

## Lecture 13,14: Cell Cycle

# Chromosome, Cell Division: Mitosis

*Chromosome number and structure, Cell division. Mitosis: Importance of mitosis, Stages of mitosis. Types of reproduction,*

### **Chromosome**

*Chromosome, microscopic structure within cells that carries the molecule deoxyribonucleic acid (DNA), the hereditary material that influences the development and characteristics of each organism.*

### **Chromosome Number and Structure**

Following facts about chromosomes need to know for better understanding of mitosis, and meiosis.

1. Every 'body cell' in an organism has the same number of chromosomes (**chromosome number**).
2. The body cells of all normal individuals of the same species have the same chromosome number. A normal human cell has 46 chromosomes, a crayfish 200, a fruit fly 8, and a garden pea 14.
1. The chromosomes in each body cell normally occur in pair. The chromosomes in a **homologous pair** are similar in structure and in the arrangement of genetic information they carry. Such a pair of chromosomes is called a homologous pair. Thus the 46 chromosomes in a human cell make up 23 homologous pairs. The genetic information of the chromosomes is located at specific points or position called **genes**. The number of chromosomes in a complete set of homologous chromosomes is called the diploid number. This number is represented by  $2n$ . Thus the **diploid number (2n)** for human is 46. Every body cell that we have contains the diploid number of chromosomes. That is  $2n = 46$ . This diploid number is arranged in 23 homologous pairs.
2. A gamete contains one homologue from each homologous pair of chromosomes. In other words, it has half the diploid number of chromosomes. The number is called the **haploid number**. It is represent by **n**. The haploid number for humans is 23. That is,  $n = 23$ . A human sperm (male gamete) contains 23 chromosomes (one of each homologous pair). A human egg (female gamete) also contains 23 chromosomes (one of each homologous pair). During **fertilization**, the sperm and egg unite to form zygote. The **zygote** will have 46 chromosomes, in 23 homologous pairs. Thus fertilization has restored the diploid number of chromosomes. All our body cells came from that zygote by **mitosis**. Therefore, all our body cells also have diploid number of chromosomes, which is 46. Some diploid ( $2n$ ) body cells in our reproductive organs produce haploid ( $n$ ) gametes by **meiosis**.

### **Cell Division**

**Reproduction** is important to the existence of species. All organisms existing today are present because their ancestors reproduced. These ancestors can be traced backwards in geological time to the origin of life about 3.8 billion years ago. Some of the organisms that existed at that time reproduced, and their offspring reproduced, and so on through evolution to the present day.

The **cell theory** consisted of three points:

1. Cells are the structural units of all living things.
2. Cells are the functional units of all living things.
3. All cells come from living cells.

All new cells come from previously existing cells. New cells are formed by the process of cell division, which involves both replication of the cell's nucleus (**karyokinesis**) and division of the cytoplasm (**cytokinesis**).

There are two types of nuclear division: **mitosis** and **meiosis**.

### **Mitosis**

**Mitosis** typically results in new somatic (body) cells. Formation of an adult organism from a fertilized egg, asexual reproduction, regeneration, and maintenance or repair of body parts is accomplished through mitotic cell division.

#### **Importance of Mitosis**

The goal of mitosis is to produce two identical daughter cells from one cell. In sexually reproducing multicellular organisms, mitosis is often concerned with increasing cell numbers, for example:

- a unicellular zygote divides to produce the billions of cells necessary to form an adult multicellular organism
- skin cells divide to replace tissue lost due to injury or wear (repair).

*Mitosis ensures genetic continuity. That is, it ensures that the daughter cells carry the same genetic information as the mother cell.*

It does this by making sure that each daughter cell has the same number and kind of chromosomes as the mother cell. Every cell in an organism has the same number of chromosomes. In fact, the body cells of all normal individuals of the same species have the same number of chromosomes. For example, all normal human cells have 46 chromosomes, and all onion plant cells have 16.

#### **Stages of Mitosis**

The process of mitosis is divided into 6 stages.

1. The Interphase,
2. Prophase,
3. Metaphase,
4. Anaphase,
5. Telophase, and
6. Cytokinesis.

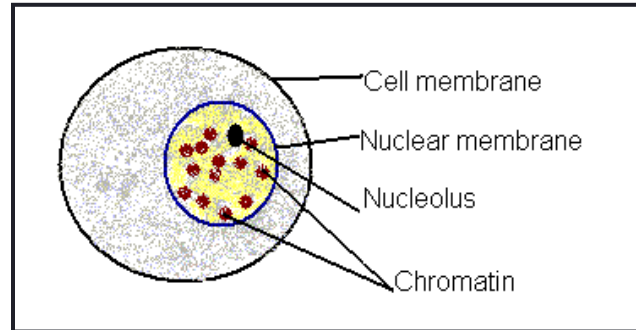
At Interphase, there is only one cell, but after cytokinesis there are two identical cells.

Before mitosis can take place, the cell needs to store enough energy to drive the chemical processes during the cell division. During this period of time, there is intense cellular activity. The cell grows in size. The length of the grow phase varies between a few hours to a few months. When the cell has stored enough energy, it is ready to divide itself.

The following pictures shows a series of steps of how chromosomes divide. Note that for simplicity, only a few chromosomes are drawn.

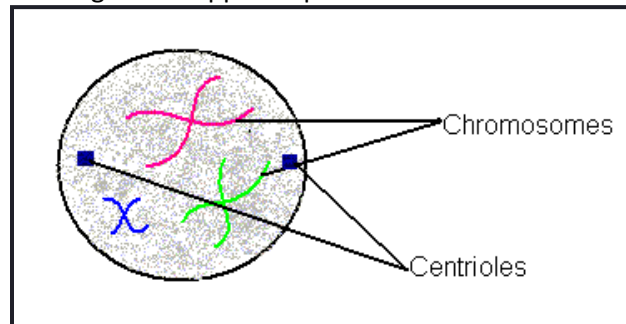
### 1. Interphase

- DNA has replicated, but has not formed the condensed structure of chromosome. They remain as loosely coiled chromatin.
- The nuclear membrane is still intact to protect the DNA molecules from undergoing mutation.



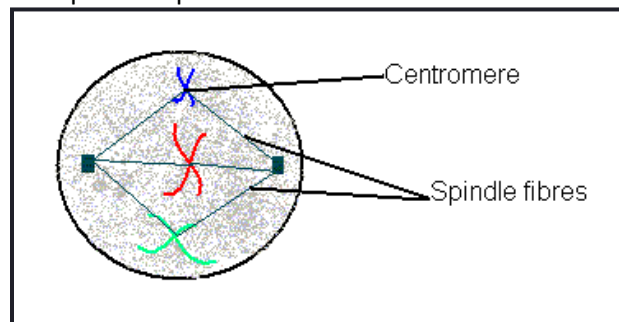
### 2. Prophase

- The DNA molecules progressively **shorten** and **condense** by coiling, to form chromosomes. The nuclear membrane and nucleolus are no longer visible.
- The Centrosomes has migrate to opposite poles of the cell.



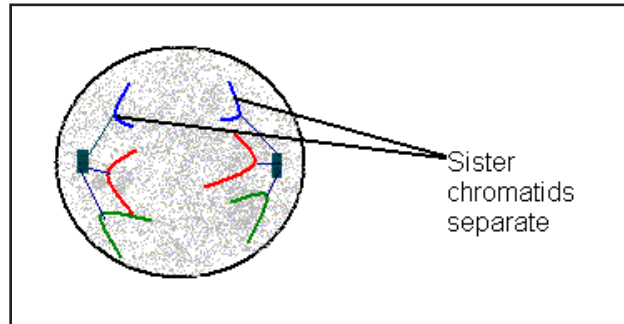
### 3. Metaphase

- The spindle fibers attach themselves to the centromeres of the chromosomes and align the chromosomes at the equatorial plate.



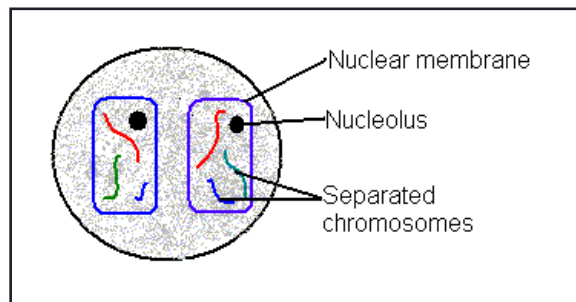
### 4. Anaphase

- The spindle fibers shorten and the centromere splits, separated sister chromatids are pulled along behind the centromeres.



## 5. Telophase

- The chromosomes reach the poles of their respective spindles. Nuclear envelope reform before the chromosomes uncoil. The spindle fibers disintegrate.



## 6. Cytokinesis

This is the last stage of mitosis. It is the process of splitting the daughter cells apart. A furrow forms and the cell is pinched in two. Each daughter cell contains the same number and same quality of chromosomes.

### Review Questions:

1. Define mitosis. What the stages of mitosis?
2. Describe the importance of mitosis.
3. What is a chromosome?
4. What is meant by "chromosome number"?
5. What are homologues? What is the origin of each homologue of a homologous pair?
6. Distinguish between the diploid and the haploid number of chromosomes.
7. Why must gametes contain only the haploid number of chromosomes?

# Meiosis

*Meiosis: Importance of meiosis, Stages of meiosis. Difference between mitosis and meiosis. Types of reproduction: Sexual and asexual reproduction; Summary.*

## Meiosis

The process of meiosis takes place only in the cells, which will form either the sperm or egg. Meiosis results in the formation of either gametes (in animals) or spores (in plants). These cells have half the chromosome number of the parent cell.

### Importance of Meiosis

*The goal of meiosis is to produce four cells with half the original genetic information of the mother cell. Each daughter cell must end up with a complete set of genes, but only half the number of copies found in the original cell. Meiosis involves two divisions and only the first division results in a reduction (by 1/2) of the homologous chromosomes. No two chromosomes of a homologous pair segregate together.*

We began life when a sperm cell from our father united with an egg cell from our mother. A cell called a **zygote** was formed by this union. If the sperm and egg each had 46 chromosomes, the zygote would have 92. You developed from the zygote by mitosis. Therefore, every cell in your body would have 92 chromosomes. But this is not so. If it were, you would not be a human. Clearly something has happened along the way to reduce the number of chromosomes from possible 92 to 46.

*A process called meiosis ensures that the chromosomes number stays constant from generation to generation. Also, meiosis contributes to genetic variation of the offspring.*

### Stages of Meiosis

Meiosis comprises two successive nuclear divisions with only one round of DNA replication. That is, two cell divisions occur to produce four daughter cells. This results in each daughter cell, or gamete, receiving the haploid number of chromosomes (half the number of the mother cell). Four stages can be described for each nuclear division.

#### *First Division of Meiosis (Chromosomal Reduction Division)*

1. *Prophase 1*
2. *Metaphase 1*
3. *Anaphase 1*
4. *Telophase 1*
- 5.

#### *Second Division of Meiosis: Gamete Formation*

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

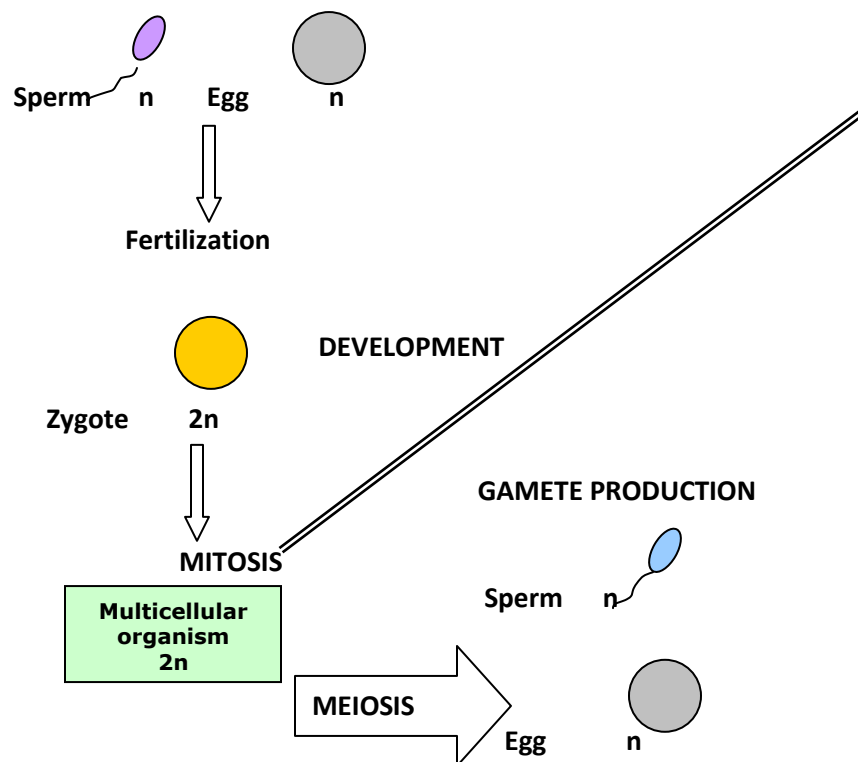
One parent cell produces four daughter cells. Daughter cells have half the number of chromosomes found in the original parent cell and with crossing over, are genetically different.

### ***Differences Between Mitosis and Meiosis***

<b><i>Mitosis</i></b>	<b><i>Meiosis</i></b>
Takes place in most cells	Takes place only in sex cell
One cell → Two cells	One cell → Four cells
Original diploid cell → Two new diploid cells	Original diploid cell → Four new haploid cells
Original cell is same in genetic content as new cells	Original cell is not same in genetic content as new cells

### ***Summary of Mitosis and Meiosis***

**Meiosis** ensures genetic continuity by reducing the chromosome number of male and female gametes to the haploid number (***gamete formation***). Then, when these gametes unite to form a zygote during fertilization, the diploid number is restored. The zygote develops through **mitosis** and cell division into an organism with body cells that have the diploid number of chromosomes (***development***).



***Gamete production occurs by meiosis. Growth and development occurs by mitosis.***

### **Types of Reproduction**

**Reproduction** is the process whereby all living organisms produce offspring. There are basically two types of reproduction: **sexual** and **asexual** reproduction.

### ***Sexual Reproduction***

In sexual reproduction, two special sex cells unite. These reproductive cells are called **gametes**. In some species, the gametes are alike. However, in many species the two gametes are different. In this case, one is called a **male gamete**, or **sperm**. The other is called a **female gamete**, or **egg**. Usually a male parent reproduces the sperm and female parent produces the egg. However, some species can produce both sperm and egg in one individual. Such individuals are called **hermaphrodites**. The earthworm is a hermaphrodite as are many species of snails. Most flowering plants are also hermaphrodite. They produce male and female gametes in each flower.

*When a male gamete unites with a female gamete, a cell results that is called a **zygote**. The process by which gametes unite is called **fertilization**.*

### ***Asexual Reproduction***

*Asexual reproduction is the formation of a new individual from cells of the parent, without the union of gametes (sex cells, sperm and egg), meiosis, gamete formation, or fertilization. The offspring of organisms that reproduce asexually are genetically identical to their parents and to each other. Without sexual reproduction, the species cannot benefit from the variability introduced by mixing genes. Therefore, evolutionary adaptation to changing environmental conditions may proceed slowly.*

There are several types of asexual reproduction.

- 1. Binary Fission:** Binary fission is the simplest form and involves the division of a single organism into two complete organisms, each identical to the other and to the parent. Fission is common among unicellular organisms such as bacteria, many protists, some algae such as *Spirogyra* and *Euglena*, as well as a few higher organisms such as flatworms and certain species of polychaete worms.
- 2. Regeneration:** A similar form of asexual reproduction is regeneration, in which an entire organism may be generated from a part of its parent. The term regeneration normally refers to **re-growth** of missing, or damaged body parts in higher organisms, but whole body regeneration occurs in *Hydra*, starfish, and many plants.
- 3. Asexual Spore:** Spores are another form of asexual reproduction and are common among bacteria, protists, and fungi. Spores are DNA-containing capsules capable of sprouting into new organisms; unlike most seeds, spores are produced without sexual union of gametes, that is, reproductive cells.
- 4. Budding:** Budding is another method of asexual reproduction in which a group of self-supportive cells sprouts from and then detaches from the parent organism. Unlike eggs or spores, buds are multicellular and usually contain more than one cell layer. *Hydra* and sea squirts reproduce by budding.
- 5. Vegetative Reproduction:** Vegetative reproduction is common among plants and consists of certain parts that grow out from a main parent plant and eventually root and sprout to form

new, independent plants. Examples are the runners of strawberries, the tubers of potatoes, and the bulbs of onions.

- 6. Parthenogenesis:** Parthenogenesis is an important means of asexual reproduction in which new individuals are formed from unfertilized eggs. It occurs in some insects, amphibians, reptiles, and birds and in some species of plants.

### Review Questions

1. Define the terms: homologous chromosomes, diploid cells, haploid cells, crossing over, centromere, chromatids.
2. Define meiosis. What are the stages of meiosis?
3. Draw the stages of meiosis.
4. What is the importance of meiosis?
5. Distinguish between mitosis and meiosis.
6. Summarize the process of mitosis and meiosis with a diagram.
7. Distinguish between sexual reproduction and asexual reproduction.
8. Define the following terms: gametes, zygote and fertilization.