







Gene expression 4: Regulating gene expression

Components

	NAME	DESCRIPTION	AUDIENCE
	<i>Regulating gene expression</i> teacher guide	This guide includes questions to promote class discussion after watching a video about gene regulation.	teachers
	<i>Gene regulation</i> animation	This animation shows how gene expression is controlled by a series of molecular interactions during transcription and translation. Control factors include proteins, RNA, regulating genes and protein complexes.	students
	<i>How is gene expression regulated?</i> background sheet	This background sheet provides detailed information on molecules that regulate gene expression.	teachers
	<i>RNA and gene regulation</i> fact sheet	This fact sheet introduces students to coding and non-coding RNA, and the role of RNA in gene expression and regulation.	students
	<i>Gene expression and regulation</i> worksheet	This student worksheet contains review questions based on information presented in the animation.	students
	<i>Gene glossary</i> fact sheet	This glossary defines terms used in gene expression and regulation.	students

Purpose

To **Explain** how gene expression is regulated by complex molecular interactions, and that these processes are important in increasing organism adaptability, flexibility and complexity.

Outcomes

Students:

- understand gene expression is controlled by a complex series of molecular interactions collectively known as gene regulation;
- are introduced to key molecular components of the gene expression regulatory system including: promoter, enhancer, transcription factors, spliceosome and elongation factors;
- recognise gene expression occurs in response to changes in the internal and external environment of a cell;
- understand gene regulation results in cell diversity and differentiation;
- recognise gene regulation is energy efficient and results in increased organism complexity;
- appreciate that coding and non-coding RNA molecules, such as mRNA (messenger RNA) and miRNA (micro RNA), play an important role in gene expression and regulation; and
- understand mutations may disrupt regulation of gene expression.

Activity summary

ACTIVITY	POSSIBLE STRATEGY
Show animation, <i>Gene regulation</i> , and discuss with the class using questions and discussion topics below.	whole class
Students read the fact sheet, <i>RNA and gene regulation</i> .	individually
Students complete worksheet, <i>Gene expression and regulation</i> .	individually

Teacher notes

Gene regulation is a complex process involving many molecular interactions. It has been considerably simplified for the purpose of this resource. The animation and accompanying fact sheet draw attention to only a few of the molecules that play significant roles in control of gene expression. Students should be made aware there are many more facets to these processes.

Discussion questions and points to be raised after viewing the animation may include:

QUESTIONS AND DISCUSSION TOPICS	SUGGESTED RESPONSE
Name some examples of gene expression.	Typical answers may include production of insulin, other hormones or any protein.
Why is gene expression regulated?	<p>Not every gene is expressed (turned on) in every cell, as this is energetically inefficient. Cells only require products of particular genes at certain times.</p> <p>Gene regulation allows cells to produce specific gene products (usually proteins) as needed by a cell. This is determined by monitoring of signals from the internal and external environment.</p>
Do mutations impact gene expression and regulation?	<p>Gene regulation is a complex process and there are many opportunities for things to go wrong. Cell repair mechanisms are present in all cells but sometimes mistakes are not corrected.</p> <p>Mutations can play a significant role in the breakdown of gene expression and regulation. They may occur in both coding and non-coding DNA sequences.</p>
How do mutations in coding DNA cause melanoma?	<p>Mutations in coding DNA may result in changes to gene expression and hence a gene product (protein).</p> <p>Multiple mutations are associated with melanoma. Mutation of the BRAF gene is an example. This gene produces the BRAF protein, part of the MAP kinase/ERK signalling pathway.</p> <p>Under normal circumstances BRAF protein transfers signals from outside a cell to its nucleus. Scientists have discovered that over 50% of melanomas have a mutated BRAF gene: the most common mutation type being a single base mutation from thymine to adenine.</p> <p>The mutated BRAF gene results in production of a mutant BRAF protein. This mutated protein is continuously active, triggering the cell-signalling cascade and pushing cell growth into overdrive.</p>
What are effects of non-coding DNA mutations?	<p>Mutation of non-coding DNA may disrupt gene regulation and result in changes to gene expression. Mutations may occur in regulatory DNA sequences, such as the promoter, or molecular regulators, such as transcription factors - these changes will impact gene regulation.</p> <p>Gene regulation often relies on molecular recognition of specific nucleotide sequences, or motifs. If these are altered through mutation then appropriate regulating molecules are unable to bind to the correct site and control can breakdown.</p> <p>Mutational changes often result in altered gene expression and may impact on individual health outcomes.</p>

QUESTIONS AND DISCUSSION TOPICS	SUGGESTED RESPONSE
Can regulating DNA sequences, such as the promoter, become mutated?	<p>Mutations may occur within promoter regions of genes, which may result in altered gene expression and regulation.</p> <p>For example, a mutated promoter may cause transcription factors to no longer recognise the correct binding site, or the binding site may be absent or in a different location.</p> <p>If a transcription factor cannot bind to the appropriate site then transcription may be disrupted or silenced.</p>
Can regulating proteins, such as transcription factors, become mutated?	<p>Mutations may occur in regulating proteins, including transcription factors.</p> <p>If a mistake is made during transcription or translation the resulting protein product will contain an error. A mutated protein may not be able to carry out its cellular function. If the protein has a regulating role then cell processes may begin to breakdown.</p> <p>Mutations in transcription factors are associated with human disease, including cancer.</p>
What happens to a cell if regulation breaks down due to cell damage or mutation?	When cell regulation breaks down a cell may stall in one of its lifecycle stages. For example, an unregulated cell may undergo uncontrolled growth or enter the apoptosis phase of its life cycle.
What research is necessary to fully understand complexities of gene expression and regulation?	Ongoing research into the role of non-coding DNA and regulating molecules, such as microRNA, is needed to understand the complexity of gene regulation within cells.
How might our understanding of gene regulation help in the fight against cancer?	<p>Understanding mechanisms of gene regulation may lead to new treatments for human diseases, such as cancer.</p> <p>Cancer is a genetic disease, characterised by uncontrolled cell growth. Many genes are differentially expressed in cancer cells and play a role in disease progression. Understanding the cellular function of these genes may lead to discovery of new molecular therapies that could improve treatment outcomes.</p> <p>For instance, microRNAs are able to silence gene expression by halting translation. By developing therapeutic microRNAs it may be possible to halt the progress of some types of cancer.</p>

Technical requirements

The teacher guide, background sheet, fact sheet and worksheet require Adobe Reader (version 5 or later), which is a free download from www.adobe.com. The worksheet is also available in Microsoft Word format.

A modern browser is required to view the animation. This is a free download from www.apple.com/quicktime. A high quality MP4 version is available on CD-ROM or download from the SPICE website. The video contains closed captions.

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Associated SPICE resources

Gene expression 4: Regulating gene expression may be used in conjunction with related SPICE resources to address the broader topic of gene expression and regulation.

DESCRIPTION	LEARNING PURPOSE
<p><i>Gene expression (overview)</i></p> <p>This learning pathway shows how a number of SPICE resources can be combined to teach the topic: gene expression and regulation.</p> <p>All resources use a human disease context, melanoma, which helps students relate to advances in biotechnology and our understanding of molecular genetics.</p>	
<p><i>Gene expression 1: Melanoma risk factors</i></p> <p>Students use an interactive learning object to investigate risk factors associated with melanoma developing.</p>	Engage
<p><i>Gene expression 2: Polymerase chain reaction</i></p> <p>Students simulate polymerase chain reaction in the classroom.</p>	Explore
<p><i>BioDiscovery activity (optional)</i></p> <p>Students attend the LotteryWest Biodiscovery Centre at the Harry Perkins Institute of Medical Research to participate in a SPICE-developed PCR laboratory activity. See <i>Gene expression (overview)</i> for details.</p>	Explore
<p><i>Gene expression 3: Measuring gene expression</i></p> <p>Students measure gene expression via a microarray simulation conducted in the school laboratory.</p>	Explore
<p><i>Gene expression 4: Regulating gene expression</i></p> <p>An animation explains how gene expression is regulated by complex molecular interactions. These processes are important in increasing organism adaptability, flexibility and complexity.</p>	Explain
<p><i>Gene expression 5: Personalised medicine</i></p> <p>Students explore an interactive story to discover how increased understanding of molecular biology and advances in biotechnology have led to development of personalised medical treatments for melanoma patients.</p>	Elaborate