Regulation of Gene Expression in Bacteria

*Trp* operon

*Lac* operon

Two-component Regulatory system (PhoR/PhoB system)

Bacteria

Gene expression is highly regulated to adjust the cell’s enzymatic machineries and structural Components for environmental conditions

Synthesize only those proteins required for cell growth

~50% genes are clustered into operons and genes in the same operon are functionally related

How do bacteria cells respond to the environmental changes?

Change in

Nutrients

Temperature

Energy Sources

(a) Prokaryotes

*E. coli* genome

trp operon

Start site for *trp* mRNA synthesis

Start sites for protein synthesis

Translation

Proteins
How do bacteria cells respond to the environmental changes?

**Change in**
- Nutrients
- Temperature
- Energy Sources

**Advantages:**

**Disadvantages:**

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### The Lac Operon

When the bacterium is in an environment that contains lactose:  

\[ E. \text{Coli} \text{ bacteria needs three enzymes required for utilizing lactose.} \]

- **LacZ (beta-galactosidase):** Hydrolyzes the bond between the two sugars, glucose and galactose.
- **LacY (Lactose Permease):** This enzyme spans the cell membrane and brings lactose into the cell from the outside environment. (The membrane is otherwise impermeable to lactose)
- **LacA (Thiogalactoside transacetylase):** Transfers an acetyl-CoA to β-galactosides
**Promoter**---determines the initiation rates

- **Strong promoter**
- **Weak promoter**

Lac operon has a weak promoter.

**Transcription is repressed**

In low lactose and high glucose environment, *E. coli* uses glucose

The Lac repressor protein binds to an operator that overlaps the promoter at the start site.

The repressor protein is a tetramer of identical subunits.

In the presence of both lactose and glucose, *E. coli* uses glucose first.

When most of glucose is used up, then lactose is used.

Lactose binds to the repressor

Repressor has two binding sites: operator and lactose

Binding of lactose changes conformation of the repressor such that it weakens the DNA binding capacity.*

Release of the repressor from the DNA allows binding of RNA polymerase at the promoter to initiate transcription.

When glucose is used up, *E. coli* is ready to use lactose.
Does lactose bind to free repressor to upset an equilibrium or directly to repressor bound at the operator?

Transcription is activated

Sigma factor controls binding to DNA

E. Coli has several sigma factors.

RNA polymerase encounters a dilemma in reconciling its needs for initiation with those for elongation.

Initiation----tight binding only to promoters

Elongation----requires close association with all sequences that the RNA polymerases encounter during transcription

σ70 is used for general transcription, and the other sigma factors (σ32, σ54, σ28) are used under special conditions.

σ70 binds directly to DNA upon association with RNA polymerase.

(exception is σ54, which can bind to DNA independent of RNA polymerase)
$\sigma^{54}$ RNA polymerase requires other activators to bind to sites that is distant from the promoter.

Similar to Promoters and Enhancers (Eukaryotic regulators)

Enhancers can be more than a kilobase away from a start site. NtrC binding at the enhancer allow formation of a DNA loop between the two binding sites (NtrC and $\sigma^{54}$ RNA polymerase).

**Two-Component Regulatory Systems**

1. Phosphate concentration change
2. Activation of the PhoR kinase domain
3. Phosphorylation of PhoB
4. Activation transcription by activated PhoB
5. Increase in expression of genes that help cells to cope with low phosphate conditions