Unit

8

Biotechnology

After studying this chapter the students will be able to:

- Describe the structure and function of nucleus and the importance of hereditary material (Chromosomes, genes, RNA, DNA) found in it.
- Identify the relationships among nucleic acids (DNA and RNA), genes and chromosomes.
- Describe the molecular basis of heredity including DNA replication.
- Describe the purpose and processes of cellular reproduction.
- Explain the common genetic disorders
- Analyze the role of genetic engineering and biotechnology in the present world.
- Investigate careers that require an understanding of reproductive biology.

INTRODUCTION

All living organisms have the ability to produce the organism of their own kind by sexual or asexual mode of reproduction. Genetic traits are transmitted to the next generation by the process of reproduction and this characteristic of living organisms is known as heredity. During sexual reproduction the union of male and female gametes occur. The offsprings produced by this method resemble their parents but are not exactly identical to them or to each other. In a sexually reproducing species, the offsprings inherit genes from their two parents and therefore, possess unique traits. Therefore, no two organisms are exactly alike. The unlimited differences among living organisms are known as variations.

The field of science dealing with heredity and variations is called genetics. With the advent of technological advancements in the field of biology, separate disciplines of investigation have arisen. Among these, biotechnology is one of the leading fields of biology which has tremendous implications on our day to day life.

Biotechnology is defined as the use of living microorganisms or biological processes for industrial, agricultural or medicinal processes for the welfare of man. Man has been using the ability of the microorganisms to carry out fermentation for hundreds of years to produce foods such as yogurt, cheese, bread, etc. All these substances are made by fermentation process brought about by yeast, bacteria or fungi. Citric acid is produced commercially by the action of bacteria or fungi whereas the antibiotic penicillin is produced by mould fungi or bacteria. In this chapter you will study the nature of genetic material and application of biotechnology and genetic engineering in your daily life.

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8.1 NATURE OF HEREDITARY MATERIAL

In the previous classes you have studied a brief description about the cell and its organelles. Recall that a typical cell consists of; cell wall (in case of plant cell), cell membrane, cytoplasm with organelles and the nucleus. In the following section you will study more about structure and function of nucleus and the importance of hereditary material found in it.

8.1.1 NUCLEUS

Nucleus is a spherical structure found in the center of animal cell and young plant cell but it occupies a peripheral position in a mature plant cell. Nucleus is the most prominent organelle in the cell which constitutes about 10 percent of the cell's volume. Nucleus is separated from the cytoplasm by the nuclear membrane. Generally a cell has only one nucleus (uninucleate). However, in some cells the nucleus is absent (enucleate), for example, red blood cells. Whereas some cells consist of two or more nuclei (multinucleate), for example, slime moulds.

Structure of Nucleus

A nucleus consists of a nuclear membrane, nucleoplasm, nucleolus and chromosomes. Nucleoplasm,(also known as karyoplasm) is the matrix present inside the nucleus.

Nuclear Membrane

Nuclear material is enclosed in a nuclear membrane which is double-layered membrane. The outer layer of this membrane is connected to the endoplasmic reticulum. A fluid-filled space is present between the two layers of a nuclear membrane. The nuclear membrane has several openings called nuclear pores. These pores provide a passage for exchange of materials like different types of proteins and ribonucleic acids between the nucleus and cytoplasm.

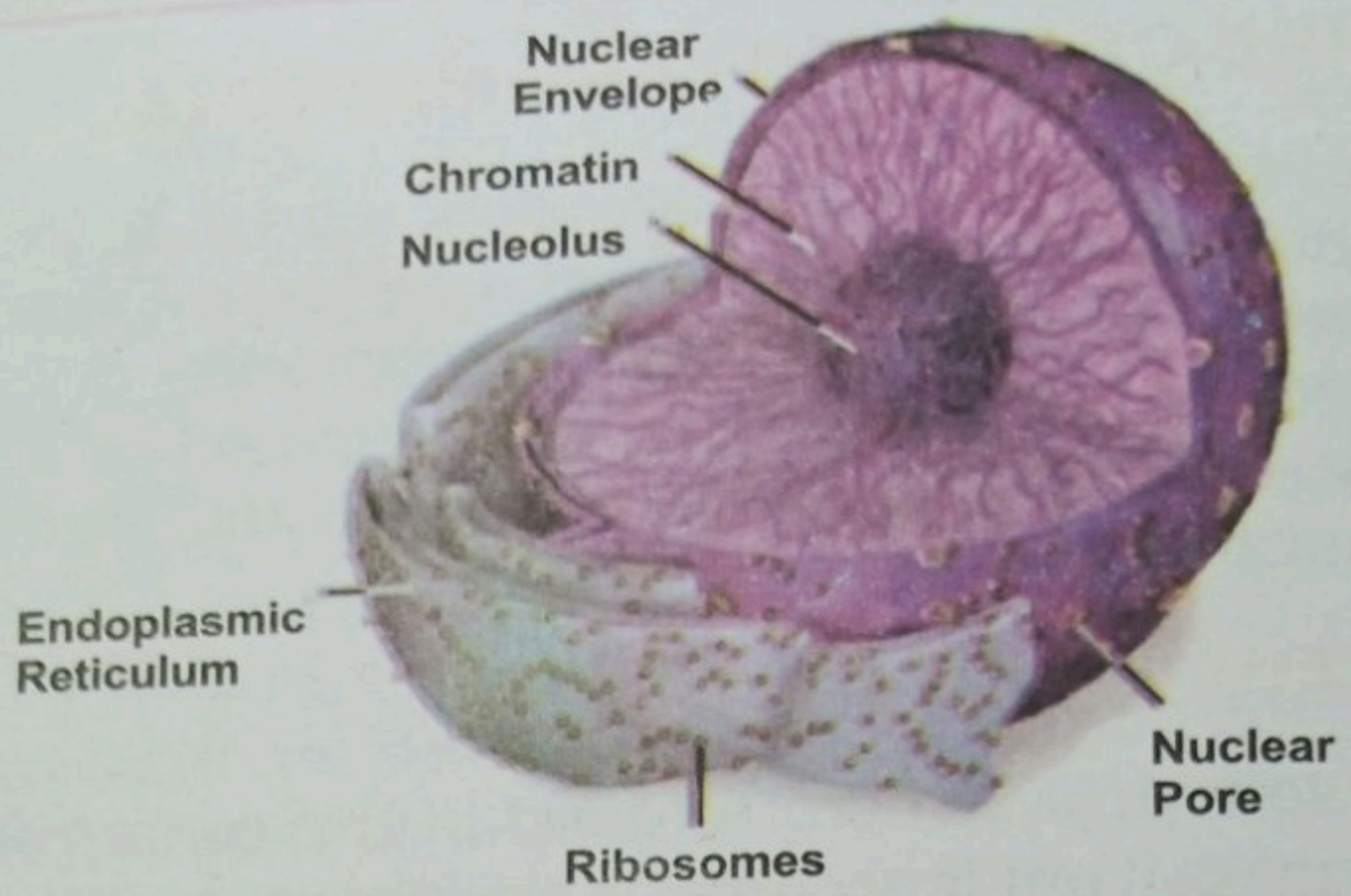
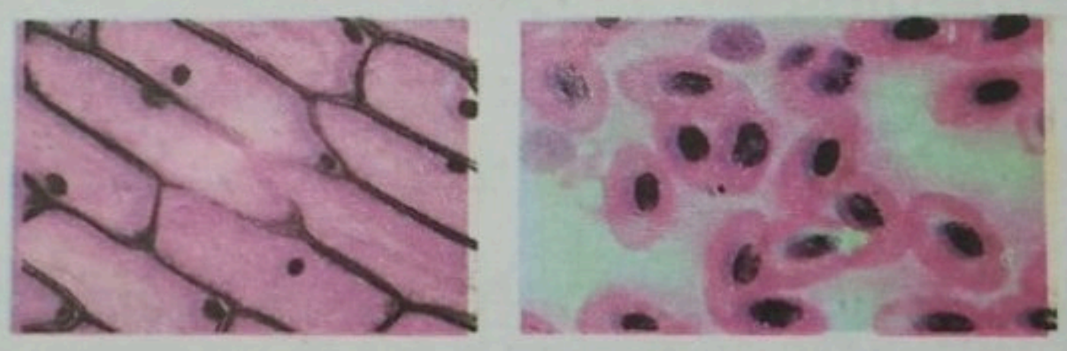


Fig: 8.1 Structure of nucleus.

ACTIVITY

Observe under the microscope peeled epidermal cell of onion and frog blood cells with the help of prepared slides.



FOR YOUR INFORMATION

Difference between Prokaryotic and Eukaryotic Cells

Biologists have divided cells into two types, namely prokaryotic and eukaryotic cell. The organisms made of prokaryotic cells are called prokaryotes. Prominent differences between prokaryotic cell and Eukaryotic cell is that prokaryotes are without a membrane bound nucleus and eukaryotic cells have membrane bound nucleus. Examples of Prokaryotes are bacteria and blue green algae. Examples of eukaryotes are all other unicellular and multicelluar organisms such as algae, plants and animals.

Chromosomes

The nucleoplasm (protoplasm of the nucleus) contains chromatin network and one or two nucleoli. During cell division, the chromatin network is converted into thick, uncoiled thread like structures called chromosomes. Each chromosome is composed of deoxyribose nucleic acid (DNA) and a protein called histone.

Chromosome carry genetic information in the form of genes which are transmitted from one generation to another.

Number of chromosomes is specific in each species, for example, it is 46 in man, 26 in frog, 14 in pea, 48 in potato and so on.

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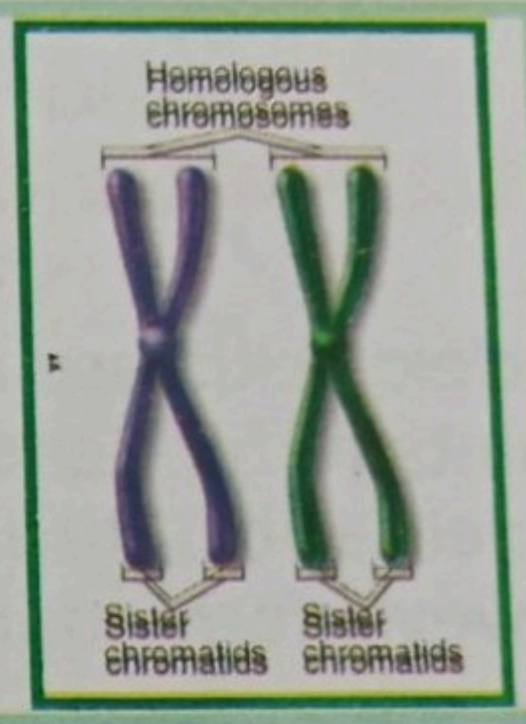
Chromosomes in an organism are present in pairs and these pairs are called homologous chromosomes because in each pair shape and size of the chromosomes are identical.



Nucleolus

Besides chromosomes, the other prominent structures in the nucleus, are the nucleoli. They are dark staining bodies. There may be one or more nucleoli per nucleus, generally depending on the species. They are composed of DNA and protein. From the DNA of the nucleoli ribosomal RNA (rRNA) is made. Nucleoli are responsible for the manufacturing and exporting to the cytoplasm the material responsible for the production of the ribosomes on which protein are synthesized.

Functions of Nucleus

Following are some of the important functions of the nucleus.

- Nucleus is the site of storage of hereditary material in the form of genes. It also stores different types of proteins and RNA in the nucleolus.
- Messenger RNA (mRNA) and ribosomes are formed in the nucleus which are responsible for protein synthesis.
- It is a site for the exchange of hereditary molecules (DNA and RNA) between the nucleus and the rest of the cell.
- When cell divides, chromatin network breaks into chromosomes which are then equally transmitted into offsprings.

8.1.2 Nucleic Acids, Genes and Chromosomes

Nucleic acids are a major class of organic compounds required to maintain life. Genes are the heredity material and are composed of nucleic acids. Nucleic acids are also the messenger substances that convey information from the genes to the rest of the cell.

Nucleic acid molecules are long polymers of smaller building-block units called nucleotides which are composed of still smaller parts; a 5-carbon sugar, a phosphate group, and a nitrogen- containing base.

Nitrogenous bases are of four types namely, adenine, guanine, thymine and cytosine. Both the phosphate group and the nitrogenous base are covalently bonded to the sugar molecule.

DNA is a polynucleotide chain. The most important fact about DNA is that it has a specific sequence of nitrogenous bases, which carries information in the form of genes that can be transferred from generation to generation. This genetic information is needed to produce countless number of proteins from various combinations of twenty amino acids. The four different types of bases can be arranged in any linear order along a strand of DNA. Each sequence of bases represents a unique set of genetic instructions.

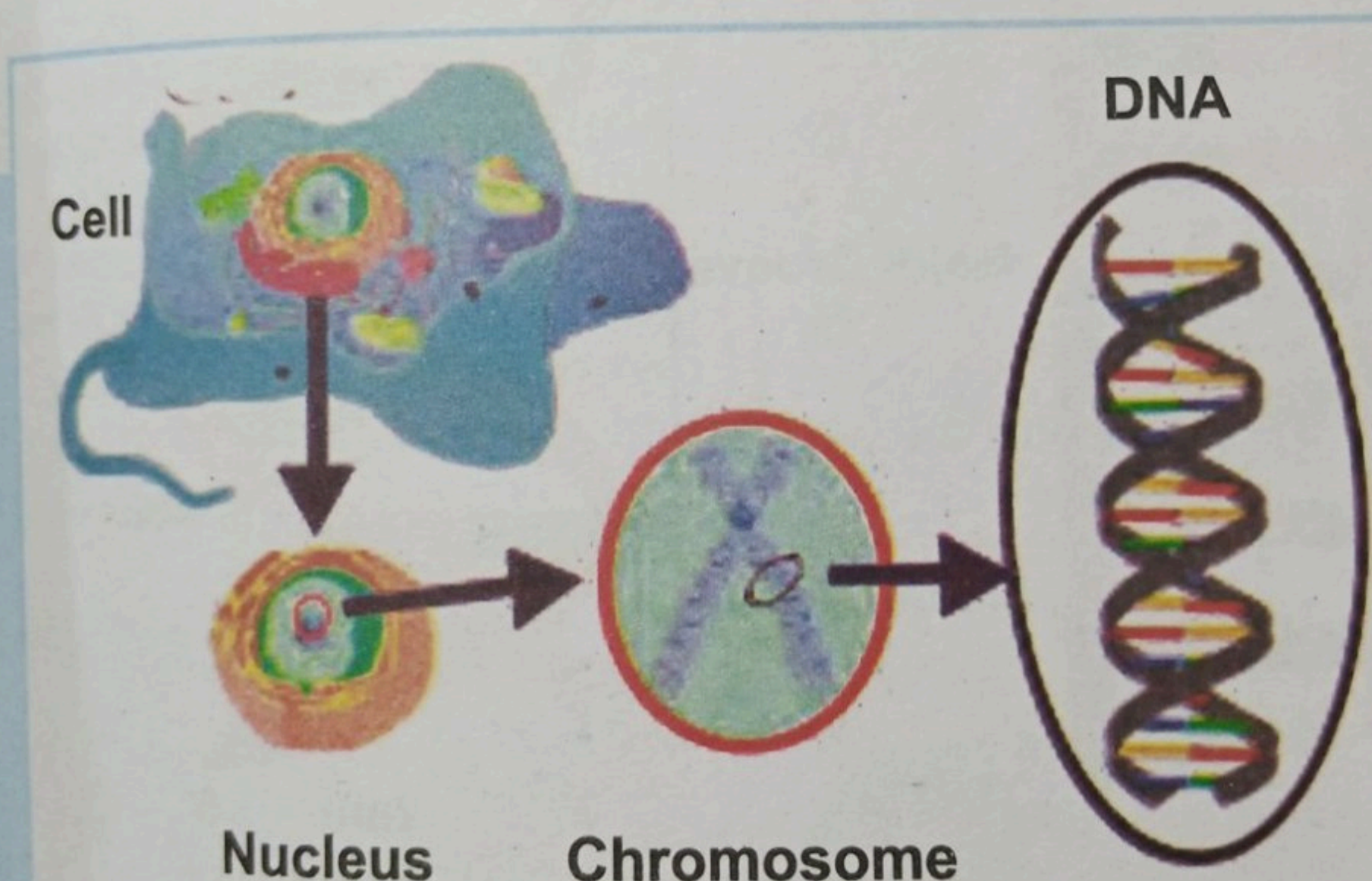


Fig: 8.2 Location of DNA in a cell.

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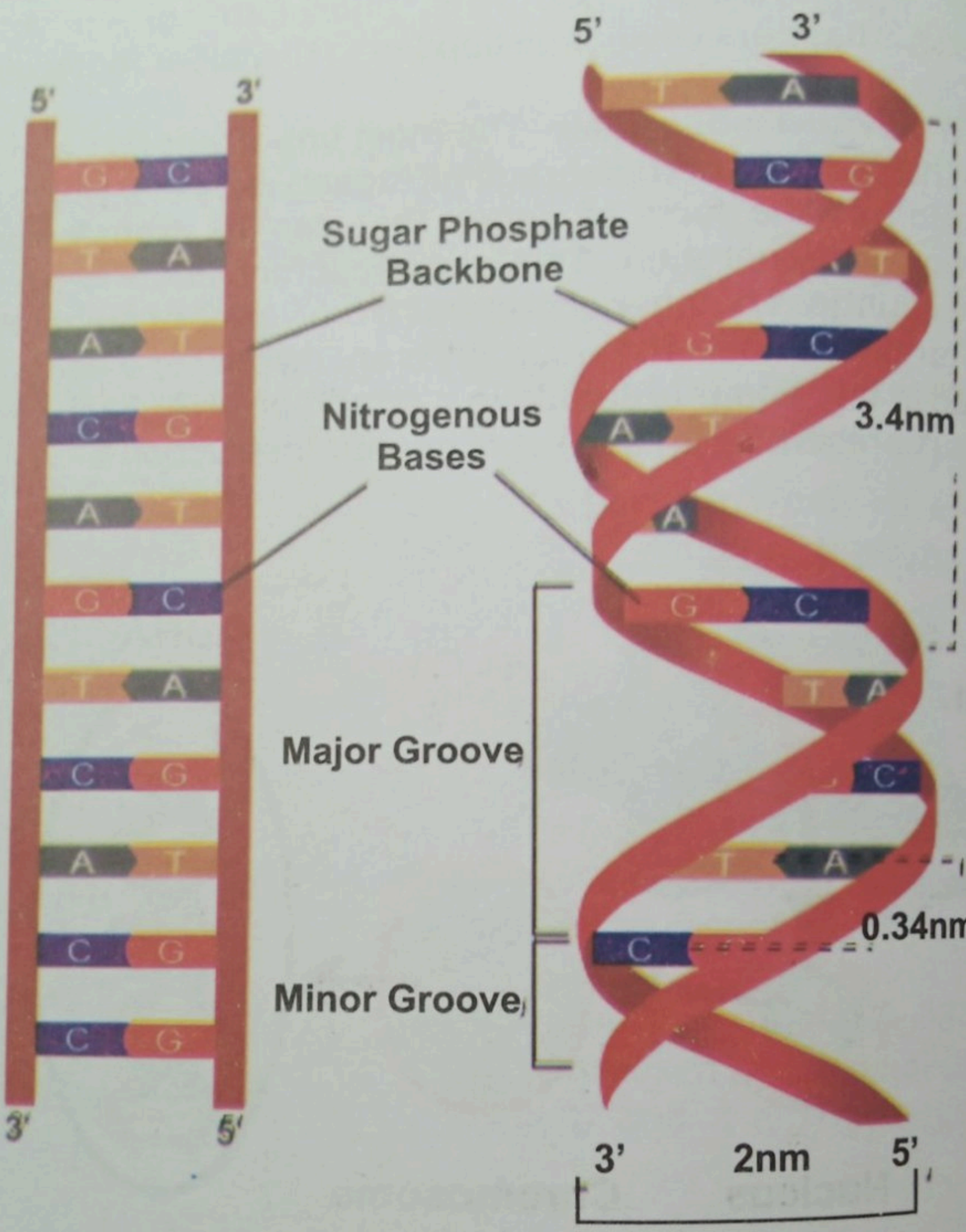

Fig: 8.3 Structure of DNA.

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RNA as a carrier of information

DNA is not directly involved in protein synthesis and is just the store house of genetic information that is transferred to RNA. There are three types of RNA i.e. messenger RNA or mRNA, transfer RNA or tRNA and ribosomal RNA or rRNA. Each has its own specific role in protein synthesis. The messenger RNA (mRNA) carries information from the DNA according to which protein is synthesized. The transport of amino acids to the site of protein synthesis is carried out by the transfer RNA (tRNA).

Ribosomal RNA (rRNA) in the ribosome cooperates with tRNAs to translate mRNAs into peptides. Genetic information from the DNA to mRNA and then to cytoplasm takes place in two steps i.e transcription and translation.

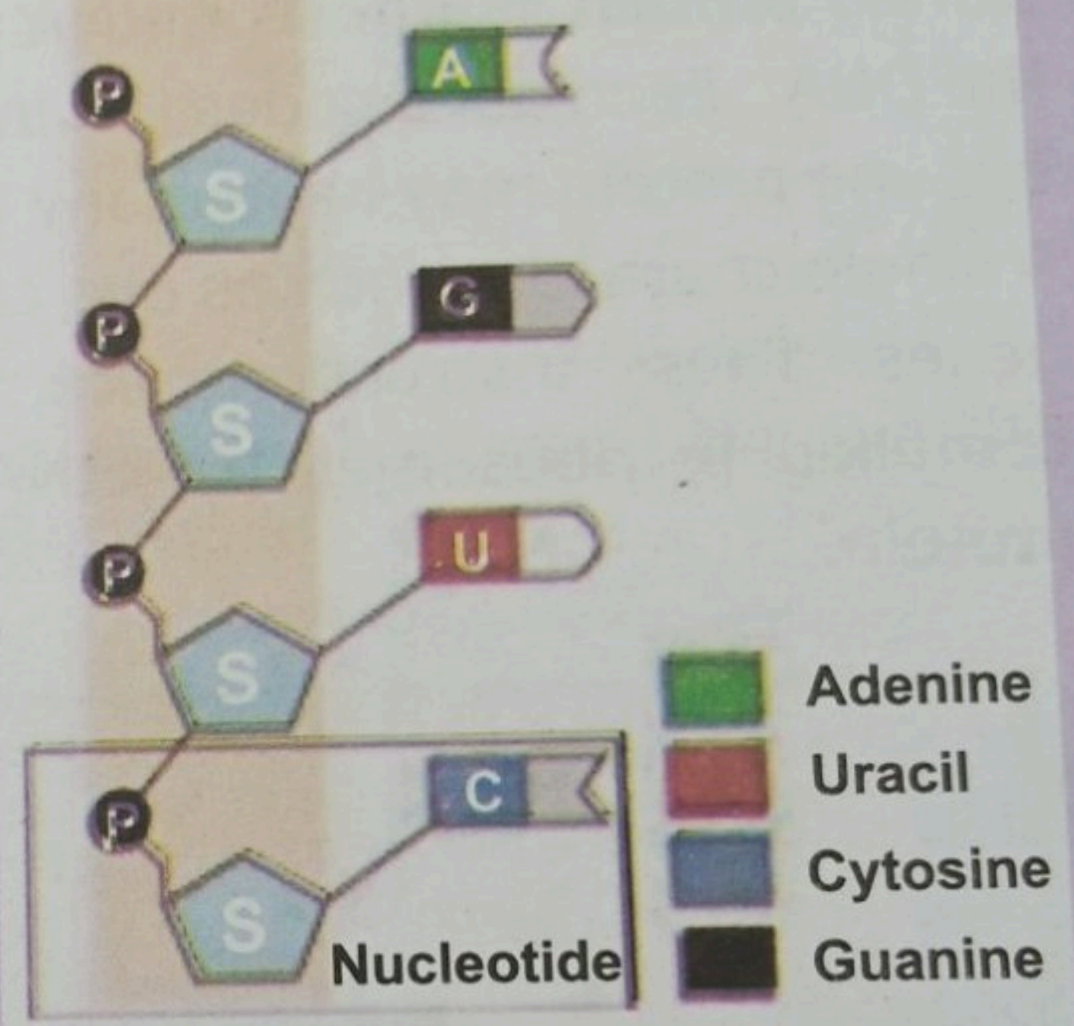

Fig: 8.4 Structure of RNA.

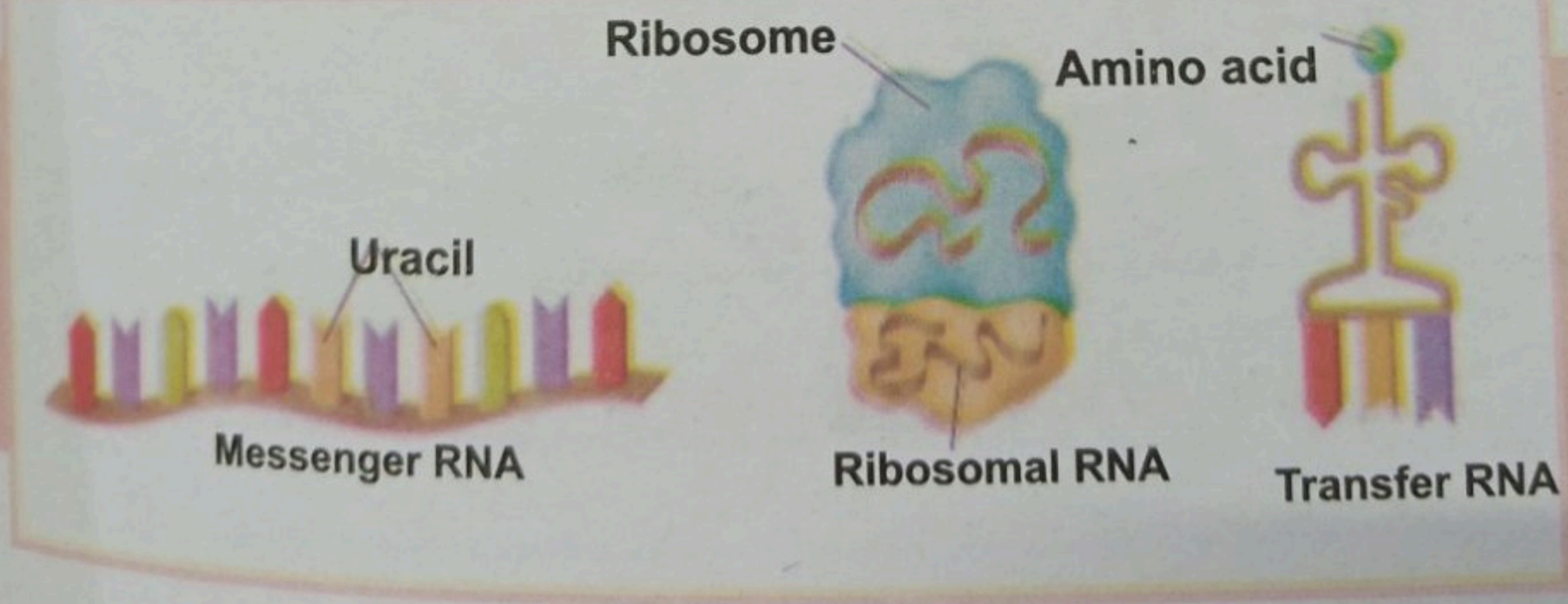

Fig: 8.5 Three types of RNA.

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Transfer of Genetic Information

You have learnt in the previous section that nucleus contains genes which are the carrier of information. All the characters of the living organisms are expressed through genes which are made up of DNA. Genes not only control our body characters but they also influence behavioural characteristics like intelligence.

During protein synthesis mRNA copies the instructions present in the DNA . Each gene codes the instruction for a single protein only, but one protein may have many different roles in the human body. A single character, such as eye colour, may be influenced by many genes. These instructions are transferred by tRNA and are compiled in ribosomes by rRNA into polypeptide chain for the protein.

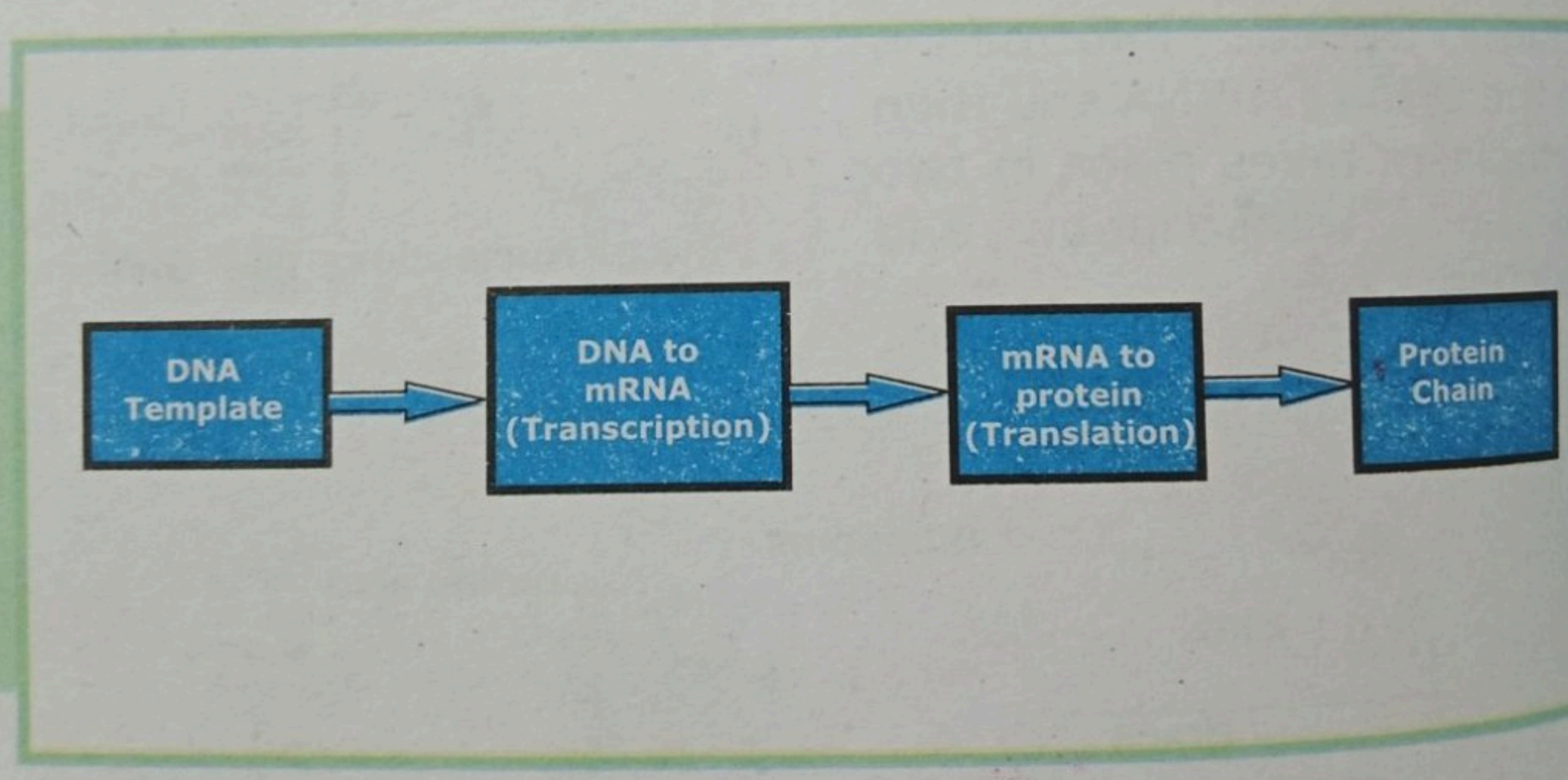

Fig: 8.6 Flow Chart of Transfer of Genetic Information.

The encoding of instructions from the DNA to RNA takes place in the presence of specific enzymes. In this process the sequence of nucleotides of DNA with the corresponding sequence of nucleotides on mRNA is as follows.

DNA nucleotide	RNA nucleotide
Thymine	Adenine
Adenine	Uracil
Cytosine	Guanine
Guanine	Cytosine

It shows that mRNA serves as interpreter between DNA and the sequence of amino acid in a specific protein.

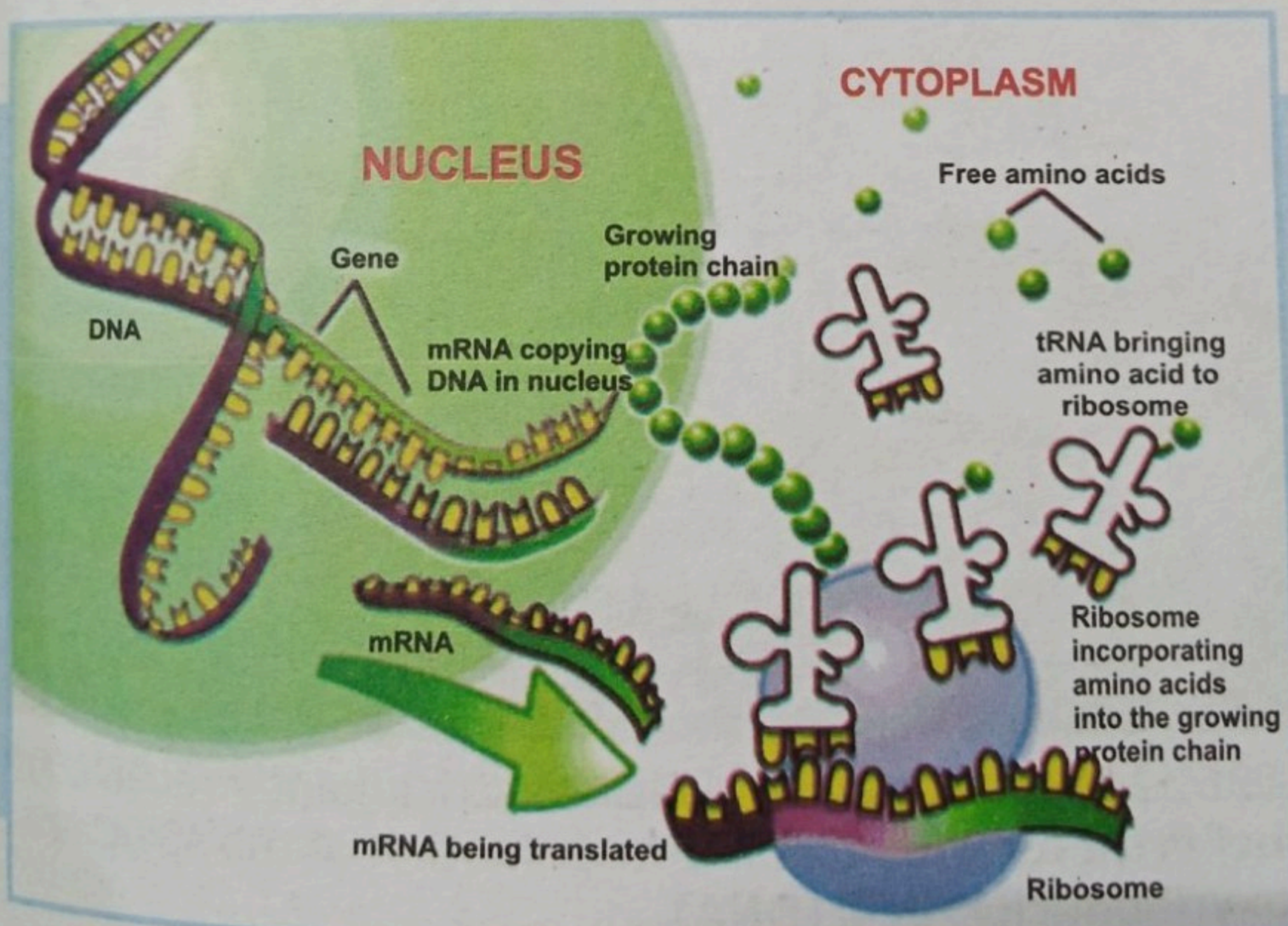

Fig: 8.7 An overview of protein synthesis process.

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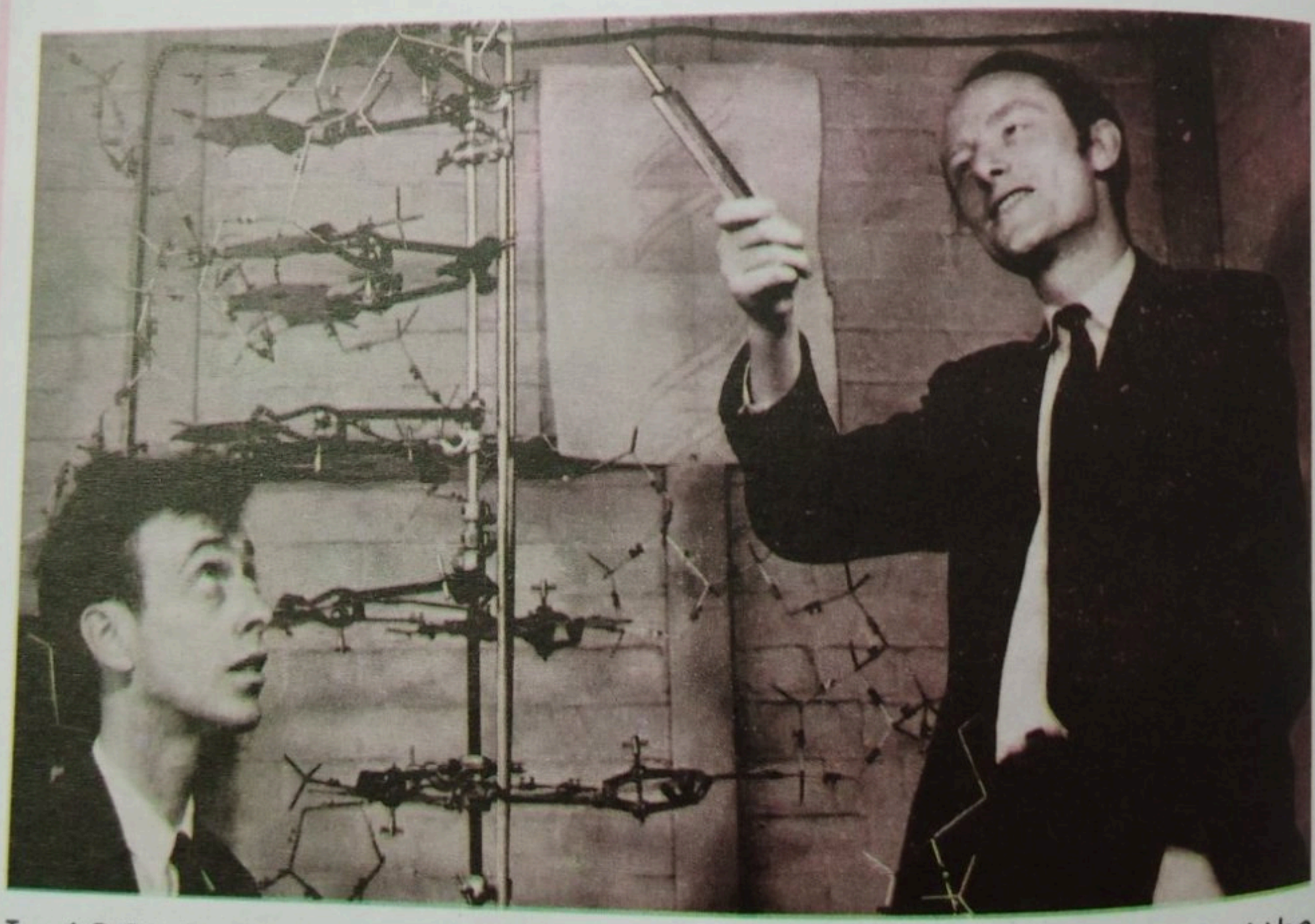
8.1.3 Molecular Basis of Heredity

Genetic information in the cell is present in the nucleus. In order to know the nature of this information present in the DNA we have to see the chemical nature of DNA.

Chemical composition of DNA

DNA is composed of chemical units known as nucleotides. Each nucleotide is composed of smaller parts; a 5-carbon sugar, a phosphate group, and a nitrogen- containing base. Both phosphate group and nitrogenous base are covalently bonded to the sugar.

FOR YOUR INFORMATION



In 1962 James Watson and Francis Crick jointly received the Nobel Prize for their 1953 determination of the structure of deoxyribonucleic acid (DNA).

Structure of DNA

Watson and Crick proposed a model to explain the structure of DNA. According to this model each DNA molecule is composed of two strands that wind around each other. The sugar phosphate chain is located on outer side while the nitrogenous bases project towards the center.

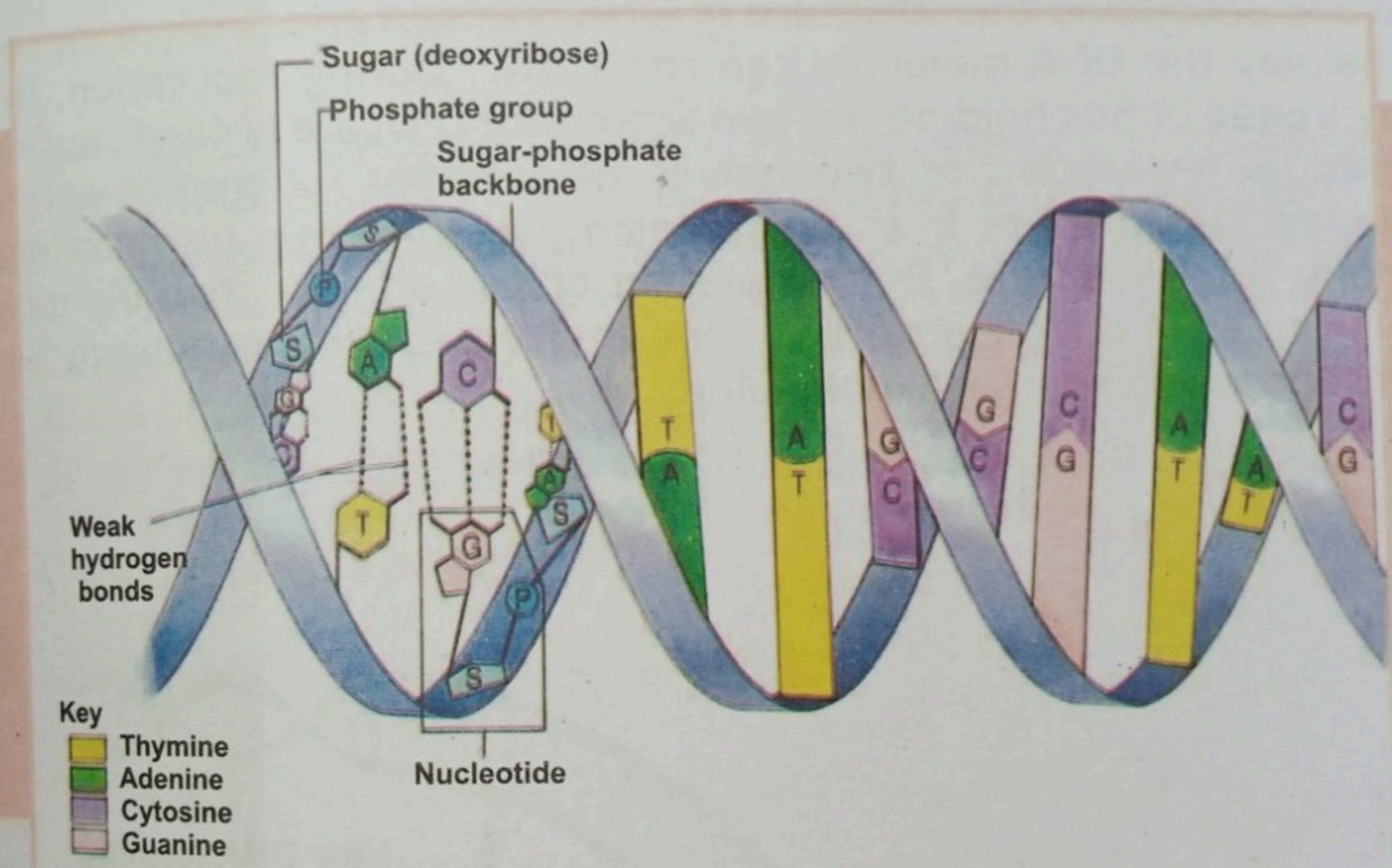


Fig: 8.8 Ladder like structure of DNA.

Nitrogenous bases of two strands are held together by hydrogen bonds. An Adenine on the chain always pairs with Thymine on the other chain, while Guanine always pairs with Cytosine. This relationship is known as complementarity, that is strands of the DNA molecule are complementary to each other and run in opposite directions.

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DNA has equal numbers of adenine and thymine (A=T) and equal numbers of guanine and cytosine bases (C=G). These relationships show that A+G=T+C. These relationships help in determining how genetic information is encoded in DNA and passed from one generation to the next.

Replication of DNA

While describing the structure of DNA, Watson and Crick proposed the way the DNA molecule can replicate. During replication, the hydrogen bonds holding the two strands of DNA are broken causing gradual separation of two halves of a zipper. Complementary nucleotides present in the cytoplasm join to form a new strained along the older one. By completion of the process, two identical molecules of double stranded DNA are formed. Replication process produces two new DNA molecules.

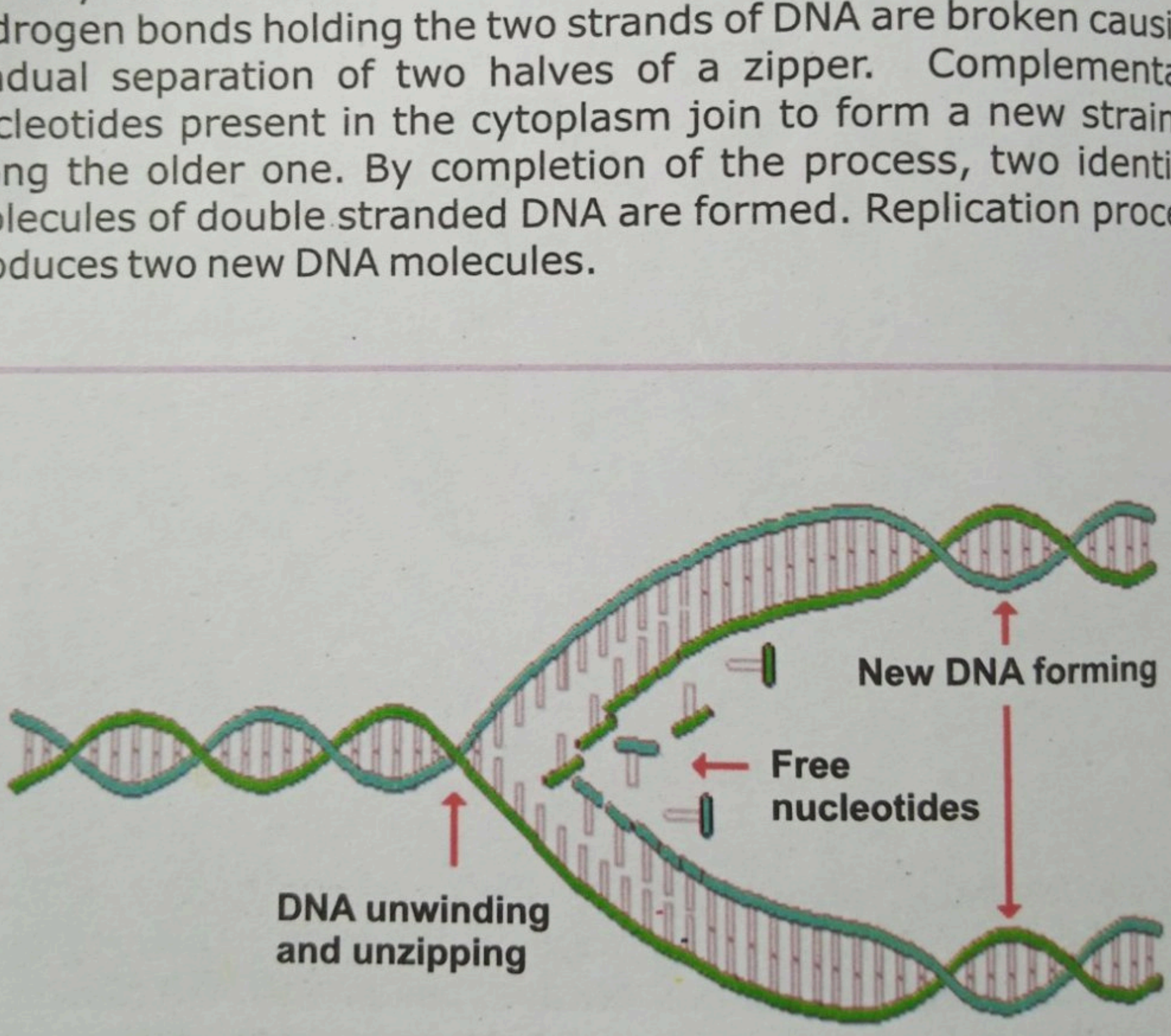

Fig: 8.9 replication of DNA .

8.2 CELL DIVISION

Reproduction is defined as the ability of living organisms to produce offsprings like themselves. Reproduction is essential for continuity of life and survival of the species. Cell division ensures growth and development of an organism and at the same time it helps in the production of gametes (sperms spores and eggs) which are involved in sexual reproduction and in the continuity of a species generation after generation.

Every cell has the power of growth and multiplication. Cells reproduce themselves by cell division. In unicellular animals like Amoeba, the whole organism divides to produce two-daughter Amoebae. In multicellular organisms like human being, zygote (the fertilized egg) develops into an organism by repeated cell divisions. All cells of the body arise from pre-existing cells by cell division. Cell division provides basis for growth, reproduction and heredity.

8.2.1 Types of Cell division

There are two major types of cell division.

1. Mitosis
2. Meiosis

1. Mitosis (Somatic Cell Division)

Mitosis may be defined as the regular process of cell division by which each of the daughter cells receive exactly the same number and the same kind of chromosomes that a parent cell contains.

Mitosis is a common method. It occurs in the body cells of all animals and plants. As Mitosis occurs in the body (or soma) therefore, it is also called somatic cell division.

Mitosis is completed in six steps.

1. Interphase

The resting phase between any two mitotic division is called interphase. During this phase nucleus and cytoplasm become active. The nucleus prepares itself for division.

2. Prophase

During prophase the centrosome divides into two halves and each half is surrounded by fine fibers called astral rays. This constitutes an aster. Now the two asters start moving away from each other and finally reach the opposite sides of the nucleus. Between the two asters appear fine fibres. These fibres form a spindle, which is broad in the middle to form the equator and narrow towards the asters which are now known as poles.

During this whole process the chromatin material of the nucleus is converted into chromosomes. The nucleolus and the nuclear membrane disappear and the chromosomes attach themselves to the spindle fibres.

3. Metaphase

During metaphase the centromere of each chromosome divides. The daughter chromosomes or chromatids so formed are attached to the half spindle fibers and arrange themselves on equator forming equatorial plate.

4. Anaphase

During anaphase the chromatids separate. At the same time the spindle fibers contract which results in the movement of chromatids towards their respective poles.

5. Telophase

During Telophase the chromatids reach the poles where they meet each other to form a chromatin network. In each network nucleolus reappears. Nuclear membrane is reformed around each chromatin network. Thus two daughter nuclei are formed. Each daughter nucleus contains the same number of chromosomes as in the parent cell. The spindle fibres and astral rays disappear.

6. Cytokinesis

Division of cytoplasm is called Cytokinesis. After the formation of two daughter nuclei, a constriction appears in the middle of cytoplasm in the region of equator. This constriction is called cleavage furrow. This cleavage furrow deepens and divides the parent cell into two daughter cells. When the division of the cell is completed, two daughter cells are formed. These two daughter cells are the exact copies of the parent cell. The daughter cells pass into the interphase. During interphase they grow to their normal size.

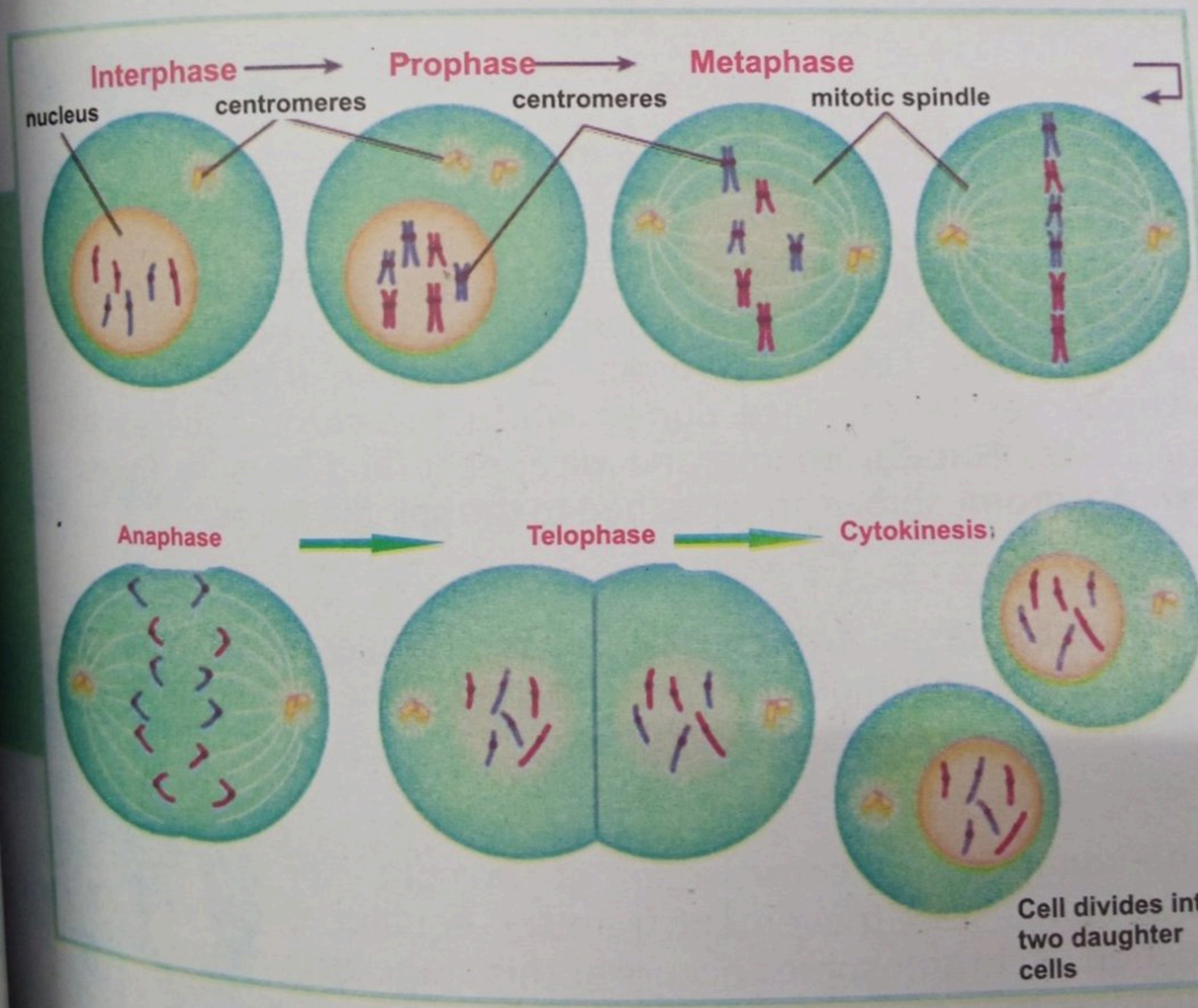

Fig: 8.10 Different stages of mitosis.

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Significance of Mitosis

Mitosis plays an important role in growth of an organism and keeps the number of chromosomes constant. The hereditary characters are equally transmitted into the daughter cells. It also helps in healing of wounds and formation of new cells.

2. Meiosis

The term "Meiosis" means reduction. In this type of cell division, the number of chromosomes is reduced to half. This process occurs in the reproductive organs (testes or ovaries). In animals, meiosis produces gametes while in plants it produces spores. During meiosis four daughter cells are formed from one parent cell. Meiosis is completed in two steps, Meiosis I and Meiosis II.

I. Meiosis I or Reduction Division

This stage is divided into the following sub phases.

A. Prophase I:

During this phase coiling and condensation of chromosomes take place. The homologous chromosomes form pairs and this process is called synapsis. Later on crossing over between the homologous chromosomes takes place during which the chromatids exchange their parts. Nuclear membrane disappear and spindle fibres are formed. Chromosomes are attached to the spindle fibres.

B. Metaphase-I:

During metaphase-I the chromosomes arrange themselves on the equator. These chromosomes are attached to the spindle fibres by the centromere.

C. Anaphase-I:

During anaphase-I contraction of spindle fibres occurs. The chromosomes start movement from the equator towards the poles. Reduction of chromosomes occurs at this stage as one from each pair of chromosomes move to each pole.

D. Telophase - I:

During Telophase-I these chromosomes reach the poles. Chromosomes form a chromatin network. Nuclear membrane appears around the network. A new nucleolus appears. Thus two daughter nuclei are formed.

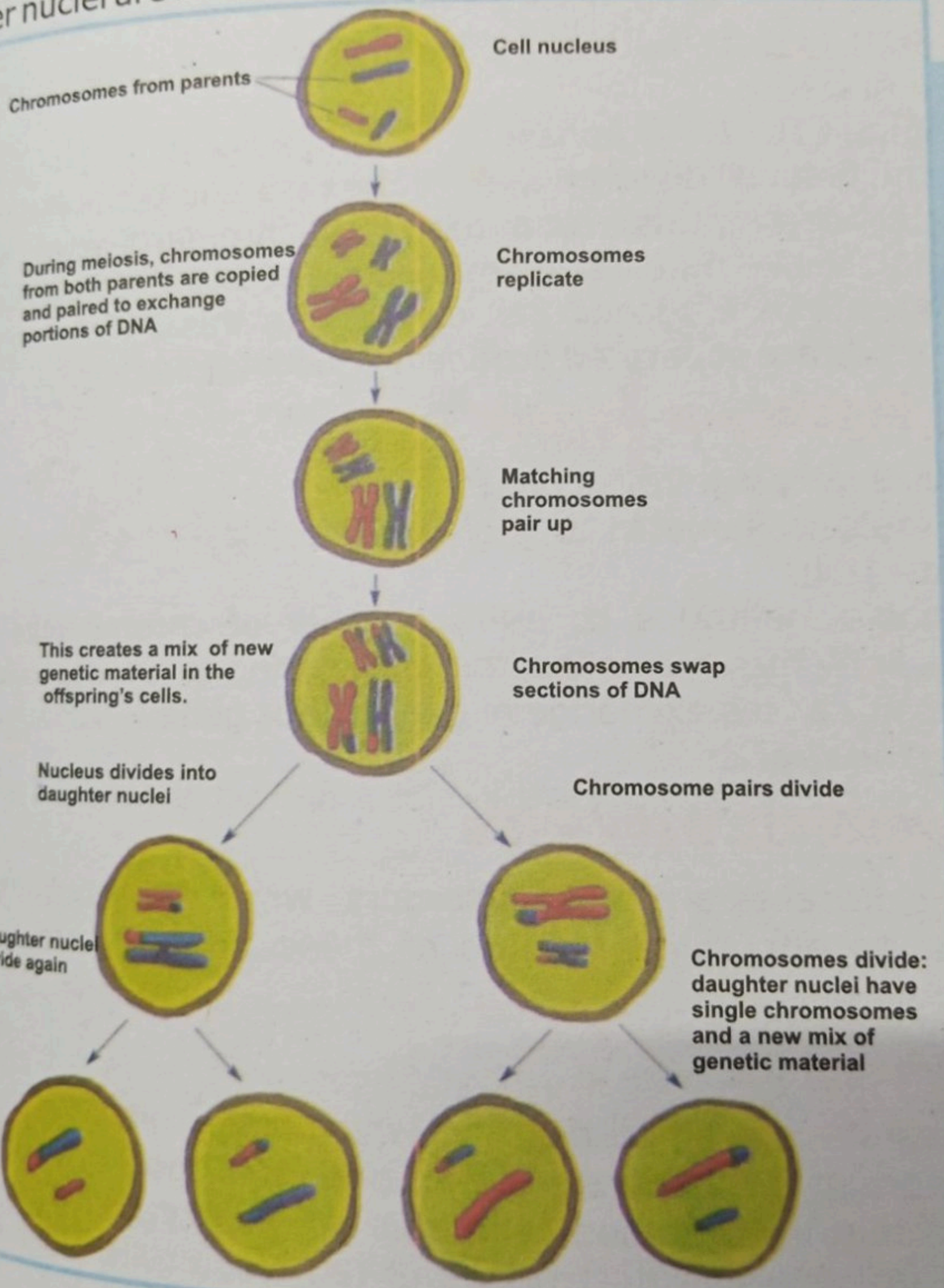

Fig: 8.11 Different stages of meiosis.

Then a groove is formed in the cell membrane. This groove becomes deeper and deeper and divides the cell into two daughter cells. The spindle fibres and the astral rays disappear. The centriole persists in each daughter cell. In this way two daughter cells are formed.

ii. Meiosis II:

Meiosis II is just like mitosis. Meiosis II is completed through the following steps.

1. Prophase II 2. Metaphase II 3. Anaphase II 4. Telophase II

After the first cell division, each of the resulting cells contains a pair of sister chromatids—-one maternal chromatid and the other paternal. Unlike mitosis, meiosis does not end after one division; it continues with a second cell division. In this division, the sister chromatids are separated producing four haploid cells.

SIGNIFICANCE OF MEIOSIS

Meiosis is very significant because;

1. In meiosis gametes are formed which are the sexual units of reproduction.
2. Meiosis maintains constant number of chromosomes in the organism by the union of haploid cells during sexual reproduction.
3. Meiosis causes exchange of genes, thus genetic variation occurs among the species.

8.3 GENETIC DISEASES

Genetic diseases are those disorders which are transmitted from parents to offsprings. Some of these disorders are discussed below:

a. Thalassemia

Thalassemia is a blood disorder which is hereditary in nature. In this disorder the body makes an abnormal form of haemoglobin (the protein in red blood cells that carries oxygen). The disorder results in excessive destruction of red blood cells which leads to anaemia.

Thalassemia occurs when there is a defect in a gene that controls the production of haemoglobin. Untreated thalassemia leads to heart failure and liver problems, and makes a person vulnerable to infections. Frequent blood transfusions can help control some symptoms. However it may result in accumulation of iron, which can damage heart, liver, and endocrine system.

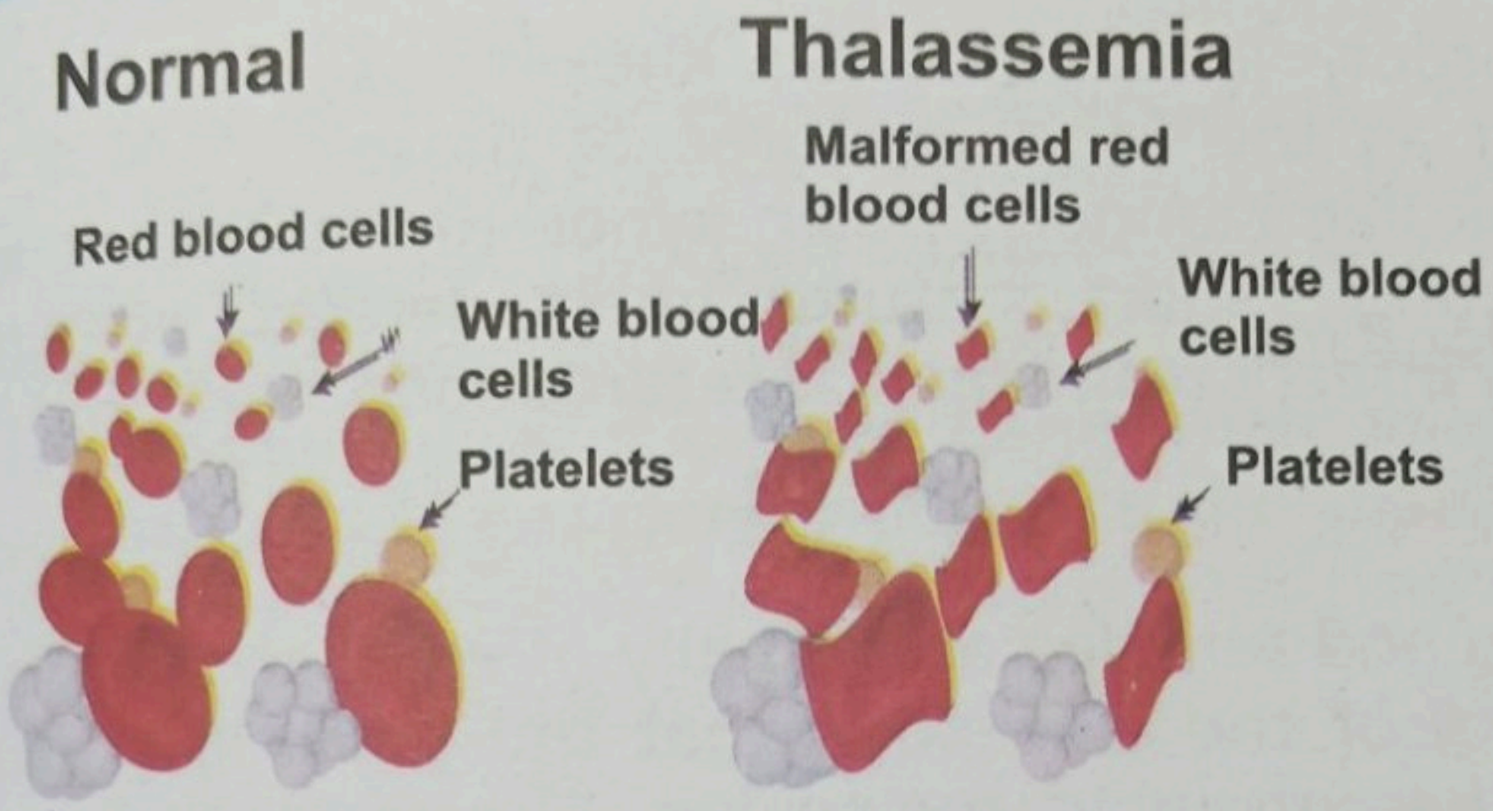

Fig: 8.12 Comparison of normal and malformed redblood cells.

Thalassemia is caused by mutations in the DNA of cells that make haemoglobin.

TIDBIT

Mutation is a sudden change in DNA, the hereditary material of life. Mutations can be beneficial, neutral, or harmful for the organism.

b. Down's Syndrome

In human being there are 23 pairs of chromosome. Each chromosomal pair is numbered from 1 to 23. Down's Syndrome disorder is concerned with chromosome number 21 where instead of a pair there are three chromosomes. So an extra chromosome is present.

This disorder is commonly known as Mongolism as the facial features of these people look like Mongols. Down syndrome includes characteristic facial features, short stature, heart defects, susceptibility to respiratory infection and mental retardation.

TIDBIT

Anaemia is a condition in which the body does not have enough healthy red blood cells. Red blood cells provide oxygen to body tissues.

c. Sickle cell anaemia

Both males and females are equally affected by this disease. The direct effect of the disease is that the red cells produced have abnormal haemoglobin molecules. The molecules tend to link together and crystallize, especially when oxygen content of the blood is lower than usual. The shape of the cells become sickle-like, which are rapidly destroyed by the body. The cell count is rapidly decreased, causing anaemia and general weakness of the body. This disease is the most common inherited among people of Africa.

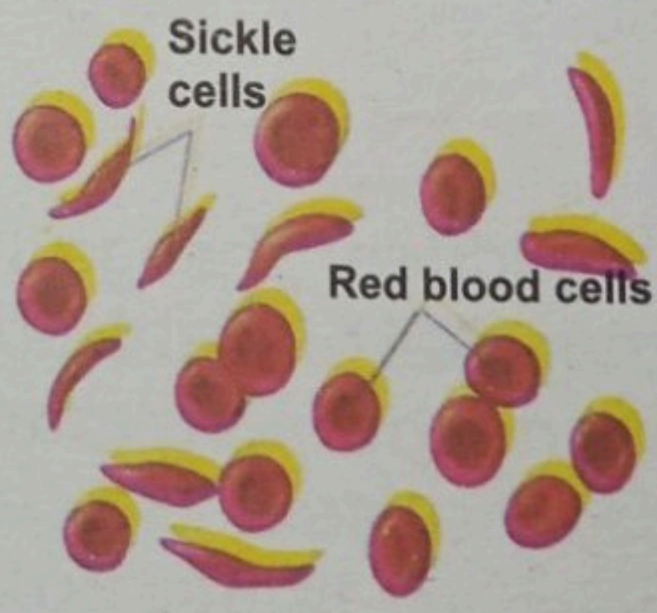

Fig: 8.13 Sickle shaped cells in blood.

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8.4 GENETIC ENGINEERING AND BIOTECHNOLOGY

Genetic engineering is a technique which is used for the transfer of genes from one organism to another. It allows genetic information to be transferred between organisms belonging to the same or different species.

Biotechnology has been practiced by human society since the beginning of recorded history in such activities as baking bread, brewing alcoholic beverages, or breeding food crops or domestic animals. Biotechnology is "the commercial application of living organisms or their products which involves the deliberate manipulation of their DNA molecules". Biotechnology deals with different technologies such as gene manipulation and gene transfer, DNA typing and cloning of plants and animals.

FOR YOUR INFORMATION

Mechanism of Genetic Engineering

In genetic engineering, the genes of choice of an organism are cut off by restriction enzymes and inserted into the cells of another organism of the same or different species. For the transfer of gene, a victor usually a plasmid, is used which is small circular DNA molecule carrying genes found in bacterium. The gene, once transplanted inside the bacterium, begins to express itself and start producing the protein specified by the gene for example Insulin.

8.4.1 Cloning

Cloning is the production of multiple identical offsprings. A clone is an animal who is genetically identical to its donor "parent". Cloning can be achieved using cells derived from a microscopic embryo, a fetus, or from an adult animal.

Fig: 8.14 Dolly: The First cloned sheep.

Cloning from adult animals was introduced to the public in 1997 when scientists announced the birth of Dolly, the first animal cloned in this way. Since Dolly, several scientists have cloned other animals including cows and mice.

Dolly is the result of cloning of only one parent. Scientists transferred genetic material from the nucleus of an adult sheep's udder cell to an egg whose nucleus had been removed. There have now been hundreds of clones produced from skin cells taken from adult sheep, cattle, goats, and mice.

8.4.2 Transgenic Animals and Plants

Genes or genetic material can be transferred naturally, or by a number of genetic engineering techniques from one organism to another. A transgenic organism (plant or animal) is one that carries a foreign gene that has been deliberately inserted into its DNA. This inserted gene can create proteins which are useful for the mankind.

Transgenic animals are created to study human diseases and to develop and identify the drug useful to treat these diseases. Gene transfer is done in animals to increase the milk production and to produce useful proteins.

Presently, traditional method of plant breeding is replaced by the creation of transgenic plants. Such transgenic plants have genes for resisting infections and attacking insects.

FOR YOUR INFORMATION

Responsible scientists, farmers, food manufacturers, and policy makers recognize that the use of transgenic organisms should be considered very carefully to ensure that they pose no environmental and health risks. Society should be provided with a balanced view of the fundamentals of biotechnology and genetic engineering and the benefits and risks of the new technology.

8.5 Application of Biotechnology and Genetic Engineering

Biotechnology and genetic engineering have wide range of applications in the present world.

The two significant features of genetic engineering are:

- production of beneficial proteins and enzymes in surplus quantities
- creation of genetically modified organisms with useful characters

Some of the applications of biotechnology and genetic engineering in present world are as follows.

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i. Biotechnology and Genetic Engineering in the field of Agriculture

Agricultural biotechnology is the area of biotechnology involving applications to agriculture. Agricultural biotechnology has been practiced for a long time, as people have sought to improve agriculturally important plants by selective breeding. An example of traditional agricultural biotechnology is the development of disease-resistant wheat varieties by cross-breeding different wheat types.

Today, this technology has reached a stage where scientists can take one or more specific genes from nearly any organism including plants, animals, bacteria or viruses, and to introduce those genes into plants to get the required characteristics in those plants.

Fig: 8.15 Biotech crops are profitable.

ii. Biotechnology and Genetic Engineering in the field of Live stock and dairy products

Biotechnology is being used to speed up breeding programmes for livestock and fish and to extend the range of useful traits. Animal feeds and feeding practices are being changed by biotechnology to improve animal nutrition and to reduce environmental wastes.

Biotechnology is used in the diagnosis of various diseases. It is also being used in the production of vaccines which help animals to fight against several diseases. Biotechnology has made possible the production of enzymes, single-cell proteins and antibiotic feed additives. These products have been widely used to improve the availability of nutrients from feeds and the productivity of livestock and aquaculture.

Gene-based technologies are used to improve animal nutrition. This is done either through modifying the feeds to make them more digestible or through modifying the digestive and metabolic systems of animals to enable them to make better use of the available feeds.

One example of commercial success is the use of somatotropin, a hormone that results in increased milk production and accelerated growth in dairy cows.

iii. Biotechnology and Genetic Engineering in the field of food processing

Biotechnology has found its role in food processing techniques. This has helped us to convert relatively bulky, perishable and typically inedible raw materials into more useful and edible foods and drinks. Food is also processed in order to improve its quality and safety.

Collecting DNA samples

Blood is an excellent source of DNA. It is collected from the white blood cells (mature red blood cells do not contain DNA). DNA can also be obtained from hair follicles, or from any other cellular tissue.

iv. Biotechnology and Genetic Engineering in the Field of Pharmaceuticals

Micro-organisms have been used for decades as living factories for the production of life-saving antibiotics including

Fig: 8.16 *Penicillium*.

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penicillin, from the fungus *Penicillium*, and streptomycin from the bacterium *Streptomyces*. Human insulin for diabetics is now being produced using biotechnology.

Genetically engineered vaccines are being developed to protect fish and livestock against pathogens and parasites.

FOR YOUR INFORMATION

Forensic analysis using biotechnology methods is important in criminal investigations. Analysis of proteins in blood (serology), other body fluids and body tissues has a long tradition in forensic analysis in criminal investigation.

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KEY POINTS

- Genetic traits are transmitted to the next generation by the processes of reproduction and this characteristic of living organisms is known as heredity.
- A typical cell consists of; cell wall (in case of plant cell), cell membrane, cytoplasm with organelles and the nucleus.
- Cytoplasm contains about 90 percent water and the remaining 10 percent are the fundamental molecules of life such as insoluble waste products and storage products.
- The nucleus is the most prominent organelle as compared to other cell organelles.
- Nucleus consists of a nuclear membrane (nuclear envelope), nucleoplasm, nucleolus and chromosomes. Nucleoplasm, also known as karyoplasm, is the matrix present inside the nucleus.
- The nucleus communicates with the remaining of the cell or the cytoplasm through several openings called nuclear pores.
- Genes are the heredity material and are composed of nucleic acids. These acids are also the messenger substances that convey information from the genes to the rest of the cell.
- DNA has a specific sequence of nitrogenous bases, which carries information in the form of genes that can be transferred from generation to generation.

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- RNAs are of three types i.e. messenger RNA or mRNA, transfer RNA or tRNA and ribosomal RNA or rRNA. These RNAs have specific role in protein synthesis.
- DNA has equal numbers of adenine and thymine (A=T) and equal numbers of guanine and cytosine residues (C=G).
- Cell division ensures growth and development of an organism and at the same time it helps in the production of gametes and in the continuity of a species generation after generation.
- Mitosis is a cell division by which each of the daughter cells receive exactly the same number and the same kind of chromosomes as in the parent cell.
- Meiosis maintains constant number of chromosomes in the organism by the union of haploid sperm with the haploid egg during sexual reproduction.
- Genetic diseases are those disorders which are transmitted from parents to the offsprings.
- In thalassemia the body makes abnormal form of haemoglobin, the protein in red blood cells that carries oxygen.
- Biotechnology can be broadly defined as using living organisms or their products for commercial purposes.
- A clone is an animal who is genetically identical to its donor "parent".

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EXERCISE

A. Select the correct answers in the following questions.

1. **The normal human chromosome diploid number is:**
   a. 23
   b. 24
   c. 46
   d. 48

2. **In meiosis, crossing over occurs in:**
   a. Metaphase I
   b. Prophase I
   c. Metaphase II
   d. Prophase II

3. **Each section of information necessary for the synthesis of a single polypeptide is:**
   a. Chromosome
   b. DNA
   c. Gene
   d. Protein

4. **A highly coiled, condensed form of chromatin formed in the cell nucleus during meiosis and mitosis is:**
   a. Chromosome
   b. Spindle fibers
   c. DNA
   d. centromere

5. **A double helical molecule, consisting of two strands of four different nucleotides containing a genetic information is:**
   a. Chromosome
   b. DNA
   c. Gene
   d. Aster

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6. **Proteins are synthesized in:**
   a. Lysosome
   b. Mitochondrion
   c. Plasmid
   d. Ribosomes

7. **A process of cell division where each of the two daughter cells receives a complete set of chromosomes is called:**
   a. Cytokinesis
   b. Amitosis
   c. Mitosis
   d. Meiosis

8. **A specialized protein that binds to DNA and organize its structure in the nucleus**
   a. Chromosome
   b. Histone
   c. Hormone
   d. Enzyme

9. **Chromosomes can be counted best at the stage of:**
   a. Metaphase
   b. Anaphase
   c. Telophase
   d. Prophase

10. **The stage in which daughter chromosomes move toward the poles of the spindle is:**
    a. Anaphase
    b. Metaphase
    c. Prophase
    d. Telophase

11. **Which of the following cellular structures always disappears during mitosis and meiosis?**
    a. Plasma membrane
    b. Nucleolus and nuclear envelope
    c. Plastids
    d. none of these

12. **During meiosis I, the number of chromosomes is:**
    a. Halved
    b. Tripled
    c. Doubled
    d. Quadrupled

13. **The diploid chromosome number for the house fly is 12. The haploid number of chromosomes found in their gametes would be:**
    a. 1 b. 3
    c. 6 d. 12

14. **Which of the following is NOT a function of cell division?**
    a. growth of multicellular organisms
    b. repair of multicellular organisms
    c. reproduction of single-celled organisms
    d. aerobic cellular respiration of multicellular organisms

15. **Which of the following statements about mitosis is NOT correct?**
    a. Mitosis is cell division that produces two daughter cells.
    b. Each daughter cell formed by mitosis has the same number of chromosomes as the parent cell.
    c. The parent cell and the daughter cells are genetically identical.
    d. During mitosis, the centromeres divide and the sister chromatids stay together.

16. **Which of the following is the correct sequence of phases of mitosis?**
   a. Anaphase, prophase, metaphase, telophase
   b. Prophase, anaphase, metaphase, telophase
   c. Prophase, metaphase, anaphase, telophase
   d. Prophase, metaphase, telophase, anaphase

17. **Which of the following statements is NOT correct when cells undergo meiosis?**
   a. Meiosis ensures that the chromosome number remains constant generation after generation.
   b. Meiosis ensures that each generation has a different genetic makeup than the previous one.
   c. Meiosis ensures that each newly formed daughter cell receives the same number and kinds of chromosomes.
   d. Meiosis results in four daughter cells.

18. **Thalassemia is due to**
   a. abnormal blood
   b. abnormal haemoglobin
   c. abnormal white blood cell
   d. abnormal platelets in the blood

B. Write short answers of the following questions.

1. What is the role of nuclear pores in the nucleus?
2. List down four major functions of nucleus.
3. Write the role of RNA as a carrier of information?
4. Name the four types of nitrogenous bases found in the DNA molecule.
5. Define interphase.
6. Briefly write about the significance of mitosis.
7. What do you mean by genetic disorders?

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C. Write detail answers of the following questions.

1. Describe the structure and function of nucleus.
2. Describe the importance of hereditary material found in nucleus.
3. Identify the relationships among nucleic acids (DNA and RNA), genes and chromosomes.
4. Describe the molecular basis of heredity.
5. Give an overview of the process of DNA replication.
6. Describe the process of mitosis in detail.
7. Describe the process of meiosis in detail.
8. Explain thalassemia and Down's syndrome as common genetic disorders.
9. Analyze the role of genetic engineering and biotechnology in the fields of agriculture and food processing.

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