

Section 7.4: Controlling Gene Expression

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1. (a) An operon is a cluster of genes that codes for the proteins involved in one cellular process. For example, the *lac* operon codes for the proteins that are involved in the metabolism of lactose. An operon consists of an operator, a promoter, and the coding region.
(b) An operator is the region of an operon that binds regulatory factors and controls transcription.
(c) A corepressor is a molecule that binds to a repressor protein to reduce the expression of an operon's genes.
(d) A repressor is a factor that binds to the operator to repress gene transcription.
(e) Housekeeping genes are genes that are continuously transcribed and translate proteins that regulate metabolism growth and DNA replication and transcription.
(f) An inducer is a signal molecule that triggers the expression of an operon's gene.
2. Eukaryotes have a more complex system of gene regulation than prokaryotes because eukaryotic gene expression requires more steps. Each level of gene expression—transcription, post-transcription, translation, and post-translation—has its own regulation. For example, transcription is regulated by modifications to histone proteins that remodel wrapped DNA, making it accessible.
3. The *lac* operon and *trp* operon both use repressor proteins, which are coded upstream of the operon, to regulate operators, which control gene expression. The *lac* operon uses lactose as an inducer, which inactivates the repressor protein, enhancing gene transcription. The *trp* operon uses tryptophan as a corepressor, which activates the repressor protein inhibiting gene expression.
4. Answers may vary. Sample answer: The *lac* operon regulates the production of the enzymes needed to metabolize lactose in the following ways:
 - In the absence of lactose, the upstream *lacI* gene synthesizes the *lac* repressor protein, which binds to the *lac* operator to stop RNA polymerase from binding and stop the transcription of the *lacZ*, *lacY*, and *lacA* genes that code for the proteins involved in lactose metabolism.
 - When lactose is made available to the cell, some of it binds to the *lac* repressor protein, inactivating it so that it cannot bind to the operator.
 - This allows RNA polymerase to bind to the promoter, and allows the transcription of the downstream *lacZ*, *lacY*, and *lacA* genes.
 - Translation of the mRNA produces the three lactose-metabolizing enzymes.
 - If lactose is removed from the cell's environment, the repressor will become active and will bind to the operator, preventing further transcription of the lactose metabolizing genes.
5. The *trp* repressor protein is continuously coded upstream of the *trp* operon by the *trpR* gene. When the level of tryptophan is low, the *trp* repressor protein is inactive and does not bind to the operator. This allows RNA polymerase to bind to the promoter and transcribe the *trpE*, *trpD*, *trpC*, *trpB*, and *trpA* genes that code for enzymes involved in tryptophan production. If tryptophan is made available to the bacteria, it will bind to the *trp* repressor and cause a conformational change that activates the repressor, allowing it to bind to the operator and block RNA polymerase from binding to the promoter. The result would be a reduction in the transcription of the *trpE*, *trpD*, *trpC*, *trpB*, and *trpA* genes.

6. (a) Answers may vary. Sample answer: A regulatory mechanism that occurs during eukaryotic transcription is methylation of cytosine bases in the promoter region; this silences the gene and prevents transcription.

(b) Answers may vary. Sample answer: A regulatory mechanism that occurs during eukaryotic translation is the addition of a variable-length adenine tail.

(c) Answers may vary. Sample answer: A regulatory mechanism that occurs after eukaryotic translation is the chemical modification of some of the residues on the protein to render it active.

7. Answers may vary. Sample answer: Eukaryotic transcription is generally controlled by the binding of regulatory proteins to DNA sequences, rather than by the modification of RNA polymerases because eukaryotes possess many genes in their DNA that need to be silenced most of the time. It is more efficient to regulate the packing structure of the DNA than it is to modify RNA polymerases.

8. The agouti mouse phenotype is caused by the demethylation of the agouti gene, which was previously silenced by methylation. Exposure to bisphenol A causes demethylation of genes and could result in an agouti phenotype mouse.

9. Cells can become cancerous if they lose control of proper gene regulation, for example, the loss of regulation of telomerase genes can lead to the constant lengthening of telomeres in cancer cells. As an organism ages the number of mutations in its genome increases, as does the level of deregulation. These mutations are passed on to daughter cells. If a cell deviates from normal cell division, it can produce a mass of undifferentiated cells called a tumor. If the mass grows uncontrollably, invades surrounding tissue, and begins to affect the functions of the organism, it is called a malignant tumor or cancer.