Heredity

1. Accumulation of Variation During Reproduction

Reproduction creates new individuals that are similar to their parents but have subtle differences, known as **variations**.

- **Subtle Differences:** Reproductive processes give rise to new individuals that are similar but subtly different from their parents.
- **Asexual vs. Sexual Reproduction:** While asexual reproduction produces some variation, the number of successful variations is maximized by sexual reproduction.
- **DNA Copying Inaccuracies:** In organisms like bacteria, very minor differences are generated due to small inaccuracies in DNA copying.
- **Environmental Selection:** Depending on the nature of these variations, different individuals gain different advantages; for example, heat-resistant bacteria survive better during a heatwave.

2. Rules for the Inheritance of Traits (Mendel's Laws)

Gregor Mendel established that both parents contribute an equal amount of genetic material to their child. This means every trait is influenced by two versions (paternal and maternal) of DNA.

Key Terms

- **Gene:** A section of DNA that provides information for a specific protein, which then controls a characteristic (like height).
- **Genes and Proteins:** A gene is a section of DNA that provides instructions for making a specific protein.
- **Dominant Trait:** A trait that is expressed even if only one copy of the gene is present (e.g., Tallness represented by 'T').
- **Recessive Trait:** A trait that only appears if two copies of the gene are present (e.g., Shortness represented by 't').
- Based on the PDF provided, Gregor Mendel’s experiments with pea plants are the foundation of our understanding of heredity. He used several contrasting visible characters—such as tall/short plants and round/wrinkled seeds—to determine how traits are passed from parents to offspring.
  The experiment can be broken down into two main types of crosses:

- **1. The Monohybrid Cross (Single Trait)**

- Mendel first looked at how a **single** trait, like height, was inherited.
- **The Cross:** He bred a "pure" Tall plant (TT) with a "pure" Short plant (tt).

- **The F1 Generation:** All offspring were **Tall**. The PDF notes there were "no halfway characteristics"—meaning no medium-height plants. This proved that Tallness is the **dominant** trait.
- **The F2 Generation:** When he let the F1 plants self-pollinate, the "Short" trait reappeared. He found that **1/4 (25%)** were short and **3/4 (75%)** were tall.
- **Conclusion:** This created the famous **3:1 ratio**, showing that traits are carried as "factors" (genes) that don't disappear even if they are hidden.

- ### 2. The Dihybrid Cross (Two Traits)

- Mendel then tested if different traits were linked together or if they were independent. He crossed plants with two different characteristics: **Tall plants with Round seeds** (TTRR) and **Short plants with Wrinkled seeds** (ttrr).
- **The F1 Generation:** All plants were **Tall and Round**.
- **The F2 Generation:** When these were self-pollinated, the offspring showed "new combinations" that didn't exist in the parents, such as **Tall-Wrinkled** and **Short-Round** plants.
- **Conclusion:** This resulted in a **9:3:3:1 ratio**, proving the **Law of Independent Inheritance**—the gene for height and the gene for seed shape are inherited separately.

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3. How Traits are Expressed (DNA & Proteins)

The PDF explains the biological "why" behind these experiments in section 8.2.3:

- **The Information Source:** Cellular **DNA** is the instruction manual for making proteins in the cell.
- **The Mechanism:** A specific section of DNA (a **gene**) provides the instructions for an **enzyme** (a type of protein).
- **The Physical Result:** In tall plants, the enzyme works efficiently to produce growth hormones. If the gene is altered (recessive), the enzyme is less efficient, less hormone is produced, and the plant remains short.

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Summary Table

Feature	Monohybrid Cross	Dihybrid Cross
Traits Studied	One trait (e.g., Height)	Two traits (e.g., Height + Shape)

PDF Example	Tall (TT) / Short (tt)	Tall/Round (TTRR) /Short/Wrinkled (ttrr)
F2 Ratio	**3:1**	**9:3:3:1**
Purpose	To identify Dominant vs. Recessive traits.	To show Independent Inheritance of traits.

Experiment	Traits Observed	F2 Phenotypic Ratio	Key Discovery
Monohybrid	One (e.g., Height)	**3:1**	Dominance and Segregation
Dihybrid	Two (e.g., Height + Shape)	**9:3:3:1**	Independent Inheritance

Mendel's Observations

- **First Generation (F1):** When crossing a pure tall plant (TT) and a short plant (tt), all offspring are tall (Tt). The tallness "dominates" the shortness.
- **Second Generation (F2):** When F1 plants self-pollinate, the hidden recessive trait reappears. The result is a **3:1 ratio**: three tall plants for every one short plant.
- **Independent Inheritance:** Mendel found that different traits (like seed shape and seed color) are inherited independently from each other. A tall plant doesn't *have* to have round seeds; new combinations can form.

1. The Parents (P Generation)

- **Parent 1:** Tall with Round seeds. Genotype = **TTRR**
- **Parent 2:** Short with Wrinkled seeds. Genotype = **ttrr**
  Before we can use a Punnett square, we must determine what "germ cells" (gametes) the parents can provide.
- The **TTRR** parent can only give a **T** and an **R**. (Gamete: **TR**)
- The **ttrr** parent can only give a **t** and an **r**. (Gamete: **tr**)

	TR (from Parent 1)
tr (from Parent 2)	**TtRr**

2. The First Generation (F1)

Mendel crossed plants that differed in two distinct traits: height and seed shape.

- **Parent 1:** Tall plant with Round seeds (TTRR).
- **Parent 2:** Short plant with Wrinkled seeds (ttrr).

3. The Second Generation (F2)

Each F1 parent (TtRr) has two copies of each gene. When they produce gametes (sperm or egg), these pairs separate. Because they separate independently, one parent can produce **four different types** of gametes:

1. **TR** (Both dominant)
2. **Tr** (Dominant height, recessive shape)
3. **tR** (Recessive height, dominant shape)
4. **tr** (Both recessive)
   When the F1 plants are allowed to self-pollinate, the genes recombine to form a variety of offspring.

- **Tall & Round (9 boxes):** Look for any box with at least one **T** AND at least one **R**.
- *Genotypes:* TTRR (1), TTRr (2), TtRR (2), TtRr (4) = **Total 9** (Pure Tall)
- **Tall & Wrinkled (3 boxes):** Look for at least one **T** but two small **rr** (Tall carriers).
- *Genotypes:* TTrr (1), Ttrr (2) = **Total 3**
- **Short & Round (3 boxes):** Look for two small **tt** but at least one **R (**Short carriers).
- *Genotypes:* ttRR (1), ttRr (2) = **Total 3**
- **Short & Wrinkled (1 box):** Look for the box with all recessive letters.
- *Genotype:* ttrr = **Total 1**(short)

	TR	**Tr**	**tR**	**tr**
TR	**TTRR**	**TTRr**	**TtRr**	**TtRr**
Tr	**TTRr**	**TTrr**	**TtRr**	**Ttrr**
tR	**TtRr**	**TtRr**	**ttRR**	**ttRr**
tr	**TtRr**	**Ttrr**	**ttRr**	**ttrr**

Phenotype	**Genotype Possibilities**	**Count**

Tall, Round	TR (Dominant, Dominant)	9
Tall, Wrinkled	Trr (Dominant, Recessive)	3
Short, Round	ttR (Recessive, Dominant)	3
Short, Wrinkled	ttrr (Recessive, Recessive)	1

1. The Genetic Makeup (Genotype)

- **Inheritance:** Each parent contributes one set of genes to the offspring.
- **The Process:** The tall/round parent (TTRR) provides the genes **T** and **R**, while the short/wrinkled parent (ttrr) provides **t** and **r**.
- **The Result:** All F1 plants end up with one dominant and one recessive version for both traits (TtRr).

2. The Physical Appearance (Phenotype)

- **Dominant Rules:** According to Mendel's rules, a single copy of a dominant trait (like T or R) is enough to make that trait show up physically.
- **Observation:** Because T (Tall) is dominant over t (Short), and R (Round) is dominant over r (Wrinkled), all these TtRr plants appear **Tall and have Round seeds**.
- **No Mixture:** There are no "halfway" characteristics; you won't see medium-height plants or semi-wrinkled seeds in this generation.

3. The "Carrier" Status

- **Hidden Information:** Even though the plants look tall and round, they are not genetically "pure" like their parents.
- **Potential for Variety:** They carry the "hidden" recessive genes for shortness (t) and wrinkled seeds (r).
- **Future Generations:** These hidden traits will only reappear in the **Second Generation (F2)** when these F1 plants are self-pollinated and the recessive genes have a chance to pair up again (tt or rr).

3. The Mechanism of Inheritance

Inheritance works through independent pieces of DNA called **chromosomes**.

- **Chromosomes in Pairs:** Most human cells have 22 pairs of regular chromosomes plus one pair of sex chromosomes.
- **Germ Cells (Gametes):** These specialized cells (sperm and egg) carry only **one set** of genes instead of the usual two.
- **Restoration:** When an egg and sperm combine (fertilization), they restore the normal double set of chromosomes in the offspring.

3. Independent Inheritance of Traits

Mendel also studied what happens when two different traits are bred together, such as seed shape (round/wrinkled) and seed color (yellow/green).

- **Independent Assortment:** Traits like height and seed shape are inherited independently.
- **New Combinations:** This independence allows for new combinations in the F2 generation, such as tall plants with wrinkled seeds or short plants with round seeds.
- **Two-Trait Crosses:** When breeding plants with two different characteristics (like tall/round seeds and short/wrinkled seeds), the F1 generation shows only the dominant traits.

4. How Traits are Expressed

The physical appearance (phenotype) of an organism is driven by cellular chemistry.

- **DNA as Information Source:** Cellular DNA is the source for making proteins; a section of DNA providing information for one specific protein is called a **gene**.
- **Protein/Enzyme Efficiency:** For example, a plant's height depends on growth hormones. If the gene produces an efficient enzyme, more hormones are made, and the plant becomes tall.
- **Gene Alterations:** If a gene is altered (mutated), the enzyme becomes less efficient; less hormone is produced, and the plant remains short.

4. Sex Determination in Humans

In humans, sex is determined genetically rather than by environmental factors like temperature.

- **The Chromosome Set:** Humans have 22 perfect pairs of chroosomes, and one "odd" pair called sex chromosomes.
- **Female Chromosomes:** Women have a perfect pair of sex chromosomes: **XX**.
- **Male Chromosomes:** Men have a mismatched pair: one normal **X** and one shorter **Y** (**XY**).
- **The Determination Rule:** All children inherit an **X** from their mother.
    - The **father** determines the sex: if he contributes an **X**, the child is a girl; if he contributes a **Y**, the child is a boy.

Crossing Over