5.3 The *lac* operon

How *E. coli* uses genetic control of the *lac* operon to organise synthesis of proteins

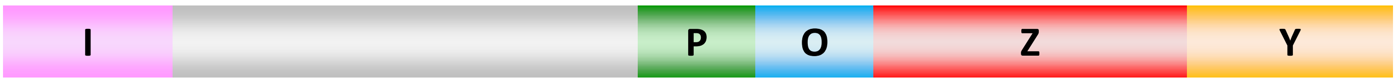
The *E. coli* bacterium

Escherichia coli (commonly known as *E. coli*) is a bacterium which usually respires glucose, although when **lactose** is available, it can use lactose as a respiratory substrate. If the bacteria are grown in a medium where there is lactose present, they produce two enzymes: **β-galactosidase** (to break down lactose into glucose and galactose) and **lactose permease** (to transport the lactose into the bacterial cell). These are needed for the respiration of lactose. However, when *E. coli* is grown in a medium without any lactose, and then placed in a growth medium with lactose, the *E. coli* initially has minuscule amounts of these enzymes. It takes a while before the enzymes are produced and the bacteria are able to respire lactose.

This suggests that the enzymes are only produced when lactose is present: and this means lactose must be the trigger of production for these enzymes. It is known as the **inducer** for β-galactosidase and lactose permease.

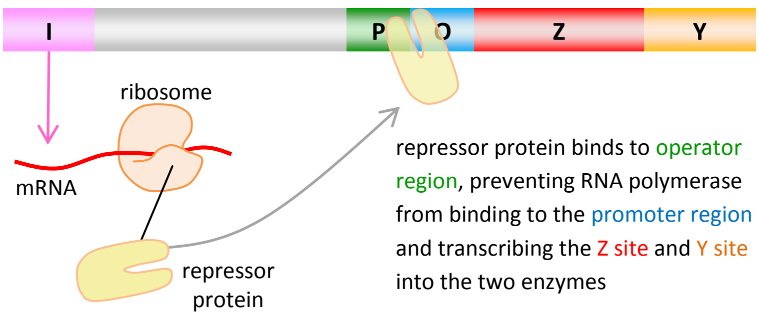
The *lac* operon

An **operon** is a length of DNA, which is made up of structural genes and **control sites**. The structural genes code for proteins, in this case specific enzymes, and the control sites consist of an **operator region** and a **promoter region**. These two regions are genes, but they do not code for polypeptides, their role is to regulate the operon.



- There are two structural genes: the **Z site** codes for the enzyme β-galactosidase, and the **Y site** codes for the enzyme lactose permease, and both have a base pair sequence which is transcribed to mRNA and translated to protein
- The **operator region** is a length of DNA alongside the structural genes, Z and Y, and can switch them on and off
- The **promoter region** is another length of DNA which the enzyme *RNA polymerase* binds to in order to begin transcribing the mRNA for synthesising the enzymes from Z and Y when appropriate
- The **regulator gene** (I) is some distance from the operon itself, and not an actual part of the operon

Whether there is or isn't any lactose in the medium, the **regulator gene** is *expressed* (transcribed and translated into protein) so that the **repressor protein** is synthesised. The repressor protein itself can bind to the operator region, and has a second binding site so that lactose can bind to it.



RNA polymerase transcribes the regulator gene and mRNA is translated into the repressor protein

When lactose is *absent* from the growth medium:

1. The regulator gene is expressed and the repressor protein produced
2. Since there is no lactose present to bind to the repressor protein, the protein binds to the operator region of the operon, which also binds to part of the promoter region (where RNA polymerase normally attaches to begin transcription)
3. As the repressor protein has bound itself to the operon, RNA polymerase cannot bind to the promoter region to transcribe the structural genes into mRNA to be expressed
4. Without the mRNA being produced, the two enzymes are not synthesised

The advantage of not manufacturing the enzymes β-galactosidase and lactose permease when there is no lactose present is simply that useful resources are not wasted by making unnecessary enzymes. If there is no lactose present, the enzymes are not needed, and so there is no point in wasting resources and energy making them. When there is lactose present in the growth medium or environment, however, it is more beneficial in the long-run to make the enzymes.

When lactose is *present* in the growth medium:

1. The regulator gene is expressed as normal, so the repressor protein is still produced
2. The *inducer* molecule lactose binds to the repressor protein, causing the shape of the repressor protein to alter so that its other binding site will not fit on the operon
3. The repressor protein therefore does not bind to the operator region (or breaks away if it is already on the operon)
4. The RNA polymerase therefore is able to bind to the promoter region and transcribe Z and Y into β-galactosidase and lactose permease, so lactose can be brought into the cell, broken down and respired