Lesson 5: How to Make a Protein

Introduction

You have learned that both proteins and DNA are chains made from smaller molecules. Proteins are composed of amino acids bonded in a specific sequence, while DNA is composed of four nucleotides bonded in a specific sequence. The sequence of nucleotides in a segment of DNA called a gene code for the amino acid sequence of a particular protein. In this lesson, you will learn more about how the sequence of nucleotides in a gene code for a specific protein.

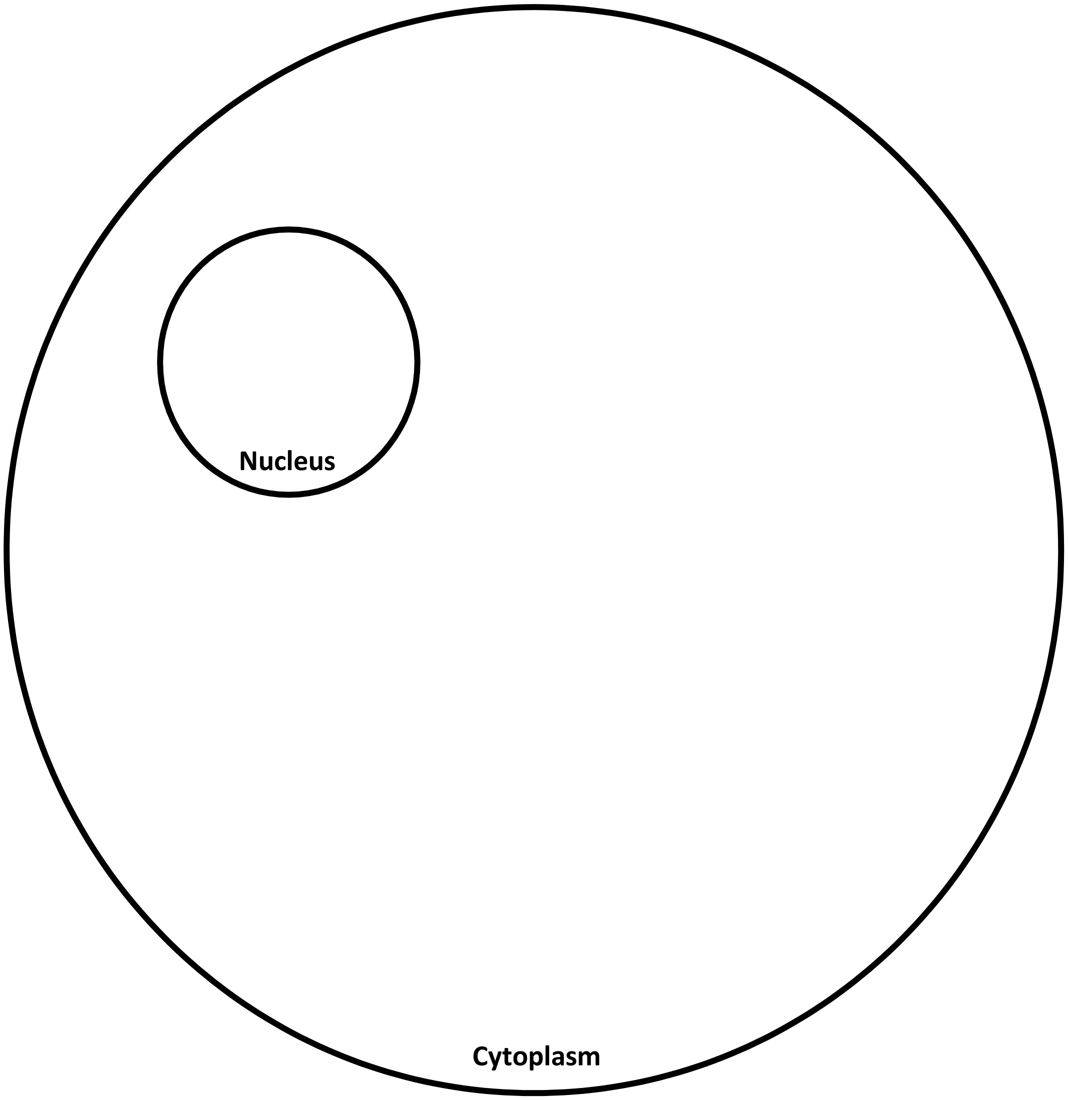
Process and Procedure

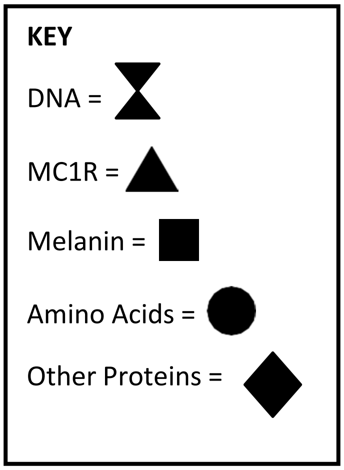
Lesson Focus Question

1. Write the focus question for this lesson in the box below. After you have written the focus question, write your best ideas in the space below the box, leaving room to revise your ideas.

Getting Information from One Part of a Cell to Another

2. Add the symbols in the key to the cell diagram in the proper quantity and location within the cell.





3. You have been studying the MC1R protein in jaguars and have learned that a portion of the MC1R protein is missing in black jaguars. This difference in the MC1R protein can explain some of the variations we see among individual jaguars.

   To learn more about MC1R and how it is different in jaguars, we will explore the process by which DNA provides the instructions to make a protein.

   To begin, examine the DNA sequence of a small part of the gene for MC1R in a spotted jaguar:

   GTG CTG GAG ACG GCC GTC ATG CTG CTG CTG GAG GCG GGC ACC CTG GCC GGC

   What do you notice about the sequence?

   Next, use the key below to write the sequence for a strand that is complementary to the one given. The sequence is copied again below. Write the letters that go with each of the nucleotides.

   Key:
   For every G, write a C.
   For every C, write a G.
   For every A, write a U.
   For every T, write an A.

GTG CTG GAG ACG GCC GTC ATG CTG CTG CTG GAG GCG GGC ACC CTG GCC GGC

4. Draw a cell that fills the lower section of the page. Then, complete the Etch-a-Sketch for the reading: *Making a Protein: What Happens in the Nucleus*

Making a Protein: What Happens in the Nucleus

Step 1: You represented the first step in making a protein at the end of step 3! In cells, enzymes in the nucleus do the same process you did on paper. These enzymes are able to separate the two strands of DNA. The enzymes make a new strand of a slightly different nucleic acid, called ribonucleic acid, or RNA. The DNA is available to be transcribed again and again. The process of making an RNA copy of the DNA is called **transcription**. The enzymes complete the process by using the following base pairing rules: If there is a G in DNA, RNA pairs a C. If there is a C in DNA, RNA pairs a G. If there is a A in DNA, RNA pairs a U. If there is a T in DNA, RNA pairs an A.	Step 2: Once the DNA is transcribed into RNA, the RNA moves out of the nucleus into the cytoplasm. The RNA that is made in the nucleus of a cell is called messenger RNA, or mRNA. It is named that because it carries the *message* between the nucleus, where the DNA is, and the cytoplasm of the cell, where proteins are made. The DNA stays in the nucleus where it is protected from chemicals and enzymes in the cytoplasm.	Step 3: The mRNA copy of genetic information serves as a guide for making proteins in the cytoplasm. The process of making a protein from mRNA is called **translation.**

5. Read and annotate the article below.

Translating the Message in mRNA

mRNA acts like a blueprint for making a protein, the same way blueprints guide the construction of a building or a machine. The process of converting the code in mRNA to a sequence of amino acids in a protein is called **translation**. The same way someone can translate words from English to another language, cells can translate the language of RNA into an amino acid sequence, the language of proteins. Because the mRNA travels out of the nucleus, the process of translation takes place in the cytoplasm of the cell.

The Genetic Code

Even though there are just 20 amino acids, they can be put in different orders to make an amazing number of proteins. Each amino acid must be identified specifically by the information in the mRNA. But it cannot be a 1:1 translation. If every nucleotide coded for an amino acid, then there could only be four different amino acids. If there were two RNA nucleotides to code for an amino acid, that would mean there could only be 16 amino acids (4 nucleotide possibilities in the first position multiplied by four nucleotide possibilities in the second position). Instead, the genetic code involves three nucleotides per one amino acid. Each three-letter sequence is called a **codon.** By having three-nucleotide codes, there are 64 possible sequences. Because there are only 20 amino acids, that means that several codons may code for the same amino acid.

First letter	Second letter				Third letter
	U	C	A	G	
U	phenylalanine phe	serine ser	tyrosine tyr	cysteine cys	U
	phenylalanine phe	serine ser	tyrosine tyr	cysteine cys	C
	leucine leu	serine ser	stop	stop	A
	leucine leu	serine ser	stop	tryptophan trp	G
C	leucine leu	proline pro	histidine his	arginine arg	U
	leucine leu	proline pro	histidine his	arginine arg	C
	leucine leu	proline pro	glutamine gln	arginine arg	A
	leucine leu	proline pro	glutamine gln	arginine arg	G
A	isoleucine ile	threonine thr	asparagine asn	serine ser	U
	isoleucine ile	threonine thr	asparagine asn	serine ser	C
	isoleucine ile	threonine thr	lysine lys	arginine arg	A
	(start) methionine met	threonine thr	lysine lys	arginine arg	G
G	valine val	alanine ala	aspartate asp	glycine gly	U
	valine val	alanine ala	aspartate asp	glycine gly	C
	valine val	alanine ala	glutamate glu	glycine gly	A
	valine val	alanine ala	glutamate glu	glycine gly	G

Starting and Stopping

Study the chart for the genetic code again. You will see that some codons do not specify an amino acid. These codons signal a *stop* in translation, meaning the end of the protein. Another special codon is AUG. This codon specifies the amino acid methionine. It also signals the *start* of translation, to begin building a protein. It can occur in the middle of a gene's sequence as well, but there it means add the amino acid methionine.

The Genetic Code is Universal

One of the most remarkable things about the genetic code is that it is universal. Only a small number of organisms have been discovered that have variations in the code. Although bacteria, reptiles, and mammals all have very different features, they all use the same genetic code. That similarity is an important piece of evidence that supports the idea that all life evolved from one common ancestor.

6. Use what you have learned about transcription and translation to determine the amino acid sequence of a short segment of the MC1R gene in a black jaguar:

DNA	GTG	CTG	GAG	ACG	GCC	GTC	ATG	CTG	CTG	ACG	GCC	GGC
RNA												
Amino Acid												

Changing the Information

7. In Lesson 3 and in this lesson, you have observed that a piece of the MC1R protein is missing in black jaguars. The protein has a different structure because the DNA sequence is different. You may wonder how the DNA sequence changed. Read *DNA Mutations* to find out more.
   - As you read, underline any information that helps you explain how the DNA sequence changed.
   - Put a star next to any information that helps you predict what the offspring of a black jaguar might look like.
   - Put a question mark next to any sentence you do not understand.

DNA Mutations

Using a template is generally a good way to transmit accurate information. However, no matter what you are using a template to do, there can be changes to the original information. In DNA, these changes are rare, but when they do happen, it is often during a process called **replication**. Every time your cells divide--which can be pretty often--the DNA has to becopied correctly and completely. If it were not, the new cells would not have all the genetic information they need.

Cells divide for many reasons. It might be because an organism is growing or has an injury that needs to be repaired. Some types of cells, such as skin cells, are replaced every few weeks. At any given time, DNA is being copied somewhere in your body. Enzymes carry out this work of copying all 3 billion nucleotides. Any time a change is made in the DNA, it is called a **mutation**.

Types of Mutations

One type of mutation happens when the enzyme slips over one or more nucleotides and does not copy them. This makes a DNA molecule that is missing that small piece. This is called a **deletion mutation**. Another type of mutation occurs when the enzyme adds one or more nucleotides to the DNA molecule. This is called an **insertion mutation**. A third type of mutation is called a **substitution mutation**. In this case, the wrong nucleotide is added at a place along the sequence.

Organisms have enzymes that detect and repair mutations. However, they are not always able to find and correct all mutations. That means that sometimes mutations become a permanent change in DNA.

Effects of Mutations

If a mutation takes place in a single cell, it often does not have serious effects. If a mutation takes place in a cell that makes gametes, such as sperm and eggs, that mutation can be passed down to offspring.

However, some mutations are in areas of DNA that are not used by cells. These mutations have no consequences. Other mutations can cause only mild effects. Sometimes these are helpful and sometimes they are harmful. These mild mutations can be passed from generation to generation and lead to more variation in a population.

Other mutations can have larger effects. These may be beneficial, such as a mutation that causes a change in the coloration of an animal. Other mutations can cause serious developmental problems. These mutations are so harmful that they may kill the organism long before it is able to reproduce. Natural selection is a strong mechanism to keep these mutations from accumulating in a species.

8. In Lesson 1, you read about mosquitos that are resistant to insecticides. The resistance is the result of a mutation. Study the DNA sequences below for mosquitoes that are affected by insecticide and for those that are not. Note that only a small portion of the DNA sequence is shown. The whole gene is made of several thousand DNA nucleotides and begins with a start codon and ends with a stop codon.

   Typical mosquito DNA:

   CGG CGG CAG TAC GAC ACC TAG AAG CCC CCA CCG AAG ATG AGG CCC TGA CGG

   Insecticide resistant mosquito DNA:

   CGG CGG CAG TAC GAC ACC TAG AAG CCC CCA TCG AAG ATG AGG CCC TGA CGG

   a. Draw a circle around the mutation.
   b. What type of mutation caused some mosquitoes to be resistant to insecticide? What is your evidence?

   c. What is the effect of the mutation? Be specific about the amino acids that would be changed from the typical mosquito to the insecticide resistant mosquito. Remember that the sequences above are DNA sequences.

Synthesize and Summarize Key Science Ideas

9. Look back at your initial answer to the focus question. Revise or add to your ideas using a different color.

10. In Lesson 1, you saw three possible explanations to answer the unit central question, "What is the best explanation for the similarities and differences we see in individuals within a species—not only for one species, but for every species of plant and animal?"

    Look back over what you have learned in Lessons 1 through 5. In the table below, write evidence that will help you answer the unit central question.

    Place a check mark in the column for any explanation the evidence supports.

Lesson	Evidence	Parents	Genes	Mutation
1				
2				
3				
4				
5				