SOS in Biochemistry, Jiwaji University, Gwalior

M.Sc. II Semester (2019-20)

Paper BCH 205: Fundamentals of Molecular Biology (Unit III)

Regulation of Gene Expression in Prokaryotes

(Basic Concepts)

THE REGULATION OF GENE EXPRESSION IS CRITICAL FOR ALL ORGANISMS

WHY GENE REGULATION?

1) Developmental Changes
2) Cell Specialization
3) Adaptation to the environment
4) Prevents creation of unwanted product

NEED FOR GENE REGULATION

In Prokaryotes

Gene regulation allow prokaryotes to respond to their environment in an efficient and economic manner

In Eukaryotes

(the purpose is different in higher eukaryotes)

Higher eukaryotes need to regulate their genes for cell specialization (cell differentiation).

(Higher eukaryotes respond to the environmental signals altogether through different mechanism i.e., by evolving signal transduction mechanism.)

LEVELS OF GENE REGULATION

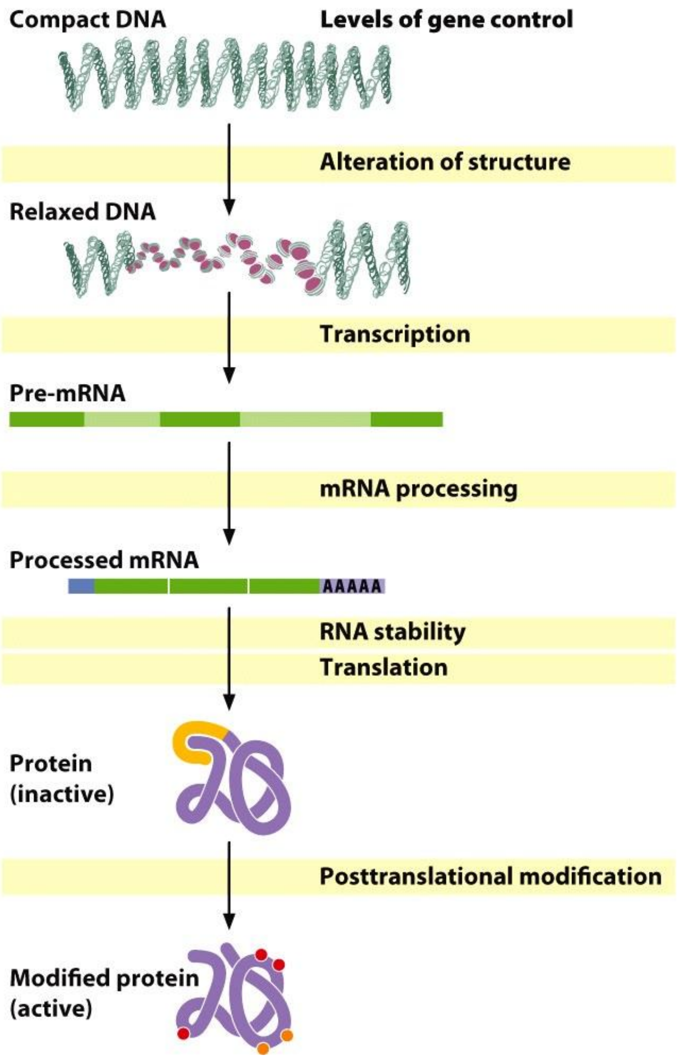
Genes may get regulated at four different levels :

1. Through the alteration of DNA or chromatin structure

2. At the level of transcription & pre-mRNA processing

3. Regulation of mRNA stability & translational level control

4. Posttranslational modification



QUESTION ?

Why is transcription a particularly important level of gene regulation in both bacteria and eukaryotes?

ANSWER

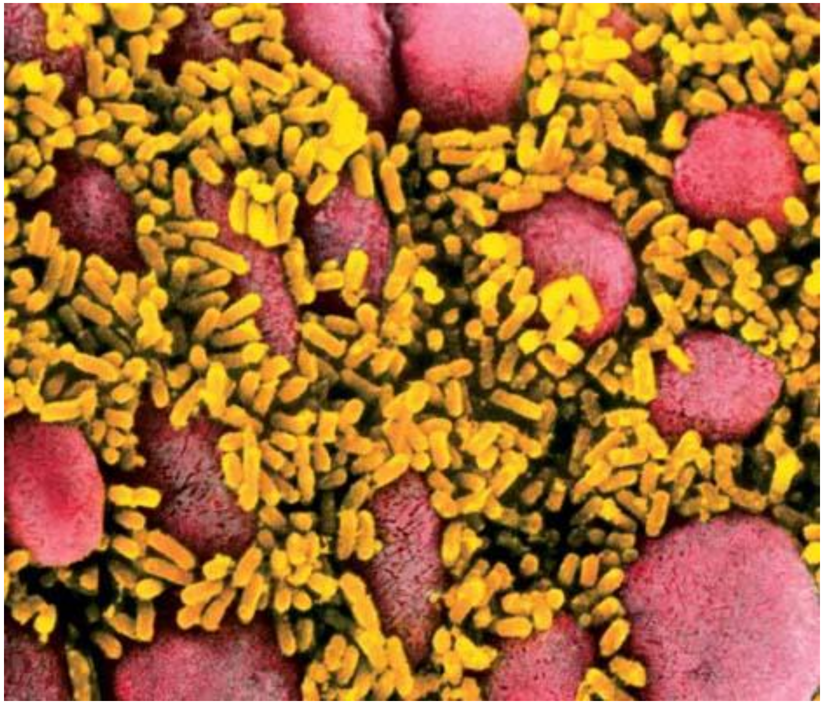
- **Because it is the first stage of gene expression**

and

- **Gene regulation at the first stage will be <u>quick</u> and <u>will save a lot of energy</u> in the organism that can be utilized by the cell for other useful purposes.**

GENE REGULATION IN PROKARYOTES

***E.coli* bacteria eat whatever we eat!**



But ALL organisms must adjust to changes in their environment and all have evolved numerous control mechanisms

GENE REGULATION IN PROKARYOTES

- *E. coli* is found in the intestines of humans.
- Normally *E. coli* uses glucose as a food sourse.
- However, when you drink cow's milk, the sugar present is a two part sugar, or disaccharide, composed of glucose and galactose.
- *E. coli* must alter it's proteins in order to break down this new sugar.

Gene Regulation in bacteria primarily occur at the transcriptional level.

Purpose of gene regulation:

To respond to their environment

Reason of regulation at transcriptional level:

It is quick that saves lot of energy

The basic concept of the gene regulation at the transcription level in prokaryotes can be explained with the help of OPERON MODEL that was proposed by Francois Jacob and Jacques Monod in 1961.

NOBEL PRIZE - 1965

(Physiology or Medicine)

Work:

1. Genetic Control of Enzyme

2. Virus Synthesis

Nobel Prize for Physiology or Medicine in 1965

<u>François Jacob</u>

Born: 17 June 1920, Nancy, France
Died: 19 April 2013, Paris, France
Field: Genetics, Molecular Biology
Prize share: 1/3

<u>Jacques Monod</u>

Born: 9 February 1910, Paris, France
Died: 31 May 1976, Cannes, France
Field: Genetics, Molecular Biology
Prize share: 1/3

<u>André Lwoff</u>

Born: 8 May 1902, Ainay-le-Château, France
Died: 30 September 1994, Paris, France
Field: Genetics, Molecular Biology
Prize share: 1/3

- **Work: "For discoveries concerning genetic control of enzymes and virus synthesis"**

Jacob and Monod distinguished between following two types of sequences in DNA:

1. **Sequences that encode for *trans*-acting products (usually proteins) and**
2. ***cis*-acting DNA sequences**

Gene activity (expression) is regulated by the specific interactions of the diffusible *trans*-acting protein products with the *cis*-acting DNA sequences.

GENES & REGULATORY ELEMENTS

- **Structural Genes:** **encode proteins**

- **Regulatory Genes:** **encode products that interact with other sequences and affect the transcription and translation of these sequences**

- **Regulatory Elements:** **DNA sequences that are not transcribed but play a role in regulating other nucleotide sequences**

GENES & REGULATORY ELEMENTS

- **Constitutive Expression:** continuously expressed under normal cellular conditions

- **Positive Control:** stimulate gene expression

- **Negative Control:** inhibit gene expression

OPERON

It is a complete and coordinated unit of prokaryotic Gene Expression and Regulation.

Operon include following three things:

1. **A set of Structural Genes**

   (whose products are required by the prokaryotes to complete a metabolic (catabolic/anabolic) pathway

2. **A Regulator Gene**

   (whose product is required to regulate the expression of structural genes)

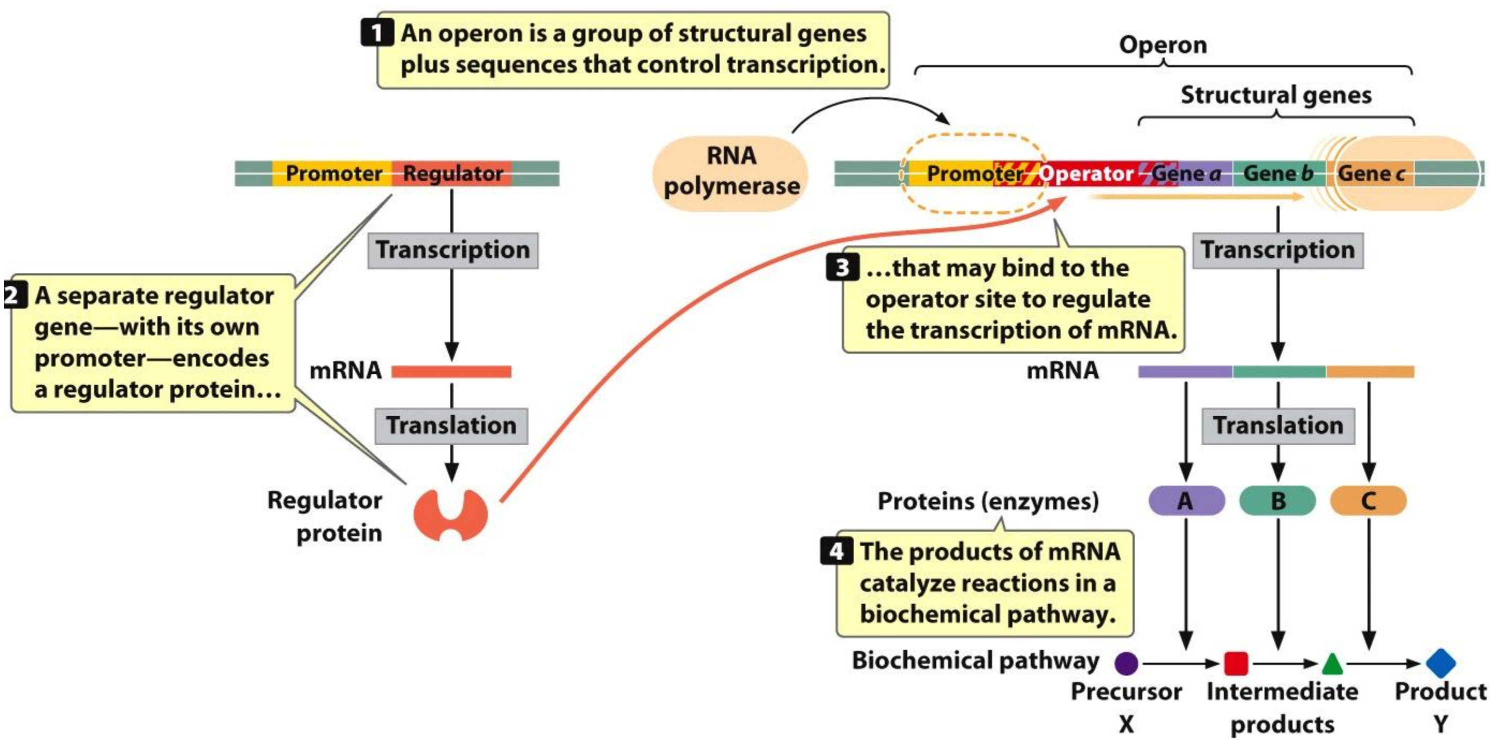
3. **Control Elements**

   a) Promoter
   b) Operator

   (control elements will be recognized by the Regulator Gene Product)

OPERON STRUCTURE

- **Operon:** promoter + additional sequences that control transcription **(operator)** + structure genes
- **Regulator gene:** DNA sequence encoding products that affect the operon function, but are not part of the operon



NEGATIVE AND POSITIVE CONTROL

(INDUCIBLE AND REPRESSIBLE OPERONS)

- **Inducible Operons:**

  Transcription is usually off and needs to be turned on.

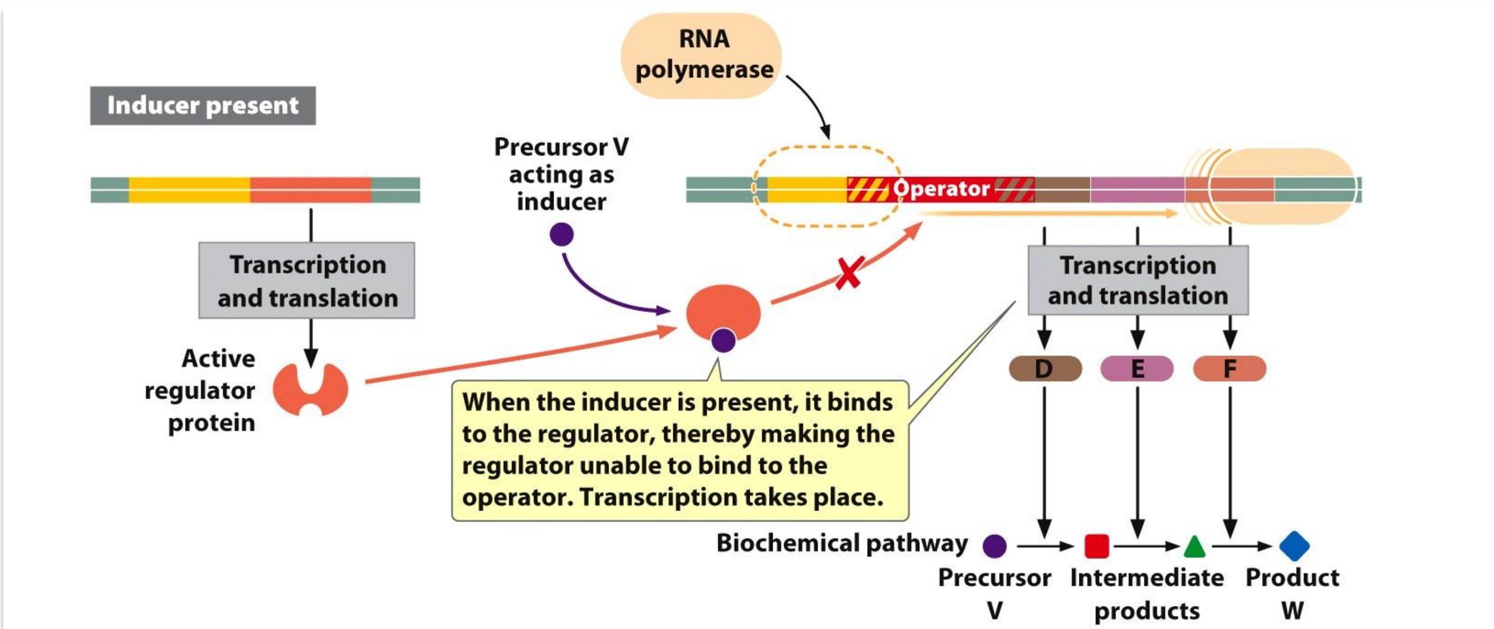
- **Repressible Operons:**

  Transcription is normally on and needs to be turned off.

NEGATIVE AND POSITIVE CONTROL

(INDUCIBLE)

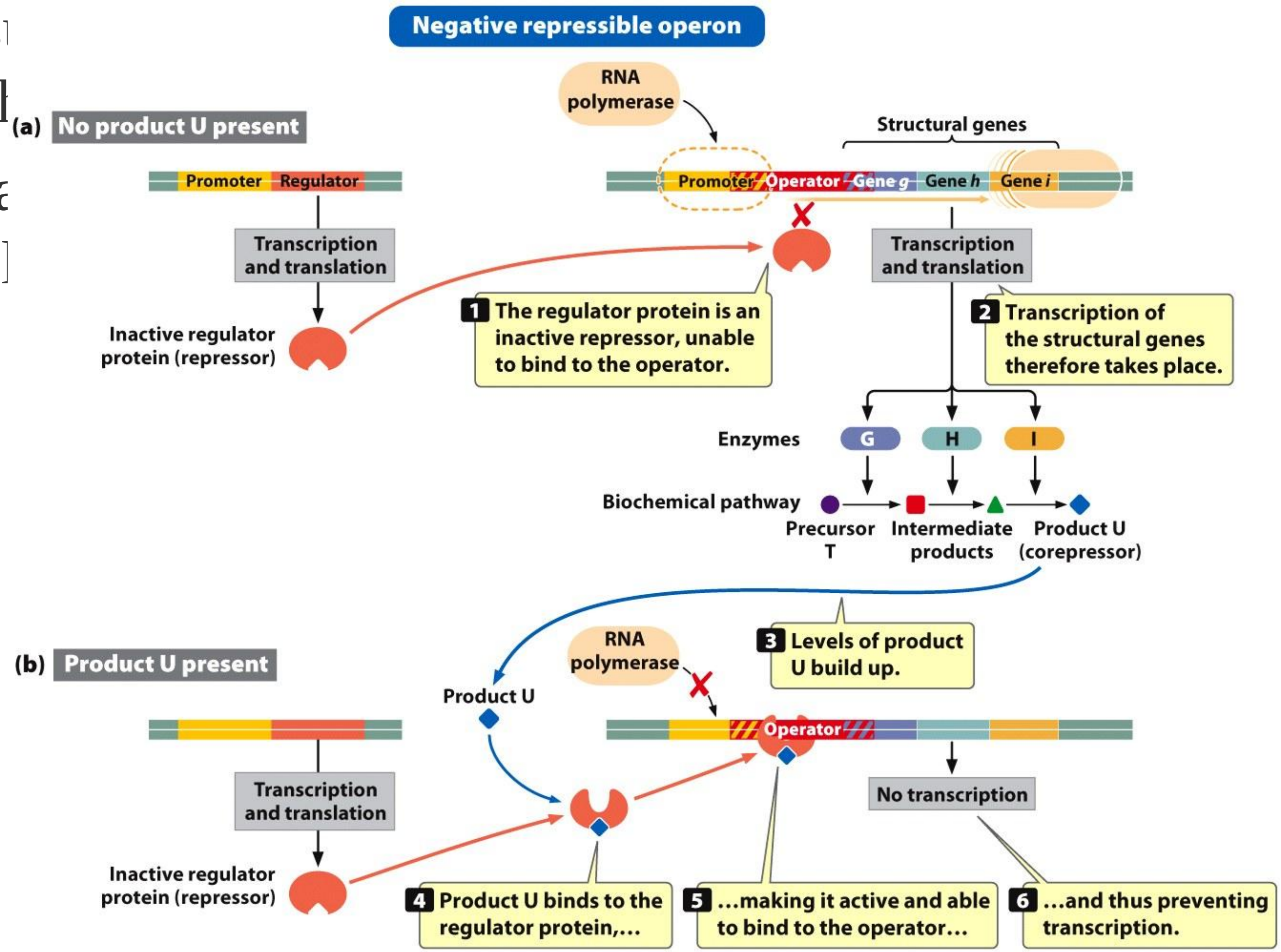
- **Negative inducible operons:** The control at the operator site is negative. Molecule binding is to the operator, inhibiting transcription. Such operons are usually off and need to be turned on, so the transcription is inducible.
- **Inducer:** small molecule that turns on the transcription



NEGATIVE AND POSITIVE CONTROL

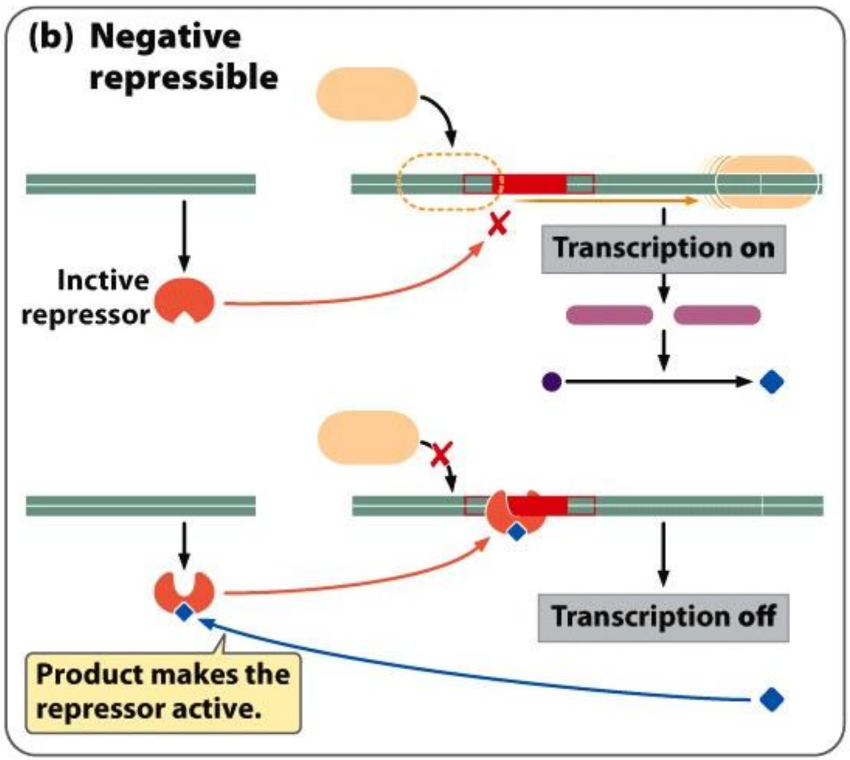
(REPRESSIBLE OPERONS)

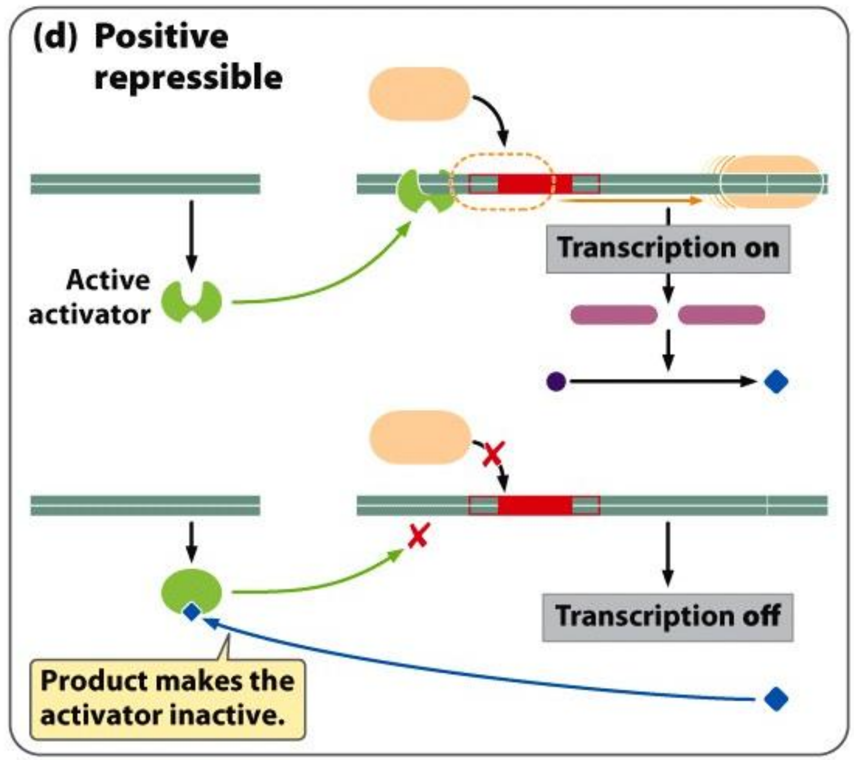
- **Negative repressible operons:** The control at the operator site is negative. But s
turned off, so t
- **Corepressor:** a
makes it capab
transcription.



NEGATIVE AND POSITIVE CONTROL
(INDUCIBLE AND REPRESSIBLE OPERONS)

- Positive inducible operon
- Positive repressible operon





SOME OPERONS IN BACTERIA

Operon(s)	Number of Genes	Functions
lac	3	Hydrolysis and transport of β-galactosides
his	10	Synthesis of histidine
gal	3	Conversion of galactose to UDP-glucose
leu	4	Conversion of α-ketoisovalarate to leucine
trp	5	Conversion of chorismate to tryptophan
ara	4	Transport and utilization of arabinose
pyr	5	Conversion of aspartate to UMP