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 U · 3

Her n = 7 is right for a cell going into meiosis II, and it holds at metaphase II. Her mistake is the stage: at anaphase II the centromeres have split, so each of the 14 chromatids is now a chromosome with its own centromere. The cell has **14 chromosomes and 14 chromatids** (7 moving to each pole). Only after cytokinesis does each new cell have 7 single chromosomes.
(The unit's table for a human cell agrees: 46 chromosomes and 46 chromatids at anaphase II, with n = 23.)

MARKING SCHEME

- ✓ 7 chromosomes with 14 chromatids is metaphase II, not anaphase II.
- ✓ At anaphase II the centromeres split, and chromosomes are counted by centromeres.
- ✓ 14 chromosomes, 14 chromatids.

2 Name the stage from the numbers

ANSWER A · 5

i. **2n = 12.** P has 6 bivalents, one per pair, so n = 6; S, a final cell of meiosis, also has 6.
ii. P: **metaphase I**. Q: **anaphase of mitosis** (12 double chromosomes have become 24 single ones). R: **a cell after meiosis I** (n chromosomes, still double). S: **a cell after meiosis II** (n single chromosomes). T: **anaphase II** (6 double chromosomes have split; no group holds a whole pair, and anaphase of mitosis would show 24).

MARKING SCHEME

- ✓ 2n = 12, from the 6 bivalents (or from S).
- ✓ P: metaphase I.
- ✓ Q: anaphase of mitosis.
- ✓ R: after meiosis I; S: after meiosis II.
- ✓ T: anaphase II, with a reason (no homologs in a group, or mitosis would show 24).

3 Read the measurements

ANSWER A · 4

i. **Meiosis**: the DNA doubles once (8 → 16) and then halves twice (16 → 8 → 4), ending at half the start. Mitosis would halve once and return to 8.
ii. Point 1 is G_1, which is 2C, so **1C = 4 pg**. Point 2 (12 pg, between 8 and 16) is partway through S.
iii. **No.** At anaphase the chromatids move apart but are still inside one cell: a human cell at anaphase of mitosis still has 4C. The DNA in each cell halves when the **cytoplasm divides**, after telophase.

MARKING SCHEME

- ✓ Meiosis, because one doubling is followed by two halvings.
- ✓ 1C = 4 pg.
- ✓ Point 2 is in S phase.
- ✓ Asmita is wrong: the chromatids are still in one cell; the DNA per cell halves at cytokinesis.

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4 What if?

ANSWER A · 4

i. $2^3 = 8$ **nuclei**.

ii. Each nucleus has **16** (karyokinesis shares the chromosomes equally), so $8 \times 16 = 128$ **chromosomes** in all.

iii. Each nucleus has 2C, so $8 \times 2C = 16C$.

iv. Any one: threads of a fungus such as *Mucor*; the liquid endosperm of a young coconut. (Skeletal muscle fibers have many nuclei too, but form by the joining of cells.)

MARKING SCHEME

✓ 8 nuclei.

✓ 16 in each nucleus, 128 in all.

✓ 16C.

✓ A real example (*Mucor*, coconut endosperm).

5 Estimate it

ANSWER A · 3

i. $2{,}000{,}000 \times 60 \times 60 \times 24 = 2 \times 10^6 \times 86{,}400 = \mathbf{1.7 \times 10^{11}}$ a day, about 170 billion.

ii. $2^{44} \approx 1.76 \times 10^{13}$ (17.6 trillion) and $2^{45} \approx 3.52 \times 10^{13}$ (35.2 trillion), so **45 rounds**.

iii. 45×24 h = **45 days**. Not all cells go on dividing: many leave the cycle into G_0 (most nerve cells for life), and cells that wear out are replaced, as in i, so many divisions only keep the number up.

MARKING SCHEME

✓ 1.7×10^{11} a day.

✓ 45 rounds, from $2^{44} < 3 \times 10^{13} < 2^{45}$.

✓ 45 days, and one reason (cells stop dividing in G_0, or divisions replace worn-out cells).

6 Trace the mistake

ANSWER A · 5

n = 2.

i. The pair stays together in one cell of meiosis I, so one cell has 3 double chromosomes and the other has 1. Meiosis II shares them: gametes with **3, 3, 1, 1**.

ii. Meiosis I is normal. The cell with normal meiosis II gives 2, 2; the other gives 3, 1: **2, 2, 3, 1**.

iii. $3 + 2 = 5$ chromosomes.

iv. n = 23: gametes with **24, 24, 22, 22**; the zygote has $24 + 23 = 47$. With three copies of chromosome 21, this is **Down syndrome**.

MARKING SCHEME

✓ i. 3, 3, 1, 1.

✓ ii. 2, 2, 3, 1.

✓ iii. 5.

✓ iv. 24, 24, 22, 22 and 47.

✓ Down syndrome.

7 Count the gametes

ANSWER A · 4

i. n = 4, so $2^4 = 16$ kinds.

ii. All four must be the father's: only 1 kind, so **1/16**.

iii. The father's chromosome can be from any one of the 4 pairs, the rest the mother's: **4** kinds.

iv. **Crossing over** in pachytene gives each chromosome a new mixture of genes, so a gamete's chromosomes aren't whole copies of the parent's.

MARKING SCHEME

✓ 16 kinds.

✓ 1/16.

✓ 4 kinds.

✓ Crossing over makes new chromosomes.

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8 Predict, then explain

ANSWER HA · 3

It stops at **metaphase** (or just before anaphase): the cell doesn't go on until every chromosome is attached to both poles (the spindle checkpoint). It has **46 chromosomes and 92 chromatids**, since the DNA was copied in S and the centromeres haven't split.

MARKING SCHEME

- ✓ It stops at metaphase, before anaphase.
- ✓ The spindle checkpoint: no going on until every chromosome is attached to both poles.
- ✓ 46 chromosomes and 92 chromatids.

9 Which explanation fits the evidence?

ANSWER HA · 4

Sujata's. The tuber plants all die or all live: 0 or 200, nothing between. That is what a clone does: the same genes mean every plant has the same resistance. The seedlings give a part-way result to each strain because each plant has different genes, and some carry resistance. Strain 2 rules out Birendra: there the tuber plants did better (200 against 118), so seedlings aren't simply stronger.

MARKING SCHEME

- ✓ Sujata's explanation.
- ✓ All-or-none in the tuber plants shows the same genes, a clone.
- ✓ A part-way result in the seedlings shows variation.
- ✓ Strain 2: tuber plants beat the seedlings, so Birendra's idea fails.

10 Design a fair test

ANSWER A · 4

i. She changes the time of day the tips are cut (morning, evening) and works out the **mitotic index** (cells dividing ÷ total cells × 100%) of each.

ii. Any three: the same kind of onion; same age and length of root; same water and place; same fixing, softening and staining; same part of the root (the meristem); same objective.

iii. Use many tips from several onions at each time, and count many cells; take the average; repeat on other days.

iv. A clearly higher mitotic index in the morning tips, on average, in repeat after repeat.

MARKING SCHEME

- ✓ Changes the time of cutting; works out the mitotic index.
- ✓ Any three things kept the same.
- ✓ Several tips and many cells counted, with averages or repeats.
- ✓ Support: a higher mitotic index in the morning.

11 Draw and compare

MARKING SCHEME A · 3

- ✓ Mitosis: 4 double chromosomes in one row, fibers from both poles.
- ✓ Metaphase I: 2 bivalents, one homolog each side of the equator.
- ✓ Metaphase II: 2 double chromosomes in one row, fibers from both poles.

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12 Correct the misconceptions

ANSWER U · 3

1. Meiosis **I** halves the number (at anaphase I, 2n → n). Meiosis II halves only the DNA in each cell (2C → 1C); the number stays n.
2. **No DNA is copied in interkinesis**: each chromosome is already double. DNA is copied once, before meiosis I.
3. Crossing over is between **non-sister** chromatids of homologous chromosomes. Sister chromatids are identical, so swapping between them would change nothing.

MARKING SCHEME

- ✓ Meiosis I, not II, halves the chromosome number.
- ✓ No DNA copying in interkinesis.
- ✓ Crossing over is between non-sister chromatids.

13 Think

ANSWER HA · 3

Right: identical twins are natural clones **of each other**, the same genes from one zygote split by mitosis. Wrong: they don't have their mother's genes. The zygote formed by **fertilization**, from an egg and a sperm made by meiosis, so it has half its chromosomes from each parent, in a new mixture. A clone from asexual reproduction uses mitosis alone, with one parent, so it does have the parent's genes.

MARKING SCHEME

- ✓ Right: the twins have the same genes as each other (one zygote, mitosis).
- ✓ Wrong: the zygote came from meiosis and fertilization, so it differs from the mother.
- ✓ An asexual clone comes by mitosis alone from one parent, so it has the parent's genes.

14 Make your own

ANSWER HA · 2

For example, 2n = 10, G_1 2C: G_2 10, 20, 4C; anaphase of mitosis 20, 20, 4C; metaphase I 10, 20, 4C; after meiosis II 5, 5, 1C. **5 bivalents**, $2^5 = 32$ kinds of gamete.

MARKING SCHEME

- ✓ A correct table of four stages for the chosen 2n.
- ✓ Bivalents = n, and kinds of gamete = 2C, both right.

See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **A Giant Pumpkin** (exhibit): Each seed formed when a pollen grain fertilized an egg cell in the flower, so no two seeds are alike: sexual reproduction brings variation.
- **Indian Strawberry** (garden): Its runners root into clones of the parent, while its flowers make seeds, each a new mix: asexual and sexual reproduction on one plant.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	6	32	12	**50**

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