Mc Graw Hill Education

#Microbiology

Prescott's MICROBIOLOGY

ELEVENTH EDITION

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Chapter 14

Regulation of Bacterial Cellular Processes

Common Regulatory Mechanisms in Bacteria

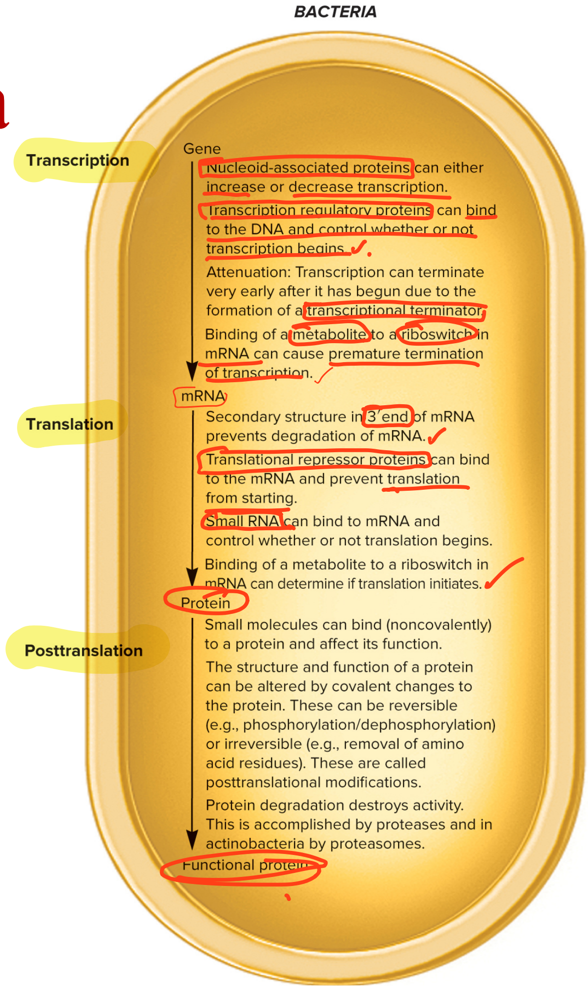
Regulation of gene expression.

- Transcription initiation.
- Transcription elongation.
- Translation.

Alter activity of enzymes and proteins.

- Posttranslational.

Three domains of life differ in genome structure and regulatory mechanisms used.



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Regulation of Transcription Initiation

Replacement of degraded enzymes.

- Constitutive genes—housekeeping genes that are expressed continuously by the cell.
- Inducible genes—genes that code for inducible enzymes needed only in certain environments (such as b-Galactosidase).

Inducible Genes β-Galactosidase Enzyme

Inducible enzyme functions in a catabolic pathway.

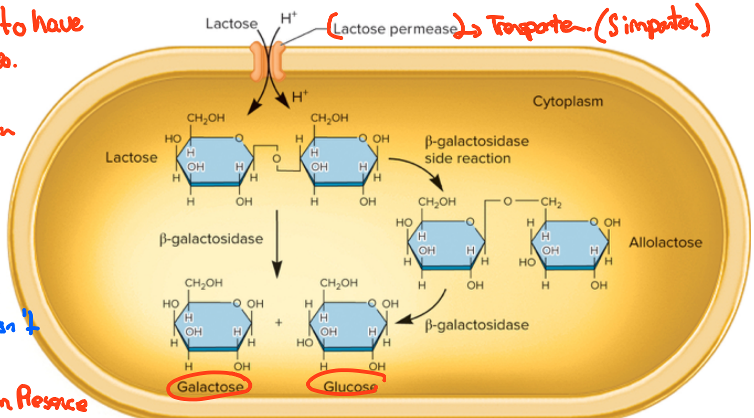
Inducible enzymes are present only when their substrate (inducer-effector molecule) is available.

β-galactosidase catalyzes hydrolysis of lactose into galactose and glucose. Involved in degrating lactos.

In Order for the Bacteria to Metabolise Any type of sugars → it's a must to have specific enzymes.

*In order to Start the mechanism Lactose must enter the cell.
↓
once lactose is inside the cell the cell Degragate it in the presence of B.galactosidase → So if the cell doesn't Have the lactose
So synthesis of B.galactosidase Happens in Presence of Inducer (Lactose) → if it's absence cell doesn't have to synthesis it.

Lactose (Disaccaride) → Degragate into → Glucose and Galactose.



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→ Inducible Genes are Regulated → (Synthesised at Certain Conditions).
*We Have another type of Regulated Genes
↓
Repressible Genes.

Repressible Genes

→ Involved in Biosynthitic Pathway.
→ In the Inducible Genes → Catabolic
But in the Repressible → Anabolic Pathway
تبني

Enzymes that function in biosynthetic pathways are products of repressible genes.

Generally these enzymes are always present unless the end product in the biosynthetic pathway is available.

* Repressible genes → Anabolic pathways (Bulding up molecules)
* triptophane is an aminoacid → if triptophane was in the media → so it wont synthesis it
  → if the media was not supported with triptophan → cell will synthesis it
* So repressible genes are genes that usually synthesis all the time unless the product was already in the media (synthesis enzymes the support the production of triptop

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Control of Transcription Initiation by Regulatory Proteins

Induction and repression occur because of the activity of regulatory proteins and DNA-binding domains.

These proteins either inhibit transcription (negative control) or promote transcription (positive control).

Negative Transcriptional Control

Binding of regulatory protein at DNA regulatory site inhibits initiation of transcription.

- mRNA expression is reduced.

inhibition.

Repressor proteins.

- Exist in active and inactive forms.
- Inducers/corepressors alter activity of repressor by binding.

* if we have Inducer the Repressor → Inactive (can't Bind to the operator).

Active → No Binding to Inducer (No Inducer)

Positive Transcriptional Control

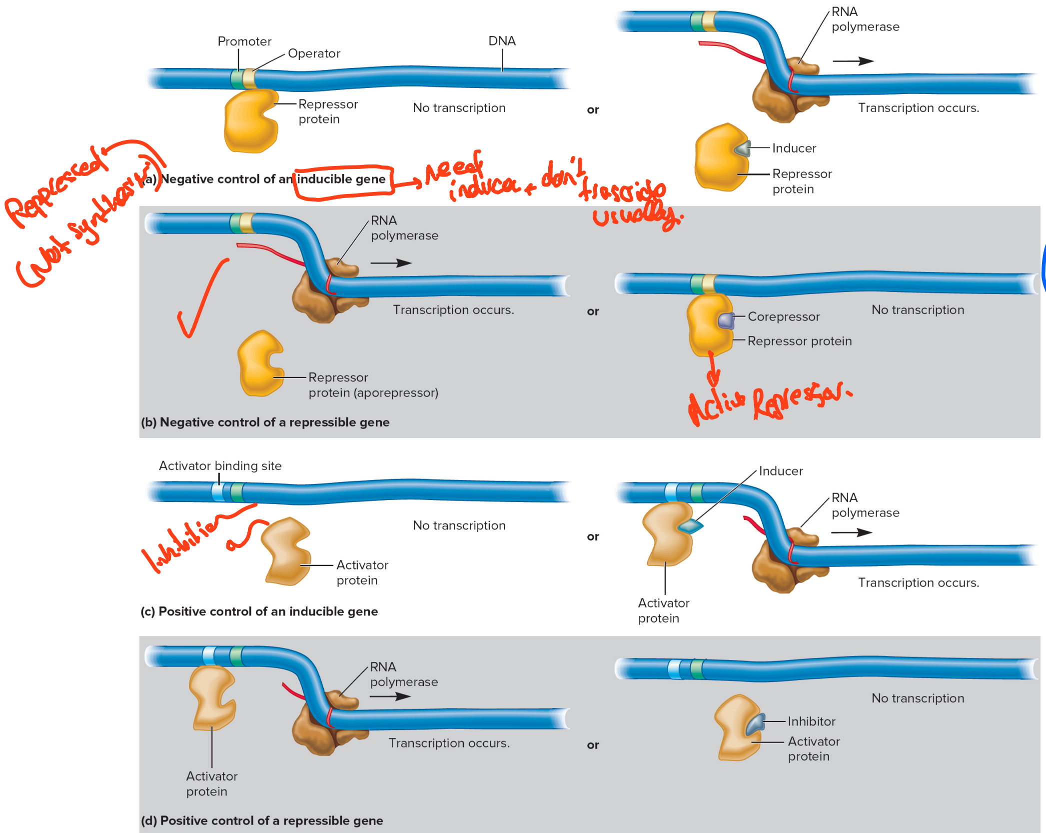
Binding of a regulatory protein at a regulatory region on DNA promotes transcription initiation.

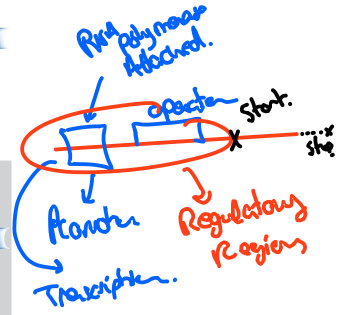
- mRNA synthesis is increased.

Activation.

- Inactive protein is activated by inducer.
- Active protein is inactivated by inhibitor.

Examples of Transcriptional Control





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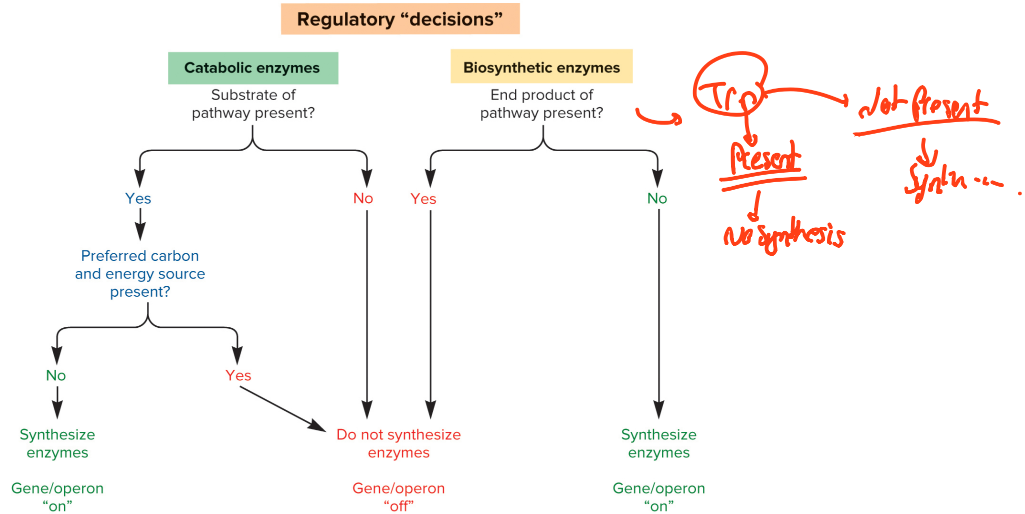
Regulatory decision.

"Decision" Process in Gene Expression

Enzymes of catabolite pathway only needed (increased mRNA synthesis) when preferred substrate is available.

Enzymes not synthesized when substrate absent.

Efficient use of energy and materials.



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Negative Control of Lactose (*lac*) Operon

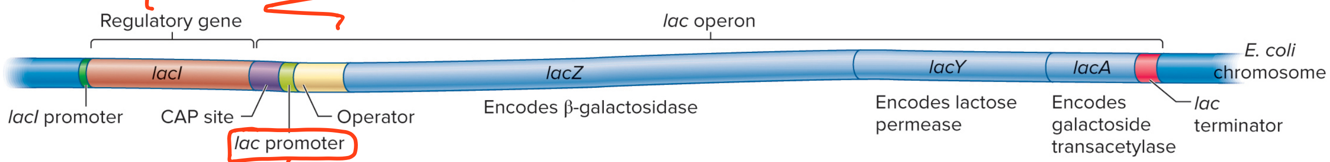
group of genes that Are Regulated by 1 Promoter

Inducible genes

- Three structural genes coding for lactose uptake and metabolism
- *lac* repressor (*lac*I) binds operator, inhibits transcription

Enzymes normally not produced unless lactose present

Repressor the transcript



Transcribe LacZ / LacY / LacA

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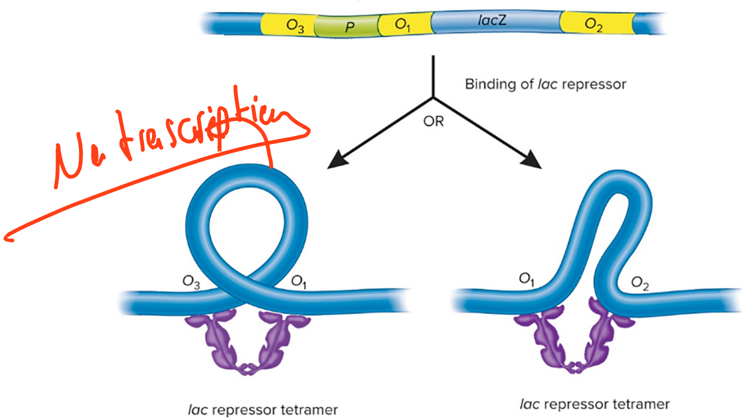
lac Repressor

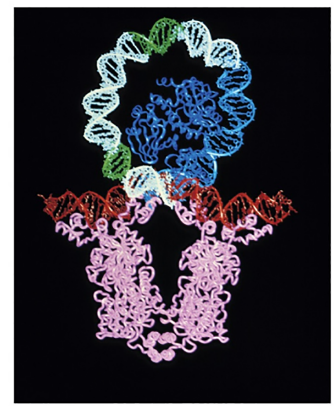
Tetramers of repressor form and bind to three operator sites (O1, O2, O3).

Bends DNA, prevents RNA polymerase from accessing promoter

Presence of allolactose binds repressor—no longer binds operator



(a) DNA loops generated by binding of the *lac* repressor



(b) *lac* repressor bound to O_1 and O_3 (red)

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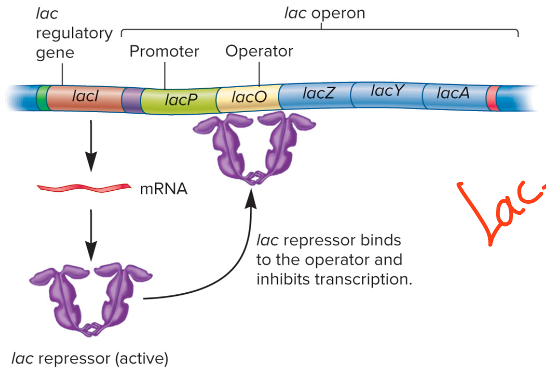
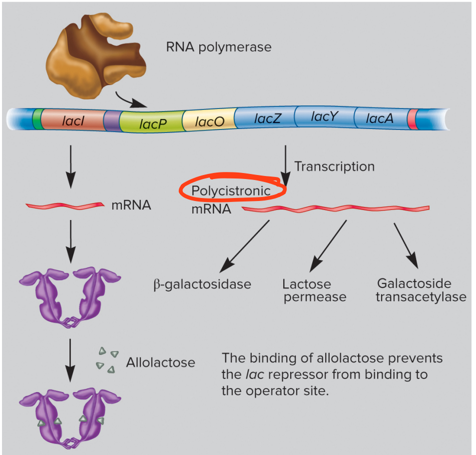


(a) No lactose available



(b) Lactose present

Regulation of *lac* Operon by *lac* Repressor

lac → inducible

Regulated by catabolite activator protein (CAP).

Activator → Proteins can bind

- Regulates in response to presence or absence of glucose.
- Allows for preferential use of glucose.

initiate trans of operon

Attached with CAP

Monocistronic

CAP is Active when Glucose ↓ ↑cAMP

Function of Adenylate cyclase.

AMP to → cAMP

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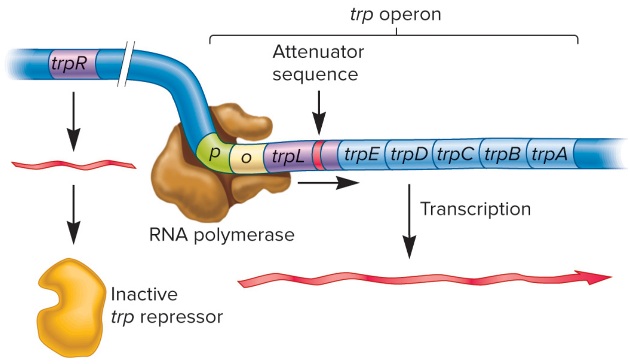
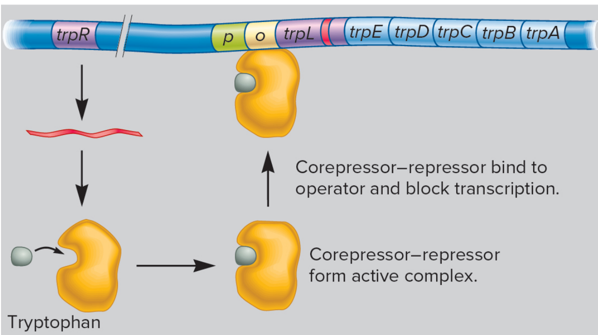
The Tryptophan (*trp*) Operon



(a) Low tryptophan levels, transcription of the entire *trp* operon occurs



(b) High tryptophan levels, repression occurs

Consists of 5 structural genes which code for enzymes needed to synthesize tryptophan.

Negative transcriptional control of repressible genes by *trp* repressor.

Operon only functions in the absence of tryptophan.

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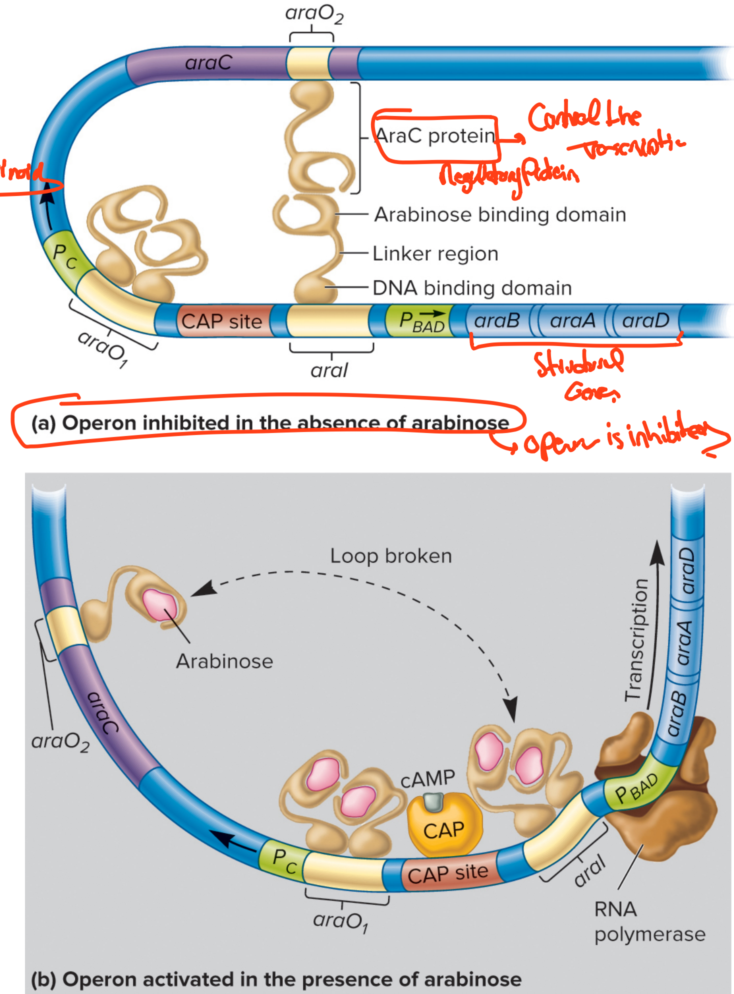
The Arabinose (*ara*) Operon

→ Involved in the degradation of arabinose

Transcriptional control by a protein (AraC) that acts both positively and negatively

- Activity depends on environmental conditions
- Inactive when arabinose present
- Active when arabinose absent



(a) Operon inhibited in the absence of arabinose

(b) Operon activated in the presence of arabinose

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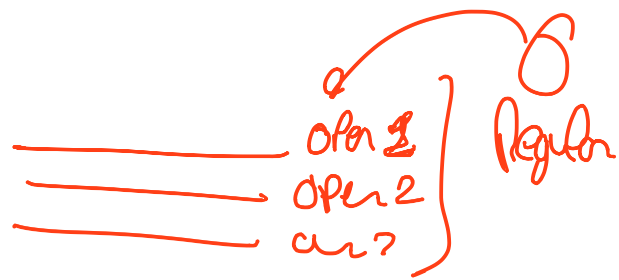
Global Regulatory Systems

Regulatory systems that affect many genes, operons, and pathways simultaneously.

Important for bacteria since they must respond rapidly to wide variety of changing conditions.

Regulon—genes or operons controlled by a common regulatory protein.



Mechanisms Used for Global Regulation

Global regulatory systems often use many types of regulation such as:

- Two-component signal transduction systems.
- Phosphorelay systems.
- Alternate sigma factors.
- Second messengers.

Two-Component Signal Transduction and Phosphorelays

Many genes and operons are turned on or off in response to environmental conditions.

- The regulatory proteins involved are part of a two-component signal system which links external events to regulation of gene expression.

Two-Component Signal Transduction Systems

Found in all three domains of life.

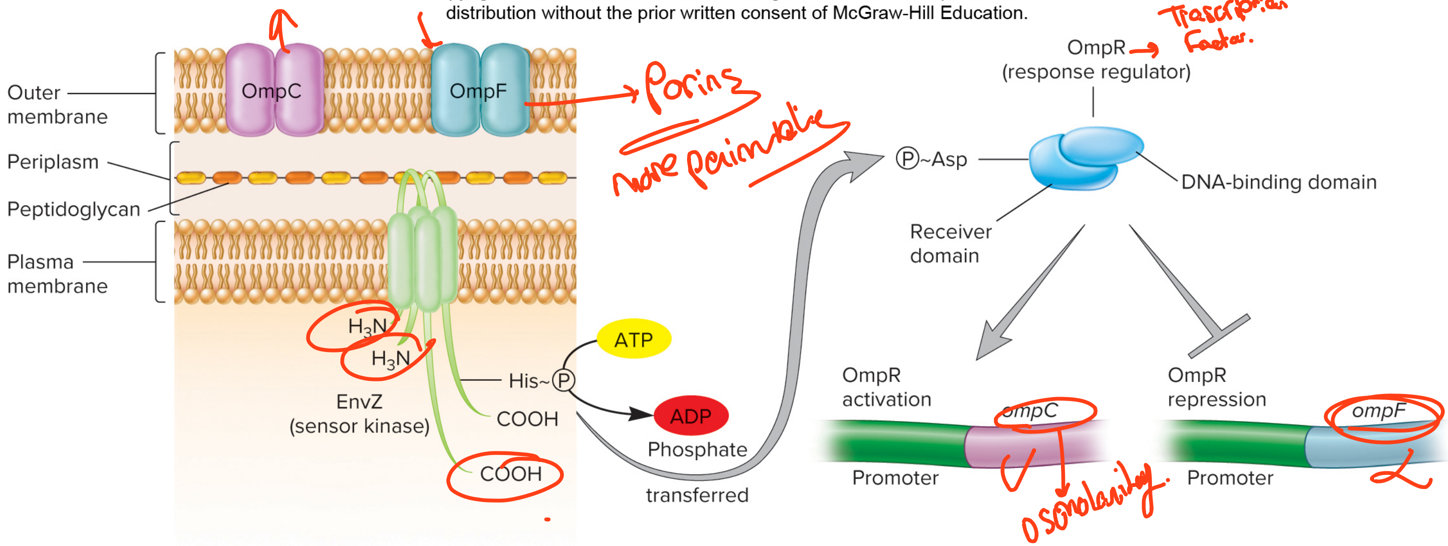
Two proteins govern pathway:

- Sensor kinase—extracellular receptor for metabolite; intracellular communication pathway.
- Response regulator—activated by sensor kinase .

Some response regulators form homodimers that bind to DNA:

- Activator—enhances transcription needed.
- Repressor—inhibits transcription unless needed.

Regulation of Porin Proteins by a Two-Component Signal Transduction System



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Phosphorelay System of Porin Proteins

Env Z (sensor kinase).

- Autophosphorylates in high osmolarity.

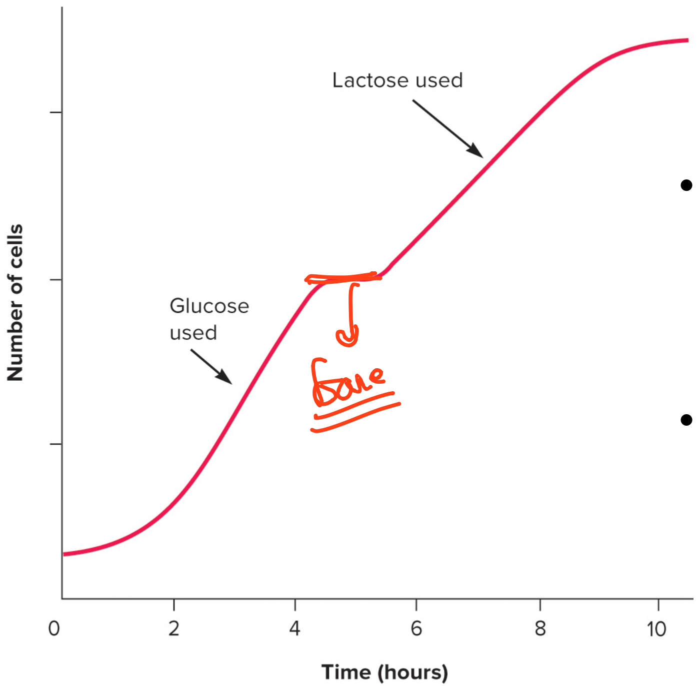
OmpR (response regulator).

- Phosphorylated and regulates transcription.

Once OmpR is phosphorylated, it regulates transcription so that *ompF* is repressed and *ompC* is activated.

- OmpC is smaller porin protein—lower levels of diffusion.
- Omp F is larger porin protein—allows more diffusion of solutes.

Catabolite Repression



Regulation of transcription by both repressors and activators.

Diauxic growth.

- A biphasic growth pattern—preferential use of one carbon source over another when both are available in environment
- Lag occurs—after preferred substrate is exhausted, growth resumes using the second carbon source.

Catabolite repression plays a role in this pattern of growth.

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Quorum Sensing

Cell-to-cell communication mediated by small signaling molecules such as N-acyl-homoserine lactone (AHL).

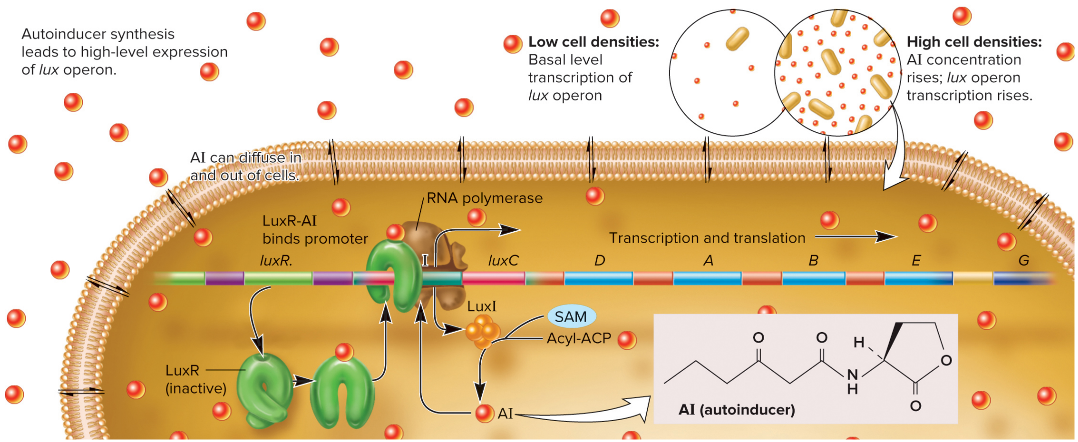
Couples cell density and intercellular communication to transcription regulation.

Plays an essential role in the regulation of genes whose products are needed for the establishment of virulence, symbiosis, biofilm production, and morphological differentiation in a wide range of bacteria.

Quorum Sensing in *V. fischeri*

High concentrations of AHL produced by increased density of cells diffuse back into the cell, bind to the transcriptional regulator LuxR and activate transcription.

LuxR stimulates transcription of the genes for AHL synthase (luxl) and proteins needed for light production.



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Response to Autoinducers by *V. harveyi*

Responds to three autoinducers.

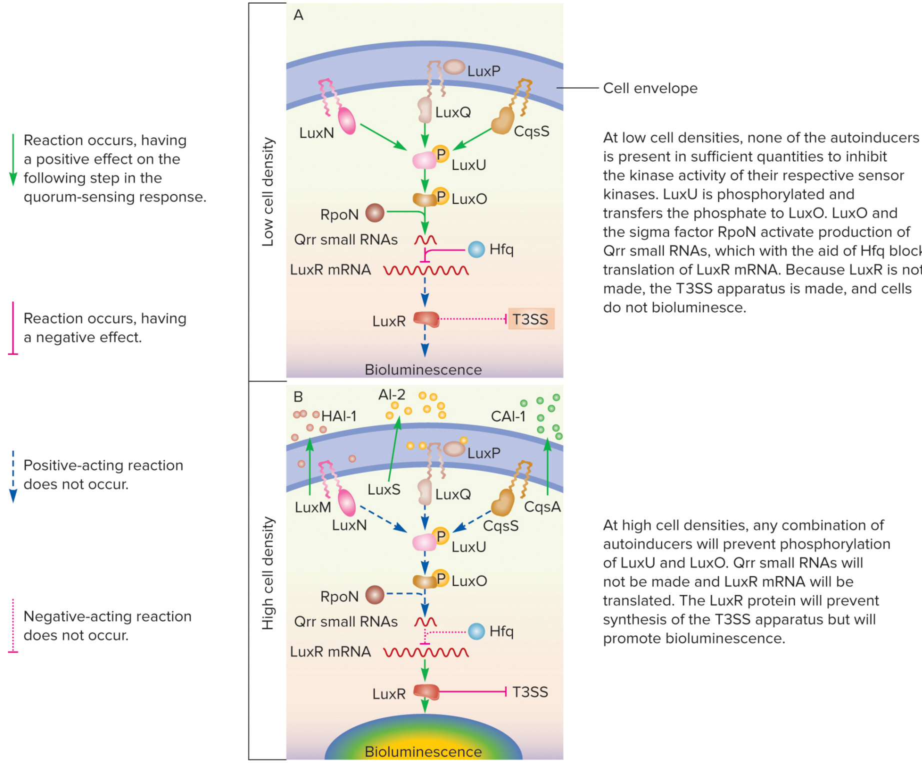
- Maximizes expression of bioluminescence.

Low cell density.

- Low autoinducers present.
- LuxR not made, no bioluminescence.

High cell density.

- Any combination of inducers.
- LuxR made, bioluminescence occurs.



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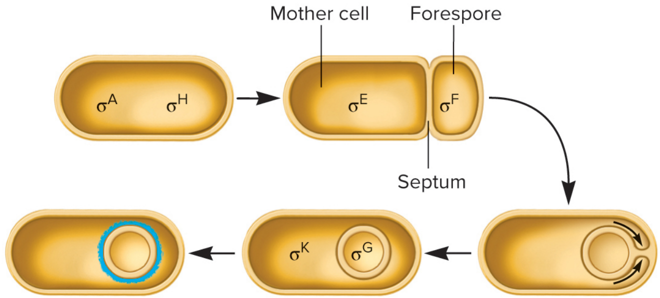
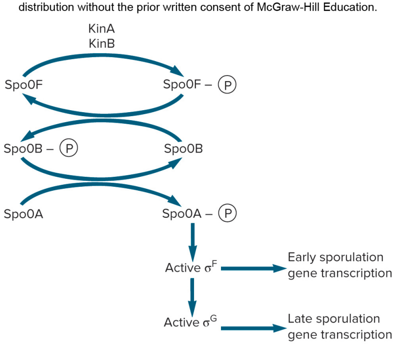
Sporulation in Bacillus subtilis

Another example of a global regulatory system in which phosphorelay, posttranslational modification of proteins, transcription initiation regulatory proteins and alternative sigma factors play a role.

Starvation signal induces production of alternative sigma factors.



(a)



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