
GENETICS

INTRODUCTION

Welcome to the Genetics and Heredity Division of the Mars HAB. Here, you'll explore the laws of inheritance first discovered by a monk named Gregor Mendel and apply them to the organisms of another planet. You'll use Punnett squares to predict traits, like whether a plant will have round or wrinkled seeds, or whether a baby born on Mars will have dimples, freckles, or a taste for green space spinach.

But Mendel's rules are just the beginning.

You'll investigate codominance, where two traits show up at the same time (like a roan-colored cow with both red and white hairs). You'll decode the mystery of incomplete dominance, where traits blend into something new—like red + white = pink. You'll learn how multiple alleles affect traits like blood type, and why your sex chromosomes might determine more than you thought. And you'll explore sex-linked traits, where inheritance isn't equal between boys and girls—especially when it comes to things like color blindness.

Then there are the deeper tools: pedigrees to track traits through generations. Karyotypes to examine chromosomes under the scope. Polygenic traits to explain why no two humans (or Martian-born lifeforms) are ever exactly the same.

So buckle up, geneticist. You're about to unlock the code that shapes every living thing—on Earth, and maybe beyond.

VOCABULARY

Vocabulary Word	Definition
allele	
codominance	
dominant	
F1 generation	
F2 generation	
gametes	
genetics	

Vocabulary Word	Definition
genome	
genotype	
heredity	
heterozygous	
homozygous	
hybrid	
incomplete dominance	

Vocabulary Word	Definition
karyotype	
law of segregation	
monohybrid cross	
multiple alleles	
pedigree	
P generation	
phenotype	
polygenic trait	

Vocabulary Word	Definition
probability	
Punnett square	
recessive	
sex-linked traits	
pedigree	
test cross	

PHENOMENON

The Inheritance Protocol

Mission Log – Sol 102

Location: Mars HAB – Life Sciences Division

It started with the twins...

Born just three sols apart in the HAB's experimental birthing pod, both infants were healthy. But something didn't add up. One had bright blue eyes. The other? Deep brown. According to their genetic profiles, both should've had blue eyes. In fact, most of their traits were supposed to match.

But that was only the beginning.

A litter of Mars-bred rodents, both parents with solid brown coats, gave rise to pups in every shade: white, black, and even patchy brown-and-white, like a living checkerboard. Meanwhile, red-veined lettuce in Hydroponics Bay had started sprouting pink and purple leaves, unlike anything in the seed bank. Something was clearly happening with trait inheritance—and it wasn't following the rules you expected.

But what truly changed the game was the emergency alert from the medical bay.
A child in the colony had been injured during a simple fall. The scrape should have clotted and healed—except it didn't. The bleeding wouldn't stop. Tests revealed the child had hemophilia, a rare X-linked disorder that prevents normal blood clotting.

His mother was a carrier. His father? Genetically healthy. The inheritance pattern checked out—but the implications were massive.

You begin running simulations.

Using Punnett squares, you track which traits are following classic dominant and recessive patterns... and which ones aren't.
Some traits show incomplete dominance—blending together, like red and white snapdragons forming pink petals. Others reveal codominance, like cattle with both red and white fur visible. You explore blood type inheritance using multiple alleles, and even spot a chromosome set with an extra 21st chromosome in one karyotype—an unmistakable case of trisomy 21.

Command has issued a priority directive:: Initiate the Inheritance Protocol.

Your mission:

- Analyze inheritance using Mendel's laws and Punnett squares

- Predict and explain patterns in monohybrid and dihybrid crosses
- Investigate incomplete dominance, codominance, and multiple alleles
- Identify and track X-linked traits, including hemophilia
- Use pedigrees to understand how traits pass through generations
- Interpret karyotypes to detect chromosomal disorders
- Understand how these patterns will affect the future of Mars-born life

Your discoveries will help protect the next generation of Martian colonists—and may be the key to ensuring life on Mars is not only possible... but sustainable.

The genome is no longer just a theory.

On Mars, it's a survival plan.

IMPORTANCE OF GENETICS / HEREDITY

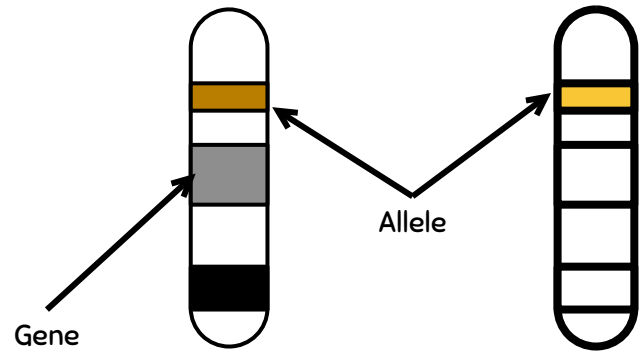
The Importance of Genetics and Heredity

- The study of **genetics** and **heredity** is fundamental to various fields, including biology, medicine, and family planning. In biology, genetics provides insights into the mechanisms of evolution and the diversity of life forms. Understanding how traits are inherited allows scientists to explore the relationships between different species and the adaptations that have evolved over time.
- In medicine, genetics plays a crucial role in understanding genetic disorders, guiding treatments, and improving diagnostic techniques. By studying inheritance patterns, healthcare professionals can identify at-risk individuals, provide genetic counseling, and develop personalized medicine approaches tailored to an individual's genetic makeup.
- Family planning also benefits from genetic knowledge. Couples can make informed decisions about having children, particularly if there is a history of genetic disorders in their families. Genetic testing and counseling can help parents understand potential risks and outcomes, allowing them to prepare for the challenges that may arise.
- Overall, the implications of genetics and heredity extend beyond individual families to impact societal health, agricultural practices, and the conservation of biodiversity.

MENDELIAN GENETICS

- Gregor Mendel, the father of genetics, conducted experiments on pea plants to understand how traits are inherited. He established several key principles:
  - Key Terms:

- **Allele**: One of the alternative **forms** of a **gene** that governs a **characteristic** (e.g., flower color).



A

Dominant: The **expressed** form of a trait.

a

Recessive: The trait that is **not expressed** when the **dominant** form is present.

Aa

Genotype: The entire **genetic** makeup of an **organism**.

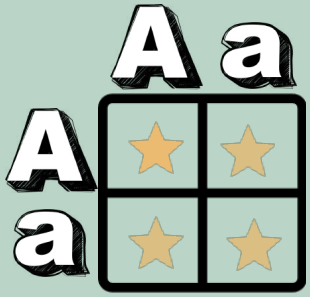
Phenotype: An organism's **appearance** or detectable **characteristic**.

Aa

Heterozygous: Having **two different** alleles for a trait (e.g., Aa).

AA \ aa

Homozygous: Having **identical alleles** for a trait (e.g., AA or aa).

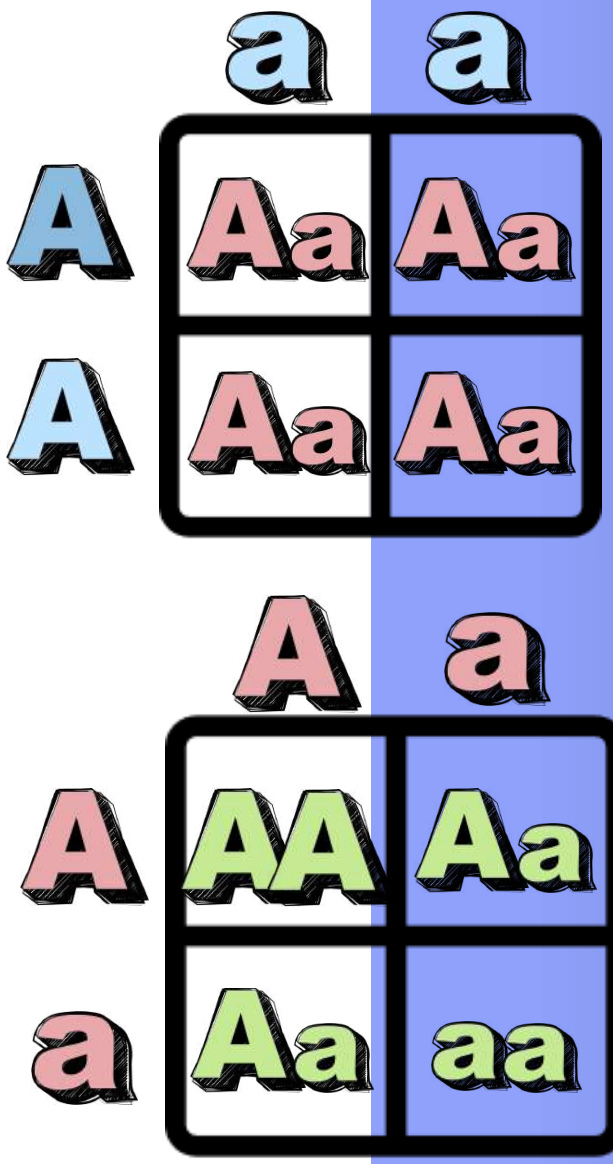


Hybrid: **Offspring** of crosses between **parents** with **different** traits.

P1 Generation: The **parental** generation, the first two individuals that mate in a genetic cross.

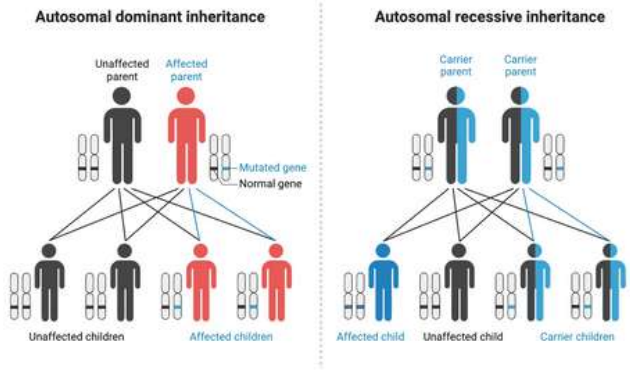
F1 Generation: The **first** generation of offspring obtained from an experimental cross.

F2 Generation: The **second** generation of offspring, obtained from an experimental cross of the F1 generation.



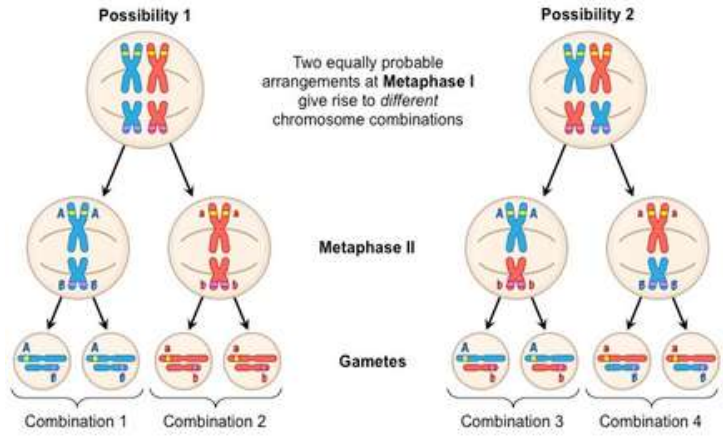
- **Mendel's Laws:**
  - **Law of Segregation**: During gamete formation, the two alleles for a trait separate so that each gamete receives only one allele.

LAW OF SEGREGATION



  - **Law of Independent Assortment**: Genes for different traits assort independently of one another during gamete formation, which contributes to genetic diversity.

LAW OF INDEPENDENT ASSORTMENT

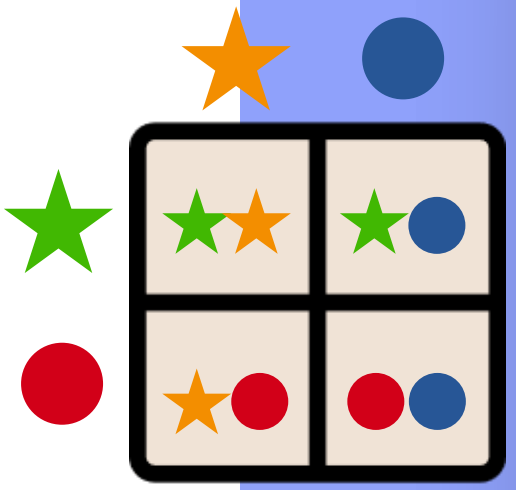


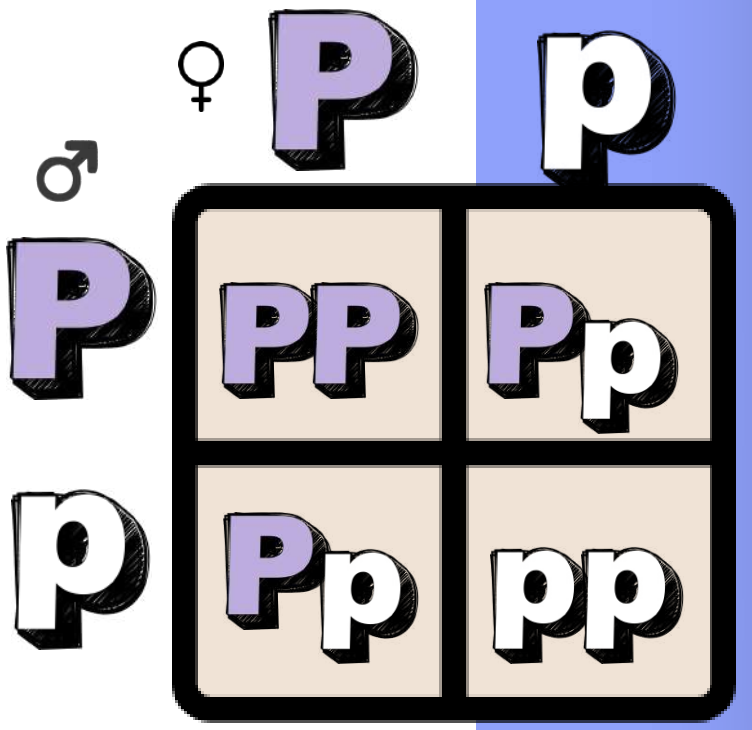
Punnett Squares - Monohybrid

- **Punnett squares** are used to **predict** the genetic **outcomes** of **crosses**.
- **Monohybrid** Cross: crossing **one** trait
  - **Example Problem:** Let's cross two **heterozygous** pea plants for flower color, where **purple** (P) is dominant over **white** (p).

♂ ♀

Parents: Pp x Pp





  - **Outcomes**:
    - **25%** or 1 in 4 PP **Genotype** or (Purple - **Phenotype**)
    - **50%** or 2 in 4 Pp **Genotype** or (Purple - **Phenotype**)
    - **25%** or 1 in 4 pp **Genotype** or (White - **Phenotype**)

- What is a monohybrid cross, and what does it help us study?
- How do Punnett squares help biologists predict the traits of offspring?
- What do the capital and lowercase letters in a Punnett square represent?
- Why might the actual traits of offspring be different from what a Punnett square predicts?
- Can you explain how we can use the genotypes of parents to predict the traits of their offspring using a Punnett square?

PUNNETT SQUARES - DIHYBRID

Dihybrid Cross: comparing **2 Traits**

- **Example Problem:** Consider the traits of seed shape (round, R; wrinkled, r) and seed color (yellow, Y; green, y). We will cross a **heterozygous** round yellow plant (RrYy) with a **homozygous** wrinkled green plant (rryy).

Parents: R r Y y r r y y

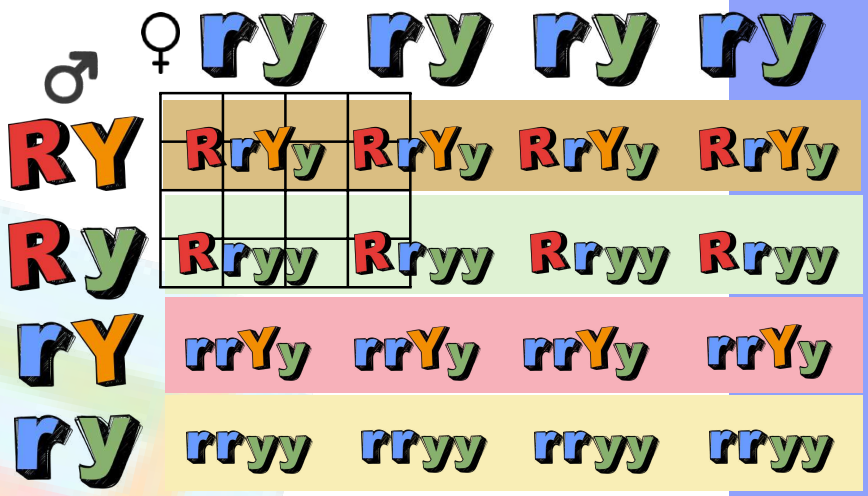
Find the Gamete Combinations for each Parent

- **Parent 1:** RrYy **= RY, Ry, rY, and ry…(*repeat the first letter 2x's, repeat the second letter 2x's, alternate the last 2 letters or F.O.I.L. - First, Outer,Inner,Last*)**
- **Parent 2:** rryy **= ry, ry, ry, ry**

- **Outcomes**:
  - **25%** or 4/16 Round Yellow (**RrYy**)
  - **25%** or 4/16 Round Green (**Rryy**)
  - **25%** or 4/16 Wrinkled Yellow (**rrYy**)
  - **25%** or 4/16 Wrinkled Green (**rryy**)

♂ \ ♀	ry	ry	ry	ry
RY	RrYy	RrYy	RrYy	RrYy
Ry	Rryy	Rryy	Rryy	Rryy
rY	rrYy	rrYy	rrYy	rrYy
ry	rryy	rryy	rryy	rryy

- Outcomes:
  - **25%** or 4/16 Round Yellow (**RrYy**)
  - **25%** or 4/16 Round Green (**Rryy**)
  - **25%** or 4/16 Wrinkled Yellow (**rrYy**)
  - **25%** or 4/16 Wrinkled Green (**rryy**)



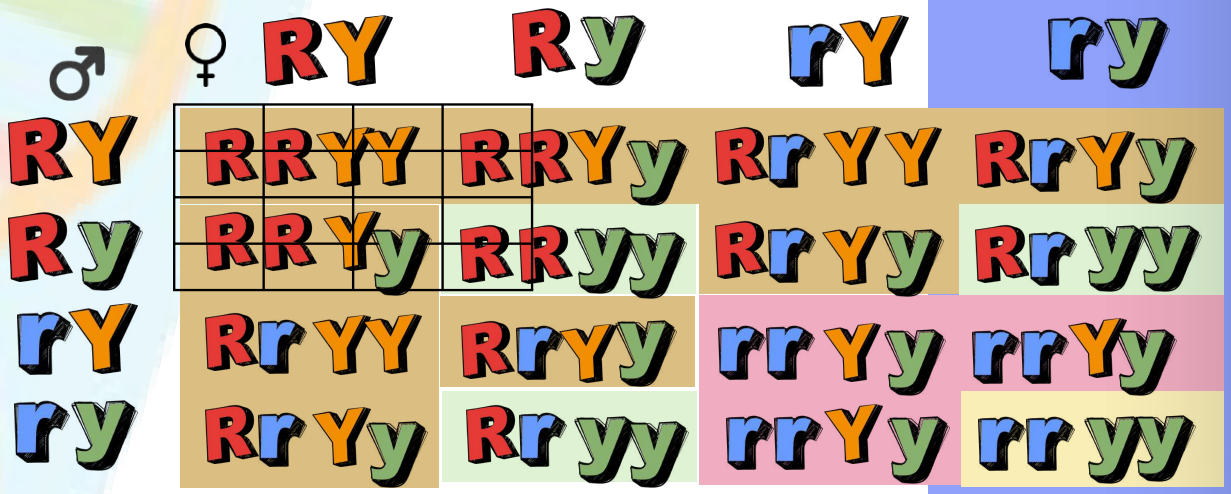
BUT WHAT IF...

- If **both** parents are **heterozygous** for **both** traits (RrYy x RrYy), the phenotypic ratio will be 9:3:3:1

  R r Y y ⚔ R r Y y

- **Parent Gametes:** Repeat the first letter twice, second letter twice, then alternate the last two...
  - **RY, Ry, rY, ry**
- Outcomes: **Phenotypic Ratio** is **ALWAYS**...
  - **9** Round Yellow: **R_Y_**
  - **3** Round Green: **R_yy**
  - **3** Wrinkled Yellow: **rrY_**
  - **1** Wrinkled Green: **rryy**

9:3:3:1

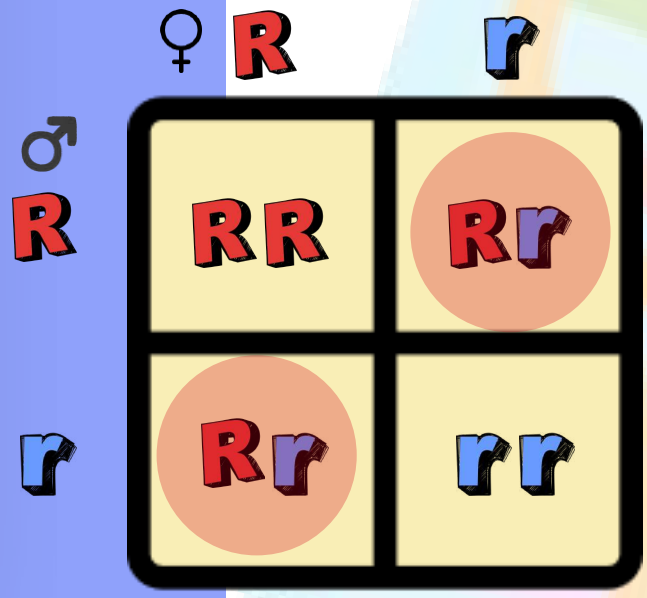


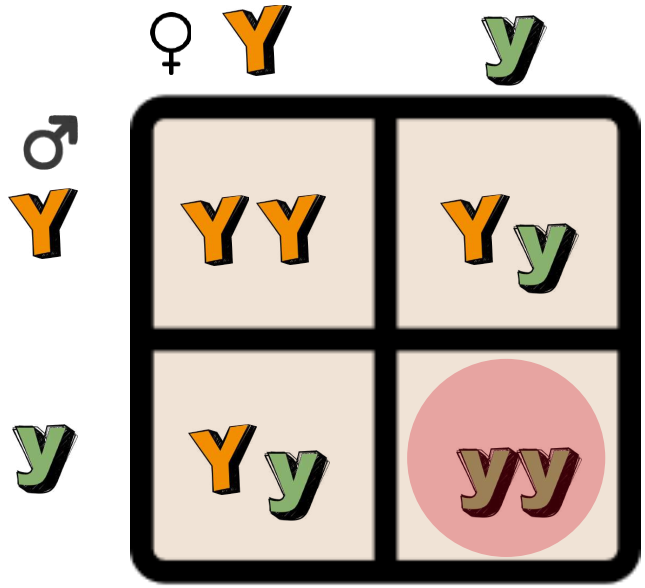
Punnett Squares How are they related - Probability?

s, but using 2 Monohybrids to determine the Probability of a
notype!

e Problem: Consider the traits of seed shape (round, R; wrinkled, r)
ed color (yellow, Y; green, y). We will cross a **heterozygous** round,
lant (RrYy) with a **Heterozygous** round, yellow plant (RrYy).

♂ R r Y y × ♀ R r Y y





- What is the probability of having the **Genotype: R r y y?**

1. Find All **Rr** boxes : **2/4...**
2. Find all **yy** boxes: **1/4...**
3. Use the rule of multiplication to find the probability of the genotype appearing in a dihybrid cross.

$$\frac{2}{4} \times \frac{1}{4} = \frac{2}{16}$$

Go Back and Check your Square!

♂ \ ♀	RY	Ry	rY	ry
RY	RRYY	RRYy	RrYY	RrYy
Ry	RRYy	RRyy	RrYy	Rryy
rY	RrYY	RrYy	rrYy	rrYy
ry	RrYy	Rryy	rrYy	rryy

- What is a dihybrid cross, and what traits does it help us study?
- How does a Punnett square show the possible combinations of two traits, like pea color and pod shape?
- What does the 9:3:3:1 ratio in a dihybrid cross tell us about the phenotypes of the offspring?
- Why is it important to track two traits at once in a dihybrid cross?
- Can you explain how to use the genotypes of the parents to predict the 9:3:3:1 ratio of offspring traits?

WHAT IF GENES DONT FOLLOW RULES?

Non-Mendelian Genetics

INCOMPLETE DOMINANCE

- **Incomplete Dominance**: condition in which a **trait** in an **individual** is **intermediate (blending)** between the **phenotype** of the individual's two parents because the **dominant** allele is **unable** to express itself **fully**

- **Example Problem:** In snapdragons, red flowers (R) and white flowers (W) exhibit incomplete dominance, resulting in pink flowers (RW). Let's cross a red flower with a white flower.

♂ ♀

Parents: RR x WW

♂ \ ♀	W	W
R	RW	RW
R	RW	RW

Outcomes:

- **100% Pink (RW)**

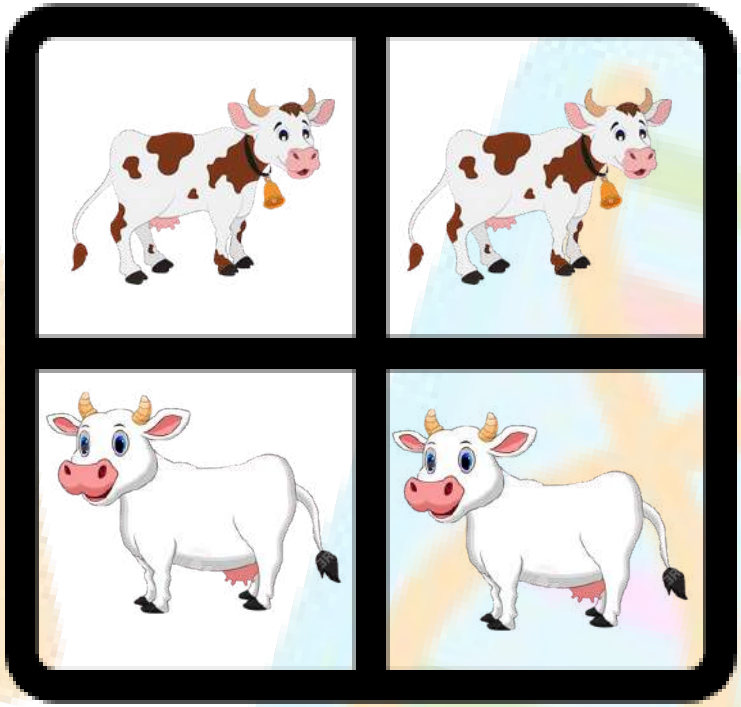
Explanation: In **incomplete dominance**, the **heterozygous** phenotype (RW) is a **blend** of the two **homozygous** phenotypes.

CODOMINANCE

- **Codominance**: a condition in which **both** alleles for a **gene** are **fully** expressed
- **Example Problem**: In roan cattle, the allele for red coat color (R) and the allele for white coat color (W) are codominant. If we cross a red roan cow (RW) with a white cow (WW).

♂ ♀

Parents: RW x WW

♀	W	W
♂ R		
W		

Outcomes:

- **50% Red Roan (RW)**
- **50% White (WW)**
- **Real-Life Examples:** Codominance is seen in **fur** color and **flower** color. We also see some of this in **Blood** Types.

- Who is Gregor Mendel, and why are his pea plant experiments important in genetics?
- What happens when traits show incomplete dominance, and can you give an example from the video?
- How is codominance different from incomplete dominance, and what's an example of codominance from the video?
- Why do we say incomplete dominance is like mixing paint colors, while codominance is like seeing both traits together?
- Can you explain how the alleles in a snapdragon (incomplete dominance) are different from those in a speckled chicken (codominance)?

MULTIPLE ALLELES

- **Multiple Alleles**: **more** than **two** alleles (versions of a gene) for a genetic trait
  - **Example Problem**: Blood type is determined by multiple alleles: A (IAIA or IAi), B (IBIB or IBi), and O (i). If a type A individual (IAi) is crossed with a type B individual (IBi).

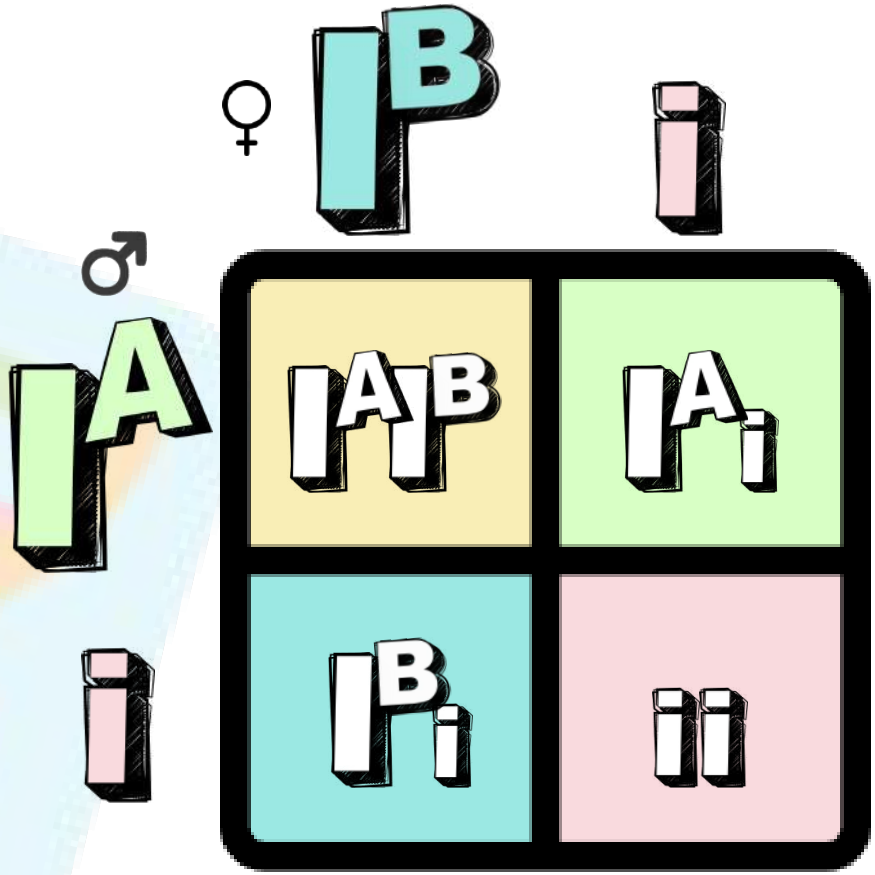
♂ ♀

Parents: IAi x IBi

	Type A	**Type B**	**Type AB**	**Type O**
Alleles	**IAIA, IAi**	**IBIB, IBi**	**IAIB**	**ii**
Antigen	Antigen A	Antigen B	Antigen A+B	None
Antibody	Anti-B antibody	Anti-a antibody	None	Both Anti A + B antibody
Donor / Accept	To A or AB / From A or O	To B or AB / From B or O	To AB Only / From All others	To All others, From O Only

Outcomes:

- **25% Type AB (IAIB)**
- **25% Type A (IAi)**
- **25% Type B (IBi)**
- **25% Type O (ii)**



EPISTASIS

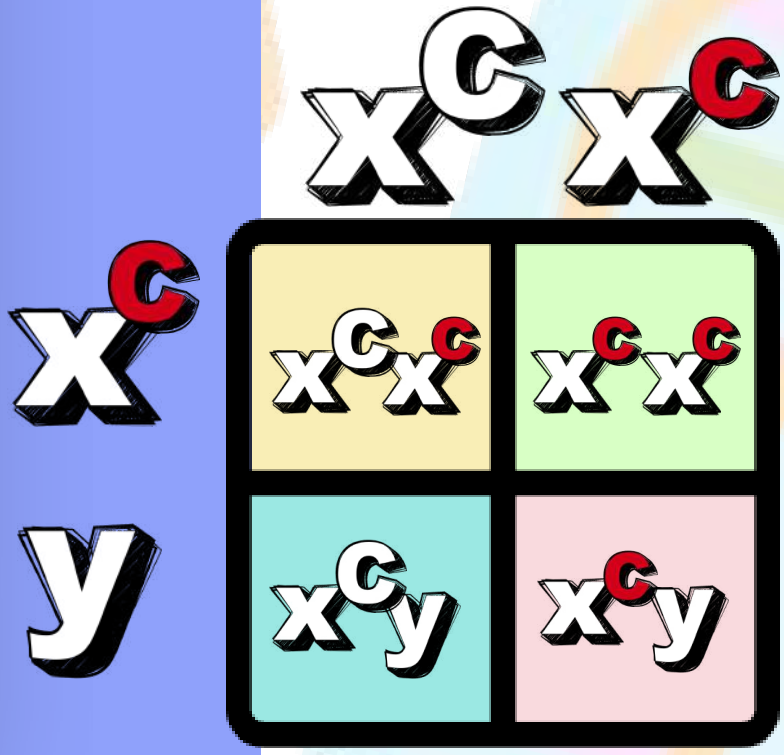
- What is Epistasis?
  - **Epistasis** is when **one** gene **controls** or **hides** the effect of **another** gene.
  - It's like one gene being the "boss" and telling the other gene what to do—or not to do.

- Genes Work Together
  - Most **traits** (like hair color, eye color, or fur color in animals) are **affected** by **more** than one **gene**.
  - In epistasis, one **gene** can **turn off** or **change** how **another** gene works.
- Example – **Labrador Dogs**
  - Labradors can be black, brown, or yellow.
  - One gene decides black or brown.
  - Another gene decides if the color shows up or not.
  - If the second gene says “no color,” the dog is yellow, even if it has the black or brown gene!
- Example – **Red Hair in Humans**
  - A gene called MC1R affects red hair.
  - If a person has two copies of a special version of this gene, they may have red hair.
  - But other genes can change how strong the red color shows.
  - In some people, these other genes make red hair look more blond or brownish, even if they have the MC1R gene!

Sex (X) Linked Traits

- **X-Linked Traits**: a trait that is **determined** by a **gene** found on **one** of the **sex chromosomes**, such as the **X chromosomes** or the **Y chromosomes** in humans - **Hemophilia**, **colorblindness**...
  - **Example Problem**: Color blindness is an X-linked recessive trait. If a color-blind man (XcY) has children with a woman who is a carrier (XCXc), what are the possible genotypes of their children?

Parents: X^cY x X^CX^c



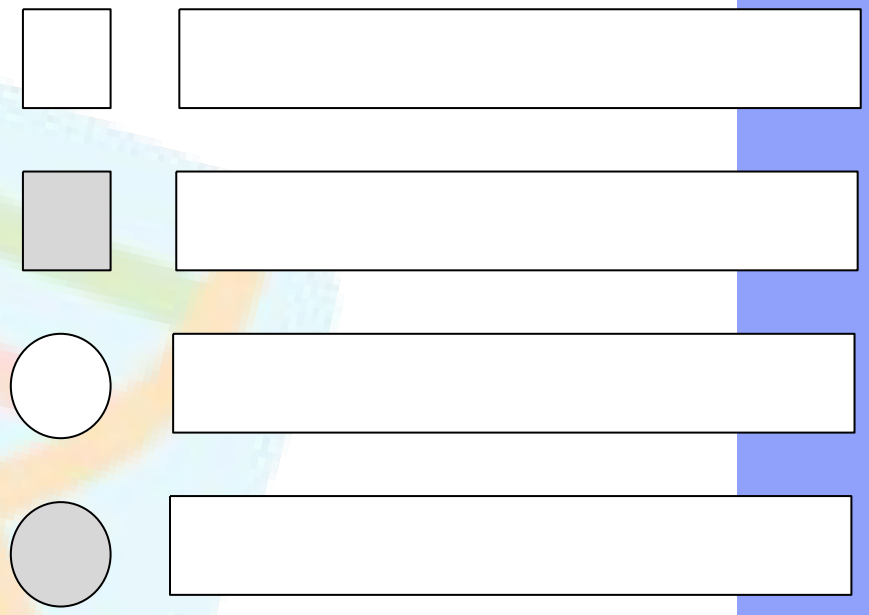
Outcomes: Total children

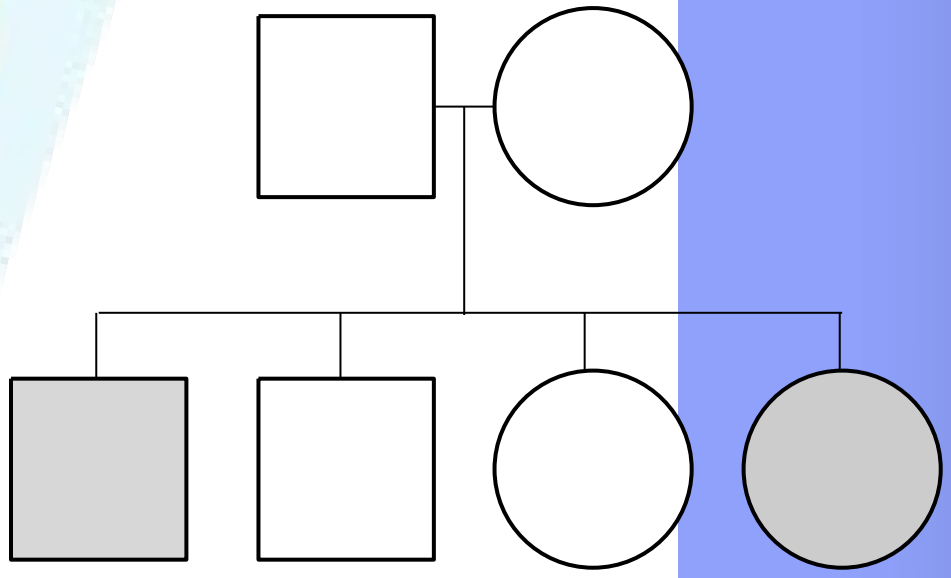
- **25% XCXc** (Carrier or Hybrid Female)
- **25% XcXc** (Color Blind Female)
- **25% XCY** (Normal Male)
- **25% XcY** (Color Blind Male)

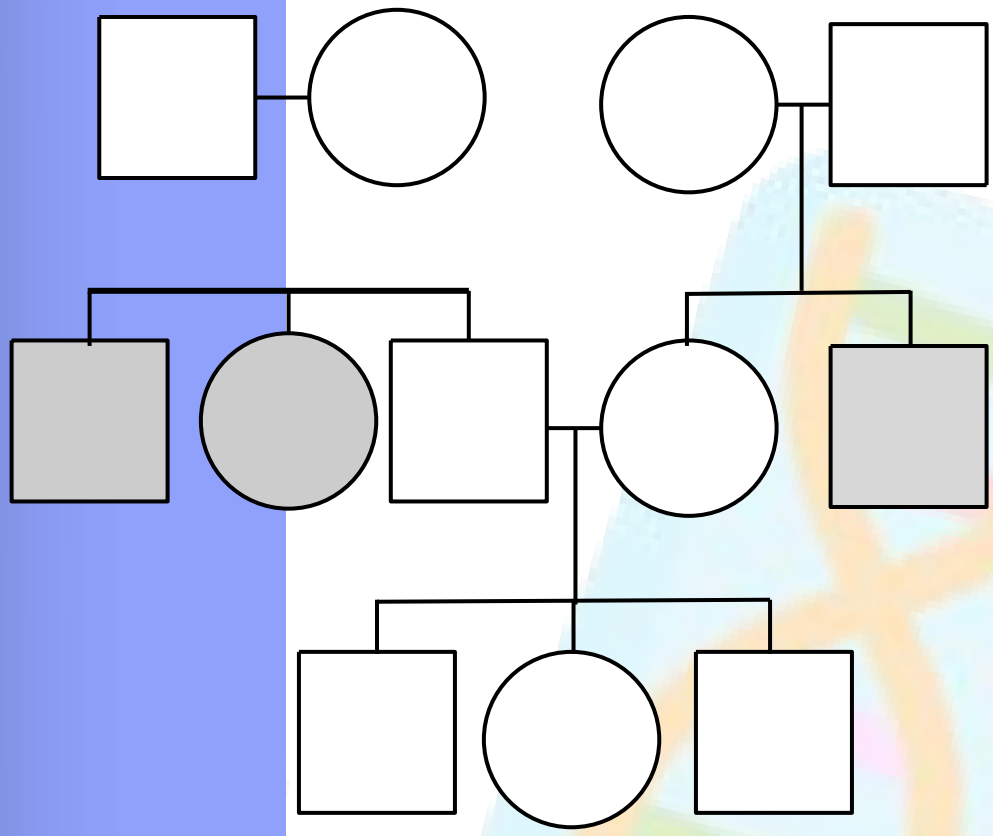
- What does it mean for a trait to be X-linked, and how is it different from traits on other chromosomes?
- Why are males more likely to express X-linked traits than females?
- How do we use Punnett squares to predict the inheritance of X-linked traits?
- Can you give an example of an X-linked trait from the video and explain how it is passed down?
- How can knowing about X-linked inheritance help predict the likelihood of a son or daughter inheriting a genetic condition?

PEDIGREES

- A **pedigree** is a **diagram** that shows the **occurrence** of a genetic **trait** across **generations** in a family.
- **Autosomal (non-sex (x) linked) Recessive** Pedigree:
  - Characteristics:
  - The **trait** can **skip** generations.
  - **Males** and **females** are **equally** likely to be **affected**.
  - Example: **Cystic fibrosis**.







- **Autosomal Dominant Pedigree**:
- Characteristics:
  - The trait **appears** in **every** generation.
  - **Affected** individuals have at **least** one **affected parent**.
  - Example: **Huntington's disease.**

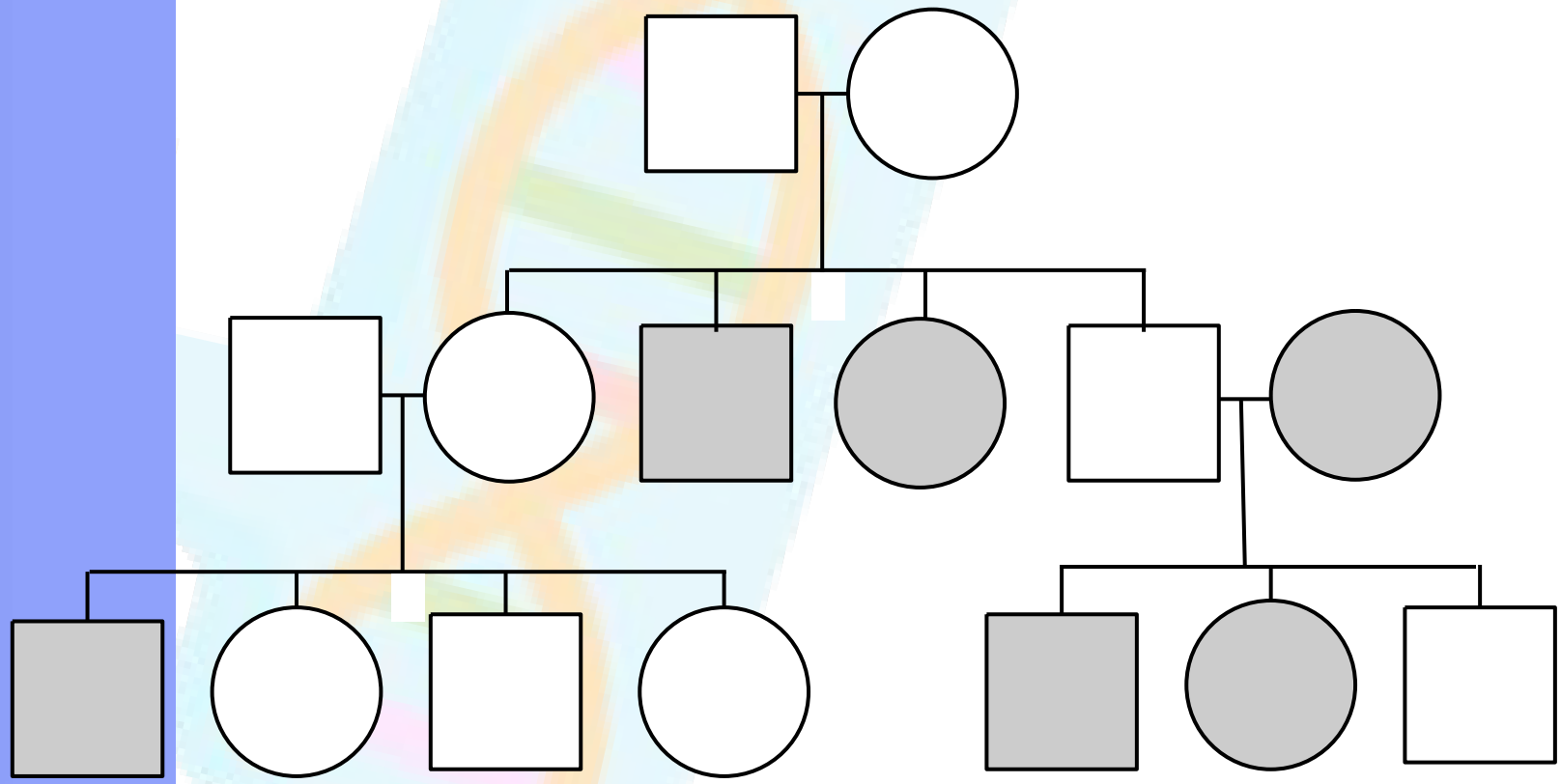
General Observations to Differentiate:

- **Autosomal Recessive:**
  - Affected individuals **can have** unaffected parents (carriers).
  - **Equal** likelihood of **affecting males** and **females**.
- A**utosomal Dominant:**
  - Affected individuals have at **least one** affected **parent**.
  - **Equal** likelihood of **affecting males** and **females**.

What About X Chromosomes?

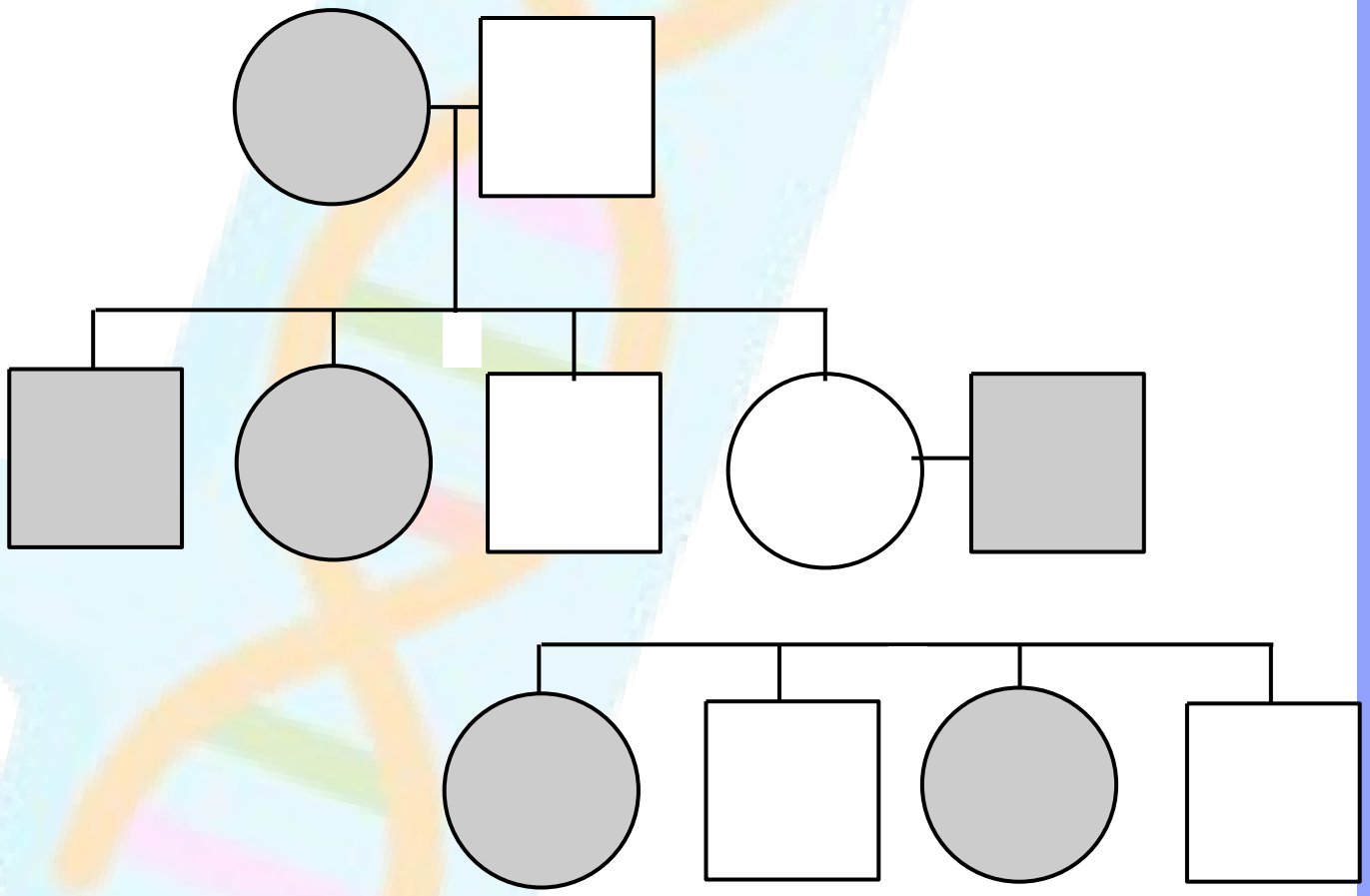
X-Linked Recessive Pedigree:

- Characteristics:
  - More **males** are **affected** than females.
  - The **trait** may **skip** generations.
- **Key Observations:**
  - **Affected fathers** pass the **trait** to all **daughters**.



X-Linked Dominant Pedigree:

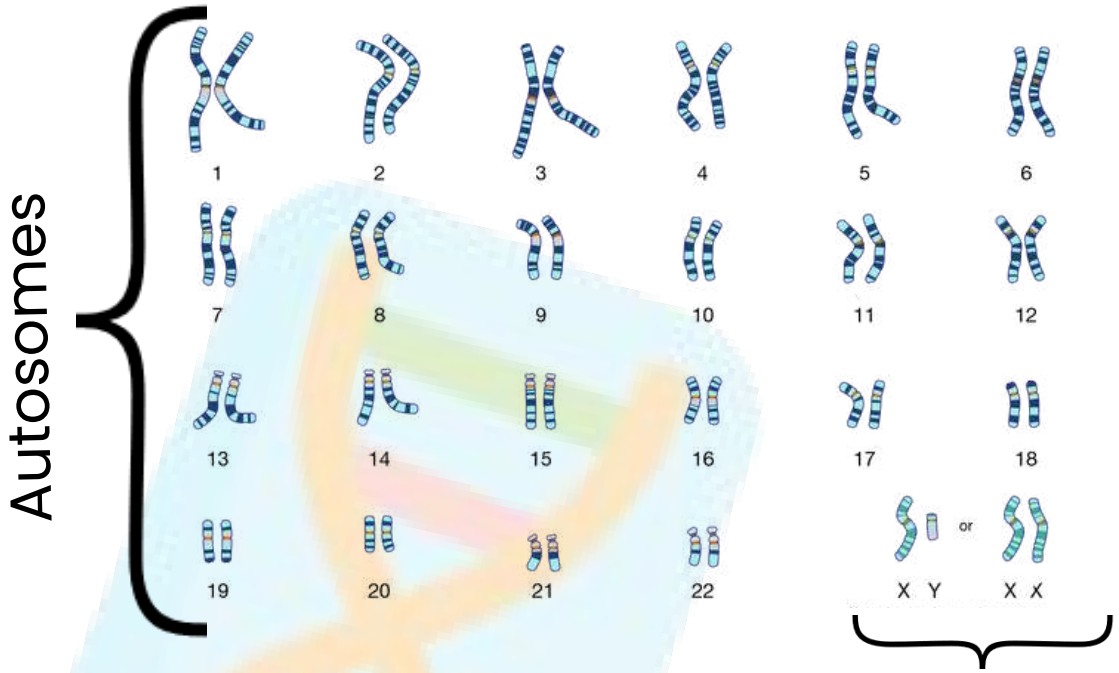
- Characteristics:
  - **Affected males** pass the **trait** to all **daughters** and **no sons**.
  - The trait **does not** skip generations.
- **Key Observations:**
  - **Affected females** can **pass** the trait **to both** daughters and sons.



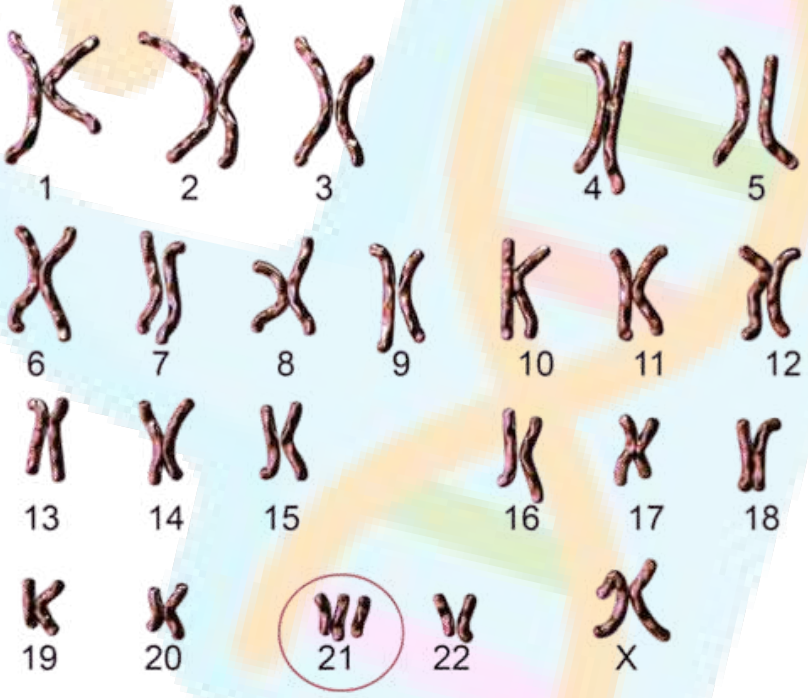
- What is a pedigree, and how is it used in genetics?
- How can you tell if a trait is dominant or recessive by looking at a pedigree?
- What are some symbols used in pedigrees, and what do they represent?
- Why are pedigrees important for understanding how traits are passed down in families?
- Can you explain how a pedigree helps predict the likelihood of an offspring inheriting a certain trait?

KARYOTYPING - GENETIC MAPPING

- A **karyotype** is the **complete** set of **chromosomes** in an individual's cells, organized by **size**, **shape**, and **number**. It helps **identify** chromosomal **abnormalities**.
  - **Humans** have **46** chromosomes **arranged** in **23 pairs** (22 pairs of **autosomes** and 1 pair of **sex chromosomes**).
  - **Abnormalities** in the karyotype can **lead** to genetic **disorders**, such as **Down syndrome** (trisomy 21).



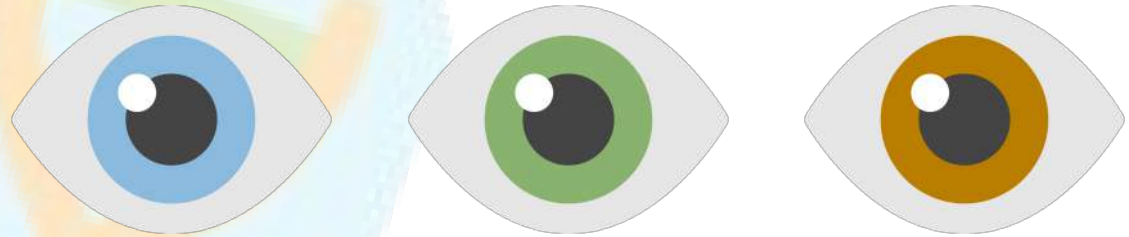
NORMAL



TRISOMY 21 (DOWNS SYNDROME)

Polygenic traits

- **Polygenic** traits are **characteristics** controlled by **multiple genes,** leading to a wide **range** of **phenotypes**, such as **skin color** and **height** in humans.
- The inheritance patterns for these traits are more complex than those governed by a single gene.



Summary

- How are traits passed from parents to offspring through dominant and recessive alleles?
  - "Traits are passed down through alleles, which can be either _____ or _____."
  - "A dominant allele shows up in the phenotype when _____."
- How can Punnett squares be used to predict traits in offspring for monohybrid and dihybrid crosses?
  - "A Punnett square helps predict genetic outcomes by showing _____."
  - "In a dihybrid cross, we use _____ to see how two traits are inherited together."
- What are incomplete dominance and codominance, and how do they affect how traits appear?
  - "Incomplete dominance happens when both alleles blend, creating _____."
  - "Codominance means that both alleles are fully seen, like _____."
- What makes sex-linked traits, like hemophilia, different from traits found on other chromosomes?
  - "Sex-linked traits are carried on the _____ chromosome and often affect males more than females because _____."
  - "Hemophilia is an example of a sex-linked disorder because _____."
- 5. How can multiple alleles control traits like blood type, and what makes this different from simple dominant and recessive inheritance?
  - "Blood type is controlled by three alleles—A, B, and O—which makes it a _____ trait."
  - "Unlike simple dominant-recessive traits, multiple alleles create _____.

- How do pedigrees and karyotypes help scientists understand inherited traits and genetic disorders?
  - "A pedigree shows how a trait is passed through _____."
  - "A karyotype helps identify chromosome disorders like _____ by showing _____."

RESOURCES

FuseSchool – Global Education. (2017, February 15). Punnett Squares | Genetics | Biology | FuseSchool [Video]. YouTube. https://www.youtube.com/watch?v=BRMcTdKNpOA

Amoeba Sisters. (2021, October 27). Mega Genetics Review: Mendelian and Non-Mendelian Genetics [Video]. YouTube. https://www.youtube.com/watch?v=jLmoJPxihjA

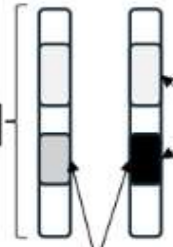
Khan Academy. (2018, July 19). Pedigrees | Classical genetics | High school biology | Khan Academy [Video]. YouTube. https://www.youtube.com/watch?v=11s5Biyi9q4

Bozeman Science. (2011, July 30). Mendelian Genetics [Video]. YouTube. https://www.youtube.com/watch?v=NWqgZUnJdAY

Genetics

characteristics

46



Sexual reproduction

Segment of DNA
Codes for traits

Different forms

A

a

	A	a
A		
a		

- **A** – Purple
- **a** - White

Same - AA or aa

Different - Aa

AA, aa, or Aa

Allele Combinations

tall, red, or curly

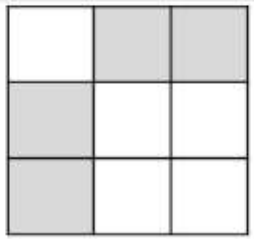
Appearance

	R	W
R		
W		

- R – Red
- **W** – White
- RW: Roan

	X	X
X		
Y		

Mom is a carrier married and affected man (Hemophilia, color-blindness)



Mom: O, Dad is AB

	A	B
A		
B		

- **A** – Red
- **B** – White
- **AB**: Pink

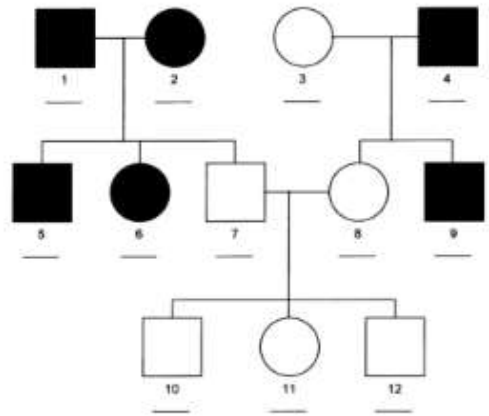
AaBb x AaBb

Phenotypic Ratio

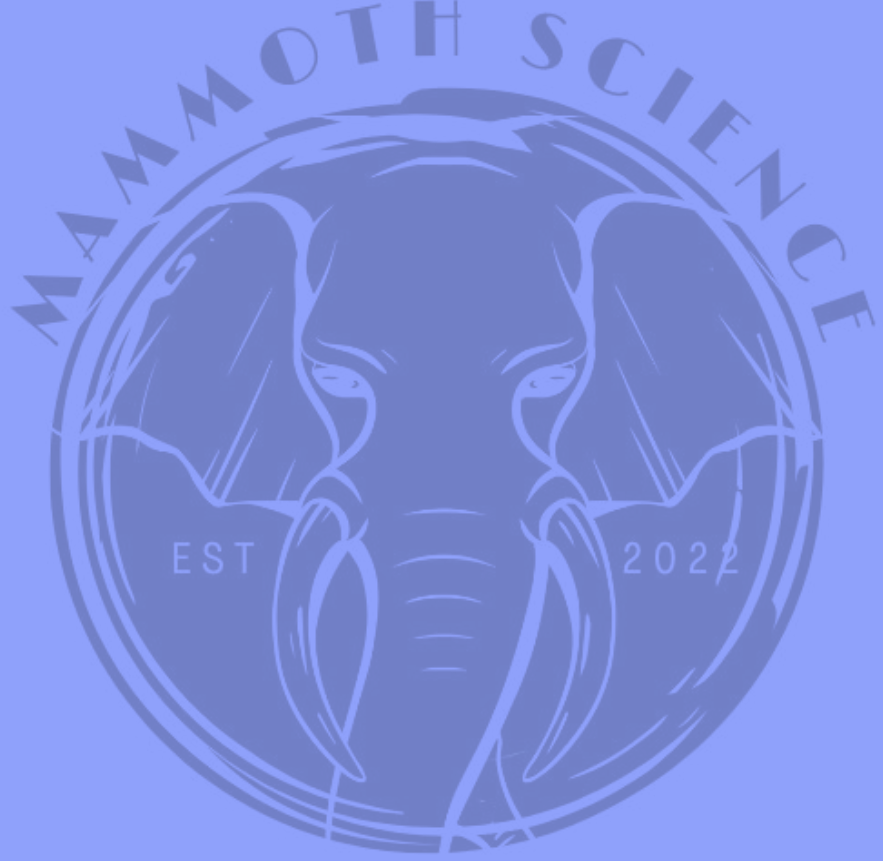
- **A_B_**
- **A_bb**
- **aaB_**
- **aabb**

If both parents are heterozygous for both traits, the phenotypic ratio is ALWAYS: ____ : ____ : ____ :____

AABb x Aabb **Identify all possible offspring:**



Dominant or Recessive?
Autosomal or X-linked?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