

Punnett square practice – Honors KEY

- 1) Yellow seeds are dominant over recessive green seeds. Cross a homozygous dominant yellow seeded-plant with a green-seeded plant. What are the odds of getting a plant with green seeds?

Legend: **Y** = yellow seeds **y** = green seeds Parent 1: **YY** Parent 2: **yy**

	Y
y	Yy

Phenotype ratio: **1 : 0 , yellow : green**

Answer: **0% green seeds**

- 2) Pea plants can have round seeds (dominant) or wrinkled seeds (recessive). Cross a heterozygous round-seed plant with a plant that has wrinkled seeds. What is the phenotype ratio of the offspring?

Legend: **R** = round seeds **r** = wrinkled seeds Parent 1: **Rr** Parent 2: **rr**

	R	r
r	Rr	rr

Phenotype ratio: 1 : 1 , round : wrinkled

- 3) Sickle cell anemia is a recessive disorder in humans. Therefore, not having sickle cell is dominant, and having sickle cell is recessive. Cross a heterozygous mother with a father who has sickle cell anemia. What are the odds that their child will have sickle cell?

Legend: **A** = NO sickle cell anemia
a = YES sickle cell anemia mom: **Aa** dad: **aa**

	A	a
a	Aa	aa

50% chance of child with sickle cell anemia (aa)

- 4) Polydactyly (having a 6th toe or finger) is a dominant condition in humans. Mom has polydactyly and dad does not, and they have 1 son who had polydactyly at birth, and 2 other children who did not. With this information, identify the genotypes of both parents.

Legend: **P** = polydactyly **p** = no polydactyly

mom: has polydactyly (dominant phenotype); could be PP or Pp
dad: does not have polydactyly (recessive phenotype); must be pp

	P		P	p
p	Pp	p	Pp	pp

Since Dad is homozygous recessive, only a heterozygous mother could have children without polydactyly . . . therefore MOM: heterozygous, Pp DAD: homozygous recessive, pp

- 5) Huntington's disease is a dominant trait (not having Huntington's is recessive) that unfortunately does not show any obvious symptoms until a person reaches age 40-50. Most people have children by then and pass on their genes before they know they have a genetic disorder. A father is heterozygous for Huntington's and the mother does not have Huntington's. What are the odds that their children might inherit the disorder?

Legend: **H** = yes disease **h** = no disease dad: **Hh** mom: **hh**

	H	h
h	Hh	hh

50% chance of child with Huntington's disease (Hh)

- 6) Cystic fibrosis is another human genetic disorder caused by one gene. Not having cystic fibrosis is dominant, and cystic fibrosis is recessive. You are a genetic counselor advising 2 parents who are both heterozygous and do not have cystic fibrosis. What are the odds that they could have a child with the condition?

Legend: **F** = yes disease **f** = no disease dad: **Ff** mom: **Ff**

	F	f
F	FF	Ff
f	Ff	ff

25% chance of child with cystic fibrosis (ff)

- 7) Pea plants can have large leaves (recessive) or small leaves (dominant). Two small-leaf plants are crossed, and 50 offspring are planted. 36 of the offspring have small leaves, and 14 of the offspring have large leaves. Identify the genotypes of the parents.

Legend: **L** = small leaves **l** = large leaves dad: **small leaves** mom: **small leaves**

Parents both have small leaves . . . so neither parent can be homozygous recessive (ll)

	L
L	LL

If parents are both homozygous dominant (LL), then 0% chance of offspring with large leaves (ll).

	L	l
L	LL	Ll

If one parent is homozygous dominant (LL) and one parent is heterozygous (Ll), then 0% chance of offspring with large leaves (ll).

	L	l
L	LL	Ll
l	Ll	ll

If parents are both heterozygous (Ll), then 25% chance of offspring with large leaves (ll).

PARENTS ARE BOTH HETEROZYGOUS (Ll)

One-trait problems with chi-square statistics

- 8) A student working with fruit fly cultures gets the following results through 3 generations.

Original P generation:	male wild-type red eyes crossed with female black eyes	
F ₁ generation:	32 males wild-type red eyes 28 females wild-type red eyes	0 black eyes
F ₂ generation:	26 males wild-type red eyes <u>24 females wild-type red eyes</u> = 50 total wild-type red eyes	11 males black eyes <u>11 females black eyes</u> = 22 total black eyes

- a) Wild-type red eyes appears dominant. Black eyes appear to be recessive. The following Punnett square would explain why the F₁ generation has ZERO flies with black eyes.

	R
r	Rr

The P generation is probably homozygous dominant male (RR) and homozygous recessive female (rr). The F₁ generation is 100% heterozygous with wild-type red eyes.

- b) If male and female F₁ flies mate to create the F₂ generation, what results should we expect to get in the next generation (phenotype ratio)?

Legend: R = wild-type red eyes r = black eyes both F₁ parents: Rr

	R	r
R	RR	Rr
r	Rr	rr

Phenotype ratio: 3 : 1 , wild-type red eyes : black eyes

- c) Do these actual results above support this model of inheritance presented above? Does the chi-square value support the model? ($p < 0.05$)

Null hypothesis

H₀: there is no significant difference between actual data and expected results for this model of inheritance.

72 total flies in F₂ generation. $(0.75)(72) = 54$ expected red eyes = e (calculated from Punnett square)

50 observed red eyes = o (from actual data)

$(0.25)(72) = 18$ expected black eyes = e (calculated using Punnett square)

22 observed black eyes = o (from actual data)

$$\chi^2 = \sum \frac{(o - e)^2}{e} = \frac{(50 - 54)^2}{54} + \frac{(22 - 18)^2}{18} = \mathbf{1.19} = \chi^2$$

2 observed phenotypes . . . therefore, $(2 - 1) = 1$ degree of freedom.

Consult critical value chart at $p < 0.05$

Critical value = 3.84

$1.19 < 3.84$, so the null hypothesis is not rejected. The data IS close enough to the expected values to support the model of inheritance.

- 9) A student is working with the model that wild type normal wings are dominant over recessive vestigial (messed-up) wings. He believes that is crossing a homozygous dominant fly with a homozygous recessive fly. He gets 7 wild type offspring and 5 vestigial wing offspring.

Explain why the results reject the hypothesis that the parents were homozygous dominant and homozygous recessive.

Hypothesis: N = normal wings n = vestigial wings parent: NN (normal wings)
parent: nn (vestigial wings)

	N	
n	Nn	Hypothesis predicts offspring that are 100% heterozygous with normal wings and 0% vestigial wings. Actual experiment resulted in 7 normal wings and 5 vestigial wings. Hypothesis is not supported.

Propose an alternate hypothesis, create a new Punnett square and determine if your new hypothesis is supported by the results (7 wild-type; 5 vestigial) according to a chi-square test.

NEW hypothesis: parent: Nn (phenotype is still normal wings)
parent: nn (vestigial wings)

	N	n	
n	Nn	nn	NEW hypothesis predicts offspring that are 50% heterozygous with normal wings and 50% homozygous recessive with vestigial wings

Null hypothesis

H₀: there is no significant difference between actual data and expected results for this model of inheritance.

12 total flies observed. (0.50)(12) = 6 expected normal wings = e (calculated from Punnett square)

7 observed normal wings = o (from actual data)

(0.50)(12) = 6 expected vestigial wings = e (calculated using Punnett square)

square)

5 observed vestigial wings = o (from actual data)

$$\chi^2 = \sum \frac{(o - e)^2}{e} = \frac{(7 - 6)^2}{6} + \frac{(5 - 6)^2}{6} = \mathbf{0.33} = \chi^2$$

2 observed phenotypes . . . therefore, (2 - 1) = 1 degree of freedom.

Consult critical value chart at p < 0.05

Critical value = 3.84

0.33 < 3.84, so the null hypothesis is not rejected. The data IS close enough to the expected values to support the model of inheritance.

10) A student is crossing two heterozygous flies and gets 83 flies with the dominant phenotype, and 31 flies with the recessive phenotype. Does this data support the student's understanding of the genetic cross ($p < 0.05$)?

Legend: **R** = dominant **r** = recessive parent: **Rr** parent: **Rr**

	R	r	
R	RR	Rr	expected 3 : 1 phenotype ratio 75% dominant; 25% recessive
r	Rr	Rr	

Null hypothesis

H_0 : there is no significant difference between actual data and expected results for this model of inheritance.

114 total flies observed. $(0.75)(114) = 85.5$ expected dominant = e (calculated from Punnett square)
 83 observed dominant = o (from actual data)
 $(0.50)(114) = 57$ expected recessive = e (calculated using Punnett square)
 31 observed recessive = o (from actual data)

$$\chi^2 = \sum \frac{(o - e)^2}{e} = \frac{(83 - 85.5)^2}{85.5} + \frac{(31 - 28.5)^2}{28.5} = \mathbf{0.29} = \chi^2$$

2 observed phenotypes . . . therefore, $(2 - 1) = 1$ degree of freedom.

Consult critical value chart at $p < 0.05$

Critical value = 3.84

$0.29 < 3.84$, so the null hypothesis is not rejected. The data IS close enough to the expected values to support the model of inheritance.

Test cross problems (see figure 6.16, p. 185)

11) You cannot observe a difference between a homozygous dominant plant and a heterozygous plant just by looking at them – why not?

homozygous dominant and heterozygous have the same phenotype

Let's say purple stem is dominant over green stem, and you have a homozygous dominant purple stem plant (**PP**) and a heterozygous purple stem plant (**Pp**).

One way farmers can tell these two apart is to breed the purple stem plant with a **green** plant – we do this because we know this plant's genotype: **homozygous recessive (pp)**

This is called a **testcross**. Draw Punnett squares for both crosses and explain how this testcross can differentiate homozygous dominant and heterozygous.

Legend: **P** = purple stem **p** = green stem parent: **PP or Pp** parent: **pp**

	P
p	Pp

PP crossed with pp
has 0% chance of
green stem offspring

	P	p
p	Pp	pp

Pp crossed with pp
has 50% chance of
green stem offspring

12) Ranchers use genetics to breed for desirable traits. More meat = more money. Let's say there is one gene that causes cows to be super-sized. Super-size is dominant over normal size, which is recessive. A rancher only has one super-size cow right now. When he bred his super-size cow with a normal-size cow, he found that 3 of the offspring calves were super-size and 5 were normal size. What was the genotype of the original super-size cow? What could the rancher do in the future to ensure all super-size offspring?

Legend: **M** = super size **m** = regular size parent: **MM** or **Mm** parent: **mm**

	M
m	Mm

	M	m
m	Mm	mm

With the farmer's current cows, there is no way to ensure all super-sized offspring.

MM crossed with mm results in 0% chance of regular-sized cows. So, this farmer's super-sized cow can't be MM.

Mm crossed with mm results in 50% chance of regular-sized cows. So, this farmer's super-sized cow must be heterozygous (Mm).

The only way to ensure ALL offspring are supersized would be to acquire at least 1 homozygous dominant male (MM) and 1 homozygous dominant female (MM).

Two trait Punnett square problems

These problems are similar to one-trait (or monohybrid) Punnett square problems, but we are considering the inheritance of two different traits simultaneously. These Punnett squares demonstrate that you understand the connection between meiosis and Punnett squares.

Determining gametes: Remember that Punnett squares have **gametes** lined up on top and on the side. Follow these 2 basic rules to determine gametes:

- Gametes always have half the letters of an individual
- Gametes must have one of each letter (or one of each type of chromosome)

For example, an SsTt individual can make the following gametes: ST, sT, St, st

An MmEe individual can make the following gametes: ME, mE

Determine the gametes for the following individuals:

- IiHh possible gametes: **Ih** or **ih**
- XXcc possible gametes: **Xc**
- ZzFF possible gametes: **ZF** or **zF**
- BbNn possible gametes: **BN** or **Bn** or **bN** or **bn**

Sample: Purple flowers and yellow seeds are dominant, and white flowers and green seeds are recessive. Cross two parent plants who are heterozygous for both traits. What are the odds of getting offspring that have purple flowers and green seeds?

Key: P = purple flowers p = white flowers Y = yellow seeds y = green seeds

Crossing PpYy x PpYy

		PpYy			
		PY	Py	pY	py
PpYy	PY	PPYY	PPYy	PpYY	PpYy
	Py	PPYy	PPyy	PpYy	Ppyy
	pY	PpYY	PpYy	ppYY	ppYy
	py	PpYy	Ppyy	ppYy	ppyy

Overall phenotype ratio: 9 : 3 : 3 : 1

purple flowers : purple flowers : white flowers : white flowers
yellow seeds green seeds yellow seeds green seeds

17) Round seeds are dominant over wrinkled seeds, and purple stems are dominant over green stems. One parent plant is homozygous dominant for round seeds and heterozygous with purple stems. The other parent is heterozygous for both traits. What are the odds of getting offspring with round seeds and green stems?

Legend: R = round seeds r = wrinkled seeds
 P = purple stems p = green stems

parent: RRpp parent: RrPp
gametes: RP, Rp gametes: RP, Rp, rP, rp

	RP	Rp	rP	rp	
RP	RRPP	RRPp	RrPP	RrPp	2/8 = 25% chance of round seeds AND green stems
Rp	RRPp	RRpp	RrPp	Rrpp	

18) Inflated seed pods are dominant over constricted seed pods. Tall plants are dominant while short plants are recessive. One parent is homozygous dominant for inflated seed pods, but is short. The other parent is heterozygous for inflated pods and homozygous dominant for being tall. What are the odds of getting offspring who are heterozygous for both traits?

Legend: I = inflated seed pods i = constricted seed pods
 T = tall t = short

parent: Iitt parent: iITT
gametes: It gametes: IT or iT

	IT	iT	
It	IITt	IiTt	1/2 = 50% chance of heterozygous for both genotypes

Chi-square statistics with two-trait Punnett squares:

19) The black eye mutation and vestigial wing mutation are based on genes found on two different chromosome pairs in fruit flies. Both mutations are recessive compared to the dominant wild-type trait (red eyes and normal wings). If two doubly-heterozygous flies are crossed (the so-called dihybrid cross), what results would you expect to get?

legend: **R** = red eyes **r** = black eyes
 N = normal wings **n** = vestigial wings

parent: **RrNn** parent: **RrNn**
 gametes: **RN, Rn, rN, rn** gametes: **RN, Rn, rN, rn**

	RN	Rn	rN	rn
RN	RRNN	RRNn	RrNN	RrNn
Rn	RRNn	RRnn	RrNn	Rrnn
rN	RrNN	RrNn	rrNN	rrNn
rn	RrNn	Rrnn	rrNn	rrnn

Overall phenotype ratio: **9 : 3 : 3 : 1**

 red eyes : red eyes : black eyes : black eyes
 normal wings vestigial wings normal wings vestigial wings

If the actual results are as follows:

red eyes, normal wings: 80 flies
 black eyes, normal wings: 26 flies

red eyes, vestigial wings: 32 flies
 black eyes, vestigial wings: 8 flies

Do these results support the Mendelian model of inheritance presented above? ($p < 0.05$)

Null hypothesis

H_0 : there is no significant difference between actual data and expected results for this model of inheritance.

146 total flies observed. 4 phenotypes. So, 3 degrees of freedom. Critical value ($p < 0.05$) is 7.82

$(9/16)(146) = 82$ expected red eyes & normal wings = e (calculated from Punnett square)

80 observed red eyes & normal wings = o (from actual data)

$(3/16)(146) = 27$ expected red eyes & vestigial wings = e (calculated from Punnett square)

32 observed red eyes & vestigial wings = o (from actual data)

$(3/16)(146) = 27$ expected black eyes & normal wings = e (calculated from Punnett square)

26 observed black eyes & normal wings = o (from actual data)

$(1/16)(146) = 9$ expected black eyes & vestigial wings = e (calculated from Punnett square)

8 observed black eyes & vestigial wings = o (from actual data)

$$\chi^2 = \sum \frac{(o - e)^2}{e} = \frac{(80 - 82)^2}{82} + \frac{(32 - 27)^2}{27} + \frac{(26 - 27)^2}{27} + \frac{(8 - 9)^2}{9} = \mathbf{1.12} = \chi^2$$

1.12 < 7.82, so the null hypothesis is not rejected. The data IS close enough to the expected values to support the model of inheritance.

20) A student is working with two genes that are on separate chromosome pairs as well. Curly wings are recessive as are yellow body coloration (versus the wild type normal wings and brown body coloration).

A student is crossing (they think) a doubly heterozygous fly (for both traits) with a doubly homozygous recessive fly. Create a Punnett square prediction of the results they expect.

legend: **N** = normal wings **n** = curly wings
 B = brown body **b** = yellow body

expected parent: **NnBb** expected parent: **nnbb**
 gametes: **NB, Nb, nB, nb** gametes: **nb**

	NB	Nb	nB	Nb
nb	NnBb	Nnbb	nnBb	nnbb

Overall phenotype ratio: **1 : 1 : 1 : 1**

 normal wings : normal wings : curly wings : curly wings
 brown body yellow body brown body yellow body

If the actual results are as follows:

normal wings, brown body: 32

curly wings, brown body: 28

normal wings, yellow body: 27

curly wings, yellow body: 30

Do these results support the Mendelian model of inheritance presented above? ($p < 0.05$)

Null hypothesis

H_0 : there is no significant difference between actual data and expected results for this model of inheritance.

117 total flies observed. 4 phenotypes. So, 3 degrees of freedom. Critical value ($p < 0.05$) is 7.82

$(1/4)(117) = 29.25$ expected normal wings & brown body = e (calculated from Punnett square)

32 observed normal wings & brown body = o (from actual data)

$(1/4)(117) = 29.25$ expected normal wings & yellow body = e (calculated from Punnett square)

27 observed normal wings & yellow body = o (from actual data)

$(1/4)(117) = 29.25$ expected curly wings & brown body = e (calculated from Punnett square)

28 observed curly wings & brown body = o (from actual data)

$(1/4)(117) = 29.25$ expected curly wings & yellow body = e (calculated from Punnett square)

30 observed curly wings & yellow body = o (from actual data)

$$\chi^2 = \sum \frac{(o - e)^2}{E} = \frac{(32 - 29.25)^2}{29.25} + \frac{(27 - 29.25)^2}{29.25} + \frac{(28 - 29.25)^2}{29.25} + \frac{(30 - 29.25)^2}{29.25} = \mathbf{0.50} = \chi^2$$

$0.50 < 7.82$, so the null hypothesis is not rejected. The data IS close enough to the expected values to support the model of inheritance.

Sex-linked trait Punnett square problems (see Ch 7, p. 201-202)

Sex-linked traits involve genes that are on the sex chromosomes. In this course, we will only be tracking genes on the X chromosome – there are very few genes on the Y. Since males have XY chromosomes and females have XX chromosomes, males only have 1 allele while females have the standard two alleles. Because the genes exist ONLY on the X chromosome, we write the chromosomes in addition to the alleles in the Punnett square.

Sample: Colorblindness is a human disorder caused by a gene on the X chromosome. Not being colorblind is dominant, and being colorblind is recessive. Cross a father who is not colorblind with a heterozygous mother. What are the odds of having a colorblind daughter? How about a colorblind son?

		$X^B Y$ (does not carry "B" gene)		
		Dad: $X^B Y$		
		X^B	Y	
Mom: $X^B X^b$	X^B	$X^B X^B$	$X^B Y$	Colorblind daughter odds: <u>0 possibilities</u> = 0 % 2 total daughters
	X^b	$X^B X^b$	$X^b Y$	
	X^b	$X^B X^b$	$X^b Y$	Colorblind son odds: <u>1 possibility</u> = 50 % 2 total sons
				Colorblind child odds: <u>1 possibility</u> = 25 % 4 total children

21) Based on the answer above, do males or females have recessive sex-linked disorders more often? Why? Does mom or dad pass the recessive allele to the son?

Males have sex-linked recessive traits more often because they only have one X chromosome. The recessive phenotype will be expressed in males with only 1 recessive allele. Females require 2 recessive alleles in order to express the recessive sex-linked trait, because they have 2 X chromosomes.

Mom passes on a recessive sex-linked allele to her son, because a son will always have one X and one Y chromosome. The Y must come from Dad and doesn't have the sex-linked allele. The X chromosome must come from Mom and will have the sex-linked allele.

22) Hemophilia is another sex-linked human genetic disorder. Hemophilia is also recessive, so not having hemophilia is dominant. If dad has hemophilia while mom is homozygous dominant, what are the odds of having a child (boy or girl) with hemophilia?

Legend: X^H = no hemophilia X^h = yes hemophilia
 Dad: $X^h Y$ gametes: X^h or Y
 Mom: $X^H X^H$ gametes: X^H

X^h	X^H $X^H X^h$	phenotype ratio 1 : 1 50% male NO hemophilia : 50% female NO hemophilia 0% chance of a child with hemophilia
Y	$X^H Y$	

23) Having bar-shaped eyes in fruit flies is a sex-linked recessive trait. In a cross between unknown parents, half the female offspring and half the male offspring have bar-shaped eyes (the others have normal eyes). Draw a Punnett square that leads to this result and identify the genotypes of the parents.

Legend: X^B = wild-type normal eyes X^b = bar-shaped eyes

HYPOTHESIS:

Dad: X^bY gametes: X^b or Y
 Mom: X^BX^b gametes: X^B or X^b

	X^B	X^b	
X^b	X^BX^b	X^bX^b	→ 50% of females (1/2 females) have a chance of bar-shaped eyes (X^bX^b)
Y	X^BY	X^bY	→ 50% of males (1/2 males) have a chance of bar-shaped eyes (X^bY)

Overall phenotype ratio 1 : 1 : 1 : 1
 normal eyes female : bar-shaped eyes female : normal eyes male : bar-shaped eye male

Pedigrees

Pedigrees study the family history of a specific trait. Geneticists study pedigrees to determine the pattern of inheritance of the trait. The pedigrees below all represent different patterns of inheritance. The pedigrees could either be autosomal dominant, autosomal recessive, or sex-linked recessive (there are other patterns of inheritance, but we'll simplify here).

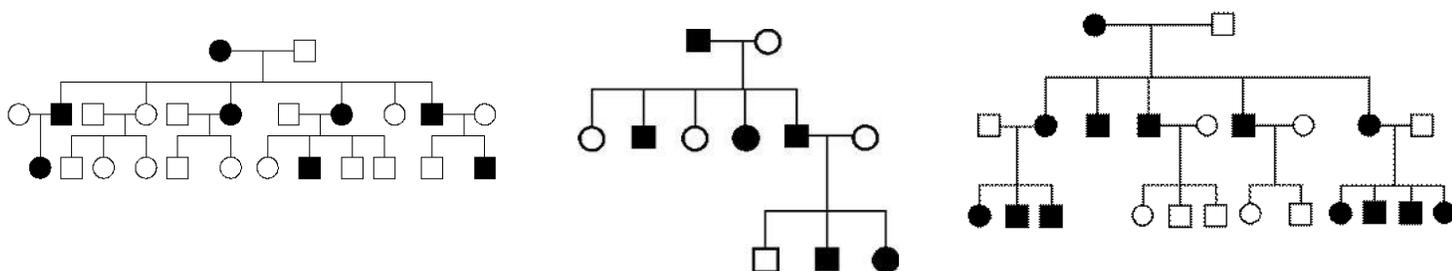
Pedigree legend:

male without disorder = □ female without disorder = ○ marriage = (kids below) □—○

male with disorder = ■ female with disorder = ●

Sample autosomal dominant pedigrees:

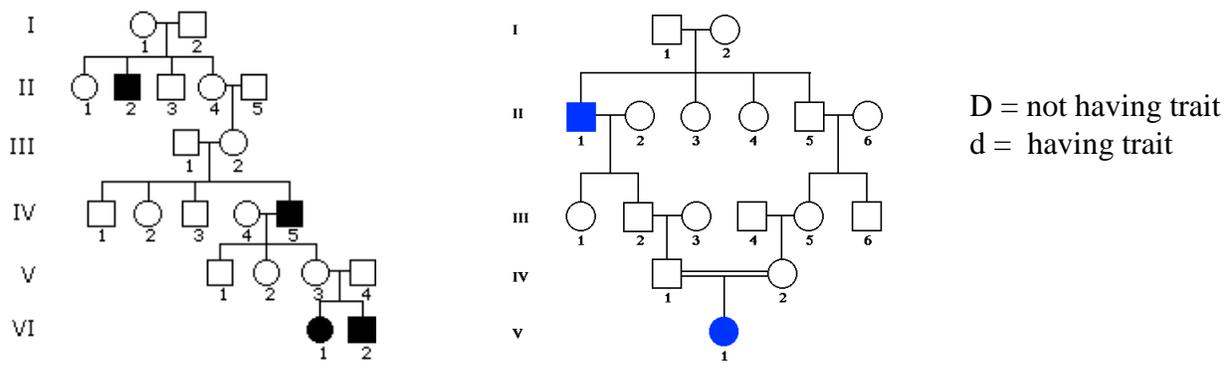
R = having trait
 r = not having trait



24) What seems to be the pattern for identifying a pedigree as being autosomal dominant?

Autosomal trait appears to be about equal numbers of male or female with the trait.
 Dominant trait appears in every generation.

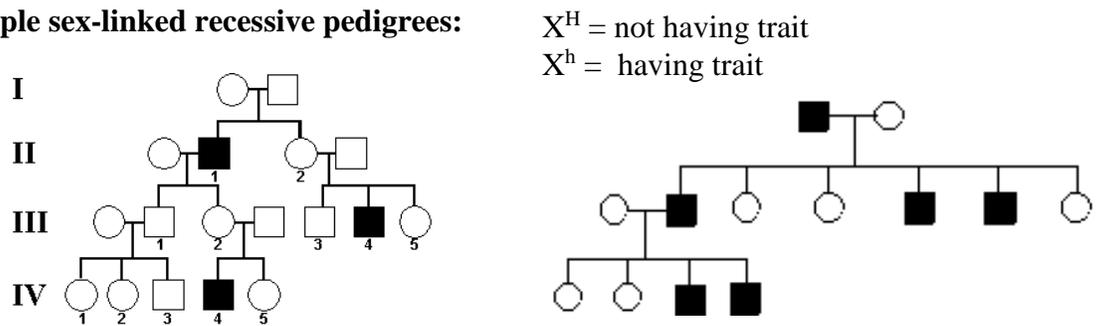
Sample autosomal recessive pedigrees:



25) What seems to be the pattern for identifying a pedigree as being autosomal recessive?

Autosomal trait appears to be about equal numbers of male or female with the trait.
Recessive trait appears to skip generations.

Sample sex-linked recessive pedigrees:

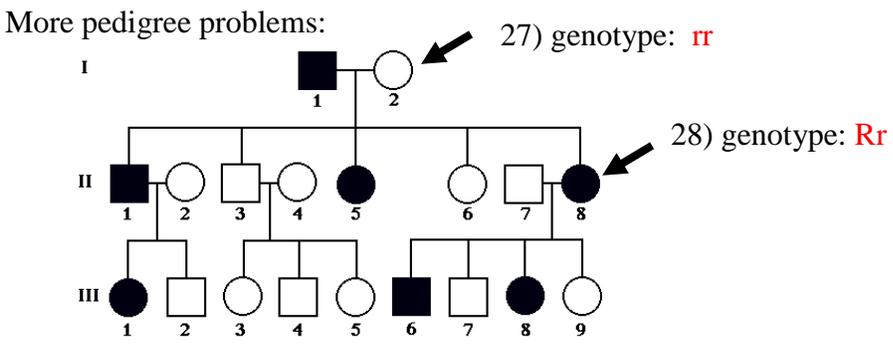


26) What seems to be the pattern for identifying a pedigree as being sex-linked recessive?

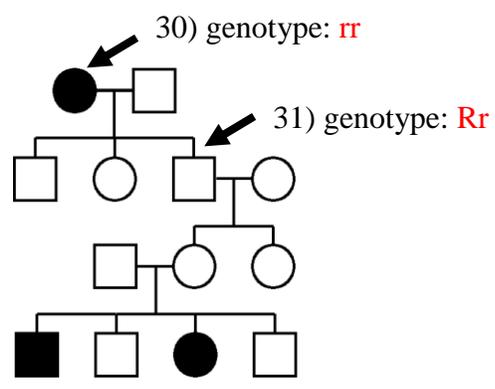
Sex-linked (not autosomal) trait appears more often in males.

Pedigree legend:
 male without trait = □ female without trait = ○
 male with trait = ■ female with trait = ●

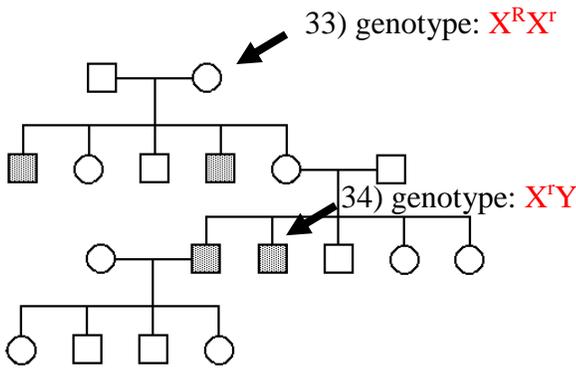
More pedigree problems: Legend: **R = dominant** **r = recessive**



29) pattern of inheritance: **autosomal dominant; trait appears about equal numbers in male and female and appears in each generation**



32) pattern of inheritance: **autosomal recessive; trait appears about equal numbers in male and female and skips generations**



35) pattern of inheritance: **sex-link recessive; appears more often in males.**