31.1 Mutations and gene editing

Name: _____ Class: _____ Date: _____ **Total: 26 marks**

KEY WORDS mutation • substitution • frameshift • mutagen • somatic • gene editing

Objective

Build the skills to answer exam questions on **mutations and gene editing** : substitutions, insertions and deletions, causes of mutation, cancer, and gene editing.

You must be able to:

- describe base substitutions, insertions and deletions, and their effects on proteins
- state causes of mutation and explain why mutation is random
- distinguish germ-line and somatic mutations, and link mutations to cancer
- explain why mutation is the original source of genetic variation
- explain gene knockout, CRISPR–Cas9 gene editing and highly conserved sequences

1 Key knowledge and worked examples

Mutations and gene editing

Gene mutation: a change in the base sequence of a gene.

type	change	effect
substitution	one base replaced	one codon changes: same amino acid, a different amino acid, or a stop codon
insertion	one or more bases added	if not a multiple of 3, a **frameshift**: every later codon changes
deletion	one or more bases lost	frameshift, usually a non-working protein

Causes: mutagens such as **ionizing radiation** (X-rays, gamma rays), **UV light**, and chemicals (e.g. in tobacco smoke), plus copying errors in replication. Mutation is **random**: no mechanism directs a change to a particular gene, although some sites mutate more often.

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Germ-line mutations (in cells that form gametes) can be **inherited**; **somatic** mutations (body cells) are not passed to offspring but can cause **cancer** if they affect genes that control cell division. Mutation is the original source of all new **alleles**, so it provides the **variation** that natural selection acts on.

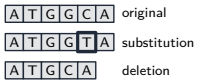
HL: in a **gene knockout**, a gene is made inactive in an organism (e.g. a mouse) to find its function. **CRISPR–Cas9**: a **guide RNA** matches the target sequence; the **Cas9** enzyme cuts the DNA there; the cell repairs it, which can disable the gene or insert a new sequence. **Highly conserved sequences** change very little between species, because mutations in them are harmful and removed by selection.

Worked example. Coding strand ATG GCA TTT. Deleting the C gives ATG GAT TT…: from the second codon on, every codon changes: a frameshift.

Answer shapes: base change → codon change → amino acid change → shape/function change.

2 Practice

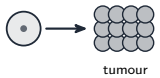
2.1 Distinguish between a substitution and a deletion. [2]



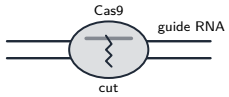
2.2 Explain why a deletion of one base usually has a bigger effect than a substitution. [3]



2.3 Explain why a mutation in a skin cell cannot be inherited, but can still be harmful. [3]



2.4 Describe how CRISPR–Cas9 is used to edit a gene. [3]



2.5 Explain why some DNA sequences are highly conserved between species. [3]

G C T A A G C T	human
G C T A A G C T	mouse
G C T A A G C C	fish
G C T C A G C T	yeast

3 Exam-style questions

3.1 The coding strand of part of a gene is ATG TTT GCA AAA.

codon	**AUG**	**UUU**	**GCA**	**AAA**	**GAA**	**CAA**	**UAA**
amino acid	Met	Phe	Ala	Lys	Glu	Gln	stop

(a) Give the amino acid sequence coded by this DNA. [1]

A	T	G	T	T	T	G	C	A	A	A	A
	1		2		3			4			

(b) The second base of codon 3 (C) is deleted. Write the new codons and amino acids, as far as the table allows. [2]

(c) A substitution changes AAA to UAA in the mRNA. Explain its effect. [2]

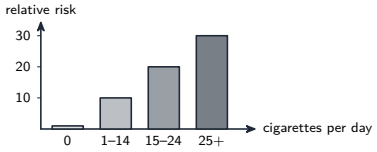
(d) State one mutagen. [1]

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3.2 The graph shows the risk of lung cancer in people who smoke different numbers of cigarettes per day.

(a) Describe the relationship shown. [1]

(b) Explain how smoking can cause lung cancer. [3]



(c) Explain why mutation is important for evolution. [2]

Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

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

2.1

substitution: one base is replaced by another; deletion: a base is removed, shifting the reading frame

2.2

a substitution changes only one codon, and may not change the amino acid (degenerate code); a deletion shifts the reading frame (frameshift); every codon after it changes, so many amino acids change / an early stop codon appears

2.3

it is a somatic mutation, not in a germ-line cell / gamete, so it is not passed to offspring; if it affects a gene that controls cell division; the cell can divide uncontrollably, forming a tumour / cancer

2.4

a guide RNA is made to match the target DNA sequence; Cas9 is guided to that sequence and cuts the DNA; the cell repairs the cut, which can disable the gene or insert a new sequence

2.5

they code for vital functions, e.g. histones / ribosomal RNA; most mutations in them are harmful; so individuals with those mutations die / do not reproduce, and natural selection removes them

3.1

(a) Met–Phe–Ala–Lys

(b) ATG TTT GAA AA…: codons AUG UUU GAA A…; Met–Phe–Glu: every codon after the deletion changes, so Ala and Lys are lost: a frameshift

(c) UAA is a stop codon; translation stops early, so the protein is shorter and probably does not work

(d) any one: X-rays / gamma rays / UV light / chemicals in tobacco smoke

3.2

(a) the more cigarettes per day, the higher the risk (positive correlation)

(b) tobacco smoke contains mutagens / carcinogens; these cause mutations in the DNA of lung cells; mutations in genes that control cell division make cells divide uncontrollably, forming a tumour

(c) mutation creates new alleles; this gives the genetic variation on which natural selection acts

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