

Regulation of Gene Expression

Learning objective 6.5.A Describe the types of interactions that regulate gene expression, and how the location of regulatory sequences relates to their effect.

Name: _____ Date: _____ Period: _____

Use the tool **On Unless Stopped, Off Unless Started**. Part 1 uses **The lac operon**, Parts 2 and 3 use **On or off by default**, and Parts 4 and 5 use **Where the sequence sits**. The claim to test in Part 1 is the one you have probably already been given: that lactose switches the lac operon on. Fill the table in before you decide whether it is true.

Part 1 • Every environment the cell can be in

Set the two sugars independently and record what happens in each of the four environments. Transcription is reported as **none**, **low** or **high** — not as on or off.

Lactose	Glucose	Repressor on the operator?	CAP bound?	Transcription
Absent	Absent			
Absent	Present			
Present	Absent			
Present	Present			

1. Define an operon, and explain what the operator does.

2. Look down your Transcription column. Explain why “lactose switches the operon on” does not describe this table.

Part 2 · Two controls, two different jobs

Each control answers a different question. Work out which, using your table from Part 1 — do not look them up.

Control	What it responds to	What question it answers for the cell	What it cannot do on its own
The repressor			
CAP			

3. Explain why the operon is transcribed only weakly when both sugars are present, and why that is sensible behavior for the cell.

4. A student claims the glucose control is unnecessary because lactose already decides the answer. Use two rows of your Part 1 table to show this is wrong.

Part 3 · The opposite default

Switch to **On or off by default**. Reduce each operon to a single input — is its small molecule present? — and fill in the two columns.

Small molecule present?	lac operon: transcribed?	trp operon: transcribed?
No		
Yes		

5. Distinguish between an inducible and a repressible operon, and state which of these two is which.

6. Explain why the lac operon's default is off and the trp operon's default is on, using what their genes are for.

Part 4 · Breaking things on purpose

Open **Where the sequence sits** and use the table of regulatory sequences. For each one, predict what a mutation that destroyed it would do to the operon.

Sequence	Where it sits	Effect of destroying it
Promoter		
Operator		
Regulatory gene		
Enhancer		

7. Two of these mutations give the same phenotype by different routes. Identify them, and explain what that means for a scientist who has only observed the phenotype.

8. Explain how an enhancer thousands of bases from a gene can control whether that gene is transcribed.

Part 5 · How a few proteins specify many cells

Use the transcription-factor buttons. With three factors there are eight combinations; record which genes are expressed in each.

TF-A	TF-B	TF-C	Genes expressed
—	—	—	
—	—	✓	
—	✓	—	
—	✓	✓	
✓	—	—	
✓	—	✓	
✓	✓	—	
✓	✓	✓	

9. State how many states k transcription factors can produce, and calculate how many 10 factors would give.

10. Explain how this arithmetic lets an organism with about twenty thousand genes build hundreds of distinct cell types.

11. Name the two earlier topics in which you met this same counting argument, and state what was being counted in each.

What the model simplifies

Transcription is reported as none, low or high. Real transcription is continuous, and even a fully repressed operon is transcribed at a very low background rate — which is what allows the first molecules of lactose to get into the cell at all.

The repressor is treated as bound or not bound. In reality it binds and releases constantly, and lactose shifts the proportion of time it spends bound rather than removing it once and for all. “Off” means rarely transcribed, not never.

CAP is shown as a simple second switch. It works by binding cyclic AMP, whose concentration falls when glucose is present, so glucose acts on the operon through two intermediate steps rather than directly.

Lactose is named as the molecule that binds the repressor. The molecule that actually binds it is allolactose, an isomer made from lactose inside the cell.

Part 5 treats each transcription factor as simply present or absent and each gene as requiring an exact combination. Real factors vary in amount, bind with different strengths, and combine more gradually than a truth table allows — the 2^k figure is an upper bound on the distinguishable states, in the same way the 2^n splice-variant count in Topic 6.3 was.