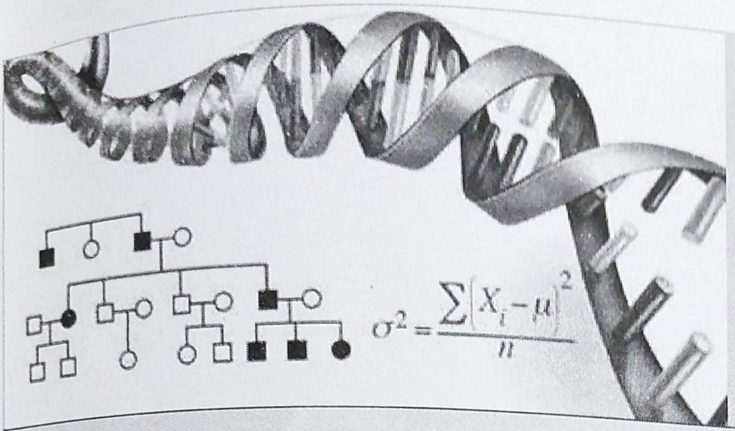

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History : Pre- and Post-Mendelian Concepts of Heredity

INTRODUCTION

The science of genetics is of recent origin. The foundation of genetics was laid by Mendel in 1866 when he derived basic principles of heredity. However, it was actually born in 1900 when Mendel's results were rediscovered independently by three scientists [Hugo de Vries from Holland, Carl Correns from Germany and Tschermak from Austria]. The term genetics was coined by William Bateson in 1905, a British biologist. The term genetics has been defined in various ways. Some definitions of genetics are given below.

1. The branch of biology which is concerned with the study of heredity and variation in living organisms is known as genetics.
2. Genetics is the scientific study of the principles of heredity and the variation of inherited traits among related organisms.
3. Genetics is the branch of biology that deals with heredity [mechanisms of transmission of traits from parents to their offspring] and the variation [resemblances and differences] of inherited characteristics among similar or related organisms.
4. Genetics is the study of the structure, composition and function of genes in an organism. In other words, it is the study of the genetic features and constitution of a single organism, species, or group.
5. Genetics is the branch of biology that studies heredity and variation in plants and animals.

BRANCHES OF GENETICS

There are two major branches of genetics, *viz.*, plant genetics and animal genetics. The branch of biology that deals with the principles of heredity and the variation of inherited traits in plants is referred to as plant genetics. There are five important areas of plant genetics, *viz.*, Mendelian genetics, quantitative genetics, radiation genetics, population genetics, molecular genetics, genomics and cytogenetics. These are defined as follows :

1. Mendelian Genetics: It deals with the inheritance of simply inherited or monogenic or oligogenic characters in plant species.

2. Quantitative Genetics: In this branch of plant genetics we study inheritance of those characters which are governed by several genes or polygenes. In other words, it is the study of quantitative traits. It is also known as biometrical genetics, statistical genetics or mathematical genetics. The foundation of this branch of genetic was laid by Nilsson Ehle, 1916 and Sir RA Fisher in 1918.

3. Radiation Genetics: The study of the effects of various types of radiations such as X-rays, gamma rays, alpha rays, beta rays, fast neurons, slow neutrons, etc. on chromosomes and genes is called radiation genetics.

4. Population Genetics: In this area of plant genetics, we study the frequency of genes and genotypes and effect of evolutionary forces on these frequencies in plant species. The foundation of this branch of genetics was laid by Hardy and Weinberg in 1908.

5. Molecular Genetics: In this branch of genetics, we study structure, composition and function of genetic material [DNA and RNA].

6. Genomics: This is a new branch or area of genetics which deals with the structure and function of genome in plant species.

7. Cytogenetics: This branch of plant genetics, deals with combined study of cytology and inheritance of traits in plant species.

HISTORY OF GENETICS

The history of genetics can be arbitrarily divided in two periods, *viz.*, pre-Mendelian era and post-Mendelian era. These are briefly discussed as follows:

A. Pre-Mendelian Era

Various views were prevalent about heredity before the discovery of laws of inheritance by Mendel. A brief account of pre-Mendelian concepts about heredity is presented as follows:

***(i)* Pre-formation Theory:** This theory states that development of human takes place from the miniature human [homunculus] already present in the egg and sperm. This theory was proposed by two Duch biologists, Swammerdam and Bonnet [1720-1793]. As this concept could not be proved scientifically, it was soon given up.

***(ii)* Theory of Epigenesis:** This theory states that development and differentiation of various body parts occurs from zygote after union of male and female gametes. This theory was proposed by Wolff, a German biologist [1738-1794]. This concept is universally accepted broad sense.

***(iii)* Theory of Acquired Character:** This theory states that a new character once acquired will pass on to the next generation. This theory was proposed by Lamarck [1744-1829]. This was disapproved by Weismann. He cut the tail of mice for 22 generations and always got the baby mice with tail. This concept is not accepted.

***(iv)* Theory of Pangenes:** This theory states that the new individual develops from small and invisible copies of the each body organ [gemules] transported to the gamets by blood. This concept was proposed by Charles Darwin [1809-1882]. This theory was soon givenup, because it did not have scientific basis.

***(v)* Germplasm Theory:** This theory states that transmission of characters from one generation to other takes place only through germplasm. This theory was proposed by Weismann [1889]. This theory is accepted in broad sense.

B. Post-Mendelian Era

The post-Mendelian era can be divided into three periods, *viz.*, (*i*) Classical era, (*ii*) molecular era and (*iii*) genomic era. Brief account of important concepts developed during these three eras is presented as follows:

***(i)* Classical Era:** The classical era started with the discovery of principles of inheritance in 1900. Important concepts developed during this era are presented as follows:

1. Rediscovery of Mendel's results by de Vries, Correns and Tschermak.
2. Mutation theory by de Vries [1901].
3. Chromosomal theory of inheritance by Sutton-Boveri [1903].
4. Laid the foundation of Population Genetics by Hardy and Weinberg [1908].
5. Laid the foundation of Quantitative Genetics by Nilsson Ehle in 1908.
6. Proposed Linkage theory by T.H. Morgan in 1910.
7. Proposed one gene one enzyme hypothesis by Beadle and Tatum [1941].

***(ii)* Molecular Era:** The molecular era started with the study of DNA and RNA molecules from 1944 onwards. The important concepts developed during this era are listed as follows:

1. Proposed double helical model of DNA structure by Watson and Crick in 1953.
2. First suggested triplet code by Gamov in 1954.
3. Operon hypothesis by Jacob and Monod in 1961.
4. Wobble hypothesis by Crick in 1966.
5. Lyon hypothesis in 1969 by Lyon.

***(iii)* Genomic Era:** This era started from 1972 onwards. During this period, the genome of several crop plants was sequenced. The important events in the history of genetics for three eras are presented in Table 1.1

TABLE 1.1 : Important Events in the History of Genetics

Year	Scientist(s)	Organism Used	Major Findings/Work
A. Classical Genetics			
1865	Gregor Mendel	Field Pea	Experiments on Plant Hybridization
1900	De Vries, Correns and Tschermak	Pea	Rediscovered Mendel's results.
1900	Hugo de Vries	Oenothera	Coined the term mutation.
1903	Walter Sutton	Pea	Chromosome rate hereditary units.
1905	William Bateson	Pea	Coined the term genetics.
1905	Bateson and Punnett	Pea	Gave coupling and repulsion phases of linkage.
1908	Hardy and Weinberg	Theoretical	Laid the foundation of population genetics.
1918	R.A. Fisher	Theoretical	Laid foundation of quantitative genetics.
1928	Frederick Griffith	Diplococcus pneumoniae	DNA is genetic material.
1941	Beadle and Tatum	Neurospora	One gene one enzyme hypothesis.
B. DNA Era			
1944	Avery, McLeod & McCarty	Diplococcus pneumoniae	DNA is genetic material.
1950	Erwin Chargaff	Theoretical	In DNA amount of adenine is equal to that of thymine.
1950	Barbara McClintock	Maize	Discovered jumping genes.
1952	Harshey & Chase	T22 Phage of *E. coli*	Genetic material is DNA.
1953	Watson and Crick	Theoretical	Proposed double helical model of DNA.
1954	Gamov	Theoretical	First suggested triplet code.
1958	Meselsson and Stahl		DNA replicates in semi-conservative mode.
1960	Jacob and Monod	*E. coli*	Proposed operon model of gene regulation in prokaryotes.
1966	Crick	Theoretical	Proposed Wobble hypothesis.
1969	Britten and Davidson	Theoretical	Proposed gene regulation model for eukaryotes.
1970	Tamin & Baltimore	HIV	Reported reverse transcription.
C. Genomic Era			
1972	Walter Fiers	Bacteriopage, MS2	Determined sequenced of a gene.
1976	Walter Fiers & Team	Bacteriopage, MS2	Determined complete sequence of genes.
1977	Sanger, Gilbert & Maxam	Bacteriophage ϕ-X174	Sequenced the entire genome.

1983	Kary Mullis	Theoretical	Discovered Polymerase Chain Reaction.
1995	Team of Scientists	*Haemophilus influenzae*	The entire genome was sequenced.
2000	Team of Scientists	*Arabidopsis thaliana*	Genome mapping was completed. Genome size is 125 Mb and genes are 25,500.
2002	Team of Scientists	Rice	Genome mapping was completed. Genome size is 430 Mb and genes are 56,000.
2005	Syngenta	Rice	A new variety called *Golden Rice 2.*
2005	A Team of Scientists	Rice	Sequenced Rice genome under International Rice. Genome Sequencing Project.
2006	Tuskan *et al.*	Poplar	Sequenced genome of poplar (*Populus tricocarpa*).
2007	Jaillon *et al.*	Grapes	Sequenced genome of Grapes and Papaya.
2008	Ming *et al.*	Apple	Sequenced genome of Applé.
2009	Scnable *et al.*	Maize	Sequenced genome of Maize.
2009	Paterson *et al.*	Sorghum	Sequenced genome of Sorghum.
2010	Schmutz *et al.*	Soybean	Sequenced genome of Soybean.
2010	Chang *et al.*	Castor	Sequenced genome of Castor bean.
2011	Varshney *et al.*	Pigeon pea	Sequenced genome of Pigeon pea.
2011	PGS Consortium	Potato	Sequenced genome of Potato.
2011	Wang *et al.*	Mustard	Sequenced genome of Mustard (*Brassica rapa*).
2012	Zheng *et al.*	Fox tail millet	Sequenced genome of Foxtail millet.
2012	Wang *et al.*	Flax	Sequenced genome of Flax.
2012	Wang *et al.*	Cotton	Sequenced genome of Cotton (*Gossypium raimondii*).
2013	Ling *et al.*	Wheat	Sequenced A genome of wheat (*Triticum urartu*).
2013	Genome Biology	Tobacco	Sequenced A genome of *Nicotiana sylvestris*.
2014	Kim *et al.*	Pepper	Sequenced Pepper (*Capsicum annuum*) genome.
2015	CSIR	Tulsi	Sequenced Tulsi (*Oscimum sanctum*) genome.

INVOLVEMENT OF OTHER DISCIPLINES

Important other disciplines which have played significant role in the advancement of plant genetics include cytology, biochemistry, biophysics, statistics and biotechnology. Each of these disciplines has played an important role in developing various genetic concepts which are presented in Table 1.2.

TABLE 1.2 : Disciplined Involved in Advancement of Genetics

S.No.	Name of Discipline	Helped in developing concept of
1.	Cytology	1. Cytological proof of crossing over.
		2. Sex determination.
		3. Locating genes on chromosomes.
		4. Parallel behaviour of chromosomes and genes.
2.	Biochemistry	1. DNA as genetic material.
		2. Double helical model of DNA.
		3. One gene one enzyme hypothesis.
		4. Gene regulation.
3.	Biophysics	1. DNA structure [X-ray diffraction].
		2. Gene amplification [PCR].
		3. Gene cloning and sequencing.
4.	Statistics	1. Quantitative genetics.
		2. Population genetics.
5.	Biotechnology	1. Genome mapping and gene sequencing.
		2. Genetic transformation.
		3. Development of transgenic plants.

PLANTS USED FOR GENETIC STUDIES

Various crop plants have helped in the developing of various genetic concepts. The plant species which have been widely used for genetic investigations include, garden pea (*Pisum sativum*), corn (*Zea Mays*), *Arabidopsis thaliana*. A brief account of various concepts developed using these plant species is presented below.

Garden Pea [*Pisum sativum* L.]

Garden pea belongs to the family Fabaceae. The somatic chromosome number of garden pea is 14. Important genetic concepts developed with garden pea are listed below.

1. Principles of heredity [by Gregor Mendel]
2. Coupling and repulsion phases of linkage [Bateson and Punnett]
3. Complementary gene interaction [Bateson]

Corn [*Zea mays* L.]

Corn belongs to the family Poaceae. The somatic chromosome number of corn is 20. Important genetic concepts developed with corn crop are listed below.

1. Cytoplasmic inheritance [Male sterility]
2. Jumping gene [Barbara McClintock]
3. Sex determination

4. Heterosis and inbreeding depression
5. Linkage and crossing over, etc.

Four O'Clock Plant [*Mirabilis jalapa*]

This plant has been rarely used for genetic investigations. The first case of incomplete dominance was reported in this plant. A cross between red and white flowered plants produced plants with pink colour in F_1 generation and red, pink and white flowered plants in 1:2:1 ration in F_2 generation.

Evening Primerose [*Oenothera lamarckiana*]

The somatic chromosome number of Oenothera is 14. The mutant plant was first discovered in Oenothera by Hugo de Vries in 1900. Later on balanced lethal system was discovered in this plant by Renner.

Arabidopsis thaliana

Arabidopsis is a weedy relative of mustard and belongs to the family Cruciferae. This plant has been widely used for genetic studies. In plants, genome mapping work was first completed in Arabidopsis in 2000. The genome size of this species is 125 Mb and 25,500 genes have been identified so far.

Rice [*Oryza sativa* L.]

Rice belongs to the family Poaceae and its somatic chromosome number is 24. This crop has been widely used for genome sequencing. The genome size of this species is 430 Mb and 56,000 genes have been identified so far. The genome mapping work of this crop was completed in 2002.

APPLICATIONS IN CROP IMPROVEMENT

Plant genetics has wide practical applications in the field of crop improvement. Major applications of plant genetics are improvement of crop plants and tracing genetic origin of various crop plants. These aspects are briefly discussed as follows :

1. Improvement of Field Crops: Various genetic concepts are widely used for development of superior varieties of field crops in terms of productivity, resistance to biotic [insects, diseases and parasitic weeds] and abiotic [drought, salinity, acidity, frost, heat, metal toxicity, etc.] stresses, wider adaptability, earliness, plant stature and quality of economic product. Both true breeding varieties and hybrid varieties of field crops, vegetable crops and horticultural crops can be developed using genetic principles.

2. Tracing Genetic Origin: The second important application of plant genetics is tracing genetic origin of crop plants. The genetic origin of various crop plants such as wheat, cotton, tobacco, maize, oats and many other crops has been traced through polyploidy and interspecific hybridization.

3. Creation of New Crops: Plant genetics has played significant role in the development of new crop species. Triticale is the best example of such application.

4. Characterization: DNA finger printing is useful in the characterization of crop cultivars and germplasm and thus developing varietal information system and genepool data base in termps of molecular characterization.

QUESTIONS

1. Define plant genetics. What are areas of plant genetics?
2. Describe in brief the history of plant genetics.
3. Discuss the concepts developed during the period of classical genetics.
4. Discuss the concepts developd during DNA era of plant genetics.
5. Define the following terms
   (*i*) Mendelian genetics
   (*ii*) Quantitative genetics
   (*iii*) Radiation genetics
   (*iv*) Population genetics
   (*v*) Cytogenetics
   (*vi*) Molecular genetics
   (*vii*) Genomics
6. Describe the role of various discipline in the development of plant genetics.
7. Give a brief description of various plants used for genetic investigations and concepts developed.
8. Describe briefly various applications of plant genetics in crop improvement.
9. Describe the contribution of following scientists:
   (*a*) Gregor Mendel
   (*b*) Jacob and Monod
   (*c*) Barbara McClintock
   (*d*) Beadle and Tatum
10. Describe the contribution of following scientists:
    (*a*) Hugo de vries
    (*b*) William Bateson
    (*c*) Britten and Davidson
    (*d*) Temin and Baltimore
11. Give list of Nobel Prize winners in genetics. Describe contribution of any three of them.

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