Prokaryotic Gene Expression  (Learning Objectives)

1. Learn how bacteria respond to changes of metabolites in their environment: short-term and longer-term.
2. Compare and contrast transcriptional control of bacterial biosynthetic and breakdown pathways and their control mechanisms.
3. Explain the organization of bacterial genomes and the molecular components of their regulation: operon, structural genes, promoter, operator, repressor and co-repressor, inducer, activator, and activator binding site.
4. Compare and contrast the molecular mechanism (on/off switches) controlling expression of repressible and inducible operons.
Review of Basic concepts!

• Living cells are efficient systems that do not waste energy or resources
  *Live within their means- no banking or credit*

• Biochemical pathways: biosynthetic or breakdown

• Feedback inhibition and organisms response to their environment

• A protein is produced only when a gene is present and transcribed

• A transcription unit (gene) consist of RNA coding region and a promoter region

• Conformation of an allosteric protein can be modified impacting its interaction with other biological molecules
Metabolism and Metabolites

Metabolism
Set of chemical reactions that synthesize or breakdown molecules

Metabolites
Substances produced or take part in cellular metabolism
Control mechanisms of biosynthetic Pathways in Bacteria

In response to Environmental changes

- Short-term
  Adjust the activity of enzymes of existing pathways (feedback inhibition).

- Longer-term
  Regulate gene transcription.
Control of Tryptophan Biosynthesis in Bacteria

- Feedback inhibition
- Turning off specific gene expression (transcription)
Operons are gene clusters that share the same promoter region.
Genetic Components of Bacterial Operons and their molecular control

- **Structural genes** transcribed as one long mRNA molecule (polycistronic mRNA)

- **Promoter** region-RNA polymerase binding

- **Operator** region “on-off switch” between the promotor and the first gene

- **Regulatory gene** coding for a specific allosteric repressor protein
On-Off switch of Transcription

• The **operator** DNA region- binding site for the **repressor** protein

• Operons have different operator sequences

• Switch is **off** - repressor can bind to the operator sequence (active repressor)

• Switch is **on** - repressor cannot bind to the operator (inactive repressor)
### Transcriptional Control of Bacterial Operons

<table>
<thead>
<tr>
<th>Operons of biosynthetic (anabolic) pathways</th>
<th>Operons of degradation (catabolic) pathways</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Normally turned on but can be turned off or shut down</td>
<td>• Normally turned off but can be turned on</td>
</tr>
<tr>
<td>• Repressible operons (<em>trp</em> operon)</td>
<td>• Inducible operons (<em>lac</em> operon)</td>
</tr>
</tbody>
</table>
Both repressible and inducible operons demonstrate negative control because active repressors can only have negative effects on transcription.
Single Switch

Repressor-mediated control

Inducible Operon: *lac operon*
State in absence of lactose

Repressible Operon *trp operon*
State in absence of tryptophan
Single Switch

Activator-mediated control
Expression induced by an active activator
Example, *Arabinose* operon
Molecular Controls of Prokaryotic Gene Expression

A. Single Switch

1. Repressor-mediated control

2. Activator-mediated control

B. Combination Switch
Activator & repressor-mediated control
Tryptophan operon: An example of a repressible operon

http://highered.mcgraw-hill.com/sites/0072437316/student_view0/chapter18/animations.html#

(a) Tryptophan absent, repressor inactive, operon on
Role of Tryptophan as a co-repressor

Impact of level of tryptophan on
- conformation of repressor
- state of *trp* operon expression
Human Connections

<table>
<thead>
<tr>
<th>Lactose</th>
</tr>
</thead>
</table>
| ➢ Lactose intolerance  
  • Lactase deficiency  
  • Fermentation of bacteria inhabiting intestines |
**lac Operon**

- Inducible operon - presence of lactose
- Has a double combination switch-only when glucose is absent
Combination Switch
Activator & repressor-mediated control

Dual control
Expression induced by an active activator and an inactive repressor
Example. lac operon
lac Operon: An Inducible Operon

- Usually on or off?
- Repressor is in active or inactive conformation?
- Repressor bound or unbound to lac operator?

(a) Lactose absent, repressor active, operon off
Role of Allolactose as inducer of $lac$ operon expression or its active transcription

Virtual Cell Animation Collections
http://vcell.ndsu.edu/animations/lacOperon/movie-flash.htm
Combination Switches of the \textit{lac} operon

Complex control of \textit{lac} operon

- Bacteria prefer to use glucose
- Other sugars are used only when glucose is absent
- An additional molecular mechanism is necessary

Combination of Switches

http://highered.mcgraw-hill.com/sites/0072437316/student_view0/chapter18/animations.html#