

1 Removed stamens from purple flower

2 Transferred sperm-bearing pollen from stamens of white flower to egg-bearing carpel of purple flower

Parental generation (P)

3 Pollinated carpel matured into pod

4 Planted seeds from pod

First generation offspring (F₁)

5 Examined offspring: all purple flowers

Gregor Mendel (1822 - 1884)

- offspring were all purple like the female parent
- What would you do next?

Crossing

P Generation
(true-breeding parents)

Purple flowers × White flowers

F₁ Generation
(hybrids)

All plants had purple flowers

Where did the white flowers go?

F₂ Generation

3 (purple) : 1 (white)

Monohybrid

Trait	Phenotypes
Seed shape	Round × Wrinkled
Seed color	Yellow × Green
Pod shape	Inflated × Constricted
Pod color	Green × Yellow
Flower color	Purple × White
Flower and pod position	Axial (on stem) × Terminal (at tip)
Stem length	Tall × Dwarf

Mendel noticed:

- one trait always masked the other
- we call this the **dominant trait**
- it didn't matter whether the trait came from the mother or father
- **IMPORTANT!** Dominant does not mean most common in the population. The recessive allele might be more common.

Purple P
White p

Pea traits

Character	Dominant Trait	×	Recessive Trait	F ₂ Generation Dominant:Recessive	Ratio
Flower color	Purple	×	White	705:224	3.15:1
Flower position	Axial	×	Terminal	651:207	3.14:1
Seed color	Yellow	×	Green	6022:2001	3.01:1
Seed shape	Round	×	Wrinkled	5474:1850	2.96:1
Pod shape	Inflated	×	Constricted	882:299	2.95:1
Pod color	Green	×	Yellow	428:152	2.82:1
Stem length	Tall	×	Dwarf	787:277	2.84:1

Mendel's results

Mendel developed a hypothesis consisting of three ideas:

- Genes occur in different versions, called alleles. Remember each gene resides at a specific locus on a specific chromosome.
- For each trait, an organism inherits two alleles, one from each parent.
- The dominant allele masks the presence of the other, recessive allele, and determines the appearance of the organism.

Allele for purple flowers (P)

Locus for flower-color gene

Allele for white flowers (p)

Homologous pair of chromosomes

He developed two laws that govern inheritance:

- Law of Segregation**
The two alleles for a trait separate during gamete production and end up in different gametes.
- Law of Independent Assortment** says that the alleles segregate independent of one another.

How does an allele affect a phenotype?

Which allele is this?

Which allele is it with the mutation?

mutation → enzyme → makes a purple pigment

Mendel's observations

Phenotype (appearance)	Genotype (genetic makeup)
Purple	<i>same</i> PP (homozygous) dominant
Purple	Pp (heterozygous) <i>diff.</i>
White	pp (homozygous) recessive

Vocab

1. Serendipity played a big part in Mendel's choice of the garden pea. Explain.
2. Explain how the dominant phenotype can have more than one genotype.
3. A mother has two alleles for a given trait. How many does she give to an offspring? What principle of genetics describes this?
4. Plants grown by vegetative propagation (*i.e.*, by cuttings) have exactly the same traits as the parent plants. Plants grown from seeds may vary from the parent plants in many ways. Explain.
5. What principle of genetics states that the inheritance of one characteristic does not affect the inheritance of another?
6. Does the height of a pea plant affect the color of its flowers? Why or why not?
7. Is it possible to be heterozygous for a trait and show the recessive phenotype? Explain.
8. Of all the chromosomes in one of your cells, half came from each of your parents. About what fraction came from each of your grandparents? Your great-grandparents?

CQ

A purple-flowered plant and a white-flowered plant are crossed. Both parents are true breeding (*i.e.*, homozygous). Find the genotype and phenotype of the F₁ and F₂ offspring.

Step 1 - What are the genotypes of the parents?

 PP x pp

Step 2 - What are all possible combinations of alleles in gametes?
 - separate the letters
 P, p

Step 3 - What are all possible combinations of gametes?
 - put the letters together
 Pp, Pp, Pp, Pp
 all purple

Now for the F₂:
 Step 1 - What are the genotypes of the parents?
 - the parents are taken from F₁
 Pp x Pp

Step 2 - What are all possible combinations of alleles in gametes?
 P, p

Step 3 - What are all possible combinations of gametes?
 - write the gametes from one parent at the top
 - write the gametes from the other parent along the side
 - fill in the square to show the combinations

	P	p
P	PP	Pp
p	Pp	pp

Handwritten notes: "2 things mixed together", "an individual that is heterozygous for one trait is called a **monohybrid**", "a cross between two heterozygotes is called a **monohybrid cross**".

Monohybrid

e.g. Use a Punnett square to determine the offspring of a cross between a heterozygous purple plant and a white plant.

With Punnett square

	P	p
P	Pp	Pp
p	Pp	pp

Without Punnett square

P x pp
 gametes P, p x p, p
 F₁ Pp, Pp, pp, pp

2 purple : 2 white phenotype?

Important points:
 - remember, these are POSSIBILITIES for offspring
 - we are saying that, from this cross, there are two possible types of offspring
 - we cannot say anything about how many offspring of which phenotype are *actually* produced

How do we choose symbols for traits?

Punnett square

In German Shepherd dogs, the floppy ear trait is due to a dominant gene, while pricked ears is due to a recessive allele. If two heterozygous dogs with drooping ears are mated, what percentage of pups will be expected to have drooping ears?

Handwritten diagram:
 P Ff x Ff
 gametes F, f x F, f
 F₁ FF, Ff, Ff, ff
 3 : 1 75%

1 trait practice

Imagine you have an organism with a dominant phenotype. Is it homozygous or heterozygous?
 - use a test cross to find out
 - cross the unknown with a homozygous recessive

Handwritten notes: "If pp, then all offspring purple.", "If Pp, then 1/2 offspring purple and 1/2 offspring white."

A Punnett square can also be used to figure out the genotypes of the parents from the offspring.

	b	b
B or b?	Bb	Bb
B or b?	Bb	Bb

	f	f
F or f?	Ff	Ff
F or f?	ff	ff

Test cross

9. In a monohybrid cross between homozygous dominant and homozygous recessive parents, there are 32 offspring in the F₂ generation. How many of the offspring would you expect to show the recessive trait?
10. What is a test cross? Why does one use it? Explain the two possible outcomes and what it tells you.
11. In sheep, white coat is dominant. Black is recessive. Occasionally, a black sheep appears in a flock. Black wool is worthless. How could a farmer eliminate the genes for black coat from the flock?
12. In a certain animal, one variety always has a hairy tail while another always has a naked tail. How would you determine which trait is dominant?

CQ

Remember how alleles are separated into gametes?

Chromosome pair 1

gametes

What if we consider another pair of chromosomes?

Chromosome pair 1 Chromosome pair 2

gametes

one of each letter

Notice that each gamete gets one of each letter (i.e., one allele for each trait)

Two traits

P $YYRR \times yyrr$

gametes YR (x4) yr

F₁ $YyRr$ (all yellow, round)

- remember that gametes get one of each letter
- i.e., an allele from each gene
- in this case, a "Y" and an "R"

What about F₂?

YR Yr yR yr

YR	$YYRR$ ✓	$YYRr$ ✓	$YyRR$ ✓	$YyRr$ ✓
Yr	$YYRr$ ✓	$YYrr$ ✓	$YyRr$ ✓	$Yyrr$ ✓
yR	$YyRR$ ✓	$YyRr$ ✓	$yyRR$ ✓	$yyRr$ ✓
yr	$YyRr$ ✓	$Yyrr$ ✓	$yyRr$ ✓	$yyrr$ ✓

yellow, round 9
yellow, wrinkled 3
green, round 3
green, wrinkled 1

16

Punnett square

A pea plant heterozygous for purple flowers and producing wrinkled seeds is crossed with a plant homozygous for purple flowers and heterozygous for round seeds. Find the genotype + phenotype

P $PpRr \times PPrr$

Gametes Pp Pp Pp Pp Rr Rr Rr Rr

$PpRr$	$PPRr$	$PpRr$	$PpRr$	$PpRr$
$PpRr$	$PPRr$	$PpRr$	$PpRr$	$PpRr$
$Pprr$	$PPrr$	$Pprr$	$Pprr$	$Pprr$
$Pprr$	$PPrr$	$Pprr$	$Pprr$	$Pprr$

Phenotype? purple, round 8
purple, wrinkled 8

Common errors

- Making offspring before making gametes.
e.g. $PpRr \times PpRr$
- Not giving gametes one of each letter.
e.g. Pp, rr, PP, Rr

Two trait practice

So, how do we predict the chance of getting a certain combination?

$P = \frac{\text{\# correct outcomes}}{\text{total \# outcomes}}$

What you want

All the possibilities

0 ————— 1
no chance of occurring occurs every time

If you flip a coin, what is the chance of getting tails? $\frac{1}{2}$

If you get tails, what is the chance of getting tails the next time you flip it? $\frac{1}{2}$

Independent events - previous events do not affect future events

e.g., Toss a coin twice. What is the probability of getting heads both times?
 $P(H,H) = P(H) \times P(H)$

Rule of multiplication - probability that one event AND another event occur
 $P(1 \text{ and } 2) = P(1) \times P(2)$

Rule of addition - probability that one event OR another event occur
 $P(1 \text{ or } 2) = P(1) + P(2)$

e.g., A woman has a baby. What is the probability that it is either a boy or a girl?
 $P(\text{boy or girl}) = P(\text{boy}) + P(\text{girl})$

Probability

e.g., Two parents are heterozygous for widow's peak and free earlobes. What is the probability of having a child with widow's peak and attached earlobes?

Parents are $WwFf \times WwFf$

$P(\text{widow, attached}) = P(\text{widow}) \times P(\text{attached})$
Think of this as 2 monohybrid crosses.

$P Ww \times Ww$
F₁ WW, Ww, Ww, ww $\frac{3}{4}$

$P Ff \times Ff$
F₁ FF, Ff, Ff, ff $\frac{1}{4}$

$P(\text{widow's peak and attached earlobes})$
 $= P(\text{widow's peak}) \times P(\text{attached earlobes})$
 $= \frac{3}{4} \times \frac{1}{4}$
 $= \frac{3}{16}$

Practice

Imagine a pea plant produces purple flowers and seeds that are yellow and round. It is heterozygous for all three traits. It is crossed with a pea plant that is heterozygous for purple flowers and produces seeds that are green and wrinkled.

Find the probability that the offspring will produce white flowers and seeds that are green and round or will produce purple flowers and seeds that are green and wrinkled.

Parents $PpYyRr \times Ppyyrr$

Answer:

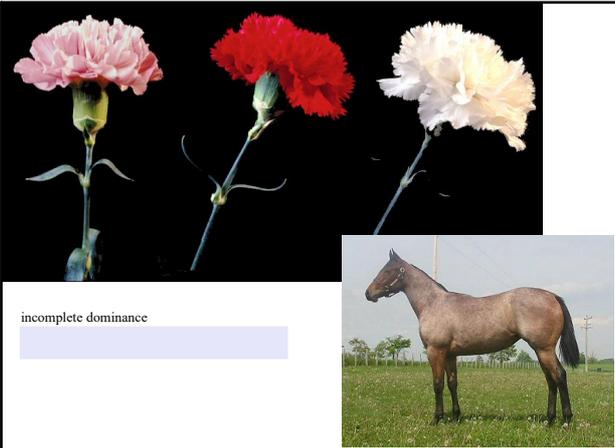
Practice

13. A couple has three sons and one daughter. What is the probability that a fifth child will be female? Explain your answer.

14. Explain why probability is a useful genetic tool.

15. Explain why a large sample is more statistically reliable than a small sample?

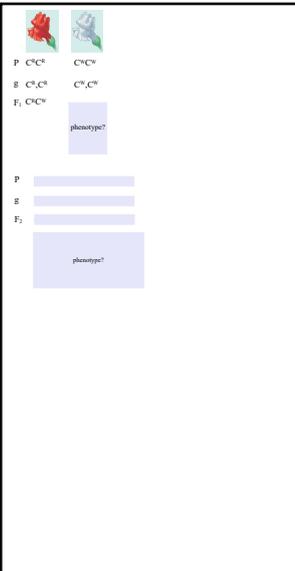
CQ



incomplete dominance

codominance

Incomplete and cominance



phenotype?

phenotype?

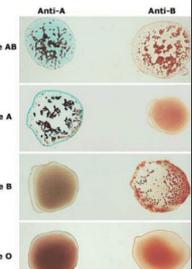
Incomplete Dominance

multiple allele inheritance

- traits that are controlled by genes for which more than two alleles exist
- remember that, although more than two exist, each individual has only two

Genotype	Phenotype (Blood Group)	Red Blood Cells
$I^A I^A$ or $I^A i$	A	A protein
$I^B I^B$ or $I^B i$	B	B protein
$I^A I^B$	AB	A and B proteins
ii	O	No proteins

The alleles are: I^A, I^B, i



e.g., The mother is heterozygous for type A and the father is heterozygous for type B.

P $I^A i \times I^B i$

gametes $I^A, i \quad I^B, i$

F₁ $I^A I^B, I^A i, I^B i, ii$

Blood types

16. A roan calf's parents were a white cow and a red bull. What is the roan's genotype? Can two roans mate and produce all roans? Explain.

17. A flower grower is looking for new varieties of petunias. He crosses a yellow flower plant with a blue one and gets green flowered plants. Explain how this is possible.

18. What makes the inheritance of human ABO blood groups interesting?

19. Mary has blood type A and she marries John, whose blood type is B. They have three children: Joan, James and Pete. Joan has blood type O, James has blood type A, and Pete has blood type B. Explain how this is possible.

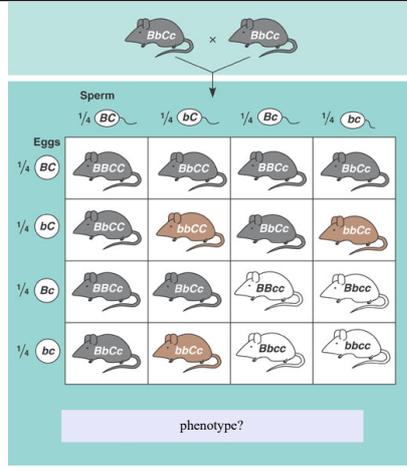
20. If a man who has type O blood marries a woman who is heterozygous for type B blood, what is the probability of them having a child with B type blood? Type O blood?

21. Mr. and Mrs. Doe had a child named Flo at the same time Mr. and Mrs. Roe had their son Joe. The Roes took Joe home, and after looking at him they claimed that Joe was not their child. They were going to sue the Hospital for the mix up. The Hospital took the blood types of all six individuals to try and prove there was no mix up. The results of the tests were as follows: Mr. Roe had A blood type; Mrs. Roe had A blood type; Joe had O blood type; Mr. Doe had O blood type; Mrs. Doe had AB blood type and Flo had A blood type. Was there a mix up? Explain.

CQ

epistasis

- one gene affects the phenotypic expression of a separate gene



phenotype?

Epistasis

In some dogs, the B allele causes black coat and the b allele causes brown coat. A separate gene controls the production of pigment. The W allele prevents pigment formation and the w allele allows it.

- wwBB -

e.g., BbWw x Bbww

Find the probability that a pup will be (a) brown, and (b) white

a)

b)

Practice

There are likely at least 16 genes responsible for human eye color
 - your actual color is determined by the amount of pigment on the back of the iris, which varies from brown to black
 - the amount of pigment in the fluid in front of the iris determines how much light is scattered to produce green and blue eyes

Polygenic

What information pattern explains each of these?

Pedigree

1. Using the following text, describing the family shown in Figure 1, write the name of each person below the correct symbol in the pedigree.
 Although Jane and Joe Smith have dimples, their daughter, Clarissa, does not. Joe's father has dimples, but his mother, and his sister, Grace, do not. Jane's father, Mr. Renaldo, her brother, Jorge, and her sister, Emily, do not have dimples, but her mother does.

2. Take another look at Figure 1. A genetic counselor analyzing this pedigree suggests that a person only needs to have one dominant allele for dimples (D) in order to have dimples. If this is true, what is the genotype of Person 1 in the third generation of Figure 1?

3. What is the genotype of Person 4 in the second generation of Figure 1?

4. What is the genotype of Person 4 in the first generation of Figure 1?

5. Construct a pedigree based on the following passage about curly hair. Write the names of each person on the pedigree next to their correct symbol.
 Andy, Penny, and Delbert have curly hair but their mother, Mrs. Cummins, does not. Mrs. Giordano, Mrs. Cummin's sister, has curly hair, but her parents, Mr. & Mrs. Lutz, do not. Deidra and Darlene Giordano have curly hair, but their sister, Katie, like her father, has straight hair.

Pedigree practice

A researcher named Morgan was working on the genetics of fruit flies. After a year of breeding them and looking for mutants, he discovered a single male with white eyes rather than the normal red.

Normal phenotype (wild type): e.g., red eyes (w^+)

Mutant phenotypes (originate as mutations): e.g., white eyes (w)

Notice the new symbols (choose the letter based on the mutation)
 Recessive mutation: lower case letter
 Dominant mutant allele: upper case letter
 Wild type is given a + superscript

e.g.,

	old	new	
Tall	T	t	What does this tell us about the mutation?
short	t	T	

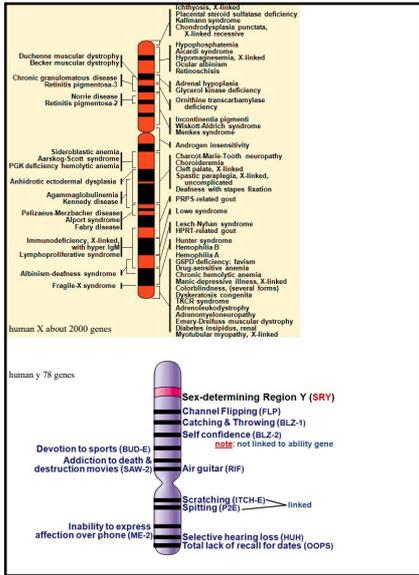
Curly wings (dominant allele mutation) Cy
 Normal wings Cy^+

New symbols

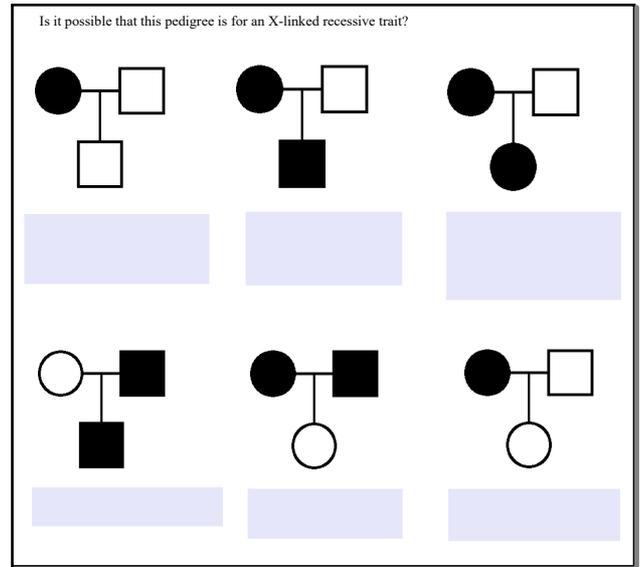
What was going on here?
 - the sex of the fly seemed to be affecting eye color
 - what if the gene is on the X chromosome?

Remember:
 X^+ = normal (dominant)
 X^y = the trait (recessive)
 y = y chromosome (male only)

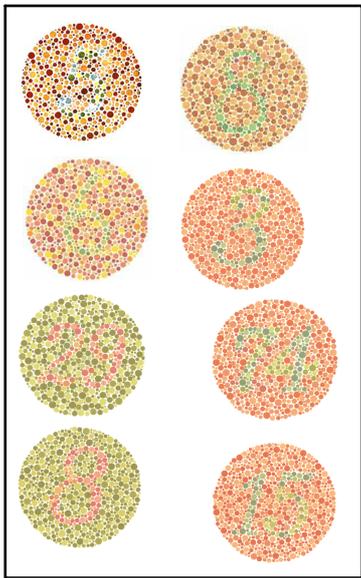
Morgan



Human sex chromosomes



Sex-linked pedigrees



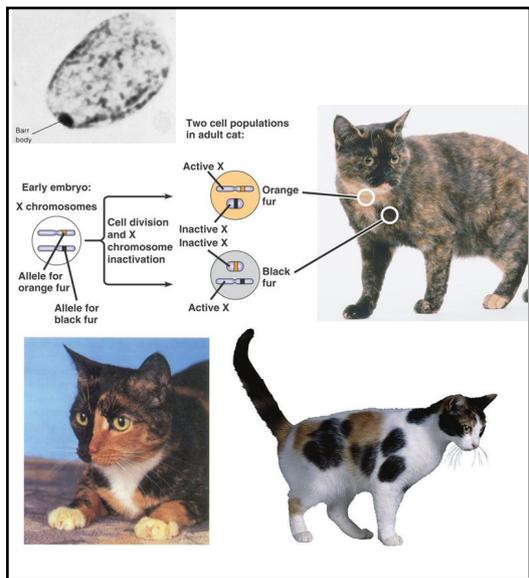
Color blind tests

22. Huntington's chorea is a dominant neurological disorder that usually appears when a person is between 35 and 45 years of age. Many people with Huntington's chorea, however, do not show symptoms until they are well into their sixties. How does the slow development of the disease explain why it has not been eliminated by natural selection.

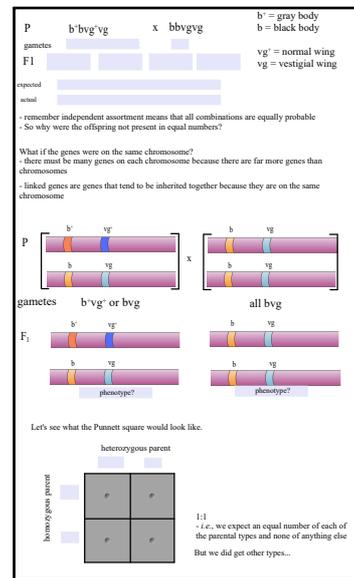
23. Explain the significance of identifying the alleles which cause genetic disorders.

24. In most cultures, it is unacceptable to marry your immediate relatives. Using the principles of genetics, explain why inbreeding in humans is discouraged.

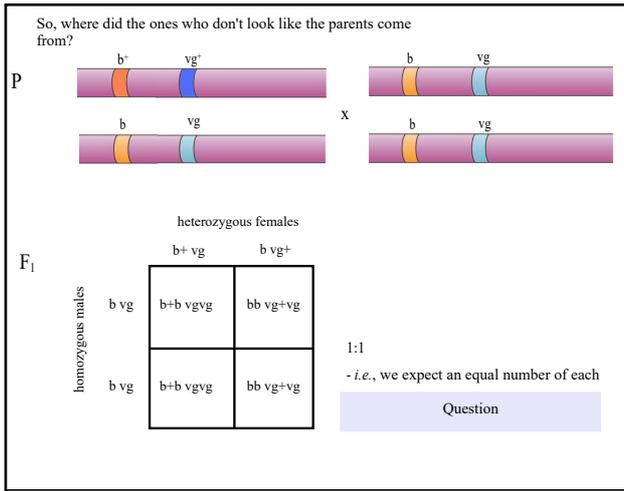
CQ



Barr body



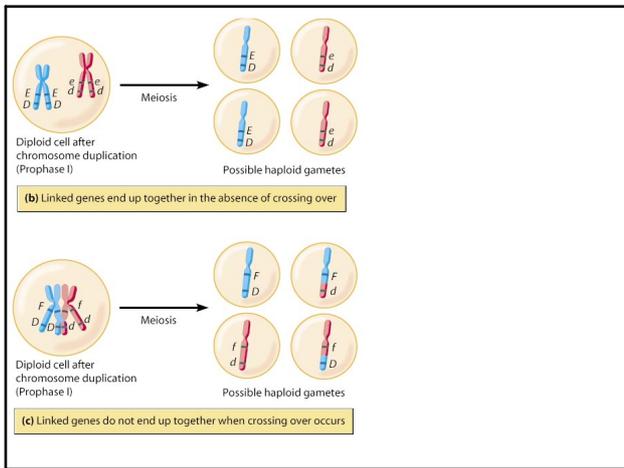
Linked genes



Linked cross over

# of times a is on the same chromosome as														
b														
c														
d														
e														
f														
g														
total														
rolls														

Crossing over data



Linked cross over

25. What does it mean if we say genes are linked? Which law of inheritance do linked genes violate?
27. What causes incomplete linkage?
28. Why are there more males with sex-linked genetic disorders than females?
29. In humans, which parent determines the sex of the offspring? Explain.
30. While examining a population of fruit flies, you notice that a certain trait never appears in males. How can you account for this?

CQ