Variation of Traits

Reflect

Genetic variability is the measure of the differences among individuals within a population. Because some traits are more suited to certain environments, creating particular niches and "fits," we know that there must be variety in that population. In other words, for a trait to be considered best suited to an environment, there must be variability among traits, and the one trait must have an advantage over the others. A healthy population is one that can withstand change easily. Changes such as temperature fluctuations or natural disasters tend to benefit some species over others. Therefore, a population with great genetic variability, or diversity, will have more chances to withstand or evolve with the environmental shift. But how does a population increase its genetic variability?

Genetic Variation

The variety of gene combinations that exist within a population.

genetic variation: the measure of the differences among individuals within a population

Sexual Reproduction

Sexual reproduction is beneficial to organisms because it increases genetic variation, but asexual reproduction has advantages as well. In **asexual reproduction**, a single parent produces offspring that are genetically identical to the parent and to each other. Asexual reproduction is mostly associated with **prokaryotes**. Other simple life forms such as the hydra and sponge may reproduce sexually or asexually at various stages of their lives.

prokaryote: a simple organism that does not have a membrane bound nucleus or other organelles

Although genetic variation is compromised in asexual reproduction, there are benefits to the parent organism. Animals that are immobile, such as sponges, would have great difficulty finding a mate. Asexual reproduction allows them to produce offspring without having to travel. Another advantage is that the parent expends much less energy in asexual reproduction than it would in sexual reproduction. This allows organisms to produce many offspring without greatly exhausting their energy or time. Finally, in a stable environment, asexual reproduction produces offspring with the necessary genetic traits to survive and thrive in their environment.

A bud, or offspring, grows out of the left side of this hydra. What do you know about the bud's genetic makeup?

Reflect

Meiosis and Genetic Variation

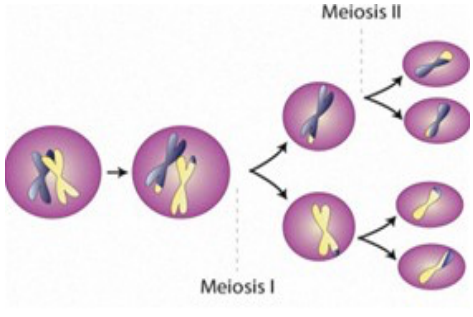
Meiosis increases genetic variation in organisms that undergo sexual reproduction. Meiosis is similar to **mitosis** in that chromosomes replicate and divide into daughter cells. However, during **meiosis**, cells undergo two divisions, meiosis I and II. This results in daughter cells with half the number of chromosomes as the parent cell, which is called **haploid**. These daughter cells are the **gametes**, or sex cells, and are also referred to as sperm and egg.

mitosis:
a form of cell division in which the material from the cell nucleus divides

When **eukaryotes** reproduce sexually, the gametes from each parent join together creating a **zygote**. The two haploid cells combine, giving the offspring a complete set of chromosomes, which is called **diploid**. Sexual reproduction creates greater genetic variety in two ways. First, an offspring inherits DNA from both of its parents. This causes new combinations of alleles, resulting in a variety of traits that differ from the mother and father. Since genes are randomly assorted when they are passed to offspring, even two siblings have different combinations of genes and traits from the same set of parents. Only identical twins have exactly the same DNA.

eukaryote: organism with a membrane bound nucleus that contains DNA

Meiosis also contributes to genetic variation through crossing over. During one phase of meiosis, **homologous chromosomes**—pairs of chromosomes containing the same genes but possibly different alleles—line up at the center of the cell. When this happens, sections of the homologous chromosomes can cross over and switch positions with other chromosomes. This **random assortment** results in a reshuffling of genes on the individual chromosomes, which provides an even greater variety of genetic combinations that can be passed on to the offspring.



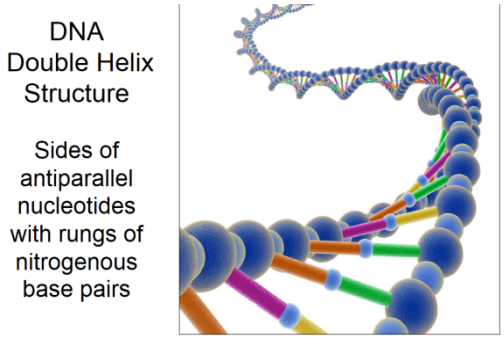
Crossing over during meiosis I in the cells shown here results in sections of the two homologous chromosomes switching places.

What Do You Think?

DNA has certain structural requirements. It must contain an extraordinary amount of information and fit inside a single cell. DNA must be stable enough to keep information intact as it passes from progenitor cells to daughter cells and from one generation to the next. It must be flexible enough, however, so that the information can be altered or added to when necessary. DNA must be accessible to the cell so that it can be expressed, but it must also resist physical damage that would destroy the information it contains.

The primary physical structure of DNA is the double helix. A helix is a three-dimensional spiral. Most DNA is double stranded. Single stranded DNA will attempt to become double stranded by binding with itself if no other DNA is around. Double stranded DNA consists of two antiparallel chains of nucleotides that form a helix, with the nitrogenous bases of one chain lining up with the nitrogenous bases of the other chain. The sugar and phosphate groups that form the backbone of each chain do not interact with their counterparts on the opposing chain.

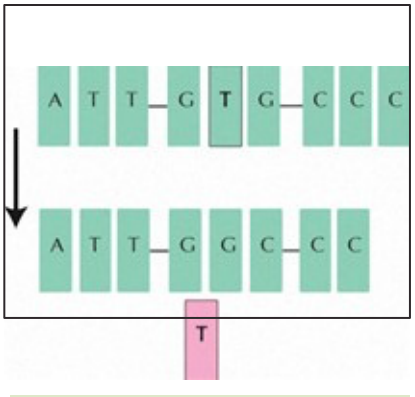
DNA
Double-Helix Structure



When DNA is signaled to make a copy of itself, it will undergo the process of replication. All cells depend on this process to continually make new and identical cells. This biological process occurs in all cells and will create an exact replica of the original cell. Because DNA replication will make exact copies, it does not allow for genetic variability within a population. However, even this highly regulated process may have errors, in which case mutations can occur.

Mutations

Changes to DNA are called **mutations**. Think about a recipe for pizza dough in a cookbook. If you substituted sugar for salt, would your dough taste the same? Probably not! In a similar way, if the genetic message changes, the protein may change or even not be created at all. Mutations are heritable, permanent changes that are passed on to the next generation of cells when the cell divides.



deletion mutation: removing a single DNA nucleotide, which shifts the entire reading frame, produces different codons in the ribosome, and results in a very different protein

What Do You Think?

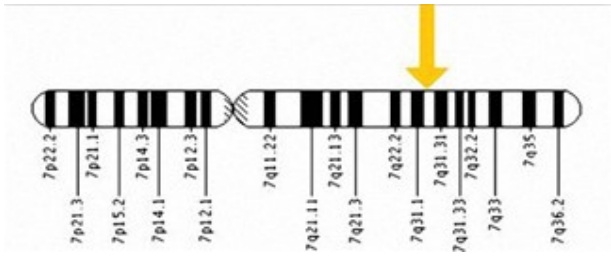
Some mutations are called **point mutations**. They occur in a single area of DNA. One type of point mutation is a **substitution**. For example, consider what happens if the codon UAC changes to UAA. UAC codes for tyrosine, whereas UAA is a stop codon. By substituting a single nucleotide for another, the message changes from add a tyrosine to stop adding nucleotides here. This results in an unusually short peptide that may not be functional in this shorter form. This single change can knock out the protein. Sometimes, substitutions do not affect the final protein. Consider a change from UAC to UAU. Although the third nucleotide has changed, both codons code for tyrosine, so the final protein is the same.

Sometimes, point mutations result in a **frame-shift mutation**. In this case, a single nucleotide is added to **(insertion)** or deleted from **(deletion)** the DNA sequence. This causes a shift in what is called the reading frame. Because DNA is read three bases at a time in a ribosome, an insertion or deletion can cause the wrong amino acids to be added to the chain. This usually results in the assembly of a nonfunctional protein.

Mutations happen on a daily basis. Some are caused by errors in the cell replication process. Others are caused by exposure to chemicals or ionizing radiation. There are proteins in the cell whose job is to constantly scan DNA and look for damage that needs repair. However, sometimes they miss damaged DNA, and the damage is passed on to the next generation of cells. Sometimes, the damage takes place in areas of DNA that are not expressed. In these cases, the changes are considered harmless. Mutations that affect cell growth cause **cancer**, which is uncontrollable cell division in the body.

Getting Technical: Gene Knockouts

Scientists will sometimes deliberately cause genetic mutations in an organism. A **gene knockout** is the process by which a gene in an organism is made nonfunctional by a directed mutation. This process can help scientists understand the function of a gene. For example, suppose scientists inactivated a particular gene in a mouse genome, and the resulting mouse was hairless. The scientists would know the gene in question was related to hair growth. Knockout organisms can also be used to study diseases. For example, scientists have bred knockout mice with various mutations in the CFTR gene in order to study cystic fibrosis. This disease is caused by mutations in the CFTR gene.



The CTFR gene is on chromosome 7, at the location indicated by the yellow arrow on this karyotype. Changing a single amino acid in this gene can cause cystic fibrosis.

Look Out!

A DNA mutation is not always harmful. If a section of DNA is changed that has no real use in a cell, the resulting mutation is harmless. Also, if the mutation occurs in a noncoding section of the DNA, it is unlikely to cause any harm. Some mutations even increase the survival rates of individuals and are therefore more likely to be passed on to future generations. For example, if a mutation causes a color change in an animal and the color change helps the animal hide from predators, that animal will likely survive and reproduce.

Other influences on gene expression could be the environment in which an organism exists or develops. Hormones, metabolism, and temperature are examples of these influences. There are case studies showing that the presence or absence of particular drugs or chemicals in a developing embryo's environment can have an effect on the number of eyes developed by certain fish. Temperature can have a direct effect on the color of rabbit fur, which is another example of environmental influences on gene expression.

Try Now

Statement	True or false?
Asexual reproduction will produce offspring different from the parent cell.	
Replication is an exact copy of a strand of DNA.	
All mutations will have a negative impact on the individual.	
Crossing over of homologous chromosomes helps increase genetic variability.	
Meiosis produces haploid cells via sexual reproduction.	
An addition or subtraction of a nucleotide is known as a point mutation.	
Temperature can affect the traits expressed within a gene sequence.	
Some mutations shift the whole reading frame, completely changing the amino acid sequence.	

Connecting With Your Child

Environmental Influences on Mutations

Ultraviolet (UV) light is a kind of radiation that can cause cancer in cells. This is known as a mutagen, an agent that causes DNA mutations. Chemical changes can occur in DNA due to overexposure to UV rays. Because sunlight is a strong source of UV rays, too much direct sunlight on your skin can cause chemical mutations in your DNA.

To help your child learn more about environmental factors that cause mutations, have your child research mutagens, such as the cancer previously discussed, and create a PowerPoint presentation or a poster that highlights their findings.

Have your child include in the research the environmental factors that cause the mutation, how the mutation occurs, and any treatments or reverse processes for the mutation.

Here are some questions to discuss with your child:

- What are mutations?
- How can the environment influence DNA?
- Can a mutation ever be beneficial?