AP Bio FRQ Fridays

2003 #1
Sex-Linked Traits & Chi Square

FRQ Friday #13

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In fruit flies, the phenotype for eye color is determined by a certain locus. ***E*** indicates the dominant allele and ***e*** indicates the recessive allele. The cross between a male wild-type fruit fly and a female white-eyed fruit fly produced the following offspring.

	Wild-type Male	Wild-type Female	White-eyed Male	White-eyed Female	Brown-eyed Female
F1	0	45	55	0	1

The wild-type and white-eyed individuals from the F1 generation were then crossed to produce the following offspring.

F2	23	31	22	24	0

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	Wild-type Male	Wild-type Female	White-eyed Male	White-eyed Female	Brown-eyed Female
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(a) Determine the genotypes of the original parents (P generation) and explain your reasoning. You may use Punnett squares to enhance your description, but the results from the Punnett squares must be discussed in your answer.

½ Wild Type Female

½ White Eye Male

	X^E	Y
X^e	$X^E X^e$	$X^e Y$
X^e	$X^E X^e$	$X^e Y$

	X^e	Y
X^E	$X^E X^e$	$X^E Y$
X^e	$X^e X^e$	$X^e Y$

¼ Wild Type Female
¼ Wild Type Male
¼ White Eye Female
¼ White Eye Male

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	Wild-type Male	Wild-type Female	White-eyed Male	White-eyed Female	Brown-eyed Female
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(a) Determine the genotypes of the original parents (P generation) and explain your reasoning. You may use Punnett squares to enhance your description, but the results from the Punnett squares must be discussed in your answer.

(a) Maximum 4 points

1 pt	Genotypes of the parents (words or symbols) X^EY (or X^+Y) and X^eX^e
1 pt	Discuss/show how these resulted in this F1 (may be annotated Punnett)
1 pt	Explain that it is a sex-linked (X-linked) gene (not just the word)
1 pt	How you know which type is dominant
1 pt	F2 results (may be annotated Punnett square)

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(a) Determine the genotypes of the original parents (P generation) and explain your reasoning. You may use Punnett squares to enhance your description, but the results from the Punnett squares must be discussed in your answer.

a) The genotypes of the original parents are X^eX^e for the female and X^EY for the male. The trait is sex-linked, only carried on the X chromosome. The female is homozygous recessive for white eyes while the male has a single dominant gene. The validity of these genotypes can be seen with a Punnett square:

	X^E	Y
X^e	X^EX^e	X^eY
X^e	X^EX^e	X^eY

In the F_1 generation, half of the offspring are females heterozygous for wild-type eyes while the other half are males with the white-eye gene.

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F2	23	31	22	24	0

(b) Use a Chi-squared test on the F2 generation data to analyze your prediction of the parental genotypes. Show all your work and explain the importance of your final answer.

Phenotype	Observed (O)	Expected (E)	O – E	$(O - E)^2$	$(O - E)^2/E$

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Phenotype	Observed (O)	Expected (E)	O – E	$(O - E)^2$	$(O - E)^2/E$
Wild-Type Male	23				
Wild-Type Female	31				
White-Eyed Male	22				
White-Eyed Female	24				
Total	100				

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The wild-type and white-eyed individuals from the F1 generation were then crossed to produce the following offspring.

F2	23	31	22	24	0

1:1:1:1

(b) Use a Chi-squared test on the F2 generation data to analyze your prediction of the parental genotypes. Show all your work and explain the importance of your final answer.

Phenotype	Observed (O)	Expected (E)	O – E	$(O - E)^2$	$(O - E)^2/E$
Wild-Type Male	23	25			
Wild-Type Female	31	25			
White-Eyed Male	22	25			
White-Eyed Female	24	25			
Total	100	100			

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1:1:1:1

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Phenotype	Observed (O)	Expected (E)	O – E	$(O - E)^2$	$(O - E)^2/E$
Wild-Type Male	23	25	– 2		
Wild-Type Female	31	25	6		
White-Eyed Male	22	25	– 3		
White-Eyed Female	24	25	– 1		
Total	100	100			

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1:1:1:1

(b) Use a Chi-squared test on the F2 generation data to analyze your prediction of the parental genotypes. Show all your work and explain the importance of your final answer.

Phenotype	Observed (O)	Expected (E)	O – E	$(O - E)^2$	$(O - E)^2/E$
Wild-Type Male	23	25	– 2	4	
Wild-Type Female	31	25	6	36	
White-Eyed Male	22	25	– 3	9	
White-Eyed Female	24	25	– 1	1	
Total	100	100			

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1:1:1:1

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Phenotype	Observed (O)	Expected (E)	O – E	$(O - E)^2$	$(O - E)^2/E$
Wild-Type Male	23	25	– 2	4	4/25
Wild-Type Female	31	25	6	36	36/25
White-Eyed Male	22	25	– 3	9	9/25
White-Eyed Female	24	25	– 1	1	1/25
Total	100	100			50/25 = 2.0

Critical Values of the Chi-Squared Distribution

Probability (p)	Degrees of Freedom (df)				
	1	2	3	4	5
0.05	3.84	5.99	7.82	9.49	11.1

2.0 < 7.82; fail to reject the null hypothesis

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(b) Use a Chi-squared test on the F2 generation data to analyze your prediction of the parental genotypes. Show all your work and explain the importance of your final answer.

(b) Maximum 4 points

1 pt Correct F2 hypothesis (1:1:1:1; or 25/genotype)

1 pt Show work (components): o e o-e $(o-e)^2$ $(o-e)^2/e$
(or correct numbers $(4/25 + 36/25 + 1/25 + 9/25 = 50/25 = 2$; or at least the last term)

1 pt Sum: correct chi-square result ~ 2.0 or 1.85

1 pt degrees of freedom = 3 (critical value is 7.82)

1 pt correct interpretation of chi-square in terms of p
p = probability that the difference between the observed and the expected value is due to chance alone.
This p value shows we accept our hypothesis.
The null hypothesis is supported in this case.
(alternative: 2 X^2 tests of white *vs.* red males and white *vs.* red females)

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(b) Use a Chi-squared test on the F2 generation data to analyze your prediction of the parental genotypes. Show all your work and explain the importance of your final answer.

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

b) The expected genotypes for generation F_2 are shown in a Punnett square:

	X^e	Y
X^E	$X^E X^e$	$X^E Y$
X^e	$X^e X^e$	$X^e Y$

Wild-type females ($X^E X^e$), white-eyed females ($X^e X^e$), wild-type males ($X^E Y$), and white-eyed males ($X^e Y$) should all show up in equal proportions (1:1:1:1). Thus, it is expected (null hypothesis) that for the 100 individuals of generation F2, 25 individuals should show each phenotype (not brown-eyed). This would be the expected count for each term in the χ^2 test.

$$\chi^2 = \frac{(23-25)^2}{25} + \frac{(31-25)^2}{25} + \frac{(22-25)^2}{25} + \frac{(24-25)^2}{25}$$

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(b) Use a Chi-squared test on the F2 generation data to analyze your prediction of the parental genotypes. Show all your work and explain the importance of your final answer.

$= \frac{4+36+9+1}{25} = \frac{50}{25} = 2$

$df = (rows-1)(cols-1) = (1)(3) = 3$

The critical value for the χ^2 test statistic at the $\alpha = 0.05$ significance level is $\chi^2 = 7.82$. Since the observed χ^2 statistic ($\chi^2 = 2$) is less than this value, it can be concluded the observed phenotypes do not vary statistically significantly from the expected counts of each phenotype. The proposed genotypes for each generation and the proposed pattern of inheritence (sex-linked) are statistically affirmed to be true.

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	Wild-type Male	Wild-type Female	White-eyed Male	White-eyed Female	Brown-eyed Female
F1	0	45	55	0	1

(c) The brown-eyed female in the F1 generation resulted from a mutational change. Explain what a mutation is, and discuss two types of mutations that might have produced the brown-eyed female in the F1 generation.

(c) Maximum 4 points

1 pt Explain what a mutation is: (heritable) change in the DNA (code)

1-2 pts Discuss 2 types of mutations

May be: Point mutation, frameshift (deletion/duplication), insertion, transposition, break, inversion within gene, base substitution, nonsense/stop, missense)

May NOT be: chromosomal aberration, nondisjunction, silent/neutral, transcription or translation or processing error

1 pt Molecular or biochemical elaboration beyond the explanation required

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ADDITIONAL PAGE FOR ANSWERING QUESTION 1

c) A mutation is the change in the genotype or DNA of an individual. A mutation, depending on what type it is, may or may not be reflected in the phenotype of the individual. In this case, a mutation was reflected in the brown-eyed phenotype of 1 individual in generation F1. This could have been the result of a base pair substitution or an inversion. A base pair substitution would have occured the DNA replication of the individual in which a single wrong base pair would have been substituted for a correct one. For example, opposite a guanine, an adenine may have been placed in the complementary strand instead of cytosine. In this case, the substitution would have changed a single

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(c) The brown-eyed female in the F1 generation resulted from a mutational change. Explain what a mutation is, and discuss two types of mutations that might have produced the brown-eyed female in the F1 generation.

codon (3 consecutive base pairs) so that it began to code for a single different amino acid, which would have changed the resulting protein the amino acid is incorporated into for eye color. Thus, the eye color would have changed. In an inversion, a sequence of base pairs would have been inverted in the DNA sequence. For example GCATTG may have been changed to GCTTAG. This inversion would have led to the change in one or more codons, resulting in the production

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

of a different amino acid than normal, resulting in a protein for brown eye color rather than the typical wild-type or white.

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