Name: _____ Date: _____

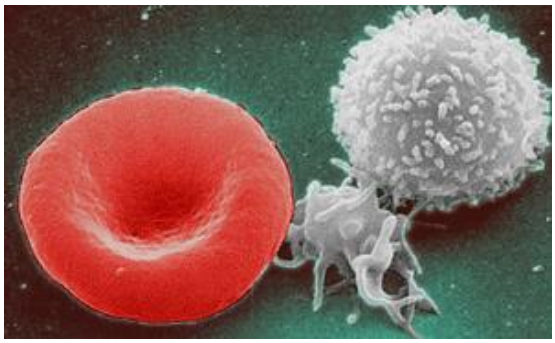
Guided Learning: Cell Differentiation and Gene Expression

Learning goals
After completing this activity, you will be able to …

- List and describe specialized cells.
- Describe the roles of DNA, RNA, and the environment on cell differentiation.
- Recognize that gene expression is a regulated process.

Vocabulary: differentiation, gene, gene expression, RNA, stem cell, transcription factor

Warm-up questions:



1. Name some different types of cells found in the human body that you have heard of.

   _____

   _____

   _____

2. If all these different types of cells originated from the same fertilized egg cell, how do you think they became different? _____

   _____

   _____

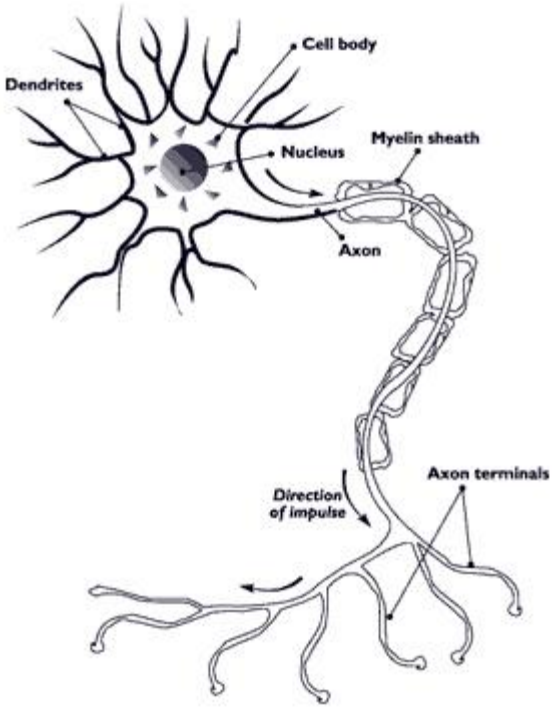
Activity A: Specialized cells
Take a look at the cells shown in the image above. The cell on the left is a red blood cell. It has a concave surface that increases its surface area and allows it to carry more oxygen throughout the body. Its red color comes from hemoglobin, the iron-rich protein in red blood cells that binds to oxygen. The cell on the right is a white blood cell. The projections on its surface allow it to recognize and attach to invading pathogens, such as bacteria and viruses.

Both of these cells are highly specialized, but both of them are descendants of the same single cell. How did a single fertilized egg cell produce specialized cells such as red blood cells, white blood cells, muscle cells, nerve cells, and so on? It all starts with a process known as **differentiation**, which begins early during the development of an organism.

A fertilized egg cell is considered to be a *totipotent* cell. Totipotent cells are able to develop into any kind of cell in the body. The first few daughter cells produced by a fertilized egg are also totipotent cells. However, soon some of these cells start to specialize into major cell types. These cells are now *pluripotent*, meaning they can develop into most, but not all of the body's cell types. Pluripotent cells and other unspecialized cells that can give rise to specialized cells are called **stem cells**.

Specialized cells, such as nerve, blood, and muscle cells, come from stem cells. As an embryo continues to develop, more and more of the cells are specialized. Soon, the organism is made up mostly of specialized cells with only a few stem cells remaining. Throughout the life of an organism, a few stem cells in the body renew and replace the body's specialized cells.

1. Examine the specialized cell shown here. It is a human nerve cell. How do you think its structure is related to its function?



2. Summarize how specialized cells arise from a fertilized egg cell.

Activity B: Gene expression

You've learned a general overview of how a stem cell can become a specialized cell, but let's look more closely at what exactly a specialized cell is. A specialized cell is only able to make certain specialized proteins and perform certain functions. Consider the nerve cell above. It contains exactly the same **genes** as a skin cell belonging to the same person. However, only the nerve cell can transmit nerve signals. And only the skin cell can produce the protein keratin, making skin cells waterproof. If nerve cells have the same genes as skin cells, why can't they also make keratin?

Nerve cells cannot make keratin because that portion of their genes was "turned off" when they became specialized. Skin cells, on the other hand, can make keratin through the process of **gene expression**. During gene expression, a certain gene is activated so that a cell can produce the protein that the gene controls. This leads to the expression of a trait.

Of course, skin cells do not produce keratin all the time. If they did, the cell would have far too much keratin, which would result in stiff, flaky skin. The body needs to be able to regulate how much keratin a skin cell can produce. The regulation of gene expression in eukaryotic cells is actually a very complex process. The main way that cells regulate gene expression is through proteins called **transcription factors**. These proteins can bind to certain areas of DNA. Some transcription factors cause a gene to be expressed when they bind to DNA. Other transcription factors prevent gene expression.

When thinking about how genes are expressed, it is important to know that the cell uses DNA to build a similar molecule, called **RNA**. RNA is used by organelles to build proteins. But scientists have recently learned that RNA has another role in gene expression. Certain specialized strands of RNA, known as microRNA, are able to block other kinds of RNA from producing proteins. In this way, microRNA can inhibit gene expression. This process is known as *RNA interference.* Thus, both microRNA and transcription factors control which genes are expressed—and which genes aren't—by any given cell.

Gene expression is regulated by factors both within the cell and from outside the cell. In some cases, cell differentiation is regulated by environmental factors. For example, the eggs of some species of crocodiles will develop as females if they are incubated at a cool enough temperature. If they are incubated at a warmer temperature, they will develop as males.

Gene expression is also regulated by signals from other cells. Many cells secrete proteins called growth factors. When these proteins attach to their target cells, they can cause temporary or permanent changes to the gene expression of that cell. If the changes are permanent the cell will become specialized.

Cells can also change based on internal changes. Many cells undergo processes that alter the structure of their chromatin in such a way that some genes become more or less accessible to transcription factors. Some of these changes can play a large role in cell differentiation.

The complex interaction between the environment, DNA, proteins, and RNA is not yet fully understood by scientists, but new discoveries are made every year.

1. How is it possible that two cells with the same DNA can specialize into completely different cells? _____

2. Is gene expression a regulated process? Explain your answer. _____

3. What is the role of DNA in cell differentiation? _____

4. What is the role of RNA in cell differentiation? _____

5. How do transcription factors influence cell differentiation? _____

6. How can the environment influence cell differentiation? _____

7. How do cells “communicate” with one another, and how does this influence cell differentiation? _____