Unit 1 · Cell Biology

ANSWER KEY · FOR TEACHERS

Full marks 46

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

1 Key words

1. karyokinesis
2. cytokinesis
3. S phase
4. kinetochores
5. synapsis
6. bivalent
7. chiasma
8. clone

K · 4

Each carries 0.5 mark.

2 Label the diagram

1. DNA copied, 8 h
2. M: mitosis and cytokinesis, 1 h
3. G_2
4. S
5. G_0: stops dividing
6. G_1

K · 3

Each carries 0.5 mark.

3 Multiple choice

i. **b.** the same number of chromosomes and twice as much DNA — U · 1

The DNA was copied in S phase (2C → 4C), but each chromosome is now double, with two chromatids on one centromere, so the number of chromosomes hasn't changed.

ii. **b.** zygotene — K · 1

The homologs pair in zygotene, held by the synaptonemal complex. In leptotene they are still apart; crossing over follows in pachytene.

iii. **c.** anaphase of mitosis and anaphase II — U · 1

Sister chromatids part when the centromeres split: at anaphase of mitosis and anaphase II of meiosis. At anaphase I whole homologous chromosomes separate, each still with both its chromatids.

iv. **b.** 12 chromosomes of two chromatids each — A · 1

Meiosis I separates the homologs, so each cell gets one of each pair, n = 12; the centromeres haven't split, so each chromosome still has two chromatids. They part in meiosis II.

v. **b.** 16 — A · 1

n = 4 pairs, so $2^4 = 16$ kinds. 256 is 16 × 16, the combinations when two flies' gametes meet.

4 Very short answers

a. MARKING SCHEME — K · 1

✓ Pachytene.

b. MARKING SCHEME — K · 1

✓ Interkinesis.

c. MARKING SCHEME — U · 1

✓ It has one centromere, and chromosomes are counted by centromeres.

d. MARKING SCHEME — U · 1

✓ Anaphase.

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5 Short answers

a. MARKING SCHEME U · 2

- ✓ The cell grows and makes proteins and organelles (G_1), and makes the proteins for division (G_2).
- ✓ It copies all its DNA (S), though the nucleus looks inactive under the microscope.

b. MARKING SCHEME U · 2

- ✓ Single chromosomes line up on the equator, the centromeres split at anaphase and the sister chromatids go to opposite poles.
- ✓ The chromosome number stays the same (n stays n): an equational division.

c. MARKING SCHEME U · 2

- ✓ Any one difference, e.g. meiosis I is reductional ($2n \rightarrow n$); meiosis II is equational ($n \rightarrow n$).
- ✓ Any second difference, e.g. homologs separate at anaphase I with the centromeres unsplit; sister chromatids separate at anaphase II as the centromeres split.

d. MARKING SCHEME U · 2

- ✓ Any one difference, e.g. a cleavage furrow in an animal cell; a cell plate in a plant cell.
- ✓ Any second difference, e.g. the furrow goes from the outside in; the cell plate grows from the center out.

e. MARKING SCHEME A · 2

- ✓ The root tip has a meristem, where cells divide rapidly, so many cells are caught in every stage.
- ✓ Roots grow easily in water, and onion has a small number (16) of large chromosomes that are easy to see when stained.

6 Long answers

a. ANSWER U · 4

1. **Leptotene:** chromatin condenses into long, thin threads with bead-like chromomeres; each is already double, but the chromatids can't be seen separately.
2. **Zygotene:** homologous chromosomes pair gene by gene (**synapsis**), held by the synaptonemal complex; each pair is a **bivalent**.
3. **Pachytene:** the bivalents shorten and thicken; four chromatids are seen (a **tetrad**); **crossing over** takes place between non-sister chromatids, exchanging pieces.
4. **Diplotene:** the synaptonemal complex dissolves and the homologs begin to separate, staying joined at the **chiasmata**, where crossing over happened.
5. **Diakinesis:** the chromosomes are most condensed; the chiasmata move towards the ends (terminalization); the nucleolus and nuclear envelope disappear and the spindle forms.

MARKING SCHEME

- ✓ Leptotene: long, thin beaded threads; zygotene: homologs pair (synapsis), forming bivalents.
- ✓ Pachytene: four chromatids seen (a tetrad); crossing over between non-sister chromatids.
- ✓ Diplotene: the homologs begin to separate, joined at the chiasmata.
- ✓ Diakinesis: most condensed, terminalization; the nucleolus and nuclear envelope disappear and the spindle forms.

b. ANSWER

1. **Crossing over** (pachytene of prophase I): non-sister chromatids of homologous chromosomes exchange pieces, so the chromosomes in the gametes carry new combinations of the parents' genes.
2. **Independent assortment** (metaphase I): each pair of homologs lines up by chance, independently of the others, so each gamete gets a random mixture of maternal and paternal chromosomes: 2^n kinds, more than 8 million (2^{23}) in humans.
3. **Random fertilization:** any sperm can fertilize any egg, so one couple could have about 2^{46} (some 70 trillion) different combinations, even before crossing over.

So each offspring is a new combination, different from its parents and from its brothers and sisters.

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MARKING SCHEME U · 4

- ✓ Crossing over in pachytene: non-sister chromatids swap pieces, making new combinations of genes on a chromosome.
- ✓ Independent assortment at metaphase I: each pair lines up by chance, giving 2Ckinds of gamete.
- ✓ Random fertilization: any sperm can meet any egg.
- ✓ For humans: 2^{23} (more than 8 million) kinds of gamete, and 2^{46} (about 70 trillion) combinations for one couple.

7 Numerical problems

a. **ANSWER** A · 2

2C = 12 pg, so 1C = 6 pg.

a. G_2 (4C): **24 pg**. b. After mitosis (2C): **12 pg**. c. After meiosis I (2C): **12 pg**. d. Gamete (1C): **6 pg**.

MARKING SCHEME

- ✓ 2C = 12 pg, so 1C = 6 pg; G_2 (4C) 24 pg; after mitosis (2C) 12 pg.
- ✓ After meiosis I (2C) 12 pg; gamete (1C) 6 pg.

b. **ANSWER** A · 3

Stage	Chromosomes	Chromatids
a. G_1	20	20
b. Metaphase of mitosis	20	40
c. Anaphase of mitosis	40	40
d. Metaphase I (10 bivalents)	20	40
e. After meiosis I	10	20
f. After meiosis II	10	10

MARKING SCHEME

- ✓ a. 20, 20; b. 20, 40.
- ✓ c. 40, 40; d. 20, 40.
- ✓ e. 10, 20; f. 10, 10.

c. **ANSWER** A · 4

Cells dividing = 28 + 6 + 4 + 10 = 48.
Mitotic index = 48 ÷ 400 × 100% = **12%**.
Interphase: 352 ÷ 400 × 20 h = **17.6 h**.
Prophase: 28 ÷ 400 × 20 h = 1.4 h = **84 minutes**.
(Anaphase, the shortest: 4 ÷ 400 × 20 h = 0.2 h = 12 minutes.)

MARKING SCHEME

- ✓ Cells dividing = 28 + 6 + 4 + 10 = 48.
- ✓ Mitotic index = 48 ÷ 400 × 100% = 12%.
- ✓ Interphase: 352 ÷ 400 × 20 h = 17.6 h.
- ✓ Prophase: 28 ÷ 400 × 20 h = 1.4 h = 84 minutes.

8 Think

ANSWER

All the plants of one variety grown from tubers are a **clone**, with the same genes. If that variety has no resistance to the disease, **no plant** has it, so the disease can destroy every field at once, as late blight did in Ireland in the 1840s. There is no variation for some plants to survive and carry on.
Farmers could grow **several different varieties** side by side, so that a disease that kills one doesn't kill all, and plant clean, disease-free seed tubers. Breeders can **cross** varieties (sexual reproduction, which makes new combinations of genes by meiosis and fertilization), grow the seedlings, pick those that resist the disease, and then multiply the best as new clones from tubers. So sexual reproduction makes the variation, and asexual reproduction keeps the useful result.

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MARKING SCHEME

- ✓ All the plants are a clone with the same genes, so if the variety has no resistance, none has it and every field can be lost.
- ✓ Farmers: grow several different varieties side by side (and clean seed tubers).
- ✓ Breeders: cross varieties to make new combinations, pick resistant seedlings and multiply the best as clones.

9 Activity: The stages in an onion root tip (Practical 1)

(not marked)

WHAT STUDENTS SHOULD FIND

Interphase: a round nucleus with a nucleolus, no chromosomes seen. Prophase: a nucleus full of threads. Metaphase: a line of chromosomes across the middle. Anaphase: two groups moving apart. Telophase: two groups at the ends, a cell plate forming between them. Most cells are in interphase, then many in prophase, fewer in metaphase and telophase, and fewest in anaphase, the shortest stage. Time in a stage is in proportion to the cells found in it.

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	10	20	13	3	**46**

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