**Chapter 1**

**Cancer 101: A Roadmap**

Introduction

 C

ancer. Sadly, in this day and age, we hear this word very often. It is highly likely that you or someone you know has been affected by cancer. It is estimated that almost 2 million new cancer cases will be diagnosed in the year 20211. Finding a cure for cancer, however, is not as simple as finding a cure for many other diseases. This is because cancer is not simply one disease—it is actually a large group of diseases that share similar characteristics. This chapter will serve as a road map of how these diseases are connected to one other so that you can build a strong foundation in your knowledge and explore further with confidence.

Obtaining a roadmap to cancer is an important step in the search for a cure. Think about this; would you search for your new classes in an unfamiliar school just by walking around until you find your new teacher? Or would you look at a map of your new school to find the best route to the new classroom? A map of your school would be much more helpful to find your new classes, and a map of fundamental cancer concepts would be very helpful to grow your knowledge on cancer.

In this chapter, we will explore what cancer is, learn about what causes cancer, and understand how cancers are related to each other. Before diving head-first though, we will need to have a molecular biology overview. It is important to remember though, even the world’s top scientists still do not fully understand cancer. What we will discuss here is based on everything that we know, and think we understand. One day, scientists may make new discoveries and realize that the information we had was incomplete. But this is simply the beauty of science—it is self-correcting and always open for discussion and correction.

**Objectives**:

**O1**: Understand what cancer is

**O2**: establish a foundational knowledge of molecular biology

**O3**: Learn what causes Cancer

**O4**: Understand how cancers are classified and are related to one another

**O.1: What is Cancer?**

Key Terms

**Cancer:**

Group of diseases where cells grow and divide uncontrollably, and spread to other parts of the body.8

**Tumor:**

Abnormal mass of tissue that forms when cells grow and divide more than they should or do not die when they should.5

**Malignant Tumor:**

Tumor that can spread its cells through the body.8

**Benign Tumor:**

Noninvasive tumor. 8

**Molecular Biology:**

Branch of science that focuses on the structure and function of DNA, proteins, and other macromolecules.9

You may hear the word “cancer” and think of a sick patient or recall some of the terrifying side effects of treatment, but do you understand what it really is? **Cancer** can be defined a group of diseases characterized by uncontrolled cell grow and division. Another very important characteristic of cancer is the ability of the cancerous cells to spread to other parts of the body. Recall, we humans are made up of cells. In fact, we have over 30 *trillion* cells that make up our body—that’s 30 with 9 zeros! Whenever something goes wrong in these cells like a mutation, which will be discussed later, the cells can grow uncontrollably. This uncontrollable growth takes away nutrients and building blocks from other cells in an unsustainable manner. Left untreated, and the patient has little chance of survival.

Whenever these renegade cells continue to divide, they create a **Tumor.** A Tumor is an abnormal mass of tissue that forms when cells grow and divide more than they should or do not die when they should5. Tumors come in types: **malignant** and **benign.** A malignant tumor is a cancerous tumor. It is one that can spread its cells through the body. A benign tumor on the other hand is one that can continue to grow, but will not spread to other parts of the body.

Now that we have a fair understanding of what cancer is, let us step aside to build some foundational knowledge about what goes on inside of the body’s cells.

**O.2: Understanding Molecular Biology**

The term “molecular biology” may sound daunting at first, but there is no need to worry! With some studying, you will be able to understand these general concepts in no time. **Molecular biology** is the branch of science that focuses on the structure and function of DNA, proteins, and other macromolecules. This field can get quite complex and you can devote many years of studying in this field before feeling comfortable with it. For our purposes, we will only need to familiarize ourselves with the Central Dogma of Molecular Biology.

***Figure 2.1***

*The Central Dogma of Molecular Biology*

*O.2.1. The Central Dogma*

You may be asking yourself “What in the world can this even mean?” The Central Dogma describes the process by which a **ribonucleic acid (RNA)** molecule is *transcribed* from the **deoxyribonucleic acid (DNA)** template and then *translated* into a protein. This process is very complex with numerous moving parts. It will be a central theme in any biology or genetics class you may take in the future. For our purposes, however, we simply need to understand what each step is and what the importance of the products is. For ease of explanation, we will be comparing these steps with the process of ordering food at a restaurant.

Key Terms

**Transcription:**

Process of converting DNA into RNA.8

**Translation:**

Process of converting RNA into a protein.8

**Protein:**

A molecule made of amino acids that carries out a specific process necessary for survival of a cell.8

**DNA:**

Genetic template that houses all of the information needed to create every protein in our body.8

**RNA:**

A messenger molecule that takes the instructions from the DNA temple and gives it to a ribosome for the synthesis of a protein.8

**Ribosome:**

Protein synthesizing machinery.8

O.2.1.1 Transcription

**Transcription** is the process of converting DNA into RNA. Recall that DNA is the genetic blueprint that houses all of the instructions for life. The RNA molecule acts as a messenger. It will be a copy of a specific segment of DNA that houses the information for the synthesis of a protein. Compare this with the process of telling a waiter your order. You possess all the knowledge to order any type of food off of the menu. However, you decide to only order one meal from all of the choices. The waiter will then write down the order and act as a messenger.

O.2.1.2 Translation

**Translation** is the process of converting RNA into a functional protein. Note, a **protein** is a type of molecule that can carry out many types of processes in the cell—we will discuss a few types later in the chapter. Relate this process to the waiter telling the chef what to make. The waiter has specific instructions to tell the chef what type of food you want. The chef can be thought of as a **ribosome.** Just like the ribosome will take the information from the RNA to produce a specific protein, the chef will take the information from the waiter to make the specific meal you ordered.

In a perfect world, these processes would continue in harmony, and every protein your body needs would be produced correctly. In reality, this is not the case. Oftentimes, this process is disrupted and mistakes are made. We know from experience that sometimes we may not get the food we ordered from the restaurant. Sometimes these mistakes have no apparent effect, and sometimes they are even beneficial. In the case of cancer, however, these changes can be very detrimental to the human body.

**O.3 What Causes Cancer?**

Key Terms

**Mutation:**

A mistake in the genetic code8

**Gene:**

A segment of DNA that codes for a protein8

**Carcinogenisis:**

The initiation of cancer8

**Proto-oncogene:**

**Oncogene:**

Genes that produce proteins that promote cell growth and division8

**Tumor Suppressor Gene:**

Genes that produce proteins that restrict cell growth and division8

**Mutagens**

Anything that can lead to DNA mutations8

Cancer is a disease of the genome6. Whenever the harmony of the processes outlined in the Central Dogma is disrupted, cancer may form. Again, this disruption can be related to our ordering analogy. Perhaps when looking at the menu, you accidentally misread the description of the item you ordered. You may have thought it was a meal for 1, but instead, it was a family-sized meal and you receive far too much food. Or you could have had the opposite issue. Maybe you intended to order an item that came with side items, but accidentally ordered it a la carte, and did not receive enough food. These mistakes in the ordering process are much like the mistakes that can lead to cancer. A **mutation** is a change in the DNA sequence that may have harmful effects on the organism. Whenever a mutation occurs, sometimes the effects cannot be seen, but at other times these mutations can lead to very severe diseases. One such disease is cancer. In this section, we will look at where these mutations occur in the genome and what causes these changes to arise.

***Figure 3.1***

*Carcinogen Warning Label*

!

**Carcinogen**

*O.3.1 The Genes of Cancer*

Within the DNA, there are specific segments that house the information for the production of proteins. These segments are known as **genes.** In Cancer, there are two primary types of genes that are related to **carcinogenesis—**Proto-Oncogenesand Tumor Suppressor Genes. A **proto-oncogene** is a gene that will produce a protein that plays role in cell growth and division. Whenever a mutation in these genes occurs, they can sometimes be converted to an **oncogene**. An oncogene produces proteins (also known as oncoproteins) that lead to the uncontrollable growth and division of our cells— recall that we defined cancer as the uncontrollable growth and division of cells. A **Tumor Suppressor Gene** on the other hand is a gene that produces a protein that restricts cell growth and division. Whenever a mutation occurs in these genes, the cell can lose the ability to restrict cell growth and division. In reality, a single mutation in Tumor Suppressor genes or proto-oncogenes usually does not lead to the development of cancer. When cancer cells from a cancer patient are analyzed, it is often found that numerous mutations in these types of genes are present2.

*O.3.2 Mutagens: The Sparks That Ignite Cancer*

Now that we understand what must happen for a cell to become cancerous, let us explore the causes of these mechanisms. This section will simply be exploring the physical causes of cancer, as they are some of the most prevalent. It is important to acknowledge that today’s cancer biologists are still expanding their knowledge on what can cause cancer. As you continue your studies you will learn that the cancer-causing agents discussed here is not a completed list, as there are much more complex biological processes that can be involved in cancer. Nevertheless, this section will provide you with a brief introduction to the topic. When exposed to the following agents, cancer is likely to arise because they can damage DNA in the critical genes mentioned above. They can be thought of as water that smeared the ink on the menu, leading you to order something that you did not fully understand the description on. If this were to occur, you may have ordered something that contains an ingredient you are allergic to, which can cause you great harm. When the instruction for genes related to cell growth and division become smeared, great harm can be done to your body

Key Terms

**UV Radiation:**

Powerful form of light that can damage the DNA8

**X-Ray Radiation**

Form of light more powerful that UV Radiation

**Carcinogen**

Cancer-causing substance8

O.3.2.1 Invisible light that causes cancer?

Growing up, you likely heard adults telling you to put on sunscreen before going outside to play, but why is this? Believe it or not, there are types of light that humans are not able to see with the naked eye. Some of these types of light are more dangerous than others. Let us now answer the question from the heading. The sun is a major source of **UV Radiation**, a powerful form of light that can damage the DNA (specifically, in the genes we discussed earlier) and cause cancer. Another cancer-causing form of light is **X-Ray radiation**. This type is much more powerful, thus more dangerous than the UV light from the sun3. Just as UV can damage the delicate genes of our DNA, X-ray radiation can act in the same way. However, X-rays are much more powerful than UV rays, so it takes less exposure to X-rays to cause the same damage that UV rays can cause. Do not fear, though! Exposure to X-rays is much less common. We are mostly exposed to them during X-ray imaging while visiting a doctor or dentist, and these professionals understand how to give you the proper dose to ensure that you are not exposed to too much radiation. There are other sources of radiation that can damage DNA and lead to cancer, but you are far less likely to encounter these forms in your day-to-day life so they will not be discussed

O.3.2.2 Chemical exposure

There are many types of chemicals that can cause cancer as well. These chemicals are known as **carcinogens**. These chemicals, like UV and X-rays, can damage or alter DNA. This damage can ultimately lead to cancer. How these chemicals react with your DNA can follow many mechanisms. Ultimately how they react with your DNA will rely on the chemical structure of each carcinogen.

In the modern world, it is impossible to escape exposure to carcinogens. Do not worry too much though. As we discussed earlier, exposure to any one of these agents in any one instance is unlikely to cause cancer. This is because cancer develops from a series of mutations. This being said, taking active measures to prevent exposure to carcinogens can help us from developing cancer later in life.

**O.4 Classification of Cancers**

The physicians of today have developed many ways to classify cancers.  Traditionally, cancers have been classified in terms of where they originated, the type of tissue they are in, their relative size, and their spread pattern. In recent times, new technologies have even given rise to a new way to classify cancer based on its genetic profile7! Here is a quick glance at some ways cancer can be classified in today’s day and age.

*O.4.1 Site of Origination*

This classification type is one that almost anybody is familiar with. Whenever you hear “Liver Cancer” or “Pancreatic Cancer”, you are hearing classifications based on the site of origination. This means that the cancer first formed in the organ listed. This is a rather broad classification however and should act only as a bookmark to save your page when studying cancers. As we mentioned at the beginning of this chapter, each type of cancer is a unique disease and they have various levels of complexity.

*O.4.2 Spread Pattern*

Another common way to classify cancers is by their stage of spread. This is the classification that you hear of whenever you hear something like “Stage 4, Pancreatic Cancer”. This classification looks to describe cancer in terms of how it has spread to its current state. The specific stages have been summarized in Figure 4.1.

***Figure 4.1***

***Stages of Cancer Based on Spread Patterns***

**In Review**

Cancer is a devastating illness that affects millions worldwide. Unlike a disease caused by a pathogenic infection, cancer is derived from our own genome. This characteristic makes it particularly difficult to defeat.

In this chapter, we defined what cancer is and established a foundation of knowledge in the field of molecular biology to help us better understand it. In addition to this, we looked into some of the causes of cancer as well as how cancers can be classified.

With the new set of knowledge gained from this chapter, you are now prepared to continue further studies into this topic. More importantly, you now have the knowledge to be able to take steps in your everyday life to prevent the formation of this terrible illness.

**References**

1. American Cancer Society. Cancer Facts & Figures 2021. Atlanta: American Cancer Society; 2021
2. Boland, C. R., & Ricciardiello, L. (1999). How many mutations does it take to make a tumor?. Proceedings of the National Academy of Sciences of the United States of America, 96(26), 14675–14677. <https://doi.org/10.1073/pnas.96.26.14675>
3. Electromagnetic spectrum. (n.d.). Retrieved March 11, 2021, from http://teacherlink.ed.usu.edu/tlnasa/reference/imaginedvd/files/imagine/docs/science/know\_l1/emspectrum.html#:~:text=Ultraviolet%20radiation%20falls%20in%20the,eV%20(or%20100%20keV)
4. How do healthy cells become cancerous? (n.d.). Retrieved March 11, 2021, from https://www.medanta.org/patient-education-blog/how-do-healthy-cells-become-cancerous/
5. NCI dictionary of Cancer TERMS. (n.d.). Retrieved March 11, 2021, from https://www.cancer.gov/publications/dictionaries/cancer-terms/def/tumor
6. Cancer: A Disease of the Genome Francis Collins Cancer Res May 1 2007 (67) (9 Supplement) PL01-01
7. Carbone A. (2020). Cancer Classification at the Crossroads. Cancers, 12(4), 980. <https://doi.org/10.3390/cancers12040980>
8. NCI dictionary of Cancer TERMS. (n.d.). Retrieved March 25, 2021, from <https://www.cancer.gov/publications/dictionaries/cancer-terms>
9. Tabery, J., Piotrowska, M., & Darden, L. (2019, June 27). Molecular biology. Retrieved March 25, 2021, from https://plato.stanford.edu/entries/molecular-biology/