1. Details of Module and its structure

Module Detail	
Subject Name	Biology
Course Name	Biology 01 (Class XI, Semester - 1)
Module Name/Title	Interphase – Part 2
Module Id	kebo_11002
Pre-requisites	General knowledge cell structure and function
Objectives	After going through this lesson, the learners will be able to understand the following : 1. M Phase 1.1. Prophase 1.2. Metaphase 1.3. Anaphase 1.4. Telophase 2. Cytokinesis
Keywords	M Phase, *Prophase*, *Metaphase*, *Anaphase*, *Telophas*, Cytokinesis

2. Development Team

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1. Introduction

When cell division is observed under a microscope, a series of changes, ranging from chromosome condensation to chromosome alignment and segregation, take place within just 1 hour in human cells. Such dramatic changes, however, are not frequently repeated. More than 20 hours are necessary for the next dynamic change to occur. What kind of work and preparation do cells carry out during this period between cell divisions? When cells multiply, the process in which the structural components of the cell, such as chromosomes, are doubled and segregated into two cells is repeated. This process is called the cell cycle. During the cell cycle, the phase in which cells divide is called the mitosis phase (M phase), whereas the phase in which DNA is replicated is called the synthesis phase (S phase). Between the M and S phases is the gap 1 phase (G1 phase), and between the S and M phases is the gap 2 phase (G2 phase). Assuming the G1 and G2 phases are the preparative phases for DNA synthesis and cell division, respectively, the cell cycle can be described as a repeated series of events in which cell division and replication alternate in the following order: M phase, G1 phase, S phase, and G2 phase (and back to the next M phase). Multicellular organisms including human beings have countless cells in the gap 0 phase (G0 phase), which are cells in their quiescent state (a statein which cells stop multiplying

even though they have proliferating potency). The cell cycle for human cells to multiply takes about 1 day, during which the S phase lasts for 6–8 hours and the M phase, for approximately 1 hour. The following paragraphs look closer at the features of each phase of the cell cycle.

2. Staining of the Cell

Microscopy can be used to visualize condensed chromosomes as they move through meiosis and mitosis. Various DNA stains are used to treat cells such that condensing chromosomes can be visualized as the move through prophase.

The giemsa G-banding technique is commonly used to identify mammalian chromosomes, utilizing the technology on plant cells was difficult due to the high degree of chromosome compaction in plant cells. G-banding was fully realized for plant chromosomes in 1990. During both meiotic and mitotic prophase, giemsa staining can be applied to cells to elicit G-banding in chromosomes. Silver staining, a more modern technology, in conjunction with giesma staining can be used to image the synaptonemal complex throughout the various stages of meiotic prophase. To perform G-banding, chromosomes must be fixed, and thus it is not possible to perform on living cells.

Fluorescent stains such as DAPI can be used in both live plant and animal cells. These stains donot band chromosomes, but instead allow for DNA probing of specific regions and genes. Use of fluorescent microscopy has vastly improved spatial resolution.

3. M Phase

This is the most dramatic period of the cell cycle, involving a major re-organisation of virtually all components of the cell. Since the number ofchromosomes in the parent and progeny cells is the same, it is also called a s*equational division*. Though for convenience mitosis has been dividedinto four stages of nuclear division, it is very essential to understand that celldivision is a progressive process and very clear-cut lines cannot be drawnbetween various stages. Although many of the details of mitosis vary among different organisms, the fundamental processes that ensure the faithful segregation of sister chromatids are conserved in all eukaryotes. These basic events of mitosis include chromosome condensation, formation of the mitotic spindle, and attachment of chromosomes to the spindle microtubules. Sister chromatids then separate from

each other and move to opposite poles of the spindle, followed by the formation of daughter nuclei. Mitosis is divided into the following four stages:

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

3.1 Prophase

Prophase which is the first stage of mitosis follows the S and G2 phases ofinterphase. In the S and G2 phases the new DNA molecules formed are notdistinct but intertwined. Prophase is marked by the initiation of condensationof chromosomal material. The chromosomal material becomes untangledduring the process of chromatin condensation (Figure 10.2 a). The centriole, which had undergone duplication during S phase of interphase, now beginsto move towards opposite poles of the cell. The completion of prophase canthus be marked by the following characteristic events:

- Chromosomal material condenses to form compact mitoticchromosomes. Chromosomes are seen to be composed of twochromatids attached together at the centromere.
- Initiation of the assembly of mitotic spindle, the microtubules, the proteinaceous components of the cell cytoplasm help in theprocess.
- Cells at the end of prophase, when viewed under themicroscope, do not show golgi complexes, endoplasmic reticulum, nucleolus and the nuclear envelope.

3.2 Metaphase

The complete disintegration of the nuclear envelope marksthe start of the second phase of mitosis, hence thechromosomes are spread through the cytoplasm of the cell.

By this stage, condensation of chromosomes is completedand they can be observed clearly under the microscope. Thisthen, is the stage at which morphology of chromosomes ismost easily studied. At this stage, metaphase chromosomeis made up of two sister chromatids, which are held togetherby the centromere (Figure 10.2 b). Small disc-shapedstructures at the surface of the centromeres are calledkinetochores. These structures serve as the sites of attachment of spindle

fibres (formed by the spindle fibres) to the chromosomes that are moved into position at the centre ofthe cell. Hence, the metaphase is characterised by all the chromosomes coming to lie at the equator with one chromatidof each chromosome connected by its kinetochore to spindle fibres from one pole and its sister chromatid connected by its kinetochore to spindle fibres from the opposite pole (Figure10.2 b). The plane of alignment of the chromosomes atmetaphase is referred to as the metaphase plate. The keyfeatures of metaphase are:

- Spindle fibres attach to kinetochores ofchromosomes.
- Chromosomes are moved to spindle equator and getaligned along metaphase plate through spindle fibres to both poles.

3.3 Anaphase

At the onset of anaphase, each chromosome arranged atthe metaphase plate is split simultaneously and the twodaughter chromatids, now referred to as chromosomes ofthe future daughter nuclei, begin their migration towardsthe two opposite poles. As each chromosome moves awayfrom the equatorial plate, the centromere of eachchromosome is towards the pole and hence at the leadingedge, with the arms of the chromosome trailing behind (Figure 10.2 c). Thus, anaphase stage is characterised by the following key events:

- Centromeres split and chromatids separate.
- Chromatids move to opposite poles.

3.4 Telophase

At the beginning of the final stage of mitosis, i.e., telophase, the chromosomes that have reached their respective poles decondense and lose their individuality. The individualchromosomes can no longer be seen and chromatin materialtends to collect in a mass in the two poles (Figure 10.2 d).

This is the stage which shows the following key events:

i) Chromosomes cluster at opposite spindle poles and their identity is lost as discrete elements.

ii) Nuclear envelope assembles around the chromosome clusters.

iii) Nucleolus, golgi complex and ER reform.

4. Cytokinesis

Mitosis accomplishes not only the segregation of duplicatedchromosomes into daughter nuclei (karyokinesis), but the cell itself is divided into two daughter cells by a separateprocess called cytokinesis at the end of which cell division iscomplete (Figure 10.2 e). In an animal cell, this is achievedby the appearance of a furrow in the plasma membrane.

The furrow gradually deepens and ultimately joins in thecentre dividing the cell cytoplasm into two. Plant cellshowever, are enclosed by a relatively inextensible cell wall, thererfore they undergo cytokinesis by a differentmechanism. In plant cells, wall formation starts in the centreof the cell and grows outward to meet the existing lateralwalls. The formation of the new cell wall begins with theformation of a simple precursor, called the cell-plate thatrepresents the middle lamella between the walls of twoadjacent cells. At the time of cytoplasmic division, organelleslike mitochondria and plastids get distributed between thetwo daughter cells. In some organisms karyokinesis is not followed by cytokinesis as a result of which multinucleatecondition arises leading to the formation of syncytium (e.g., liquid endosperm in coconut).

5. Significance of Mitosis

a. **Genetic stability:** Mitosis produces two nuclei which have the same number of chorosomes as the parent cell. Since, these chromosomes were derived from parental chromosomes by the exact replication of their DNA, they will carry the same genetically identical to the parent cell and no variation in genetic information can therefore be introduced during mitosis. This results in genetic stability within populations of cells derived from the same parental cells.
b. **Growth:** The number of cells within an organism increases by mitosis. This is the basis of the development of a multicellular body from a single cell, i.e., zygote and also the basis of the growth of a multicellular body.
c. **Cell replacement:** In some parts of body, e.g. skin and digestive tract, cells are constantly sloughed off and replaced by new ones. New cells are formed by mitosis and so are exact copies of the cells being replaced. In like manner, red blood cells have short lifespan (only about 4 months) and new RBCs are formed by mitosis.

d. **Regeneration:** Some organisms can regenerate body parts. The production of new cells in such instances is achieved by mitosis. For example, starfish regenerate lost arms through mitosis.
e. **Asexual reproduction:** Some organisms produce genetically similar offspring through asexual reproduction. For example, the hydra reproduces asexually by budding. The cells at the surface of hydra undergo mitosis and form a mass called a bud. Mitosis continues in the cells of the bud and this grows into a new individual. The same division happens during asexual reproduction or vegetative propagation in plants.

6. Comparison of Mitosis in Animal and Plant cells

While the main purpose of mitosis remains the same in plants and animals, the process contains similarities and differences between these two types of eukaryotic cells.

Similarities

- During Prophase, chromosomes condense
- In Prometaphase, the nuclear envelope breaks down, the chromosomes move towards the metaphase plate, and the spindle grabs the chromosomes
- In Metaphase, the chromosomes align at the equator
- In Anaphase, they move towards opposite poles
- In Telophase, the nuclear envelope appears again, chromosomes de-condense, and the spindle breaks down.

Knowing the basics about these various stages of mitosis is something that is essential for understanding the differences between mitosis in plants vs animals. Though the basic premise and the process is the same, there are some fundamental differences between the two. The most important difference between the two is that animal cells do not exist in a rigid shape. This happens because animals are mobile and the external environment that they live in changes from time to time. On the other hand, plant cells always exist in one fixed shape and moreover, they are designed to carry out photosynthesis, which is essential for their survival. As a result, their shapes and functions are quite different, and this ultimately affects them during the process of mitosis as well. Additionally, animal cells also have smaller vacuoles than plant cells. Vacuoles

are small pockets in the cells that contain water that are essential for the preservation of the cells. After mitosis has been completed and cytokinesis starts, plant cells see the formation of a cell plate. This occurs when the cells start separating from each other, but this is not seen in animal cells. In place of this, a cleavage furrow occurs in animal cells and this is what ultimately separates both the daughter cells from each other after mitosis. The purpose of a cell plate and a cleavage furrow is to separate the resulting nuclei from each other. Centrioles are another distinction between the two cells during mitosis, as they are present in animal cells but absent in plant cells, especially during the metaphase of mitosis. Centrioles are structures that the spindle fibers get attached with, in order to pull the cell apart during the division, and the purpose they fulfill is absolutely vital.

These were the fundamental differences between animal mitosis vs plant mitosis, and these eventually lead to variations in the mitosis process for both these kinds of cells. The appearance of the process, the amount of time it takes and other subtleties of the process also vary from each other as a result of these differences.

7. Summary

Mitosis or the equational division is usually restricted to the diploid cells only. However, in some lower plants and in some social insects haploid cells also divide by mitosis. It is very essential to understand the significance of this division in the life of an organism. Are you aware of some examples where you have studied about haploid and diploid insects?

Mitosis usually results in the production of diploid daughter cells with identical genetic complement. The growth of multicellular organisms is due to mitosis. Cell growth results in disturbing the ratio between the nucleus and the cytoplasm. It therefore becomes essential for the cell to divide to restore the nucleo-cytoplasmic ratio. A very significant contribution of mitosis is cell repair. The cells of the upper layer of the epidermis, cells of the lining of the gut, and blood cells are being constantly replaced. Mitotic divisions in the meristematic tissues – the apical and the lateral cambium, result in a continuous growth of plants throughout their life. To summarise:

- It is an equational division through which identical daughter cells are produced having the same amount and type of genetic constitution as that of the parent cell.

- It is responsible for growth and development of multi-cellular organisms from a single-celled zygote.
- The number of chromosomes remains the same in all the cells produced by this division. Thus, the daughter cells retain the same characters as those of the parent cell.
- It helps the cell in maintaining proper size.
- Mitosis helps in restoring wear and tear in body tissues, replacement of damaged or lost part, healing of wounds and regeneration of detached parts (as in tail of a lizards).
- It is a method of multiplication in unicellular organisms.
- If mitosis remains unchecked, it may result in uncontrolled growth of cells leading to cancer or tumour.