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Preface

Genetics, the science of heredity, is the unifying science in biology covering all organisms in the universe. The laws of heredity are universal. The study of chromosomes, the bearer of genes, vehicles of heredity, are basic to genetics. The analysis of chromosomes in the finest details from cellular to molecular level provide with an idea of location and behaviour of genetic material essential for the study of genetics. The cell science or cytology, covering chromosomes and cell organelles, is thus a prerequisite for the study of genetics. Thus the two disciplines, the cytology and genetics, the cytogenetics gives an integrated picture of the genetic material, its behaviour and transmission in heredity. Simultaneously, the evolution of organisms differing from each other, originate primarily through changes in genes, either in number or structure. As such, this book covers all the three disciplines, namely, Cytology, Genetics and Evolution.

The science of genetics, owes its initiation to the discovery of Mendelian laws and concept of chromosomes by Baranetsky in the latter half of the nineteenth century. A concrete shape of the science of heredity was given at the beginning of twentieth century. A breakthrough in the knowledge of exact chemical nature of the gene and its mechanism of expression, was the discovery of double helical configuration of DNA by Watson and Crick in 1953 which could explain all the properties of genes. This was followed by a series of inventions leading to the establishment of the language of heredity. The concept of the genetic code explaining the mechanism of translation of nucleic acid language of genes to the amino acid language of protein was a signal development. Once the nature of the gene and genetic code was realized, tremendous developments in technique led to the fact, that the genes can now be isolated, synthesized, analyzed and can be manipulated and transferred directly

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Introduction

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All organisms collectively grouped under different species, represent a specific set of characters which differentiate one species from another. Each character on the other hand is controlled by a gene or a set of genes. As such every character be it a flower, a leaf or a root is the manifestation of ultimate expression of a series of biochemical reactions triggered at the gene level. The genes on the otherhand lie in a linear order in the chromosome, the latter maintaining a constancy in number in the species. The chromosomes are located inside the nucleus, which is the most important organelle of the cell. However in the plant system, the genetic material also exists in two other organelles, namely, chloroplastids and mitochondria. The former is involved in the process of photosynthesis and the latter in respiration.

The multitude of cells ultimately constitute the different organs vis-à-vis the entire body itself. The expression of diverse characters in an organism is a reflection of diversity of its gene content and their expression.

CYTOLOGY

The *cytology* and *cell science* deals with an understanding of cell structure and function of its constituents. The structural characteristic and functional details of all cell organelles with special emphasis on the most important component—the nucleus, come within the purview of cytology. The way in which the chromosome—the vehicles of hereditary material—the genes, behave in the life of an organism obviously comes within the scope of *cytology or cell science*. In fact, cytology deals with all organelles of the cell including the details of structural characteristics of chromosome, the physical and chemical, and their behaviour both in the somatic and reproductive cells. The influence of their behaviour on the maintenance of hereditary stability on the one hand and diversity on the other leading to origin of species too, come within its purview.

GENETICS

Genetics by implication, is the science of genes and heredity. The study of genes, its physical and chemical characteristics as well as its property and behaviour form the main theme of genetics. The way through which genes replicate and perpetuate in different biological systems and the mechanism of gene expression controlling all characters form some of the basic themes of genetics. The mechanism through which the nucleic acid language of heredity is translated into the amino acid language of proteins and enzymes constitutes genetic code. The different factors which affect the expression of gene as well as their interaction with each other, come under the category of gene interaction. The mapping of gene in chromosomes, utilizing the data of linkage and crossover in meiosis, and the correlation between the genotypes and phenotypes follow some of the established concepts of genetics. The characteristic behaviour of cytoplasmic genes as well as their involvement in sex differentiation are also included within the scope of genetics.

CYTOGENETICS

Cytogenetics on the other hand deals with all aspects of genetic behaviour as can be studied at the cellular level. The expression of genetic behaviour originating at the cellular level and culminating at the expression in the phenotype is within the scope of cytogenetics. The chromosome study in detail, its behaviour in replication, reproduction, organ development as well as evolution of species are included within the discipline of cytogenetics. The origin and analysis of genome as deduced at the chromosome level and their behavioural characteristics in hybrids and mutants, also come within domain of cytogenetics. The identification of gene sequences at the chromosome level, and through cytological and genetic method, form an important component of cytogenetics as well. The cytogenetics being a overlapping discipline area, it is often very difficult to demarcate the border between genetics and cytogenetics. In practice, the cytogenetics is concerned with all aspects of cellular behaviour with special reference to chromosomes, cell cycle differentiation, reproduction, hybridization and evolution.

CHRONOLOGY OF CHIEF EVENTS

Year	*Investigator/s*	*Event*
1665	Robert Hooke	Discovered cell
1831	Robert Brown	Described presence of nucleus in cell
1838	M. J. Schleiden & T. S. Schwann	Formulated Cell Theory
1861	Schultzee	Proposed Protoplasm Theory
1866	Gregor Johann Mendel	Formulated the Laws of Heredity

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1870	F. Meischer	Isolated nucleoprotein
1879	W. Flemming	Described chromatin in nucleus
1882	W. Flemming	Described cell division (Mitosis)
1883	Schimper	Named chloroplasts
1885	O. Hertwig & E. Strasburger	Proposed the role of nucleus in heredity
1888	W. E. Waldeyer	Described chromosomes
1898	C. Benda	Named mitochondria
1898	C. Golgi	Described Golgi complex
1902	C. E. McClung	Discovered sex chromosomes
1903	W. S. Sutton	Propounded Chromosome Theory
1905	J. B. Farmer & J. E. Moore	Coined the term Meiosis
1910	T. H. Morgan	Discovered linkage
1913	A. H. Strutvant	Built up the first chromosome map
1927	H. J. Muller	Artificially induced mutation by x-ray irradiation
1931	C. Stern, H. Creighton & B. McClintock	Cytologically demonstrated crossing over
1937	A. E. Blakeslee	Induced polyploidy with colchicine
1941	G. W. Beadle & E. L. Tatum	Propounded one gene one enzyme theory
1949	L. Pauling	Demonstrated that protein structure is under genetic control
1950	B. McClintock	Proposed the concept of jumping gene
1952	M. Chase & A.D. Hershey	Showed that the gene is DNA
1953	J.D. Watson & F.C. Crick	Demonstrated double helical model for DNA
1955	A. Kornberg & S. Ochoa	*In vitro* synthesis of nucleic acid
1957	Seymour Benzer	Gave the concept of cistron, recon & muton
1958	M.S. Meselson & F.W. Stahl	Experimentally confirmed semiconservative replication of DNA
1958	F.H.C. Crick	Proposed the central dogma of molecular biology
1961	F.H.C. Crick	Evidenced the triplet nature of the genetic code
1961	M.W. Nirenberg & J.H. Mathaei	Deciphered the genetic code
1961	F. Jacob & J. Monod	Proposed operon concept
1970	H. Khorana	Synthesized an artificial gene from DNA nucleotides
1970	H. Temin & D. Baltimore	Discovered reverse transcription
1972	Paul Berg	Use of restriction enzyme to produce recombinant DNA
1973	Stanley Cohen & Herberd Boyer	Genetic engineering

contd.

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1974	A. Claude & G. Palade	Ultrastructure of cell
1974	T. Kornberg	Propounded nucleosome model of chromosome
1975	E. M. Southern	Southern blotting
1976	Clarke & Carbon	c-DNA library
1977	A.M. Maxam & W. Gilbert, Frederick, F. Sanger & Coulson	Sequencing of DNA
1979	Alwine *et al*	Northern blotting
1980	Zambryski, Van Montagu & Schell	Development of transgenic plant (*Agrobacterium* mediated)
1981	Harbes, Jahner & Jaenisch	Transgenic mice development
1983	Zimmerman *et al*	Direct DNA transfer by electroporation
1997	Clayton *et al*	Complete genome sequencing of unicellular organism (yeast)
2000	*Arabidopsis* Genome Initiative	Genome sequencing of *Arabidopsis thaliana*
2001	Craig Venter (Human Genome Project)	Complete sequencing of human genome
2002	Goff *et al*, Yu *et al*	Rice genome sequencing

Cell 2

The *cell* is "the basic structural and functional unit of living organisms", capable of carrying out all the activities necessary for life. *Robert Hooke* in 1665 observed hollow spaces in thin slices of cork under microscope which were termed by him as cells (L., *cella*—hollow space). In 1838, *Schleiden and Schwann* discovered that tissues of all living organisms consist of cell which is referred as the *Cell Theory*.

PROKARYOTIC CELL VS. EUKARYOTIC CELL

Two types of cells are recognized namely prokaryotic and eukaryotic cells. *Prokaryotic cells* do not have membrane bound nucleus (Fig. 2.1) e.g. Bacteria, Blue green algae. *Eukaryotic cells* have membrane bound nucleus (Fig. 2.2A & B) e.g. most plants and animals. Prokaryotes and eukaryotes differ fundamentally in many ways (Table 2.1).

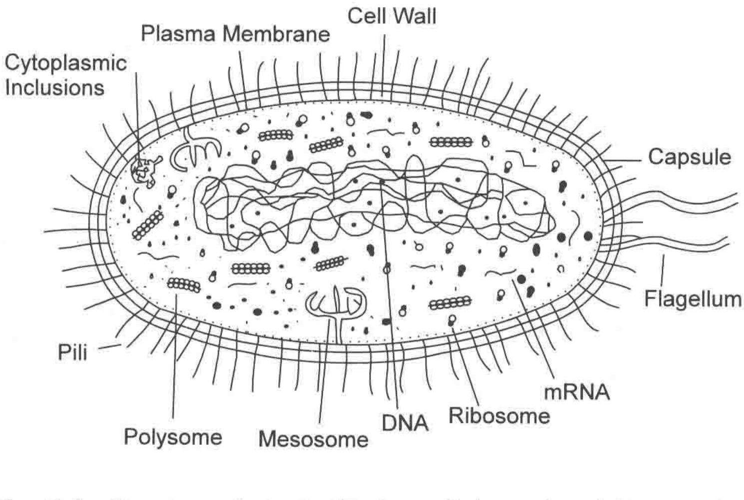

Fig. 2.1 Structure of a typical Prokaryotic bacteria cell (From Dubey & Maheshwari 1999).

Table 2.1 Differences between prokaryotic and eukaryotic cells.

Features	*Prokaryotic cell*	*Eukaryotic cell*
1. Size	Mostly 1-10 μm	Mostly 10-100 μm
2. Organization	Unicellular, rarely multicellular	Multicellular, rarely unicellular
3. Cell wall	Present in most but not in all cells; with mucopeptide	Present in plant and fungal cells; without mucopeptide
4. Nucleus	Absent	Present
(i) Nuclear membrane	Absent	Present
(ii) Nucleolus	Absent	Present
(iii) Chromatin with histone	Absent	Present
(iv) Genetic material	Circular or linear double stranded DNA; genes are not interrupted by intron	Linear double-stranded DNA; genes frequently interrupted by intron
(v) Mitotic apparatus	Absent	Present
5. Cellular organelles	Not membrane bound	Membrane bound except ribosome
(i) Mitochondria	Absent	Present
(ii) Endoplasmic reticulum	Absent	Present
(iii) Lysosomes	Absent	Present
(iv) Chloroplasts	Absent	Present (only in plants)
(v) Centrioles	Absent	Present (only in animals)
(vi) Ribosomes	Present (70S – 50S + 30S)	Present (80S - 60S + 40S)
(vii) Microtubules	Absent	Present
6. Vacuoles	Absent	Present
7. Flagellae	Simple structure composed of the protein flagellin	Complex 9 + 2 structure of tubulin and other protein

PLANT CELL VS. ANIMAL CELL

The plant cell differs from animal cell in many respects (Table 2.2 and Figs. 2.2, 2.3).

Table 2.2 Differences between animal cell and plant cell

Animal cell	*Plant cell*
1. Cell wall is absent	1. Cell wall is present
2. Plastid is absent except few protozoans	2. Plastids are present
3. Vacuoles are many and small	3. Large mature vacuoles are present in cells
4. Centrosome is present	4. Centrosome is absent

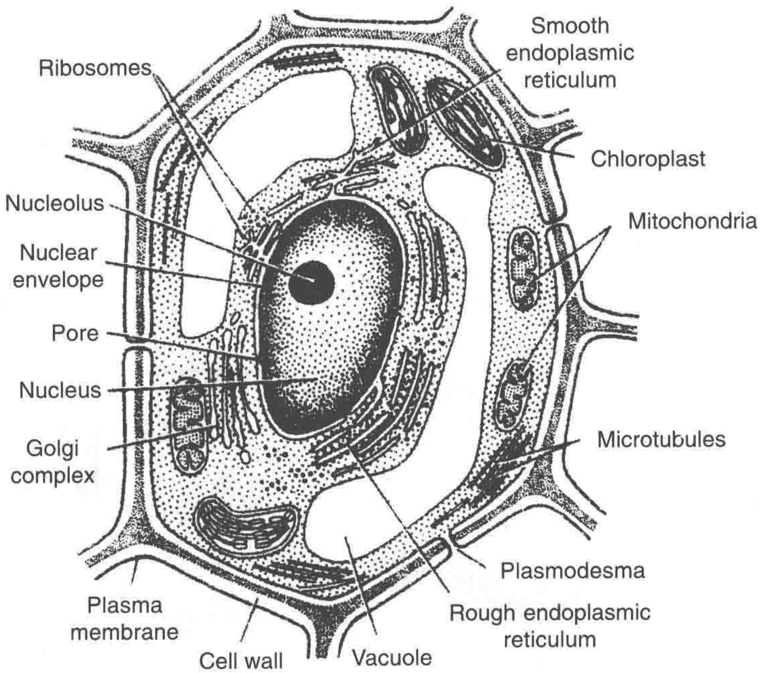

Fig. 2.2 Structure of a typical eukaryotic plant cell (From P.K. Gupta 1999).

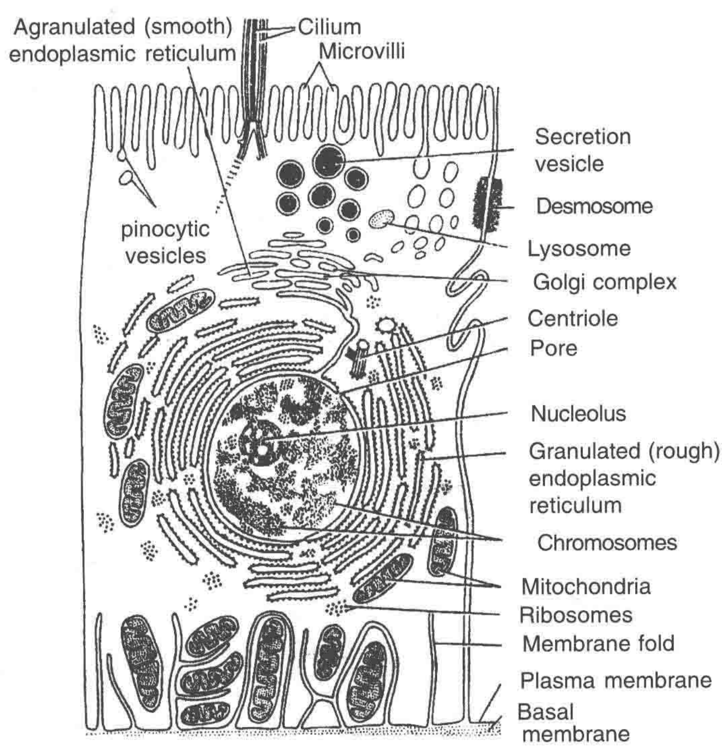

Fig. 2.3 Structure of an eukaryotic animal cell (From P.K. Gupta 1999).