

Gene Expression in Prokaryotes

Prokaryotes only transcribe genes that their end-products are needed at the time. They do this in order to save up energy and increase efficiency. The regulation of gene expression is depended mainly on their immediate environment, for example on the presence and absence of nutrients. Gene expression in prokaryotes occurs primarily at the level of transcription.

What are OPERONS?

== .bacteria genes that encode for proteins with closely related functions are found grouped along with cis-acting regulatory elements that determine the transcription of these genes, thus these genes are regulated in a coordinated way. These clusters of genes are called operons, and their transcription product is a single polycistronic mRNA. Organization of genes in operons contributes to the regulation of gene expression. The operon can therefore be categorized as inducible or repressible. Inducible operons: ==

- The include genes that encode for enzymes that take part in metabolic pathways and the expression of the gene is controlled by the substrate
- Example: the "Lac Operon"

Repressible operons:

- The include genes that encode for enzymes involved in biosynthetic pathways, and the expression of the gene is controlled by the end-product of the pathway
- Example: the "Trp Operon"

What are OPERATORS?

These are segments of DNA that regulate the activity of the structural genes of the operon.

- If the operator is not bound by a repressor molecule, then the RNA polymerase can pass over the operator and move to the protein coding genes
- If the operator, on the other hand, is bound by a repressor molecule, then the RNA polymerase is blocked behind the repressor molecule.
- However, when an "Inducer molecule" is present, it binds the repressor molecule causing it to change shape, rendering it incapable of binding the operator. The RNA polymerase moves freely.

The lactose operon

- The lactose operon contains 3 genes, Lac Z, Y and A. These genes encode for enzymes required to metabolize lactose --> beta-galactosidase, lactose permease, and beta-galactoside transacetylase.
- Another regulatory gene, Lac I, is expressed separately and lies upstream of the operon. This gene encodes for the lac repressor which regulates the expression of Lac Z, Y and A
- In the absence of lactose:

1. The lac repressor binds to a DNA sequence called the "operator" (found between the lac Z gene and the lac promoter)
2. In this way the lac repressor blocks the path of RNA polymerase to reach the lac Z, Y and A genes --> operon remains switched off.

- In the presence of lactose:

1. Lactose molecules are metabolized by the lac enzymes, an intermediate is formed called allolactose (an isomer of lactose)
2. Allolactose acts as an inducer by binding to the lactose repressor and changing its conformation --> therefore it can no longer bind to the operator.



- In the presence of glucose (even if present together with lactose):

1. Glucose is preferred because it requires less energy expenditure to be broken down
2. The operon senses the glucose presence and by a mechanism called "catabolite repression" it is switched off.
3. The regulatory protein "CAP" (Catabolite Activator Protein) binds to a DNA sequence upstream to the lac promoter and enhances binding of the RNA polymerase leading to an increased transcription of the operon.
4. However, CAP will only bind behind the promoter only if cAMP is bound on it. Adenylate cyclase though, the enzyme required for the synthesis of cAMP, is inhibited by glucose and the operon will be eventually expressed at very low rate.

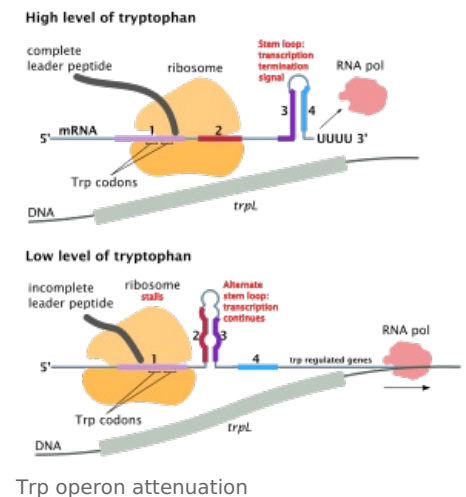
- The oposite also applies.

The Tryptophan operon (Trp operon)

- It includes 5 genes involved in Tryptophan synthesis
- The genes are expressed as a single mRNA strand, transcribed from an upstream promoter
- Another regulatory gene encodes for a trp repressor.
- There is also the trp operator that is found just downstream from the promoter
- If tryptophan is present it will bind the trp repressor. This enables it to bind the operator and block the RNA polymerase. This is a model of end-product inhibition, since tryptophan is the end product of tryptophan biosynthesis.

Attenuation

- Alternatively another method of suppressing gene expression is "attenuation". This is only possible in prokaryotes since it has to do with the fact that the mRNA is translated as soon as it is being transcribed.
 - The trp mRNA can form 2 stem-looped structures between the trp-promoter and the 1st trp gene. The large stem loop does not influence transcription and occurs upstream of the smaller stem loop which acts as a transcription terminator. If the large stem loop is not present then the short stem-loop will be formed.
 - The formation of the stem-loops on the mRNA depends on the binding of ribosomes to the mRNA.
 - Just prior to the stem-loop region of the mRNA, there is an open reading frame of 14 codons, of which 2 of them code for tryptophan.
 - If the tryptophan is present in adequate levels in the cytoplasm, it will be translated and the ribosome will keep translocating following closely behind the RNA polymerase preventing the formation of the large loop structure, allowing the terminator structure to form further on and transcription ends.
 - If tryptophan is lacking, the ribosome will be stalled as it tries to translate the coding region. This will allow the RNA polymerase to move ahead and leave enough space for the larger stem-loop structure to form, thus allowing the transcription to continue.
- Overall the trp repressor determines whether to switch on or off the entire operon while the method of attenuation determines the efficiency of transcription, according to the level of tryptophan available.



Links

Related articles

- Structure and Function of Prokaryotes
- Prokaryotic Chromosomes

External links

Sources

References

Bibliography

- NUSSBAUM, Robert L – MCINNES, Roderick R – WILLARD, Huntington F. *Genetics in Medicine*. 7th edition. Philadelphia : Saunders Elsevier, 2007. 585 pp. ISBN 9781416030805.
- CHAMPE, Pamela C – HARVEY, Richard A – FERRIER, Dennis R. *Lippincott's Illustrated Reviews : Biochemistry*. 4th edition. Philadelphia : Lippincott Williams & Wilkins, 2008. 520 pp. ISBN 978-1-6083-1521-5.

Further reading