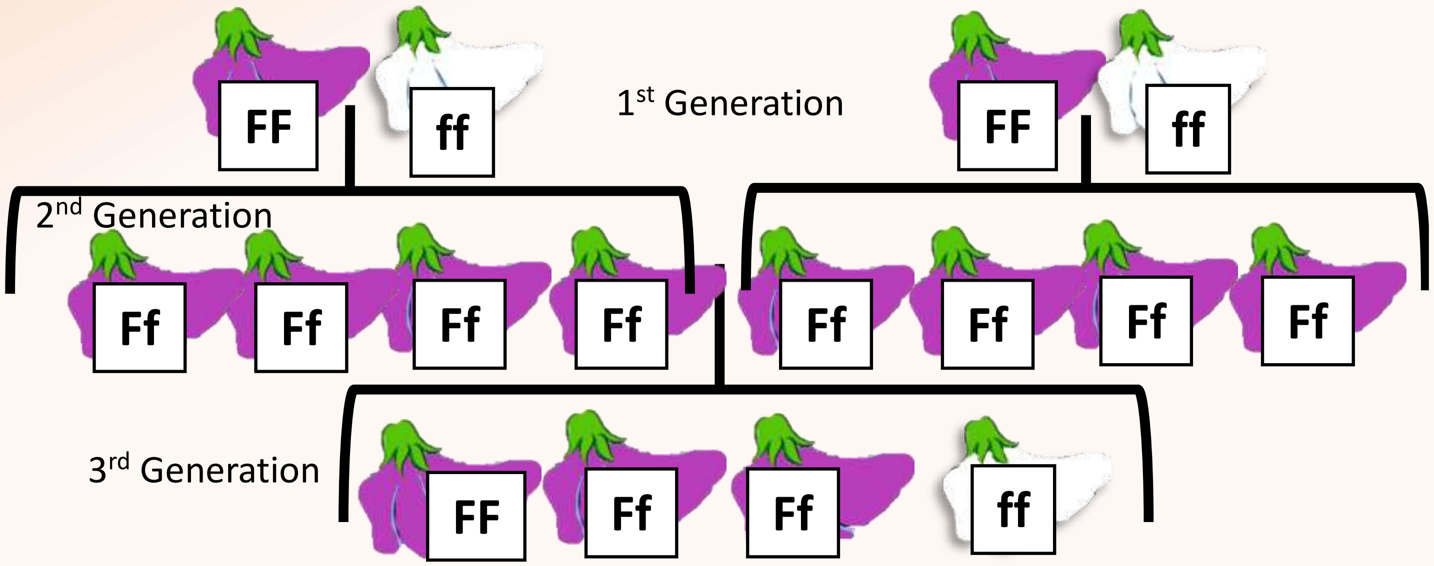
WUHS Biology: Traits & Genes Unit

Week 3 – Can we predict traits?



Traits & Genes Unit – W2 Driving Questions

- **Driving Question: Can we predict traits?**
  - How do different kinds of genes interact with each other, especially if one gene is dominant and another is recessive?
  - How do different combinations of genes result in different traits?
  - How can we use a Punnett square to predict an offspring's traits?
  - What are co-dominant, incompletely dominant, and polygenic traits?

Image Source: Farmers Weekly

Recap of Week 1

Asexual reproduction results in offspring that are genetically identical to their parents.

Sexual reproduction results in offspring that have a mixture of traits from their parents.

Sexual reproduction increases genetic diversity, which increases the resiliency of a species to disturbances.

Gametes, such as sperm and egg cells, are haploid, meaning they have half the amount of genetic material. Gametes are produced through meiosis.

Meiosis consists of a few key steps, including…
a) duplicating DNA and packing it into chromosomes
b) dividing into 2 diploid cells (2 copies of each gene)
d) separating the chromosomes copies again.
e) dividing each diploid cell to form 4 haploid cells.

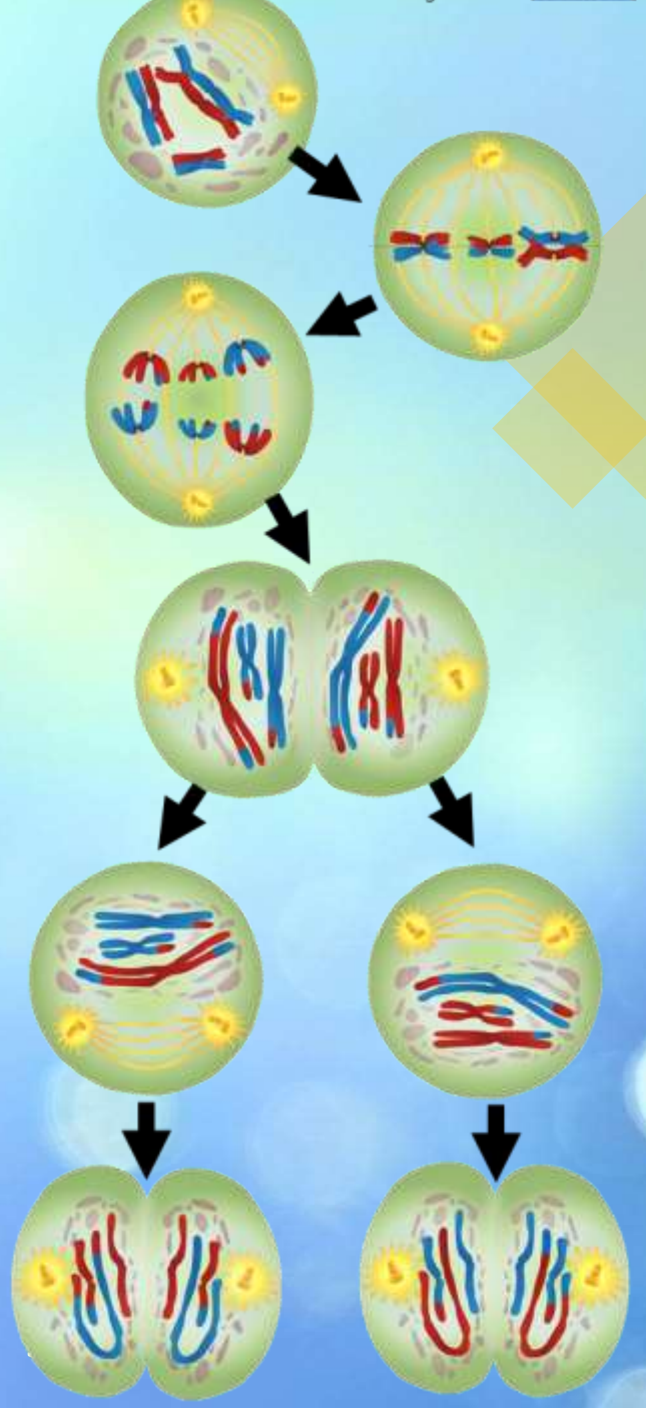


Image Source: Wikimedia

Recap of Week 1

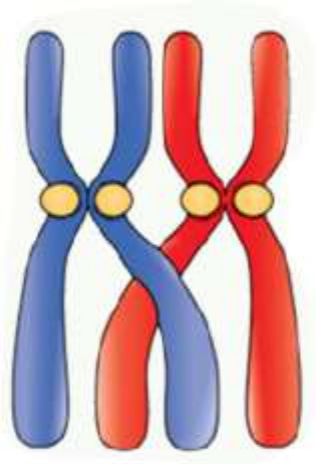
The haploid cells created during meiosis form the gametes (sperm and egg cells).

During meiosis pairs of chromosomes will undergo a process called crossing over where duplicated chromosomes can exchange segments of DNA →

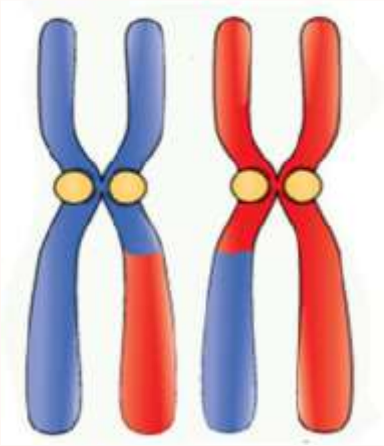
The closer that two genes are to each other, the more likely it is that they will be inherited together when an egg cell is fertilized by a sperm cell. This is called gene linkage.

During sexual reproduction, gametes from both parents fuse to form a new cell in a process called fertilization.

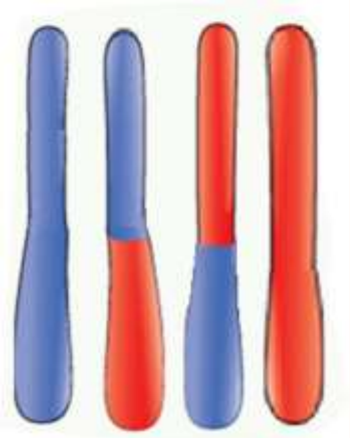
Duplicated chromosomes overlap copies of genes



Chromosomes exchange segments of DNA



Four unique copies of chromosomes emerge

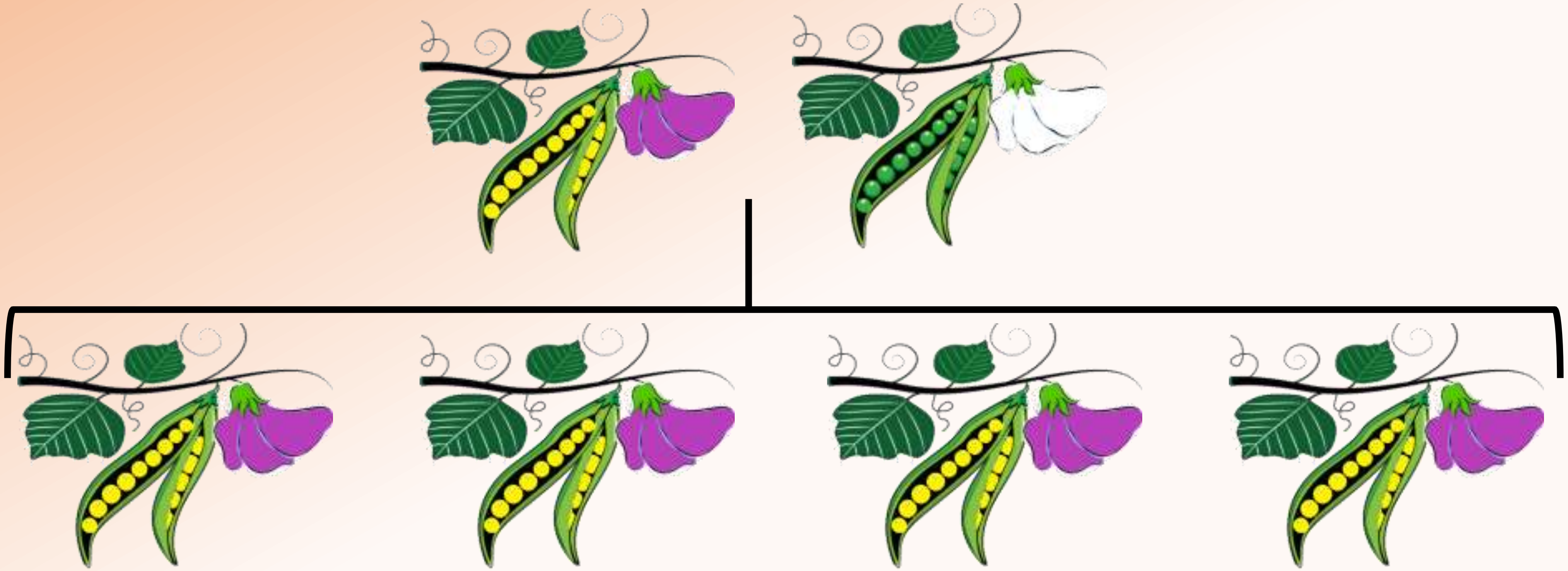


Gregor Mendel

- **In the mid-1800s, a monk named Gregor Mendel observed the traits of peas as they reproduced in his garden.**
  - Plant pollen contains sperm cells; pollen is what fertilizes egg cells in plants (similar to how fertilization occurs in animals).
- **Mendel observed that crossing pea plants with different traits resulted in predictable patterns.**
  - For example, crossing yellow and green pea plants usually resulted in mostly yellow pea offspring.
  - Crossing purple flowers with white flowers resulted in mostly purple flower offspring.
  - In each case, the offspring only resembled one of the parents.

Image Source: Wikimedia

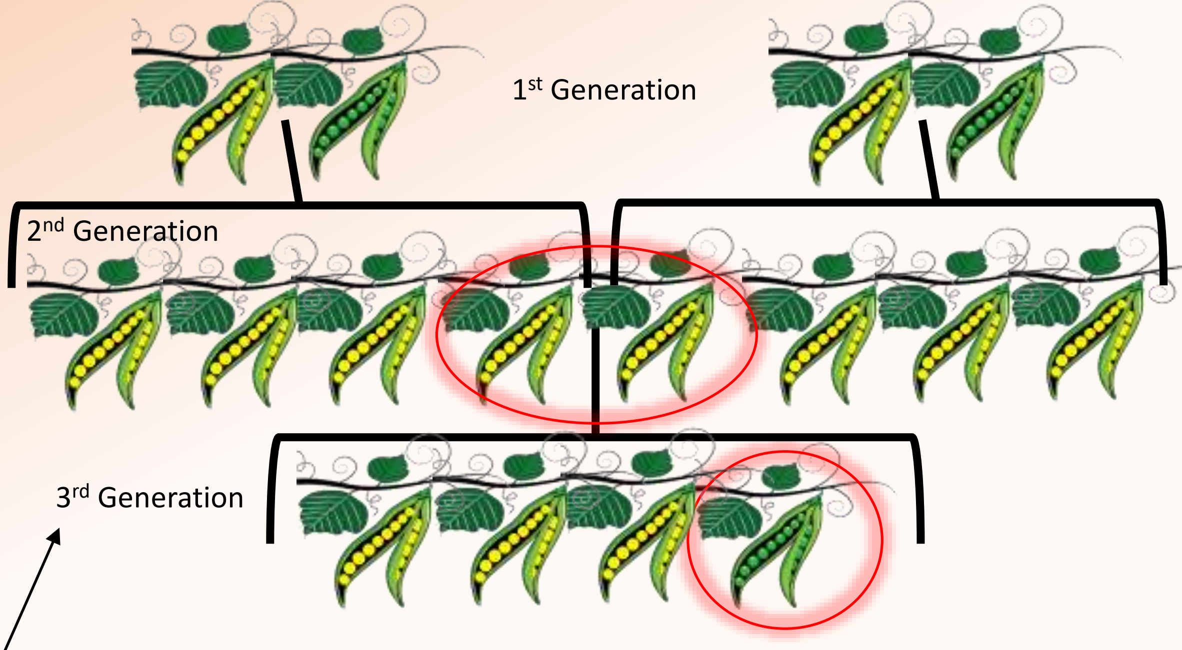
Mendel’s Peas



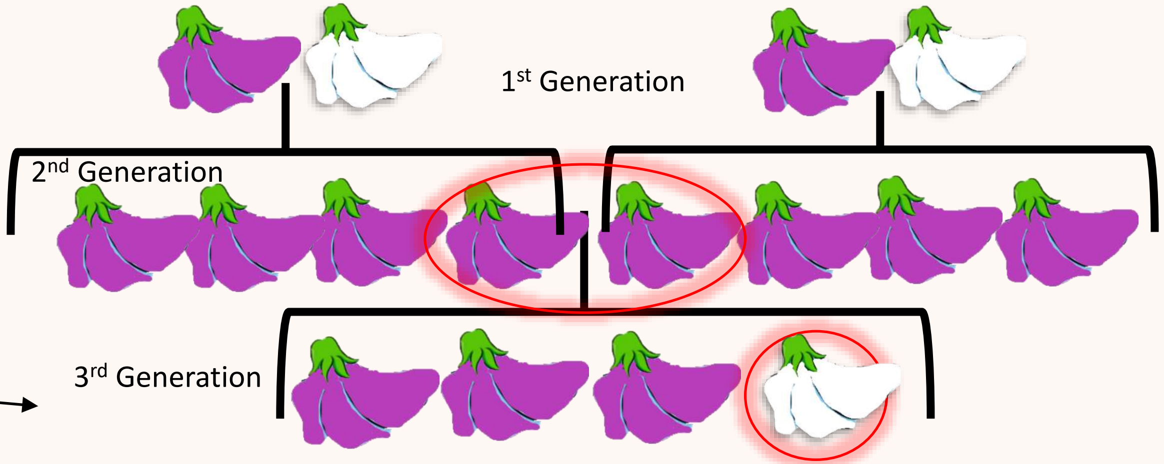
- **Mendel initially crossed plants that had yellow peas and purple flowers with plants that had green peas and white flowers.**
- **The offspring of these plants all had yellow peas and purple flowers.**

Gregor Mendel

- **However, when Mendel continued these experiments, he made some unexpected findings.**
  - Crossing the second generation of pea plants (yellow peas & purple flowers) resulted in multiple kinds of offspring.



- **For example, one fourth of the 3rd generation had green peas even though both parents had yellow peas.**
  - Similarly, about one fourth of the 3rd generation offspring had white flowers even though both parents had purple flowers.



Dominant vs. Recessive

- **We now know that observable traits are the result of how proteins are assembled in cells.**
  - We also know that DNA contains the instructions for assembling proteins; a *gene* is a section of DNA containing the instructions for a specific protein.
  - Finally, we know that most organisms have at least two copies of every gene (one inherited from each parent).
  - When sperm and egg cells are formed during meiosis, they each randomly receive one of the two copies of each gene found in the parent's cells.

- **The genes that code for the assembly of proteins can be dominant or recessive.**
  - If an organism has a dominant gene, the traits associated with that gene will always be expressed.
  - If an organism has a recessive gene, the traits associated with that gene are only expressed if there are no dominant genes.

Dominant genes are always expressed.

Recessive genes are only expressed if there are no dominant genes present.

When dominant & recessive genes are both present, *only* dominant genes are expressed.

Mendel’s Peas

- **When Mendel first crossed green and yellow peas, he was creating a cross between plants with only dominant or only recessive traits.**
  - The yellow pea color is a dominant trait. The green pea color is recessive.
  - Similarly, purple pea flowers are dominant. The white flowers are recessive.

Dominant traits

Recessive traits

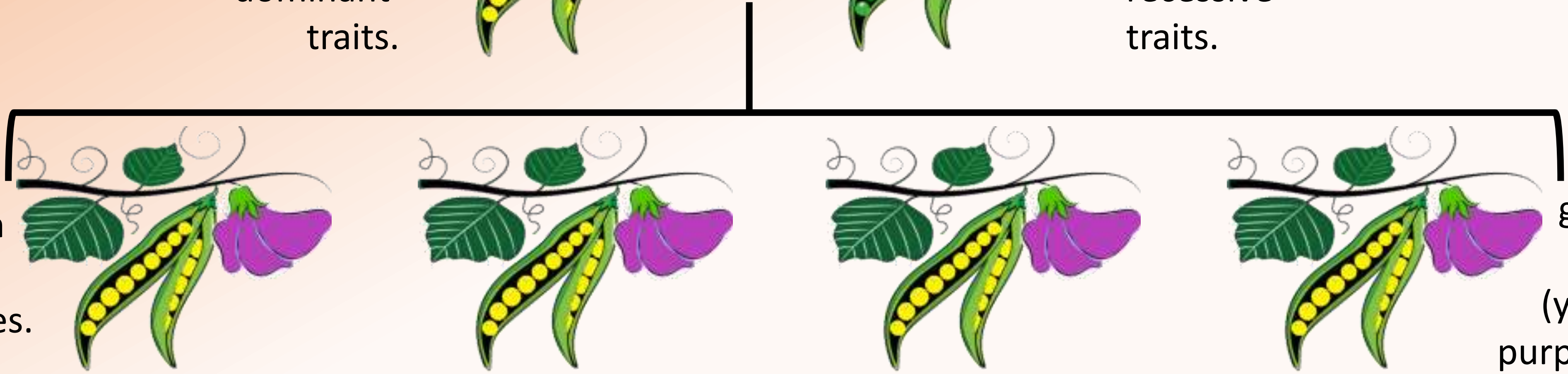
- **When a pea plant with green peas and purple flowers was crossed with a plant with yellow peas and white flowers, the offspring inherited both dominant and recessive genes for these traits.**
  - If both dominant and recessive alleles (or *versions of genes*) are inherited, only dominant genes will be expressed as traits.
  - In this case, the offspring all had green peas and purple flowers.

Mendel’s Peas

Yellow peas and purple flowers are dominant traits.

Green peas and white flowers are recessive traits.

The offspring inherited both dominant and recessive genes.



Only the dominant genes were expressed (yellow peas, purple flowers).

- **Mendel initially crossed plants that only had dominant genes (yellow peas, purple flowers) with plants that had only recessive genes (green peas, white flowers).**
  - This resulted in offspring with both dominant and recessive genes for these traits.
  - The offspring only exhibited dominant traits (yellow peas, purple flowers).

Heterozygous vs. Homozygous

- **Because organisms generally have two copies of each gene, we can use specific terms to describe the possible combinations of genes.**
  - If an organism only has dominant genes for a trait, they are homozygous dominant for that trait.
    - *These individuals exhibit the dominant trait.*
  - If an organism only has recessive genes, they are homozygous recessive for that trait.
    - *These individuals exhibit the recessive trait.*
  - If an organism has a dominant allele and a recessive allele, they are heterozygous for that trait.
    - *These individuals exhibit the dominant trait.*

Homozygous dominant genes are symbolized with two uppercase letters.

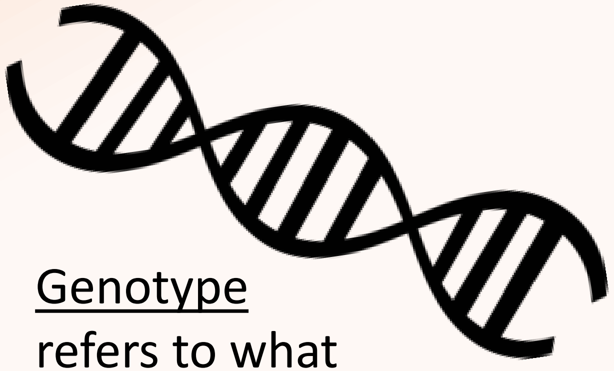
Homozygous recessive genes are symbolized with two lowercase letters.

Heterozygous genes are symbolized with both uppercase and lowercase letters.

Remember: "allele" means "version of a gene"

Genotype vs. Phenotype

- **The terms *genotype* and *phenotype* clarify whether we are referring to the genes or the observable traits.**
  - <u>Genotype</u> refers to what kinds of genes an organism has (*e.g.*, homozygous dominant, heterozygous, etc.).
  - <u>Phenotype</u> refers to the observable traits that result from their genes (*e.g.*, purple or white).
- **For example, an organism with a heterozygous *genotype* (dominant and recessive alleles) would exhibit a dominant *phenotype*.**
  - Only organisms with homozygous recessive *genotype* *(ff or yy)* express the recessive phenotype.



<u>Genotype</u> refers to what genes an organism has.

<u>Phenotype</u> refers to traits we can observe (like eye color).

Homozygous Dominant | Heterozygous | Homozygous Recessive

Homozygous Dominant | Heterozygous | Homozygous Recessive

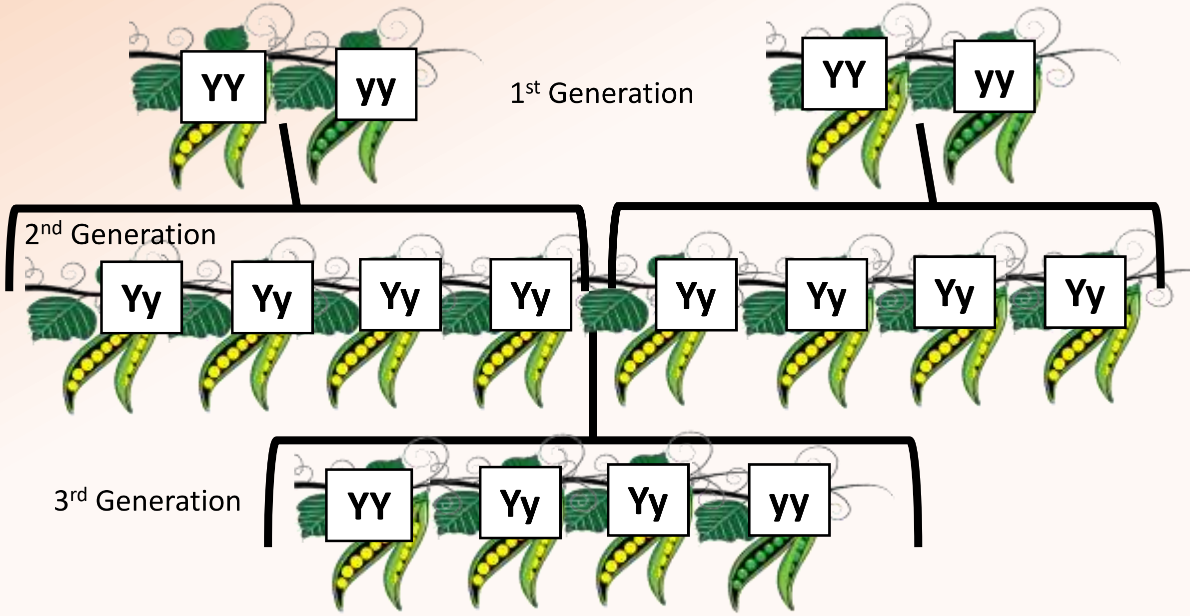
Remember:

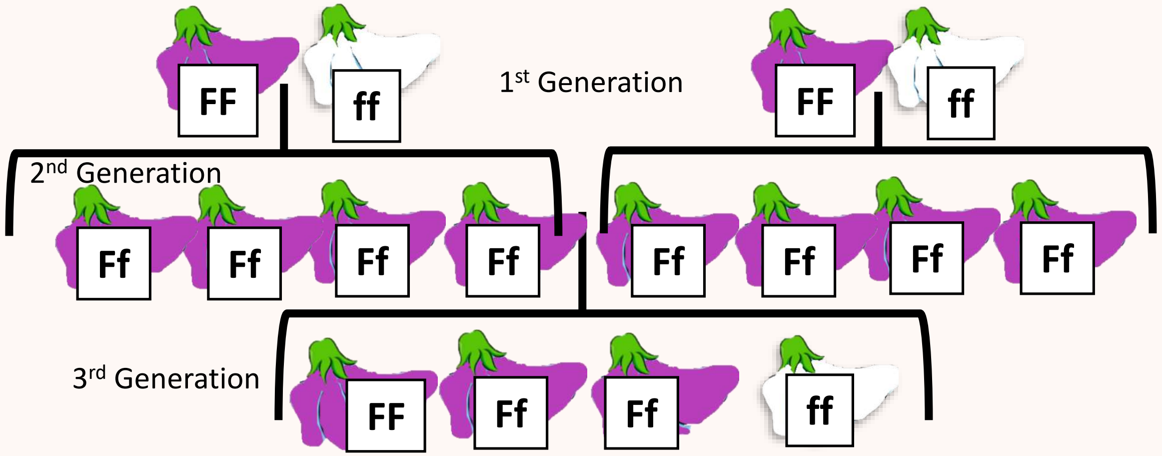
<u>Dominant genes</u> are always expressed.

<u>Recessive genes</u> are only expressed if there are no dominant genes.

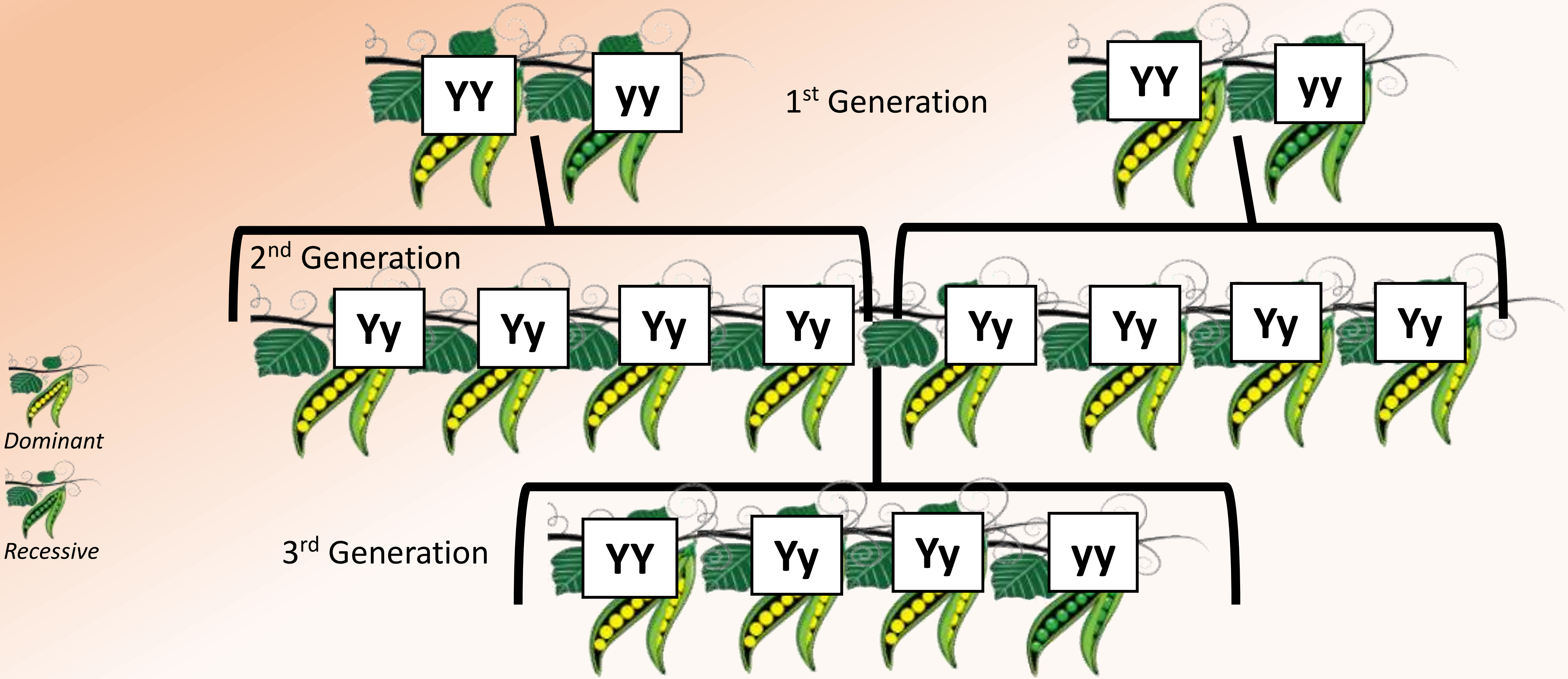
Mendel's Peas

- **Mendel's findings can be explained by genotypes and phenotypes.**
  - Mendel mated homozygous dominant plants to homozygous recessive plants (1^{st} generation).
  - This resulted in all heterozygous offspring (2^{nd} generation).
- **Mating two heterozygous individuals resulted in a mixture of genotypes in the 3^{rd} generation.**
  - The homozygous dominant and heterozygous *genotypes* resulted in the dominant *phenotype*.
  - The homozygous recessive *genotypes* resulted in recessive *phenotypes*.



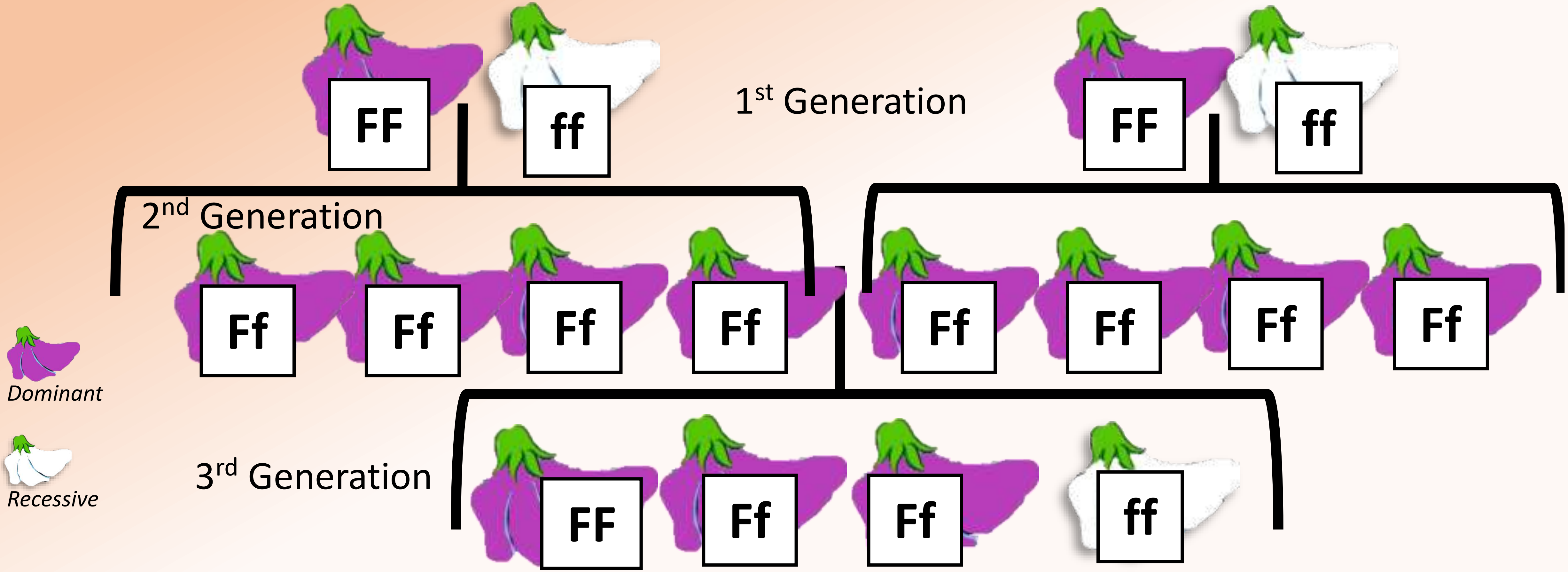


- **In the 1st generation, homozygous dominant yellow plants (YY) mated with homozygous recessive green plants (yy). This produced all heterozygous (Yy) yellow offspring in the 2nd generation.**



- **When heterozygous (Yy) yellow offspring mated, they produced 3rd generation offspring with three different kinds of genotypes: 1) homozygous dominant (YY) yellow; 2) heterozygous (Yy) yellow; and 3) homozygous recessive (yy) green.**

- **In the 1st generation, homozygous dominant purple flowers (FF) mated with homozygous recessive white flowers (ff). This produced all heterozygous (Ff) purple offspring in the 2nd generation.**



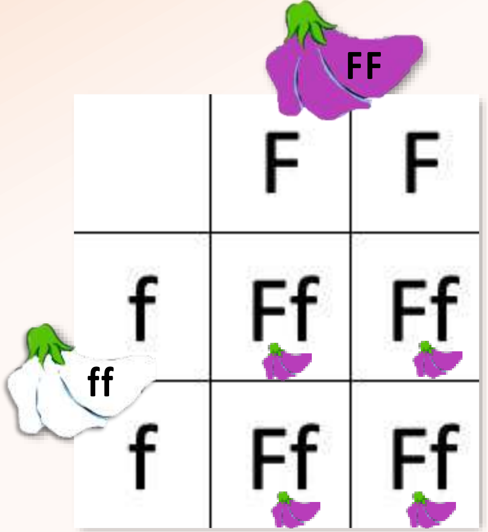
- **When heterozygous (Ff) purple offspring mated, they produced 3rd generation offspring with three different kinds of genotypes: homozygous dominant (FF) purple; heterozygous (Ff) purple; and homozygous recessive (ff) white.**

Punnett Squares

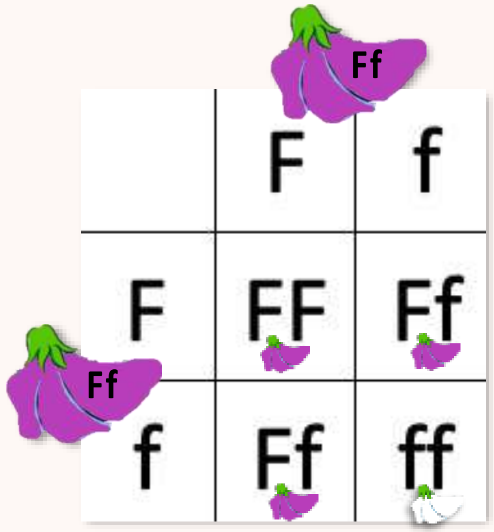
- **A <u>Punnett square</u> is a tool that can be used to determine the likelihood of possible genotypes and phenotypes of the offspring from two individuals.**
  - Punnett squares show all the possible combinations of genotypes and phenotypes that could exist in offspring.
- **Punnett squares use letters to represent dominant and recessive alleles.**
  - An uppercase letter represents a gene that is dominant.
  - A lowercase letter represents a gene that is recessive.
- **Punnett squares indicate the *probability* of different possible outcomes.**
  - A Punnett square can accurately determine what outcomes are possible or not possible.
  - However, it cannot exactly predict the traits (or exact ratios of traits) that will occur among offspring*.

**Unless only one trait is possible, as in the top example on this slide.*

Remember: a "gene" is a stretch of DNA that codes for a specific protein.



This p-square shows why this mating can only result in purple offspring (with 0% white flowers).



This p-square predicts that ¼ of offspring will be white in this case.

Images by [Mac McRae]

Reading Punnett squares

- **When sperm and egg cells form through meiosis, they randomly receive one of the two copies of each gene.**
  - Because we can't predict which copies each sperm and egg cell receive, a Punnett square can show us the likelihood of different combinations.
- **Steps to set up a Punnett Square:**
  - 1. Identify which traits are dominant vs. recessive (using uppercase letters vs. lowercase letters).
  - 2. Determine parents' genotypes.
  - 3. "Split up" the letters of parents' genotypes.
  - 4. Fill in the blanks of the Punnett square by matching the letters.
  - 5. Assign phenotypes using genotypes.

1. Double fins are dominant (A) to a single fin (a).

2. The parents' genotypes are aa and Aa.

This information will be provided to you in most cases.

	A	a
a		
a		

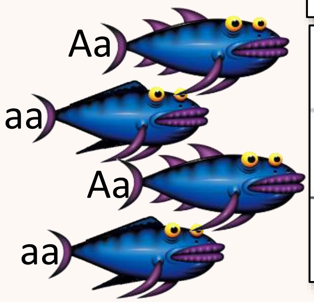
3. Split up the letters of the parents' genotypes to start the P-square.

	A	a
a	Aa	
a		

4. In the blanks, match letters from each parent (as indicated by these arrows).

	A	a
a	Aa	aa
a		

Continue filling in the remaining boxes by matching letters from each parent.



	A	a
a	Aa	aa
a	Aa	aa

5. Determine the possible phenotypes of offspring (50% single fins, 50% double fins in this case).

Exceptions to Dominant/Recessive Genes

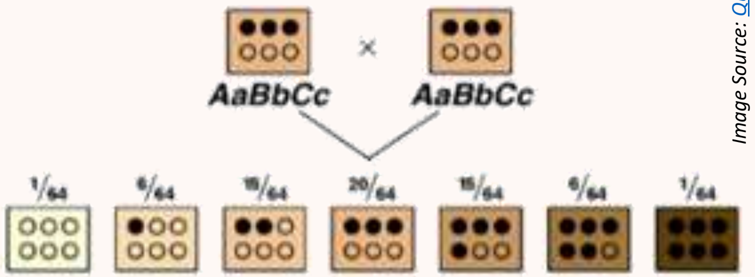
- **Most often, genes are either dominant or recessive.**
  - However, there can be exceptions to this.
- **In some cases, genes can be <u>codominant</u>.**
  - In this case, both genes are expressed because each gene is dominant (e.g., roan horses).
- **In some cases, neither gene of two genes are dominant; these genes are <u>incompletely dominant</u>.**
  - Individuals with both genes will have traits that are a blend or mixture of the two traits (e.g., wavy hair).
- **Some traits are determined by more than two genes; these are known as <u>polygenic traits</u>.**
  - For example, skin color is determined by six genes.
  - The more dominant pigment genes an individual inherits, the darker their skin pigmentation.

In some horses, white AND red are dominant. Roan horses look pink but have both red and white hair.

Image Source: Wikimedia

People with wavy hair have genes for both straight and curly hair.

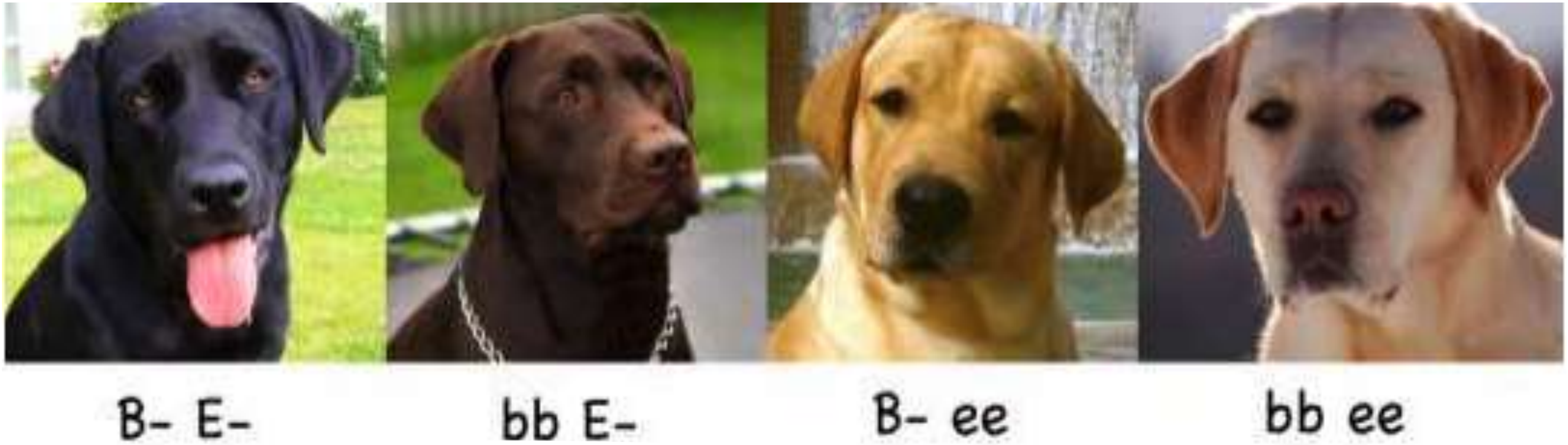
Image Source: Pinterest



Skin pigmentation is a polygenic trait because it is determined by six genes.

Image Source: Quora

Gene Interactions



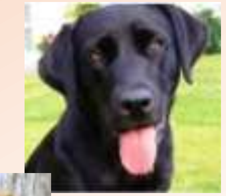
Source: http://www.bio.miami.edu/dana/pix/lab_genetics.jpg

- **Genes can also sometimes affect the expression of other genes.**
  - For example, two genes determine the hair color of Labrador retrievers.
  - The E gene determines whether a dark (black/brown) or light (yellow/white) pigment is expressed.
  - The B gene determines how intensely that pigment is expressed.
- **A Labrador puppy with dominant B and E genes would be a black lab.**
  - A puppy that is either bbEe or bbEE would be a chocolate lab.
  - A puppy that is either Bbee or Bbee would be a yellow lab.
  - A puppy has all recessive genes (bbee) would be a white lab.

Zola's Puppies

- **Zola was a black Labrador retriever who recently gave birth to a litter of puppies.**
  - Her litter consisted of every kind of Labrador retriever: black, chocolate, yellow, and white.
- **The interactions among genes explain how this happened.**
  - Each parent randomly contributes one of each gene.
  - The genotypes of the parents enable all four phenotypes in their puppies.

BbEe



Bbee

Sperm and egg cells will randomly receive one of each gene (B & E). This means there can be four possible combinations of these genes in the sperm and egg cells of each parent.

	BE	Be	bE	be
Be	BBEe	BBee	BbEe	Bbee
Be	BBEe	BBee	BbEe	Bbee
be	BbEe	Bbee	bbEe	bbee
be	BbEe	Bbee	bbEe	bbee

Genes and Environmental Factors

- **While genes provide the instructions for assembling proteins, genes are not the only factors that affect the expression of traits.**
  - The environment in which an organism exists also has a significant influence on whether a trait is expressed and to what extent.
- **For example, how large an organism grows depends on genes for proteins like growth factors.**
  - However, an organism’s access to food also affects the eventual size of an organism.
  - Malnourished organisms will be smaller than those that are properly fed even if they share identical genes.
- **<u>Heritability</u> refers to the extent to which genetic factors affect the expression of a trait.**
  - Some traits, like eye color, are almost entirely affected by genes, with little or no impact from environmental factors. These are highly heritable traits.
  - Other traits, like growth or personality, are strongly affected by environmental factors. These traits have low heritability.

Eye color is a trait with high heritability. It is primarily determined by genetic factors.

Revising Our Claims

- **Revisit your ideas from Part 1. How could you improve your responses to our Driving Questions?**
- **Can we predict traits?**
  - How do different kinds of genes interact with each other, especially if one gene is dominant and another is recessive?
  - How do different combinations of genes result in different traits?
  - How can we use a Punnett square to predict an offspring’s traits?
  - What are co-dominant, incompletely dominant, and polygenic traits?

Image Source: Max Pixel

Looking Ahead: Part 3 Investigation

- **In Part 3 you will be practicing your abilities to predict genotypes and phenotypes across a series of different case studies.**

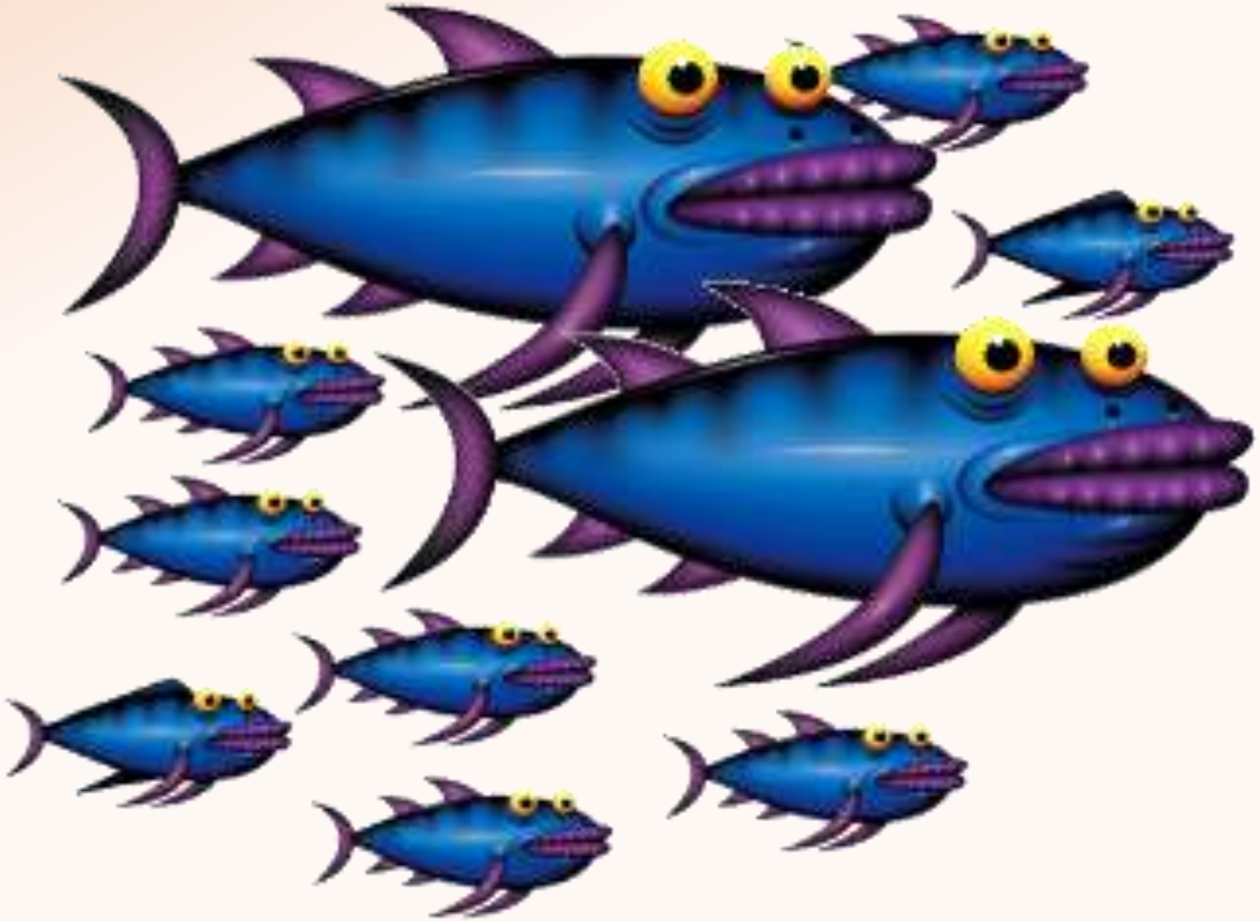
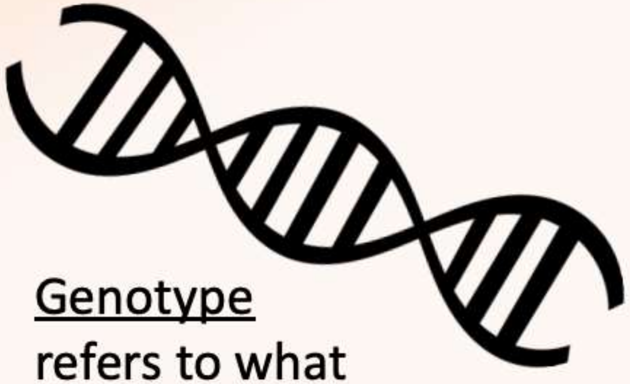


Image Source: Pinterest

Key Points

- **When sperm and egg cells are formed during meiosis, they each randomly receive one of the two copies of each gene found in the parent's cells.**
- **Genes can be dominant (always expressed) or recessive (only expressed if no dominant genes are present).**
- **Organisms with two dominant genes for a trait are homozygous dominant.**
  - Those with two recessive genes are homozygous recessive.
  - Those with dominant and recessive genes are heterozygous.
- **Genotype refers to what kinds of genes an organism has (*e.g.*, homozygous dominant, heterozygous, etc.).**
  - Phenotype refers to the observable traits that result from their genes (*e.g.*, purple or white).



Genotype refers to what genes an organism has.

Phenotype refers to traits we can observe (like eye color).

Remember:

Dominant genes are always expressed.

Recessive genes are only expressed if there are no dominant genes.

Key Points

- **If an organism has a dominant gene, they express a dominant phenotype.**
  - An organism will only express a recessive phenotype if they have no dominant genes.
- **A <u>Punnett square</u> is a tool that can be used to determine the probability of different genotypes and phenotypes of offspring.**
  - Punnett squares show all the possible combinations of genotypes and phenotypes that could exist in offspring.
  - Punnett squares use letters to represent dominant (uppercase) and recessive (lowercase) genes.
- **To set up a Punnett square, split up the letters of the parents' genotypes. Then match each letter from each parent to show the possible combinations that could result →**

	A	a
a		
a		

	A	a
a	Aa	
a		

	A	a
a	Aa	aa
a		

	A	a
a	Aa	aa
a	Aa	aa

Key Points

- **Not all genes are simply dominant and recessive.**
  - <u>Codominant</u>: each gene is expressed because each gene is dominant, resulting in the expression of both traits (e.g., roan horses are red AND white).
  - <u>Incompletely dominant</u>: neither gene is dominant, resulting in traits that blend together (e.g., wavy hair occurs when individuals inherit genes for both straight and curly hair).
  - <u>Polygenic traits</u>: the trait is determined by more than two genes (e.g., skin color is determined by six genes).
- **Genes can also sometimes affect the expression of other genes.**
  - E.g., the color of Labrador retrievers is determined by the interactions of two genes.

Image Source: Wikimedia

In some horses, white AND red are dominant. Roan horses look pink but have both red and white hair.

Image Source: Pinterest

People with wavy hair have genes for both straight and curly hair.

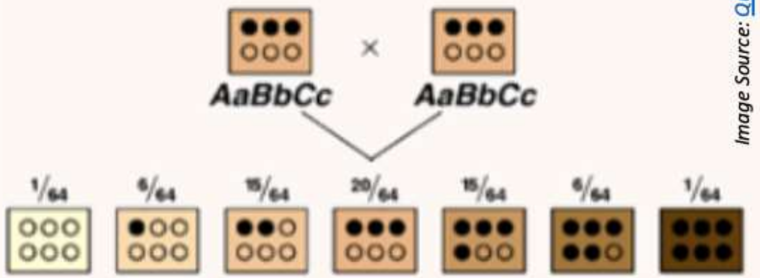


Image Source: Quora

Skin pigmentation is a polygenic trait because it is determined by six genes.

Key Vocab

- **<u>Dominant gene</u>: the traits associated with that gene are always expressed.**
- **<u>Recessive gene</u>: the traits associated with that gene are only expressed if there are no dominant genes.**
- **<u>Allele</u>: version of a gene.**
- **<u>Homozygous dominant</u>: having two dominant genes.**
- **<u>Homozygous recessive</u>: having two recessive genes.**
- **<u>Heterozygous</u>: having both a dominant and recessive gene.**
- **<u>Genotype</u>: what kinds of genes an organism has (*e.g.*, homozygous dominant).**
- **<u>Phenotype</u>: the observable traits that result from genes (*e.g.*, purple or white).**
- **<u>Punnett square</u>: a tool that can be used to determine the likelihood of possible genotypes and phenotypes of the offspring from two individuals.**
- **<u>Codominant</u>: each gene is expressed because each gene is dominant, resulting in the expression of both traits (e.g., roan horses are red AND white).**
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