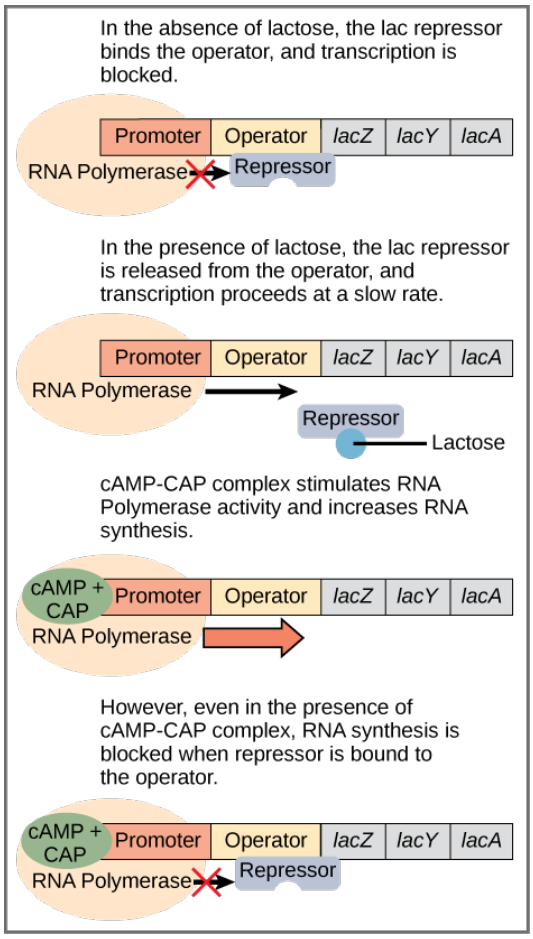
Biology 2e
Unit 3: Genetics
Chapter 16: Gene Expression

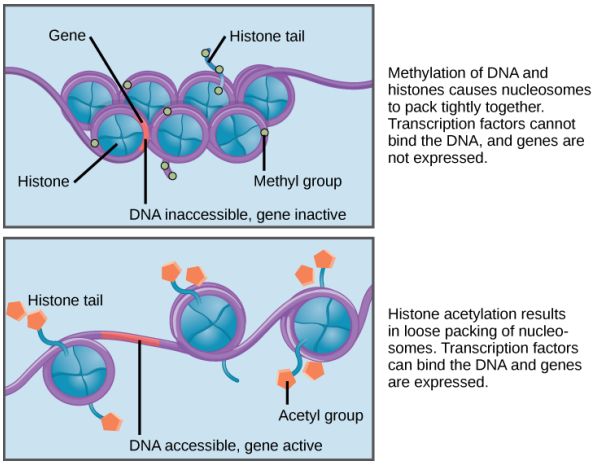
Visual Connection Questions

1. In *E. coli*, the *trp* operon is on by default, while the *lac* operon is off. Why do you think that this is the case?



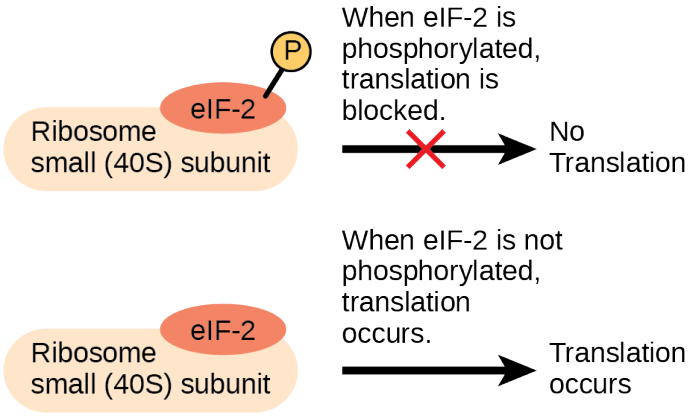
Tryptophan is an amino acid essential for making proteins, so the cell always needs to have some on hand. However, if plenty of tryptophan is present, it is wasteful to make more, and the expression of the *trp* receptor is repressed. Lactose, a sugar found in milk, is not always available. It makes no sense to make the enzymes necessary to digest an energy source that is not available, so the *lac* operon is only turned on when lactose is present.

2. In females, one of the two X chromosomes is inactivated during embryonic development because of epigenetic changes to the chromatin. What impact do you think these changes would have on nucleosome packing?



The nucleosomes would pack more tightly together.

3. An increase in phosphorylation levels of eIF-2 has been observed in patients with neurodegenerative diseases such as Alzheimer's, Parkinson's, and Huntington's. What impact do you think this might have on protein synthesis?



Protein synthesis would be inhibited.

Review Questions

4. Control of gene expression in eukaryotic cells occurs at which level(s)?

d. epigenetic, transcriptional, posttranscriptional, translational, and posttranslational levels

5. Post-translational control refers to:

b. regulation of gene expression after translation

6. How does the regulation of gene expression support continued evolution of more complex organisms?
d. Both A and B.

7. If glucose is absent, but so is lactose, the *lac* operon will be _____.
b. repressed

8. Prokaryotic cells lack a nucleus. Therefore, the genes in prokaryotic cells are:
d. b and c are both true (transcribed and translated almost simultaneously and transcriptionally controlled because translation begins before transcription ends)

9. The *ara* operon is an inducible operon that controls the breakdown of the sugar arabinose. When arabinose is present in a bacterium it binds to the protein AraC, and the complex binds to the initiator site to promote transcription. In this scenario, AraC is a(n) _____.
a. Activator

10. What are epigenetic modifications?
a. the addition of reversible changes to histone proteins and DNA

11. Which of the following are true of epigenetic changes?
d. all of the above (allow DNA to be transcribed, move histones to open or close a chromosomal region, are temporary)

12. The binding of _____ is required for transcription to start.
c. RNA polymerase

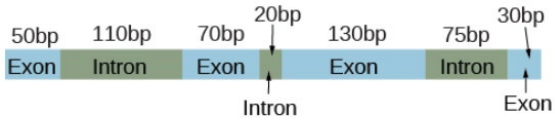
13. What will result from the binding of a transcription factor to an enhancer region?
b. increased transcription of a distant gene

14. A scientist compares the promoter regions of two genes. Gene A's core promoter plus proximal promoter elements encompasses 70bp. Gene B's core promoter plus proximal promoter elements encompasses 250bp. Which of the scientist's hypotheses is most likely to be correct?
b. Transcription of Gene A involves fewer transcription factors.

15. Which of the following are involved in post-transcriptional control?
d. all of the above (control of RNA splicing, control of RNA shuttling, control of RNA stability)

16. Binding of an RNA binding protein will _____ the stability of the RNA molecule.
d. either increase or decrease

17. An unprocessed pre-mRNA has the following structure.



Which of the following is not a possible size (in bp) of the mature mRNA?

a. 205bp

18. Alternative splicing has been estimated to occur in more than 95% of multi-exon genes. Which of the following is not an evolutionary advantage of alternative splicing?

c. Alternative splicing creates shorter mRNA transcripts.

19. Post-translational modifications of proteins can affect which of the following?

a. protein function

20. A scientist mutates eIF-2 to eliminate its GTP hydrolysis capability. How would this mutated form of eIF-2 alter translation?

b. The large ribosomal subunit would not be able to interact with mRNA transcripts.

21. Cancer causing genes are called _____.

c. oncogenes

22. Targeted therapies are used in patients with a set gene expression pattern. A targeted therapy that prevents the activation of the estrogen receptor in breast cancer would be beneficial to which type of patient?

c. patients with lots of the estrogen receptor expressed in their tumor

Critical Thinking Questions

23. Name two differences between prokaryotic and eukaryotic cells and how these differences benefit multicellular organisms.

Eukaryotic cells have a nucleus, whereas prokaryotic cells do not. In eukaryotic cells, DNA is confined within the nuclear region. Because of this, transcription and translation are physically separated. This creates a more complex mechanism for the control of gene expression that benefits multicellular organisms because it compartmentalizes gene regulation. Gene expression occurs at many stages in eukaryotic cells, whereas in prokaryotic cells, control of gene expression only occurs at the transcriptional level. This allows for greater control of gene expression in eukaryotes and more complex systems to be developed. Because of this, different cell types can arise in an individual organism.

24. Describe how controlling gene expression will alter the overall protein levels in the cell.

The cell controls which proteins are expressed and to what level each protein is expressed in the cell. Prokaryotic cells alter the transcription rate to turn genes on or off. This method will increase or decrease protein levels in response to what is needed by the cell. Eukaryotic cells change the accessibility (epigenetic), transcription, or translation of a gene. This will alter the amount of RNA and the lifespan of the RNA to alter the amount of protein that exists.

Eukaryotic cells also control protein translation to increase or decrease the overall levels. Eukaryotic organisms are much more complex and can manipulate protein levels by changing many stages in the process.

25. Describe how transcription in prokaryotic cells can be altered by external stimulation such as excess lactose in the environment.

Environmental stimuli can increase or induce transcription in prokaryotic cells. In this example, lactose in the environment will induce the transcription of the *lac* operon, but only if glucose is not available in the environment.

26. What is the difference between a repressible and an inducible operon?

A repressible operon uses a protein bound to the promoter region of a gene to keep the gene repressed or silent. This repressor must be actively removed in order to transcribe the gene. An inducible operon is either activated or repressed depending on the needs of the cell and what is available in the local environment.

27. In cancer cells, alteration to epigenetic modifications turns off genes that are normally expressed. Hypothetically, how could you reverse this process to turn these genes back on?

You can create medications that reverse the epigenetic processes (to add histone acetylation marks or to remove DNA methylation) and create an open chromosomal configuration.

28. A scientific study demonstrated that rat mothering behavior impacts the stress response in their pups. Rats that were born and grew up with attentive mothers showed low activation of stress-response genes later in life, while rats with inattentive mothers had high activation of stress-response genes in the same situation. An additional study that swapped the pups at birth (i.e., rats born to inattentive mothers grew up with attentive mothers and vice versa) showed the same positive effect of attentive mothering. How do genetics and/or epigenetics explain the results of this study?

Swapping the pups at birth indicates that the genes inherited from the attentive or inattentive mothers do not explain the rats' stress-responses later in life. Instead, researchers found that the attentive mothering caused the methylation of genes that control the expression of stress receptors in the brain. Thus, rats that received attentive maternal care exhibited epigenetic changes that limited the expression of stress-response genes, and that the effect was durable over their lifespans.

29. Some autoimmune diseases show a positive correlation with dramatically decreased expression of histone deacetylase 9 (HDAC9, an enzyme that removes acetyl groups from histones). Why would the decreased expression of HDAC9 cause immune cells to produce inflammatory genes at inappropriate times?

Histone acetylation reduces the positive charge of histone proteins, loosening the DNA wrapped around the histones. This looser DNA can then interact with transcription factors to express genes found in that region. Normally, once the gene is no longer needed, histone deacetylase enzymes remove the acetyl groups from histones so that the DNA becomes tightly wound and inaccessible again. However, when there is a defect in HDAC9, the deacetylation

may not occur. In an immune cell, this would mean that inflammatory genes that were made accessible during an infection are not tightly rewound around the histones.

30. A mutation within the promoter region can alter transcription of a gene. Describe how this can happen.

A mutation in the promoter region can change the binding site for a transcription factor that normally binds to increase transcription. The mutation could either decrease the ability of the transcription factor to bind, thereby decreasing transcription, or it can increase the ability of the transcription factor to bind, thus increasing transcription.

31. What could happen if a cell had too much of an activating transcription factor present?

If too much of an activating transcription factor were present, then transcription would be increased in the cell. This could lead to dramatic alterations in cell function.

32. A scientist identifies a potential transcription regulation site 300bp downstream of a gene and hypothesizes that it is a repressor. What experiment (with results) could he perform to support this hypothesis?

The easiest way to test his hypothesis would be to mutate the site in a cell, and monitor levels of the mRNA transcript made from the gene. If the levels of transcript increase in the mutated cell, then the site was repressing transcription.

33. Describe how RBPs can prevent miRNAs from degrading an RNA molecule.

RNA binding proteins (RBP) bind to the RNA and can either increase or decrease the stability of the RNA. If they increase the stability of the RNA molecule, the RNA will remain intact in the cell for a longer period of time than normal. Since both RBPs and miRNAs bind to the RNA molecule, RBP can potentially bind first to the RNA and prevent the binding of the miRNA that will degrade it.

34. How can external stimuli alter posttranscriptional control of gene expression?

External stimuli can modify RNA-binding proteins (i.e., through phosphorylation of proteins) to alter their activity.

35. Protein modification can alter gene expression in many ways. Describe how phosphorylation of proteins can alter gene expression.

Because proteins are involved in every stage of gene regulation, phosphorylation of a protein (depending on the protein that is modified) can alter accessibility to the chromosome, can alter translation (by altering the transcription factor binding or function), can change nuclear shuttling (by influencing modifications to the nuclear pore complex), can alter RNA stability (by binding or not binding to the RNA to regulate its stability), can modify translation (increase or decrease), or can change post-translational modifications (add or remove phosphates or other chemical modifications).

36. Alternative forms of a protein can be beneficial or harmful to a cell. What do you think would happen if too much of an alternative protein bound to the 3' UTR of an RNA and caused it to degrade?

If the RNA degraded, then less of the protein that the RNA encodes would be translated. This could have dramatic implications for the cell.

37. Changes in epigenetic modifications alter the accessibility and transcription of DNA. Describe how environmental stimuli, such as ultraviolet light exposure, could modify gene expression.

Environmental stimuli, like ultraviolet light exposure, can alter the modifications to the histone proteins or DNA. Such stimuli may change an actively transcribed gene into a silenced gene by removing acetyl groups from histone proteins or by adding methyl groups to DNA.

38. A scientist discovers a virus encoding a Protein X that degrades a subunit of the eIF4F complex. Knowing that this virus transcribes its own mRNAs in the cytoplasm of human cells, why would Protein X be an effective virulence factor?

Degrading the eIF4F complex prevents the pre-initiation complex (eIF-2-GTP, $tRNA_i$-Met, and 40S ribosomal subunit) from being recruited to the 5’ cap of mature mRNAs in the cell. This allows the virus to hijack the translation machinery of the human cell to translate its own (uncapped) mRNA transcripts instead.

39. New drugs are being developed that decrease DNA methylation and prevent the removal of acetyl groups from histone proteins. Explain how these drugs could affect gene expression to help kill tumor cells.

These drugs will keep the histone proteins and the DNA methylation patterns in the open chromosomal configuration so that transcription is feasible. If a gene is silenced, these drugs could reverse the epigenetic configuration to re-express the gene.

40. How can understanding the gene expression pattern in a cancer cell tell you something about that specific form of cancer?

Understanding which genes are expressed in a cancer cell can help diagnose the specific form of cancer. It can also help identify treatment options for that patient. For example, if a breast cancer tumor expresses the EGFR in high numbers, it might respond to specific anti-EGFR therapy. If that receptor is not expressed, it would not respond to that therapy.