Factors That Influence Gene Expression

What determines whether a gene gets turned on or turned off? Factors both inside and outside cells can influence whether a gene is expressed. When an organism is developing, its cells take on different structures by expressing different sets of genes. Gene expression can also be responsible for changes that occur once the organism is grown. When the environment changes, some genes may need to be turned off, while others need to be expressed more frequently.

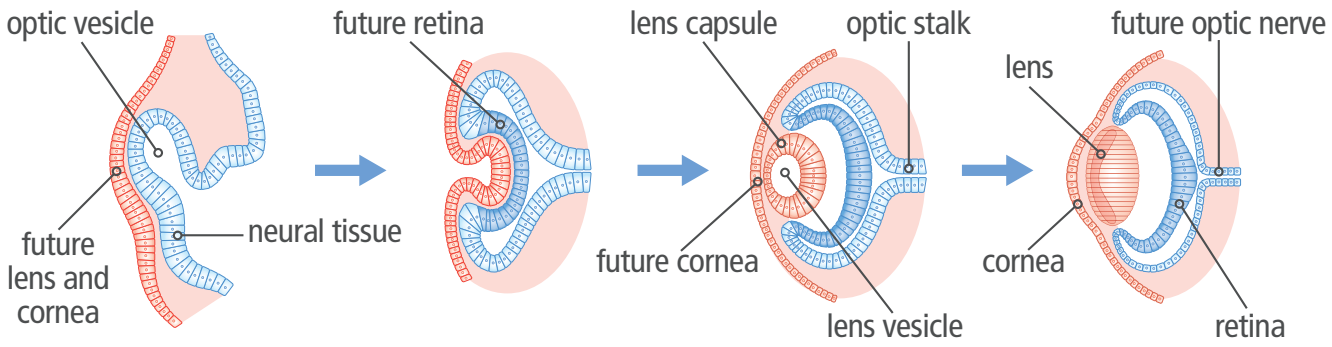
Gather Evidence As you read, gather evidence to make a claim for how gene expression is related to cell differentiation.

Internal Factors

As an organism develops, its cells take on different structures by expressing different combinations of genes. Several internal factors regulate this process. One internal factor is the genetic makeup of the zygote. Many of the instructions for differentiation are included in the zygote's genome. These genes are expressed early in embryonic development and begin differentiation. Another factor that affects cell differentiation is the unequal distribution of molecules in the cytoplasm of the zygote during early stages of division. As cells divide, some cells have higher concentrations of certain molecules. These molecules regulate gene expression and help determine what type of cell each one becomes.

Cells in a developing embryo also influence the cells around them by sending and receiving diffusible molecules that act as signals. Signals also come from molecules embedded in the cell membrane. Some of these proteins turn genes on and off to direct the developmental path of a cell. Still other molecules are enzymes that regulate gene expression by rapidly breaking down proteins made by translation.

FIGURE 9: During embryonic development, cell differentiation and growth form tissues and organs such as the eye.



Structure and Function Make a claim for how the cells in an organism can take on different structures and functions even though they all have the same genetic material.

External Factors

Factors in an organism's external environment can also affect gene expression. For example, a transcription factor called hypoxia-inducible factor, or HIF, is produced when oxygen concentrations are low. This transcription factor mediates important developmental processes such as apoptosis and blood vessel development. In tissues experiencing low oxygen concentrations, or hypoxia, HIF allows for the transcription of genes related to blood vessel development.

Light and Temperature

Environmental factors such as light and temperature can affect gene expression. For example, an Arctic fox's fur color changes from white during the winter to gray-brown in the summer months to better match its surroundings. This change in fur color is due to differences in melatonin secretion. In the winter, when day length is shorter, melatonin is secreted, so the pigment melanin is not produced and the fox's fur color is white. In the summer season, when daylight hours are longer, melatonin secretion is repressed, melanin is produced, and the fox's fur is gray-brown in color.

Model Draw a flow chart to illustrate how changes in the external environment lead to changes in gene expression that affect the Arctic fox's fur color.

FIGURE 10: The Arctic fox expresses different colors of fur depending on the season.

Environmental temperature can also influence gene expression. Trees and other plants have mechanisms to adapt to changes in temperature, most of which function through the control of gene expression. In extreme heat conditions, which can cause stress in plants, multiple genes interact to reduce the rate of photosynthesis and stop plant growth. By studying the relationship between gene expression and photosynthesis, geneticists can work to improve the stability of crop plants during extreme weather conditions.

Drugs and Chemicals

Pregnant women are strongly advised to avoid a variety of drugs and chemicals, including tobacco, alcohol, and many medications. These substances can disrupt the normal timing of gene expression in a developing fetus. For example, a drug called thalidomide was sometimes prescribed to treat morning sickness in the late 1950s and early 1960s. However, doctors discovered that it interfered with limb formation in the developing embryos. Children born to mothers who took this drug were often born with shortened and improperly formed limbs.

Analyze Why is a developing fetus especially susceptible to chemicals that affect gene expression?

Explain Researchers have found that cancerous tumor tissue is often hypoxic, or deficient in oxygen. As a result, HIF is currently being considered as a possible tool in the fight against cancer. Explain how HIF-related approaches could be used to suppress tumor growth, and how this is related to regulating gene expression.