AP BIOLOGY | UNIT 6 | TOPICS 6.5 AND 6.6

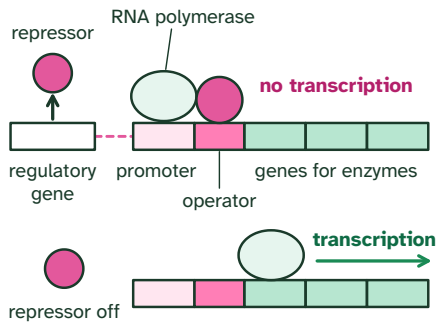
REVISION ON TWO PAGES

Genes, *on and off*

What to know, what to draw and what to say. Nothing else.

THE ONE IDEA

Cells hold the same genes but express different ones. Regulatory proteins bind regulatory sequences to set how much.



Off, then on. A repressor on the operator blocks RNA polymerase. With the repressor off, the genes are transcribed.

6.5.B START HERE

An operon: one switch for *several genes*

- An **operon** is a group of prokaryotic genes with one **promoter** and one **operator**. They are transcribed together into one mRNA, so they are regulated together.
- A regulatory gene elsewhere makes a **repressor**: a protein whose shape depends on a small molecule. On the operator it sits in the path of RNA polymerase and blocks transcription.
- **Location explains function.** A DNA site acts only where it sits. A regulatory protein travels through the cell, so its gene can lie anywhere.

THREE PARTS, AND WHAT LOSING EACH ONE DOES

P Promoter
RNA polymerase binds here. Lost: never transcribed

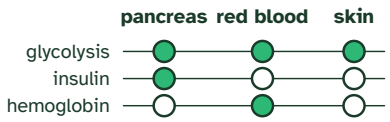
O Operator
the repressor binds here. Lost: cannot be switched off

R Regulatory gene
makes the repressor. Lost: cannot be switched off

6.5.A 6.6.B SAME DNA

One genome, many *cells*

- Nearly every cell of an organism holds the same genes. Cells differ because they **express different genes**.
- Gene regulation gives **differential gene expression**, so cells make different products and do different jobs.
- Phenotype is set by which genes are expressed and at what level: the **function and amount** of each product.



Green: transcribed. Every cell holds all three genes, and every cell needs the enzymes of glycolysis.

6.5.A SEQUENCES AND PROTEINS

On, off and *in between*

- A gene is "on" when it is being transcribed and "off" when it is not. Many sit in between.
- **Regulatory sequences** are stretches of DNA. **Regulatory proteins** bind them and raise or lower transcription.
- A regulatory sequence codes for nothing: it is a place on the DNA where one protein fits.
- Some regulatory proteins help RNA polymerase begin; others get in its way.

Constitutive genes always on
Expressed all the time, because the cell always needs the product.

Inducible genes on when needed
Expressed only when a signal or a substance is present.

6.5.B COORDINATE REGULATION

One signal, *many genes*

- Prokaryotes and eukaryotes both regulate genes in groups.
- One signal can switch on a whole set: every gene with a copy of the sequence responds.
- **Example:** estrogen enters a cell and binds a receptor protein. Together they act as a transcription factor.

Prokaryotes operons
The genes share one promoter and one operator.

Eukaryotes a shared sequence
Each gene has its own promoter. Genes with the same regulatory sequence answer to the **same transcription factor**, even on different chromosomes.

6.5.B REPRESSIBLE AND INDUCIBLE

Two operons, *opposite ways*

	REPRESSIBLE: THE TRP OPERON	INDUCIBLE: THE LAC OPERON
Usual state	**On**	**Off**
Its enzymes	Build the amino acid tryptophan.	Take up lactose and break it down.
The small molecule	Tryptophan, the **product**. It binds the repressor, which changes shape and **fits the operator**.	A molecule made from lactose, the **substance to use**. It binds the repressor, which changes shape and **lets go of the operator**.
Result	Plenty of tryptophan: transcription stops.	Lactose present: transcription starts.

In both, the repressor is a negative regulatory molecule: it binds DNA and blocks transcription.

trp and lac are examples

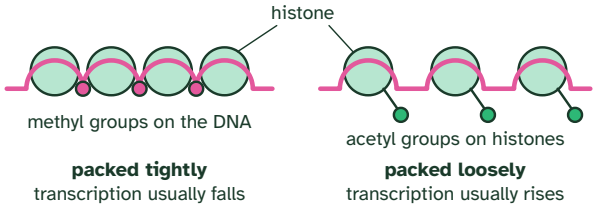
Eukaryotes: *tags*, transcription factors and small RNAs

AP BIOLOGY · UNIT 6

6.5.A EPIGENETIC CHANGES

Tags that open and close the *DNA*

- Eukaryotic DNA is wound on **histones**. Where it is packed tightly, a gene is hard to transcribe.
- **Epigenetic changes** are chemical tags on the DNA or the histones that change gene expression.
- The **base sequence is unchanged**, and the changes are **reversible**: enzymes add each tag and others remove it.



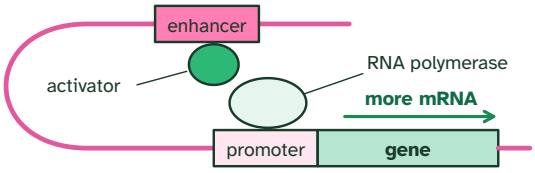
packed tightly
transcription usually falls

packed loosely
transcription usually rises

6.6.A STARTING TRANSCRIPTION

Transcription factors and *enhancers*

- RNA polymerase and **transcription factors** bind **promoter or enhancer** sequences to start transcription.
- These sequences can be **upstream or downstream** of the transcription start site. A distant enhancer still acts, because the DNA loops.
- **Negative regulatory molecules** inhibit expression by binding DNA and blocking transcription.



the DNA loops

6.6.B AFTER TRANSCRIPTION

Small RNAs *silence* a message

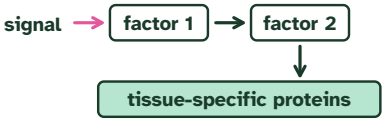
- Regulation does not end at transcription: an mRNA can be spliced in different ways, and can last a long or a short time.
- Certain **small RNA molecules** regulate expression. One pairs with a matching mRNA, which is then **broken down or not translated**.

mRNA differs between two cells	Look for regulation at transcription.
mRNA equal, protein not	The regulation is after transcription.

6.5.A DIFFERENTIATION AND DEVELOPMENT

Genes switched on *in order*

- **Differentiation** can be seen: cells express genes for **tissue-specific proteins**.
- In development, transcription factors are induced one after another. Each switches on genes that include the next factor: **sequential gene expression**.



the cell differentiates

6.6.B IN ORDER

Five places a eukaryotic cell can *regulate* a gene

1 PACKING	2 TRANSCRIPTION	3 SPLICING	4 THE MRNA	5 PROTEIN
Can it be reached? Tags open or close the DNA.	**Does it start?** Factors start it or block it.	**Which mRNA?** One gene, more than one mRNA.	**Does it last?** Kept, silenced or broken down.	**How much?** Function and amount set the phenotype.

WATCH OUT

Five mistakes that *cost points*

- ✕ **A gene that is not expressed is still there.** A skin cell keeps its insulin gene, switched off.
- ✕ **An enhancer makes nothing.** It is a site on the DNA; the activator that binds it is a protein with a gene of its own.
- ✕ **A repressor blocks transcription.** It does not destroy the gene or the mRNA, and it is not an enzyme.
- ✕ **An epigenetic change is not a mutation.** It changes whether a sequence is read, never what it says.
- ✕ **A small RNA does not switch the gene off.** The gene is still transcribed; less protein comes from each mRNA.

COVER THE SHEET

Can you *answer these?*

1. Explain how cells with the same genes can differ.
2. Describe how constitutive and inducible genes differ.
3. Explain how a repressor stops transcription.
4. Predict how the trp operon behaves with no repressor.
5. Describe one epigenetic change and its usual effect.
6. Explain how a distant enhancer can raise transcription.
7. Explain how one signal can switch on many genes.
8. Identify the stage regulated if mRNA is equal but protein is not.

IN THE EXAM

Ask first: is the part a site on the DNA, or the gene for a protein? A site acts only where it sits; a protein travels. Then say what binds where, and what transcription does.

GO FURTHER

Animated figures, a dry lab and a marked Check are in the full guide online.