MITOTIC CELL DIVISION IN 3D

A LEARNING EXPERIENCE WITH AUGMENTED REALITY

by: **Profs. Francisco López, Claudio Palma y Lic. Camilo Ibacache**

At the beginning of the second half of the 19th century two German researchers, Rudolf Virchow and Robert Remarck, stated that "all cell comes from a previously existing cell" (omnis cellula ex cellula). This statement allowed the establishment of a clear relationship between cell division and continuity of life.

In eukariotic unicellular organisms the mitotic cell division determines the reproduction itself of that organism and species perpetuation. One cell divides originating two genetically identical daughter cells, and so the genetic identity of the species is maintained.

In multicellular organisms, the mitotic cell division, is responsible for growth as well as renewal and tissue repair, and also is involved in its reproduction processes.

An average human being of 1.70 m height and 70 Kg weight, has approximately 37 billion cells (Bianconi et al., 2013), all originating by successive divisions from a single cell, the zygote. In humans, similar as in all multicellular organisms, different tissues show various degrees of cellular damage, therefore they have to be renewed constantly. An example are the approximately 2.5 x 10^{10} red blood cells existing in an adult human that have only an average life span of 120 days. To keep this number more or less constant, about two millions eritrocytes per second are produced by mitotic cell divisions from the pluripotent mother cells of the haemotopoietic tissue. On the other hand, the epithelial cells from the intestine have a life span between 2 and 4 days, plus all other cell populations that are in constant renewal in an adult human, and estimated 20 million mitotic cell divisions are performed per second.

To download the application that goes with this e-book (IOS and ANDROID with QR and link)

Disponible en el App Store

DISPONIBLE EN Google play

EUKARIOTIC CELL CYCLE

Cells that make a renewal of all tissues possible divide themselves by mitosis originating two genetically identical daughter cells, and afterwards one or both can divide again. In this way a cycle of dell division or cell cycle is established. This cell cycle is defined as a period starting from the beginning of one division until the beginning of the following, and so on. During this period following phases can be recognized: G_1, S, G_2, that together correspond to the Interphase and M or Mitosis.

When dividing cells are observed under a microscope, the most relevant processes of the cell cycle are the nuclear division, called Mitosis, it usually is continued by the cell division into two, called Cytokinesis. Together both processes are the M Phase of the cell cycle. The period between one M Phase and the next one is called Interphase, where Phases G_1, S and G_2 are included.

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INTERPHASE

G_1 Phase

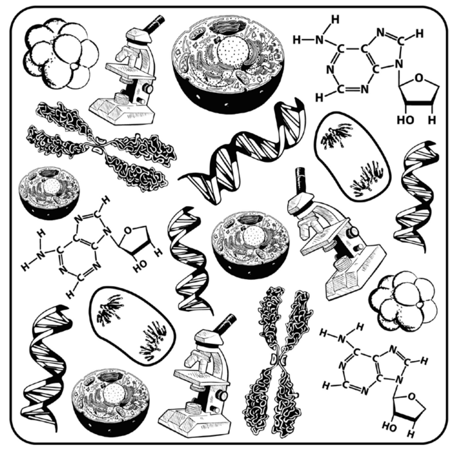
This stage follows after cytokinesis and intense biochemical activity is performed during this period. Cell increases in size and synthesizes all proteins and enzymes needed for the future duplication of its genetic material.

S Phase

This stage follows after G_1, during which DNA duplicates as well as the chromatin fibers.

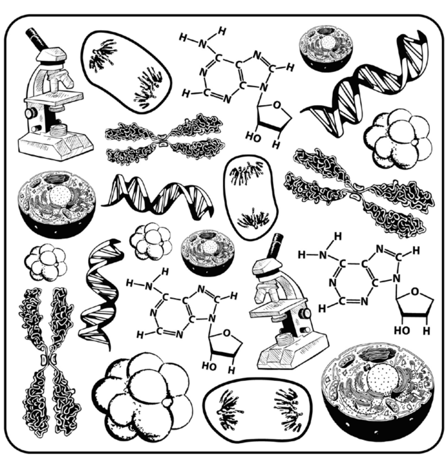
G_2 Phase

This is the previous stage to the M phase. During this stage DNA repair and synthesis of necessary proteins for the mitosis takes place. In this stage the chromatin fibers, they are the future chromosomes, are duplicated but joined through the centromere.



M PHASE (MITOSIS)

During mitosis, the previously duplicated genetic material is evenly distributed through two sets of chromosomes, identical to each other and to that of the progenitor cell. This process is continuous, but conventionally it is divided into four discrete stages: Prophase, Metaphase, Anaphase and Telophase.



Prophase

In the nucleus, the already duplicated chromatin fibers begin to condense, becoming shorter and thicker until they become chromosomes formed by two chromatids joined by the centromere. In animal cells the centrioles, already duplicated, form the centrosomes, which are separated at the beginning of the Profase and migrate towards the poles of the cell and generate the microtubules of the mitotic spindle. Plant cells form spindles without the intervention of centrioles since they lack them.

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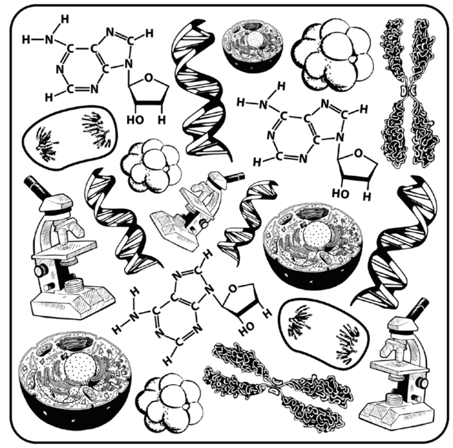
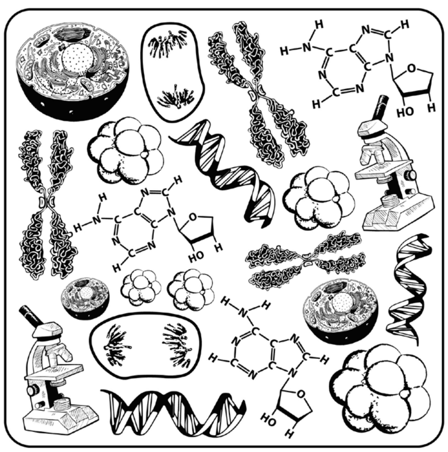
Metaphase

At this stage the chromosomes reach the highest degree of condensation and move, aided by the spindle united to each chromosome by the kinetochore, to aligne along the equatorial plate of the cell.



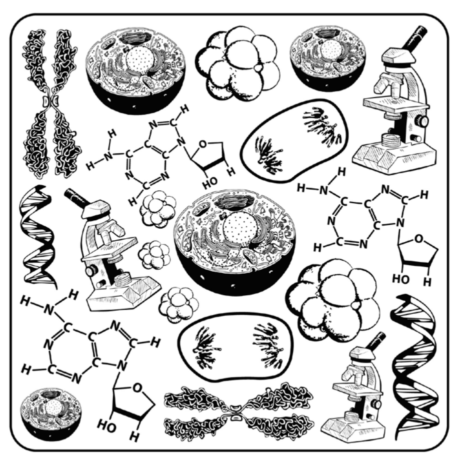


Anaphase

At this stage the sister chromatids are separated forming each a chromosome, , which move towards opposite poles of the cell. This movement is mediated by the microtubules of the mitotic spindle attached to the kinetochore.

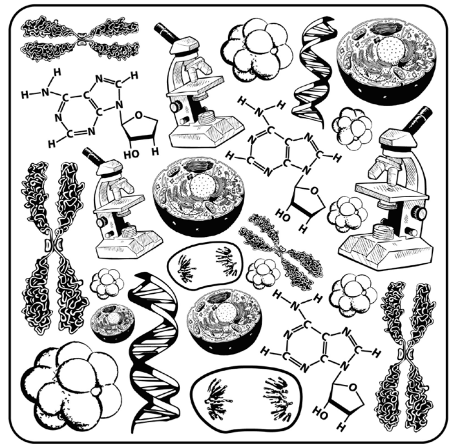
Telophase

The chromosomes reach the poles of the cell and begin their decondensation, the spindle is disassembled and the nuclear envelope of the two new nuclei as well as the nucleoli are reorganized.



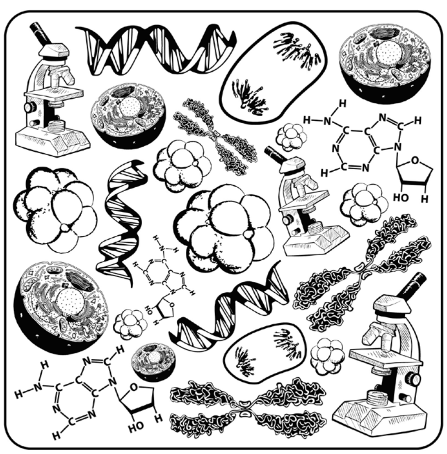
CYTOKINESIS

It is the division of the cytoplasm that begins in the telophase and divides the cell into two cells. In animal cells, it begins with the appearance of a segmentation groove that surrounds the cell, which is deepened until dividing it into two cells. In plant cells, cytokinesis is produced by the formation of a phragmoplast derived from the Golgi system, which is located between the two new nuclei. The result are two genetically identical daughter cells.



CHROMOSOMAL MORPHOLOGY

The chromosomes observable under the microscope and that are the product of the duplication and condensation of chromatin have a characteristic morphology.



Chromatid

In mitotic metaphase, each chromosome consists of two sister chromatids bound by the centromere. This condition is different in the anaphase where each chromosome is constituted by a single chromatid.

Centromere and Kinetochore

The centromere is the constricted point at which the two sister chromatids forming the chromosome are joined together. On both sides of this zone a protein structure is formed, called kinetochore, to which the microtubules of the spindle will attach.

Telomere

Is the natural end of a chromosome and serve to stabilize the chromosome.

EVALUATE WHAT YOU HAVE LEARNED WITH THIS EXPERIENCE

1.- What difference can you observe between Metaphase and Anaphase chromosomes?

2.- Considering what was observed in this app. What is the number of chromosomes that each cell will have at the end of this cell division?

3.- If the onset of anaphase is blocked, but allows the separation of the sister chromatids. What is the number of chromosomes present in the daughter cell?

4.- If we assume that the initial cell presented in the App contains 12 picograms of DNA.

How many picograms of DNA would be present at the cell in Prophase?

How many picograms of DNA would be present at the cell in Metaphase?

How many picograms of DNA would be present at the cell in Anaphase?

How many picograms of DNA will be present in the cells at the end of this cell division?

5.- Which stage of the process of mitotic division is characteristic the chromosome that is shown isolated in this App?

1) Print out this page on a rigid material.
2) Cut out the cube following the lines.
3) Go to the app Cell Division 3D and focus on the cube with your cell phone