Genes and Cancer

Cancer begins when some of the genes in a cell become abnormal, causing the cell to grow and divide out of control. Here you can learn more about how changes in a cell's genes can lead to cancer.

Gene Changes and Cancer

Mutations are abnormal changes in the DNA of a gene and can sometimes lead to cancer. Find out common causes.

Oncogenes, Tumor Suppressor Genes, and DNA Repair Genes

The main types of genes that play a role in cancer are oncogenes, tumor suppressor genes, and DNA repair genes. Learn more here.

Cancer-related Genomic Testing and Genetic Testing

Genetics focuses on individual genes and their effects, while genomics is the study of a person's entire set of genes (their genome). Learn about what genomic and genetic testing can show.

Related Topics

Genetics and Cancer Risk

Some types of cancer run in certain families, but most cancers are not clearly linked to the genes we inherit from our parents. Gene changes that start in a single cell over the course of a person's life cause most cancers.

Biomarker Tests and Cancer Treatment

Finding certain genes or mutations can help diagnose and treat cancer. Learn more here.

Precision or Personalized Medicine

Gene Changes and Cancer

other genes that it doesn't need. Turning on some genes and turning off others is how a cell becomes specialized, such as becoming a muscle cell or a bone cell, for example. Some genes stay active all the time to make proteins needed for basic cell functions. Other genes are shut down when their job is finished and can be turned on again later if needed.

Changes in genes

While we all have basically the same set of genes, we also have differences in our genes that make each of us unique.

The ‘code’ or ‘blueprint’ for each gene is contained in chemicals called **nucleotides.** DNA is made up of 4 nucleotides (A, T, G, and C), which act like the letters of an alphabet. Each gene is made up of a long chain of nucleotides, the order of which tells

Inherited versus acquired gene mutations

Gene variants, including mutations, can be either inherited or acquired.

An **inherited gene mutation**, as the name implies, is inherited from a parent, so it's present in the very first cell (once the egg cell is fertilized by a sperm cell) that eventually becomes a person. Since all the cells in the body came from this first cell,

Some of the changes inside cells that can lead to cancer don't involve gene variants or mutations. Cells can turn some of their genes on and off in other ways, and some of these might also affect how a cell grows and divides.

As mentioned earlier, different genes are more active in some cells than in others. Even within a certain cell, some genes are active at some times and inactive at others. Turning these genes on and off isn't done by changing the DNA sequence (as is the case with variants and mutations). Instead, the changes in gene activity occur by other means known as **epigenetic changes**. There are several types of these changes:

- **DNA methylation:** In this type of change, a small chemical group called a *methyl group* is attached to the DNA so that the gene can't start the process of making the protein it codes for. This basically turns off the gene. On the other hand, removing the methyl group (in a process called *demethylation*) can turn a gene on.
  Histone acetylation/histone modification: Chromosomes are made up of strands of DNA wrapped around proteins called *histones*. Histone proteins can be changed by adding (or subtracting) a small chemical group called an *acetyl group*. Adding acetyl groups (acetylation) can activate (turn on) that part of the chromosome, while taking them away (deacetylation) can deactivate it (turn it off). Drugs called *histone deacetylase (Daj 0 g /F2 12 Tf 0 0 0an deathe gene. On the other handribitore proteins can be ch*

- Changes in genes that normally help cells grow, divide, or stay alive can lead to these genes being more active than they should be, causing them to become **oncogenes**. These genes can result in cells growing out of control.
  Genes that normally help keep cell division under control or cause cells to die at the right time are known as

National Cancer Institute. The Genetics of Cancer. 2017. Accessed at

Oncogenes, Tumor Suppressor Genes, and DNA Repair Genes

The main types of genes that play a role in cancer are:

- Oncogenes
- Tumor suppressor genes
- DNA repair genes

Cancer is often the result of changes in more than one of these types of genes within a cell.

Oncogenes

Proto-oncogenes are genes that normally help cells grow and divide to make new cells, or to help cells stay alive. When a proto-oncogene mutates (changes) or there are too many copies of it, it can become turned on (activated) when it is not supposed to be, at which point it's now called an **oncogene**. When this happens, the cell can start to grow out of control, which might lead to cancer.

A proto-oncogene normally functions in a way much like the gas pedal on a car. It helps the cell grow and divide. An oncogene is like a gas pedal that is stuck down, which causes the cell to divide out of control.

Oncogenes can be turned on (activated) in cells in different ways. For example:

- **Gene variants/mutations:** Some people have differences in the ‘code’ of their genes that can cause an oncogene to be turned on all the time. These types of gene changes can be inherited from a parent, or they can occur during a person’s life, when a mistake is made when copying the gene during cell division.
- **Epigenetic changes:** Cells normally have ways of turning genes on or off that don’t involve changes in the genes themselves. Instead, different chemical groups can be attached to genetic material (DNA or RNA) that affect whether a gene is turned on. These types of epigenetic changes can sometimes lead to an oncogene being turned on. For more on epigenetic changes, see Gene Changes and Cancer.
- **Chromosome rearrangements:** Chromosomes are long strands of DNA in each cell that contain its genes. Sometimes when a cell is dividing, the sequence of the DNA in a chromosome can be changed. This might put a gene that functions as a type of ‘on’ switch next to a proto-oncogene, keeping this gene turned on even when it shouldn’t be. This new oncogene can result in the cell growing out of control.
- **Gene duplication:** Some cells have extra copies of a gene, which might lead to

them making too much of a certain protein.

A small number of family cancer syndromes[1] are linked to an inherited change in an oncogene. These types of changes can sometimes be the first step in a cell becoming a cancer cell. But most changes involving oncogenes are acquired during a person's lifetime, rather than being inherited.

Tumor suppressor genes

Tumor suppressor genes are normal genes that slow down cell division or tell cells to die at the right time (a process known as *apoptosis* or *programmed cell death*). When tumor suppressor genes don't work properly, cells can grow out of control, which can lead to cancer.

A tumor suppressor gene is like the brake pedal on a car. It normally helps keep the cell from dividing too quickly, just as a brake keeps a car from going too fast. When something goes wrong with a tumor suppressor gene, such as a pathogenic variant (mutation) that stops it from working, cell division can get out of control.

Inherited changes in tumor suppressor genes have been found in some family cancer syndromes[2]. They cause certain types of cancer to run in families. But most tumor suppressor gene mutations are acquired during a person's lifetime, not inherited.

For example, *TP53* is an important tumor suppressor gene. It codes for the p53 protein, which helps keep cell division under control. Inherited changes in the *TP53* gene can lead to Li-Fraumeni syndrome. Family members with this syndrome have an increased risk of several types of cancer, because all of their cells have this *TP53* gene change.

Changes in the *TP53* gene are also very common in cancer cells in people *without* an inherited cancer syndrome. These *TP53* changes are acquired during the person's life. These changes can help the cancer cells grow, but they are found only in the cancer cells, not in other cells in the body, so they can't be passed on to a person's children.

DNA repair genes

When a cell divides to make new cells, it needs to make a new copy of all of its DNA. This is a complex process, and sometimes it results in mistakes in the DNA.

Genes known as **DNA repair genes** act like a person who repairs a car. They help fix mistakes in the DNA, or if they can't fix them, they trigger the cell to die so the mistakes

can’t cause any further problems.

When something goes wrong with one of these DNA repair genes, it can allow more mistakes to build up inside the cell. Some of these might affect other genes, which could lead to the cell growing out of control.

As with other types of gene changes, changes in DNA repair genes can either be inherited from a parent or acquired during a person’s lifetime.

Examples of DNA repair genes include the *BRCA1* and *BRCA2* genes. People who inherit a pathogenic variant (mutation) in one of these genes have a higher risk of some types of cancer, particularly breast and ovarian cancer among women. (For more information, see Family Cancer Syndromes[3].) But changes in these genes are also sometimes seen in tumor cells in people who did not inherit one of these mutations.

Hyperlinks

1. www.cancer.org/cancer/risk-prevention/genetics/family-cancer-syndromes.html
2. www.cancer.org/cancer/risk-prevention/genetics/family-cancer-syndromes.html
3. www.cancer.org/cancer/risk-prevention/genetics/family-cancer-syndromes.html

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Last Revised: August 31, 2022

Cancer-related Genomic Testing and Genetic Testing

Over the past few decades, researchers have learned a great deal about the thousands of different genes inside the cells in our bodies, how they interact with each other, and how many of these genes might be related to cancer.

You may have heard terms such as genomics (and genomic testing) and genetics (and genetic testing) and wondered what they mean. Here we'll talk about these terms, how they're related, and how they're different, especially in the context of cancer.

What are genomics and genetics?

Genomics and genetics are related fields of study.

Genetics refers to the study of genes and their roles in inheritance – in other words, it's about how genes affect the way that certain traits or conditions are hereditary, or passed down from one generation to another. Genetics focuses mainly on the study of individual genes and their effects. **Genes** are pieces of DNA in our cells that carry the instructions for making proteins, which direct the activities of cells and functions of the body.

Genomics is the study of a person's entire set of genes (their **genome**), including how these genes interact with each other and with the person's environment.

On a broad level, genomics is helping researchers learn more about the gene and protein changes inside different cancer cells. This is being used to develop newer cancer treatments aimed at these gene and protein changes. You can learn more about how changes in a cell's genes can lead to cancer in Genes and Cancer.

Genomics is also becoming an important part of care for many people with cancer.

What is genomic testing?

When it comes to cancer, **genomic testing** most often refers to tests done to look at

To learn more about genetic testing as it relates to cancer risk, see Genetic Testing for Cancer Risk[2].

Hyperlinks

1. www.cancer.org/cancer/diagnosis-staging/tests/biomarker-tests.html
2. www.cancer.org/cancer/managing-cancer/treatment-types/precision-medicine.html
3. www.cancer.org/cancer/risk-prevention/genetics/genetic-testing-for-cancer-risk.html

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Last Revised: November 2, 2023

Written by

The American Cancer Society medical and editorial content team (https://www.cancer.org/cancer/acs-medical-content-and-news-staff.html)

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