IGCSE BIOLOGY • EXERCISE SHEET

17.1.1 From gene to protein: mRNA, ribosomes and why cells differ

Name: _____ Class: _____ Date: _____ **Total: 36 marks**

KEY WORDS protein 蛋白质 • amino acids 氨基酸 • genes 基因 • allele 等位基因 • mrna 信使

Objective

Sheet 17.1 gave you the words – chromosome, gene, allele – and the inheritance of sex. This sheet is the Supplement half of 17.1: how a **base sequence** 碱基序列 becomes a **protein** 蛋白质, what **haploid** 单倍体 and **diploid** 二倍体 really mean, how **DNA** controls what a cell does, and why a nerve cell and a pancreas cell behave differently although they carry exactly the same genes. Every answer here is a sequence of steps in a fixed order. This sheet covers syllabus 17.1.

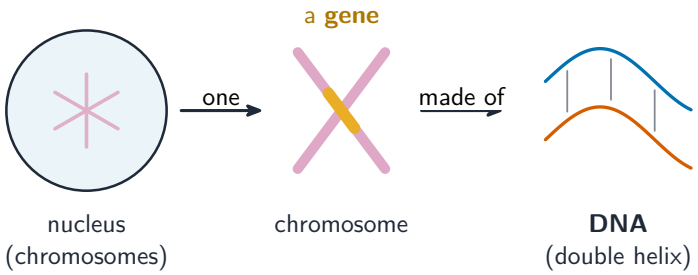
You must be able to:

- state that chromosomes are made of DNA, which carries genetic information as **genes** 基因, and define a gene and an **allele** 等位基因
- describe the inheritance of sex in humans using the X and Y chromosomes
- state that the sequence of bases in a gene determines the sequence of **amino acids** 氨基酸 in a protein
- explain that different amino acid sequences give proteins different **shapes** 形状
- explain that DNA controls cell function by controlling the proteins made, including **enzymes** 酶, **membrane carriers** 膜载体 and **receptors** 受体 for neurotransmitters
- explain how a protein is made: the gene stays in the nucleus, **mRNA** 信使 RNA copies it and moves to the cytoplasm, it passes through a **ribosome** 核糖体, and the ribosome joins amino acids in the order the bases specify
- explain that most body cells contain the same genes, but that many are not **expressed** 表达
- describe a haploid nucleus and a diploid nucleus, and state that a human diploid cell has 23 pairs

1 Worked examples

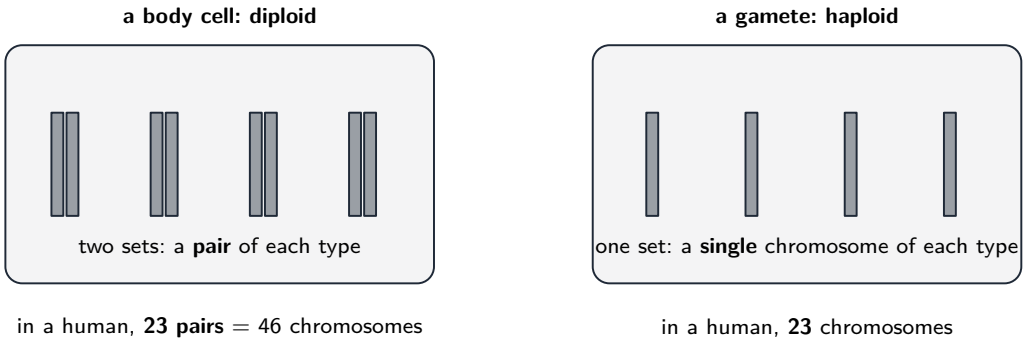
Study these first. Each one shows a **method** that a question later on this sheet needs.

The words, nested



- A **chromosome** 染色体 is made of **DNA**.
- A **gene** is a **length of DNA that codes for a protein**. Learn that wording – "a gene controls a characteristic" is not the definition.
- An **allele** is an **alternative form of a gene**, for example B and b.
- **Sex** is inherited through the sex chromosomes: a female is **XX** and a male is **XY**. The egg always carries an X, so it is the **sperm** that decides, and the chance of a boy is $\frac{1}{2}$.

Haploid and diploid: count sets, not chromosomes



in a human, **23 pairs** = 46 chromosomes

in a human, **23** chromosomes

Define them by *sets*, not by numbers: diploid means **two sets**, haploid means **one set**. The human figures are then an example, not the definition.

- **Diploid** means the nucleus contains **two sets** of chromosomes – a **pair** of each type. Human body cells are diploid, with **23 pairs**, so 46 chromosomes.
- **Haploid** means the nucleus contains **a single set**. Human gametes are haploid, with **23** chromosomes.
- Answer with *sets*. "46 chromosomes" is a human fact, not a definition, and it earns nothing if the question is about a species with a different number.

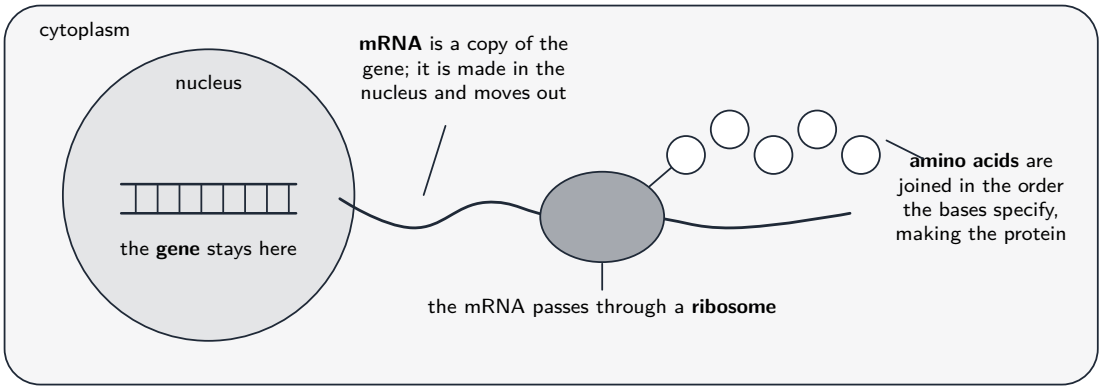
From bases to a working protein

The chain the exam wants runs in one direction only:

sequence of bases → sequence of amino acids → shape of the protein → what the protein does

- A different base sequence gives a **different order of amino acids**, which folds into a **different shape**.
- Shape decides the job. An **enzyme** only works because its **active site** has a shape complementary to its substrate; a **membrane carrier** only moves one kind of molecule; a **receptor** only binds one neurotransmitter.
- So "DNA controls the cell" means: DNA controls **which proteins are made**, and the proteins do the work.

Making a protein, in the six steps the mark scheme lists

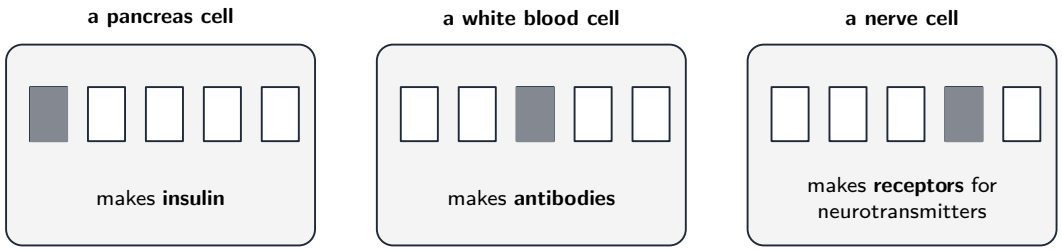


Six steps, in this order: the gene stays in the nucleus; mRNA copies it; the mRNA leaves the nucleus; it passes through a ribosome; the ribosome joins amino acids; their order is set by the order of the bases.

1. The **gene** coding for the protein **stays in the nucleus**.
2. **mRNA** is made in the nucleus as a **copy of the gene**.
3. The mRNA **moves out of the nucleus** into the cytoplasm.
4. It **passes through a ribosome**.
5. The ribosome **joins amino acids** together into a protein molecule.
6. The **order of the amino acids** is set by the **order of the bases** in the mRNA.

- You are not asked for any detail beyond these six points – no names of bases, no transfer RNA, no codons.
- Why does the mRNA exist at all? Because the gene cannot leave the nucleus, and the ribosome is in the cytoplasm. A copy is the only way the message can travel.

■ Same genes, different cells



the same five genes are present in all three cells; a filled gene is one that is **expressed**

> The genes are not missing – they are simply **not expressed**. A cell makes only the proteins it needs, and that is what makes one cell different from another.

Almost every body cell in an organism carries **the same genes**, because they all came from the same **zygote** 受精卵 by mitosis.

> A cell only makes the proteins it needs, so many of its genes are **not expressed**. That is what makes one cell different from another.

- The genes are **present but switched off**, never missing. "The nerve cell has no insulin gene" is wrong.

2 Practice

Now use the methods above.

2.1 Define a gene, and define an allele. [2]

2.2 Describe what is meant by a haploid nucleus and by a diploid nucleus. [2]

2.3 State the number of chromosomes in a human body cell and in a human sperm cell. [2]

2.4 Explain why a change in the base sequence of a gene can stop the protein it codes for working. [3]

2.5 State **three** kinds of protein whose production is controlled by DNA. [3]

2.6 Explain why an mRNA copy of the gene has to be made, instead of the gene itself going to the ribosome. [2]

3 Exam-style questions

3.1 Which statement about the body cells of one person is correct? [1]

A	B
C	D

A Different cells contain different genes, so they make different proteins.
B Different cells contain the same genes, but express different ones.
C All cells express all of their genes.
D Only the cells of the pancreas contain the gene for insulin.

3.2 A protein is made in a cell.

(a) Describe how the protein is made, from the gene in the nucleus to the finished protein. [6]

(b) Explain how the sequence of bases in the gene decides what the protein is able to do. [3]

3.3 The diagram in the worked examples shows three cells from the same person.

(a) State why all three cells contain the same genes. [1]

(b) Explain why the nerve cell does not make insulin, although it carries the insulin gene. [2]

(c) A nerve cell makes receptors for neurotransmitters. Explain why a receptor binds only one kind of neurotransmitter. [3]

(d) Sperm cells and body cells both come from the same person. State the difference between their nuclei, and name the type of division that produces sperm cells. [3]

(e) A woman's egg is fertilised by a sperm carrying a Y chromosome. State the sex of the child and explain why the father, not the mother, determines it. [3]

Solutions

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

2.1

- a gene is a **length of DNA that codes for a protein**
- an allele is an **alternative form of a gene**

2.2

- haploid: a nucleus containing a **single set** of chromosomes
- diploid: a nucleus containing **two sets** of chromosomes, a pair of each type

2.3

- body cell: **46** chromosomes, in 23 pairs
- sperm cell: **23** chromosomes

2.4

- the order of the bases sets the **order of the amino acids** in the protein
- a different order of amino acids gives the protein a **different shape**
- the protein's shape is what lets it do its job, so a changed shape may stop it working – for an enzyme, the **active site** no longer fits its substrate

2.5

- **enzymes**
- **membrane carriers**, which move substances across a cell membrane
- **receptors** for neurotransmitters

2.6

- the gene cannot leave the nucleus, but the ribosomes are in the **cytoplasm**
- so a **copy** of the gene is made, as mRNA, and it is the copy that travels to the ribosome

3.1 B

- all the body cells came from one zygote by mitosis, so they carry the same genes
- they differ because each one **expresses** only the genes for the proteins it needs
- **A** and **D** say the genes are missing, which they are not; **C** would make every cell identical

3.2

(a)

- the **gene** stays in the **nucleus**
- **mRNA** is made in the nucleus as a **copy of the gene**
- the mRNA **moves out of the nucleus** into the cytoplasm
- it **passes through a ribosome**

- the ribosome **joins amino acids** together into a protein
- the **order of the amino acids** is determined by the **order of the bases** in the mRNA

(b)

- the base sequence sets the **sequence of amino acids**
- a different sequence of amino acids folds into a **different shape**
- the shape decides what the protein can bind to, and so what it does – an enzyme's active site, a carrier's channel, a receptor's binding site

3.3

(a)

- they all developed from the **same zygote** by **mitosis** 有丝分裂, which produces genetically identical cells

(b)

- the insulin gene is present but is **not expressed** in a nerve cell
- a cell only makes the proteins it needs, and a nerve cell has no use for insulin

(c)

- the receptor is a protein whose **shape** is set by the order of its amino acids
- only a neurotransmitter with a **complementary** shape can fit and bind to it
- a molecule of any other shape does not fit, so it has no effect on that cell

(d)

- a body cell nucleus is **diploid**, with two sets of chromosomes (23 pairs)
- a sperm cell nucleus is **haploid**, with a single set (23 chromosomes)
- sperm cells are produced by **meiosis** 减数分裂

(e)

- the child is a **boy**
- every egg carries an **X** chromosome, so the mother can only ever contribute an X
- a sperm carries either an X or a **Y**, so it is the sperm that decides whether the pair is XX or XY