Regulation of Gene Expression
Chapter 18

1. Bacteria often live in erratic environments. Propose a selective advantage for bacteria that are able to regulate gene expression. (Cells that can express only genes that are necessary in a given environment have an advantage over those that cannot. They conserve the resources that would be used expressing genes that are not useful in a given environment.)

2. a) Explain how the trp operon allows the production of the enzymes required to synthesize tryptophan only in the absence of tryptophan.
b) Predict what would happen to the trp operon as a cell uses up its store of tryptophan. (As the concentration of tryptophan in the cell decreases, eventually there will be none bound to trp repressor molecules. These will then change into their inactive shapes and dissociate from the operator, allowing transcription of the operon to resume. The enzymes for tryptophan synthesis will be made, and they will again synthesize tryptophan in the cell.)

3. Describe how the binding of the *trp* corepressor to the *trp* repressor alters repressor function and transcription. Describe how binding of the *lac* inducer to the *lac* repressor alters transcription. (Binding by the trp corepressor (tryptophan) activates the trp repressor, which binds to the trp operator, shutting off transcription of the trp operon. Binding by the lac inducer (allolactose) inactivates the lac repressor, so that it can no longer bind to the lac operator, leading to transcription of the lac operon.)

4. Describe the difference between a repressible and an inducible operon. (The transcription of a repressible operon is usually on but can be inhibited (repressed) when a specific small molecule binds to a regulatory protein. An inducible operon is usually off but can be stimulated (induced) to be on when a specific small molecule interacts with a different regulatory protein.)

5. Bacterial cells are grown in the absence of lactose and then lactose is added to the culture medium. Describe the change you would expect to see in the lac operon.

6. When *E. coli* cells are grown in the presence of lactose and glucose, they preferentially use glucose, not lactose. Explain how the cells are able to avoid using lactose even though it is present in the culture medium. (When glucose is scarce, cAMP is bound to CAP and CAP is bound to the lac promoter, favoring the binding of RNA polymerase. In the absence of lactose, the lac repressor is bound to the lac operator, blocking RNA polymerase binding to the lac promoter and preventing transcription.)

7. A certain mutation in *E. coli* changes the lac operator so that the active repressor cannot bind. Describe how this would affect the cell's production of β-galactosidase. Predict whether this mutation would be adaptive or not. (The cell would continuously produce β-galactosidase and the two other enzymes for using lactose, even in the absence of lactose, thus wasting cell resources.)

8. All cells of an organism have the same genes, yet cells are able to be differentiated. Explain how this possible. (A subset of genes is expressed in each cell type, and these uniquely expressed genes allow these cells to carry out their specific function. The differences between cell types are due not to different genes being present, but to the expression of different genes by cells with the same genome.)

9. a) Describe the effect of histone acetylation on gene expression. (In general, the acetylation of

histone tails loosens the packing of DNA, allowing transcription.)
b) Describe the effect of methylation of bases on gene expression. (In general, methylation of bases reduces transcription.)

10. Most eukaryotic genes have segments of noncoding DNA associated with them that serve as binding sites for proteins called transcription factors. Describe the function of these so-called control elements. (Transcription factors bind to the control elements and regulate transcription.)

11. Both liver cells and lens cells have the genes for making the proteins albumin and crystallin, but only liver cells make albumin (a blood protein) and only lens cells make crystallin (the main protein of the lens of the eye). (The specific transcription factors made in a cell determine which genes are expressed. All the activator proteins required for high-level expression of the albumin gene are present in liver cells only, whereas the activators needed for expression of the crystallin gene are present in lens cells only.)

12. Use the concept of control elements to propose a mechanism by which several, related genes in a given cell could be activated by a single signal. (Coordinate gene expression depends on every gene of a dispersed group having a specific combination of control elements. Activator proteins in the nucleus that recognize the control elements bind to them, promoting simultaneous transcription of the genes, no matter where they are in the genome.)

13. Suppose you compared the nucleotide sequences of the distal control elements in the enhancers of three genes that are expressed only in muscle cells. Make a claim about the sequences. Support your claim. (The three genes should have some similar or identical sequences in the control elements of their enhancers. Because of this similarity, the same specific transcription factors in muscle cells could bind to the enhancers of all three genes and stimulate their expression coordinately.)

14. Regulation of translation initiation, degradation of the mRNA, activation of the protein (by chemical modification, for example), and protein degradation are four mechanisms to regulate the amount of a protein in a cell once the mRNA encoding that protein reaches the cytosol. Describe each mechanism.

15. Describe the mechanism by which am miRNA can prevent the expression of a particular gene. (A longer RNA precursor is processed by cellular enzymes into an miRNA, a single-stranded RNA of about 22 nucleotides that forms a complex with one or more proteins. The miRNA allows the complex to bind to any mRNA molecule with at least 7 or 8 nucleotides of complementary sequence. The miRNA-protein complex then degrades the target mRNA or, less often, simply blocks its translation.)

16. Imagine a particular mRNA coded for a protein that promotes cell division in a multicellular organism. Predict the effect of a mutation that disabled the gene for the miRNA that normally triggers the degradation of the mRNA. (The mRNA would persist and be translated into the cell division–promoting protein, and the cell would probably divide. If the intact miRNA is necessary for inhibition of cell division, then division of this cell might be inappropriate. Uncontrolled cell division could lead to formation of a mass of cells (tumor) that prevents proper functioning of the organism and could contribute to the development of cancer.)

17. Mitosis produces two daughter cells that are genetically identical to the parent cell. Adult organisms, the product of many mitotic divisions, are not composed of identical cells. Explain how this is possible. (Cells undergo differentiation during embryonic development, becoming different from

one another. This happens because of proteins in the cell which turn on or off specific genes.)

18. a) Describe the role of cytoplasmic determinants in the development of an early embryo. (Messenger RNA, proteins, other substances, and organelles are distributed unevenly in the unfertilized egg. After fertilization, early mitotic divisions distribute the zygote's cytoplasm into separate cells. The nuclei of these cells may thus be exposed to different cytoplasmic determinants, depending on which portions of the zygotic cytoplasm a cell received. The combination of cytoplasmic determinants in a cell helps determine its developmental fate by regulating expression of the cell's genes during the course of cell differentiation.)
    b) Describe the role of induction in early embryonic development. (Signal molecules received by a cell from neighboring cells affect gene expression, contributing to differentiation.)

19. Explain how the signaling molecules released by an embryonic cell can induce changes in a neighboring cell without entering the cell. (By binding to a receptor on the receiving cell's surface and triggering a signal transduction pathway, involving intracellular molecules such as second messengers and transcription factors that affect gene expression)

20. Predict the effect on differentiation of a cell in which a mutation in the myoD gene resulted in the production of an altered MyoD protein that could not activate the myoD gene. (The mutant MyoD protein might still be able to it could still turn on genes for the other proteins in the pathway (other transcription factors, which would turn on the genes for muscle-specific proteins, for example). Therefore, some differentiation would occur. Without the MyoD protein's activation of the myoD gene, the cell would not be able to maintain its differentiated state.)