NUCLEIC ACIDS AS GENETIC MATERIAL

Unit 3.4

Introduction

Mendelian inheritance (or Mendelian genetics or Mendelism)

- is a set of primary tenets relating to the transmission of hereditary characteristics from parent organisms to their children
- it underlies much of genetics.
- ***The tenets were initially derived from the work of Gregor Mendel published in 1865 and 1866, which was "re-discovered" in 1900***
- they were initially very controversial, but they soon became the core of classical genetics

- The laws of inheritance were derived by Gregor Mendel, a 19th century monk conducting hybridization experiments in garden peas (*Pisum sativum*).
- Between 1856 and 1863, he cultivated and tested some 28,000 pea plants. From these experiments, he deduced two generalizations that later became known as Mendel's Laws of Heredity or Mendelian inheritance.
- He described these laws in a two part paper, "Experiments on Plant Hybridization", which was published in 1866.

Mendel's Laws

- ✓ Mendel discovered that by ***crossing*** ***true-breeding white flower and true-breeding purple flower plants, the result was a hybrid offspring***. Rather than being a mix of the two colors, the offspring was purple flowered.
- ✓ ***He then conceived the idea of heredity units, which he called "factors", one of which is a recessive characteristic and the other dominant*.**
- ✓ ***Mendel said that factors*** **(later called genes)*, normally occur in pairs in ordinary body cells, yet segregate during the formation of sex cells.***
- ✓ ***Each member of the pair becomes part of the separate sex cell.***

MENDELS LAWS Contd/-

1. **Law of Dominance**: The **dominant gene**, such as the purple flower in Mendel's plants, will hide the recessive gene, the white flower.

   After Mendel self-fertilized the F1 generation and obtained an F2 generation with a 3:1 ratio, he correctly theorized that genes can be paired in three different ways for each trait: AA, aa, and Aa.

   The capital A represents the dominant factor while the lowercase a represents the recessive.

2. **Law of Segregation**: Mendel's Law of Segregation states that a diploid organism passes a randomly selected allele for a trait to its offspring, such that the offspring receives one allele from each parent.

Key Terms & Points:

- **law of segregation**: a diploid individual possesses a pair of alleles for any particular trait and each parent passes one of these randomly to its offspring
- Each gamete acquires one of the two alleles as chromosomes separate into different gametes during meiosis.
- *Heterozygotes, which posess one dominant and one recessive allele*, can receive each allele from either parent and will look identical to homozygous dominant individuals;
- **the Law of Segregation supports Mendel's observed 3:1 phenotypic ratio.**

Equal Segregation of Alleles

Mendel proposed the Law of Segregation after observing that pea plants with two different traits produced offspring that all expressed the dominant trait, ***but the following generation*** *expressed the dominant and recessive traits in a 3:1 ratio*.

Observing that true-breeding pea plants with contrasting traits gave rise to **F1 generations** that all expressed the dominant trait and **F2 generations** that expressed the dominant and recessive traits in a 3:1 ratio, Mendel proposed the law of segregation.

1. **The law of segregation states that each individual that is a diploid has a pair of alleles (copy) for a particular trait. Each parent passes an allele at random to their offspring resulting in a diploid organism.**
2. **The allele that contains the dominant trait determines the phenotype of the offspring.**
3. **In essence, the law states that copies of genes separate or segregate so that each gamete receives only one allele.**

Diagrammatic scheme of breeding

Let: T = Dominant allele that controls tall phenotype

t = Recessive allele that controls dwarf phenotype

Cross between two pure-breeding parent generations:

Parent : Tall x Dwarf (Phenotype)

TT tt (Genotype)

Meiosis Meiosis

Gamete : (T) (t)

Fertilisation

F_1 generation : Tt (Genotype)

Tall (Phenotype)

Selfing of two F_1 generations:

Parent (F_1) : Tall x Tall (Phenotype)

Tt Tt (Genotype)

Meiosis Meiosis

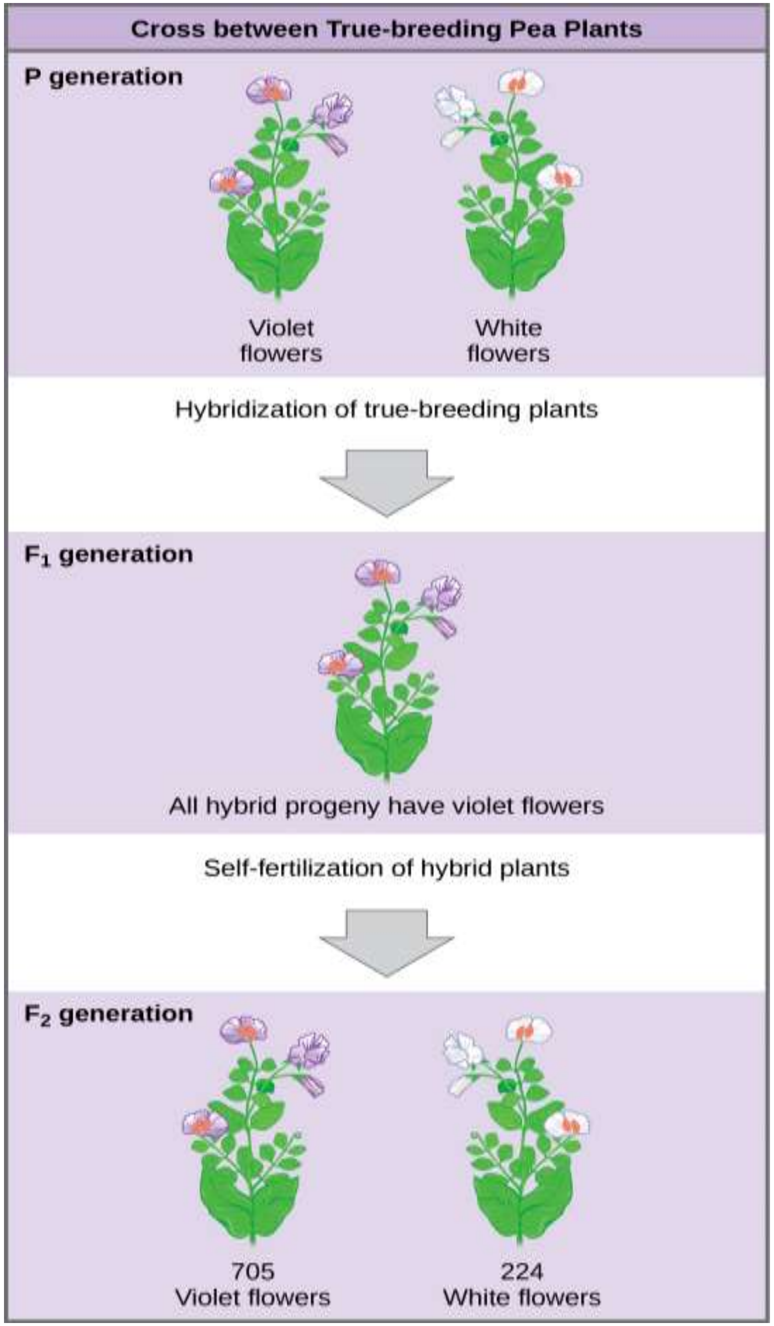
Gamete : (T) (t) (T) (t)

Fertilisation

F_2 generation : TT Tt Tt tt (Genotype)

Tall Tall Tall Dwarf (Phenotype)

The equal segregation of alleles is the reason we can apply the Punnett square to accurately predict the offspring of parents with known genotypes.



Law of Independent Assortment:

- Mendel's law of independent assortment states that genes do not influence each other with regard to the sorting of alleles into gametes: every possible combination of alleles for every gene is equally likely to occur.
- Independent assortment allows the calculation of genotypic and phenotypic ratios based on the probability of individual gene combinations.

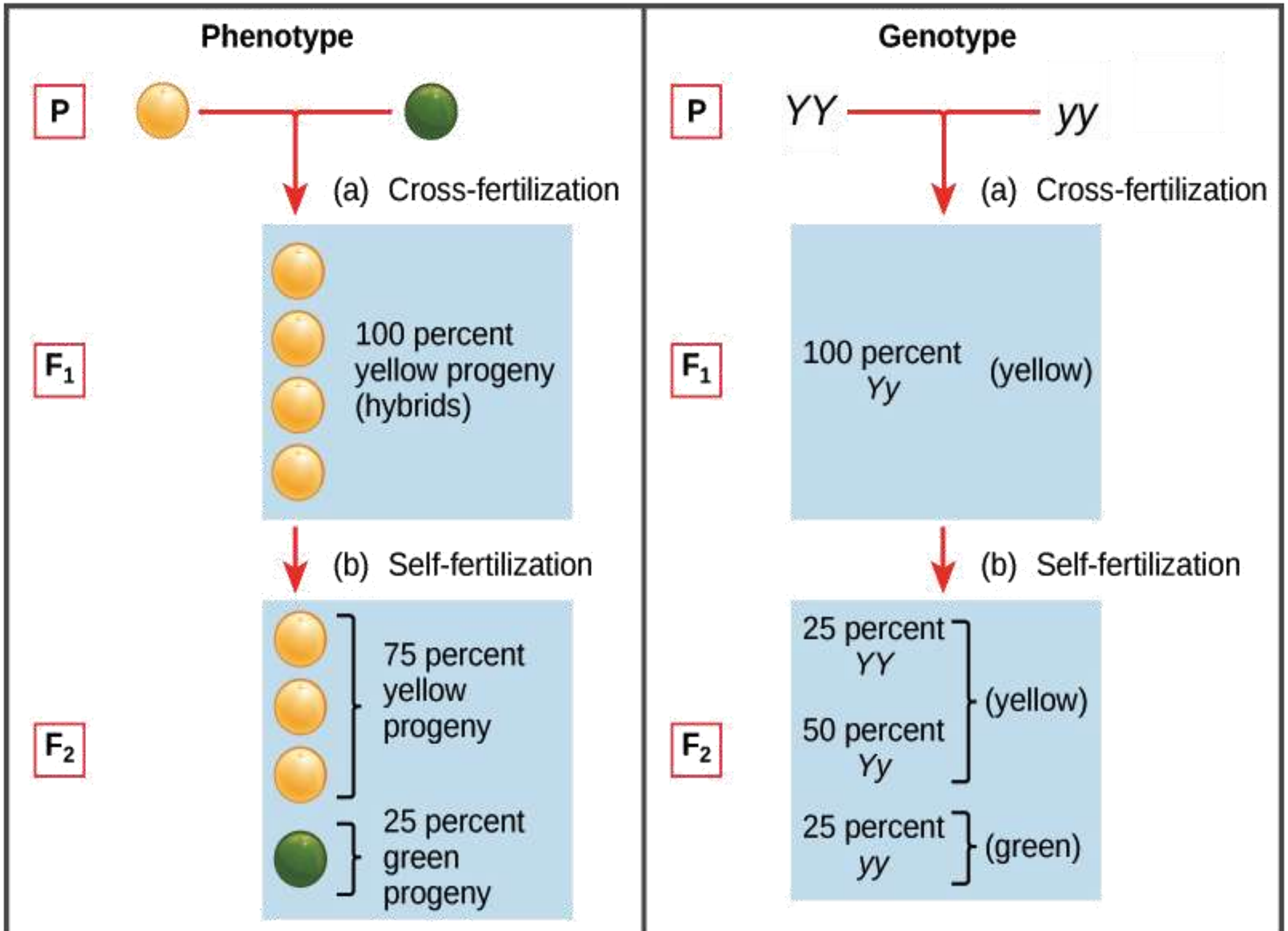
Key Terms & Points:

- In Independent Assortment, separate genes for separate traits are passed independently of one another from parents to offspring
- The calculation of any particular genotypic combination of more than one gene is, therefore, the probability of the desired genotype at the first locus multiplied by the probability of the desired genotype at the other loci.
- The **forked line method** can be used to calculate the chances of all possible genotypic combinations from a cross, while the **probability method** can be used to calculate the chance of any one particular genotype that might result from that cross.

- **Mendel's law of independent assortment states that genes do not influence each other with regard to the sorting of alleles into gametes: every possible combination of alleles for every gene is equally likely to occur.**
- The independent assortment of genes **can be illustrated by the dihybrid cross**: a cross between two true-breeding parents that express different traits for two characteristics.
- Consider the characteristics of seed color and seed texture for two pea plants: one that has green, wrinkled seeds (yyrr) and another that has yellow, round seeds (YYRR). Because each parent is homozygous, the law of segregation indicates that the gametes for the green/wrinkled plant all are yr, while the gametes for the yellow/round plant are all YR.
- Therefore, the **F1 generation of offspring all are YyRr.**

- ✓ For **the F2 generation**, the law of segregation requires that each gamete receive either an R allele or an r allele along with either a Y allele or a y allele.
- ✓ The law of independent assortment states that a gamete into which an r allele sorted would be equally likely to contain either a Y allele or a y allele.
- ✓ **Thus, there are four equally likely gametes that can be formed when the YyRr heterozygote is self-crossed as follows: YR, Yr, yR, and yr.**
- ✓ **Arranging these gametes along the top and left of a 4 × 4 Punnett square gives us 16 equally likely genotypic combinations.**
- ✓ **From these genotypes, we infer a phenotypic ratio of 9 round/yellow: 3 round/green: 3 wrinkled/yellow: 1 wrinkled/green.**
- ✓ These are the offspring ratios we would expect, assuming we performed the crosses with a large enough sample size.

Figure: Independent assortment of 2 genes:
This dihybrid cross of pea plants involves the genes for seed color and texture.



Independent assortment of 2 genes: This dihybrid cross of pea plants involves the genes for seed color and texture.

- **Because of independent assortment and dominance, the 9:3:3:1 dihybrid phenotypic ratio can be collapsed into two 3:1 ratios, characteristic of any monohybrid cross that follows a dominant and recessive pattern.**
- Ignoring seed color and considering only seed texture in the above dihybrid cross, we would expect that three-quarters of the F2 generation offspring would be round and one-quarter would be wrinkled.
- Similarly, isolating only seed color, we would assume that three-quarters of the F2 offspring would be yellow and one-quarter would be green.

- The sorting of alleles for texture and color are independent events, so we can apply the product rule.
- Therefore, the proportion of round and yellow **F2 offspring** is expected to be **(3/4) × (3/4) = 9/16**, and the proportion of wrinkled and green offspring is expected to be **(1/4) × (1/4) = 1/16.**
- These proportions are identical to those obtained using a Punnett square.
- Round/green and wrinkled/yellow offspring can also be calculated using the product rule as each of these genotypes includes one dominant and one recessive phenotype.
- Therefore, the proportion of each is calculated as:-

(3/4) × (1/4) = 3/16.

Punnet Square for Dihybrid cross