Key

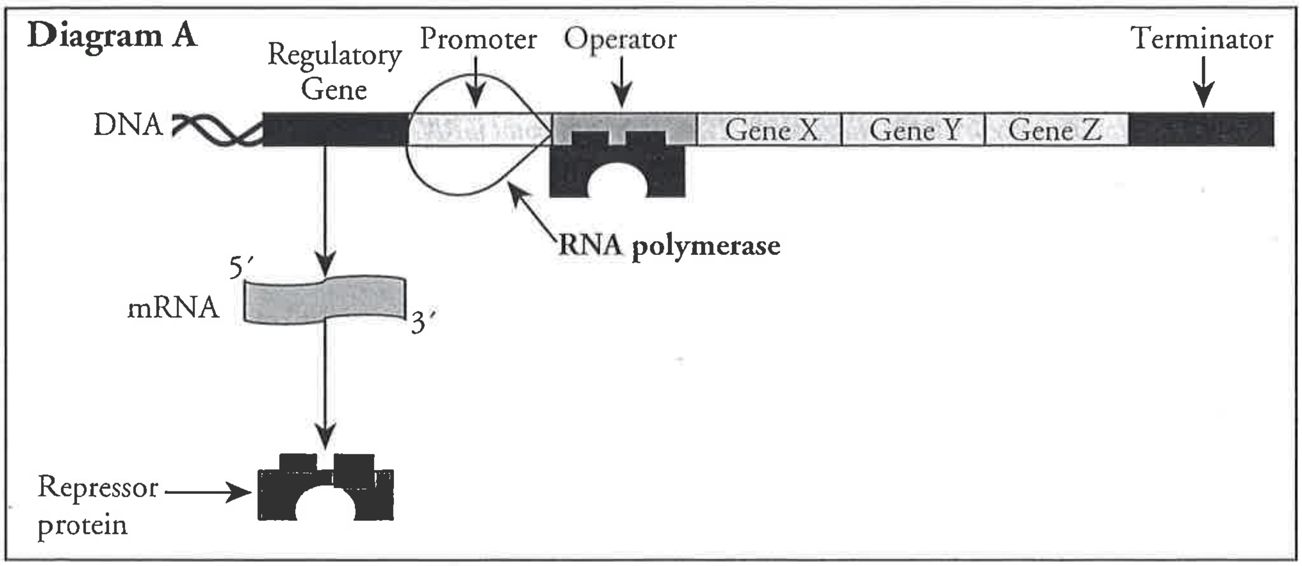
Control of Gene Expression in Prokaryotes

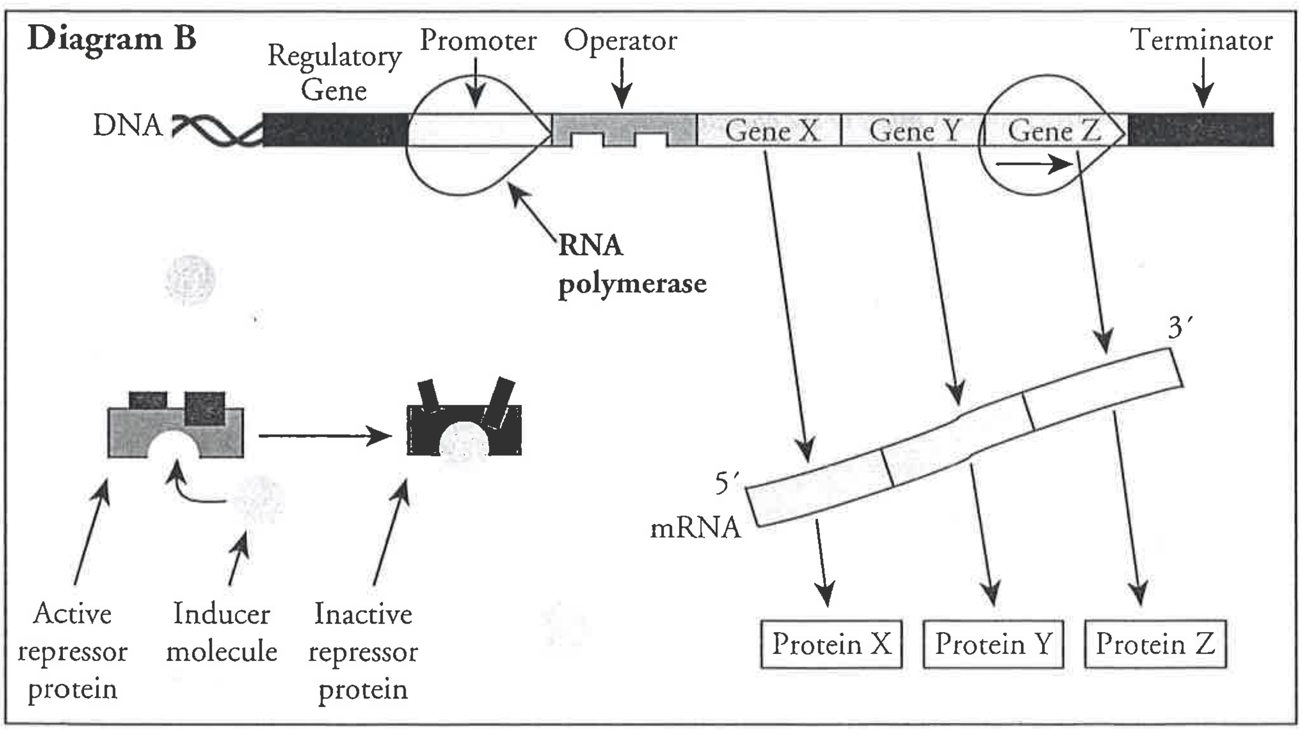
How do prokaryotes use operons to control gene expression?

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?

   An inducible operon.

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

   Three.

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

   The RNA polymerase binds to the promoter.

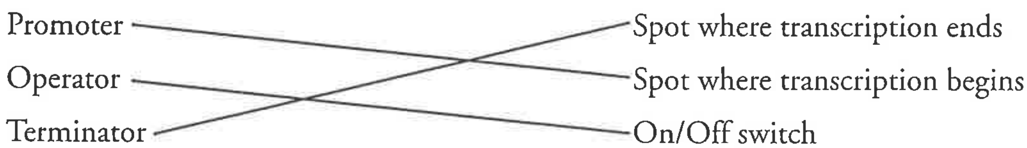
4. Which direction is the RNA polymerase moving in Model 1?

   Left to right → or from 3' end of the DNA to the 5' end of the DNA.

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.

   Transcription is occurring in diagram B. That diagram shows mRNA and proteins being made from the DNA.

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.



7. Refer to diagram A in Model 1.

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

   A repressor protein.

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

   The repressor protein binds to the operator site.

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

   The repressor protein blocks RNA polymerase so transcription of genes X, Y, and Z cannot occur.

8. Refer to diagram B in Model 1.

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

   The repressor protein changes shape.

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

   The repressor protein no longer binds to the operator and is no longer blocking RNA polymerase, so transcription can 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

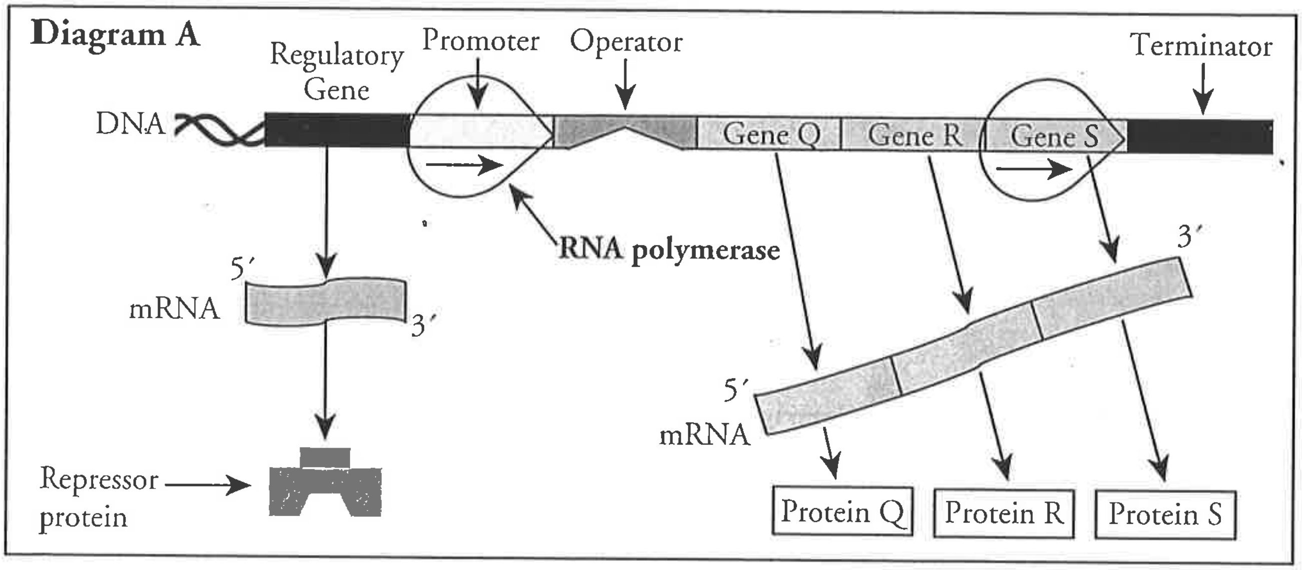
   Not enough allolactose is present. The repressor protein binds to the operator, not allowing transcription of the operon genes. Without those genes producing the correct enzymes, lactose is not metabolized.

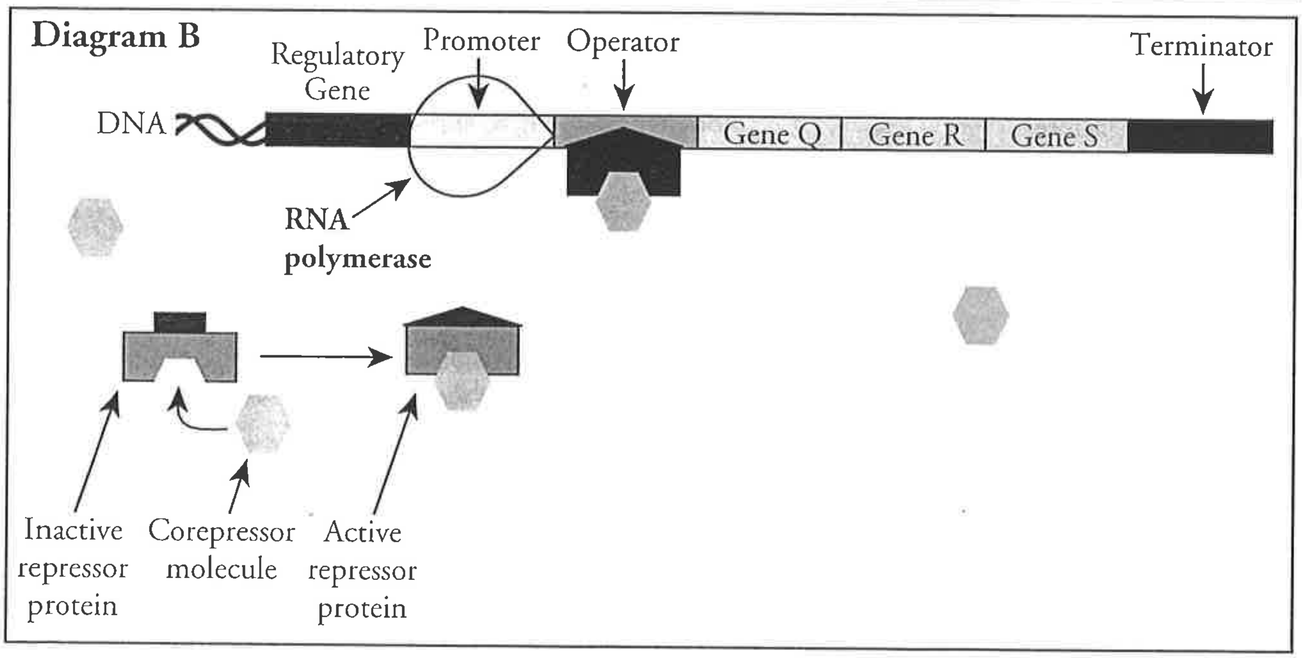
   b. High lactose

   Allolactose is present in sufficient quantities to bond to repressor protein, preventing it from bonding to the operator. This allows for transcription of the genes that will produce the proteins that will metabolize lactose.

STOP

Model 2 – A Repressible Operon





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

    RNA polymerase binds to the promoter.

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.

    Transcription is occurring in diagram A. That diagram shows mRNA and proteins being made from the genes.

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

    Inactive.

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

The corepressor molecule binds to the repressor protein changing its shape so it can bind to the promoter and prevent transcription.

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?

The corepressor is likely tryptophan.

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

Both types of operons use a repressor protein that binds to the operator to turn the genes "off." Both types of operons are affected by a specific molecule (either an inducer or corepressor). This occurs by changing the shape of the repressor protein. In an inducible operon, the genes are turned "on" in the presence of the specific molecule (inducer). In a repressible operon, the genes are turned "on" in the absence of the specific molecule (corepressor).

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.

An inducible operon would likely be used. The nutrient being metabolized would act as the inducer molecule. Therefore, when the nutrient is present, the proteins needed to metabolize it would be transcribed and translated.

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.

A repressible operon would likely be used. If the molecule needed was present in the cell, the operon would be turned off. It would act as the corepressor molecule. If the molecule was absent, then the operon would be turned on to make the molecule.

STOP

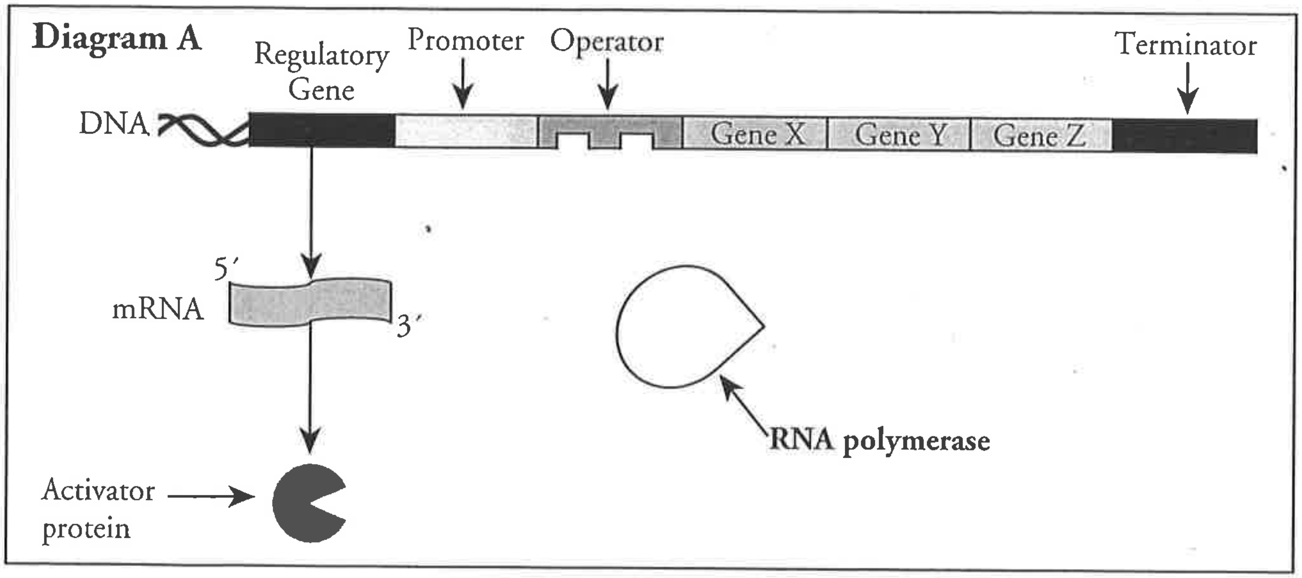
18. Propose an explanation for why operons evolved in prokaryotes. What advantage do organisms have when they group genes together with a regulatory system?

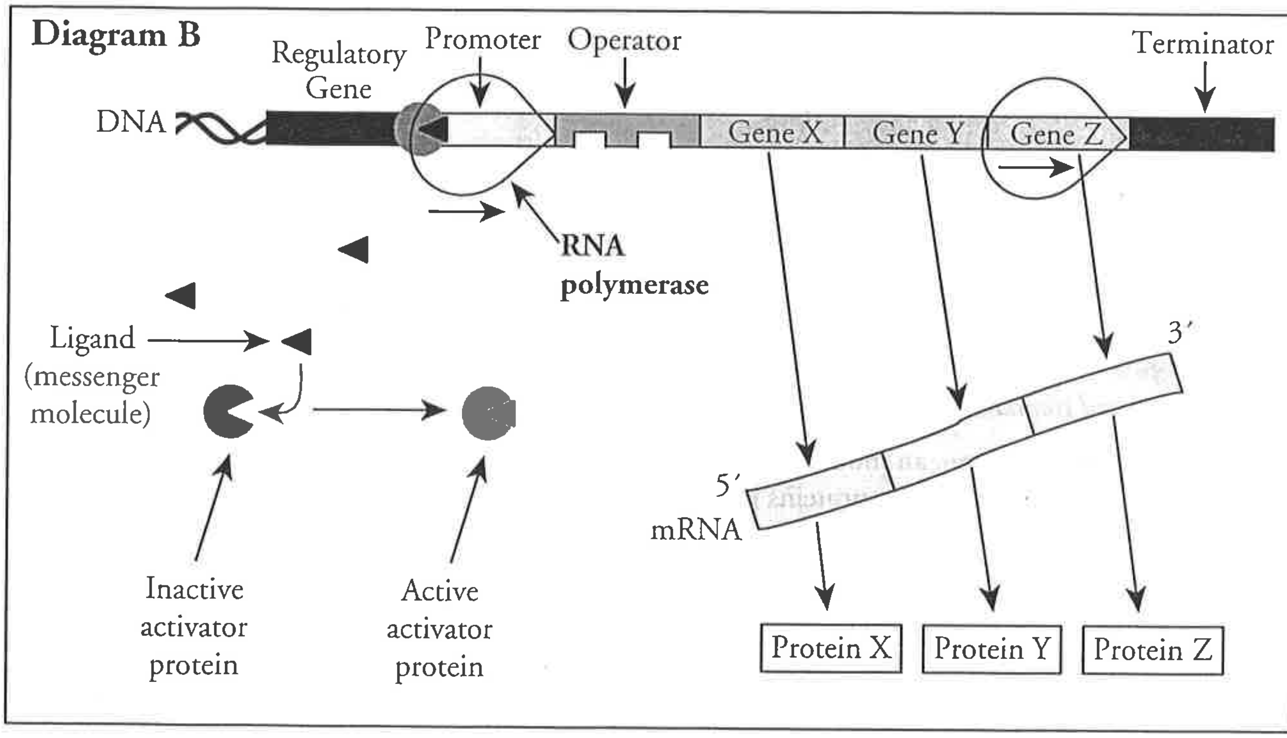
The organism can turn genes off when not needed and conserve energy and resources.

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.

    Transcription is occurring in diagram B because the diagram shows mRNA and proteins being made.

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

    The RNA polymerase binds to the promoter

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

Something is preventing it from binding. Maybe it needs the activator protein to be there first.

22. Refer to diagram A in Model 3.

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

An activator protein.

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

The activator protein binds to the promoter.

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.

No, the activator protein must bind to a ligand (messenger molecule) before it can bind to the promoter.

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

The activator protein needs to be present on the promoter for the RNA polymerase to bind to the promoter and begin transcription. Without the activator protein, the RNA polymerase does not bind to the promoter.

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

Because its presence will "activate" the operon, or turn the operon "on."

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

The positive control mechanism is about turning the operon "on" by enhancing the connection between the promoter and RNA polymerase. The negative control mechanisms are about turning the operon "off" by blocking RNA polymerase from moving down the DNA. All three systems use a regulatory gene to make a protein that requires another molecule to bind to it in order to function.

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").

Answers will vary. Student answers should indicate that the regulatory molecules (corepressor, activator or ligand) would need to be removed from the cell to lower their concentrations and return the system to its original state.

STOP