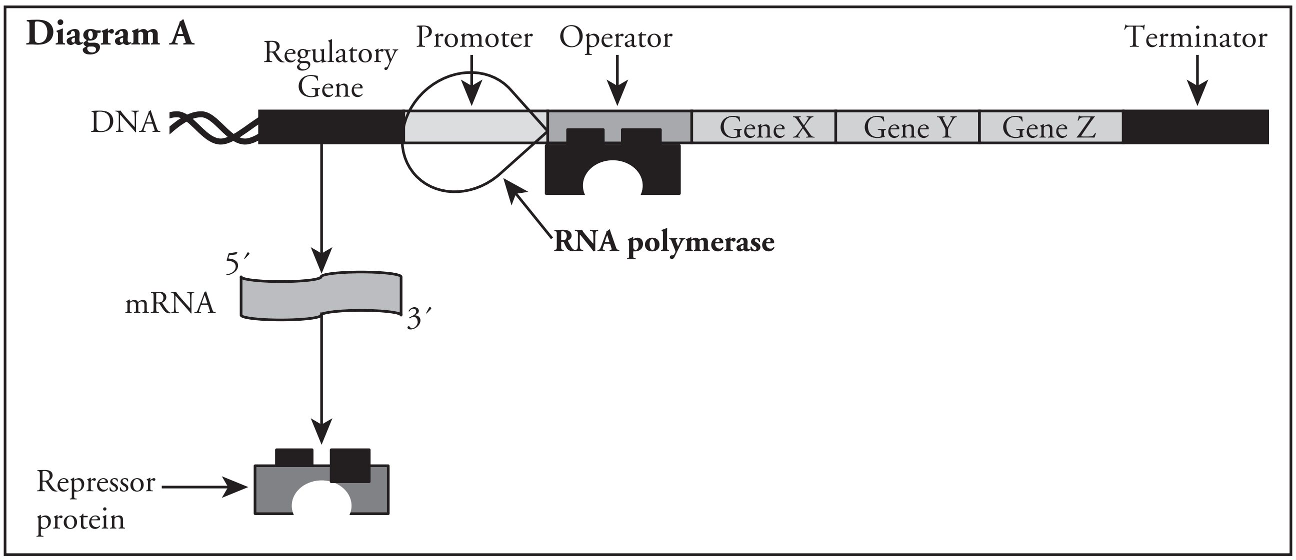
Control of Gene Expression in Prokaryotes

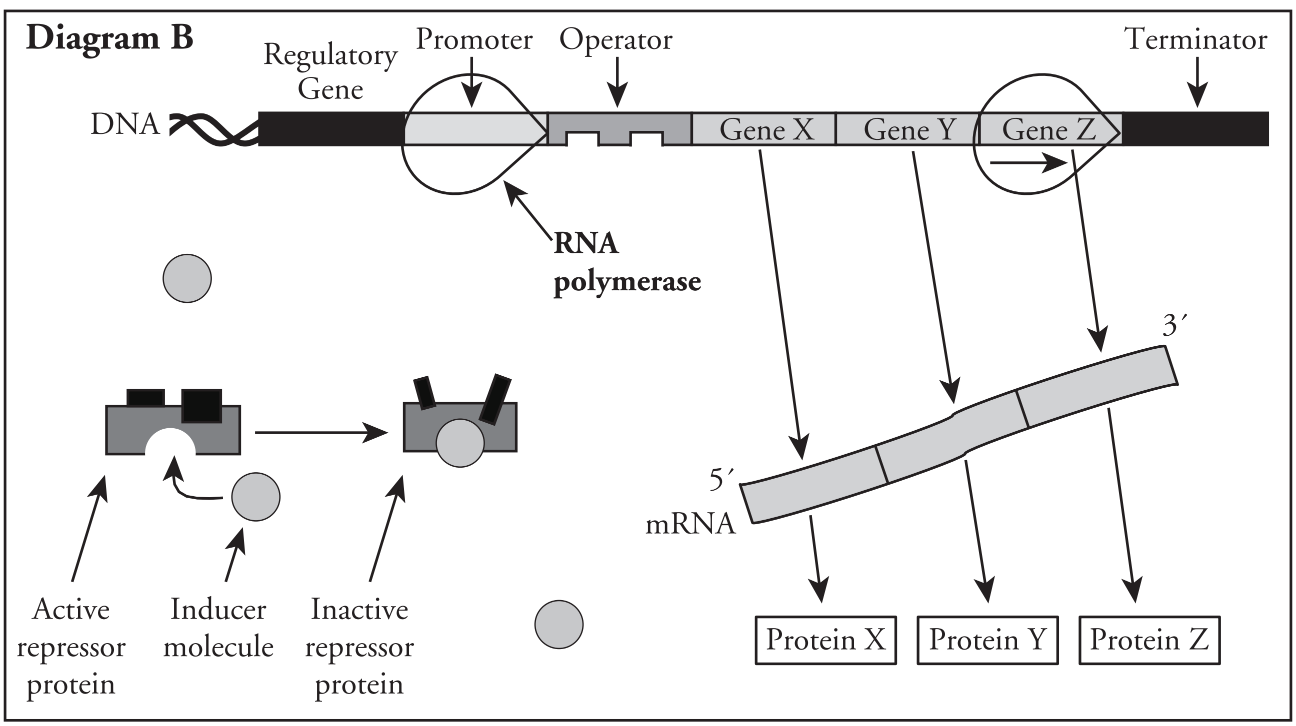
How do prokaryotes use operons to control gene expression?

Why?

Houses usually have a light source in every room, but it would be a waste of energy to leave every light on all the time, so there are switches to turn off the lights in rooms that are not in use. Sometimes one switch controls several lights in the same room. Likewise, prokaryotic cells can turn genes on and off based on environmental factors. Sometimes related genes are grouped together with one switch. This group of genes, along with the sections of DNA that regulate them, is called an **operon**.

Model 1 – An Inducible Operon





1. What type of operon is illustrated in Model 1?

2. Consider the operon in Model 1. Other than the gene that regulates the operon, how many genes are contained within the operon?

3. In Model 1, where on the DNA strand does RNA polymerase bind to start transcription, the promoter, the operator or the terminator?

4. Which direction is the RNA polymerase moving in Model 1?

5. In which diagram of Model 1 is transcription and translation occurring successfully, diagram A or diagram B? Justify your answer with evidence from Model 1.

6. Consider the nonscience meaning of the following terms. Match the purpose with each of these sections in the operon in terms of gene transcription.

Promoter	Spot where transcription ends
Operator	Spot where transcription begins
Terminator	On/Off switch

7. Refer to diagram A in Model 1.

   a. What protein does the regulatory gene in Model 1 produce?

   b. To what section of the operon does this protein bind?

   c. Propose an explanation for why transcription is not occurring in diagram A.

8. Refer to Diagram B in Model 1.

   a. When an **inducer molecule** attaches to the repressor protein, what happens to the repressor protein?

   b. How does the change identified in part *a* allow transcription of the genes in the operon to occur?

Read This!

The *lac* operon in *E. coli* is an example of an inducible operon. It codes for several genes that are necessary to metabolize lactose when it is present in the cell's environment. Allolactose, a naturally occurring isomer of lactose, acts as the inducer. When lactose is present in large quantities (and some allolactose is present), the *lac* operon is switched "on" and several proteins are produced that help move lactose into the cell and break the lactose into its monomers, glucose and galactose.

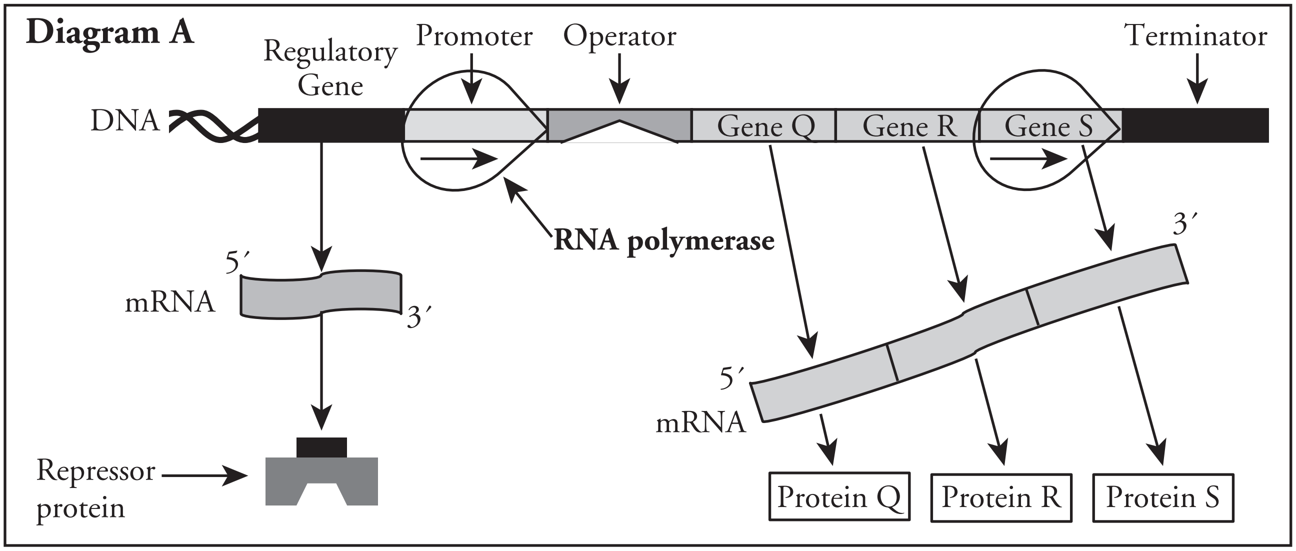
9. Explain what would happen within the *lac* operon in each of the following scenarios:

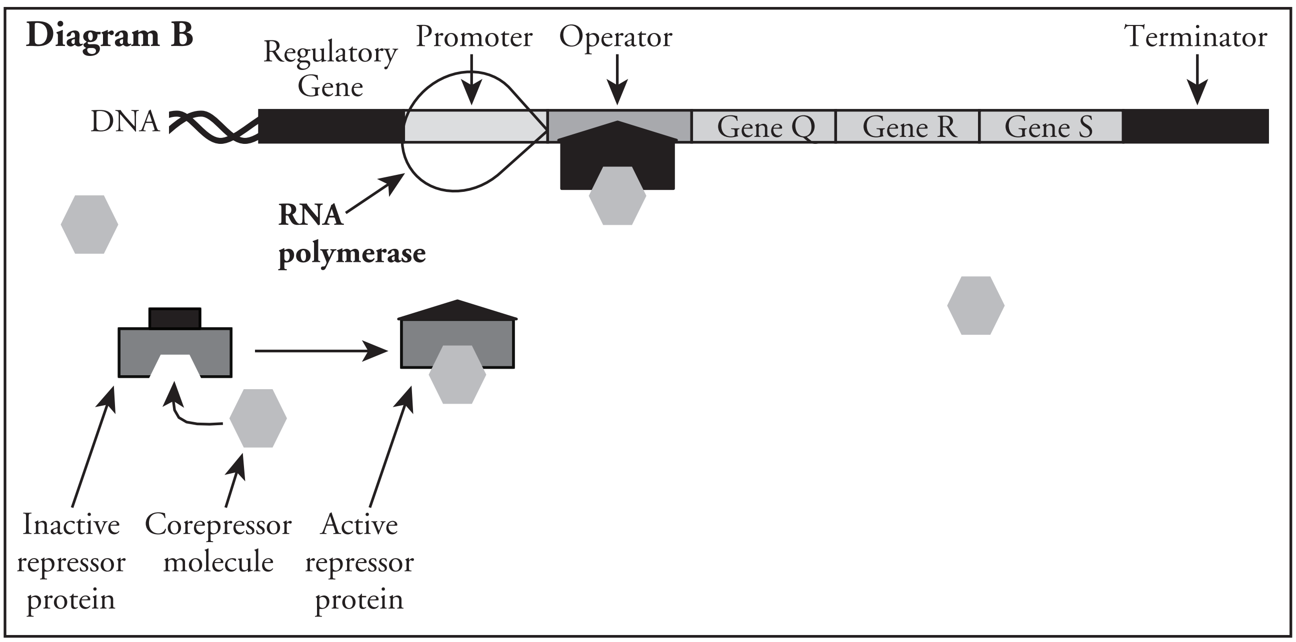
   a. Low lactose

   b. High lactose

STOP

Model 2 – A Repressible Operon





10. In Model 2, where on the DNA strand does RNA polymerase bind to start transcription?

11. In which diagram of Model 2 is transcription and translation occurring successfully, diagram A or diagram B? Justify your answer with evidence from Model 2.

12. Does the regulatory gene in Model 2 produce a protein that is an active or inactive repressor naturally?

13. Describe the role of the **corepressor** molecule in the repressible operon system shown in Model 2.

Read This!

The *trp* operon in *E. coli* is an example of a repressible operon. The group of genes contained in this operon helps the organism produce the amino acid tryptophan from other compounds when tryptophan is not present in the cell's environment. When tryptophan is present in adequate quantities, the operon is turned "off."

14. What compound could serve as the corepressor of the *trp* operon in *E. coli* based on the description above?

15. Compare and contrast an inducible operon and a repressible operon.

16. Which type of operon, an inducible one or a repressible one, would an organism likely use to produce enzymes and other proteins required to metabolize a nutrient in its environment? Justify your answer with specific details from Model 1 or Model 2.

17. Which type of operon, an inducible one or a repressible one, would an organism likely use to produce enzymes and other proteins required for the cell to manufacture a molecule needed from smaller molecules in the environment? Justify your answer with specific details from Model 1 or Model 2.

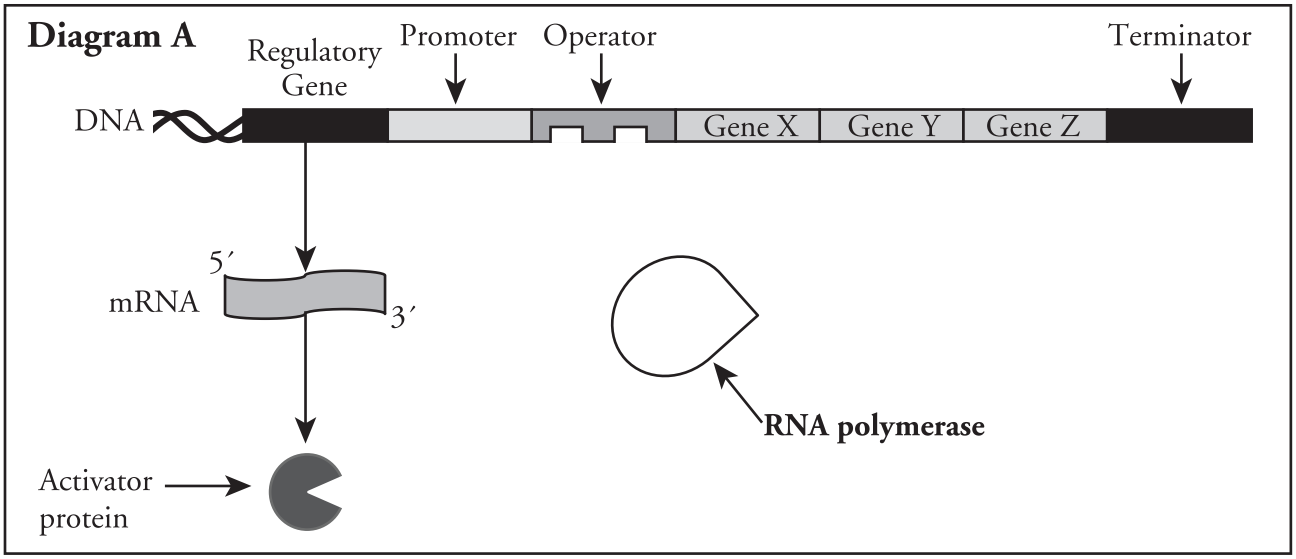
STOP

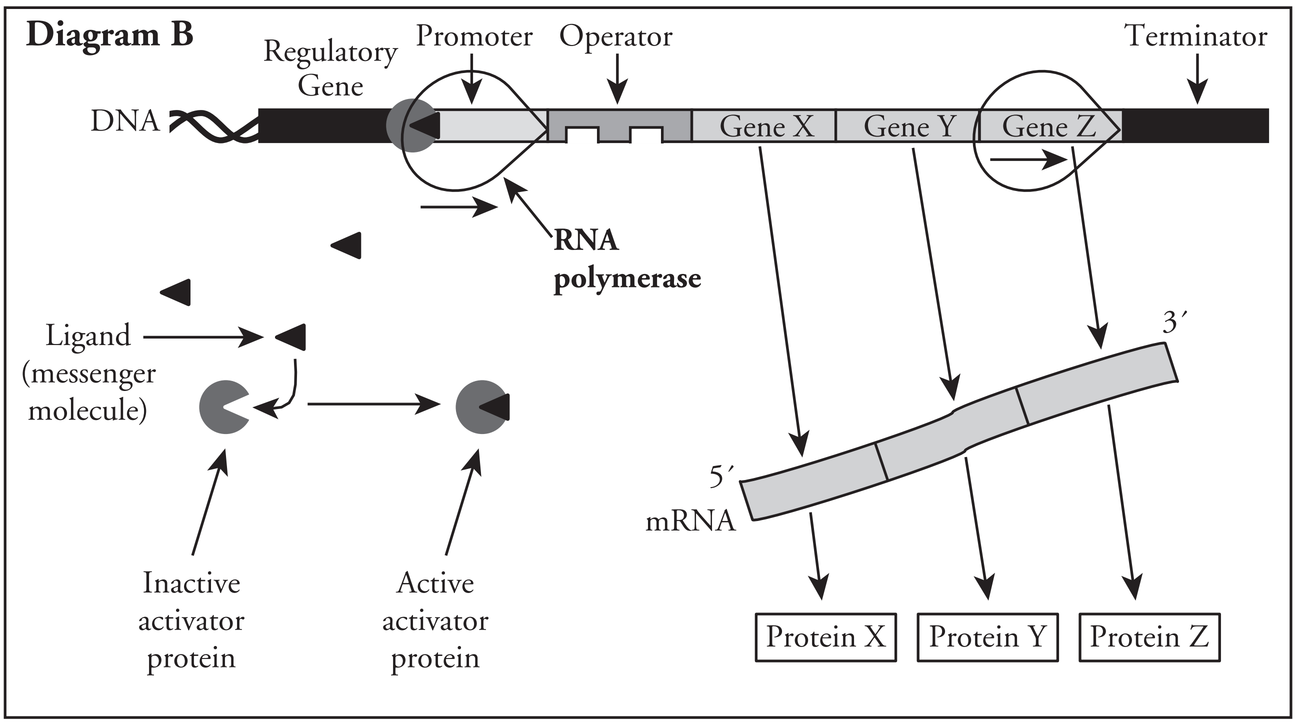
18. Propose an explanation for why operons evolved in prokaryotes. What advantage do organisms have when they group genes together with a regulatory system?

Read This!

The regulatory mechanisms in the operons in Model 1 and Model 2 of this activity are both considered **negative control** of the genes because they both involve a repressor protein that turns the operon "off." Operons are said to have **positive control** when a protein or enzyme can turn them "on" or enhance their function by making it easier for RNA polymerase to bind to the promoter.

Model 3 – Positive Control of a Gene





19. In which diagram of Model 3 is transcription occurring successfully, diagram A or diagram B? Justify your answer with evidence from Model 3.

20. In Model 3, where on the DNA strand does RNA polymerase bind to start transcription?

21. Propose an explanation for why RNA polymerase is not bound to the promoter in diagram A of Model 3.

22. Refer to diagram A in Model 3.

    a. What protein does the regulatory gene in Model 3 produce?

    b. To what section of the operon does this protein bind?

    c. Can the protein produced by the regulatory gene in Model 3 bind to the operon itself? If no, describe what must occur in order for it to bind.

    d. Propose an explanation for why transcription is not occurring in diagram A but is occurring in diagram B.

23. Propose an explanation for why the regulatory protein in Model 3 is called an "activator" protein.

24. Compare and contrast the positive control mechanism of Model 3 with the negative control mechanisms in Models 1 and 2.

25. Choose one of the Models in this activity. What conditions would need to be present in the cell in order to reverse the regulatory conditions in the model (i.e., turn the gene "off" once it has been turned "on").

STOP

Extension Questions

26. Some mutations can disable genes. What might be the result of such a mutation within the *lac* I regulatory region of the *lac* operon?

27. Some operons have both a positive and negative control mechanism built into the DNA sequence of the operon. That means both an activator protein and a repressor protein are present simultaneously. Consider a system that has both positive and repressible negative controls.

    a. Describe the four combinations of active or inactive regulatory proteins that could be present at any time in the cell.

    b. Draw diagrams similar to those in Models 1–3 to show each of the combinations in part *a*. (Divide the work among group members so that each member is drawing one diagram.)

    c. Label each of the combinations in part *b* as "operon on" or "operon off."

    d. Describe in complete sentences the cellular environment(s) that would turn the operon "on."