

2. MENDELIAN GENETICS

The term genetics was first used by W. Bateson in 1906. It is often described as a biological science which deals with heredity and variation. Heredity includes those characters which are transmitted from generation to generation and is therefore fixed for a particular individual. The differences among the individual of a species for a character constitutes the variation for that character. Variation on the other hand can be of two types.

1. Hereditary variation: refers to the differences in the inherited traits. Such variations are found not only in the progeny of different parents but also among the progeny from the same parents. Eg: Differences in pattern of stripes in zebra, differences in length of neck in giraffes.

Identical twins however are examples where there is no hereditary variation.

2. Environmental Variation: It is entirely due to environment.

Eg: 1. Difference in skin colour. 2. Under inadequate supply of water and N, a tall plant does not grow properly. So it may become dwarf.

The study of genetics, therefore, enables us to differentiate between hereditary and environmental variation. Questions pertaining to nature and the basis of heredity have occupied the thoughts of man for many centuries. But systematic attempts to seek answers to these questions began only in 18th century when several scientists began studies on plant hybridization. One of the notable workers is J. Koelreuter, who conducted extensive study on hybridization in tobacco. He noted uniformity and heterosis in F1 generation and appearance of variation in F2 generation. Gaertner used a backcross programme to convert one species into another. Other scientists like Naudin and Darwin also hybridized plants and studied the subsequent generations. However, they could not give an explanation for their results. Gregor Johann Mendel has first offered necessary explanation and hence he is known as “Father of Genetics”. With the help of experiments on garden pea, he was able to formulate laws which explained the manner of inheritance of characters. He presented his findings before the Natural History Society of Brunn in 1865. This paper entitled “Experiments in Plant

Hybridization” was presented in German language and published in the annual proceedings of the society in 1866. Although Mendel described his results in 1866, his work was recognized only in 1900 when his laws were re -discovered by Hugo devries, E.V. Tschermak and C.correns, Mendel’s original paper was republished in 1901 in the journal ‘Flora’ Vol. 89. Page 364.

Mendel’s experiments: Mendel chose garden pea (*Pisum sativum*) as the plant material for his experiments, since it has the following advantages.

- 1. Convenience of handling:** Peas could be grown easily either in field or in pots and each plant occupies only a small space.
- 2. Controlled mating:** The flower structure of pea ensures self-pollination, which was experimentally verified by Mendel. Individual pea plants are highly inbred displaying little if any genetic variation from one generation to the next. However, since the pea flowers are relatively large, emasculation and pollination is quite easy. Therefore, crossing could be carried out easily.
- 3. Short life cycle:** Peas complete their life cycle from seed to seed within 70 days, thus producing many generations in rapid succession.
- 4. Large number of fertile off-springs:** Hybrids resulted from crossing two pure strains (true breeding) were perfectly fertile and more in number. Pea seeds are large in size and do not have any problem in germination.
- 5. Presence of variation:** Peas have many sharply defined inherited differences like plant height (Tall vs. dwarf), seed shape (round vs wrinkled) etc. In the available varieties, several characters had two contrasting forms, which were easily distinguishable from each other. This permitted an easy classification of F₂ and F₃ progeny from various crosses into clear-cut classes. Although hybridization experiments were conducted by earlier workers also, they considered the individual as a whole complex of characters. Mendel’s success was based on the fact that he considered a single character at one time. Mendel chose seven pairs of contrasting characters for his study. In all the above crosses, he obtained a definite ratio of 3:1 in F₂ generation. The determining agent responsible for each trait

was called a factor. Since recessive character was not seen in F1 generation, but reappeared in F2, Mendel could predict the results to be expected in F3 generation.

Characters chosen by Mendel for his study

Character	Dominant form	Recessive form
1. Plant height	Tall	Dwarf
2. Seed texture	Round	Wrinkled
3. Seed colour	Yellow	Green
4. Flower colour	Violet	White
5. Pod colour	Green	Yellow
6. Pod shape	Inflated	Constricted
7. Position of flowers	Axial	Terminal

Reasons for success of Mendel:

1. The experiments were very well designed and conducted with great care and skill.
2. The choice of his experimental material, the common garden pea.
3. Mendel studied the inheritance of only one pair of contrasting characters at a time.
4. The characters he chose were well defined and simple; each with only two contrasting forms Eg: Seed coat colour of peas is either green or yellow, with no intermediate types.
5. The seven characters selected by Mendel showed qualitative inheritance.
6. The contrasting forms of each of the seven characters were governed by a single gene and in each case one form was completely dominant over other.
7. Of the seven characters studied by Mendel, the genes for two were located in one chromosome, while three others were present in another chromosome.
8. His greatest innovation was to count the number of progeny in each category to emerge from a given cross for every generation.

9. His knowledge on mathematics was a definite asset for the interpretation of his findings after subjecting the results to more refined mathematical analysis.
10. He maintained particulars of pedigree records, which gave him the exact ancestry of any given plant.

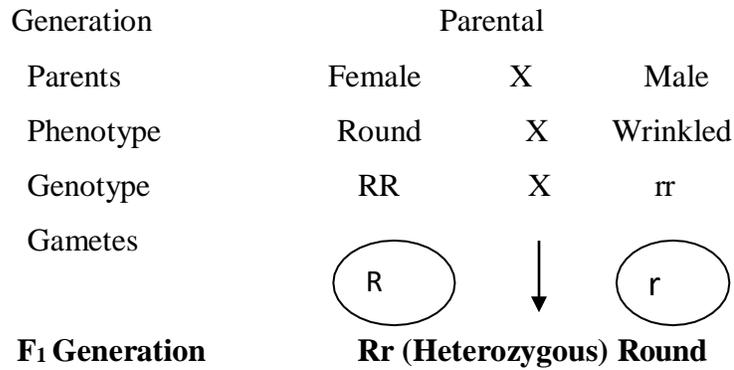
Mendelism / Laws of Mendel:

Mendel's cross breeding experiments with garden peas showed certain numerical relations among the progeny. The relationship between the character pairs and the kinds and the ratio of the progeny is known as Mendelism. Mendelism was not a theory of hereditary origin, but it was a theory of the manner in which inheritance had taken place. Mendelism can be summarized in the following laws and principals which are called Mendel's laws of inheritance.

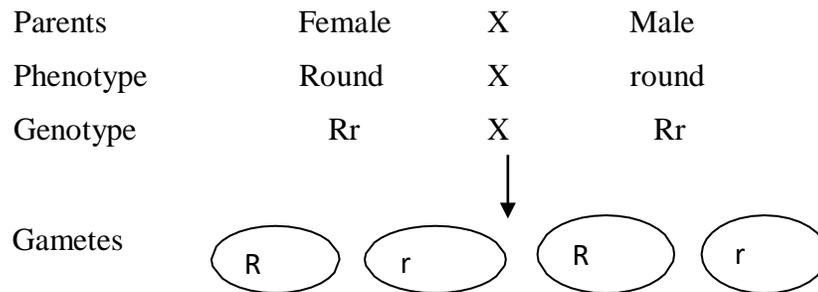
1. **The law of segregation or the law of purity of gametes:** It states that when a pair of alleles / allelomorphs is brought together in a hybrid (F₁) they remain together without contaminating each other and they separate or segregate from each other into a gamete in a complete and pure form during the formation of gametes. The law is universal in its application and it has been found to occur in plants as well as animals.
2. **Law of independent assortment:** The factors in an allelomorphic pair separates independently to the separation of factors in the other allelomorphic pair.
3. **Principal of Dominance:** States that in a hybrid one factor of the allelomorphic pair expresses itself completely over the other.
4. **Principal of unit characters:** State that each factor (gene) controls the inheritance of single character occurs in pairs in each diploid organism.

Explanation of Laws of Mendel:

Monohybrid ratio: The Mendel's first law i.e. Law of segregation or purity of gametes can be explained by considering the monohybrid ratio i.e. by studying inheritance of only one character. For example: In pea, round seed shape is dominant over wrinkled seed shape.



On selfing:



F₂ Generation

	R	r
R	RR Round	Rr Round
r	Rr Round	rr Wrinkled

Phenotype ratio: 3 round: 1 wrinkled

Genotypic ratio: 1 RR : 2Rr : 1rr

Two different alleles of the same gene i.e. 'R' and 'r' were brought together in the hybrid (F₁). Even though the hybrid was round seeded in the next generation (F₂) it produced both round and wrinkled seeded progeny. Thus, both the alleles for round shape (R) and wrinkled shape (r) remained together in the hybrid without contaminating each other. In F₂ generation (selfing of (F₁) hybrid), the different phenotypes could be recovered because the two alleles in F₁ remained pure and did not contaminate each other thus producing two types of gametes from F₁ i.e. (R)

and (r). The separation of homologous chromosomes during anaphase I of meiosis may be regarded as the reason for segregation of the two alleles of a gene. This is because the alleles of a gene are located in an identical position in the two homologous chromosomes.

Dihybrid Ratio:

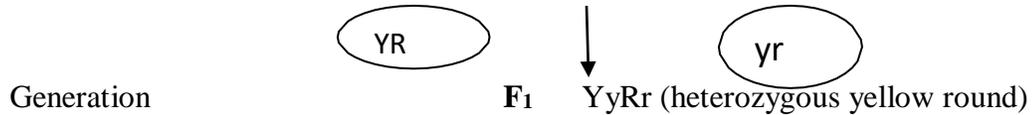
Mendel's second law i.e. Law of independent assortment can be explained by studying the inheritance of two characters at a time, simultaneously.

Independent segregation for two genes can be explained by assuming that the two genes are located in two different chromosomes. The two alleles of a gene will be located in the two homologues of the concerned chromosome. Independent separation of these two pairs of chromosomes at anaphase I of meiosis will lead to the independent segregation of the genes located in them. Thus, any allele of one gene is equally likely to combine with any allele of the other gene and pass into the same gamete. Independent segregation of two genes produces four different types of gametes in equal proportion. A random union among these gametes gives rise to sixteen possible zygotes. These zygotes yield a 9:3:3:1 phenotypic ratio, which is known as the typical dihybrid ratio.

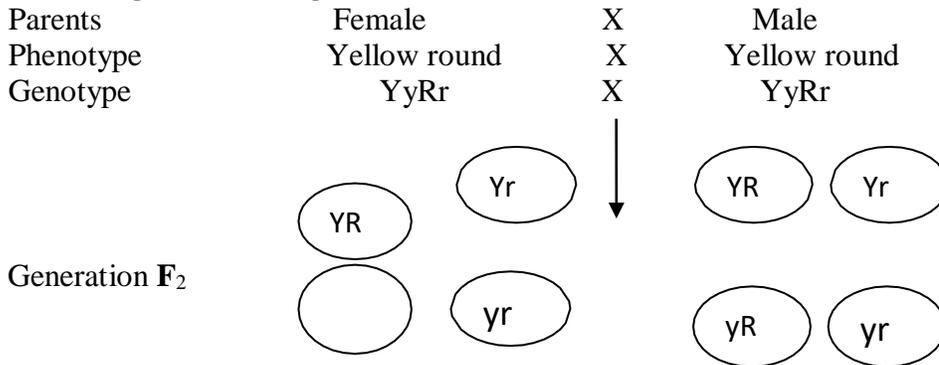
When two pairs of independent alleles enter into F1 combination, both of them have their independent dominant effect. These alleles segregate when gametes are formed but the assortment occurs independently at random and quite freely. Example: when plants of garden pea with yellow round seeds (Y Y RR) were crossed with plants having green wrinkled seeds (yyrr), yellow round seed plants (YyRr) were obtained in F1. Thus, yellow colour of seed exhibited dominance over green and round seed shape over wrinkled seed shape independently. The F1 produces four types of gametes YR, Yr, yR and yr. Selfing of F1 gives rise to yellow round, yellow wrinkled, green round and green wrinkled individuals in 9:3:3:1 ratio. This is possible only when the alleles of two genes controlling the two characters assort independently to one another.

Parents	Female	X	Male
Phenotype	Yellow round	X	Green wrinkled
Genotype	YYRR	X	yyrr

Gametes



On selfing/ intermating:



♀♂	YR	Yr	yR	yr
YR	YYRR Yellow round	YYRr Yellow round	YyRR Yellow round	YyRr Yellow round
Yr	YYRr Yellow round	YYrr Yellow wrinkled	YyRr Yellow round	Yyrr Yellow wrinkled
yR	YyRR Yellow round	YyRr Yellow round	yyRR green round	yyRr green round
yr	YyRr Yellow round	Yyrr Yellow wrinkled	yyRr green round	yyrr green wrinkled

Phenotypic ratio:

9 Yellow round: 3 Yellow wrinkled: 3 green round: 1 green wrinkled

Genotypic ratio:

1 YYRR: 2 YYRr: 1 YYrr: 2 YyRR: 4 YyRr: 2 Yyrr: 1 yyRR: 2 yyRr: 1 yyrr

Exceptions to Mendel's laws:

1. Paramutations and polyploidy are exceptions to the law of segregation or law of purity of gametes.
2. Linkage is an exception to Mendel's second law i.e. law of independent assortment.
3. Incomplete dominance is an exception to the principle of dominance.
4. Pleiotropism is an exception to the principle of unit characters.
5. Modification of F2 ratios due to incomplete -dominance, co-dominance, lethal factors, interaction of factors, epistatic factors are all exceptions.

However, Mendel failed to confirm his results when he worked with hawk weed, (*Hieraceum* sp.) because of the formation of embryo from the ovule without fertilization (diploid parthenogenesis) in this plant.