

Cell division mitosis and meiosis biology essay



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The cell cycle describes the sequence of events that occurs during the life of most eukaryotic cells. It spans through mitosis and cytokinesis,(together referred to as the M phase), then through interphase (G1, S, and G2.)

Cell division involves the distribution of identical genetic material, DNA, to two daughter cells. It consists of two phases, nuclear division followed by cytokinesis. Nuclear division divides the genetic material in the nucleus, while cytokinesis divides the cytoplasm. There are two kinds of nuclear division-mitosis and meiosis.

Mitosis divides the nucleus so that both daughter cells are genetically identical. In contrast, meiosis is a reduction division, producing genetically variable daughter cells that contain half the genetic information of the parent cell.

In either mitosis or meiosis, the whole process begins with the condensation(shortening and thickening) of the genetic material, chromatin, into tightly coiled bodies, the chromosomes. Each chromosome is made of two identical halves called sister chromatids joined at the centromere. Each chromatid consists of a single, tightly coiled molecule of DNA, the genetic material of the cell. In diploid cells, there are two copies of every chromosome, forming a pair, called homologous chromosomes. In a homologous pair of chromosomes, one homologue originated from the maternal parent, the other from the paternal parent.

Mitosis

There are four phases in mitosis - prophase, metaphase, anaphase, and telophase.

Prophase -

The nucleoli disappear and the chromatin condenses into chromosomes → the nuclear envelope is degraded → the mitotic spindle is assembled.

The development of the mitotic spindle begins as the centrosomes move apart to opposite ends (or poles) of the nucleus. As they move apart, microtubules develop from each centrosome. Microtubules from each centrosome connect to a specialized region in the centromere called a kinetochore.

Metaphase -

The chromosomes are distributed across the metaphase plate, an imaginary plane lying at the equator, between the two poles of the spindle. Metaphase ends when the microtubules, still attached to the kinetochores, pull each chromosome apart into two chromatids. Each chromatid is complete with a centromere and a kinetochore. Once separated from its sister chromatid, each chromatid is called a chromosome.

Anaphase -

Begins after the chromosomes are separated into sister chromatids. The microtubules connected to the chromatids shorten, thus, pulling the chromosomes to opposite poles. The microtubules shorten due to uncoupling of tubulin units at their chromosome ends. At the end of anaphase, each pole has a complete set of chromosomes, the same number of chromosomes as the original cell. Since they consist of only one chromatid, each chromosome contains only a single copy of the DNA molecule.

Telophase -

The process of nuclear division is completed here. A nuclear envelope develops around each pole, forming

two nuclei. The chromosomes within each of these nuclei disperse into chromatin, and the nucleoli reappear.

A constitutive part of the Telophase called Cytokinesis (in my opinion) creates two daughter cells by a process known as cytoplasmic cleavage.

Whereas conventional mitosis is all about nuclear division into two daughter nuclei, cytokinesis embodies cytoplasmic division to form two cells.

Interphase -

Sequel to completion of mitosis (cytokinesis, inclusive), interphase begins. It is the 'resting period' (The cell is not actively dividing), and arguably the 'growth period' of the cell cycle. This growth period is divided into three phases, designated G1, S, and G2 based of their inherent activities. Although the labels G1 and G2 are associated with growth and S with synthesis, it is worth noting that growth takes place during all three phases. However, S phase marks the time during which the second DNA molecule for each chromosome is synthesized. As a result of this DNA replication, each chromosome that appears at the beginning of the next

mitotic division will appear as two sister chromatids. During the G2 period of growth, materials for the next mitotic division are prepared.

Meiosis

Meiosis is very similar to mitosis, however, major distinction is that meiosis consists of two groups of divisions, meiosis I and meiosis II (both consisting of 4 sub-stages) and occurs only in sexually reproducing organisms.

In meiosis I homologous chromosomes pair at the metaphase plate, and then the homologues migrate to opposite poles, while, in meiosis II, chromosomes spread across the metaphase plate and sister chromatids separate and migrate to opposite poles. Thus, meiosis II is analogous to mitosis. A summary of each meiotic stage follows:

Meiosis I

Prophase I

Starts like prophase of mitosis. The nucleolus disappears → chromatin condenses into chromosomes → the nuclear envelope dissolves → the spindle apparatus develops. Unlike mitosis, however, once the chromosomes are condensed, homologous chromosomes pair, a process called synapsis. These pairs of homologous chromosomes are called tetrads (a group of four chromatids) or bivalents (two pairs). During synapsis, corresponding regions along non-sister chromatids form close associations called chiasmata - sites where genetic material is exchanged between non-sister homologous chromatids, a process called crossing over.

Metaphase I

Homologous pairs of chromosomes are spread across the metaphase plate. Microtubules extending from one pole are attached to the kinetochore of one

member of each homologous pair. Microtubules from the other pole are connected to the second member of each homologous pair.

Anaphase I

Commences when homologues within tetrads uncouple as they are pulled to opposite poles.

Telophase I

Chromosomes are located at their respective poles, and a nuclear membrane develops around them. Each pole forms a new nucleus that will have half the number of chromosomes, but each chromosome will contain two chromatids. Since daughter nuclei will have half the number of chromosomes, cells that they eventually form will be haploid.

As part of telophase I, the cells begin cytokinesis and form cleavage furrows or cell plates. In other species, cytokinesis is delayed until after meiosis II. Also, a short interphase II may begin. No replication of chromosomes occurs during this period. Instead, part II of meiosis begins in both daughter nuclei.

Meiosis II

Prophase II

The nuclear envelope disappears and the spindle develops. There are no chiasmata and no crossing over of genetic material as in prophase I.

Metaphase II

Chromosomes align singly on the metaphase plate (not in tetrads as in metaphase I). Single alignment of chromosomes is exactly what happens in mitosis except that now there is only half the number of chromosomes.

Anaphase II

Each chromosome is pulled apart into two chromatids by the microtubules of the spindle apparatus. The chromatids (now chromosomes) migrate to their respective poles. Similar to what happens in mitosis except that now there is only half the number of chromosomes.

Telophase II

The nuclear envelope reappears at each pole and cytokinesis occurs. The end result of meiosis is four haploid cells (chromosome makeup of each daughter cell designated by n). Each cell contains half the number of chromosomes, and each chromosome consists of only one chromatid. Later in interphase, a second chromatid in each chromosome is replicated, but the cell will still have only half the number of chromosomes.

Consequence of Meiotic Error

Sometimes, a set of chromosomes has an extra or a missing chromosome. This occurs because of non-disjunction -the chromosomes failed to separate properly during meiosis. This error, which produces the wrong number of chromosomes in a cell, results in severe genetic defects. For example, humans typically have 23 pairs of chromosomes, but individuals with Down's syndrome have three-instead of two-copies of the 21st chromosome. A condition known as trisomy and designated as $2n+1$

Chromosomal abnormalities also occur if one or more segments of a chromosome break. The most common example is translocation (a segment of a chromosome moves to another chromosome). Translocation involves transposons, DNA segments that have the ability to move around the genome. Sometimes when they move, they leave behind mutations, and they can cause mutations by inserting into a gene. Fortunately, in most cases, damaged DNA can usually be repaired with special repair enzymes.

A Comparison between Mitosis and Meiosis

Regulation of the Cell Cycle

The cell-cycle control system triggers the events of the cell cycle and ensures that these events are properly timed and occur in the correct order. The control system responds to various intracellular and extracellular signals and arrests the cycle when the cell either fails to complete an essential cell-cycle process or encounters unfavourable environmental or intracellular conditions. This control system comprises of several checkpoints - a critical control point in the cell cycle.

Major checkpoints include G1, G2, and M checkpoints

G1 checkpoint - the Restriction Point. It ensures that the cell is large enough to divide, and that enough nutrients are available to support the resulting daughter cells.

G2 checkpoint - ensures that DNA replication in S phase has been completed successfully

Metaphase checkpoint - ensures that all of the chromosomes are attached to the mitotic spindle by a kinetochore.

Cyclin-dependent protein kinases (Cdks) - as the name implies, depend on cyclin for their activity. Oscillations in the activities of various cyclin-Cdk complexes control various cell-cycle events. Thus, actuation of S-phase cyclin-Cdk complexes (S-Cdk) initiates S phase, while activation of M-phase cyclin-Cdk complexes (M-Cdk) triggers mitosis. The mechanisms that control the activities of cyclin-Cdk complexes include phosphorylation of the Cdk subunit, binding of Cdk inhibitor proteins (CIPs), proteolysis of cyclins, and changes in the transcription of genes encoding Cdk regulators. The cell-cycle control system also depends crucially on two additional enzyme complexes, the anaphase promoting complex (APC) and SCF ubiquitin ligases, which catalyze the ubiquitylation and consequent destruction of specific regulatory proteins that control critical events in the cycle.

Growth factors - Cellular plasma membranes have receptors for external molecules, or growth factors, that

stimulate a cell to divide. One such growth factor is produced by damaged cells, stimulating other cells to divide. More than 50 different growth factors are known.

Density-dependent inhibition - Conventionally, cells stop dividing when the surrounding cell density reaches a certain maximum.

Anchorage dependence - Some cells cannot divide except they are attached to an external surface, such as the flat surface of a neighbouring cell (or the side of a culture dish).

Cells Which No Longer Respond to Cell-Cycle Controls - Cancer Cells Cancer is characterized by uncontrolled cell growth and division.

Transformed/Mutated cells, cells that have become cancerous, proliferate without regard to cell cycle checkpoints (Cancer cells do not exhibit contact inhibition), density-dependent inhibition (If cultured, they continue to grow on top of each other when the total area of the petri dish has been covered), anchorage dependence, and other regulatory mechanisms (or possess abnormal signal transduction sequences which falsely convey growth signals thereby bypassing normal growth checks). Thus, cancer is a disease of the cell cycle.

Acknowledgement - All diagrams/tables were got from

<http://www.uic.edu/classes/bios/bios100/f05pm/lect13.htm>