Unit 9 · Linkage and Crossing Over

ANSWER KEY · FOR TEACHERS

Full marks 32

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

1 Key words

K · 4

1. linkage
2. linkage group
3. recombinant
4. centimorgan
5. hemizygous
6. carrier
7. non-sister
8. chiasmata

Each carries 0.5 mark.

2 Label the diagram

K · 3

1. colored, full
2. 48.2% colored, full
3. 1.8% colored, shrunken
4. new
5. all colored, full seeds
6. 1.8% colorless, full

Each carries 0.5 mark.

3 Multiple choice

i. **b.** 12 — K · 1

The two chromosomes of a homologous pair carry the same genes, so each **pair** is one linkage group: as many groups as the haploid number, 24 ÷ 2 = **12**.

ii. **b.** the genes are completely linked — U · 1

Only the two **parental** kinds of gamete were made: no crossover separated the genes. That is **complete linkage**. Genes on different chromosomes would give four kinds in equal numbers (1 : 1 : 1 : 1); incompletely linked genes four kinds, with the parental ones more common.

iii. **c.** pachytene — U · 1

The homologs pair in zygotene; the **exchange** between non-sister chromatids happens in **pachytene**; the chiasmata are seen in diplotene and move to the ends in diakinesis.

iv. **d.** none of them; but every daughter is a carrier — A · 1

The father's X, with the allele, goes only to his **daughters**, who also get a normal X from their mother: they are **carriers** with normal clotting. His sons get his Y, and a normal X from their mother. So no child has hemophilia, but each daughter can pass the allele to her own sons: criss-cross inheritance.

v. **c.** 3% — A · 1

One map unit is the distance that gives **1% recombinant gametes**, so 3 map units gives about **3%**. (This works well for genes close together; for genes far apart the percentage grows more slowly and never passes 50%.)

4 Short answers

a. MARKING SCHEME — K · 2

- ✓ Complete: no crossing over, parental gametes only, with an example.
- ✓ Incomplete: some crossing over, parental and a few recombinant gametes, with an example.

b. MARKING SCHEME — U · 2

- ✓ The allele is recessive and X-linked.
- ✓ Men need one copy (one X); women need two.

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c. MARKING SCHEME — A · 2

- ✓ Mother X^CX^c (carrier, from her father), father X^CY.
- ✓ Cross showing half the sons color-blind.

d. MARKING SCHEME — U · 3

- ✓ A first significance (e.g. new combinations, variation).
- ✓ A second (e.g. evolution and adaptation).
- ✓ A third (e.g. gene maps, or plant and animal breeding).

5 Numerical problem

ANSWER — A · 4

- Parental (the F_1's own combinations, the large classes): colored full and colorless shrunken. **Recombinant**: colored shrunken (42) and colorless full (38).
- Recombination frequency = (42 + 38) ÷ (465 + 455 + 42 + 38) × 100 = 80 ÷ 1000 × 100 = **8%**, so about **8 map units**.
- X–C 3 + C–Sh 8 = 11 = X–Sh, so C lies between: **X —3— C —8— Sh**.

MARKING SCHEME

- ✓ Recombinants: colored shrunken and colorless full.
- ✓ Recombination frequency 80 ÷ 1000 = 8%.
- ✓ Distance 8 map units.
- ✓ Order X–C–Sh.

6 Long answer

ANSWER — U · 4

Cross I: red-eyed female (X^RX^R) × white-eyed male (X^rY). All the F_1 are **red-eyed** (red dominant). $F_1 \times F_1$ (X^RX^r × X^RY): **all females red-eyed**, half the males red and half white, 3 red : 1 white, every white-eyed fly a **male**.

Cross III (reciprocal): white-eyed female (X^rX^r) × red-eyed male (X^RY). **All daughters red-eyed** (their father's X^R) and **all sons white-eyed** (their mother's X^r).

Reciprocal crosses giving different results show the gene is **sex-linked**: on the **X chromosome**, with the white allele recessive and none on the Y; a son's X comes only from his mother.

MARKING SCHEME

- ✓ Cross I: F_1 all red; F_2 3 : 1 with all white-eyed flies male.
- ✓ Cross III: daughters all red, sons all white.
- ✓ The reciprocal crosses differ, so the gene is on the X.
- ✓ Red dominant, white recessive, no allele on the Y.

7 Think

ANSWER — HA · 3

No. The genes are on the **same chromosome** in both sexes. The male gives only parental offspring because **male fruit flies make no crossovers**: complete linkage.

The female gives all four kinds, but **not 1 : 1 : 1 : 1**: about 41.5% each parental and 8.5% each recombinant. Genes on different chromosomes would give 25% each; the excess of parental kinds shows **incomplete linkage** caused by crossing over in the female.

MARKING SCHEME

- ✓ No: the genes are linked on the same chromosome in both sexes.
- ✓ Male Drosophila don't cross over, so complete linkage shows.
- ✓ The female's four kinds are mostly parental (not 25% each): incomplete linkage, not independent assortment.

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8 Activity: Crossing over with paper strips

(not marked)

WHAT STUDENTS SHOULD FIND

Recombinants form only when a crossover falls **between** the genes: 5 of the 19 places for genes 5 cm apart (about a quarter of crossovers), 12 of 19 for genes 12 cm apart (about two-thirds). The **farther apart** two genes are, the more often they are separated, which is why recombination measures distance.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	10	11	8	3	**32**

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