chapter 12

Molecular Genetics

section 4 Gene Regulation and Mutation

Before You Read

Like a DNA codon, the sentence, "The dog ran." contains only three-letter words. Insert one letter "Z" and the sentence changes to, "ThZ edo gra." On the lines below, write the sentence that results if you insert two letters, then three letters. Which sentence is easiest to read? In this section, you will read about how mutations affect gene expression.

MAIN Idea

The cell regulates gene expression, and mutations can affect this expression.

What You'll Learn

- how bacteria can regulate their genes by operons
- how eukaryotes regulate transcription of genes

Read to Learn

Mark the Text

Restate the Main Point Highlight the main point in each paragraph. State each main point in your own words.

Prokaryote Gene Regulation

Cells use **gene regulation** to control which genes are transcribed in response to the environment. Prokaryotes use operons to control the transcription of genes. An **operon** is a section of DNA that contains the genes for the proteins needed for a specific metabolic pathway. An operon contains an operator, a promoter, and a regulatory gene. The operator is like an on/off switch for transcription. The promoter is where RNA polymerase first binds to the DNA.

How does the *trp* operon work?

The tryptophan (*trp*) operon in the bacteria *Escherichia coli* (*E. coli*) is a repressible operon. Tryptophan synthesis occurs in five steps. Each step is triggered by a specific enzyme. The tryptophan operon contains five genes (*trpA* through *trpE*) needed to make the amino acid tryptophan. When tryptophan levels are low, RNA polymerase binds to the operator, turning on the transcription of the five enzyme genes needed for tryptophan synthesis.

Reading Check

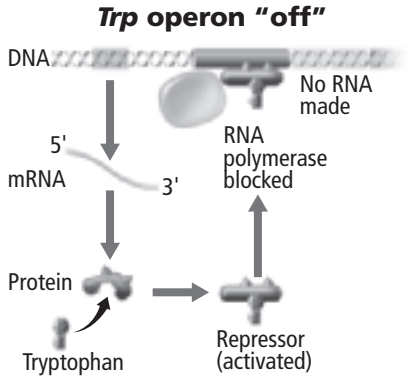
1. Explain What triggers each step in the synthesis of tryptophan?

How is the *trp* operon turned off?

The figure below shows what happens when tryptophan is abundant. The cell has no need to make tryptophan. Tryptophan binds to the repressor protein to activate it. The complex binds to the operator, keeping RNA polymerase from binding. The genes needed for tryptophan synthesis are not made.

Picture This

2. Identify Circle the operator sequence where the tryptophan-repressor complex is bound.



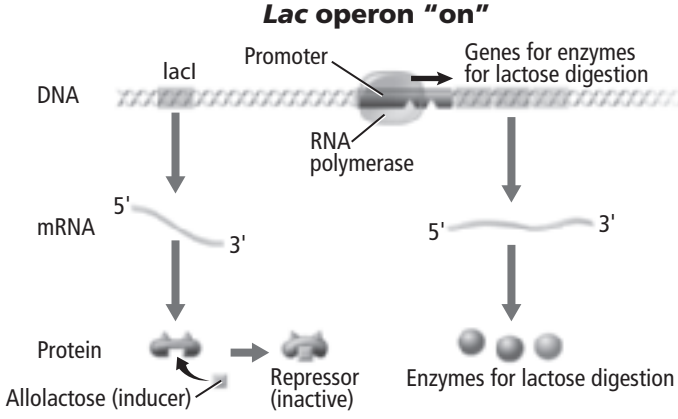
How does the *lac* operon work?

The *E. coli* lactose (*lac*) operon, an inducible operon, is shown below. The lac operon contains a promoter, an operator, a regulatory gene, and three genes that code for enzymes needed to digest the sugar lactose as food. The *lac* operon is switched on by an inducer, a molecule present in food containing lactose. The inducer binds to the *lac* repressor and inactivates it. RNA polymerase can bind to the promoter and transcription proceeds, and the lactose-digesting enzymes are made.

E. coli does not need to make lactose-digesting enzymes when lactose is not available. In that case, an inducer is not present and the regulatory gene makes a repressor protein that binds to the operator and blocks transcription.

Picture This

3. Label Circle the allolactose-repressor complex. How is the *lac* repressor different from the *trp* repressor?



Eukaryote Gene Regulation

Eukaryotes have many more genes than prokaryotes. They also use different, more complex methods of gene regulation.

How do eukaryotes control transcription?

Proteins called transcription factors control when a gene is turned on and how much of that protein is made. Some transcription factors guide the binding of RNA polymerase to a promoter. Other transcription factors control the rate of transcription.

Reading Check

4. State two ways that transcription factors control genes.

How do Hox genes work?

Homeobox (Hox) genes code for transcription factors. Hox genes control differentiation, the process through which cells become specialized in shape and function. Hox genes are used during embryo development and are active in different zones of the embryo. They control what body part will develop in different parts of the embryo.

What is RNA interference?

Another way that eukaryotic genes are regulated is RNA interference (RNAi). Interfering RNA molecules are small segments of double-stranded RNA that bind to a protein complex that breaks down one strand of the RNA. The resulting single-stranded interfering RNA and protein complex bind to mRNA sequences and prevent mRNA from being translated.

Mutations

A permanent change in a cell's DNA is called a **mutation**. Mutations that occur in a gene sequence can change the protein that is made. Mutated proteins often do not work.

What mutations involve a single nucleotide?

Point mutations occur when a single nucleotide is changed. They can result in genetic disorders. A substitution is a kind of point mutation that occurs when one base is exchanged for another. A missense mutation is a substitution in which the DNA code is changed so that it codes for the wrong amino acid. A nonsense mutation changes the codon for an amino acid to a stop codon. Nonsense mutations often cause translation to stop early, making a protein that is too short. Muscular dystrophy is an example of a disease caused by a nonsense mutation.

Reading Check

5. Name What type of mutation occurs when a stop codon replaces an amino acid codon?

What are some other types of mutations?

Insertions and deletions occur when a nucleotide is added or lost. Insertions and deletions can cause a frameshift mutation, causing the ribosome to misread the codons. THE BIG FAT CAT ATE THE WET RAT becomes THE BIG ZFA TCA TAT ETH EWE TRA. Cystic fibrosis and Crohn's disease are both caused by frameshift mutations. Some mutations involve large pieces of DNA containing many genes. A piece of a chromosome can be deleted, moved to a different location on the same chromosome, or moved to another chromosome. Such mutations often have serious effects.

In 1991, a new type of mutation was discovered. This mutation happens when repeated sequences, called tandem repeats, increase in number. Fragile X syndrome and Huntington's disease are both caused by this type of mutation.

Think it Over

6. Evaluate Would a 3-nucleotide insertion result in a frameshift? Why or why not?

How do mutations affect protein folding?

Small mutations, like substitutions, can lead to genetic disorders. Changing one amino acid for another can change how a protein folds and, as a result, change how it functions.

What causes mutations?

Some mutations occur simply because DNA polymerase makes a mistake, adding the wrong nucleotide during DNA replication. Other mutations are caused by **mutagens** (MYEW tuh junz), which are chemicals or radiation that can damage DNA.

Some mutagens resemble nucleotides so closely, that DNA polymerase mistakes them for nucleotides and adds the mutagen into the DNA chain. Chemical mutagens are being studied for possible use in treating HIV—the virus that causes AIDS.

UV radiation from the Sun can damage DNA. It can cause thymine bases that are next to each other to bind together. This creates a kink in the DNA, and it cannot replicate.

Reading Check

7. Explain How does UV light damage DNA?

How are mutations inherited?

Mutations in body cells, or somatic cells, are not passed on to the next generation. Sometimes these mutations do not cause problems for the cell. Other times they kill the cell. Some somatic cell mutations lead to cancer.

Mutations in sex cells are passed on to the organism's offspring. Every cell in the offspring will carry the mutation. Sometimes the mutations do not change how those cells function. Other times the mutations have serious effects.