

## 20 FINE STRUCTURE OF GENE

Benzer, in 1955, divided the gene into recon, muton and cistron which are the units of recombination, mutation and function within a gene. Several units of this type exist in a gene. In other words, each gene consists of several units of function, mutation and recombination. The fine structure of gene deals with mapping of individual gene locus. This is parallel to the mapping of chromosomes. In chromosome mapping, various genes are assigned on a chromosome, whereas in case of a gene several alleles are assigned to the same locus. The individual gene maps are prepared with the help of intragenic recombination. Since the frequency of intragenic recombination is extremely low, very large population has to be grown to obtain such rare combination. Prokaryotes are suitable materials for growing large population. In *Drosophila*, 14 alleles of lozenge gene map at four mutational sites which belong to the same locus (Green, 1961). Similarly, for rosy eye in *Drosophila*, different alleles map at 10 mutational sites of the same locus.

Genes can be classified in various ways. The classification of genes is generally done on the basis of (1) dominance, (2) interaction, (3) character controlled, (4) effect on survival, (5) location, (6) movement, (7) nucleotide sequence, (8) sex linkage, (9) operon model, and (10) role in mutation. A brief classification of genes on the basis of above criteria is presented below

### Classification and brief description of genes

Classification of genes	A brief description
<b>Based on Dominance</b>	
Dominant genes	Genes that express in the F <sub>1</sub>
Recessive genes	Genes whose effect is suppressed in F <sub>1</sub>
<b>Based on Interaction</b>	
Epistatic gene	A gene that has masking effect on the other gene controlling the same trait
Hypostatic gene	A gene whose expression is masked by another gene governing the same trait
<b>Based on Character Controlled</b>	
Major gene	A gene that governs qualitative trait. Such genes have distinct phenotypic effects.
Minor gene	A gene which is involved in the expression of quantitative trait. Effect of such genes cannot be easily detected.
<b>Based on Effect on Survival</b>	
Lethal gene	A gene which leads to death of its carrier when in homozygous

	condition. It may be dominant or recessive.
Semi lethal gene	A gene that causes mortality of more than 50% of its carriers.
Sub-vital gene	A gene that causes mortality of less than 50% of its carriers.
Vital gene	A gene that does not have lethal effect on its carriers.
<b>Based on Location</b>	
Nuclear genes	Genes that are found in nuclear genome in the chromosomes
Plasma genes	Genes that are found in the cytoplasm in mitochondria and chloroplasts. Also called cytoplasmic or extranuclear genes.
<b>Based on Position</b>	
Normal genes	Genes that have a fixed position on the chromosomes. Most of the genes belong to this category
Jumping genes	Genes which keep on changing their position on the chromosome of a genome. Such genes have been reported in maize
<b>Based on Nucleotide sequence</b>	
Normal genes	Genes having continuous sequence of nucleotides which code for a single polypeptide chain
Split gene	A gene having discontinuous sequence of nucleotides. Such genes have been reported in some eukaryotes. The intervening sequences do not code for amino acids
Pseudo genes	Genes having defective nucleotides which are nonfunctional. These genes are defective copies of some normal genes.
<b>Based on Sex Linkage</b>	
Sex linked genes	Genes which are located on sex or X-chromosomes.
Sex limited genes	Genes which express in one sex only
Sex influenced genes	Genes whose expression depends on the sex of individual e.g., gene for baldness in humans.
<b>Based on Operon Model</b>	
Regulator gene	A gene found in lac operon of E.Coli which directs synthesis of a repressor
Operator gene	In lac operon, a gene which control the function of structural genes
Promotor gene	A gene in lac operon of E.Coli which initiates mRNA synthesis
Structural genes	The genes in lac operon of E.Coli which control the synthesis of protein through mRNA
<b>Based on role in Mutation</b>	
Mutable genes	Genes which exhibit higher mutation rate than others e.g., which eye gene is Drosophila.
Mutator genes	Genes which enhance the natural mutation rate of other genes in the same genome e.g., dotted gene in maize.
Antimutator genes	Genes which decrease the frequency of natural mutation of other genes in the same genome. Such genes are found in bacteria and bacteriophages

## REGULATION OF GENE EXPRESSION

Genes that encode a product required in the maintenance of basic cellular processes or cell architecture are called housekeeping genes or constitutive genes. A constitutive gene is an unregulated gene, whose expression is uninterrupted, in contrast to the regulated expression of a gene. The studies of bacterial genetics indicate that all genes not only specify the structure of an enzyme but some of them also regulate the expression of other genes. These genes are called regulator genes. This concept of gene regulation has been studied by F. Jacob and J. Monod in 1961 in *A. coli*, who proposed the operon concept.

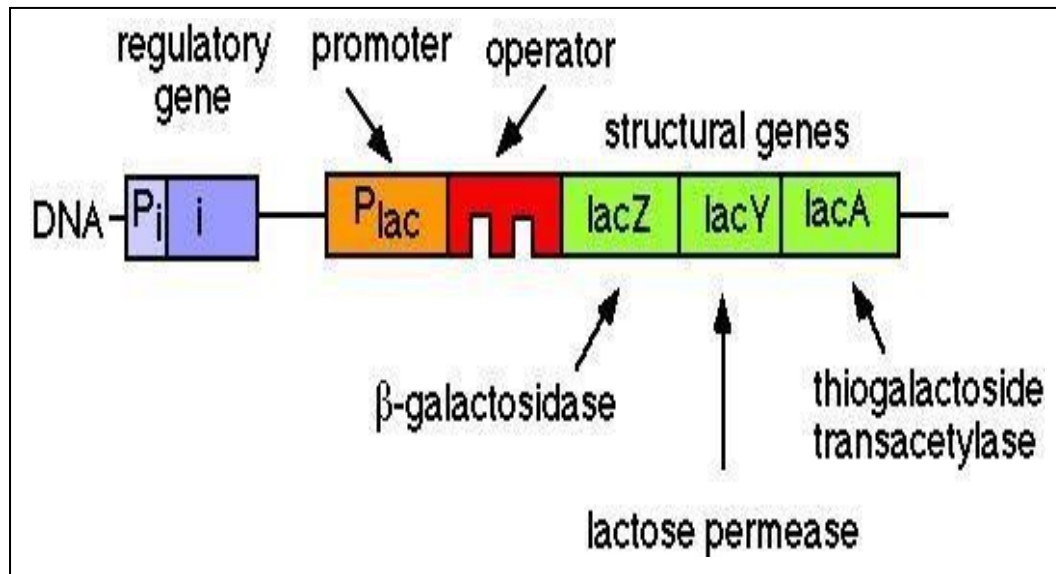
According to the operon concept, gene regulation in prokaryotes and bacteriophages involves structural genes, the operator, the promoter, the regulator genes, repressor proteins and an inducer.

### **Lac Operon of *E. coli***

A genetic unit that consists of one or more “structural genes” (cistrons that code for polypeptides) and an adjacent “operator – promoter” region that controls the transcriptional activity is called operon. Operator and promoter are upstream to the structural genes. Thus an operon refers to a group of closely linked genes which act together and code for various enzymes required for a particular biochemical pathway. Lac operon consists of several components which are briefly described below:

### **Structural genes**

The lactose operon of *E. coli* is composed of three structural genes *z*, *y* and *a*. The ‘*z*’ gene codes for an enzyme  $\beta$ -galactosidase, which converts lactose into glucose and galactose. The ‘*y*’ gene codes for an enzyme permease, which facilitates the entry of lactose into the cell. The ‘*a*’ gene specifies the enzyme thiogalactoside transacetylase, which transfers an acetyl group from acetyl co-A to  $\beta$ -galactoside. Hence all the three gene products in lac operon are required for the metabolism of lactose. Such genes, which are sequential and transcribed as a single m-RNA from a single promoter are called structural genes. The m-RNA synthesized is the polycistronic mRNA. Only the last cistron has the signals for the termination of transcription.



**Fig.: The Lac Operon - showing its genes and its binding sites**

### **The operator region**

Operator lies immediately upstream to the structural genes between the promoter and structural genes. Operator is the target site for the attachment of repressor protein produced by the regulator gene. Binding of repressor with operator prevents initiation of transcription by RNA polymerase. When operator is free, the RNA polymerase can bind to the promoter to initiate the mRNA synthesis.

### **The promoter region**

The actual site of transcription initiation is known as promoter region. It also lies upstream to the structural genes next to the operator region. mRNA transcription by the structural gene is catalysed by an enzyme RNA polymerase. This enzyme first binds to the promoter region and then moves along the operator region and structural genes.

### **Regulator gene**

Regulator gene (*i*) specifies a repressor protein, which in the absence of the inducer (lactose), bound to the operator (*o*), thereby inactivating the operator and preventing transcription of the three structural genes by RNA polymerase. In the presence of an inducer (lactose), the repressor is inactivated by interaction with the inducer. This allows the RNA polymerase to bind to the promoter allowing the transcription of the adjacent structural genes.

### **Repressor**

Repressor is a protein molecule specified by the regulator gene. Repressor may be in active form or inactive form. In the active form, repressor binds to the operator region and prevents transcription. When the repressor is in inactivate form, the transcription takes place.

### Inducer

The inducer binds to the repressor making it inactive such that it cannot bind to the operator. RNA polymerase path way is cleared allowing the expression of structural genes. A few molecules of lactose present in the cytoplasm of *E. coli* are metabolized into allolactose, which is an isomer of lactose. Such molecules that induce the expression of any operon by binding to the repressor are called inducers and such operons are inducible operons.

### Regulation of Lac Operon

In an uninduced *E. coli*, repressor protein binds to the operator. Hence, expression of structural genes is not induced. *E. coli* initially contains a few molecules of  $\beta$ -galactosidase enzyme. A few molecules of lactose slowly diffuse into cytoplasm.  $\beta$ -galactosidase present in cytoplasm metabolises lactose into allolactose which acts as an inducer. In an induced *E. coli*, allolactose binds to repressor protein. The repressor protein is detached from the operator. RNA polymerase allows the transcription of structural genes to synthesize a polycistronic mRNA. Permease synthesized from mRNA allows the rapid uptake of lactose. Large number of  $\beta$ -galactosidase molecules in the cytoplasm metabolise lactose into galactose and glucose.

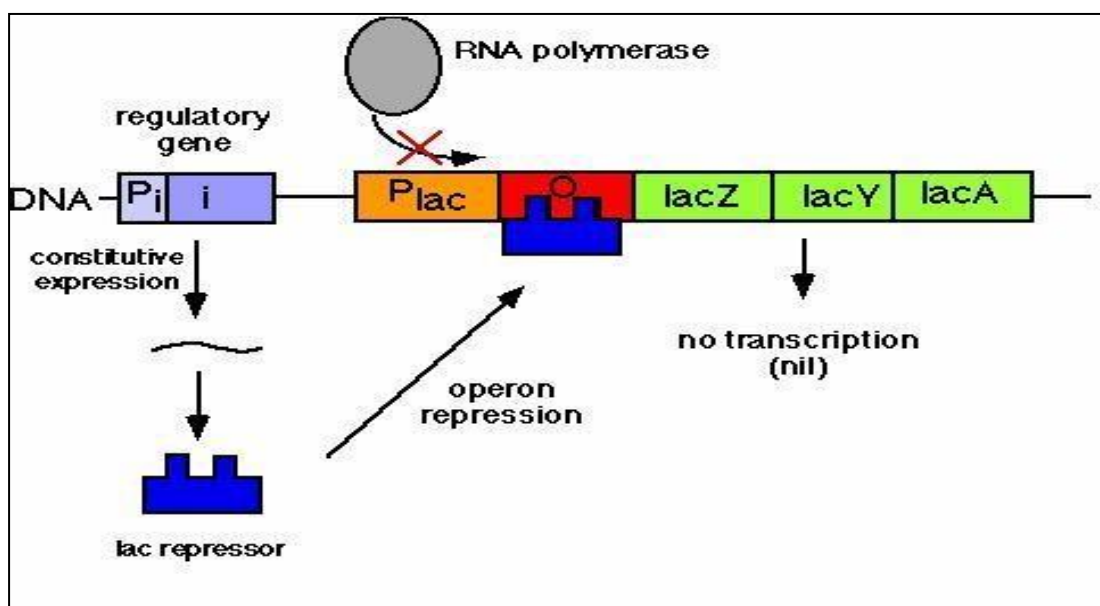


Fig.: In the "repressed or uninduced" state, the repressor bound operator

