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

1 Where are the boundaries?

ANSWER A · 4

i. p + 3p = 15, so 4p = 15, **p = 3.75 μm**.
ii. p + 1.7p = 15, so 2.7p = 15, **p = 5.56 μm** (to 2 decimal places).
iii. Telocentric: 0 μm (at the very end). Acrocentric: more than 0 and less than 3.75 μm. Submetacentric: 3.75 to 5.56 μm. Metacentric: 5.56 to 7.5 μm (the middle).

MARKING SCHEME

✓ p = 3.75 μm.
✓ p = 5.56 μm.
✓ Telocentric at 0, acrocentric up to 3.75 μm.
✓ Submetacentric 3.75–5.56 μm, metacentric 5.56–7.5 μm.

2 Check the claim

ANSWER HA · 5

(The measurements are made up.)
i.

Chromosome	A	B	C	D	E
Whole length (μm)	6.8	6.6	5.0	3.5	4.5
Arm ratio	1.13	2.3	4.0	no short arm	2.0
Type	metacentric	submetacentric	acrocentric	telocentric	submetacentric

ii. A, B, C, E, D.
iii. **C and E.** E (4.5 μm) is shorter than C (5.0 μm), yet its centromere is relatively nearer the middle: its arm ratio is 2.0 against C's 4.0. (B and E are also the same type at very different lengths.)
iv. Where the centromere is: the arm ratio, not the size.

MARKING SCHEME

✓ Lengths 6.8, 6.6, 5.0, 3.5 and 4.5 μm.
✓ Arm ratios and types correct.
✓ Order A, B, C, E, D.
✓ C and E contradict the claim (or B and E), with the numbers.
✓ The arm ratio decides the type.

3 Count them

ANSWER

Cell	Chromosomes	Chromatids	Centromeres	Autosomes
Male body cell at metaphase of mitosis	30	60	30	28
Egg	15	15 (not copied)	15	14
Sperm	15	15 (not copied)	15	14

Two kinds: 14 autosomes + X, and 14 autosomes + Y.
(Egg and sperm are haploid. Accept "one per chromosome" for their chromatids.)

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MARKING SCHEME A · 5

- ✓ Metaphase: 30 chromosomes, 60 chromatids.
- ✓ Metaphase: 30 centromeres, 28 autosomes.
- ✓ Egg: 15 chromosomes with 14 autosomes.
- ✓ Sperm: 15 chromosomes with 14 autosomes.
- ✓ Two kinds of sperm: 14 + X and 14 + Y.

4 Spot the error

ANSWER U · 3

She found the arms correctly (2 μm and 8 μm) but divided the wrong way round. The arm ratio is long arm ÷ short arm = 8 ÷ 2 = **4**. That is more than 3, so it is **acrocentric**, and J-shaped at anaphase. An arm ratio can never be less than 1.

MARKING SCHEME

- ✓ The ratio must be q ÷ p, the long arm over the short.
- ✓ Ratio = 8 ÷ 2 = 4.
- ✓ Acrocentric, J-shaped.

5 DNA in a chromosome

ANSWER A · 4

i. 8.4 cm = 84 mm; 84 ÷ 0.01 = **8,400 times**.
ii. 50,000,000 × 0.34 nm = 17,000,000 nm = 17 mm = **1.7 cm**.
iii. 17 mm ÷ 8,400 = 0.002 mm = **about 2 μm**.
iv. **Yes**: 2 μm is well above 0.2 μm, and whole chromosomes at cell division can be seen with a light microscope.

MARKING SCHEME

- ✓ 8,400 times.
- ✓ 1.7 cm.
- ✓ About 2 μm.
- ✓ Yes: 2 μm is greater than the limit of about 0.2 μm.

6 Which explanation fits the evidence?

ANSWER HA · 3

i. **Prakriti's.**
ii. Telomere repeats, TTAGGG, facing each other in the middle of the chromosome, as they would where two ends met; and the remains of a second, unused centromere, since each of the two chromosomes had one of its own.
iii. Telomere repeats belong at the ends of a chromosome, so finding them in the middle marks where two ends joined.

MARKING SCHEME

- ✓ Prakriti's explanation.
- ✓ Facing telomere repeats, and the remains of a second centromere.
- ✓ Telomere repeats mark ends, so a middle one marks a join.

7 Predict, then explain

ANSWER HA · 3

a. **It is lost.** It has no kinetochore, so spindle fibers can't attach and nothing pulls it to a pole.
b. **It is torn.** Fibers can attach at both centromeres and may pull it in opposite directions.
Without a telomere the end is unprotected: it can fray and stick to the ends of other chromosomes.

MARKING SCHEME

- ✓ No centromere: no fibers attach, so it is lost.
- ✓ Two centromeres: pulled two ways, so it is torn.
- ✓ Without a telomere the end frays and may stick to other chromosomes.

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8 Follow the eye color

ANSWER HA · 4

i. Each son gets his Y; each daughter gets his X.
ii. **No.** The allele is on his X, and his sons get his Y.
iii. **Red**: each daughter has one white allele from him and one red allele from her mother, and the red one shows. She carries the white allele.
iv. A daughter can pass the X with the white allele to a son. He has only that one X, with no second X to hide it, so he has white eyes.

MARKING SCHEME

✓ Sons get Y, daughters get X.
✓ So no son gets the white allele from him.
✓ Daughters are red-eyed and carry the white allele.
✓ A grandson gets that X from his mother and has no other X to hide it.

9 Design a fair test

ANSWER A · 4

i. Grow seeds of both varieties side by side in one field, in the same conditions, and measure the heights of many plants of each when grown. (He can also grow the same variety in the two fields.)
ii. Any three: the same soil; the same water; the same fertilizer; the same sowing date; the same spacing.
iii. The tall variety stays taller than the short one in the same field.
iv. Most characters depend on both: the genes set the range, and food and health decide where in it the plant ends up.

MARKING SCHEME

✓ Both varieties in the same conditions, with heights measured.
✓ Any three things kept the same.
✓ The difference remains in the same field.
✓ Genes set a range, and the environment decides where in it.

10 Estimate it

ANSWER A · 3

i. $248{,}000{,}000 \div 2{,}000 = \mathbf{124{,}000\ base\ pairs}$.
ii. $124{,}000 \times 0.34\ \text{nm} = 42{,}160\ \text{nm} \approx \mathbf{42\ \mu m}$.
iii. **No.** A chromosome carries genes, with a lot of other DNA between them.

MARKING SCHEME

✓ 124,000 base pairs.
✓ About 42 μm.
✓ Not fair: over 98% of the DNA isn't genes for proteins.

11 Correct the misconceptions

ANSWER U · 4

1. An egg has 23 chromosomes, of which 22 are autosomes and one is an X.
2. Homologous chromosomes carry the same genes at the same loci; only the alleles may differ.
3. TT and Tt have the same phenotype (tall), because T is dominant; only their genotypes differ.
4. A tanned face is environmental variation, which isn't passed on.

MARKING SCHEME

✓ 22 autosomes + X in an egg.
✓ Same genes at the same loci.
✓ TT and Tt: same phenotype.
✓ Tanning is environmental and isn't inherited.

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12 Think

ANSWER HA · 3

The mother. A male bird is ZZ, so every sperm carries Z. A female is ZW, so her eggs carry Z or W, and the egg decides. (In humans the mother is XX, so every egg has X, and the sperm carries X or Y.) Rice has flowers that are both male and female and has no sex chromosomes at all.

MARKING SCHEME

- ✓ The mother decides in birds.
- ✓ Female ZW gives two kinds of egg; male ZZ gives one kind of sperm.
- ✓ Rice has both parts in its flowers and no sex chromosomes.

13 Make your own

ANSWER HA · 2

For example: metacentric p = 9 μm, q = 11 μm, ratio 1.2; submetacentric p = 6 μm, q = 14 μm, ratio 2.3; acrocentric p = 2 μm, q = 18 μm, ratio 9; telocentric no short arm, q = 20 μm.

MARKING SCHEME

- ✓ All four add up to 20 μm, with ratios worked out.
- ✓ Each ratio fits its type (1–1.7; 1.7–3; over 3; no short arm).

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	7	20	20	**47**

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