3. Multiple Alleles

1. Multiple alleles control the coat color or rabbits. A gray color is produced by a dominant allele C. The C^{ch} allele produces a silver-gray color when present in the homozygous condition, $C^{ch}C^{ch}$, called chinchilla. When C^{ch} is present with a recessive gene, a light silver-gray color is produced. The allele C^{h} is recessive to both the full-colored allele and the chinchilla allele. The C^{h} allele produces a white color with black extremities. This coloration pattern is called Himalayan. An allele C^{a} is recessive to all genes. The C^{a} allele results in a lack of pigment, called albino. The dominance hierarchy is $C > C^{ch} > C^{h} > C^{a}$. The table below provides the possible genotypes and phenotypes for coat color in rabbits. Notice that four genotypes are possible for full-color but only one for albino.

Phenotypes	Genotypes
full color	CC, CC^{ch}, CC^{h}, CC^{a}
chinchilla	$C^{ch}C^{ch}$
light gray	$C^{ch}C^{h}$, $C^{ch}C^{a}$
himalaya	$C^{h}C^{h}$, $C^{h}C^{a}$
albino	$C^{a}C^{a}$

a. Indicate the genotypes and phenotypes of the F_1 generation from the mating of a heterozygous Himalayan-coat rabbit with an albino-coat rabbit.

$C^{h}C^{a}$ $C^{a}C^{a}$

	C^{h}	C^{a}
C^{a}	$C^{h}C^{a}$	$C^{a}C^{a}$
C^{a}	$C^{h}C^{a}$	$C^{a}C^{a}$

1 $C^{h}C^{a}$: 1 $C^{a}C^{a}$

1 himalaya : 1 albino

b. The mating of a full-color rabbit with a light-gray rabbit produces two full-colored offspring, one light-gray offspring, and one albino offspring. Indicate the genotypes of the parents.

CC^{a} x $C^{ch}C^{a}$ Prod

	C	C^{a}
C^{ch}	CC^{ch}	$C^{ch}C^{a}$
C^{a}	CC^{a}	$C^{a}C^{a}$

CC^{ch} + CC^{a} - full colour

CC^{a} - light gray

$C^{a}C^{a}$ - albino

c. A chinchilla-color rabbit is mated with a light-gray rabbit. The breeders know that the light-gray rabbit had an albino mother. Indicate the genotypes and phenotypes of the F_1 generation from this mating.

$C^{ch}C^{a}$

	C^{ch}	C^{a}
C^{ch}	$C^{ch}C^{ch}$	$C^{ch}C^{a}$
C^{ch}	$C^{ch}C^{ch}$	$C^{ch}C^{a}$

1 $C^{ch}C^{ch}$: 1 $C^{ch}C^{a}$

1 chinchilla : 1 light gray

2. If a silk worm having a white body is crossed with a worm having a pink body, the F_1 worms are all peach-colored bodies. From this evidence alone, what phenotypes and ratios would you expect to find if these crosses:

C^WC^W (white) C^PC^P (pink) C^WC^P (peach)

a. white crossed with white

$C^WC^W \times C^WC^W$

all C^WC^W, white

b. white crossed with peach

$C^WC^W \times C^WC^P$

	C^W	C^W
C^W	C^WC^W	C^WC^W
C^P	C^WC^P	C^WC^P

1 C^WC^W : 1 C^WC^P

1 white : 1 pink

c. pink crossed with pink

$C^PC^P \times C^PC^P$

all C^PC^P, pink

d. pink crossed with peach

$C^PC^P \times C^WC^P$

	C^P	C^P
C^W	C^WC^P	C^WC^P
C^P	C^PC^P	C^PC^P

1 C^PC^P : 1 C^PC^W

1 pink : 1 peach

3. Yellow guinea pigs (C^YC^Y) crossed with white ones (C^WC^W) always produce cream colored offspring.

a. Diagram this cross and give genotypes and phenotypes ← C^YC^W

	C^W	C^W
C^Y	C^YC^W	C^YC^W
C^Y	C^YC^W	C^YC^W

all C^YC^W

all cream

b. Two cream colored guinea pigs when crossed produce offspring in the F_2 generation. Give the ratios of the F_2 genotypes and phenotype

	C^Y	C^W
C^Y	C^YC^Y	C^YC^W
C^W	C^YC^W	C^WC^W

1 C^YC^Y : 2 C^YC^W : 1 C^WC^W

1 yellow : 2 cream : 1 white

c. Explain the inheritance pattern of color in guinea pigs.

blending (intermediate)

4. In short horn cattle, red (C^RC^R) coat color is incompletely dominant over white (C^WC^W), to give roan (C^RC^W). A breeder of short horn cattle has cows which are white and a bull which is roan. What proportion of the calves produced will be white? roan? red?

$C^WC^W \times C^RC^W$

	C^W	C^W
C^R	C^RC^W	C^RC^W
C^W	C^WC^W	C^WC^W

1 white : 1 roan : 0 red

5. Starting with a roan bull and white cows, how could you eventually establish a true breeding red herd? white herd?

Red: breed hetero's
① $C^RC^W \times C^WC^W$ ← only use roan for F_2
② $C^RC^W \times C^RC^W$
③ $C^RC^R \times C^RC^R$

White
① $C^RC^W \times C^WC^W$ ← use white offspring
② $C^WC^W \times C^WC^W$

6. When chickens with splashed white (C^WC^W) feathers are crossed with black feathered (C^BC^B) birds, their offspring are all slate blue (C^WC^B). When slate blue are crossed among themselves, they produce splashed white, slate blue and black in the ratio of 1:2:1 respectively.

a. How are these feather traits inherited?

Blended/intermediate

b. Using any appropriate symbols, indicate the genotypes for each phenotype.

C^WC^W white C^BC^B black C^WC^B blue

7. In mink, homozygous brown (C^BC^B) coat is incompletely dominant over silver (C^SC^S) giving silver blue (C^BC^S).

a. If two heterozygous mink are crossed what fraction of the offspring will be brown? silver? silver blue?

	C^B	C^S
C^B	C^BC^B	C^BC^S
C^S	C^BC^S	C^SC^S

1 Brown : 1 silver : 2 silver blue

b. If there were 12 offspring, how many of each phenotype would be expected?

3 brown : 3 silver : 6 silver blue

7. A husband and wife have normal vision, although both of their fathers were color blind, which is inherited as a sex-linked recessive condition. What is the probability that their first child will be:

$X^BY \times X^BX^b$

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

a. a normal son?

$\frac{1}{4}$ or 25%

b. a normal daughter?

$\frac{2}{4} = \frac{1}{2}$ or 50%

c. a color-blind son?

$\frac{1}{4} = 25\%$

d. a color blind daughter?

0% chance since no homozygous recessive.

8. In Drosophila, a sex-linked recessive mutation, scalloped (s), causes irregular wing margins. Diagram the F_1 and F_2 results if:

a. a scalloped female is crossed with a normal male

$X^sX^s \times X^SY$

F_1

	X^s	X^s
X^S	X^SX^s	X^SX^s
Y	X^sY	X^sY

F_2 $X^SX^s \times X^sY$

	X^S	X^s
X^s	X^SX^s	X^sX^s
Y	X^SY	X^sY

b. a scalloped male is crossed with a normal female

$X^SX^S \times X^sY$

F_1

	X^S	X^S
X^s	X^SX^s	X^SX^s
Y	X^SY	X^SY

F_2

$X^SX^s \times X^SY$

	X^S	X^s
X^S	X^SX^S	X^SX^s
Y	X^SY	X^sY

4. Blood Typing

1. Indicate the blood types possible for the mating of a male who is blood type O with a female of a blood type AB.

	I^A	I^B
i	I^Ai	I^Bi
i	I^Ai	I^Bi

geno: 1 I^Ai : 1 I^Bi

pheno: 1 A : 1 B

2. a. Could a male with blood type AB ever have a child with blood type AB? Explain.

Yes! If he mated with a type A, B or AB.

Possible female genotypes: I^Ai, I^AI^A, I^BI^B, I^Bi, I^AI^B

	I^A	I^B
I^A	I^AI^A	I^AI^B
I^B	I^AI^B	I^BI^B

	I^A	I^A
I^A	I^AI^A	I^AI^A
I^B	I^AI^B	I^AI^B

	I^B	I^B
I^A	I^AI^B	I^AI^B
I^B	I^BI^B	I^BI^B

b. Could a male with blood type AB ever have a child with blood type O? Explain.

No – each parent must at least be heterozygous for blood type O because it is a recessive trait

3. Could a man with type O blood have a child that was type B?

Yes. If he mated with a female that had of the following genotypes: I^BI^B, I^Bi, I^AI^B

4. Four babies were born in a hospital on a night in which an electrical blackout occurred. In the confusion that followed, their identification bracelets were switched. Conveniently, the babies are of four different blood groups O, A, B and AB. The four pairs of parents have the following blood groups: O and O, AB and O, A and B, and B and B. Which baby belongs to which parents?

Baby	Parents
O	O + O
A	AB + O
B	B + B
AB	A + B

5. Suppose a father of type A blood and a mother of type B blood have a child of type O blood. What blood groups are possible in their subsequent children?

	I^B	i
I^A	I^AI^B	I^Ai
i	I^Bi	ii

Possible blood groups: AB, A, B or O

6. A father with type B blood and a mother with type O blood have a child with type O blood. What are the chances that their next child will be type O? type B?

	i	i
I^B	I^Bi	I^Bi
i	ii	ii

50% type O : 50% type B

7. Suppose a father and mother claim they have been given the wrong baby at the hospital. Both parents are type A, but the baby they have been given is type O. What conclusions could be made in such a situation? If the baby had been type B what conclusions could be made?

1st situation

	I^A	i
I^A	I^AI^A	I^Ai
i	I^Ai	ii

Both parents could be heterozygous for blood type A (genotype I^Ai) so it would be possible to have a baby with type O.

2nd situation

	I^A	?
I^A	I^AI^A	I^A
?	I^A	

If the baby had type B, it couldn't be theirs. One parent would at least have to have the genotype I^AI^B because I^A and I^B are co-dominant.

5. Dihybrid Crosses

1. What kinds of gametes would be produced by organisms having the following genotypes?

   a. AaBB AB, AB, aB, aB

   b. aaBB aB, aB, aB, aB

   c. AABB AB, AB, AB, AB

   d. AaBb AB, Ab, aB, ab

   e. Aabb Ab, Ab, ab, ab

   f. AaBBCc ABC, ABC, ABC, ABc, aBC, aBC, aBc, aBc
   ↳ ABC, ABc, aBC, aBc

2. What would be the genotypes of the offspring in the following crosses?

   a. AaBb x AABB

	AB	Ab	aB	ab
AB	AABB	AABb	AaBB	AaBb

   b. AaBb x AaBb

	AB	Ab	aB	ab
AB	AABB	AABb	AaBB	AaBb
Ab	AABb	AAbb	AaBb	Aabb
aB	AaBB	AaBb	aaBB	aaBb
ab	AaBb	Aabb	aaBb	aabb

   c. AABB x aabb

	ab	ab	ab	ab
AB	AaBb	AaBb	AaBb	AaBb
AB				
AB				
AB				

   d. AaBb x aabb

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

3. In garden peas, axial flower position is dominant and terminal flower position is recessive. Tall plants are dominant to short plants. A plant that is known to be purebred for tall vine and axial flowers is crossed with a plant having short vines bearing terminal flower. What is the phenotype of the offspring? Predict the kinds of offspring that would appear in the F_2 generation, using genotypic and phenotypic ratios.

P_1: TTAA x ttaa

F_1: Only 1 type of pairing is possible from each parent
TA x ta

	TA
ta	TtAa

all offspring of P_1 have Tall vine axial flowers (100%)

P_2: TtAa x TtAa

	TA	Ta	tA	ta
TA	TTAA	TTAa	TtAA	TtAa
Ta	TTAa	TTaa	TtAa	Ttaa
tA	TtAA	TtAa	ttAA	ttAa
ta	TtAa	Ttaa	ttAa	ttaa

pheno = 9 Tall Axial : 3 Tall terminal : 3 Short Axial : 1 Short terminal

4. In horses black color is dominant to chestnut and pacer is dominant to trotter. If a homozygous black trotter is mated to a homozygous chestnut pacer, what is the phenotype and genotype of the offspring? Of an F_2 generation?

P_1: BBtt x bbTT

F_1: Only 1 combo of each is possible

	Bt
bT	BbTt

pheno: 100% Black Pacer

P_2: BbTt x BbTt

	BT	Bt	bT	bt
BT	BBTT	BBTt	BbTT	BbTt
Bt	BBTt	BBtt	BbTt	Bbtt
bT	BbTT	BbTt	bbTT	bbTt
bt	BbTt	Bbtt	bbTt	bbtt

Pheno
9 Black Pacer
3 Black trotter
3 Chesnut Pacer
1 Chesnut trotter

5. Some dogs bark while others are silent when trailing. The barking characteristic is due to a dominant gene. Erect ears are dominant to drooping ears. What kind of pups would be expected from a mating between a heterozygous erect-eared barker and a drooped-eared silent trailer?

P_1: BbEe x bbee

bbee → only produces 1 gamete 'be'

F_1:

	BE	Be	bE	be
be	BbEe	Bbee	bbEe	bbee

pheno 25% Bark Erect : 25% Bark droop : 25% Silent erect

or 1 : 1 : 1 : 1

C^RC^R: Red
C^WC^W: white
C^RC^W: roan

6. In cattle the polled (H) condition (hornless) is dominant over the horned (h), and the heterozygous condition of red coat and white coat is roan. If a homozygous polled white animal is bred to a horned red one, what will be the appearance of the F_1? Of the F_2?

P_1: $HHC^WC^W \times hhC^RC^R$

F_1: Both parents only produce 1 type of gamete

	HC^W
hC^R	HhC^RC^W

Pheno: 100% Polled (hornless) roan

P_2: $HhC^RC^W \times HhC^RC^W$

	HC^R	HC^W	hC^R	hC^W
HC^R	HHC^RC^R	HHC^RC^W	HhC^RC^R	HhC^RC^W
HC^W	HHC^RC^W	HHC^WC^W	HhC^RC^W	HhC^WC^W
hC^R	HhC^RC^R	HhC^RC^W	hhC^RC^R	hhC^RC^W
hC^W	HhC^RC^W	HhC^WC^W	hhC^RC^W	hhC^WC^W

Pheno: 3 polled red : 3 polled white : 6 polled roan : 1 horned red : 1 horned white : 2 horned roan

7. In snapdragons red flower color (C^R) and white flower (C^W) cause an intermediate inheritance of pink when heterozygous. Normal (broad) leaves (L^B) are non-dominant to narrow (grasslike) leaves (L^N), the heterozygotes having leaves of medium breadth. If a red-flowered, broad-leaved plant is crossed with a white-flowered, narrow leaved one, what will be the phenotypes and their expected ratios in the F_2 generation?

P_1: $C^RC^RL^BL^B \times C^WC^WL^NL^N$

F_1: Both parents only produce 1 type of gametes.

	C^WL^N
C^RL^B	$C^RC^WL^BL^N$

Pheno: 100% pink medium.

P_2: $C^RC^WL^BL^N \times C^RC^WL^BL^N$

	C^RL^B	C^RL^N	C^WL^B	C^WL^N
C^RL^B	$C^RC^RL^BL^B$	$C^RC^RL^BL^N$	$C^RC^WL^BL^B$	$C^RC^WL^BL^N$
C^RL^N	$C^RC^RL^BL^N$	$C^RC^RL^NL^N$	$C^RC^WL^BL^N$	$C^RC^WL^NL^N$
C^WL^B	$C^RC^WL^BL^B$	$C^RC^WL^BL^N$	$C^WC^WL^BL^B$	$C^WC^WL^BL^N$
C^WL^N	$C^RC^WL^BL^N$	$C^RC^WL^NL^N$	$C^WC^WL^BL^N$	$C^WC^WL^NL^N$

F2
Pheno: 1 red broad : 1 red narrow ; 2 red medium : 1 white broad : 1 white narrow : 2 white medium : 2 pink broad : 2 pink narrow : 4 pink medium.

6. Sex-Linkage

1. One form of hemophilia in man is due to a recessive sex-linked gene. A man whose father was hemophilic but has normal blood clotting himself marries a woman with no record of hemophilia in her ancestry. What is the chance of hemophilia occurring in their children?

$X^H Y \times X^H X^H$

	X^H	X^H
X^H	$X^H X^H$	$X^H X^H$
Y	$X^H Y$	$X^H Y$

No chance since there is no recessive allele!

2. A woman whose father was hemophilic but is not a bleeder herself marries a normal man. What is the chance of hemophilia in their children?

$X^H X^h \times X^H Y$

	X^H	X^h
X^H	$X^H X^H$	$X^H X^h$
Y	$X^H Y$	$X^h Y$

$\frac{1}{4}$ or 0.25 or 25%

3. In cats there is a gene for coat color which is codominant and sex-linked. There is one gene for yellow and one for black, but the heterozygote has a peculiar mixture of yellow and black which is called tortoise-shell. $X^Y X^Y$ = yellow $X^B X^B$ = black $X^B X^Y$ = tortoise

   a. What type of kittens would be produced from a cross between a black female and a yellow male?

   $X^B X^B \times X^Y Y$

	X^B	X^B
X^Y	$X^B X^Y$	$X^B X^Y$
Y	$X^B Y$	$X^B Y$

   2 tortoise females
   2 black males

   b. What kind of offspring would be expected from a cross of a black male and a tortoise-shell female? What are the chances of getting a tortoise-shell female from this cross?

   $X^B X^Y \times X^B Y$

	X^B	X^Y
X^B	$X^B X^B$	$X^B X^Y$
Y	$X^B Y$	$X^Y Y$

   1/4 = 0.25 = 25%

4. An albino (a), non-hemophilic man marries a normally-pigmented (A), non-hemophilic woman whose father was hemophilic (X^h) and whose mother was an albino. What kind of children could they have and in what ratio?

$aaX^HY \times AaX^HX^h$

	AX^H	AX^h	aX^H	aX^h
aX^H	AaX^HX^H	AaX^HX^h	aaX^HX^H	aaX^HX^h
aX^H	AaX^HX^H	AaX^HX^h	aaX^HX^H	aaX^HX^h
aY	AaX^HX^H	AaX^hY	aaX^HY	aaX^hY
aY	AaX^HX^H	AaX^hY	aaX^HY	aaX^hY

You can reduce the ratio to

females 1 nonalb non-hemo : 1 albino non-hemo

Males 1 nonalb nonhemo : 1 nonalb hemo : 1 albino nonhemo : 1 albino hemo

5. Baldness is a sex-linked trait. A non-bald man marries a non-bald woman. They have a son and a daughter. At the age of 35 the son becomes bald. What are the chances that the daughter will also become bald?

$X^BY \times X^BX^b$ ← son bald

	X^B	X^b
X^B	X^BX^B	X^BX^b
Y	X^BY	X^bY ← Bald son

no chance of a bald daughter!

6. The male lion has a well-developed mane which the female does not have. How could you account for this on a genetic basis?

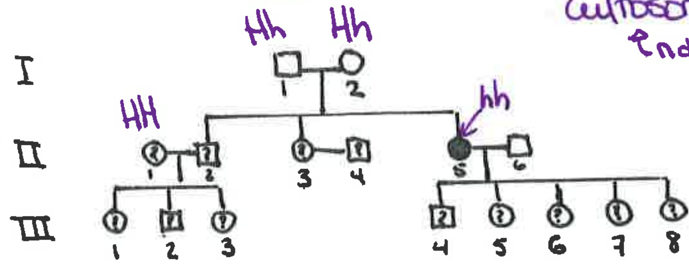
→ Possibly Y linked

→ requires "maleness" (testosterone)

7. Pedigree Problems

1. In humans, the allele for normal hearing (H) is dominant over the recessive allele for congenital (inherited) deafness (h). Use the figure to answer the following questions:

autosomal recessive!
(not sex linked



a. How is it possible for the individual II - 5 to be congenitally deaf if neither parent has the condition?

Both parents are carriers (heterozygous)!

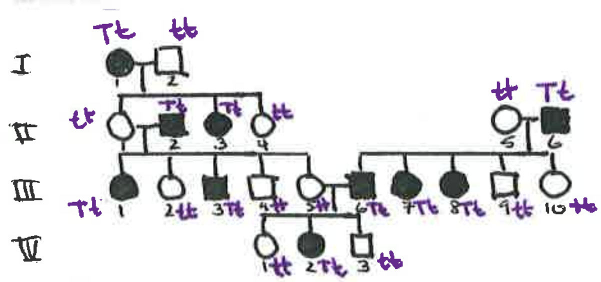
b. What is the probability that the female, III - 1 will be congenitally deaf? Assume that the person II - 1 is not a carrier of the trait.

→ HH

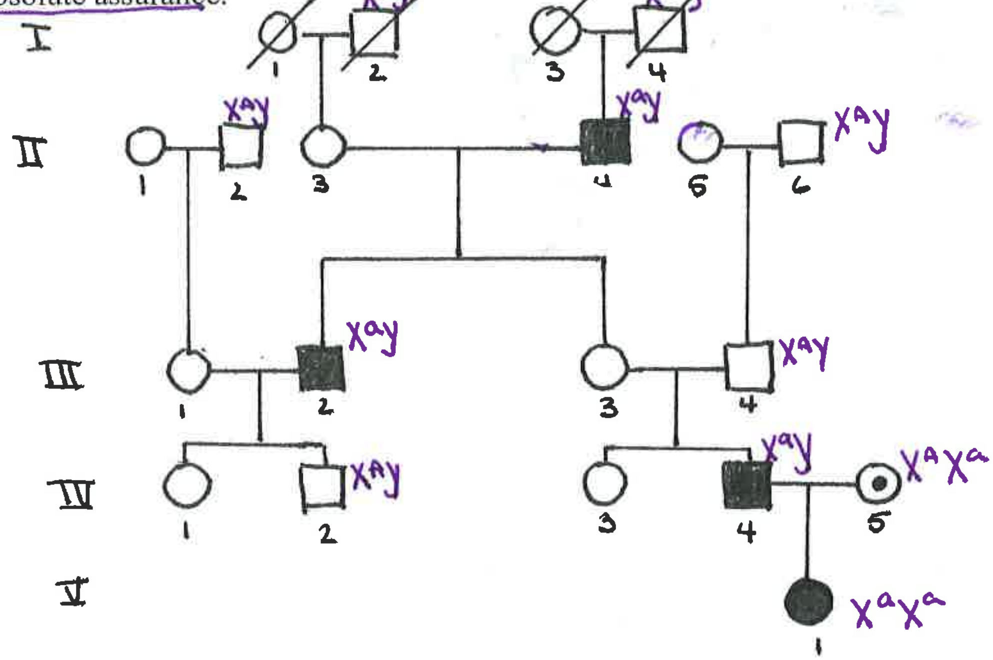
0% → even if II-2 (Dad) is a carrier, because Mom is not a carrier, II-1 could be Hh or HH only.

2. For some people, the chemical PTC has a very definite taste. But others cannot taste the chemical at all. Use the accompanying pedigree chart to try to determine which trait is dominant. The shaded areas represent the offspring who can taste the chemical. As well, determine as far as possible the genotype of the individual on the chart who can taste PTC.

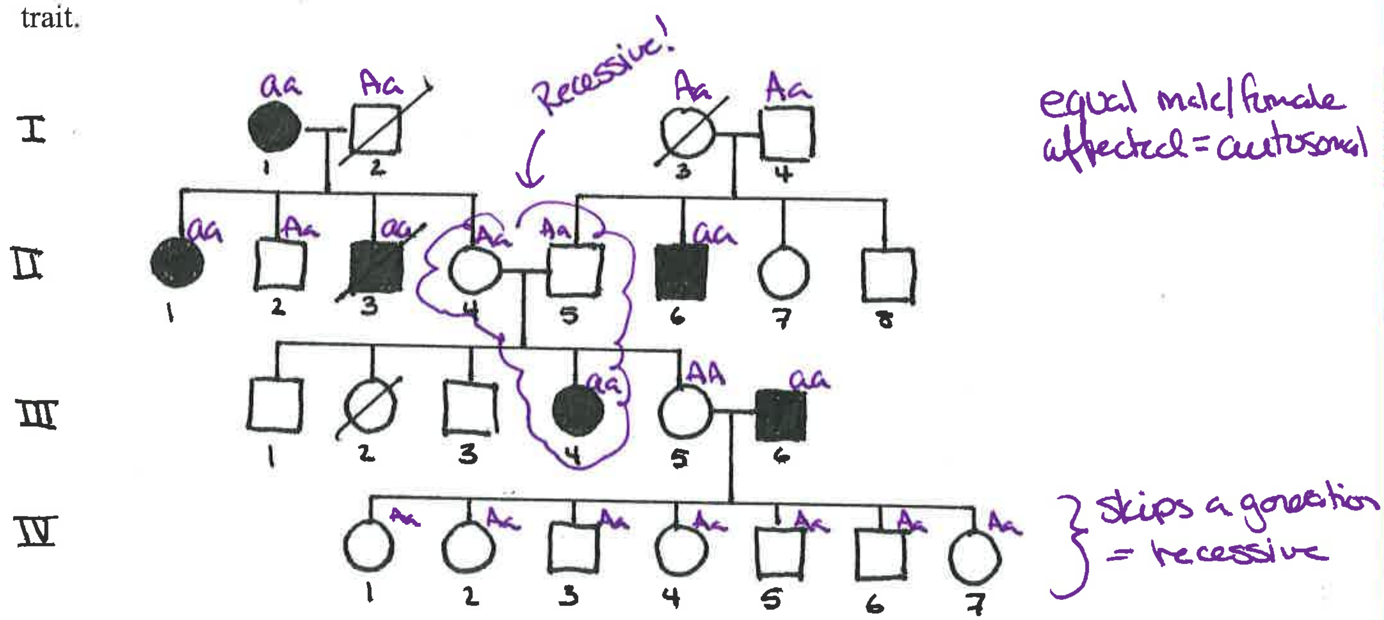
autosomal Dominant!
(every generation!



3. For the pedigree shown below, which depicts the inheritance pattern of a recessive sex-linked trait in humans (a), determine all genotypes that can be predicted with absolute assurance.

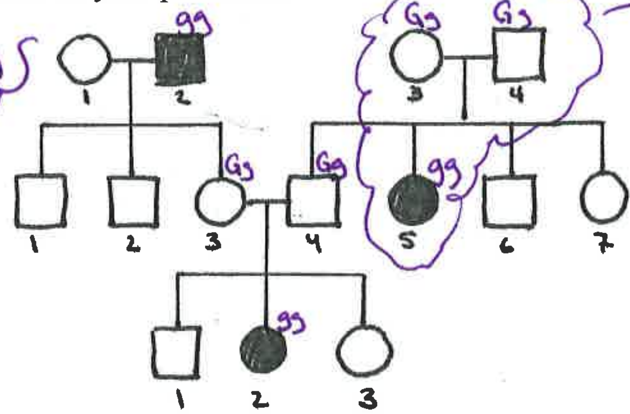


4. For the following pedigree, predict the mode of inheritance and the resulting genotype of each individual. Assume that the alleles "A" and "a" control the expression of the trait.



Mode of inheritance = autosomal recessive

5. The following pedigree is for myopia in humans. Predict if the disorder is inherited as the result of a dominant or recessive allele. Determine the most probable genotype for each individual based on your prediction.



NOT Sex-linked Dom (Dad would have given it to daughter)

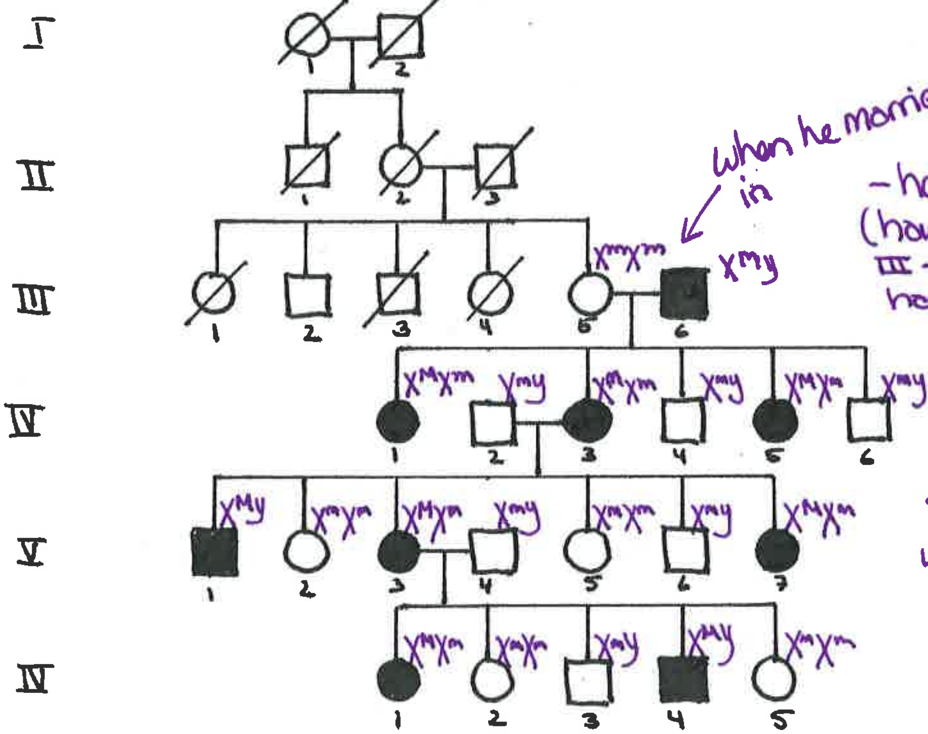
— Recessive

G - dominant
g - recessive

NOT sex-linked recessive (more ♀'s than ♂'s have it)

Mode of inheritance: Autosomal recessive

6. Analyze the following pedigree. What is the most likely mode of inheritance? Defend your answer by stating what information supports your answer and what information rules out other potential modes.



when he marries in

- has to be dominant (have not seen trait before III-6 and then most offspring have it)

III-5 can't be heterozygous otherwise we would have seen trait before...

Sex-linked would explain why not all males have it

Mode of inheritance = Sex-linked dominant