Reflect

Cookbooks describe the ingredients and steps needed to make many kinds of dishes. Some cookbooks contain hundreds of recipes. However, someone needs to use the cookbook in order to create the dishes. Without a chef as an intermediary, cookbooks are simply words on paper.

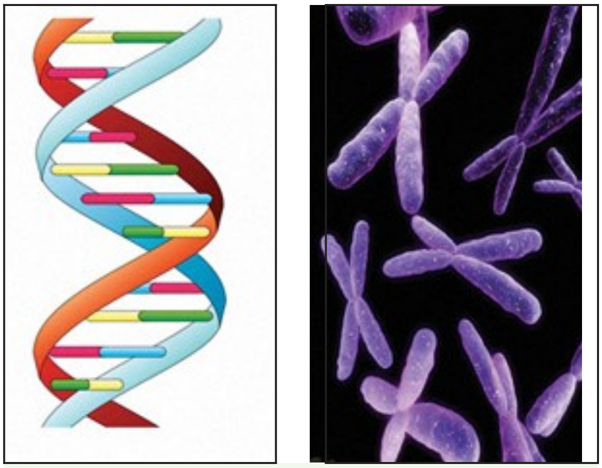
DNA (deoxyribonucleic acid) is similar to a cookbook. It contains a lot of information. But until an intermediary makes that information useful, DNA is simply a string of nucleic acids. How is DNA turned into something useful?

DNA Structure and Function

DNA is a nucleic acid made up of a string of nucleotides. These nucleotides are joined in a double helix configuration, much like a winding staircase. In eukaryotic cells, DNA is packaged in the cell nucleus as **chromosomes**. The nucleus is the control center of the cell. When a cell divides, its chromosomes are replicated, and a complete set of genetic information is passed on to each daughter cell.

chromosome: a linear strand of DNA that is wrapped around protein structures and carries the gene sequence of an organism

Genes are located on chromosomes and are sections of DNA that code for a specific protein. These proteins contribute to a specific hereditary trait or characteristic.
When a gene's code is used to produce a protein, that gene is considered to be expressed.



DNA forms a double helix, with hydrogen bonds between nucleotides holding the two strands together (left). DNA strands fold into larger chromosomes in eukaryotic cells (right).

Gene expression takes place in two steps: transcription and translation. **Transcription** is a process in which a complementary strand of RNA is formed from the section of DNA that contains a gene. The RNA is then used as a template to produce a protein through a process called **translation**. Each of these processes is tightly controlled. If something goes wrong at any step, the results can be deadly. You will learn more about the steps involved in transcription and translation later in the lesson.

Reflect

Regulating Gene Expression

A strand of DNA does not just contain genes. It also has a number of **regulatory elements** that help control gene expression. Some regulators help turn genes on, causing genes to be expressed. Certain proteins can make it easier for transcription to occur. These proteins help facilitate gene expression. Certain sections of DNA mark where a gene begins and ends. This helps the process of transcription occur in the correct area of DNA. Sections of DNA or proteins can turn genes off, preventing gene expression. Cells typically produce a specific protein only when it is needed. Some genes are **housekeeping genes** that are always turned on. These genes code for proteins that are always needed.

What Do You Think?

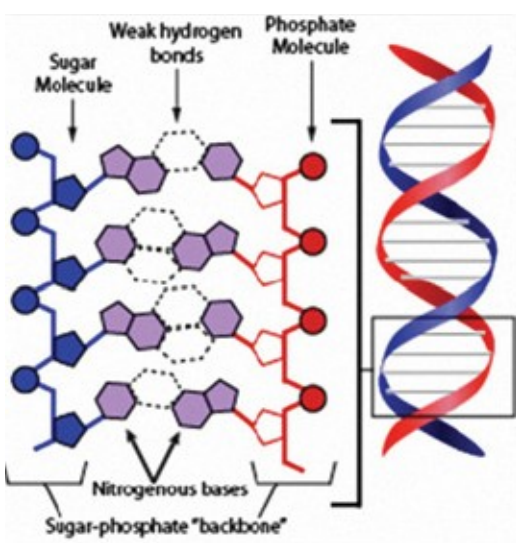
Drug companies are developing more specific drugs that target diseases with fewer side effects. This type of personalized medicine relies on identifying the genes involved in a person's disease. Some people worry that insurance companies will use this genetic information to deprive patients of insurance coverage. Is the risk of sharing your genetic information worth gaining access to lifesaving drugs?

Transcription

Transcription uses DNA as the template for making RNA. Recall that DNA is made up of four nucleotides: adenine (A), guanine (G), thymine (T), and cytosine (C). Along the outer edges of each strand, the nucleotides are linked together by strong **covalent bonds**. These bonds form between the phosphate and deoxyribose sugars of adjacent nucleotides.

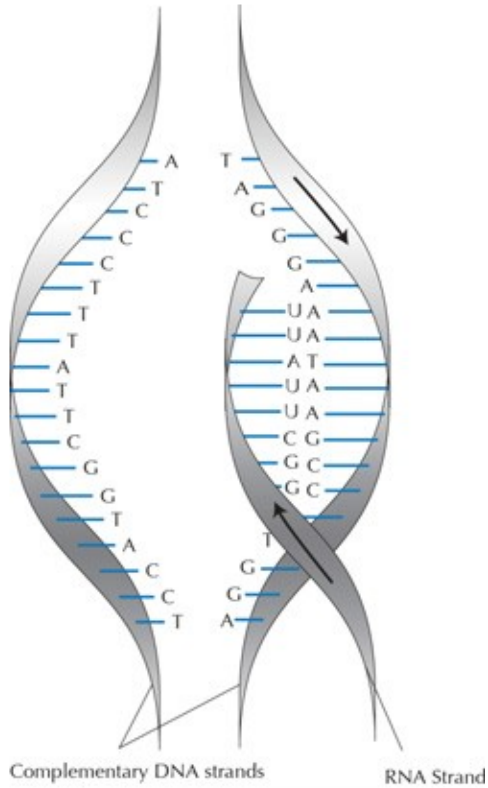
covalent bond: a chemical bond formed between atoms that share electrons

As shown in the diagram on the right, hydrogen bonds form between the two strands of DNA in a process **called base pairing.** Adenine bonds only with thymine, and cytosine bonds only with guanine. These are called **complementary base pairs**. Hydrogen bonds are much weaker than covalent bonds and occur between molecules. This bonding structure allows the two complementary strands of DNA to separate from each other during transcription. Enzymes called **helicases** are responsible for separating the DNA strands.



What Do You Think?

Transcription takes place within the cell's nucleus and is the first step in a process that will produce a protein with a specific function. First, the complementary DNA strands separate at the site of the gene to be expressed. Then, a series of proteins called **RNA polymerases** moves into the now-available DNA and synthesizes a strand of RNA based on the DNA template. (In the diagram on the right, the RNA strand is shown in green.) This RNA is called **messenger RNA**, or mRNA, because it is the message used to produce a protein.

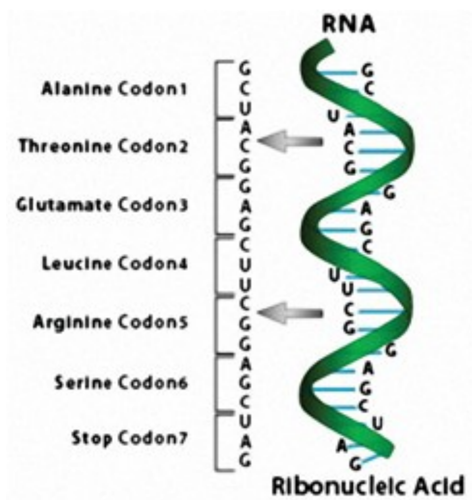


Similar to DNA, RNA is also made up of nucleotides. However, the nucleotides in RNA are slightly different: adenine, cytosine, guanine, and uracil. When mRNA is being formed, guanine is matched to cytosine in the DNA, and cytosine to guanine. Adenine still pairs with thymine in DNA. However, it is uracil that is added to mRNA as the partner for adenine.

After it is made, the mRNA separates from the DNA, leaves the nucleus, and enters the cytoplasm for the next steps in the protein production process: translation.

Translation

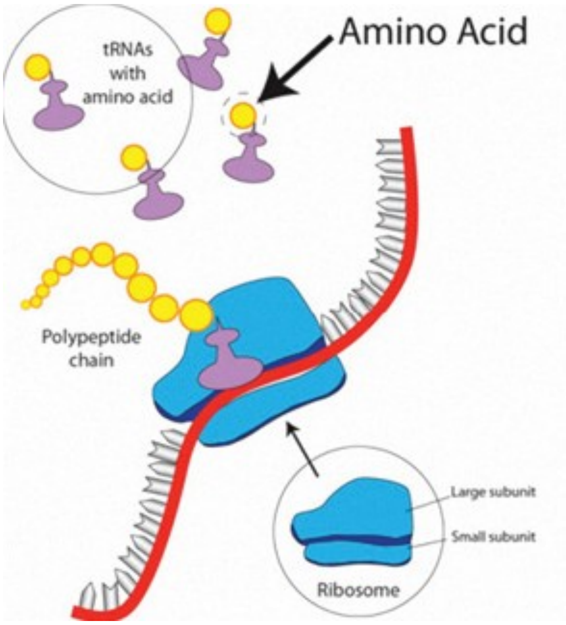
The purpose of translation is to convert the information in the mRNA into an amino acid sequence, which will form a protein. Translation takes place in a cell's cytoplasm, after the mRNA has exited the nucleus. Translation depends on "translating" three-letter groups of nucleotides in the mRNA, called **codons**. Most codons correspond to specific amino acids. Three of the codons are **stop codons**, which function as signals to stop adding amino acids.



Codons are sets of three nucleotides in mRNA that determine which amino acids are linked together to make a protein.

You can remember **transcription** if you create a mental image of someone rewriting, or transcribing, your class notes (a scribe is someone who copies words onto paper). You can remember **translation** if you think of RNA being a nucleic acid language that is translated into an amino acid language.

What Do You Think?



tRNA carries amino acids to the ribosomes, where they are added to the polypeptide chain formed by ribosomes.

Translation is carried out by organelles called **ribosomes**. Ribosomes either float freely in the cytoplasm or in eukaryotes; they can also be found attached to the endoplasmic reticulum. Ribosomes are responsible for "reading" the nitrogenous bases of the mRNA and forming the polypeptide chain that forms the primary structure of a protein. Ribosomes are miniature protein production factories made of ribosomal RNA (rRNA).

When mRNA is available in the cytoplasm, a ribosome attaches to the mRNA molecule and reads the mRNA one codon at a time. Another type of RNA, called transfer RNA or tRNA, is responsible for bringing amino acids to the ribosomes. Each tRNA carries a different kind of amino acid. tRNA molecules recognize specific codons through complementary base pairing. The recognition sequence is the opposite of the codon, so it is called the **anticodon**.

As each amino acid is brought to the ribosome, it is added to the growing polypeptide chain. Amino acids link together through peptide bonds between neighboring amino acids. This process continues until a stop codon is reached and no additional amino acids are added to the polypeptide chain. The ribosome releases the polypeptide chain, which may undergo further processing elsewhere in the cell before it reaches its final form as a fully functional protein.

Look Out!

What makes you so unique? Well, it's your DNA, of course. Although we all share the same bases (adenine, guanine, cytosine, and thymine), the order of these bases will code for specific amino acids, and then the order of those amino acids codes for a different protein. Different proteins mean different genes are expressed, which leads to the differences between each and every one of us!

Try Now

What Do You Know?

Use what you have learned about transcription and translation to complete the chart below. Read each description in the left column. Then, in the right column, write whether each is associated with transcription, translation, or both.

Description	Transcription, Translation, or Both?
A process that is a vital step in protein production	
DNA strands separate from each other	
Amino acids are linked together in a polypeptide	
Takes place in the cytoplasm	
Takes place in the nucleus	
Involves the use of helicases	
Requires tRNA and mRNA	
Uses information from a gene to produce a specific protein	

Connecting With Your Child

Codon Bingo

Codons are sequences of three nucleotides each in mRNA that code for specific amino acids. When DNA is transcribed into mRNA, these codons dictate which amino acids should be linked together in the final protein. Some codons are "stop" sequences, which end translation at that site. This game reinforces two concepts: a codon is a sequence of three nucleotides that codes for an amino acid, and multiple three-letter codons can code for the same amino acid.

To play Codon Bingo, make a large 5 x 5 grid bingo card using construction paper and a marker. Then search for an RNA codon table on the Internet. Government sites usually have accurate, reliable tables. Using the codon table, randomly enter three-letter codon codes into the boxes. Do not repeat any of the codon codes on any one card. Repeat the card-making process for anyone else playing along. A sample table is shown here:

UUU	CUU	AUU	GUU	UCU
CCU	ACU	ACA	GCU	UAU
UAA	UAG	CAU	AAU	AAA
GAU	GAC	GAG	UGU	UGC
UGA	CGC	AGU	GGU	GGG

Using the codon table you found on the Internet, begin calling out three-letter combinations at random. You may wish to use the codon chart to cross off each combination as you call it out. Each time a codon is found on the bingo sheet, your child should cross it off and write the three-letter amino acid code next to the codon.

There are two ways to win the game. The first is by "translating" five codons in a row into amino acids on the bingo card. The second is if your child has a "stop" codon on the card.

As you play the game, you may wish to discuss with your child:

- What does each codon code for? (an amino acid)
- Do you have any amino acids that appear more than once? If so, what is similar between their codons? (*some or all codons share the first two letters*)
- What happens when there is a stop codon in mRNA? (*the translation stops*)