Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Spot the error

ANSWER A · 4

i. She added the chances. To match at all 5 places a person must match at the first **and** the second and so on, so the chances multiply: $(1/10)^5 =$ **1 in 100,000**.
ii. $300{,}000 \div 100{,}000 =$ **3 people**.
iii. The expected number is $30{,}000{,}000 \div 10$C for n places. For n = 7 it is 3; for n = 8 it is 0.3. So **8 places**.
iv. Places on different chromosomes are inherited independently, and only then can the chances be multiplied.

MARKING SCHEME

✓ The chances multiply, not add: 1 in 100,000.
✓ 3 people in the town.
✓ 8 places ($30{,}000{,}000 \div 10^8 = 0.3$, while 7 places give 3).
✓ Different chromosomes are inherited independently, which is what allows multiplying.

2 An inheritance puzzle

ANSWER A · 4

i. One number from each parent: **8 and 9; 8 and 14; 11 and 9; 11 and 14.**
ii. **No.** 8 and 11 are both the mother's numbers, and a child gets one chromosome of each pair from each parent, so one number must be the father's (9 or 14).
iii. 14 can have come from the father, but 10 is in neither parent's pair, so one of these people may not be a biological parent. It could also come from a mutation or a laboratory error, which is why tests look at many places.
iv. GATA has 4 bases, so the difference is $(14 - 8) \times 4 =$ **24 bases**. The piece with **8 repeats** is smaller, so it goes farther.

MARKING SCHEME

✓ The four pairs: 8/9, 8/14, 11/9, 11/14.
✓ Not possible: both numbers are the mother's, and one must come from the father.
✓ 10 is in neither parent: a parent may not be the biological one, or a mutation or laboratory error; hence many places are tested.
✓ 24 bases; the piece with 8 repeats goes farther.

3 Check the claim

ANSWER HA · 4

i. The band at **1.5 cm**: big pieces are held back most by the gel's mesh, so the longest travel least.
ii. **Q and R.** Q has an extra band (5.0 cm) that the scene lacks, and R lacks a band (4.5 cm) that the scene has. A lane that differs by even one band came from a different person. Sharing most bands doesn't matter: unrelated people often share some.
iii. Any two: a match shows only whose DNA was at the scene, not who committed the crime, since DNA can be left there innocently or carried there; a few bands on one gel are too few, since real tests use 15 to 24 places on different chromosomes; an identical twin of P would give the same pattern.

MARKING SCHEME

✓ 1.5 cm band: long pieces travel least through the mesh.
✓ Q and R are cleared; even one band's difference (Q's extra, R's missing) means a different person.
✓ One reason: DNA shows who was there (or whose DNA was left), not who did it.
✓ A second reason: too few places tested, or an identical twin would match.

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4 What if?

ANSWER U · 3

i. **Black**: face color is decided by the genes in the nucleus, which come from the Scottish Blackface ewe.
ii. The **Finn Dorset egg donor's**: mitochondria come from the egg, not from the nucleus donor.
iii. **Male**: a clone is of the same sex as the animal that gave the nucleus.

MARKING SCHEME

✓ Black face: the nuclear genes are the Blackface ewe's.
✓ Mitochondria from the Finn Dorset that gave the egg.
✓ Male, the same sex as the nucleus donor.

5 Find the fault

ANSWER A · 3

i. Different enzymes leave different ends, so the sticky ends of gene and plasmid did not match and could not pair.
ii. Without ligase, the backbones of the paired pieces were never sealed: the ends paired, but nothing joined them into one recombinant plasmid.
iii. DNA is the same chemical in every living thing, and every living thing reads it with the same genetic code.

MARKING SCHEME

✓ Trial 1: different enzymes give sticky ends that don't match.
✓ Trial 2: no ligase, so the backbones were not sealed.
✓ The same chemical (DNA) and the same genetic code in all living things.

6 A two-step calculation

ANSWER A · 3

i. One billion ÷ 1,000 = a million, and $2^{20} = 1{,}024 \times 1{,}024 = 1{,}048{,}576$, just over a million ($2^{19}$ is under it). So 20 doublings × 20 min = 400 min = **6 h 40 min**.
ii. **20 minutes** before: one doubling time, because the number doubles in each 20 minutes.
iii. 20 × 30 = 600 min = 10 h, which is 600 − 400 = **200 minutes** (3 h 20 min) longer.

MARKING SCHEME

✓ 20 doublings, so 400 min (6 h 40 min).
✓ 20 minutes before (one doubling).
✓ 600 min, so 200 minutes longer.

7 Correct the misconceptions

ANSWER U · 3

1. "Even in its mitochondria" is wrong: a clone's mitochondria, which carry a little DNA of their own, come from the egg, not from the nucleus donor.
2. "Same age, with the parent's memories" is wrong: a clone is born as a baby, much younger than its parent, and has none of its memories.
3. "Exactly the coat pattern" is wrong: genes are switched on and off differently in different individuals. CC, the first cloned cat, looked nothing like Rainbow, who gave the nucleus, because one X chromosome in each cell is switched off by chance.

MARKING SCHEME

✓ Mitochondria come from the egg, not from the nucleus donor.
✓ A clone is born a baby, younger than its parent, without its memories.
✓ Genes are switched on and off differently (the cat CC), so the coat pattern can differ.

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8 Design a fair test

ANSWER A · 4

i. He compares trees grown from seeds with trees grafted from twigs, and measures the fruit of each tree: its size or mass and its sweetness (for example, tasters' scores out of ten, without being told which tree it came from).

ii. Any three: the same soil and field; the same water and manure; trees planted at the same time; fruit picked at the same ripeness; the same tasters.

iii. One tree could be different by chance; many trees show how much each kind varies, which is what the test is about.

iv. The grafted trees' fruit will be alike and like the parent's, since they have its genes exactly. The seedlings' fruit will vary, and some may be sour and small, since each seedling has a new mixture of genes.

MARKING SCHEME

✓ Compares seedlings with grafted trees; measures fruit size or sweetness.

✓ Any three things kept the same.

✓ Many trees, because one could differ by chance and the variation is what is being tested.

✓ Grafted fruit alike and like the parent's (same genes); seedlings' fruit varied (new mixtures of genes).

9 Read the table, judge the claim

ANSWER HA · 4

(The harvests are made up for this question.)

i. Totals: A = 40 + 42 + 6 + 0 = **88 t**; B = 30 + 31 + 22 + 25 = **108 t**. Falls: A = (42 − 6) ÷ 42 × 100% = **86%**; B = (31 − 22) ÷ 31 × 100% = **29%**.

ii. Before the fungus, the clone gave the bigger harvest each year (40 and 42 t against 30 and 31 t), since a good variety's qualities are kept exactly and the crop is uniform. Cloning's benefit is real; the risk appears when something new arrives.

iii. All of Farm A's plants have the same genes, so if one can't resist the fungus, none can. On Farm B some varieties have genes that let them survive, so only part of the crop is lost.

iv. Grow several varieties rather than one, and stop infected planting material from spreading (or plant a resistant variety).

MARKING SCHEME

✓ Totals 88 t and 108 t; falls of 86% and 29%.

✓ Years 1–2: the clone yielded more, so the claim is too simple (kept qualities, uniform crop).

✓ A: the same genes, so none resists; B: some varieties have genes to survive.

✓ Several varieties, or stopping infected planting material, or a resistant variety.

10 Judge each case by the treaties

ANSWER A · 4

i. **Does not break it:** the Protocol of 1925 banned the use of these weapons in war, not making or keeping them.

ii. **Breaks it:** the Convention (agreed 1972, in force 1975) bans stockpiling and requires them to be destroyed.

iii. **Does not break it:** peaceful research for vaccines, medicines and tests is allowed.

iv. Even keeping them is dangerous: germs escaped by accident from a secret military laboratory, and more than 60 people died in the town downwind.

MARKING SCHEME

✓ Not broken: the Protocol banned use, not keeping.

✓ Broken: the Convention bans stockpiling and requires destruction.

✓ Not broken: peaceful research is allowed.

✓ An accidental leak killed people, so keeping them is itself dangerous.

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11 A case from a clinic

ANSWER A · 4

i. **His brother.** Sister: a positive crossmatch means his antibodies would attack her kidney at once, so she can't be used. Father: both of a donor's kidneys must be healthy. Neighbor: Nepal's law lets a living person give an organ only to a close family member.

ii. An **allograft**. No: the kidney carries the donor's markers, so he takes immunosuppressants for as long as it works.

iii. An **isograft**: it is not rejected, so medicines against rejection would not be needed, because identical twins have the same genes and the same tissue type.

MARKING SCHEME

- ✓ The brother is chosen; the sister is out for a positive crossmatch.
- ✓ The father is out (kidneys not healthy) and the neighbor is out (the law: close family only).
- ✓ Allograft; immunosuppressants for as long as the kidney works.
- ✓ Isograft, not rejected, because a twin has the same genes.

12 Estimate it

ANSWER A · 3

(The center's figures are from the unit; the machine's timetable is made up.)

i. $1{,}500 \div (2025 - 2012) = 1{,}500 \div 13 \approx$ **115 a year**, which fits "well over a hundred".

ii. $3 \times 6 = 18$ sessions a week $\div$ 3 sessions a patient = **6 patients**.

iii. $115 \div 6 \approx$ **19 machines** (about 20).

MARKING SCHEME

- ✓ About 115 transplants a year.
- ✓ 6 patients a machine.
- ✓ About 19 or 20 machines.

13 Which explanation fits the evidence?

ANSWER HA · 3

Richa's. Earlier kidneys were lost because the body rejected them, and in the twins the markers on the kidney were the recipient's own. What soon allowed kidneys to be given between people who were not twins was medicines that prevent rejection. A medicine against rejection could not have made that difference if the problem had been the surgery, so rejection, not the surgeon's skill, was the barrier.

MARKING SCHEME

- ✓ Richa's explanation.
- ✓ Earlier failures were rejection; twins have the same genes and tissue type, so none occurred.
- ✓ Medicines against rejection, not new surgery, opened transplants to non-twins, which rules out Salim's idea as the main reason.

14 Two treatments, one judgment

ANSWER HA · 3

Doctor 1: only Shruti is affected, and she can agree for herself.

Doctor 2: the change passes to the person the embryo becomes and to all their descendants, none of whom can agree.

More caution is due to the embryo: the change can't be limited to one person, and it is made without the consent of those who will carry it. Scientists around the world condemned the editing of embryos announced in China in 2018. (Accept another view if it is reasoned from these facts.)

MARKING SCHEME

- ✓ Body cells affect only that person, who can consent.
- ✓ An embryo's change passes to all descendants, without their consent.
- ✓ A reasoned choice (normally more caution about the embryo).

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15 Think

ANSWER HA · 3

The nucleus came from the patient, so the tissue has the patient's own genes and the immune system does not treat it as foreign. It most resembles an **isograft** (or an autograft): tissue with the same genes as the recipient, as between identical twins, is not rejected. But the embryo was made in another person's egg, so its **mitochondria**, with their small amount of DNA, come from the egg donor.

MARKING SCHEME

- ✓ The patient's own nuclear genes, so it is not treated as foreign.
- ✓ Resembles an isograft or autograft (the same genes).
- ✓ The mitochondria's DNA comes from the egg donor.

16 Make your own

ANSWER HA · 3

For example, with bands in cm from the wells: mother 1, 2, 3, 5, 7, 9; father 1.5, 2.5, 4, 6, 8, 10; child 1, 1.5, 3, 4, 7, 8; other man 1.5, 4, 5, 6, 9, 10. The child's 8 cm band isn't in the mother's lane, so it must come from the real father; the other man has no band at 8 cm, so he can't be the father, though he shares 1.5 and 4. The positive electrode is at the far end from the wells, and the smallest piece is the band farthest from the wells.

MARKING SCHEME

- ✓ Every band of the child is found in the mother or the father, about half from each.
- ✓ The fourth lane shares some bands but lacks one that the child can only have from its father, which is the explanation.
- ✓ Wells and positive electrode at opposite ends; the smallest piece farthest from the wells.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	6	29	20	**55**

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