# Make proteins when needed

Gene expression uses genetic information to produce a functional RNA or protein. Regulation changes which genes are expressed, when and how much; it need not alter the DNA sequence.

## 1. CONTROL THE FLOW OF INFORMATION




Shown for a protein-coding gene. Reducing transcription reduces new mRNA production and can reduce later protein synthesis. Existing mRNA and proteins may persist, so the response is not always immediate.

## 2. STRUCTURAL GENES AND REGULATORY GENES

In an operon, structural genes encode products that carry out cellular tasks, such as metabolic enzymes. Regulatory genes encode products that control expression of other genes, such as a repressor. The promoter and operator are control sequences in DNA, not genes encoding those proteins.

## 3. INDUCIBLE VERSUS REPRESSIBLE ENZYME SYNTHESIS

Inducible: synthesis increases in response to an inducer. In the lac system, a lactose-derived inducer removes repression, allowing production of proteins for lactose use.

Repressible: synthesis decreases in response to a signal, often an end product. For example, abundant tryptophan activates its repressor and reduces synthesis of tryptophan-making enzymes.

Why regulate? Avoid wasting energy and materials, respond to changing conditions, and allow specialised cells to make different sets of proteins. Regulation of enzyme synthesis is distinct from inhibition of an enzyme already present.

Gene products and expression: NHGRI, Gene Expression.
Inducible and repressible systems: OpenStax, Microbiology 11.7.

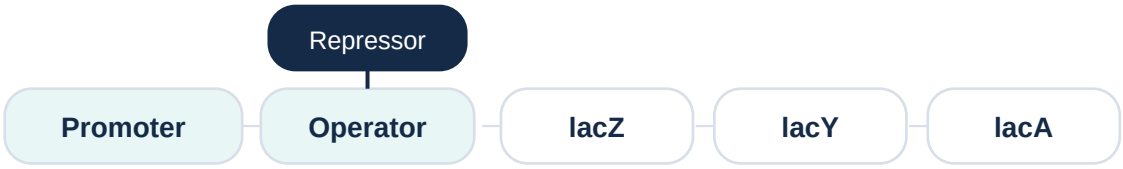
Scope: Cambridge Biology 9700, section 16.3, outcomes 1-4, p. 42.

# The lac operon: remove the block

An operon groups structural genes under shared transcriptional control. In E. coli, RNA polymerase binds the promoter; the repressor binds the operator. The lacI regulatory gene is separate.

## 1. LACTOSE ABSENT: REPRESSED

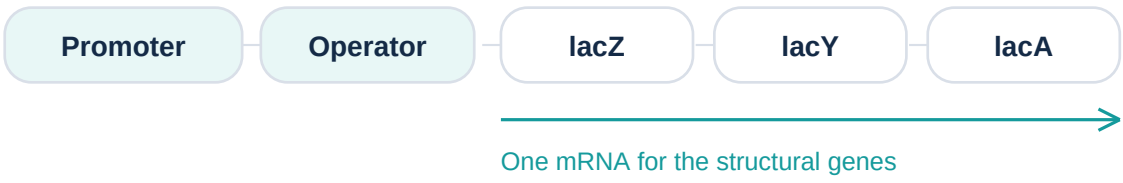
The active repressor occupies the operator and obstructs transcription. Very little lac mRNA is made; the operon is strongly repressed, not absolutely silent.




The repressor is a protein made from lacI. It is not the operator itself. Tiny basal amounts of lactose-use proteins allow the cell to respond when lactose becomes available.

## 2. LACTOSE PRESENT: REPRESSION LIFTED

Some lactose is converted to allolactose, the inducer. It binds the repressor and changes its conformation, greatly reducing operator binding. RNA polymerase can transcribe the structural genes.




lacZ encodes beta-galactosidase, which hydrolyses lactose into glucose and galactose; lacY encodes lactose permease, which transports lactose into the cell. lacA encodes a transacetylase.

Scope note: diagrams isolate repressor control and are not to scale. Strong lac expression also depends on low glucose. Cambridge does not require the cAMP mechanism.

Lactose-derived inducer, basal expression and glucose: OpenStax, Biology 2e 16.2.
Operon components and gene products: OpenStax, Microbiology 11.7.

Scope: Cambridge Biology 9700, section 16.3, outcomes 1-4, p. 42.

# Transcription factors and signals

Eukaryotic cells can change transcription in response to internal or external signals. Different patterns of expression help cells with similar genomes perform different functions.

## 1. TRANSCRIPTION FACTORS BIND DNA

Transcription factors are proteins that bind particular DNA sequences and increase or decrease transcription. They can help recruit transcription machinery or inhibit it. RNA polymerase makes the RNA; the transcription factor regulates that process. A transcription factor is not an mRNA molecule.

## 2. GIBBERELLIN REMOVES DELLA REPRESSION

### Low gibberellin

DELLA proteins persist

↓

Growth-promoting transcription factors are inhibited

↓

Lower transcription of responsive growth genes

### Gibberellin signal

DELLA proteins are degraded

↓

Transcription factors are released from inhibition

↓

Increased transcription of responsive growth genes

## 3. FROM SIGNAL TO GROWTH

Removing DELLA proteins allows growth-promoting transcription factors to act. More mRNA can lead to more proteins involved in growth, including cell elongation. Gibberellin does not directly copy DNA or act as RNA polymerase. This is control of existing genes, not creation of new alleles.

Keep the mechanisms distinct: the lac repressor binds DNA at an operator; DELLA proteins inhibit transcription factors in this plant signalling model. Both can reduce gene expression, but they act differently.

Transcription factors and DELLA: Cambridge 9700, section 16.3.3-4.
DELLA inhibition and gibberellin response: Feng et al., Nature (2008).

Scope: Cambridge Biology 9700, section 16.3, outcomes 1-4, p. 42.