Exercise walk-through

17.1.1

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

IGCSE Biology

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

You must be able to

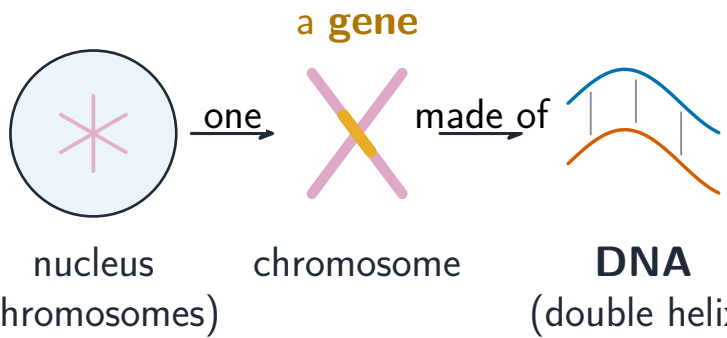
- explain that most body cells contain the same genes, but that many are not **expressed** 表达
- describe a haploid nucleus and a diploid nucleus, and state that a human diploid cell has 23 pairs

1 The method

Method — 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 $\frac{1}{2}$.

Method — The words, nested



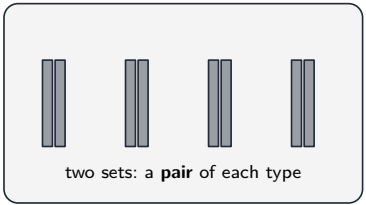
A chromosome shown as a coiled thread of DNA, with one short length of it marked as a gene

Method — Haploid and diploid: count sets, not chromosomes

- **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.

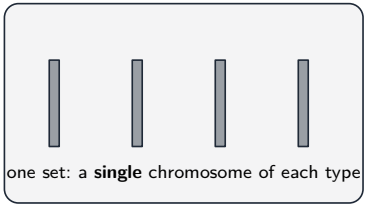
Method — Haploid and diploid: count sets, not chromosomes

a body cell: diploid



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

a gamete: haploid



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.

Method — 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 do

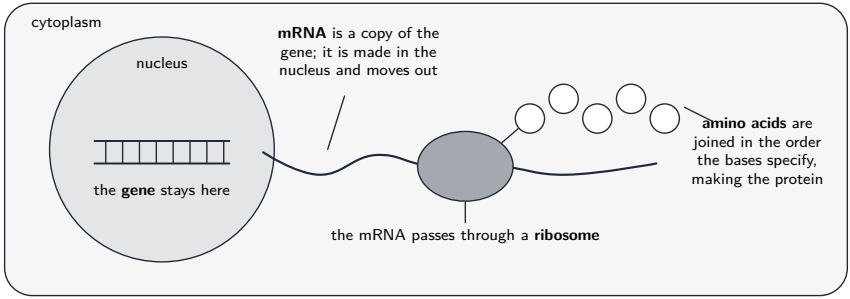
- A different base sequence gives a **different order of amino acids**, which folds into a **different shape**.
- Shape decides the job. An **enzyme** only works because its **active site** has a shape complementary to its substrate; a **membrane carrier** only moves one kind of molecule; a **receptor**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

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

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.

Method — 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.

Method — Same genes, different cells

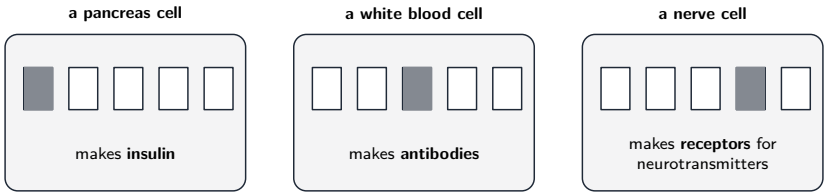
Almost every body cell in an organism carries **the same genes**, because they all came from the same **zygote** 受精卵 by mitosis.

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.

Method — Same genes, different cells

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



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.

2 Practice

Practice 2.1 ▪ 2 marks

Define a gene, and define an allele.

Solution 2.1

Method: The words, nested — p.5

Worked steps

- a gene is a **length of DNA that codes for a protein** B1
- an allele is an **alternative form of a gene** B1

Practice 2.2 ▪ 2 marks

Describe what is meant by a haploid nucleus and by a diploid nucleus.

Solution 2.2

Method: Haploid and diploid: count sets, not chromosomes — p.7

Worked steps

- haploid: a nucleus containing a **single set** of chromosomes B1
- diploid: a nucleus containing **two sets** of chromosomes, a pair of each type B1

Practice 2.3 ▪ 2 marks

State the number of chromosomes in a human body cell and in a human sperm cell.

Solution 2.3

Method: Haploid and diploid: count sets, not chromosomes — p.7

Worked steps

- body cell: **46** chromosomes, in 23 pairs B1
- sperm cell: **23** chromosomes B1

Practice 2.4 ▪ 3 marks

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

Solution 2.4

Method: From bases to a working protein — p.9

Worked steps

- the order of the bases sets the **order of the amino acids** in the protein B1
- a different order of amino acids gives the protein a **different shape** B1
- 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 B1

Practice 2.5 ▪ 3 marks

State **three** kinds of protein whose production is controlled by DNA.

Solution 2.5

Worked steps

- **enzymes** B1
- **membrane carriers**, which move substances across a cell membrane B1
- **receptors** for neurotransmitters B1

Practice 2.6 ▪ 2 marks

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

Solution 2.6

Method: Making a protein, in the six steps the mark scheme lists — p.10

Worked steps

- the gene cannot leave the nucleus, but the ribosomes are in the **cytoplasm** B1
- so a **copy** of the gene is made, as mRNA, and it is the copy that travels to the ribosome B1

3 Exam-style

Exam-style 3.1 ▪ 1 mark

Which statement about the body cells of one person is correct?

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.

Solution 3.1

Method: Haploid and diploid: count sets, not chromosomes — p.7

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.

Worked steps

B

- all the body cells came from one zygote by mitosis, so they carry the same genes B1
- they differ because each one **expresses** only the genes for the proteins it needs

Exam-style 3.2 ▪ 9 marks

A protein is made in a cell.

Exam-style 3.2 (a) ▪ 6 marks

Describe how the protein is made, from the gene in the nucleus to the finished protein.

Solution 3.2 (a)

Worked steps

- the **gene** stays in the **nucleus** B1
- **mRNA** is made in the nucleus as a **copy of the gene** B1
- the mRNA **moves out of the nucleus** into the cytoplasm B1
- it **passes through a ribosome** B1
- the ribosome **joins amino acids** together into a protein B1
- the **order of the amino acids** is determined by the **order of the bases** in the mRNA B1

Exam-style 3.2 (b) ▪ 3 marks

Explain how the sequence of bases in the gene decides what the protein is able to do.

Solution 3.2 (b)

Worked steps

- the base sequence sets the **sequence of amino acids** B1
- a different sequence of amino acids folds into a **different shape** B1
- 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 B1

Exam-style 3.3 ▪ 12 marks

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

Exam-style 3.3 (a) ▪ 1 mark

State why all three cells contain the same genes.

Solution 3.3 (a)

Method: Same genes, different cells — p.12

Worked steps

- they all developed from the **same zygote** by **mitosis 有丝分裂**, which produces genetically identical cells B1

Exam-style 3.3 (b) ▪ 2 marks

Explain why the nerve cell does not make insulin, although it carries the insulin gene.

Solution 3.3 (b)

Worked steps

- the insulin gene is present but is **not expressed** in a nerve cell B1
- a cell only makes the proteins it needs, and a nerve cell has no use for insulin B1

Exam-style 3.3 (c) ▪ 3 marks

A nerve cell makes receptors for neurotransmitters. Explain why a receptor binds only one kind of neurotransmitter.

Solution 3.3 (c)

Worked steps

- the receptor is a protein whose **shape** is set by the order of its amino acids B1
- only a neurotransmitter with a **complementary** shape can fit and bind to it B1
- a molecule of any other shape does not fit, so it has no effect on that cell B1

Exam-style 3.3 (d) ▪ 3 marks

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.

Solution 3.3 (d)

Worked steps

- a body cell nucleus is **diploid**, with two sets of chromosomes (23 pairs) B1
- a sperm cell nucleus is **haploid**, with a single set (23 chromosomes) B1
- sperm cells are produced by **meiosis 减数分裂** B1

Exam-style 3.3 (e) ▪ 3 marks

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.

Solution 3.3 (e)

Worked steps

- the child is a **boy** B1
- every egg carries an **X** chromosome, so the mother can only ever contribute an X B1
- a sperm carries either an X or a **Y**, so it is the sperm that decides whether the pair is XX or XY B1