16.3 Gene control

Name: _____ Class: _____ Date: _____ **Total: 23 marks**

KEY WORDS lac operon • regulatory gene • structural gene • transcription • transcription factor

Objective

Build the skills to answer exam questions on **gene control** – **structural and regulatory genes** / , **inducible and repressible enzymes** / , the **lac operon** , and **transcription factors** .

You must be able to:

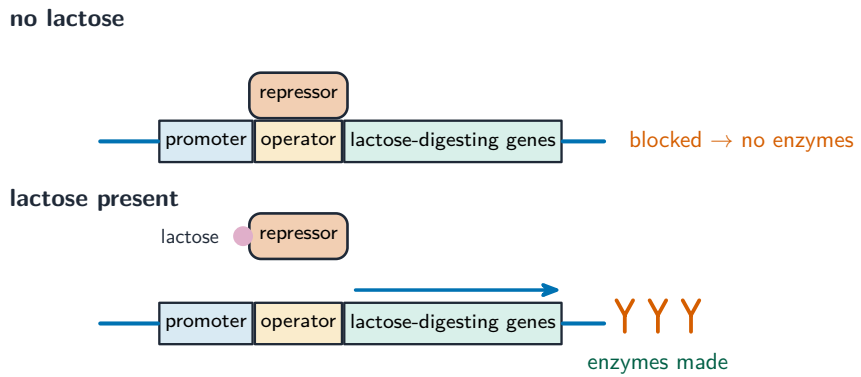
- distinguish structural and regulatory genes, and inducible and repressible enzymes
- explain the control of protein production by the lac operon
- state the role of transcription factors and explain gibberellin's action via DELLA proteins

1 Key knowledge and worked examples

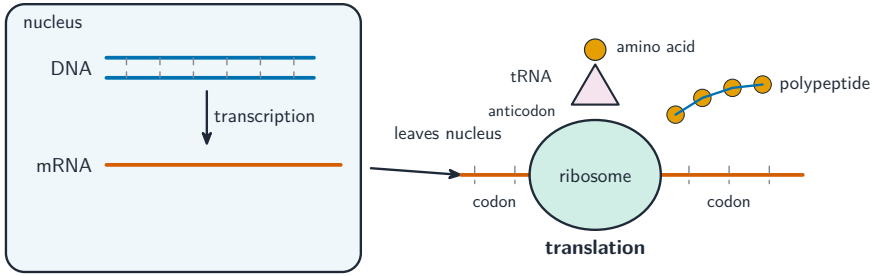
Genes and enzymes

A **structural gene** codes for a useful protein (e.g. an enzyme); a **regulatory gene** controls whether other genes are switched on. An **inducible enzyme** is made only when needed; a **repressible enzyme** is normally made but can be switched off.

The lac operon



A repressor blocks the genes until lactose pulls it off – so the enzymes are inducible



Gene control acts on transcription and translation

- **no lactose**: a **repressor** protein binds the operator and blocks **transcription** – no enzymes made.
- **lactose present**: lactose binds the repressor and pulls it off; transcription occurs and the lactose-digesting enzymes are made (they are **inducible**).

Transcription factors and gibberellin

In eukaryotes, **transcription factors** are proteins that bind DNA and raise or lower the rate of transcription. **Gibberellin** switches genes on by causing the breakdown of **DELLA** protein repressors, which normally block the factors that promote transcription.

2 Practice

2.1 State the difference between a structural gene and a regulatory gene. [2]

2.2 State what is meant by an inducible enzyme. [1]

3 Exam-style questions

3.1 In the lac operon, when **no** lactose is present, the repressor protein: [1]

- ☐ **A** is broken down
- **B** binds the operator and blocks transcription
- **C** is transcribed into mRNA
- **D** binds the lactose-digesting enzymes

3.2 What is the role of a transcription factor in a eukaryotic cell? [1]

- ☐ **A** to replicate DNA
- **B** to bind DNA and control the rate of transcription
- **C** to translate mRNA
- **D** to break down glucose

3.3 Explain how the lac operon allows a bacterium to make lactose-digesting enzymes only when lactose is present. [4]

3.4 Explain how gibberellin switches on genes by acting on DELLA proteins. [2]

3.5 In *Escherichia coli* the *lac* operon controls the enzymes that break down lactose.

(a) Distinguish between a structural gene and a regulatory gene, using the *lac* operon as your example. [3]

(b) Describe what happens at the operon when **no** lactose is present. [3]

(c) Describe what happens when lactose **is** present, and explain why the enzymes are described as inducible. [4]

(d) Explain the advantage to the bacterium of controlling these genes in this way. [2]

Solutions

Each answer shows the steps, then the **result**.

2.1

- a structural gene codes for a (useful) protein such as an enzyme; a regulatory gene controls whether other genes are switched on

2.2

- an enzyme that is made only when it is needed (e.g. when its substrate is present)

3.1 B

- With no lactose, the repressor binds the operator and blocks transcription

3.2 B

- A transcription factor binds DNA and increases or decreases the rate of transcription

3.3

- when no lactose is present, the repressor binds the operator and blocks transcription, so no enzymes are made; when lactose is present, it binds the repressor and removes it from the operator; transcription can now occur, so the lactose-digesting enzymes are made

3.4

- gibberellin causes the breakdown of DELLA protein repressors; these normally block the transcription factors, so removing them lets the genes be transcribed/expressed

3.5

(a)

- A structural gene codes for a protein used by the cell – here *lacZ*, coding for β-galactosidase; a regulatory gene codes for a protein that controls the transcription of other genes – here *lacI*, coding for the repressor

(b)

- The regulatory gene is transcribed and the **repressor** protein is made; the repressor binds to the operator region; this blocks RNA polymerase from moving along the structural genes, so no mRNA and no enzyme are made

(c)

- Lactose acts as the **inducer**: it binds to the repressor and changes its shape so that it can no longer bind to the operator; RNA polymerase is then free to transcribe the structural genes and the enzymes are made. They are *inducible* because they are produced only when their substrate is present to switch them on

(d)

- Making enzymes costs amino acids and ATP, so producing them when there is no lactose to digest would be wasteful; the bacterium makes them only when they can be used, which gives it a selective advantage