HODDER Education

Biological Sciences review

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Answers

Avian flu: understanding its impact on wild birds

Answers to practice exam questions on pp. 2–5

Martin Rowland

1 Hemagglutinin and neuraminidase are located on the surface of the virus.

Hemagglutinin enables the virus to attach to a complementary receptor on the surface of avian cells.

Neuraminidase is an enzyme that enables the progeny virus particles to leave the infected cell.

2 Segmented: more than one strand of nucleic acid (in each viral particle).

Negative-sense: the nucleic acid is ribonucleic acid / RNA.

Impact: navigating the underwater world

Answer to question in Box 2 on page 8

Sarah Dickson

1 There are six unique fins in the first sample. Fin 2 is the same individual as fin 6.

There are five unique fins in the second sample. Three of the these are ‘recaptures’. Fins 4 and A are the same individual, fins 1 and B are the same individual and fins 5 and E are the same individual.

Hence:

$$\frac{6 \times 5}{3} = 10$$

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Insect galls

Answers to practice exam questions on pp. 22–25

Martin Rowland

1 Comparison: both mutualism and parasitism involve an intimate / long-term relationship between two different organisms.

Contrast: mutualism provides benefits for both organisms (in the relationship). Parasitism benefits one of the organisms and harms the other organism / host.

2 Ecosystem engineers cause changes to the diversity / species richness of their ecosystem.

Gall wasps attract predators that would not otherwise be in the ecosystem.

Gall wasps kill / reduce the reproductive capacity of their host plants, reducing their numbers / reducing the plant species richness.

Upgrade: magnifying problems in biology

Answers to practice exam questions on pp. 26–29

Marcus Allen

1 **a** 0.4 μm

b 400 nm

c 0.0004 mm

d 0.00004 cm

2 The diameter of the nucleus on the page is approximately 93 mm. To convert to the same units as its actual length (μm, 10^{-6} m):

$93 \times 1000 = 93\,000$ μm

3 20 divisions on the stage micrometre are equivalent to 30 divisions on the eyepiece graticule.

Therefore, 1 epu = $\frac{20}{30}$ = 0.66 stage micrometre units.

If 1 stage micrometre unit = 10 mm, 1 epu = 0.66×10 mm = 6.6 mm.

The diameter of the vascular cylinder is 80 epu and is, therefore, 80×3.3 mm = 528 mm.

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Evaluating experiments: beetlemania

Suggested answers to questions on pp. 38–40

Kevin O'Dell

Question 1

Evidence from the F1 generation (where all the beetles are dark grey) suggests that beetle body colour could be controlled by a single gene where the dark-grey allele (+) is dominant to the red allele (–). The F2 phenotypes support this theory because the beetles are segregating in what appears to be in a 3 (dark grey: +/+, +/–, –/+) to 1 (red: –/–) ratio.

Question 2

If our theory – that beetle body colour is associated with variation at a single gene where the dark-grey allele is dominant to the recessive red allele – is correct, then we would expect the F2 beetles to segregate in a 3 (dark grey) to 1 (red) ratio. This can be investigated using a chi-squared test, as shown below.

Colour phenotype	Observed number	Expected number	$O - E$	$(O - E)^2$	$\frac{(O - E)^2}{E}$
Dark grey	289	300	–11	121	0.40
Red	111	100	11	121	1.21
Total	400	400			1.61

For one degree of freedom, the 5% significance limit is 3.84. Since 1.61 is less than 3.84, there is no significant difference between our observed and expected ratios. So our hypothesis that beetle body colour is associated with variation at a single gene, where the dark-grey allele is dominant to the recessive red allele, suggesting that in the F2 we would see a 3 (dark grey) to 1 (red) ratio, is supported by the data.

Question 3

If our theory – that beetle body colour is associated with variation at a single gene, where the dark-grey allele is dominant to the recessive red allele – is correct, then we would expect the F2 beetles to segregate in a 3 (dark grey) to 1 (red) ratio. This can be investigated using a chi-squared test:

Colour phenotype	Observed number	Expected number	$O - E$	$(O - E)^2$	$\frac{(O - E)^2}{E}$
Dark grey	243	225	18	324	1.44
Red	57	75	–18	324	4.32
Total	300	300			5.76

For one degree of freedom, the 5% significance limit is 3.84. Since 5.76 is more than 3.84, there is a significant difference between our observed and expected ratios. Unlike the data in the first experiment, our hypothesis that beetle body is associated with variation at a single gene, where the dark-grey allele is dominant to the recessive red allele, suggesting that in the F2 we would see a 3 (dark grey) to 1 (red) ratio, is not supported because they do not appear to be segregating in a 3:1 ratio.

Question 4

Although the data from the first and second cross are different, the beetles used in the crossing scheme (true-breeding dark grey and true-breeding red) are genetically identical, so any genetic explanation concerning the inheritance of body colour must be the same. Therefore, the differences between the two data sets must have an alternative, and presumably environmental, explanation.

The only difference between the strategies used in the two experiments is the power failure, which delayed the opportunity to record the body colour phenotypes of the beetles in the second experiment. In the first experiment the body colour of all beetles was scored as soon as they hatched, but in the second experiment this was delayed by up to 5 days.

There are also fewer beetles in the second experiment (400 vs 300), and whilst the numbers of both the dark grey (289 vs 243) and red (111 vs 57) beetles has fallen, that fall is apparently less marked in dark grey beetles (down 16%) than in the red beetles (down 49%). Therefore, it is quite possible that at hatching the beetles are in a 3 (dark grey) to 1 (red) ratio, but that in the laboratory environment over the next few days a higher proportion of red beetles die, for an as yet unidentified reason.

It could be that this is due to differences in the survival rates of dark grey and red beetles over the first 5 days of their lives under normal conditions. This may be because the red beetles are less fit because of some specific effect of the power outage, which may mean that for those 5 days the beetles were living, for example, in a darker and/or colder environment. (The key here is suggesting a plausible environmental explanation.)

Question 5

This answer will of course depend on the theories you proposed in your answer to question 4, but the only variables are environmental issues linked to the power failure, so any experiments must take this into account. For example, rather than score beetle colour phenotypes at a fixed point in time (at hatching or after 5 days), count them every day over a significant period of time, and see whether the survival rate of dark grey beetles is higher than that of red beetles. This could be repeated in a dark and/or cold environment. There is lots of scope here to test many environmental variables. They key is to use appropriate controls.

Question 6

There are at least two (or possibly more) issues that need to be addressed if you are to collect beetles from Mel's garden in a random and unbiased fashion. Taking them in turn:

(1) If we were to capture the beetles in an active fashion, such as by using hand-held nets, we may well be biased by how easy the beetles are to see. This may be a big issue here because the red beetles are likely to be easier to see, so may be collected at a higher frequency than the harder-to-see dark-grey beetles. Therefore, it may be better to use traps where (in a sense) the beetles select themselves, where their body colour is unlikely to be a factor. It remains possible that the attractant in the trap (perhaps a smell) is perceived differently by the two body colour types (as genes can be

pleiotropic), so we would need to ensure that the chosen attractant is perceived similarly by the two body colour types.

(2) The beetles may not be randomly distributed throughout what is described as a large garden, perhaps because of different predation levels linked to body colour and camouflage. Therefore, we need to collect beetles from all corners of the garden in a representative fashion.

There may be other plausible answers or issues that could be addressed here.

Question 7

The numbers of each colour type are 282 homozygous dark grey (+/+), 76 heterozygous dark grey (+/–) and 42 red (–/–). In total, 400 beetles were captured. Taking each allele in turn:

The frequency of the dark grey (+) allele is:

$$\frac{(2 \times 282) + 76}{800} = 0.8$$

The frequency of the red (–) allele is:

$$\frac{(2 \times 42) + 76}{800} = 0.2$$

Question 8

Let us define the frequency of the dark-grey allele as p and the frequency of the red allele as q. We already know (from the answer to question 7) that $p = 0.8$ and $q = 0.2$. As expected, $p + q = 1$.

The HWE allows us to predict the frequency of each genotype:

- Homozygous dark grey (+/+) should be $p^2 = (0.8)^2 = 0.64$
- Heterozygous dark grey (+/–) should be $2pq = 2 \times 0.8 \times 0.2 = 0.32$
- Homozygous red (–/–) should be $q^2 = (0.2)^2 = 0.04$

When added together these three frequencies equal 1.

The observed and predicted genotype frequencies are:

Genotype	Observed	Expected
+/+	0.705	0.640
+/–	0.190	0.320
–/–	0.105	0.040

We can perform a chi-squared test to investigate whether these differences are significant. We always do a chi-squared test on the original data – the absolute numbers of individuals – which in this case is a sample of 400. Therefore:

Genotype	Observed number	Expected number	$O - E$	$(O - E)^2$	$\frac{(O - E)^2}{E}$
+/+	282	256	26	676	2.64
+/–	76	128	–52	2704	21.13

–/–	42	16	26	676	42.25
Total	400	400			66.02

Therefore, chi-squared = 66.02.

For 2 degrees of freedom, the cut-off for 5% is 5.99, and for 1% is 9.21. Therefore, the beetles living in Mel's garden are not in Hardy–Weinberg equilibrium.

Question 9

Any plausible hypotheses must account for two observations. Firstly, according to the crosses undertaken before and during the power outage, red beetles appear to be less fit than dark-grey beetles. Secondly, according to the Hardy–Weinberg equilibrium chi-squared test, there are fewer heterozygous beetles than one might have expected.

Hypothesis 1: The beetles in the garden are not randomly distributed in Mel's garden, so there are some areas exclusively/predominantly hosting dark-grey beetles and other areas exclusively/predominantly hosting red beetles. Therefore, beetles are more likely to mate with beetles of a similar body colour, simply because they are more likely to encounter beetles of their own body colour. The non-random distribution of beetles in Mel's garden may be linked with differences in how pollution from Great Acrid Smell Power Station affects different areas of the garden to a greater or lesser extent, and therefore provides environments where dark-grey beetles and red beetles are advantaged or disadvantaged in terms of camouflage and evading predators.

Hypothesis 2: Beetles are randomly distributed in the garden, but the two body colour types show a preference for mating with their own body colour type.

Hypothesis 3: The heterozygous (+/–) beetles are less viable than either of the homozygous (+/+ or –/–) beetles. This could be some intrinsic issue with the heterozygous phenotype, in that they are simply less 'healthy', which could be a problem with their phenotype. Perhaps their colour phenotype makes them more attractive to predators. This is perhaps less likely than the other hypotheses, because we already know that the red beetles (–/–) are less viable in laboratory conditions (at least when there are power cuts).

This is not an exhaustive list, and other hypotheses are possible.

Question 10

Taking the hypotheses proposed in the answer to question 9 in turn:

Hypothesis 1: Sample beetles from Mel's garden to establish whether the red and grey forms are randomly distributed or not.

Hypothesis 2: Undertake some mating preference tests. Take each type of female and house her with one male of each type to discover which she mates with. And vice versa.

Hypothesis 3: Test the relative viabilities of the different genotypes in a variety of controlled environments.