Name: Key 2021

AP Biology Genetics Practice Problems (Chapters 14, 15) 2021

***Begin by completing the Scientific Skills Exercise on page 302 in the new version of the textbook (chapter 15) (Staple your work to this packet)

Scientific Skills Exercise

Using the Chi-Square (χ^2) Test

➤ **Cosmos plants**

Are Two Genes Linked or Unlinked? Genes that are in close proximity on the same chromosome will result in the linked alleles being inherited together more often than not. But how can you tell if certain alleles are inherited together due to linkage or whether they just happen to assort together randomly? In this exercise, you'll use a simple statistical test, the chi-square (χ^2) test, to analyze phenotypes of F_1 testcross progeny in order to see whether two genes are linked or unlinked.

How These Experiments Are Done If genes are unlinked and assorting independently, the phenotypic ratio of offspring from an F_1 testcross is expected to be 1:1:1:1 (see Figure 15.9). If the two genes are linked, however, the observed phenotypic ratio of the offspring will not match that ratio. Given that random fluctuations in the data do occur, how much must the observed numbers deviate from the expected numbers for us to conclude that the genes are not assorting independently but may instead be linked?

To answer this question, scientists use a statistical test. This test, called a chi-square (χ^2) test, compares an observed data set with an expected data set predicted by a hypothesis (here, that the genes are unlinked) and measures the discrepancy between the two, thus determining the "goodness of fit." If the discrepancy between the observed and expected data sets is so large that it is unlikely to have occurred by random fluctuation, we say there is statistically significant evidence against the hypothesis (or, more specifically, evidence for the genes being linked). If the discrepancy is small, then our observations are well explained by random variation alone. In this case, we say that the observed data are consistent with our hypothesis, or that the discrepancy is statistically insignificant. Note, however, that consistency with our hypothesis is not the same as proof of our hypothesis. Also, the size of the experimental data set is important: With small data sets like this one, even if the genes are linked, discrepancies might be small by chance alone if the linkage is weak. For simplicity, we overlook the effect of sample size here.

Data from the Simulated Experiment In cosmos plants, purple stem (*A*) is dominant to green stem (*a*), and short petals (*B*) is dominant to long petals (*b*). In a simulated cross, *AABB* plants were crossed with *aabb* plants to generate F_1 dihybrids (*AaBb*), which were then testcrossed (*AaBb* × *aabb*). A total of 900 offspring plants were scored for stem color and flower petal length.

Offspring from testcross of *AaBb* (F_1) × *aabb*	Purple stem/short petals (*A–B–*)*	Green stem/short petals (*aaB–*)	Purple stem/long petals (*A–bb*)	Green stem/long petals (*aabb*)
Expected ratio if the genes are unlinked	1	1	1	1
Expected number of offspring (of 900)	225	225	225	225
Observed number of offspring (of 900)	220	210	231	239

*If the phenotype is dominant, a dash is used for the second allele; it could be either the dominant or recessive allele.

INTERPRET THE DATA

1. The results in the data table are from a simulated F_1 dihybrid testcross. The hypothesis that the two genes are unlinked predicts that the offspring phenotypic ratio will be 1:1:1:1. Using this ratio, calculate the expected number of each phenotype out of the 900 total offspring, and enter the values in that data table.

2. The goodness of fit is measured by χ^2. This statistic measures the amounts by which the observed values differ from their respective predictions to indicate how closely the two sets of values match. The formula for calculating this value is

$$\chi^2 = \Sigma \frac{(o-e)^2}{e}$$

where Σ = sum of, o = observed and e = expected. Calculate the χ^2 value for the data using the table below. Fill out that table, carrying out the operations indicated in the top row. Then add up the entries in the last column to find the χ^2 value.

Testcross Offspring	Expected (e)	Observed (o)	Deviation (o − e)	$(o-e)^2$	$(o-e)^2/e$
A–B–	225	220	5	25	0.11
aaB–	225	210	-15	225	1.0
A–bb	225	231	-6	36	0.16
aabb	225	239	-14	196	0.87
				χ^2 = Sum	2.14

3. The χ^2 value means nothing on its own—it is used to find the probability that, assuming the hypothesis is true, the observed data set could have resulted from random fluctuations. A low probability suggests that the observed data are not consistent with the hypothesis and thus the hypothesis should be rejected. A standard cutoff point used by biologists is a probability of 0.05 (5%). If the probability corresponding to the χ^2 value is 0.05 or less, the differences between observed and expected values are considered statistically significant and the hypothesis (that the genes are unlinked) should be rejected. If the probability is above 0.05, the results are not statistically significant; the observed data are consistent with the hypothesis that the genes are unlinked.

   To find the probability, locate your χ^2 value in the χ^2 distribution table in Appendix D. The "degrees of freedom" (df) of your data set is the number of categories (here, 4 phenotypes) minus 1, so df = 3. **(a)** Determine which values on the df = 3 line of the table your calculated χ^2 value lies between. **(b)** The column headings for these values show the probability range for your χ^2 number. Based on whether there are nonsignificant ($p > 0.05$) or significant ($p \leq 0.05$) differences between the observed and expected values, are the data consistent with the hypothesis that the two genes are unlinked and assorting independently, or is there enough evidence to reject this hypothesis?

➔ **Instructors:** A version of this Scientific Skills Exercise can be assigned in **Mastering Biology**.

AP® SCIENCE PRACTICES 5, 6

Since 2.14 < 7.81, fail to reject the null.
(and these genes are likely unlinked and variation from expected to observed are likely due to chance.)

Mendelian Genetics: *Please show ALL work.*

1. In peas, yellow color is dominant to green. What will be the colors of the offspring of the following crosses? Y y
   a. homozygous yellow X green

      YY x yy 100% Yellow (Yy)

   b. heterozygous yellow X green

      Yy x yy

	y	y
Y	Yy	Yy
y	yy	yy

      50% yellow (Yy)
      50% gr (yy)

   c. heterozygous yellow X homozygous yellow

      Yy x YY 100% yellow (Yy and YY)

   d. heterozygous yellow X heterozygous yellow

      Yy x Yy 75% yellow, 25% gn
      (YY + Yy) (yy)

2. What are the expected types of offspring produced by a cross between a heterozygous black, short-haired guinea pig and a homozygous white, long-haired guinea pig? Assume that black color and short hair are dominant characteristics. B H

   BbHh x bbhh

	BH	Bh	bH	bh
bh	BbHh	Bbhh	bbHh	bbhh

   25% black/short 25% black/long 25% white/short 25% white/short

3. Two long-winged flies were mated. The offspring consisted of 77 with long wings and 24 with short wings. Is the short-winged condition dominant or recessive? What are the genotypes of the parents?

   Ll x Ll

4. The ability to roll the tongue into almost a complete circle is conferred by a dominant gene, while its recessive allele fails to confer this ability. A husband and his wife can both roll their tongues and are surprised to find that their son cannot. Explain this by showing the genotypes of all three persons. T

   Tt x Tt

   son = tt
   (25% chance)

5. A male and a female are heterozygous for tongue rolling, and have three sons. The three sons have children with females who are not tongue rollers. Assuming that each of the three sons has a different genotype, show by a diagram what proportion of their children might have the ability to roll their tongues. Tt

   3 sons: TT x tt = Tt (All tongue roller)
   Tt x tt = 50%, 50%
   tt x tt = tt (all non-roller)

6. If two fruit flies, heterozygous for genes of one allelic pair were bred together and had 200 offspring…

   Tt X Tt

	T	t
T	TT	Tt
t	Tt	tt

   a. about how many would have the dominant phenotype? 150 (200 · 0.75)
   b. of these offspring, some will be homozygous dominant and some heterozygous. How is it possible to establish which is which?

      Test cross with homozygous recessive

Polygenic inheritance problems

Polygenic Inheritance is the determination of a given characteristic, such as height or color, by the interaction of two or more genes.

1. Assume that three genes control eye color, each found on a different chromosome. Furthermore, assume that each gene has two alleles – One dominant, one recessive – represented by the following letters: gene 1, B and b; gene 2, G and g; gene 3, Y and y. The chart below shows how the eye color of an individual is determined by the number of dominant alleles in their genotype. Complete the Punnett Square for the cross between a female who is homozygous recessive for all three genes and a male who is heterozygous for each gene. Then use the chart to answer the questions below.

bbggyy x BbGgYy

# of dominant alleles	Eye Color
5-6	Black
3-4	Brown
1-2	Green
0	Blue

	BGY	BGy	BgY	Bgy	bGY	bGy	bgY	bgy
bgy	BbGgYy brown	BbGgyy green	BbggYy green	Bbggyy green	bbGgYy green	bbGgyy green	bbggYy green	bbggyy blue

a. What is the expected ratio of eye color - listed Black:Brown:Green:Blue – in the offspring?

1:6:1

b. How do you think an individual with 4 dominant alleles might compare to an individual with 3 dominant alleles?

darker brown vs. lighter brown

2. In wheat, two pairs of genes control the color of wheat kernels. These genes are R/r and S/s. Complete the Punnett Square below showing the result of a cross between two individuals **heterozygous for both genes.** RrSs x RrSs

	RS	Rs	rS	rs
RS	RRSS	RRSs	RrSs	RrSs
Rs	RRSs	RRss	RrSs	Rrss
rS	RrSS	RrSs	rrSS	rrSs
rs	RrSs	Rrss	rrSs	rrss

Use the following information to answer the questions below.

RRSS – dark red kernels
RRSs – medium dark red kernels
RrSS – medium dark red kernels
RRss – medium red kernels
RrSs- medium red kernels
rrSS – medium red kernels
Rrss – light red kernels
rrSs – light red kernels
rrss – white kernels

a. What is the phenotypic ratio of red to white kernels?

15:1

b. What is the phenotypic ratio of dark red to medium dark red kernels?

1:3

c. What is the phenotypic ratio of medium dark red to medium red kernels?

3:5

d. If you were interested in producing an entire crop of medium red "kerneled" wheat, what would be the genotype of the parental wheat?

RRSS x rrss

3. A geneticist studying the inheritance of color in flowers crossed a pure white flower (aabb) with a dark red flower (AABB) and got all pink offspring. Interbreeding the pink flowers produced the following data:

43	dark red
162	red
245	pink
166	light pink
41	white

a. Why is this particular example a case of polygenic inheritance?

more than one gene affects the same trait (A/B) (flower color)

b. What are the genotypes of…

i. The dark red flower AABB
ii. The red flower AaBB or AABb
iii. The pink flower AaBb or AAbb or aaBB
iv. The light pink flower aaBb or Aabb
v. The white flower aabb

c. Cross a red flower (AaBB) with a pink flower (AaBb). What are the expected phenotypic ratios of offspring?

1/8 Dk red 3/8 pink
3/8 red 1/8 Lt. Pint

	AB	Ab	aB	ab
AB	AABB	AABb	AaBB	AaBb
aB	AaBB	AaBb	aaBB	aaBb

d. Cross a light pink flower (aaBb) with a pink flower (AaBb). What are the expected phenotypic ratios of offspring?

1/8 red 3/8 lt. pink
3/8 pink 1/8 wht.

	AB	Ab	aB	ab
aB	AaBB	AaBb	aaBB	aaBb
ab	AaBb	Aabb	aaBb	aabb

4. Human skin color is a good example of polygenic (multiple gene) inheritance. Assume that three genes control skin color (in actuality, there are many more!). The capital letter alleles (A, B and C) control dark pigmentation because more melanin is produced. The lower case alleles of these three genes (a, b & c) control light pigmentation because they cause lower amounts of melanin to be produced. A person who has a genotype with all capital genes (AABBCC) has the **maximum** amount of melanin and very dark skin. Another way to think about it is to imagine that each capital letter allele makes one unit of melanin…by that logic, a skin cell with the genotype AABBCC would make 6 units of melanin and be dark. A cell with a genotype with all lower case allele (aabbcc) has no capital letters, and would produce little melanin and therefore, would be light in color. Remember, each capital allele produces one unit of color, so that a wide range of intermediate skin colors are produced, depending on the number of capital alleles in the genotype. For example, a genotype with three capital alleles and three lower case alleles (AaBbCc) has a medium amount of melanin and an intermediate skin color.

Suppose a female who is AABbCc has offspring with a male who is AaBbcc.

a. List all of the possible <u>genotypes of the gametes</u> that could be produced by each of the genetic parents.

female possible gametes: ABC, AbC, Abc,

male possible gametes: ABc, Abc, aBc, abc

b. What are the number of different genotypes from lightest to darkest skin coloration possible from the above cross?

Aa BB Cc AaBBCc AabbCc AABbCc

AA Bb cc AaBBcc Aabbcc AABbcc

bb AaBbCc AABBCc AAbbCc

AaBbcc AABBcc AAbbcc

c. In this cross, how many dominant alleles will offspring with the darkest skin coloration possess, and what theoretical fraction of the offspring will have this coloration?

# of Dominant alleles:	fraction:
4	4/12
3	4/12
2	3/12
1	1/12

5. What are FIVE other human traits you can think of that show continuous variation (gradual change) in phenotype instead of a clear either/or phenotype (ex. has widow's peak/doesn't have widow's peak.)

height hand size eye color
foot size hair texture hair color
(any physical structures)

6. Do you think it would be easy or hard to genetically engineer an organism to be taller? Explain your answer.

more dificult since multiple genes involved.

Sex-linked *Sex-linked genes are those found on the chromosomes that determine biological sex, usually the X chromosome (humans, fruit flies and cats).*

1. One pair of genes for coat color in cats is sex-linked. The gene B produces yellow coat, b produces black coat, and the heterozygous produces tortoise-shell coat. What kind of offspring will result from the mating of a black male (XY) and a tortoise-shell female (XX)? $X^bY \times X^BX^b$

	X^B	X^b
X^b	X^BX^b	X^bX^b
Y	X^BY	X^bY

1/4 Tortoise shell (all ♀)
1/2 Yellow
1/2 black (all ♂)

a. Explain why there can never be a male tortoise-shell cat.

must inherit two genes and males only have one X chromosome.

2. The barred pattern of chicken feathers is inherited by a pair of sex-linked genes, B for barred and b for no bars. If a barred female is mated to a non-barred male, what will be the appearance of the progeny? $X^BX^- \times X^bY$

	X^b	Y
X^B	X^BX^b	X^BY
X^-	X^-X^b	X^-Y

at least 1/2 Barred

3. A female is born with hemophelia, an inherited recessive, sex-linked clotting disorder. (h)

a. What are the possible genotypes and phenotypes of her biological parents?

X^hX^h ∴ male parent must also have hemophelia (X^hY) and female parent (X^HX^h)

	X^h	Y
X^H	X^HX^h	X^HY
X^h	X^hX^h	X^hY

b. Assuming that her biological mother has typical clotting blood, what were this girl's chances of being born with the disease? 1/2

(because 1/2 of 4 whould have Hemophilia)

c. Several cases of hemophilia in females have been reported within a small region in England where there is much close intermarriage. Explain this high frequency of hemophilia in females.

Intermarriage increases chances of inherting 2 copies of gene for hemophelia

Multiple Alleles *Multiple alleles are when there are more than two alleles possible at a gene locus.*

1. Mrs. Doe and Mrs. Roe had babies at the same hospital at the same time. Mrs. Roe brought home a baby girl and named her Zoe. Mrs. Doe received a baby boy and named him Dale. However, she was sure she had had a girl and brought suit against the hospital. Blood test showed that Mr. Doe was type O, Mrs. Doe was type AB, Mr. And Mrs. Roe were both type B. Zoe was type A and Dale was type O. Had an exchange occurred? Support your answer.

Does: O x AB Roes: B x B ∴ Zoe must Zoe Doe

Zoe A Dale O Dale must be a Roe

Type AB cannot have type O

Di and Tri hybrid crosses

1. In rabbits, spotted coat (S) is dominant to solid color (s), and black (B) is dominant to brown (b). In a large population, brown spotted rabbits are mated to solid black ones and all the offspring are black spotted.
   a. What are the genotypes of the parents? SSbb x ssBB
   b. What would be the appearance of the F_2 if two of these F_1 black spotted rabbits were mated?

   SsBb so 9:3:3:1

   c. Illustrate your answer with a diagram.

	SB	Sb	sB	sb
SB				
Sb				
sB				
sb				

2. In pea plants, tall plants (T) are dominant to dwarf (t), yellow color (Y) is dominant to wrinkled seeds (s). What would be the phenotypes of the following matings? (Can you use probabilities instead of Punnett squares here? Why is that a better strategy?)

All combinations represented

a. TtYySs X ttyyss

Tt Yy Ss
tt yy ss
tys

TtYySs ttYySs
TtyySs ttyySs
TtYyss ttYyss
Ttyyss ttyyss

b. TtyySs X ttYySs

Tt Yy SS
Ss
tt yy ss

TtYySS TtyySS
TtYySs TtyySs
TtYyss Ttyyss

ttYySS ttyySS
ttYySs ttyySs
ttYyss ttyyss

Also all combinations represented

3. The weight of the fruit in one variety of squash is determined by three pairs of genes. The homozygous dominant condition, AABBCC, results in 6-pound squashes, and the homozygous recessive condition, aabbcc, results in 3-pound squashes. Each dominant gene adds 1/2 pound to the minimum 3-pound weight. When a plant having 6-pound squashes is crossed with one have 3-pound squashes, all the offspring have 4 1/2 –pound fruit. AABBCC aabbcc = F_2 = F_1 AaBbCc
   a. What would be the weights of the F_2 fruit, if two of the F_1 plants were crossed?

AaBbCc x AaBbCc

4.5
5.0
5.5
6.0

Codominance/Incomplete dominance *-These are slightly different from a genetic standpoint but the problems are completed in the same manner.*

1. Mendel believed that hereditary factors were always either dominant or recessive. How might he have altered this view had he performed the following cross? When pure line sweet peas with red flowers are crossed with pure line plants having white flowers, all the F_1 plants have pink flowers

Since theres blending, he'd be confused!
(And probably just stop using those plants! :)

2. Outline a breeding procedure whereby a true breeding strain of red cattle could be established from a roan bull and a white cow. (Red and White are Co-Dominant producing a Roan Color when both genes are present) RW x WW

	W	W
R	RW	RW
W	WW	WW

← then cross these

	R	W
R	RR	RW
W	RW	RW

3. A cattle breeder wants to establish a pure-breeding herd of roan short-haired cattle. What could you tell them about his chances for success in such a venture?

Start w/ Red & White to get all Roan, but
2 Roans will get you 1/4 Red, 1/4 White and 1/2 Roan

4. Suppose you learned that "shmoos" may have long, oval or round bodies and that matings of shmoos resulted in the following:

   long X oval gave 52 long and 48 oval
   long X round gave 99 oval
   oval X oval gave 24 long, 53 oval, and 27 round

   a. What hypothesis about inheritance of shmoo shape would be consistent with these results? Assume that shmoos are diploid.

Incomplete dominance b/c there is blending

5. The shape and color of radishes are controlled by two independent pairs of alleles that show no dominance. The color may be red (RR), purple (RR') or white (R'R'), and the shape may be long (LL), oval (LL') or round (L'L'). Red, long radishes are crossed with white, round radishes and then the F_1's are allowed to interbreed. If 1600 F_2's are obtained, then the expected ratio of white offspring would be?

RRLL x R'R'L'L' F_1 RR'LL' x RR'LL'

RR'LL' F_2

L'L'

	L	L'
L	LL	LL'
L'	LL'	L'L'

1/4 = 400 white