Lecture 21:

Regulation of gene expression

III. Prokaryotic regulation

Course 281

Lessons for life

AIMS

- Understand what an operon is.
- Understand gene regulation in prokaryotes especially in the given examples.
- Understand the difference between inducible and repressible operons and their biological significance.
- Understand the function of lactose operon and its regulatory protein.
- Understand the function of tryptophan operon and its regulatory protein.

Operon

What is an operon?

• A set of genes that gets transcribed using one promoter and produce a single mRNA.

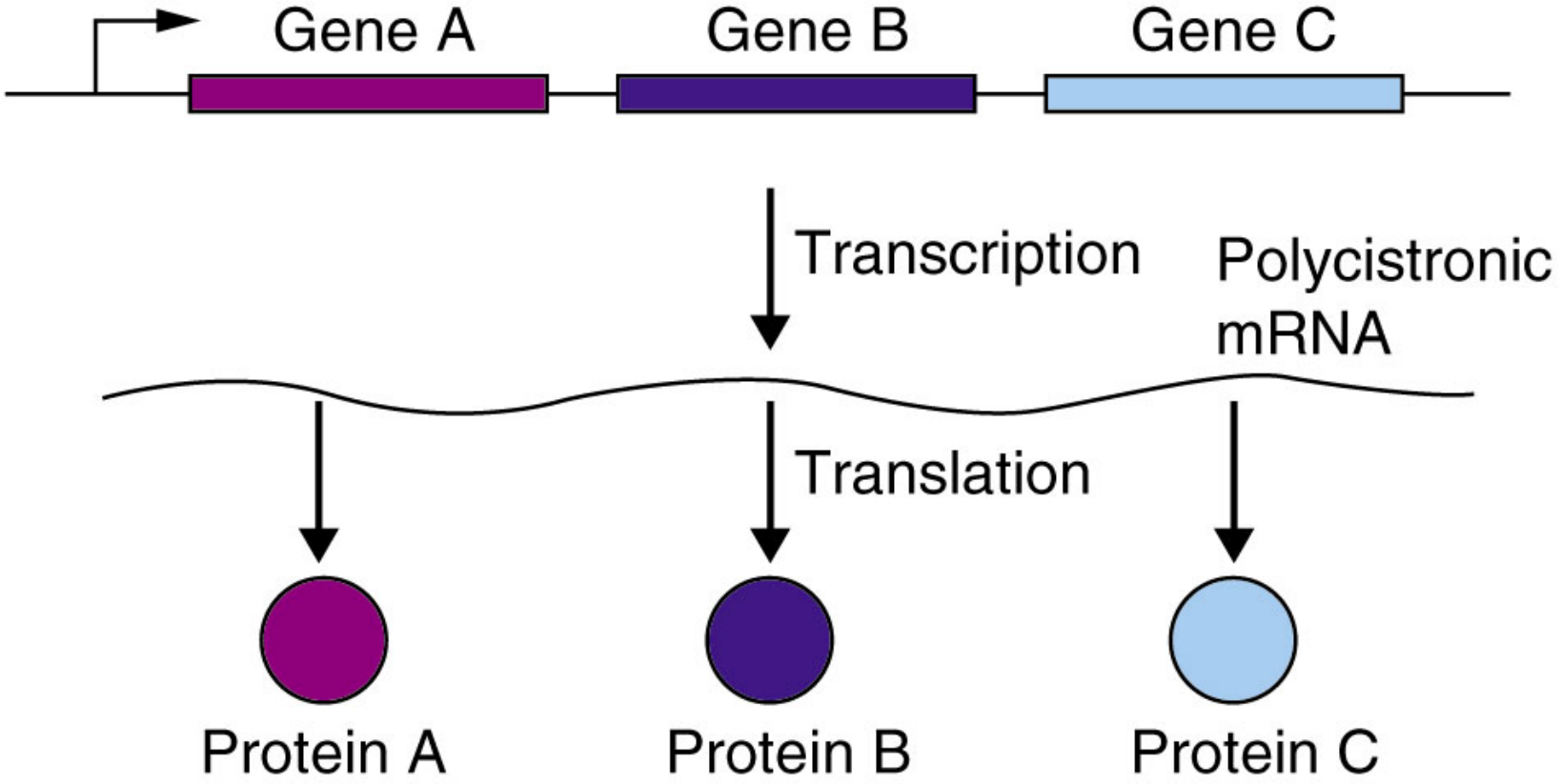
• Operons often have a regulatory signal that affects transcription.

What is the transcriptomic equivalent of the genomic operon?

Operon

What is the transcriptomic equivalent of the genomic operon?

Operon


Gene A
Gene B
Gene C
Transcription
Polycistronic
mRNA
Translation
Protein A
Protein B
Protein C

Types of operons

What are the types of operons?

1. Inducible operons

2. Repressible operons

Types of operons

1. **Inducible operons:**
A substrate needs to be present to induce the expression of the genes that breaks it down.

Examples:
Metabolic pathways such as lactose operon in bacteria

Types of operons

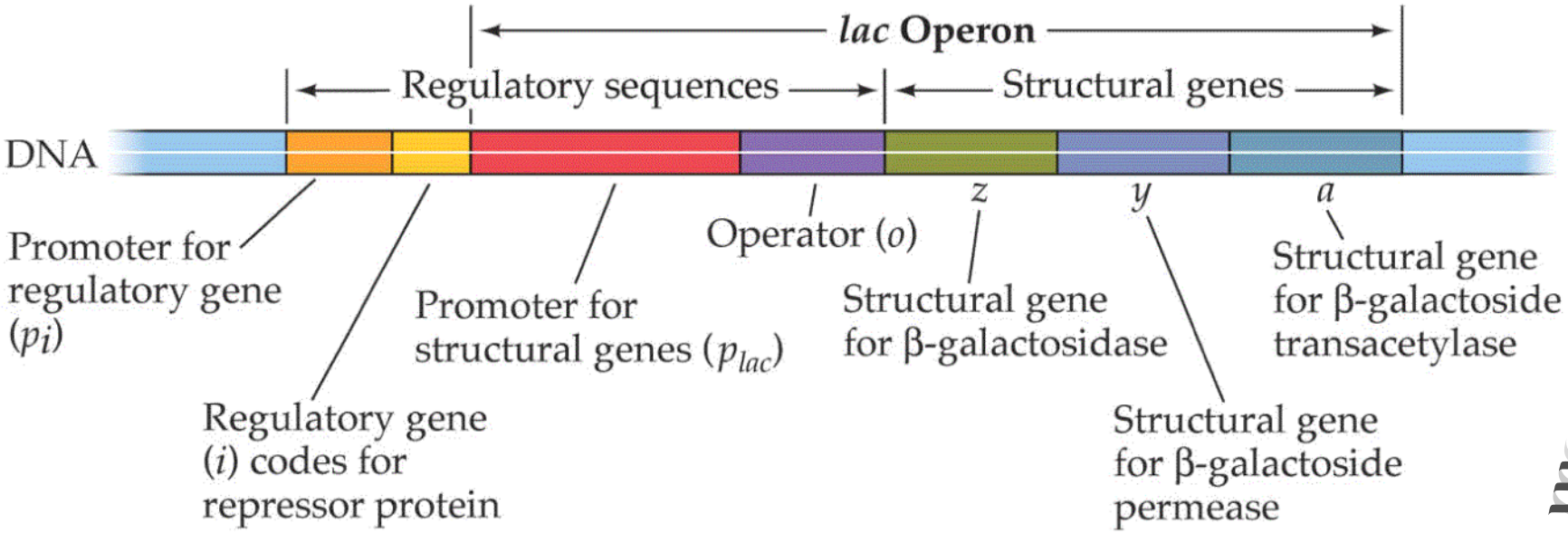
2. **Repressible operons:**
Making proteins when needed. There is no need to make a protein when it is already available in the cell.

Example:
Anabolic pathways (making stuff) Tryptophan operon in bacteria

Inducible operon – Lactose operon

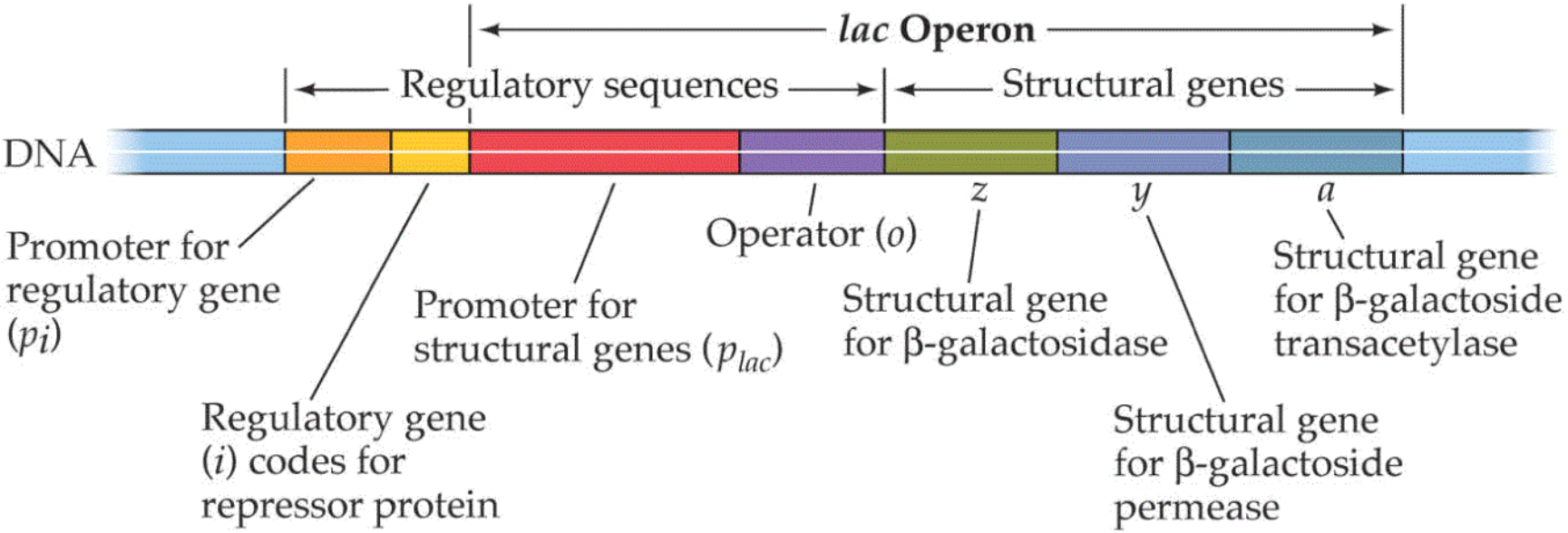
- The lactose operon in *E.coli* is called the *Lac* operon.

- The *Lac* operon contains three genes that code for three enzymes involved in the metabolism of lactose.



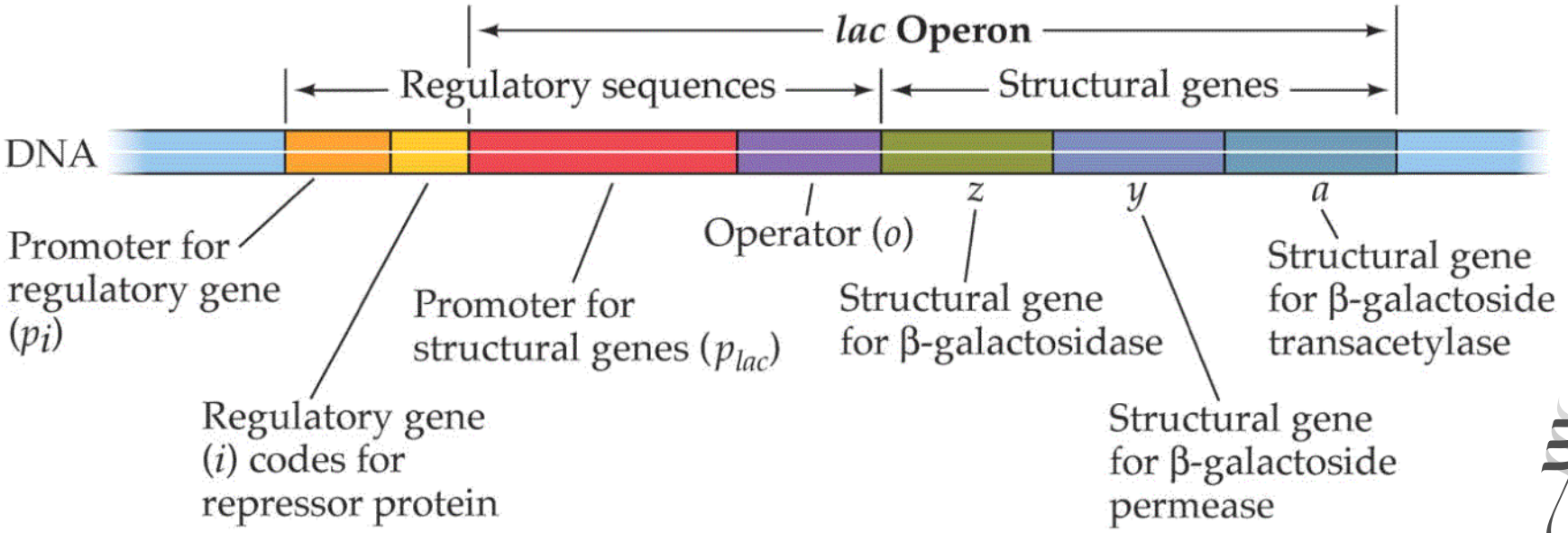
Inducible operon – Lactose operon

- The genes share a single promoter (remember it is called an operon).



Inducible operon – Lactose operon

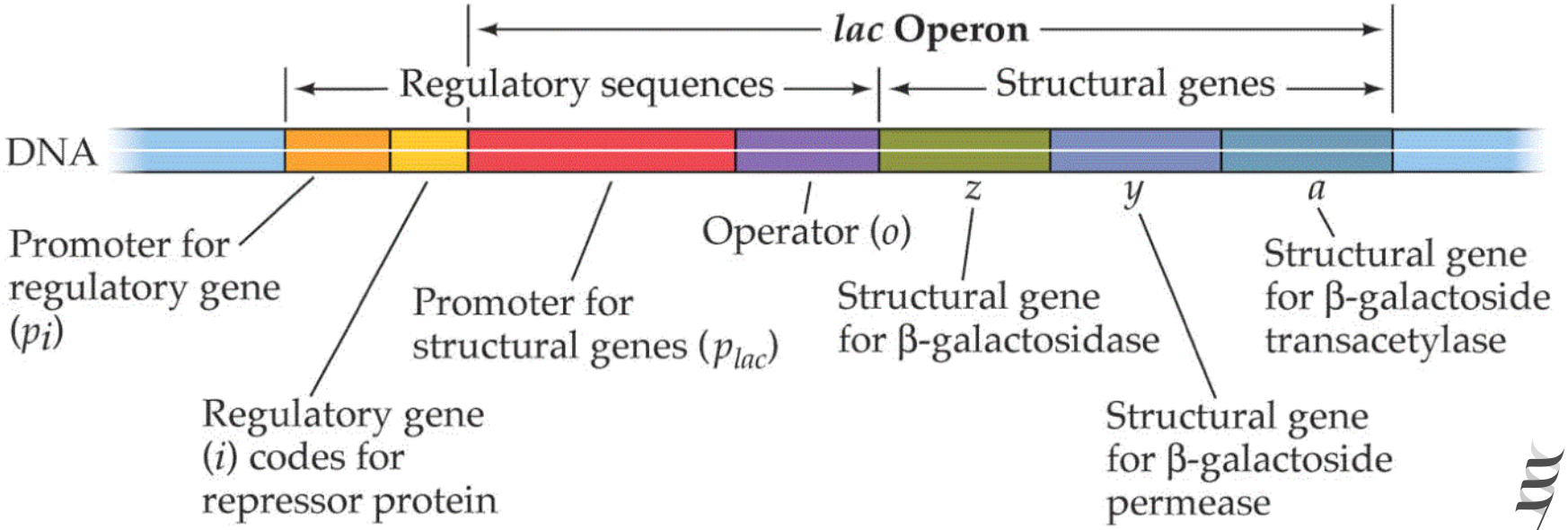
- Downstream of the *Lac* operon promoter, an operator sequence is present.
- **What is an operator sequence?**
- A regulatory gene is present upstream of the *Lac* operon and it is called the ***Lac* repressor** gene.



Inducible operon – Lactose operon

- ***Lac* repressor** gene contains its own promoter and gets expressed independent of the operon downstream.

- The expression of the *Lac* repressor gene produces the *Lac* repressor protein.

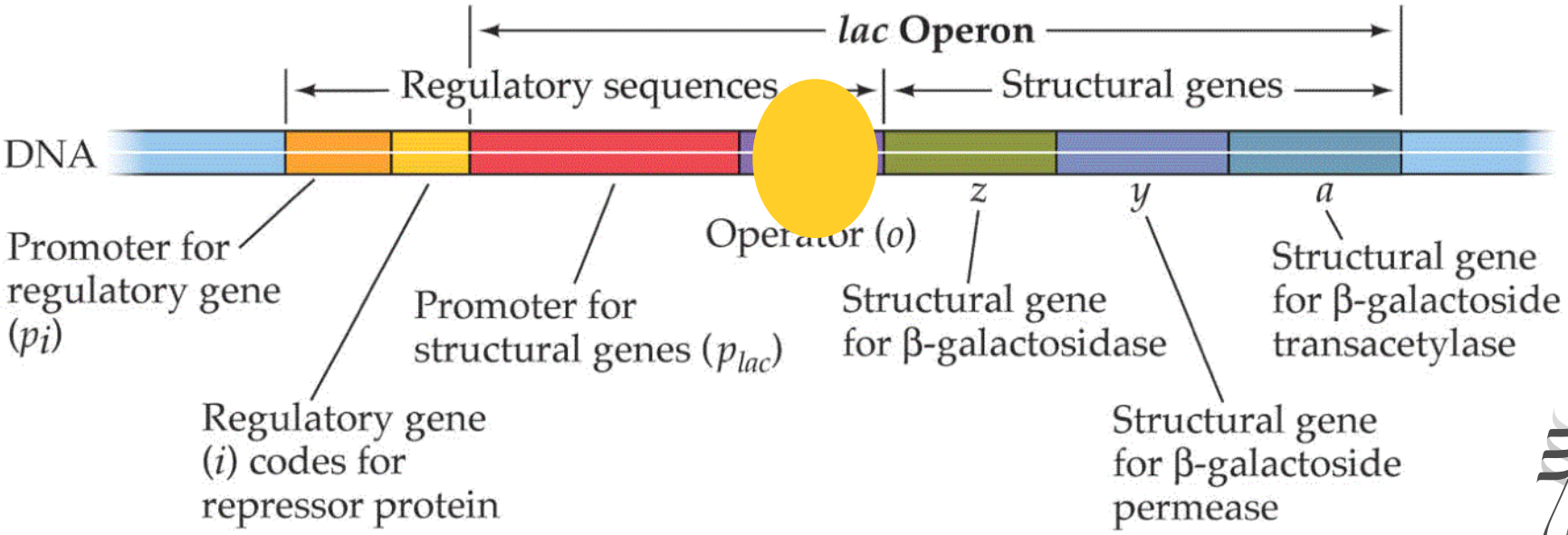


Inducible operon – Lactose operon

Where do you think the repressor protein binds?

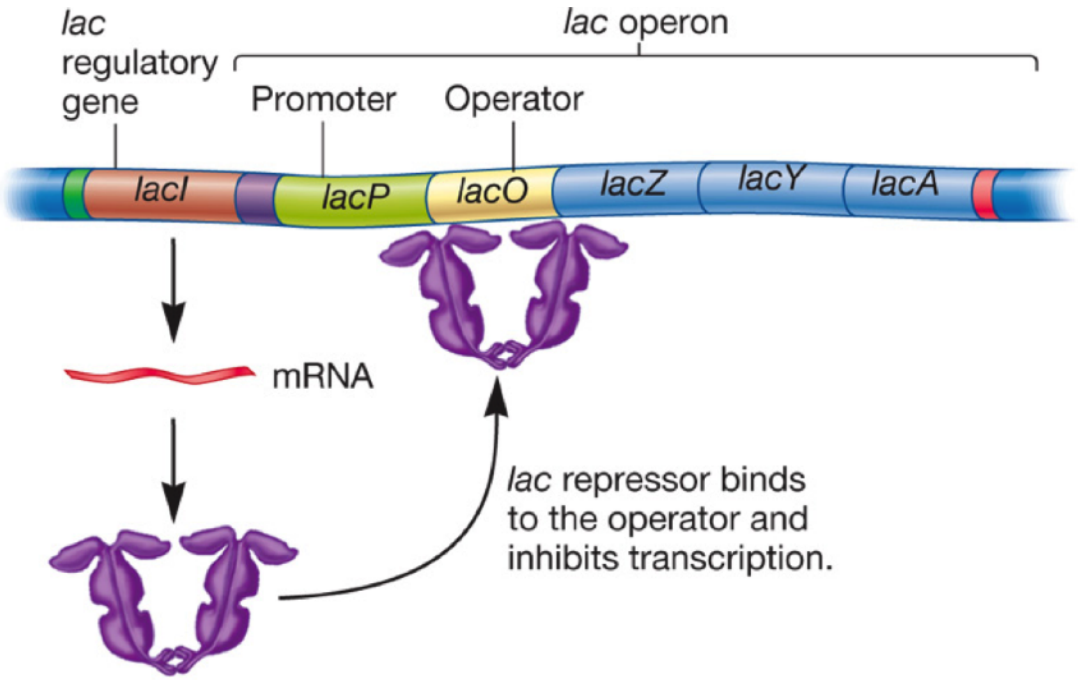
Inducible operon – Lactose operon

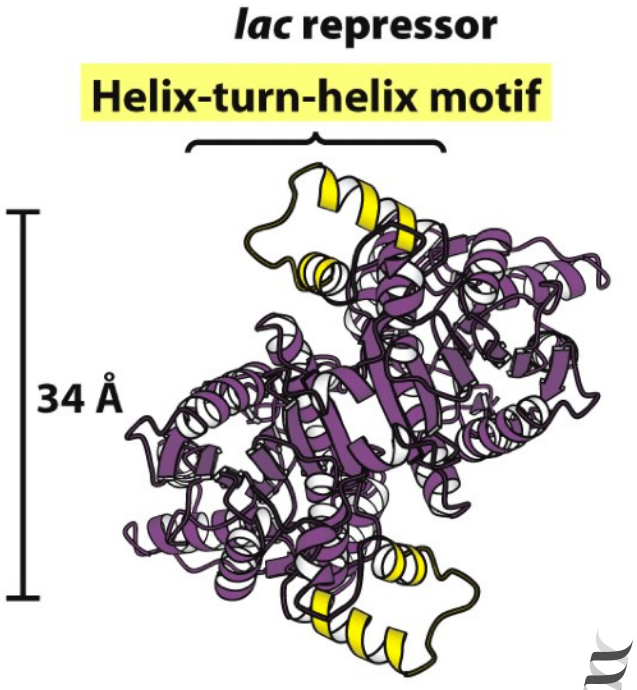
- *Lac* repressor protein recognized and binds to the operator region of the *Lac* operon.
- The repressor's binding is specific to the operator in the absence of an inducer.
- **What is an inducer?**



Inducible operon – *Lac* operon

- The *lac* repressor is helix-turn-helix regulatory protein the represses the transcription of the *lac* operon.



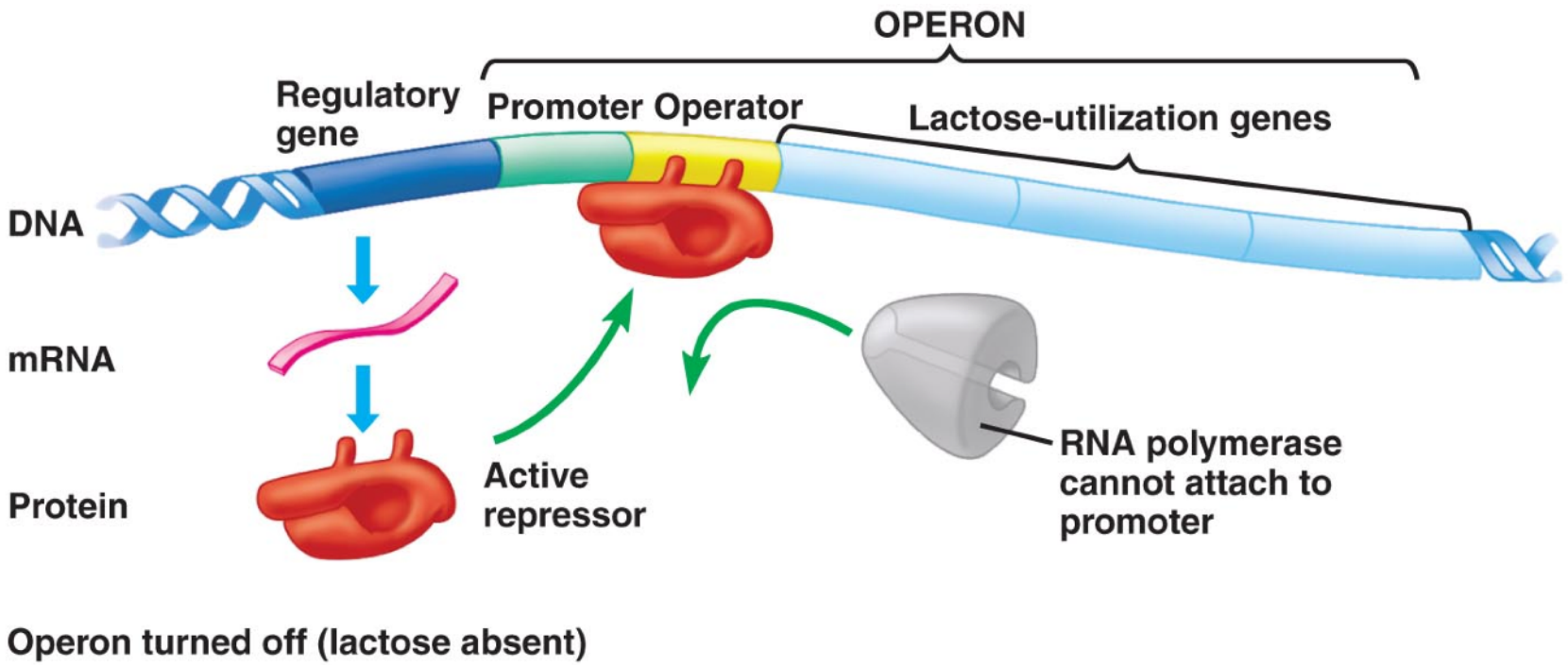


Inducible operon – *Lac* operon

What happens when active *Lac* repressor binds to its motif?

Inducible operon – *Lac* operon

- Under normal conditions (the absence of an inducer), the *lac* repressor is expressed to prevent the transcription of the *Lac* operon genes.



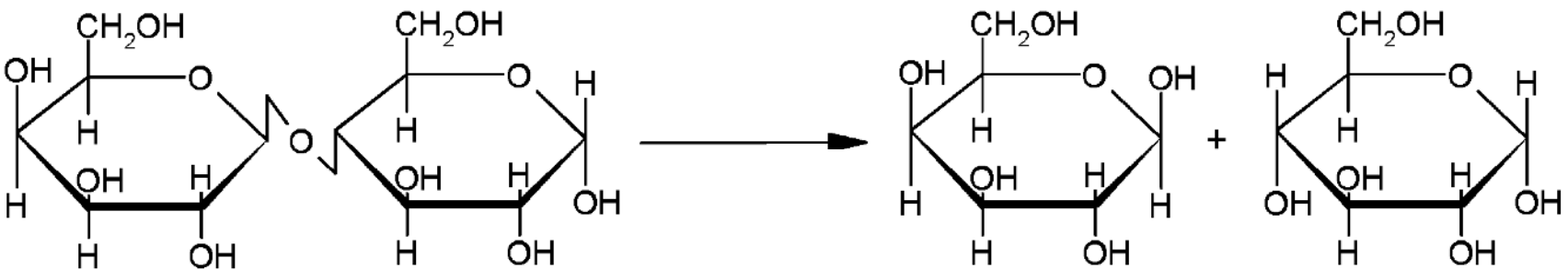
Operon turned off (lactose absent)

Inducible operon – *Lac* operon

What deactivate the *Lac* repressor and triggers the expression of the operon's genes?

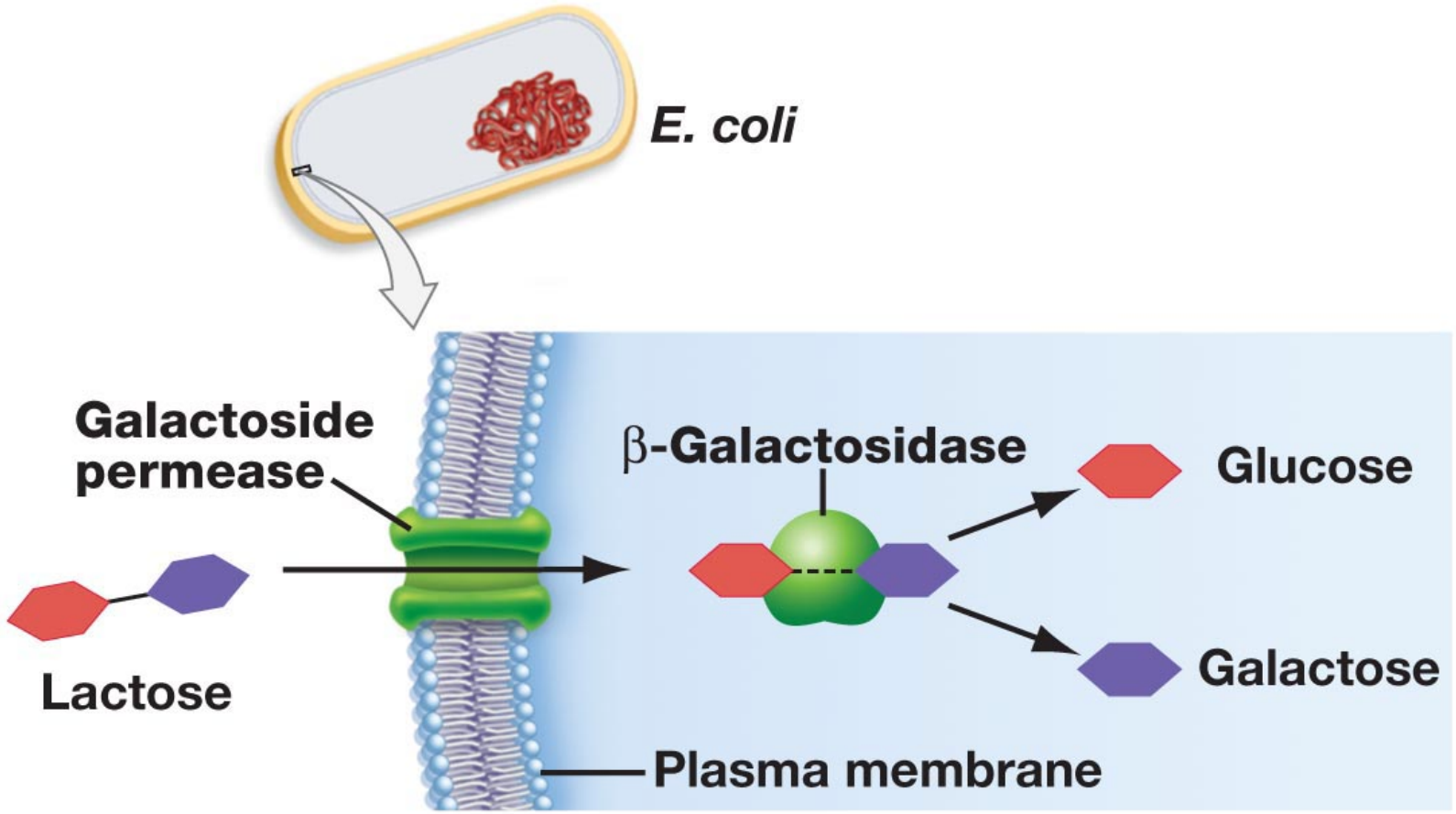
Inducible operon – *Lac* operon

- The presence of an inducer will stop the activity of the repressor.
- The *Lac* operon inducer is **lactose.**
- The presence of lactose as a source of energy for the bacteria **induces** the expression of the *Lac* operon.



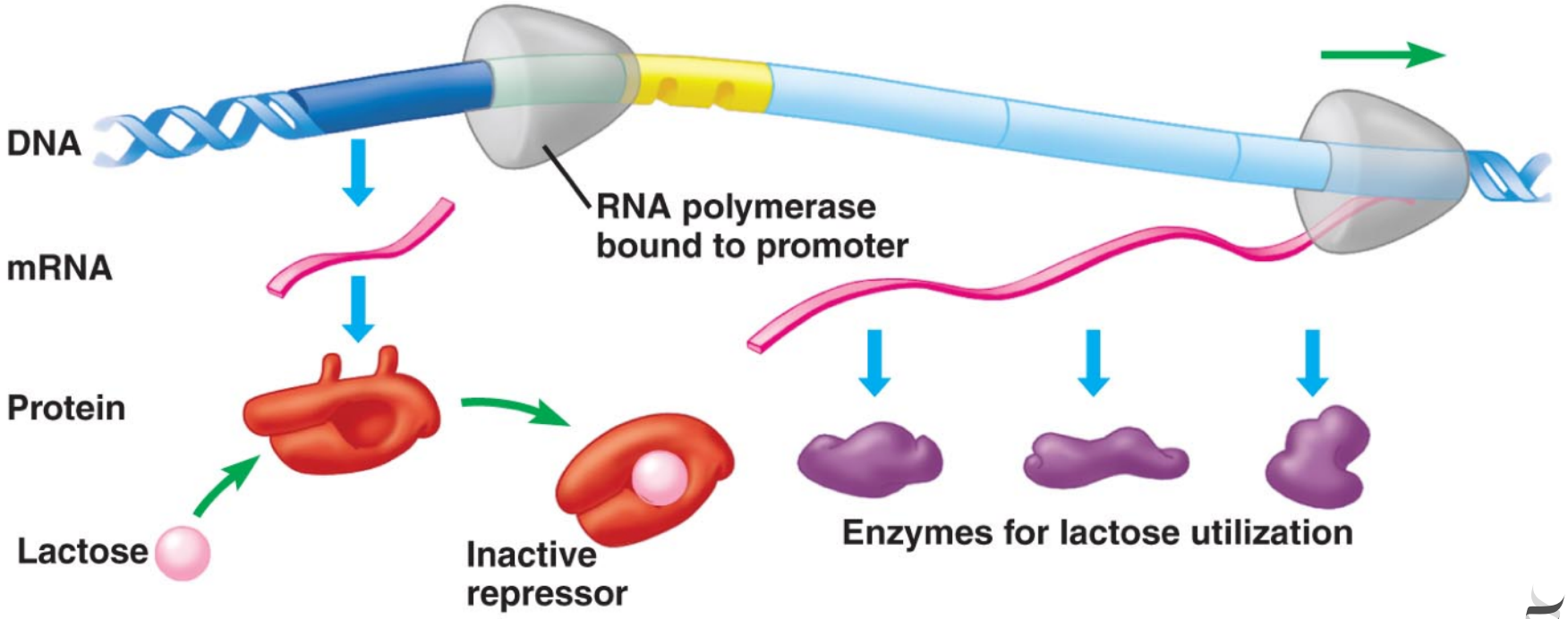
Inducible operon – *Lac* operon

Lactose entering the bacterial cell needs to be broken down into usable molecules



Inducible operon – *Lac* operon

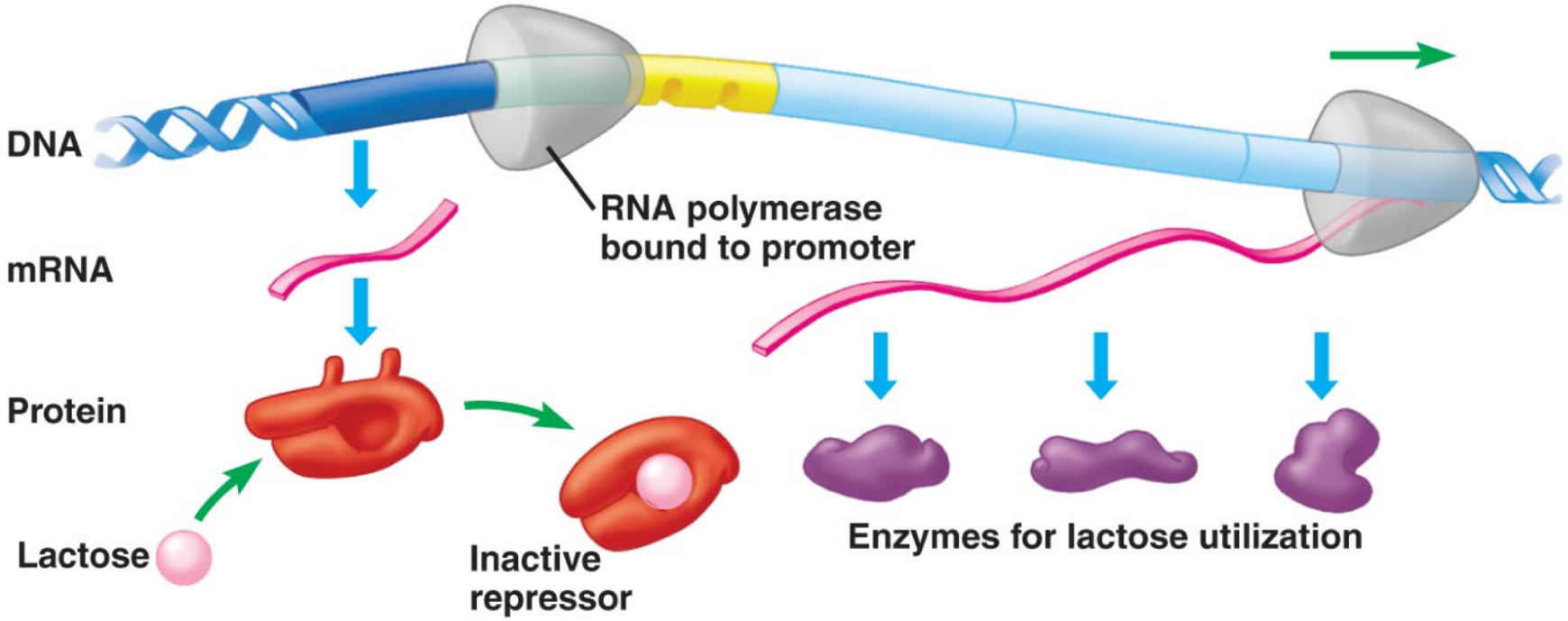
- When lactose inter the cell, it binds to the *Lac* repressor and eliminate it is ability to bind to the operator.



Operon turned on (lactose inactivates repressor)

Inducible operon – *Lac* operon

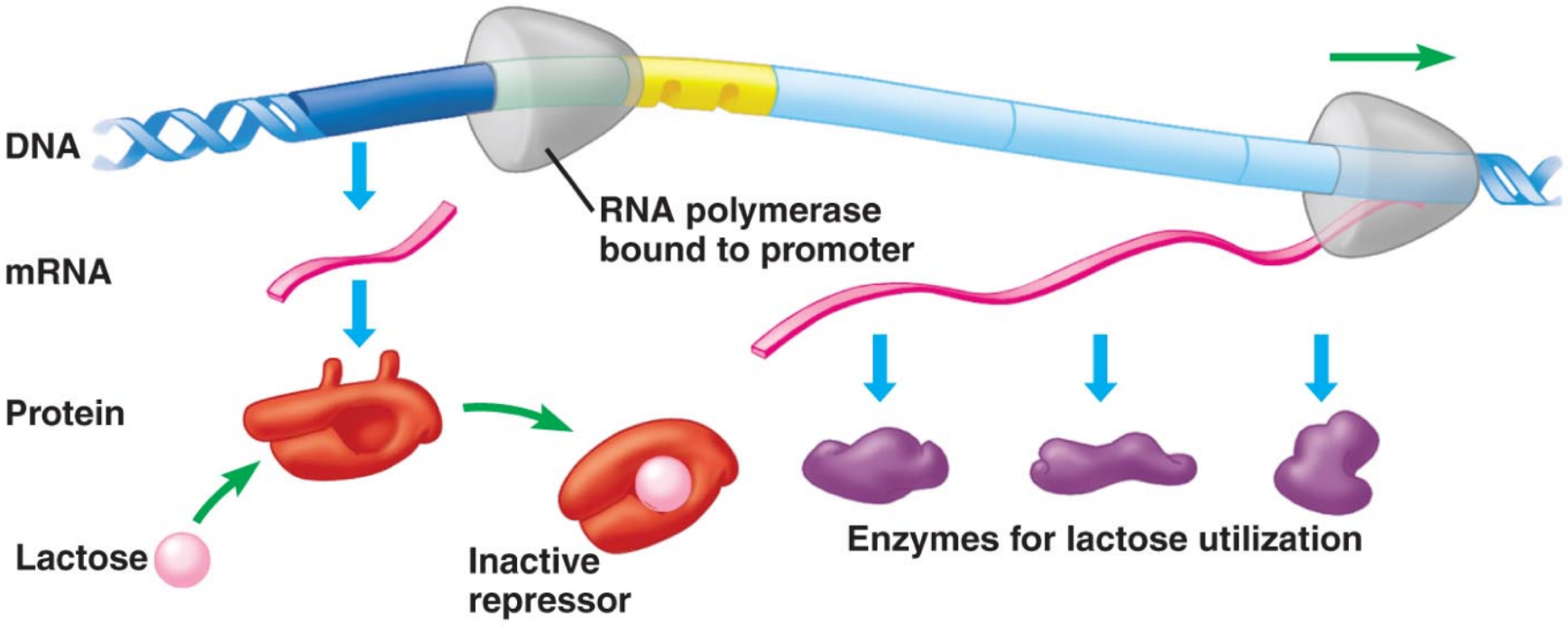
- With the repressor removed, RNA Polymerase binds to the promoter of the operon and expresses the *Lac* operon genes.



Operon turned on (lactose inactivates repressor)

Inducible operon – *Lac* operon

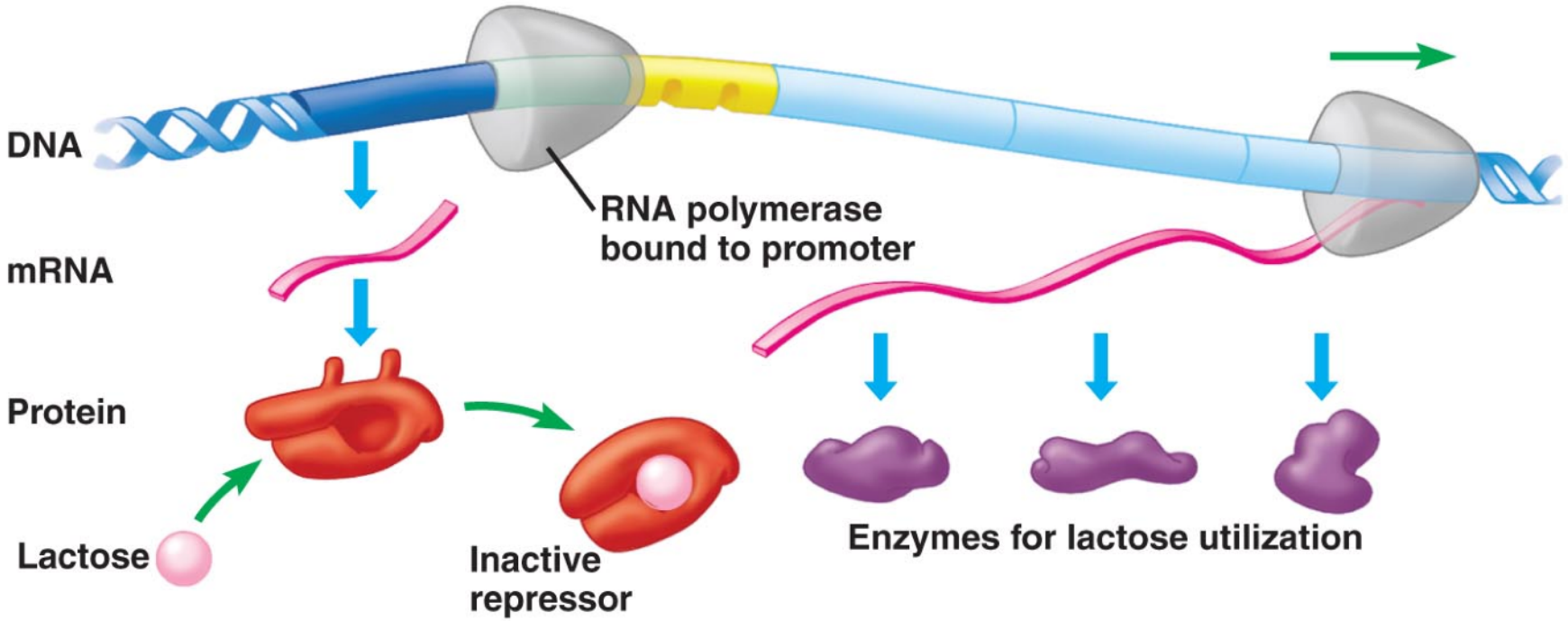
- When the genes expressed, the resulting enzymes breakdown lactose molecules in the cell.



Operon turned on (lactose inactivates repressor)

Inducible operon – *Lac* operon

- When all lactose molecules are being processed, the repressor is free of lactose and can go back to turn off the Operon.



Operon turned on (lactose inactivates repressor)

9.2 REGULATION OF TRANSCRIPTION INITIATION IN BACTERIA

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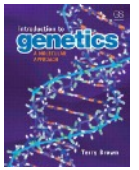

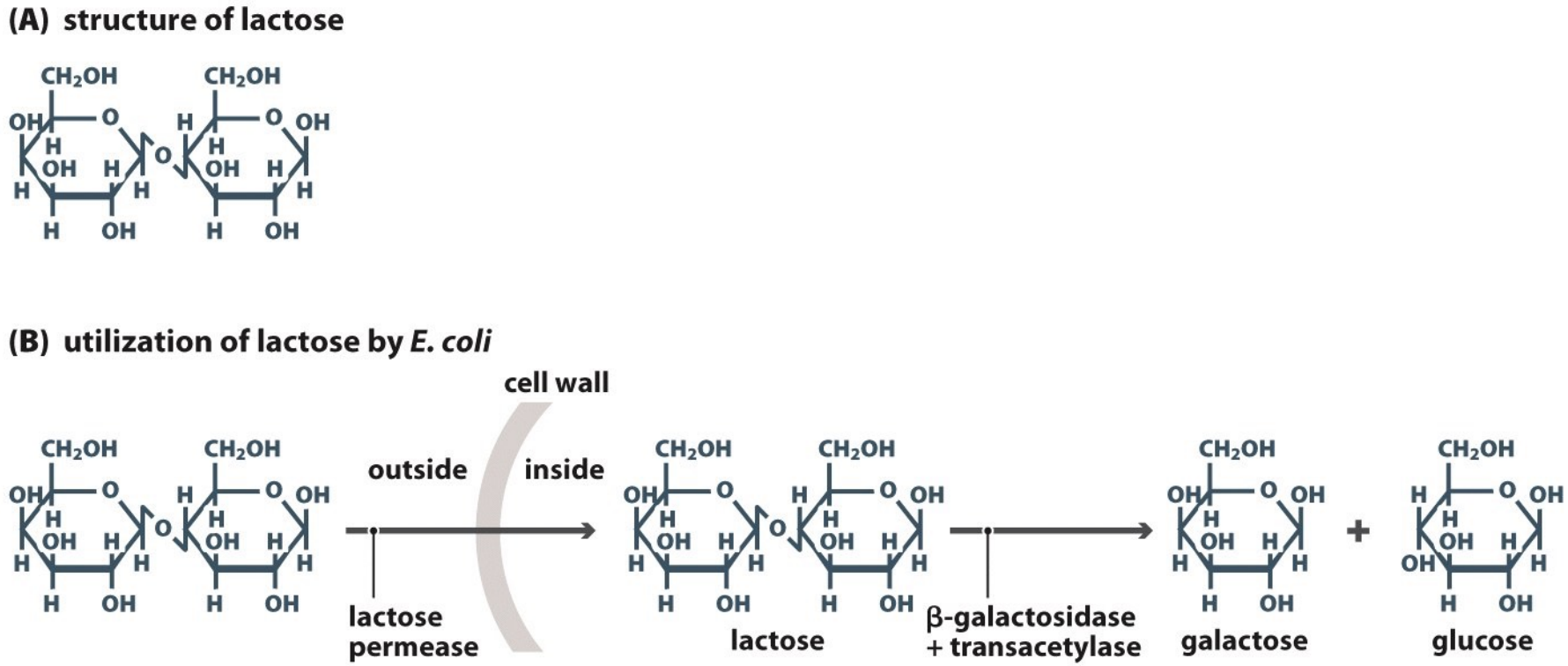

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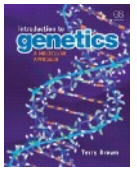


structure of lactose

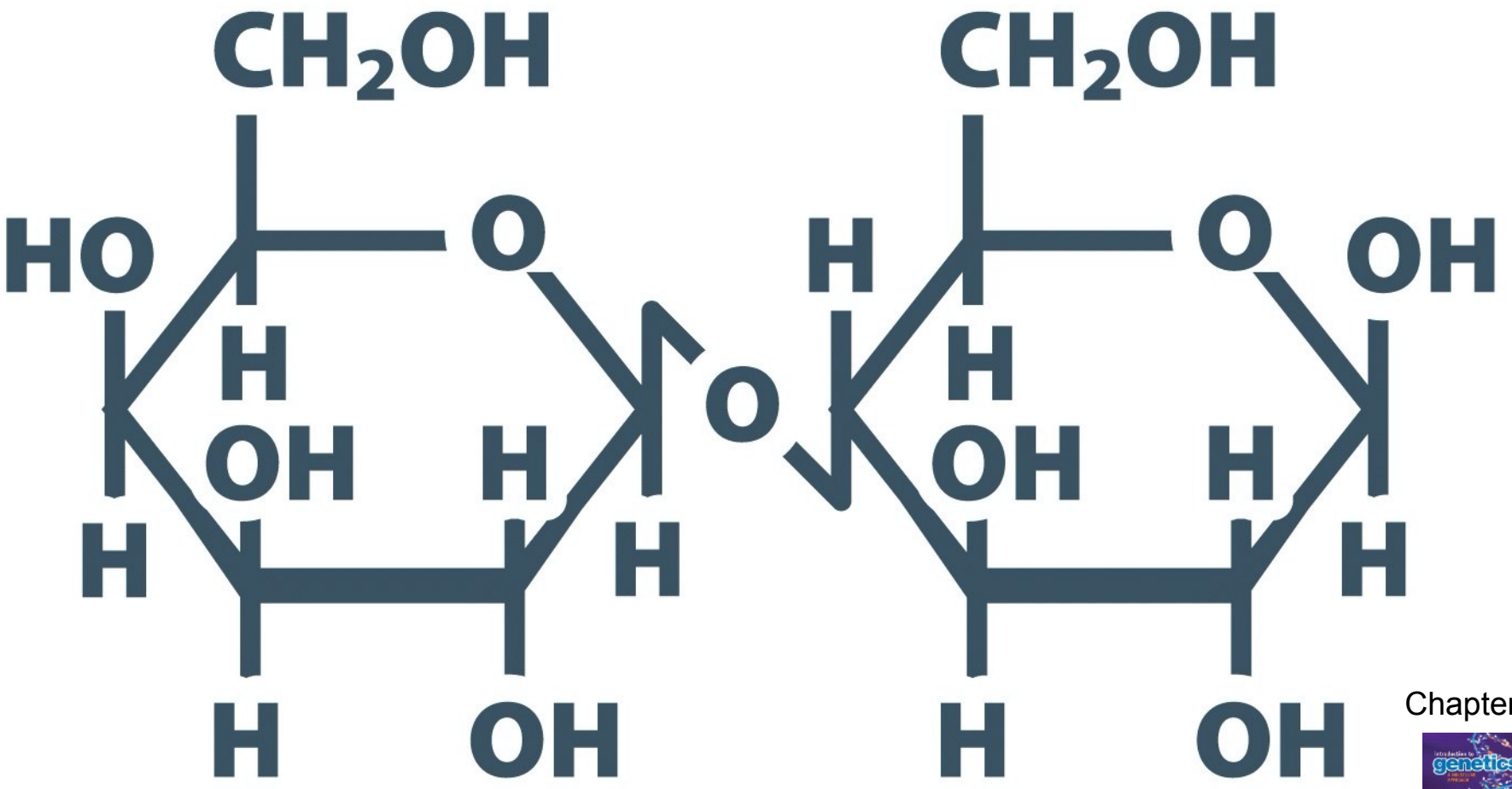
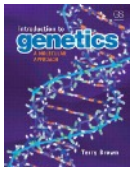
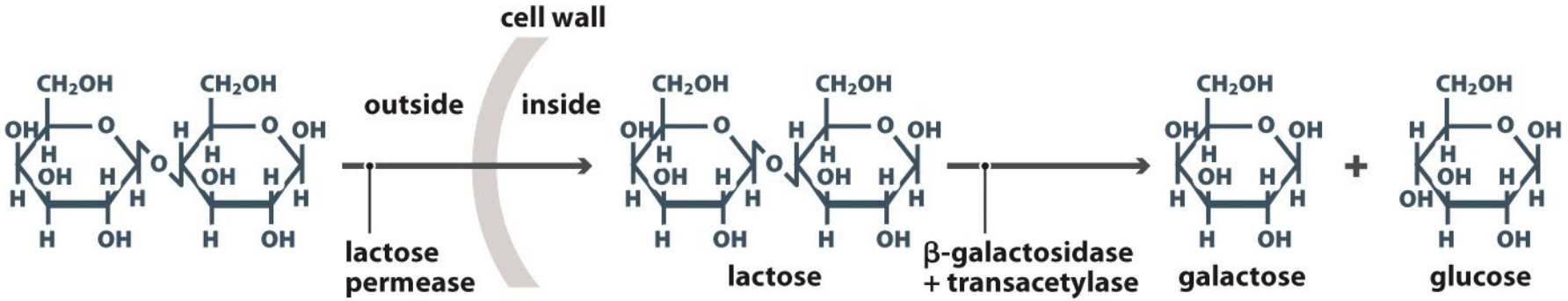


Figure 9.6a Introduction to Genetics (© Garland Science 2012)

Chapter 9



utilization of lactose by *E. coli*



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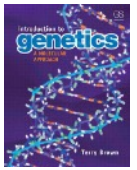

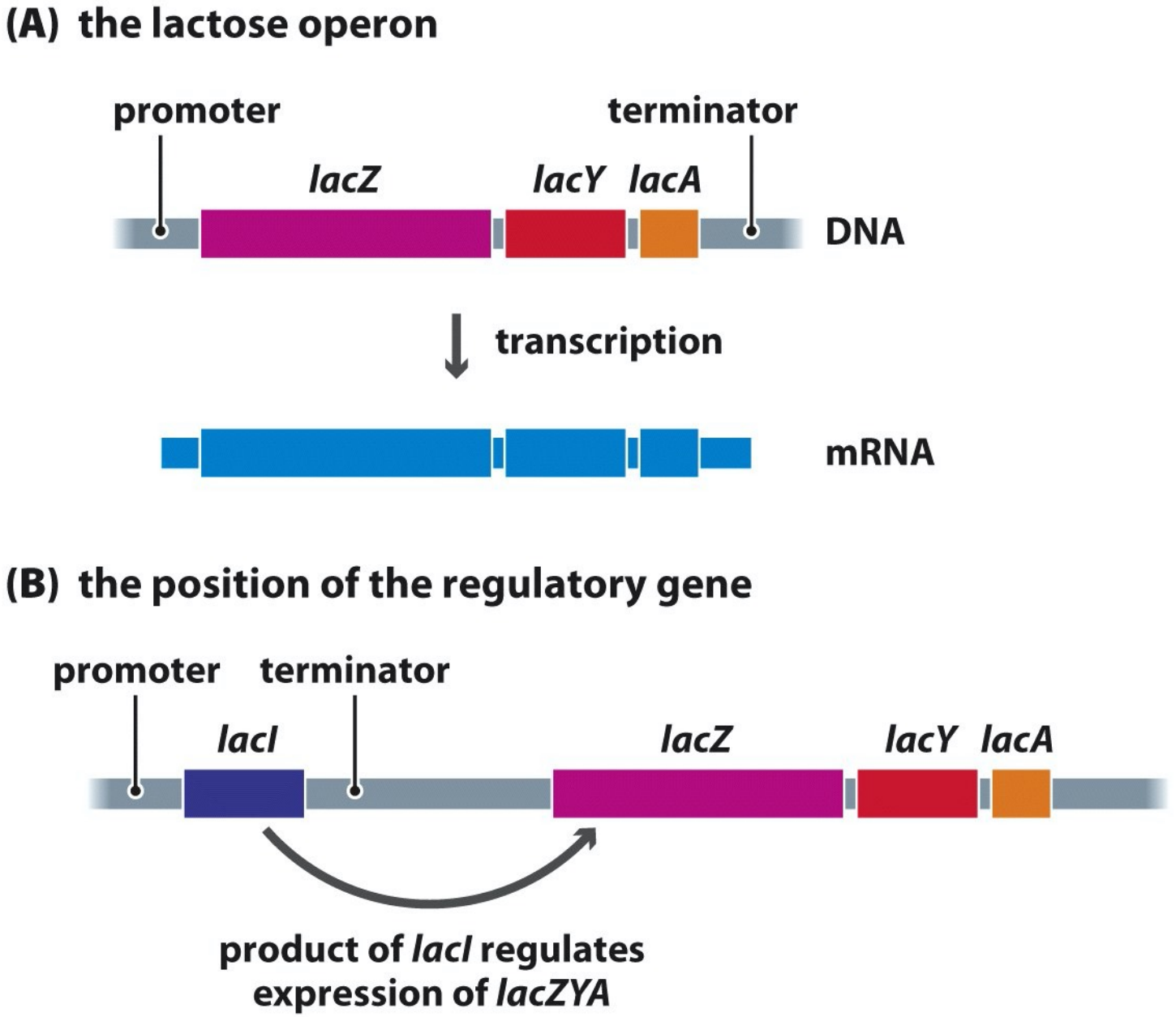

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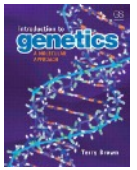
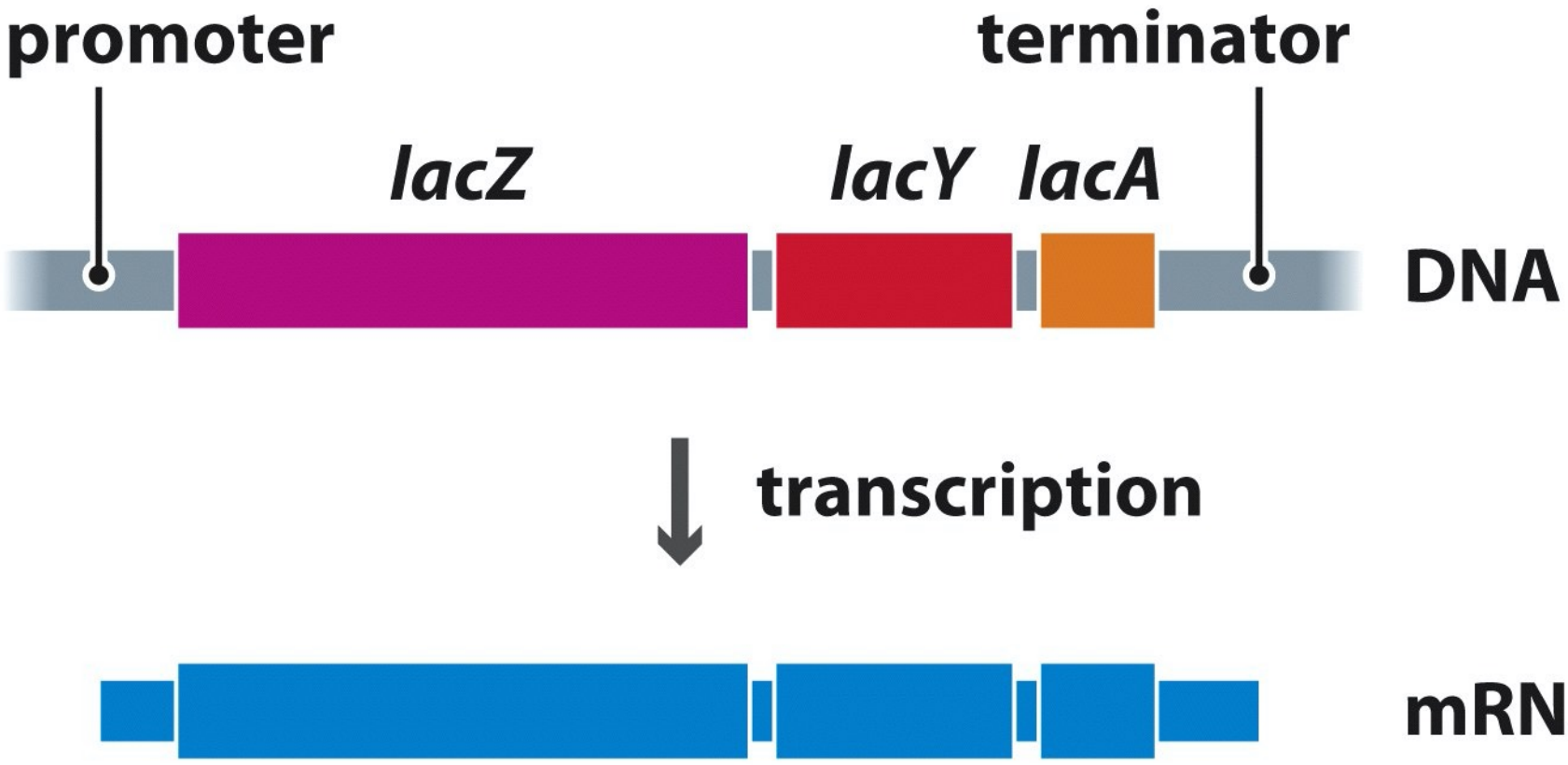


the lactose operon



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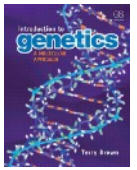

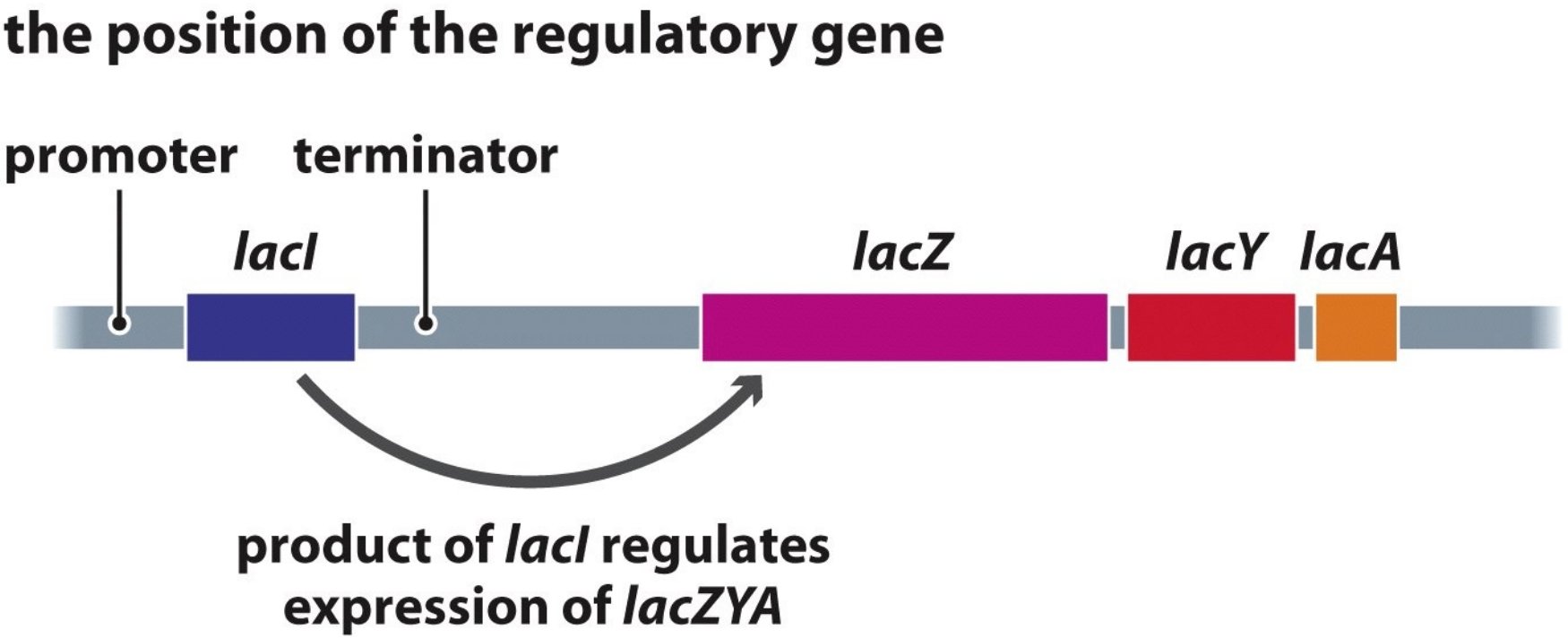

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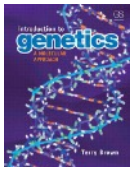

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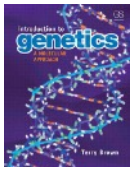

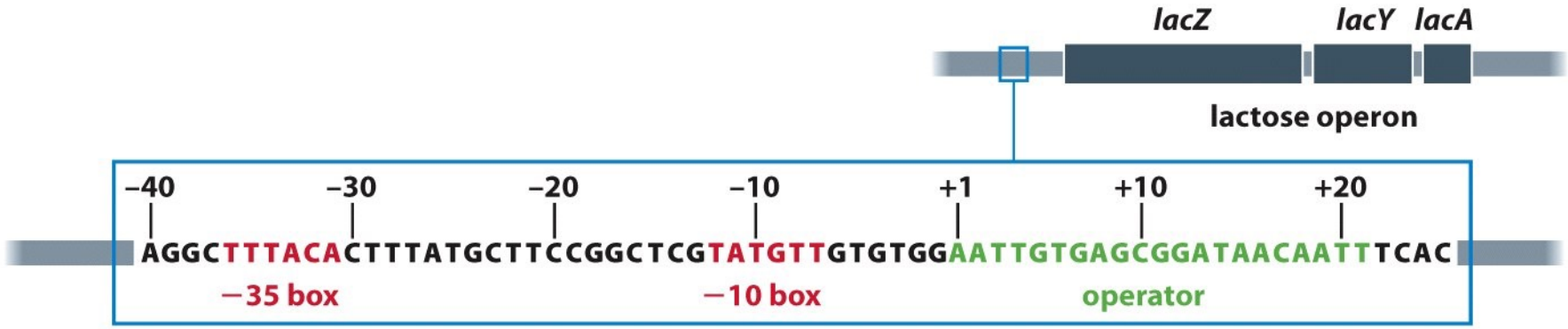

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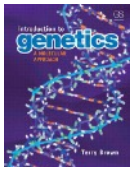

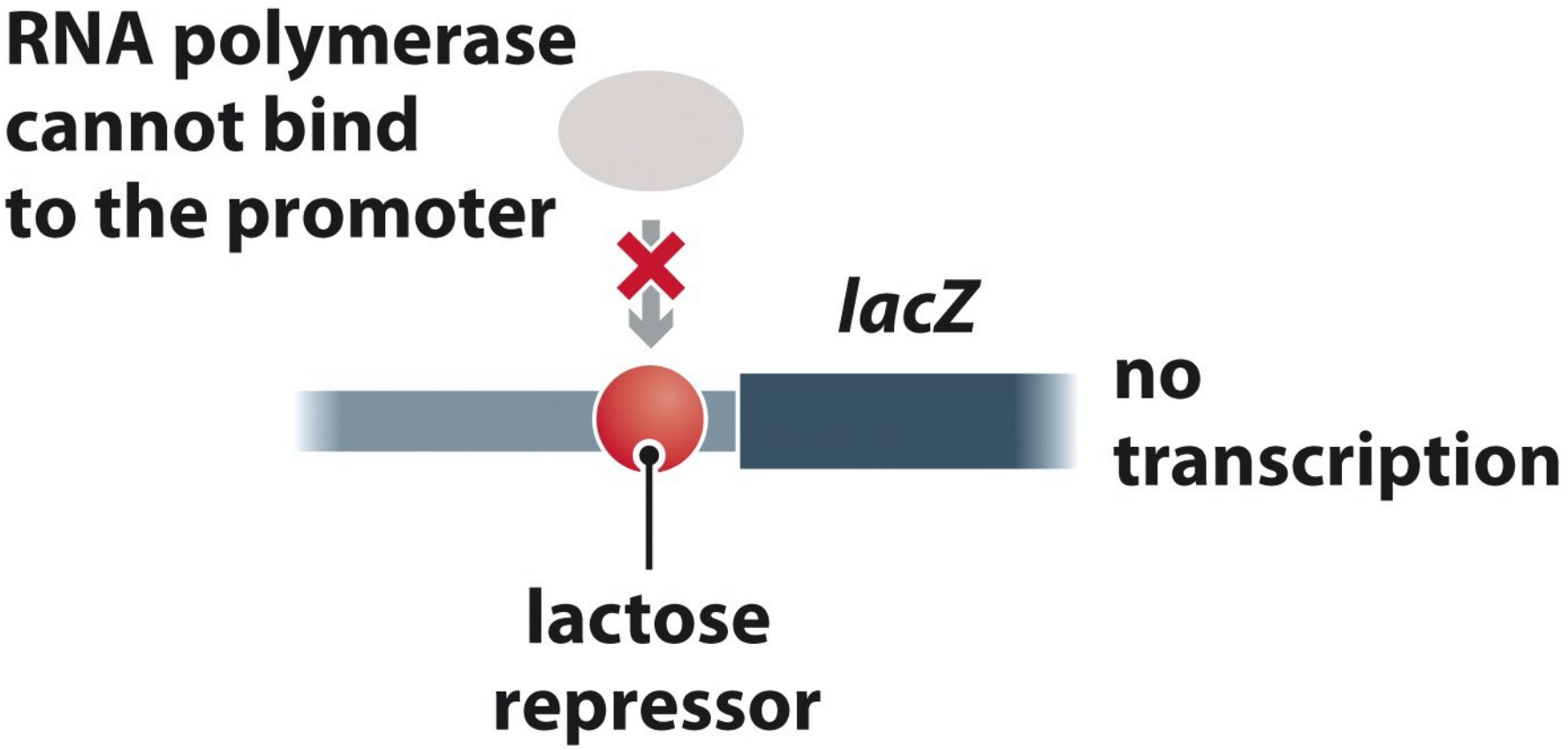

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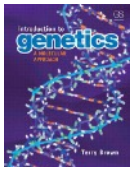

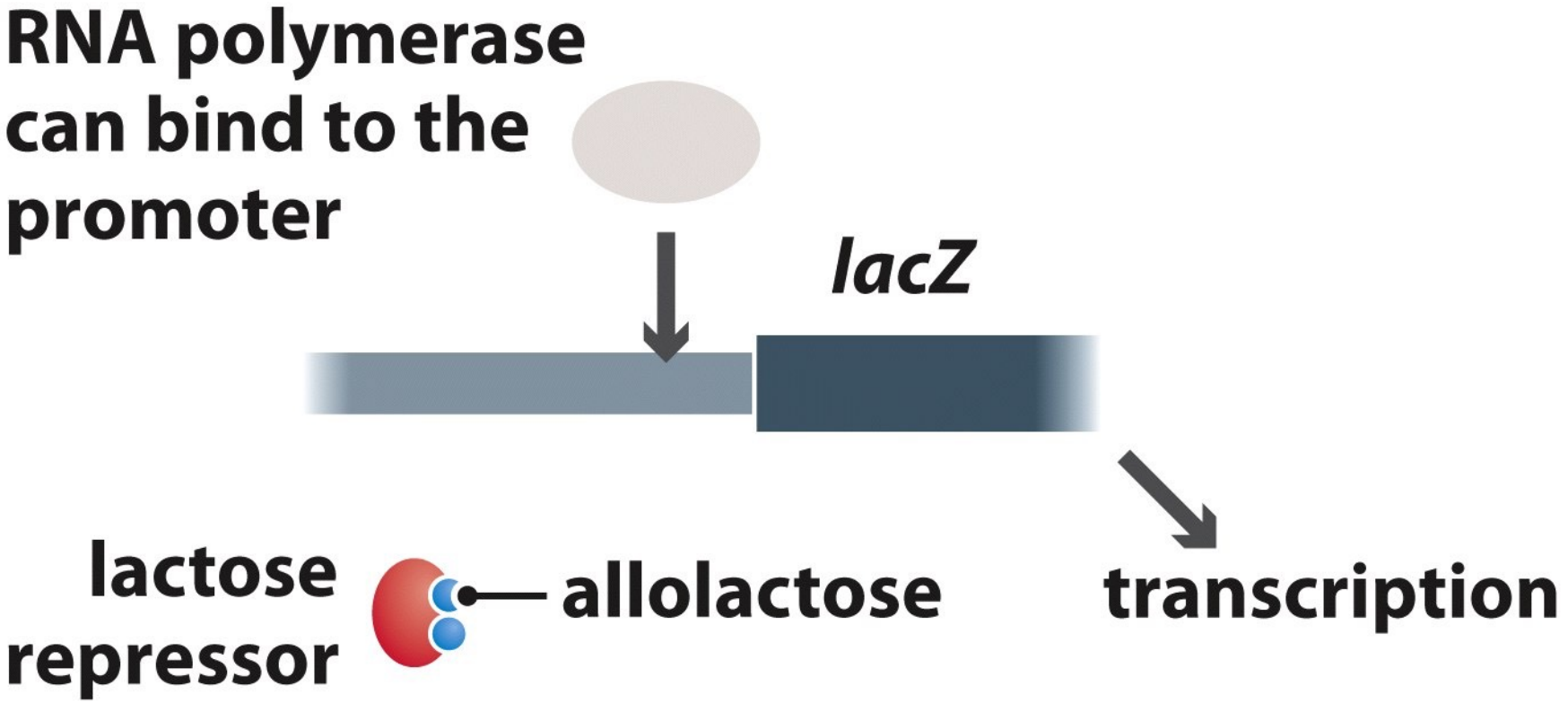

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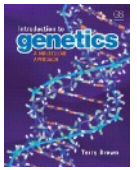

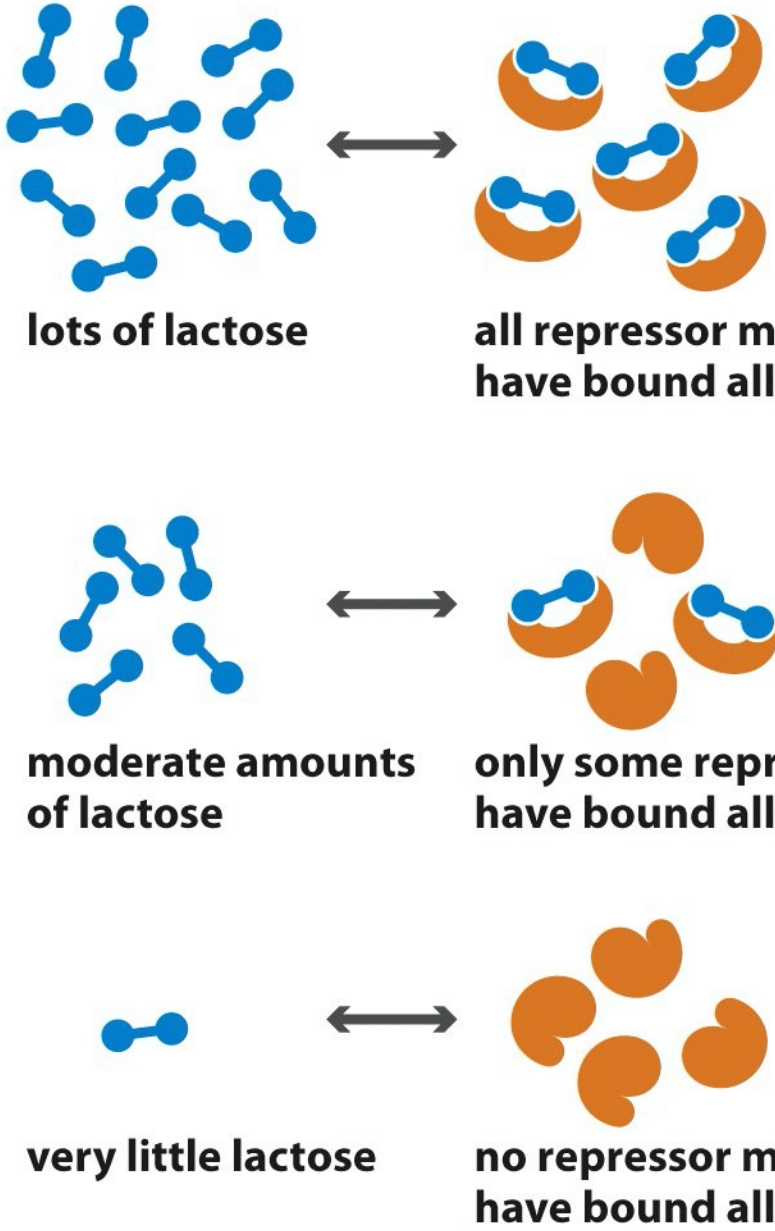

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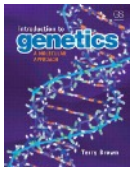

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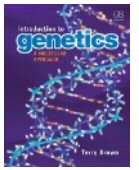

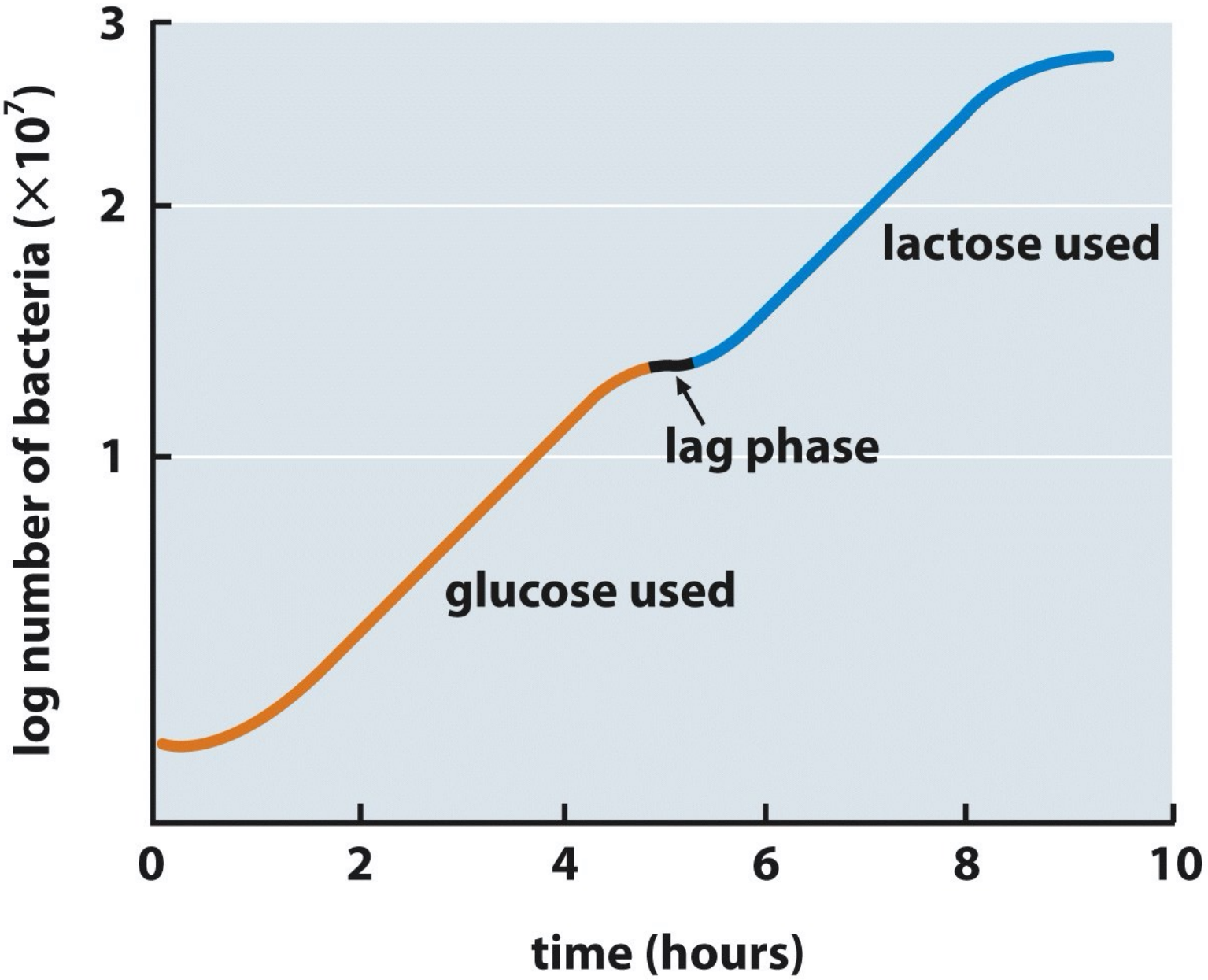

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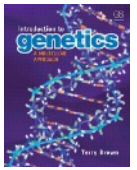
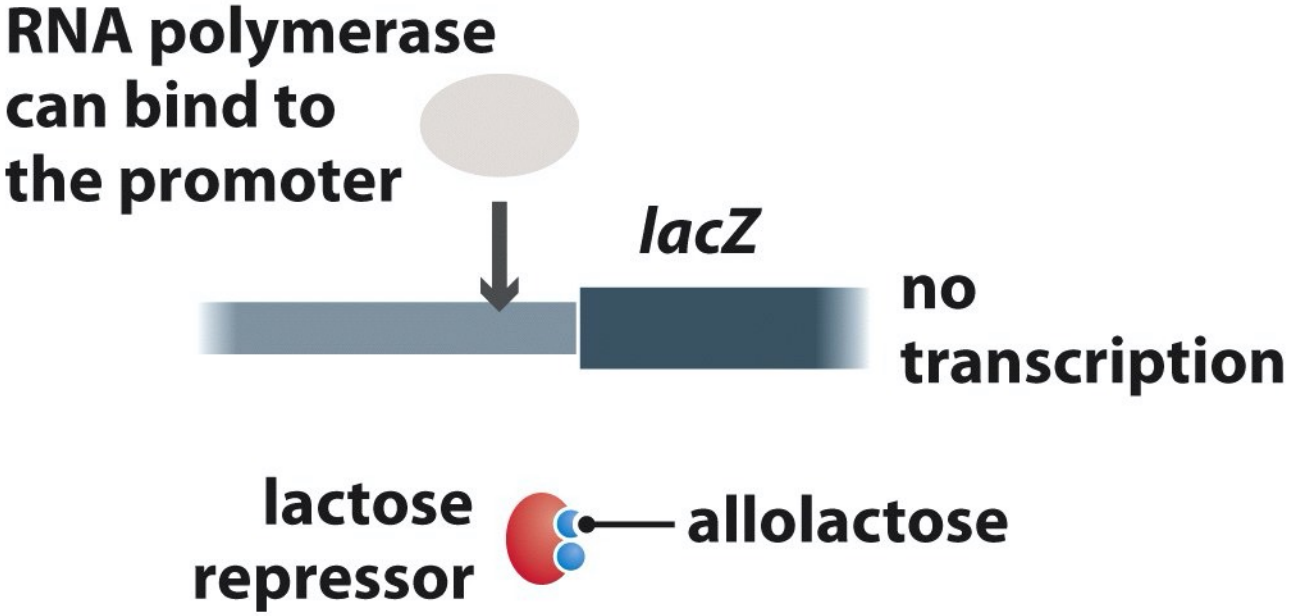


LACTOSE PRESENT
repressor–allolactose complex cannot attach to the operator



BUT…GLUCOSE ALSO PRESENT
no transcription occurs

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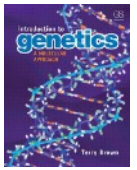
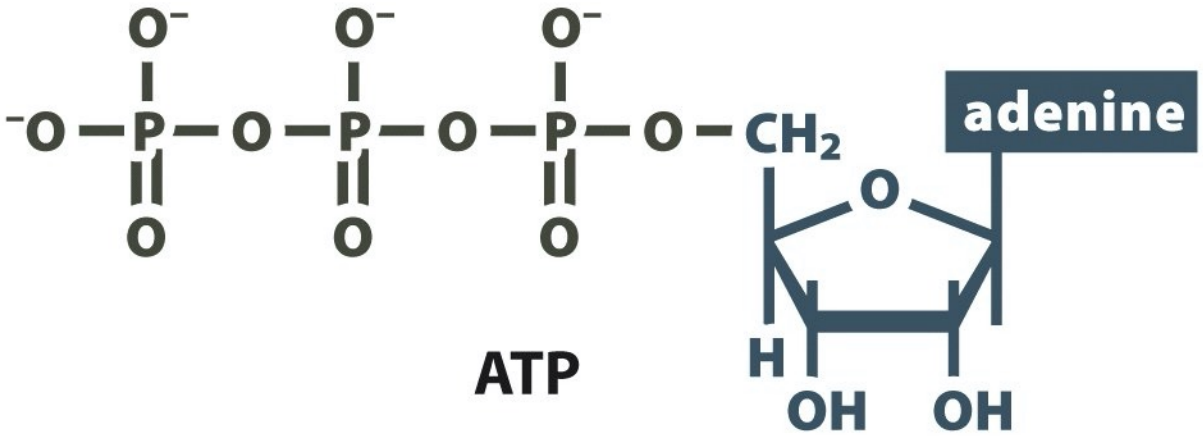
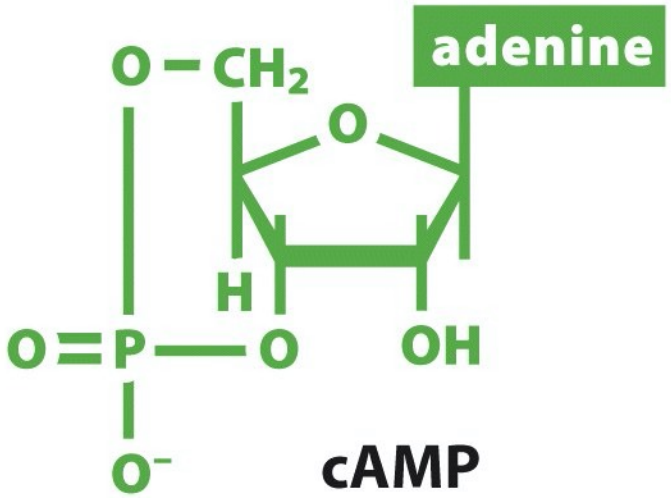




adenylate cyclase
inhibited by glucose via IIA^{Glc}



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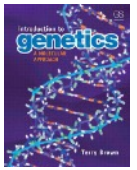

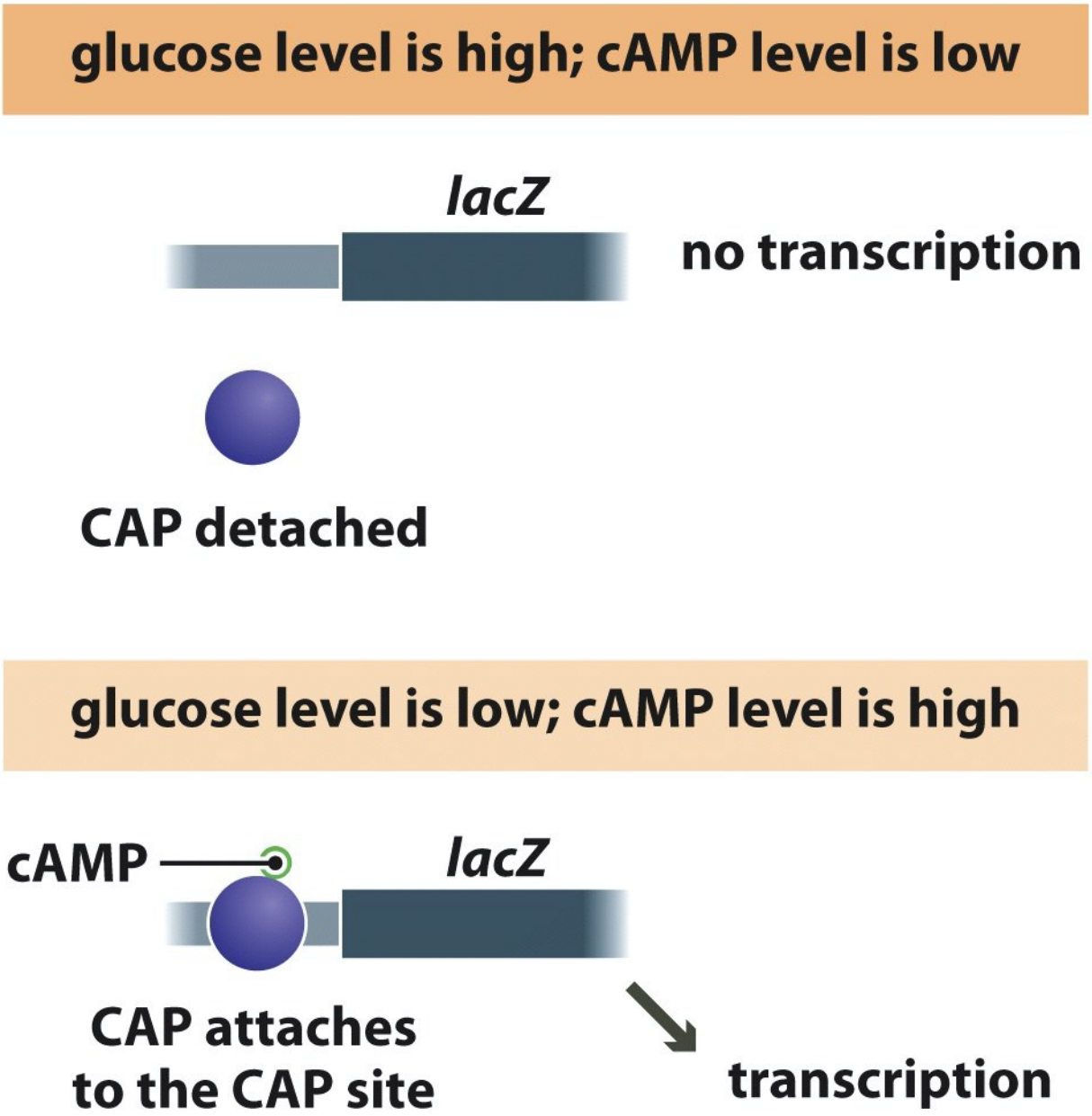

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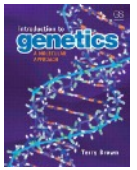
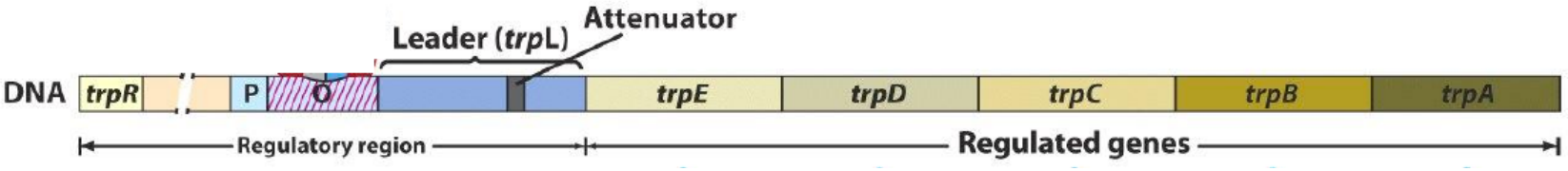


Repressible operon – Tryptophan operon

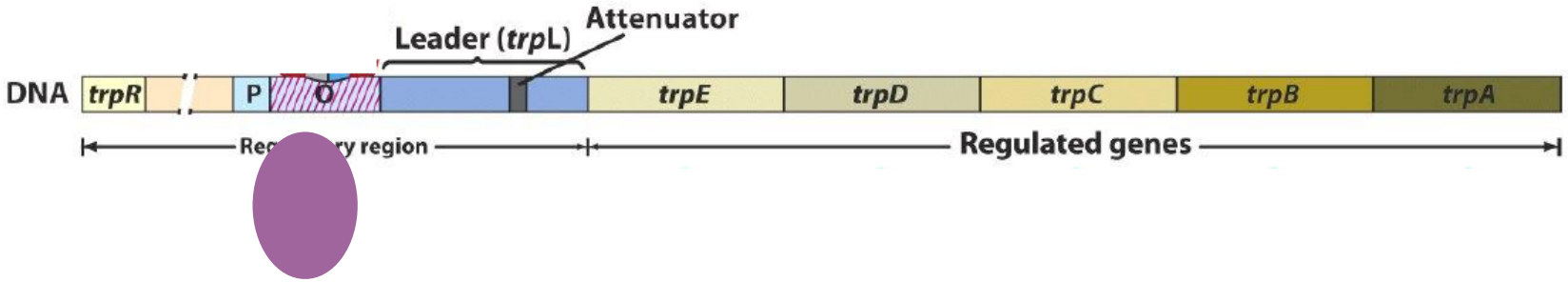
- The tryptophan operon (***trp* operon**) codes for the genes involved in the production of tryptophan amino acid.

- Upstream of the genes a shared promoter is used to transcribe the operon's genes.



Repressible operon – Tryptophan operon

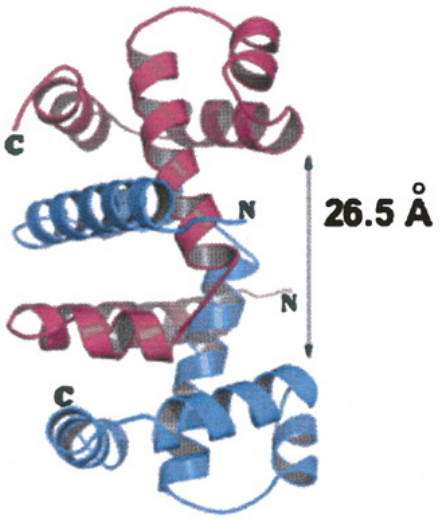
- Downstream of the operon's promoter, an operator region is located.
- Upstream of the operon, a repressor gene is located with its independent promoter and it is called ***trp* repressor**.



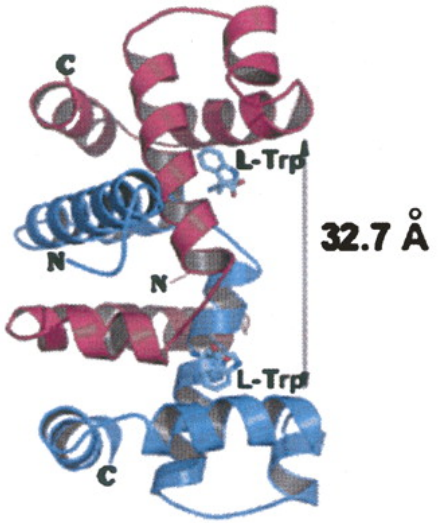
Repressible operon – *Trp* operon

- The tryptophan repressor is a helix-turn-helix regulatory protein.

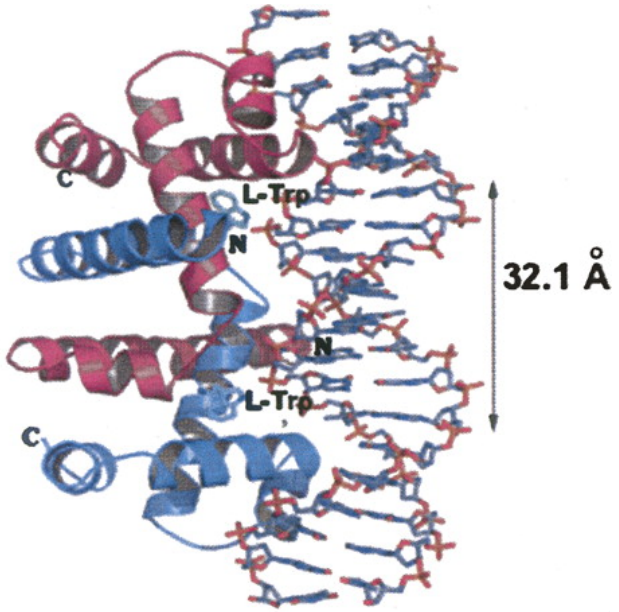
- The repressor has different shapes based on the substrate bound to it.



trp aporepressor
(no Trp)



trp repressor
(with Trp)

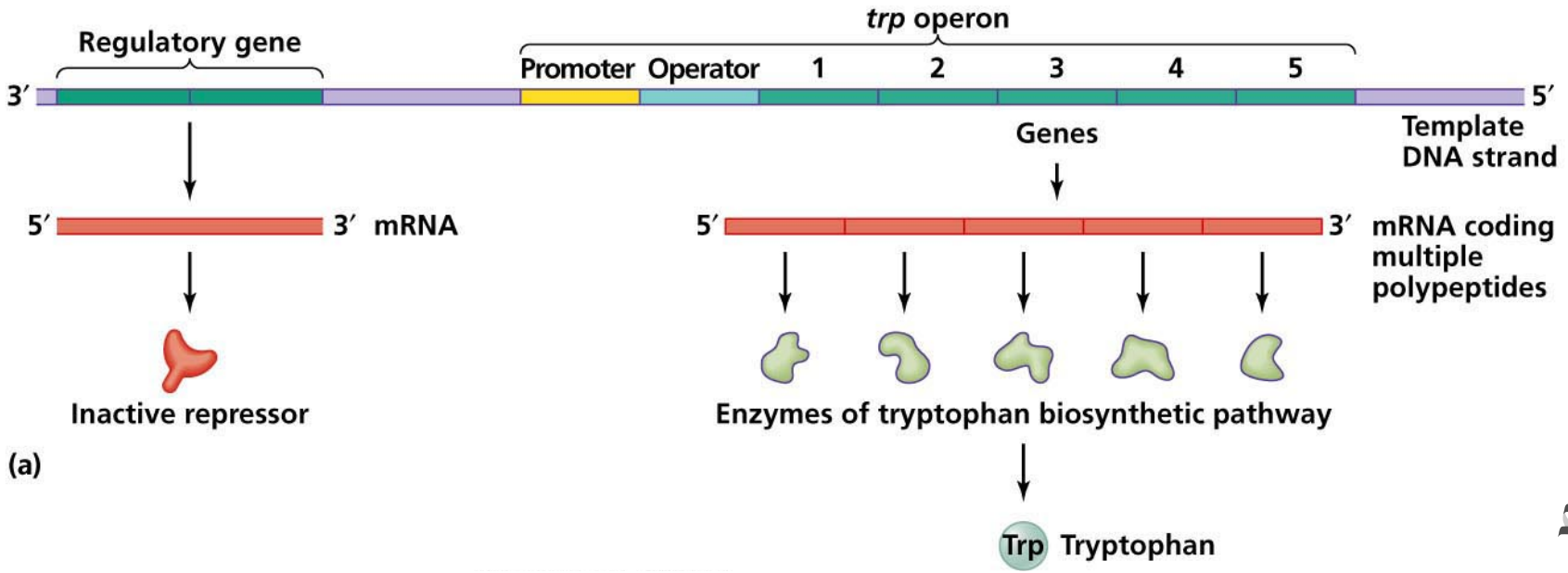


trp repressor-
operator complex

Repressible operon – *Trp* operon

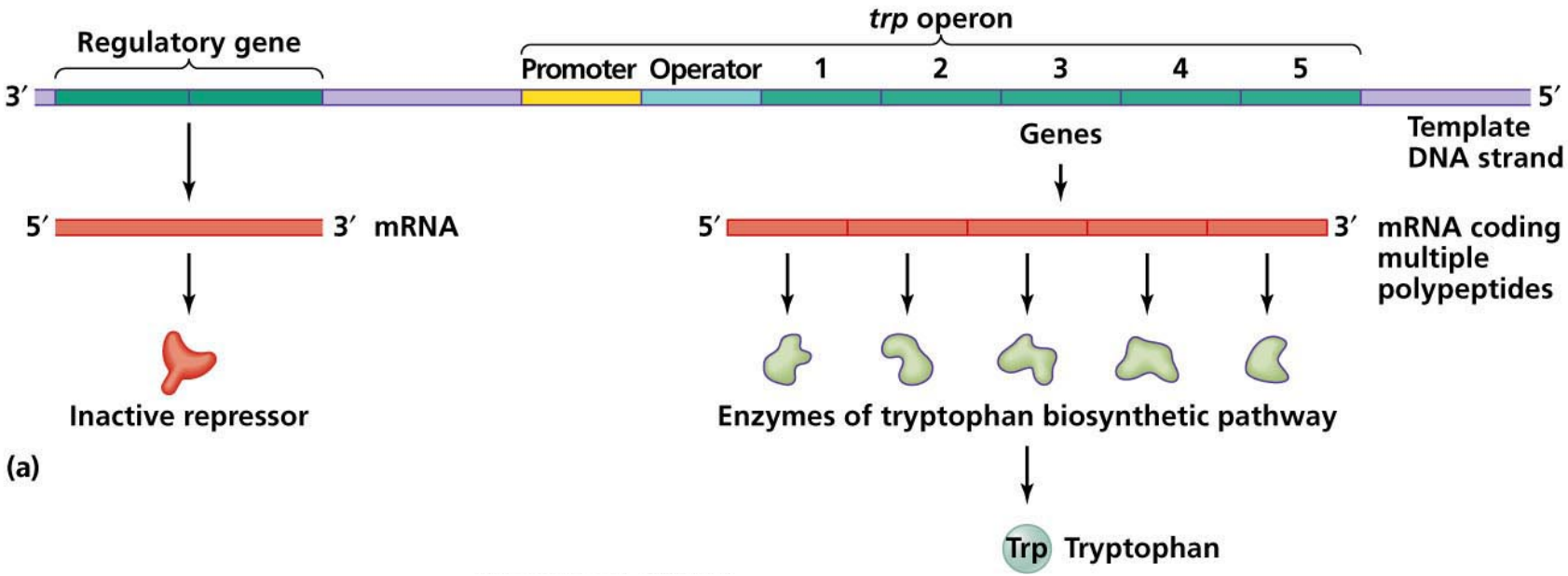
- The *Trp* repressor gets expressed in an **inactive** form.

- When the cell senses a depletion in tryptophan, the *Trp* operon gets activated and genes therein gets expressed.



Repressible operon – *Trp* operon

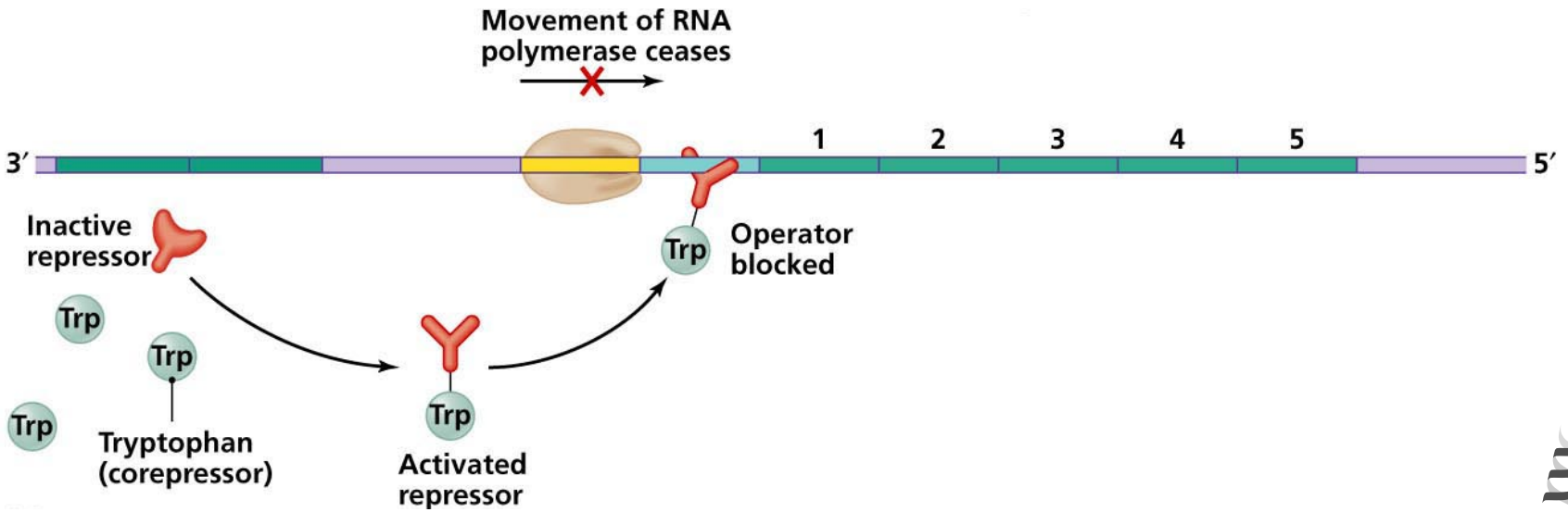
- The resulting enzymes make tryptophan.



Repressible operon – *Trp* operon

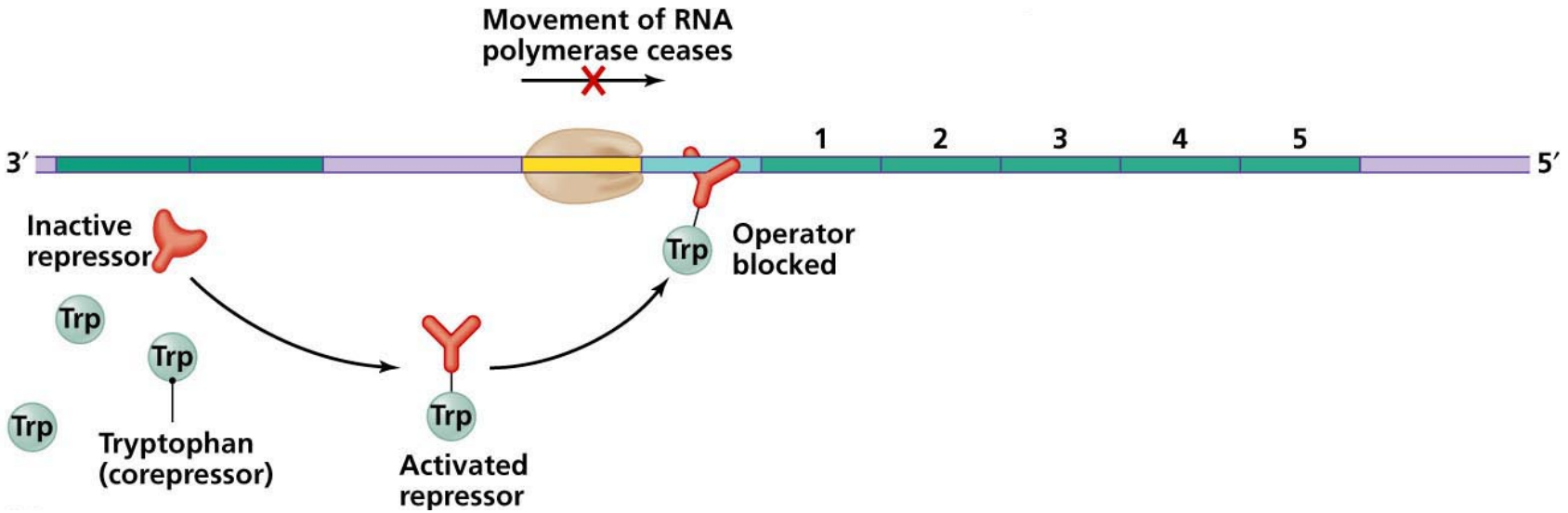
- When enough tryptophan is being produced, tryptophan binds to ***trp* repressor** protein.

- The binding of tryptophan to the repressor changes its shape and activates its repression abilities.



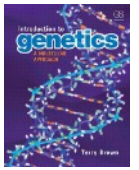
Repressible operon – *Trp* operon

- The activated ***trp*** repressor (repressor + tryptophan) blocks the expression of the *Trp* operon.



9.2 REGULATION OF TRANSCRIPTION INITIATION IN BACTERIA

- Four genes are involved in lactose utilization by *E. coli*
- The regulatory gene codes for a repressor protein
- Glucose also regulates the lactose operon
- Operons are common features in prokaryotic genomes



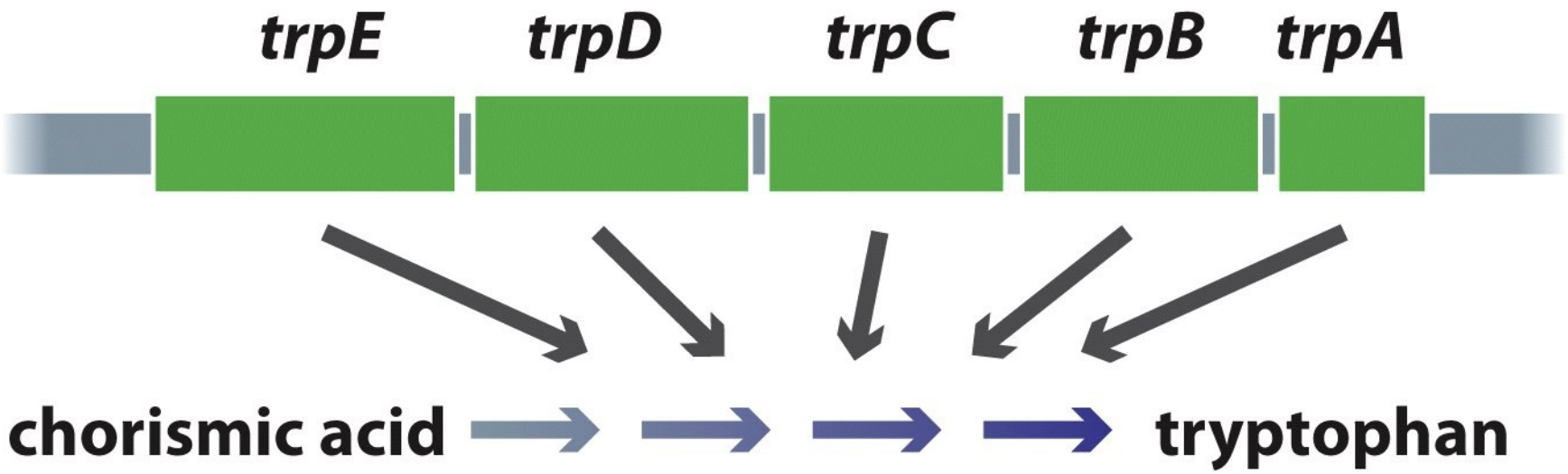
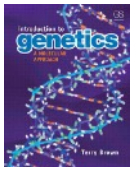


Figure 9.16 Introduction to Genetics (© Garland Science 2012)



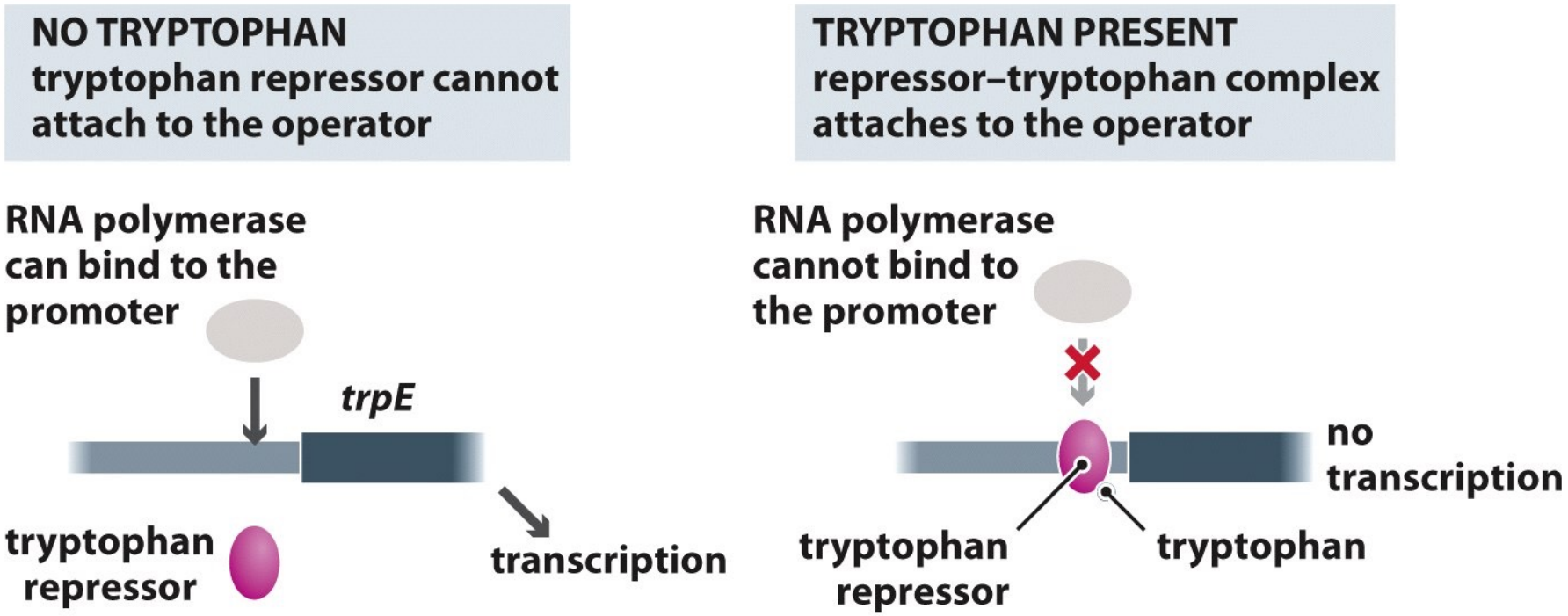
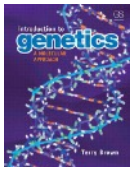


Figure 9.17 Introduction to Genetics (© Garland Science 2012)



Question

Why the *Lac* operon requires the presence of lactose to be activated?

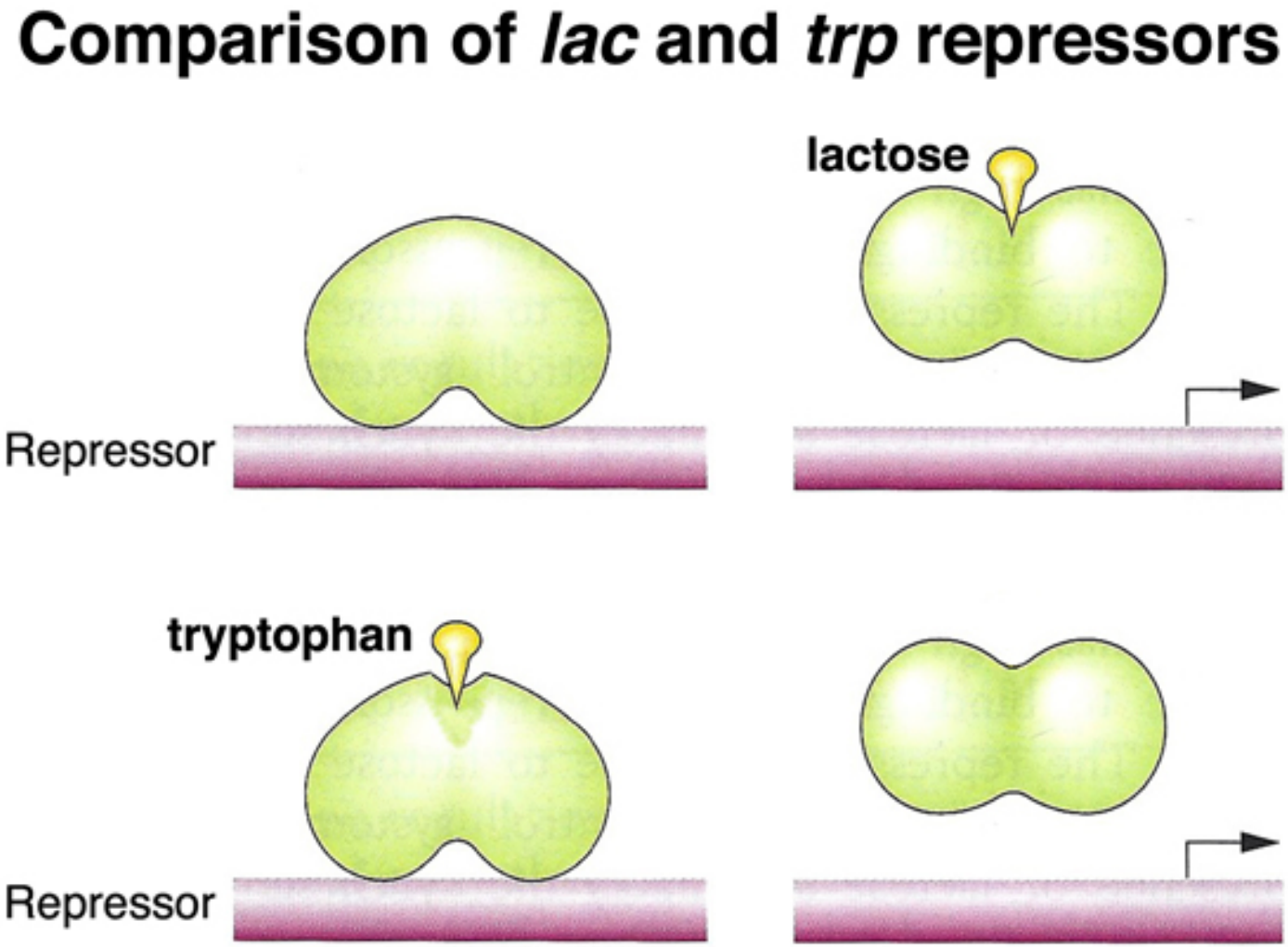
If we consider the *Lac* operon a nice car, is lactose acting like gas pedal or breaks?

Question

Why the *Trp* operon requires the presence of <u>sufficient</u> amounts of tryptophan to be deactivated?

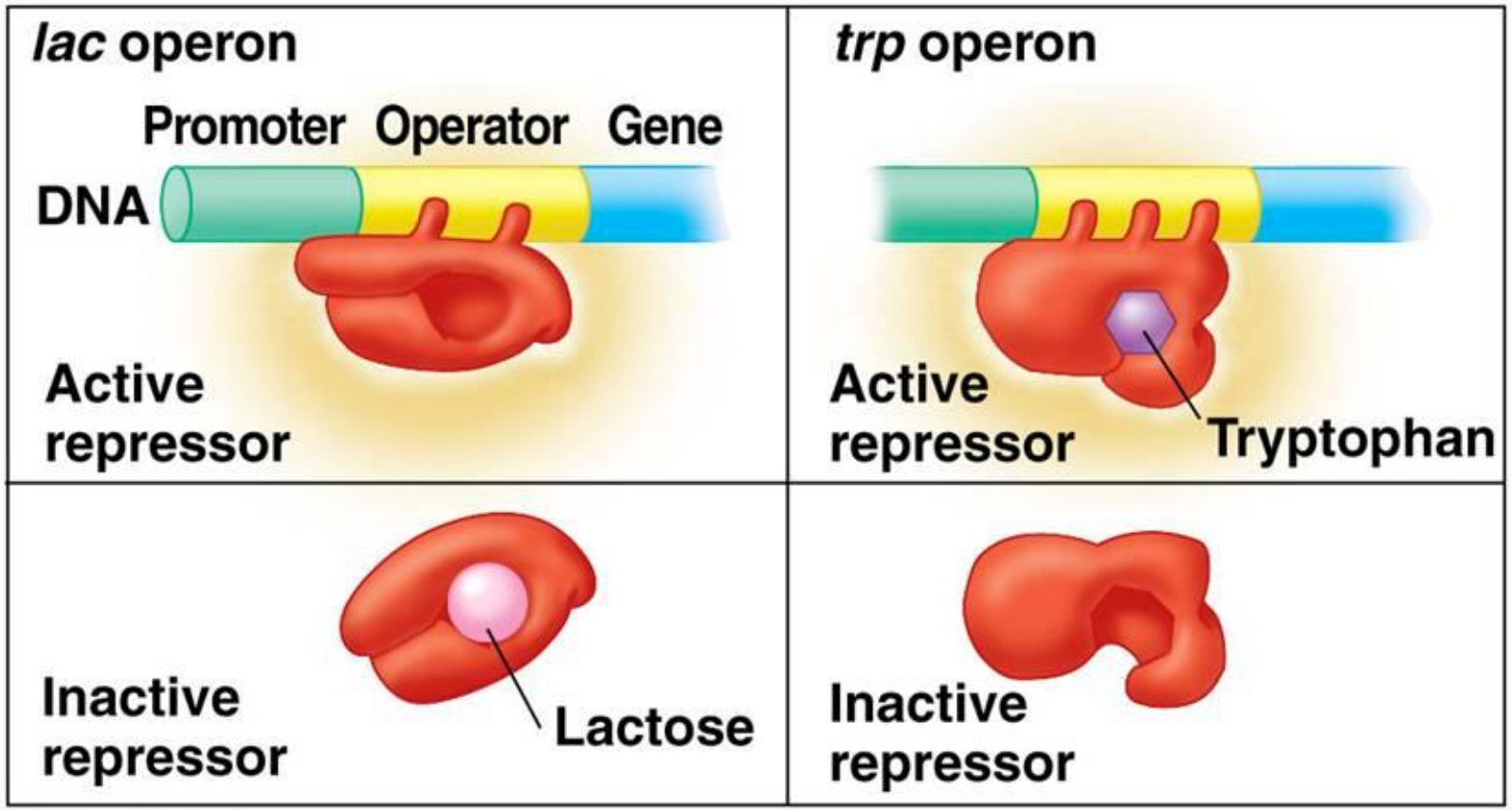
If we consider the *Trp* operon a nice car, is tryptophan acting like gas pedal or breaks?

Lac and *Trp* repressors



Question

When *Lac* repressor is active?
When *Trp* repressor is active?



To know

operon

Trp operon

Lactose operon

Helix-turn-helix

Repressible operons

Inducible operons

Lac repressor

Operator

Trp repressor

Polycistronic transcript

Tryptophan operon

Monocistronic transcript

Lac operon

Expectations

- You know operons in prokaryotes and their transcriptomic equivalent.
- You know the types of operons and why they exist.
- You know the function of the *Lac* and *Trp* operons.
- You know the difference between the *Lac* repressor and the *Trp* repressor.

For a smile