AP BIOLOGY · UNIT 6 · TOPIC 6.5

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**, Part 3 uses **On or off by default**, and Parts 4 and 5 use **Where the sequence sits**. Part 2 uses the Part 1 table. Part 1 tests the claim that lactose switches the lac operon on; complete the table before you decide whether the claim is true.

Part 1 · Every environment the cell can be in

Press the Lactose and Glucose buttons to set each of the four environments, and record what happens in each. Transcription is reported as **none**, **low** or **high**, not as on or off.

Lactose	Glucose	Repressor on the operator?	CAP helping the promoter?	Transcription
Absent	Absent			
Absent	Present			
Present	Absent			
Present	Present			

1. (a) Describe what an operon is.

(b) Explain how the operator controls transcription of the operon.

2. A common summary of the lac operon is that “lactose switches the operon on.” Using the Transcription column of the Part 1 table, explain why this summary is incomplete.

Part 2 · Two controls, two different jobs

Each control answers a different question for the cell. Complete the table using the Part 1 table, without looking up the answers.

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

3. (a) Explain why the lac operon is transcribed only at a low level when both lactose and glucose are present.

(b) Explain why this low level of transcription is an advantage to the cell.

4. A student claims that the glucose control is unnecessary because lactose alone determines the level of transcription. Using two rows of the Part 1 table, explain why the student's claim is incorrect.

Part 3 · The opposite default

Switch to **On or off by default**. Treat each operon as having a single input, whether its small molecule (lactose for lac, tryptophan for trp) is present, and fill in the two columns.

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

5. (a) Describe the difference between an inducible operon and a repressible operon.

(b) Identify which of the lac operon and the trp operon is inducible and which is repressible.

6. The lac operon is off by default and the trp operon is on by default. Using the functions of the enzymes each operon codes for, explain why each default is an advantage to the cell.

Part 4 · Breaking things on purpose

Open **Where the sequence sits** and use the table of regulatory sequences. For each sequence, record where it sits and the effect on transcription of a mutation that destroys it.

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

7. Two of the mutations in the Part 4 table give the same phenotype by different mechanisms.
(a) Identify the two mutations.

(b) Explain why a scientist who has observed only the phenotype cannot determine which of the two mutations is present.

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

Stay on Where the sequence sits. Press the TF-A, TF-B and TF-C buttons to set each of the eight combinations in the table, and record the genes expressed in each.

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

9. Each transcription factor is either present or absent.
(a) Determine the number of combinations that k transcription factors can produce.

(b) Calculate the number of combinations that 10 transcription factors can produce.

10. Explain how combinations of transcription factors allow an organism with about twenty thousand genes to produce hundreds of distinct cell types.

11. The same counting argument (n independent two-way choices give 2^n outcomes) appeared in Topic 5.2 and Topic 6.3.
(a) Describe what was counted in Topic 5.2.

(b) Describe what was counted in Topic 6.3.

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.