From teenage to old age: How cancer develops over time
BLOSSOMS Video Lesson Teacher's Guide

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Learning Objectives: Students will learn the basic concepts of cancer biology, namely: how cancer is caused by mutations that accumulate over time in cells' DNA; how the genes mutated in cancer are involved in normal cell growth & division; how different types of mutations affect the functions of the genes; how these mutations can occur in both the maternal & paternal versions of a gene (or just in one version of the gene).

NOTE: We recommend that this lesson be the first BLOSSOMS lesson on cancer, that the students use (i.e. before they use "**How scientific teams develop new anti-cancer drugs**" or "**Making it personal: Using DNA to tailor cancer treatments**").

Prerequisite Knowledge: It would be helpful (but not necessary) if the students already know:

- DNA is composed of four bases (A, C, T, G), and it encodes all RNAs & proteins in a cell.
- DNA can be changed in the context of cancer, and the effects of these mutations are carried over from DNA to RNA to protein.
- Each human has two versions of every piece of DNA in their genome, one version from their mom and one version from their dad. Thus 50% of the DNA of a child comes from the mom, and 50% from the dad.

Necessary Supplies & Time: Only paper and writing utensils are necessary, and the ability to print out or display the provided handouts. This lesson is intended to take 1-2 class periods.

Lesson Outline:

Segment #1: Alice & Tina introduce themselves, and an analogy to how cells become cancerous over time, due to an accumulation of mutations. The analogy is that Luc has a cell phone, which he drops 5 times. After the 5th drop, the phone breaks.

What occurs after Segment #1: Students discuss the following questions:

- A teen drops a cell phone 5 times, the first 4 appear to cause no damage; the fifth time, it doesn't work. Did only the 5th drop cause the damage that broke the phone?
- Did every drop cause damage to the phone?
- Was the amount and type of damage caused by each drop random or predictable?

Segment #2: Tina explains how the cell phone analogy relates to cancer (i.e. the

cell phone is a cell, and hitting the floor is damage to your DNA). This is why cancer is a disease of old age. Therefore, the more years you have lived, the higher the chance that enough mutations have occurred in the relevant genes, and thus the higher chance that a cell in your body will become a cancer cell.
What occurs after Segment #2: Students discuss the following question:
"Mutations in the cell cause cancer. So what causes mutations in the DNA?"

Segment #3: Tina explains that mutations can be caused by various factors (oxygen, the natural cellular process of DNA replication, alcohol, viruses, radiation, asbestos, pollution, arsenic, smoking, sunlight, radon, etc). She explains how these mutagens actually affect DNA. DNA is shown after being damaged by sunlight, and then it is shown how this damage can lead to a mutation.
What occurs after Segment #3: Students do a hands-on activity with a "mutation mat" (which is much like a bingo board) that shows how mutations accumulate in cells over time. Full instructions to this activity are available in the teacher packet for this activity. This activity ends with a discussion of questions listed in the instructions.

Segment #4: Alice explains that cancer is a group of diseases that are all different because each cancer results in mutation in a different set of genes. The genes chosen for the "mutation mat" were chosen because their normal functions are involved in cell growth & division. Therefore mutations in those genes can lead to cancer. Alice introduces the steam engine train analogy, in which you want the train to be able to go & stop in a controlled manner. The train has two sets of brakes, and two coal shovelers.
What occurs after Segment #4: Students do a worksheet that gives them various examples of how the train's brakes or coal shovelers might not be working properly, and asks them to predict what would go wrong with the train.

Segment #5: Alice explains that the students saw two different types of mutations in the last exercise: loss of function mutations (where the gene doesn't work), and gain of function mutations (where the gene works too much). Alice explains that loss of function mutations cause cancer when they occur in genes that normally inhibit cell growth & division (i.e. "tumor suppressor genes"). In contrast, gain-of-function mutations lead to cancer when they affect genes that normally promote cell growth & division (i.e. "oncogenes"). Alice asks the students to figure out whether one version (just the maternal or the paternal version of a gene) needs to be broken, to make the train work improperly.
What occurs after Segment #5: Students revisit the last worksheet, so as to analyze their results by comparing certain answers they got on the last worksheet, to other answers on the same sheet. This allows them to figure out if you need both train workers – or only one train worker – to lead to the development of cancer.

Segment #6: Alice explains how gain-of-function mutations only need to occur in one version of the gene, to lead to cancer (but loss-of-function mutations need to occur in both the paternal and maternal versions of the gene). Alice explains that people can be pre-disposed to cancer, if he/she inherits a mutation from his/her parents in a tumor suppressor gene, and then later accumulates a mutation in the other version of the gene.
What occurs after Segment #6: Students complete a worksheet in which they determine whether the paternal & maternal versions of a tumor suppressor gene are mutated or not, in different cell types in the body, for three patients: one without cancer, one with an inherited form of cancer, and one with a spontaneous non-inherited form of cancer.

Segment #7: Alice & Tina conclude the lesson by explaining how different tissues in the body get exposed to different mutagens, thus causing different types of cancer. Cancer can be prevented, in part, by one's lifestyle choices to limit exposure to these mutagens.