damage to our DNA. However, it is still harmful because it can generate highly reactive chemicals that do cause damage to DNA.

Even though both UVA and UVB are harmful, only certain sunscreens on the market contain chemicals such as titanium dioxide, zinc oxide, and avobenzone that protect against both UVA and UVB. Zinc oxide produces the most complete protection. Most sunscreens only contain chemicals that shield UVB rays. Even wearing clothing does not prevent UVA from penetrating deep below the skin. A good rule of thumb is to remember that clothing that can prevent sunburn is preventing some UVB from causing damage, but UVA goes right through clothing, deep into the skin to cause damage to the DNA (**Figure 14**).

Video/Activity	Address
Cancer Growth Animation	<a href="http://www.youtube.com/watch?v=WXTsxPPcTEs&amp;feature=related">http://www.youtube.com/watch?v=WXTsxPPcTEs&amp;feature=related</a>
Cancer Explained in Animation	<a href="http://www.youtube.com/watch?v=dK9UcjSPkLs&amp;feature=related">http://www.youtube.com/watch?v=dK9UcjSPkLs&amp;feature=related</a>
NASA: Deadly Radiation in Space	<a href="http://www.youtube.com/watch?v=Up7GQM2P8ss&amp;feature=related">http://www.youtube.com/watch?v=Up7GQM2P8ss&amp;feature=related</a>
Carl Sagan explains cosmic rays and neutron stars	<a href="http://www.youtube.com/watch?v=MvHHZO2wmmg">http://www.youtube.com/watch?v=MvHHZO2wmmg</a>
Lab activity to simulate effects of radiation on humans	<a href="http://www.ehow.com/info_7882754_student-activity-effects-radiation-humans.html">http://www.ehow.com/info_7882754_student-activity-effects-radiation-humans.html</a>
UV or temperature? Skin cancer related activity	<a href="http://www.sunsmart.com.au/downloads/Protecting_others/schools/secondary/activity_sheets/uv_or_temperature.pdf">http://www.sunsmart.com.au/downloads/Protecting_others/schools/secondary/activity_sheets/uv_or_temperature.pdf</a>
Activities from NOVA science for Sun and Skin	<a href="http://www.science.org.au/nova/008/008act.htm">http://www.science.org.au/nova/008/008act.htm</a>
RadTown USA/ a town in which each location highlights a particular radiation issue	<a href="http://www.epa.gov/radtown/index.html">http://www.epa.gov/radtown/index.html</a>
Radiation Calculator	<a href="http://www.epa.gov/radiation/understand/calculate.html">http://www.epa.gov/radiation/understand/calculate.html</a>
Space Faring: The Radiation Challenge (an interdisciplinary Guide on Radiation and Human Space Flight) Middle School	<a href="http://www.nasa.gov/pdf/284277main_Radiation_MS.pdf">http://www.nasa.gov/pdf/284277main_Radiation_MS.pdf</a>
Space Faring: The Radiation Challenge (an interdisciplinary Guide on Radiation and Human Space Flight) High School	<a href="http://www.nasa.gov/pdf/284273main_Radiation_HS_Mod1.pdf">http://www.nasa.gov/pdf/284273main_Radiation_HS_Mod1.pdf</a>
The p53 song	<a href="http://www.youtube.com/watch?v=iGQdwSAAz9I">http://www.youtube.com/watch?v=iGQdwSAAz9I</a>
Video and quiz on tumor suppressors	<a href="http://higherred.mcgraw-hill.com/sites/007337797x/student_view0/chapter9/animation_quiz_-_how_tumor_suppressor_genes_block_cell_division.html">http://higherred.mcgraw-hill.com/sites/007337797x/student_view0/chapter9/animation_quiz_-_how_tumor_suppressor_genes_block_cell_division.html</a>

# Space, Radiation, & Cancer: What Have you Learned?

1. Which of the following is not one of the health challenges NASA is concerned about in terms of space travel?
  - a. high-energy cosmic rays
  - b. ionizing radiation
  - c. p53 gene damage
  - d. interrupted circadian rhythm
  - e. none of the above
2. Why would someone do a “buccal swab”?
  - a. to determine a genetic predisposition for a disorder
  - b. to manipulate human DNA in animal vectors
  - c. to cleanse the inside of the mouth
  - d. to determine an appropriate treatment for cancer
  - e. all of the above
3. Which of the following is/are examples of types of protection our body has against ultraviolet radiation?
  - a. melanin
  - b. sunblocking proteins
  - c. DNA repair mechanisms
  - d. A and C
  - e. all of the above
4. You have a hot coffee in a mug and decide to cool it down by putting ice inside it. Describe the transfer of kinetic energy.
  - a. energy goes from the ice to the coffee
  - b. energy goes from the coffee to the ice
  - c. the mug absorbs all the heat
  - d. indeterminate
  - e. None of the above
5. If you found out that you have a mutation in your p53 gene, which of the following would be true:
  - a. transcription of the p53 gene would be altered
  - b. translation of the p53 gene would be disrupted
  - c. the p53 protein would be dysfunctional
  - d. A and C
  - e. None of the above
6. Which of the following indicates the correct relationship between wavelength and frequency?
  - a. short wavelength --> low frequency
  - b. long wavelength --> high frequency
  - c. short wavelength --> high frequency
  - d. A and B
  - e. none of the above

# Space, Radiation, & Cancer: What Have you Learned?

7. What kind of conditions can create tumors?
  - a. tumor suppressor genes
  - b. mutations in tumor suppressor genes
  - c. mutations in oncogenes
  - d. B and C
  - e. all of the above
8. If the purine nucleotide adenine in a gene was substituted with another purine, forming a mutation, which would it be?
  - a. guanine
  - b. cytosine
  - c. uracil
  - d. thymine
  - e. xanthine
9. Which of the following are contributing factors to the development of cancer?
  - a. random DNA mutations
  - b. aging
  - c. reactive oxygen species
  - d. A and B
  - e. All of the above
10. Suppose you need to get an x-ray. If the x-ray technician stands eight feet away from you during the x-ray exposure, how much less of a dose of ionizing radiation would the technician receive relative to standing five feet away?
  - a. 1/4 the original exposure
  - b. 25/64 the original exposure
  - c. 64/25 the original exposure
  - d. there is no difference in exposure
  - e. the difference cannot be calculated from the information given

Answers: 1-D, 2-A, 3-D, 4-B, 5-D, 6-C, 7-D, 8-A, 9-E, 10-B

A MISSION TO MARS

## **An Encounter with Radiation**

A Unit for High School Biology, Chemistry, and Physics

# **Meet the Scientists**

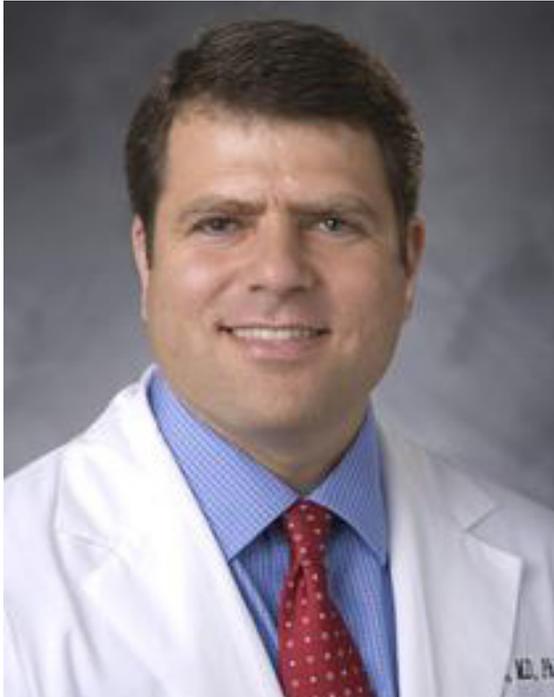
Senmiao (Mimi) Zhan

Elizabeth A. Godin

Rochelle D. Schwartz-Bloom

Duke University Medical Center





# David Kirsch, M.D., Ph.D.

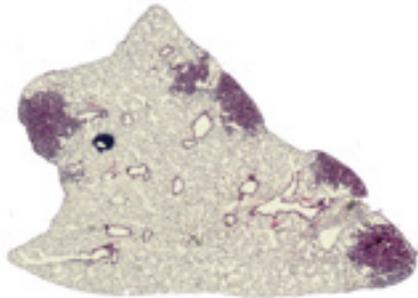
- Associate Professor in the Department of Radiation Oncology
- Associate Professor in the Department of Pharmacology & Cancer Biology

I am a physician scientist. I use radiation therapy to treat patients with cancer. In my lab, we study how radiation therapy cures cancer and causes side effects. For example, we are studying how radiation can cause cancer. This is important not only for patients treated with radiation therapy, but also for astronauts, who are exposed to radiation while traveling in space.

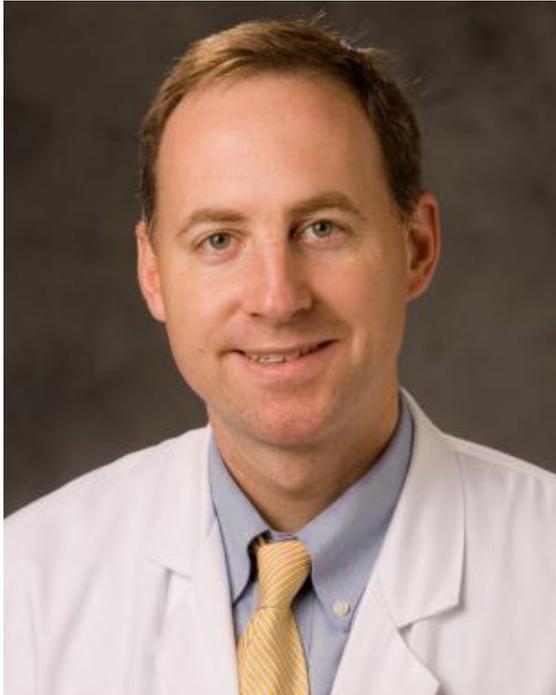
During medical school, I completed a PhD studying how cells die following stresses like radiation. After completing my clinical training as a radiation oncologist, I continued my research as a post-doctoral fellow at M.I.T. using genetically engineered mice as a model system. I developed a new mouse model of a muscle tumors (called sarcomas) that my own lab still uses to study cancer development, metastasis, and novel cancer therapies. To study which cell types are important for mediating normal tissue injury from radiation, I deleting genes in a cell-type specific manner in the mouse to study how radiation causes normal tissue injury.

When I moved to Duke to start my own lab, I continued to use the genetically engineered mice to study radiation biology. For example, we are using mice to modify the levels of the p53 tumor suppressor to determine how p53 regulates radiation-induced cancer from X-rays and from space radiation. To expose mice to space radiation, we send our mice from Duke to the Brookhaven National Laboratories in New York. You can find out more about my lab's research at our website: [www.kirschlab.org](http://www.kirschlab.org)

When I am not at work, I enjoy spending time with my family including my 3 children and our puppy Gelato.



This is a section of a lung lobe that we obtained from a mouse that developed lung tumors (dark purple areas) after irradiation with "space radiation" at the Brookhaven National Lab.



# Mark Onaitis, M.D.

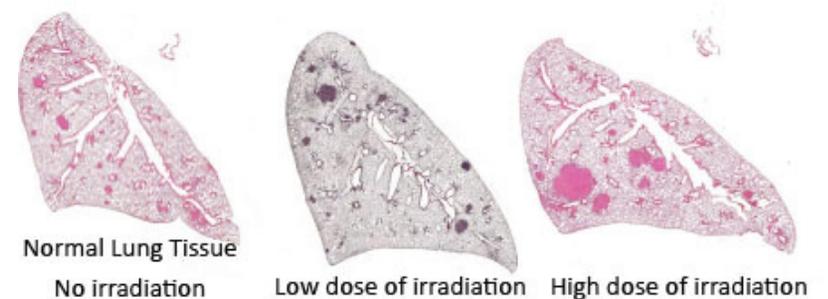
Associate Professor in the Department of Surgery

I am a surgeon researcher in the Division of Cardiothoracic Surgery. In my clinical practice, I perform lung resections to cure patients with lung cancer. In the laboratory, we study the cell-of-origin of lung cancer in order to better understand the molecular mechanisms that cause these cancers to form. The hope is that better understanding will lead to better treatments for lung cancer patients. This understanding will also help astronauts traveling in deep space in that preventative measures against lung cancer caused by radiation may be developed.

After finishing my surgical training at Duke, I spent some time with cell biologists and mouse modelers at Duke in order to learn approaches to alter genes specifically in lung epithelial cells. We have used special mice that allow changes to genes in respiratory epithelial cells but not in any other cells throughout the organs. Our NASA grant involves using these special mice to study which cells in the lungs form tumors after they are exposed to space radiation.

When I am not at work, I enjoy spending time with my family including my wife (who is also a surgeon) and my 2 boys (ages 5 and 7).

A type of mouse that normally shows lung tumors (on the left) has more and larger lung tumors when exposed to a high dose of radiation (on the right).





## Barry R. Stripp, Ph.D.

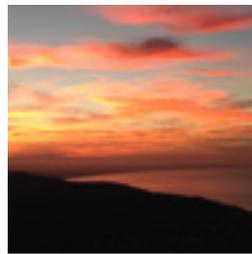
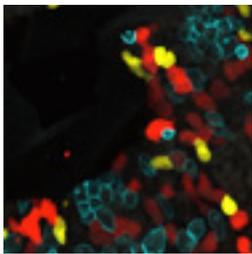
- Professor of Medicine & Biomedical Sciences, Cedars-Sinai Medical Center, Los Angeles
- Professor of Medicine, University of California Los Angeles
- Adjunct Professor of Medicine and Cell Biology, Duke University Medical Center

I am a basic stem cell and developmental biologist at Cedars-Sinai Medical Center in Los Angeles. We use animal models and patient samples to understand how the lung is normally maintained and how disease leads to changes in lung function and structure. We study how radiation impacts normal tissue maintenance. This is important to understand the health effects of radiation exposure that astronauts would experience during long-term missions in space. The research also helps us understand how therapeutic radiation exposure leads to structural and functional changes to lung tissue that impact patient health.

A native of England, I moved to the US to do research in 1982. I have worked as a member of the faculty at the University of Rochester (NY), the University of Pittsburgh (PA), and Duke University (NC) and most recently at Cedars-Sinai Medical Center (CA). We are known for pioneering work studying lung stem/progenitor cells that contribute to normal lung maintenance and repair following injury. We actually use cells from genetically-modified mice to re-grow critical mouse and human lung structures in a dish!

Our NASA-supported research investigates how different types of radiation that are encountered on earth or in space impacts the ability of lung stem/progenitor cells to grow and generate specific cells that are critical for lung function. We study how certain proteins interact within cells and between cells to regulate their response to injury and radiation exposure. An important aspect of my lab is to help train the next generation of researchers in my field of research.

Activities I enjoy when not at work include a range of outdoor activities from biking and hiking in the mountains to casual walks along the Southern California beaches and working in my garden.



The image on the left is of lung cells in a mouse that are genetically tagged with fluorescent colored chemicals to demonstrate how individual cells expand in response to exposure to either terrestrial or simulated space radiation at the Brookhaven National Lab. The image on the right is of the rising sun radiating in the Santa Monica Mountains, Malibu, Southern California.