Unit 3 · Genetics

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 53

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

Chargaff's rules hold for the **two strands together**, not for one strand. Every A on this strand faces a T on the other, so the other strand has 30% T, 10% A, 25% C and 35% G.
Whole piece: A = (30 + 10) ÷ 2 = **20%**, T = **20%**, G = (25 + 35) ÷ 2 = **30%**, C = **30%**.

MARKING SCHEME

- ✓ Chargaff's rules hold for double-stranded DNA, not one strand.
- ✓ A = T = 20%.
- ✓ G = C = 30%.

2 Three characters

ANSWER A · 4

i. $2 \times 2 \times 2 = \mathbf{8}$ kinds.
ii. $¾ \times ¾ \times ¾ = \mathbf{27/64}$; $27/64 \times 640 = \mathbf{270}$ seeds.
iii. $¼ \times ¼ \times ¼ = 1/64$; $1/64 \times 640 = \mathbf{10}$ seeds.
iv. Each gene gives 3 genotypes: $3 \times 3 \times 3 = \mathbf{27}$.

MARKING SCHEME

- ✓ 8 kinds of gamete.
- ✓ 27/64, 270 seeds.
- ✓ 10 seeds.
- ✓ 27 genotypes.

3 Work back to the parents

ANSWER A · 4

i. Round 302 + 98 = 400; wrinkled 295 + 105 = 400: **1 : 1**. Yellow 302 + 295 = 597; green 98 + 105 = 203: 597 ÷ 203 = 2.94, about **3 : 1**.
ii. 1 : 1 for shape means Rr × rr; 3 : 1 for color means Yy × Yy. The parents are **RrYy × rrYy**.
iii. Out of 800: round yellow ½ × ¾ = 3/8 = **300**; round green ½ × ¼ = 1/8 = **100**; wrinkled yellow **300**; wrinkled green **100**.

MARKING SCHEME

- ✓ Shape 1 : 1 and color about 3 : 1.
- ✓ Rr × rr and Yy × Yy.
- ✓ RrYy × rrYy.
- ✓ Expected 300, 100, 300, 100.

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4 Check the claim

ANSWER HA · 4

i. $600 \times 9/16 = \mathbf{337.5}$; $600 \times 3/16 = \mathbf{112.5}$ (twice); $600 \times 1/16 = \mathbf{37.5}$.

ii. **No.** The four kinds appearing isn't enough; the counts are far from the prediction. The two kinds that are new combinations, A– bb and aa B–, are far too few (20 and 25, not 112.5), and the parental kinds too many.

iii. The two genes are probably **linked**: close together on the same chromosome, so they tend to go into the gametes together. A little crossing over gives the few new combinations.

MARKING SCHEME

✓ Expected 337.5, 112.5, 112.5, 37.5.

✓ The claim is wrong: the counts don't fit 9 : 3 : 3 : 1.

✓ The new combinations A– bb and aa B– are far too few.

✓ The genes are linked, on one chromosome.

5 Two steps

ANSWER A · 4

i. Bases in all: $2 \times 1200 = 2{,}400$. A = 30% of 2,400 = **720**, and T = **720**. $G + C = 2400 - 1440 = 960$, so G = C = **480**.

ii. 720 A–T pairs and 480 G–C pairs: $720 \times 2 + 480 \times 3 = 1440 + 1440 = \mathbf{2{,}880}$.

iii. 1200×0.34 nm = **408 nm**; $1200 \div 10 =$ **120 turns**.

MARKING SCHEME

✓ A = T = 720.

✓ G = C = 480.

✓ 2,880 hydrogen bonds.

✓ 408 nm and 120 turns.

6 From gene to protein

ANSWER A · 5

i. **5′-AUG GCU UGG UAA-3′** (U opposite A, A opposite T, G opposite C, C opposite G).

ii. **3 amino acids**: the fourth codon, UAA, means stop.

iii. UGG is read by **3′-ACC-5′**.

iv. ATC gives the codon **UAG**, a stop. The protein ends there, with only **2 amino acids**: one base changed cuts the protein short.

MARKING SCHEME

✓ The mRNA 5′-AUG GCU UGG UAA-3′.

✓ 3 amino acids, since UAA means stop.

✓ 3′-ACC-5′.

✓ The new third codon is UAG.

✓ UAG is a stop, so the protein has only 2 amino acids.

7 Which explanation fits the evidence?

ANSWER HA · 4

i. Semi-conservative: all the DNA **halfway** in density. Whole-copy: **two bands**, one all heavy and one all light, none halfway.

ii. **Semi-conservative**: after one generation all the DNA was halfway.

iii. The 2 old strands stay in 2 molecules, out of 8 molecules after three rounds: **¼ half-heavy, ¾ light**.

MARKING SCHEME

✓ Semi-conservative: all halfway.

✓ Whole-copy: one heavy and one light band.

✓ The result (all halfway) supports semi-conservative.

✓ ¼ half-heavy and ¾ light.

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8 A family's chances

ANSWER A · 4

i. Anusha X^hX, Sunil **XY**: the son's X came from his mother.
ii. She gets X from Sunil, and X^h or X from Anusha: **½**.
iii. If she is a carrier, a son with hemophilia has a chance of ¼. So ½ × ¼ = **⅛**.
iv. Now she is surely a carrier, so half of her sons are expected to have it: **½**.

MARKING SCHEME

✓ Anusha X^hX and Sunil XY.
✓ ½.
✓ ½ × ¼ = ⅛.
✓ ½: she is now known to be a carrier.

9 Rule it out

ANSWER HA · 3

A: **Y-linked** fits, passed to every son and no daughter. It is not X-linked: a father gives his sons his Y, not his X (unless the mother also carries it, which is unlikely for a rare allele).
B: **X-linked recessive**: from a man through his carrier daughter to her son (criss-cross). It can't be Y-linked: his sons would be affected.
C: **Neither**. A woman has no Y, and an X-linked recessive daughter must have an affected father.

MARKING SCHEME

✓ A: Y-linked, as father to every son, no daughter.
✓ B: X-linked recessive, criss-cross through a daughter.
✓ C: neither, as an affected daughter would need an affected father, and has no Y.

10 Estimate it

ANSWER A · 3

i. 1/5000 × 1/5000 = 1 in 25,000,000: **about 1**.
ii. 2 × 1/5000 × 4999/5000 ≈ 0.0004: **about 1 woman in 2,500**.
iii. Very rare, but not impossible: she needs a hemophilic father and a carrier mother.

MARKING SCHEME

✓ About 1 woman in 25 million.
✓ About 1 in 2,500 are carriers.
✓ Very rare, not impossible.

11 Change the model

ANSWER A · 4

i. Use **one cup** for each parent, with each brown bean glued to a large bean (RY) and each white bean to a small bean (ry).
ii. Only **RY and ry**, half each.
iii. RRYY, RrYy and rryy in 1 : 2 : 1, so **3 round yellow : 1 wrinkled green**, with no new combinations.
iv. Real counts wander, and only many offspring come close to the ratio.

MARKING SCHEME

✓ One cup with the beans of each gene joined.
✓ Gametes RY and ry only.
✓ 3 round yellow : 1 wrinkled green, no new combinations.
✓ Many offspring, because small counts wander.

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12 What if?

ANSWER HA · 3

With four bases, two-base codons give $4^2 = \mathbf{16}$, too few for 21 meanings. **Five** kinds of base give $5^2 = 25$, enough (4 aren't). Three bases give $4^3 = 64$ codons, far more than 21, so most amino acids have more than one codon.

MARKING SCHEME

- ✓ 16 is too few for 21 meanings.
- ✓ Five kinds of base give 25.
- ✓ 64 codons for 21 meanings leave many to spare, so most amino acids have more than one.

13 Predict, then explain

ANSWER HA · 3

Sample P. P has 36% A + T, so 64% G + C: $36 \times 2 + 64 \times 3 = 72 + 192 = \mathbf{264}$ hydrogen bonds per 100 base pairs. Q has 64% A + T, so 36% G + C: $64 \times 2 + 36 \times 3 = 128 + 108 = \mathbf{236}$. G–C-rich DNA has more hydrogen bonds and stronger stacking, so it needs a higher temperature.

MARKING SCHEME

- ✓ Sample P.
- ✓ 264 per 100 base pairs for P and 236 for Q.
- ✓ More hydrogen bonds (and stronger stacking) mean a higher temperature.

14 Correct the misconceptions

ANSWER U · 3

1. They are joined by **two and three hydrogen bonds**, weak attractions, not covalent double and triple bonds.
2. A father gives his son his **Y**, so he never passes an X-linked allele to a son; he passes it to every **daughter**.
3. An RrYy plant makes **four** kinds of gamete. The 16 boxes are meetings of two gametes.

MARKING SCHEME

- ✓ Two and three hydrogen bonds.
- ✓ A father passes the allele to daughters, never to sons.
- ✓ Four kinds of gamete; 16 is the meetings.

15 Make your own

ANSWER HA · 2

For example: “A color-blind woman marries a man with normal vision. What will their children be?” She is X^cX^c, he is XY: every daughter is X^cX, a carrier, and every son is X^cY, color-blind.

MARKING SCHEME

- ✓ A puzzle that can be solved from the unit.
- ✓ A correct answer, with genotypes.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	6	28	19	**53**

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