5.6 Gene switching and transcription factors

Name: _____ Class: _____ Date: _____ **Total: 18 marks**

KEY WORDS transcription factor • epigenetics • methylation • imprinting

Objective

Practise statement 7.22: transcription factors switching genes on and off, steroid-hormone receptors acting as transcription factors, and epigenetic control by DNA methylation and histone modification.

1 Key knowledge and worked examples

■ The switch itself

A **transcription factor** is a protein that binds a gene's promoter region and either enables or blocks RNA polymerase. In this activation model, the bound factor helps assemble the transcription machinery. Different cells use different combinations of transcription factors, contributing to differentiation.

■ Steroids walk in

Steroid hormones diffuse through the cell membrane and bind an internal receptor; the activated receptor binds regulatory DNA in the nucleus and acts as a transcription factor. Testosterone and oestrogen can regulate genes this way; the hormone molecule itself is not a DNA-binding protein.

■ Epigenetics

Control WITHOUT changing the base sequence: **methylation** of cytosine at a promoter silences the gene; histone acetylation loosens the DNA (active) while deacetylation packs it tight (silent). Epigenetic marks can be maintained through cell division. Heavy methylation at some tumour-suppressor promoters can reduce protective gene expression; imprinting errors can disrupt development, including some cases of Prader-Willi syndrome.

Worked example: cancer by silence

In this simplified model, a tumour-suppressor promoter becomes heavily methylated in a lung cell lineage. This reduces transcription-factor binding and gene expression, so less protective protein is made. Weakened cell-cycle control can contribute to uncontrolled division. The explanation changes gene activity without requiring a change in DNA sequence.

2 Practice

2.1 State what a transcription factor does. [1]

2.2 Name the two epigenetic mechanisms that silence genes without changing the base sequence. [2]

2.3 Explain how a steroid hormone can alter transcription through an intracellular receptor, whereas adrenaline first binds a cell-surface receptor. [2]

3 Exam-style questions

3.1 Explain how a gene can be switched on by a transcription factor, naming where the factor binds and what changes at the gene. [4]

3.2 The RASSF1 gene is a tumour suppressor. In some cancer cells its promoter is heavily methylated. Explain how this methylation leads to uncontrolled cell division. [5]

3.3 One gene can produce several different proteins in different tissues. Explain how, referring to post-transcriptional processing of the pre-mRNA. [4]

Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

2.1 Binds the gene's promoter and switches transcription on or off.

2.2 DNA methylation and histone modification (deacetylation).

2.3 Steroids are lipid-soluble and can enter the cell; the activated intracellular receptor binds regulatory DNA in the nucleus; adrenaline is amino-acid derived and water-soluble - it binds a surface receptor and acts through intracellular signalling; this can also affect gene expression indirectly.

3.1 A transcription factor binds the promoter region upstream of the gene; the bound factor assists RNA polymerase attachment and assembly of the transcription complex; transcription of the gene begins and mRNA appears.

3.2 In the model described, heavy promoter methylation reduces transcription-factor binding; less transcription machinery assembles, reducing RASSF1 mRNA and protein production. Loss of protective protein weakens cell-cycle control and can contribute to uncontrolled division. Maintenance of the methylation pattern through cell division can pass reduced gene expression to daughter cells.

3.3 The gene is transcribed to a pre-mRNA containing all exons and introns; different tissues splice the pre-mRNA differently, keeping different exon combinations; the mature mRNAs translate to proteins with different amino-acid sequences and functions.