

# Cell division

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*Cell cycle*

## Objectives :

- Define the cell cycle
- Explain how the DNA is packaged into chromosomes (referring to nucleosomes , chromatin and chromosomes)
- Describe the stages of the cell cycle: Interphase G1, S and G2
- Explain the appearance of chromosomes after duplication
- Mitosis (prophase, metaphase , anaphase , telophase) and Cytokinesis

## Resources :

Book pages 18,19,20,21

<https://www.youtube.com/watch?v=XKZhcYetvsc> introduction

<https://www.youtube.com/watch?v=5VyQNcH3ZL0> interphase

<https://www.youtube.com/watch?v=DwAF'Zb8juMQ> phases

## Cell division <https://vcell.science/project/mitosis>

Cells reach a certain size and then divide. As cells grow, the surface area to volume ratio decreases. The **surface area** of the cell controls the rate of **material exchange**, while the **volume of the cell** controls the rate of **resource consumption**, and waste and heat production. When the cell grows, the volume increases much faster than the surface area (so the ratio decreases). As a result, material cannot be exchanged fast enough to provide enough resources for the cell to consume, and to get rid of the waste and heat produced in the cell. Therefore, the cell stops growing and divides.

# The cell cycle <https://wordwall.net/resource/36348416/cell-cycle-diagram>

The cell cycle describes the behavior of cells as they grow and divide. The cell cycle involves three main stages, interphase, mitosis and cytokinesis (figure 20).

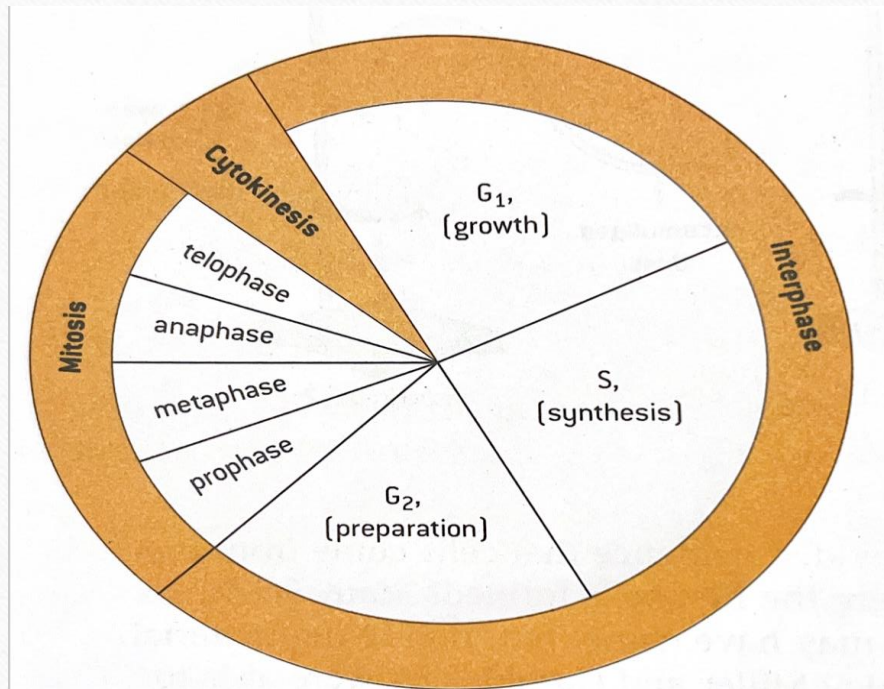


Figure 20. The cell cycle

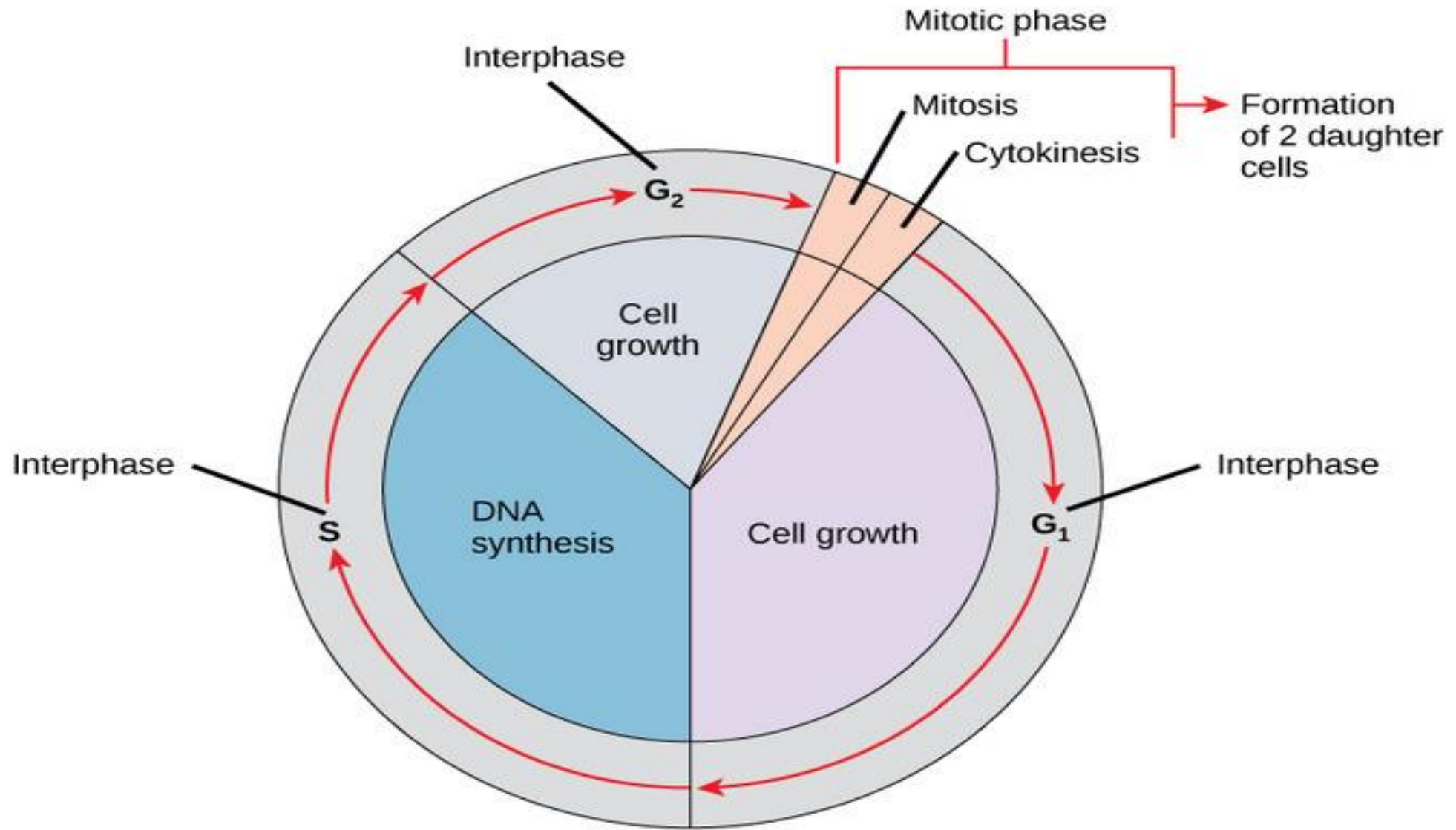
## Stage 1- Interphase <https://www.youtube.com/watch?v=5VyQNcH3ZL0&t=104s>

Interphase is the **longest** phase of the cell cycle. During this phase, the nucleus and cytoplasm pass through many processes such as DNA replication, protein synthesis and an increase in the number of organelles.

It is divided into three phases: G1, S and G2.

The main activities in each phase include:

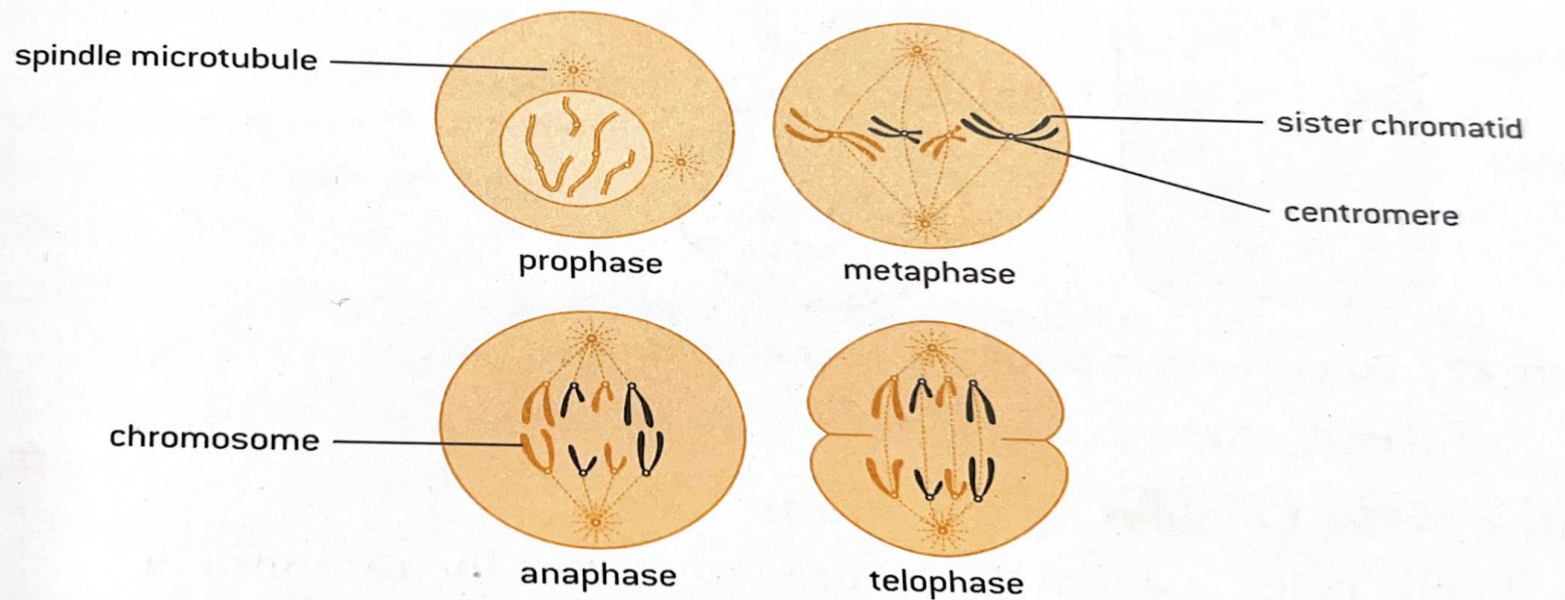
- **G1 phase:** The **cell grows in size**, **protein synthesis** takes place In the cytoplasm and organelles increase in number.
- **S phase:** **DNA replication** takes place in the nucleus.
- **G2 phase:** The cell **grows in size** and prepares for mitosis.



## Stage 2-Mitosis <https://www.youtube.com/watch?v=DwAFZb8juMQ>

Mitosis is the division of the nucleus to form two genetically identical daughter nuclei. Mitosis is divided into four main phases:

**Prophase, Metaphase, Anaphase and Telophase.**



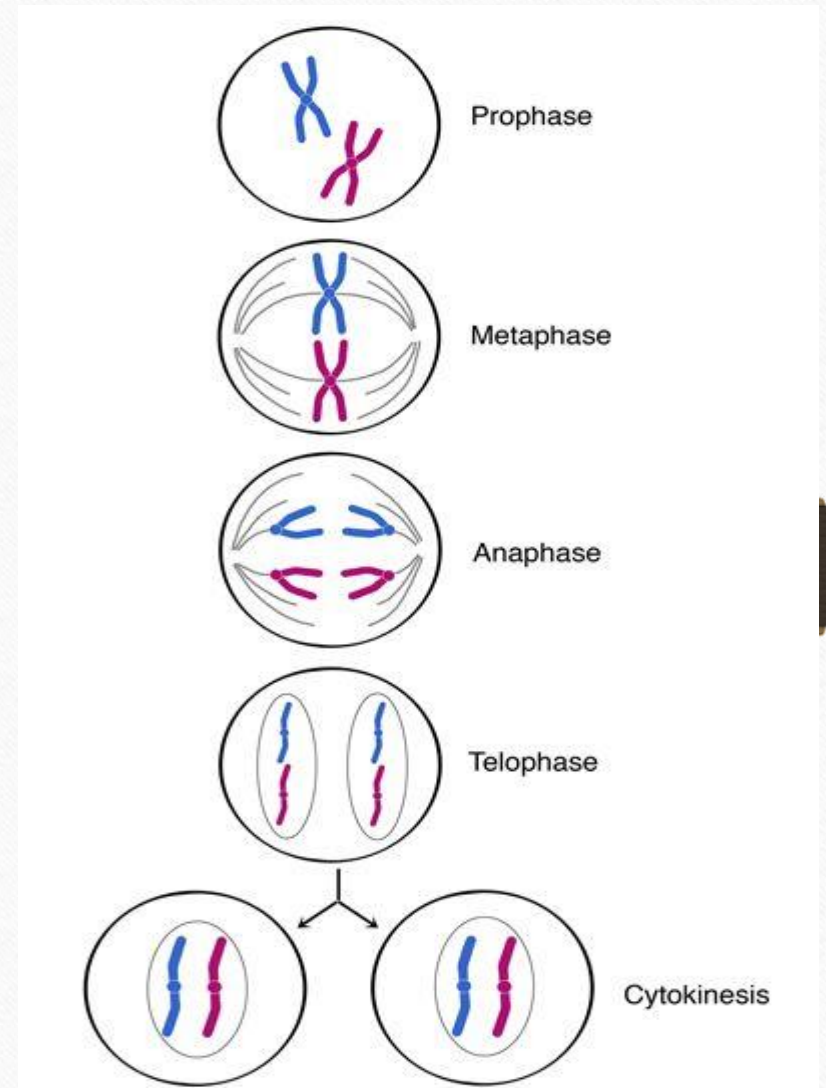
**Figure 21.** The four phases of mitosis

## Prophase

- The spindle microtubules (a component of the cytoplasm) start growing and extend from each pole to the equator.
- Sister chromatids condense, thicken, shorten and become visible.
- The nuclear membrane starts breaking down.

## Metaphase

- The sister chromatids move to the equator and line up separately,
- The spindle microtubules from each pole attach to each centromere on opposite sides.
- The spindle microtubules are fully developed.





spindle microtubule



prophase



sister chromatid

centromere

metaphase

## Anaphase

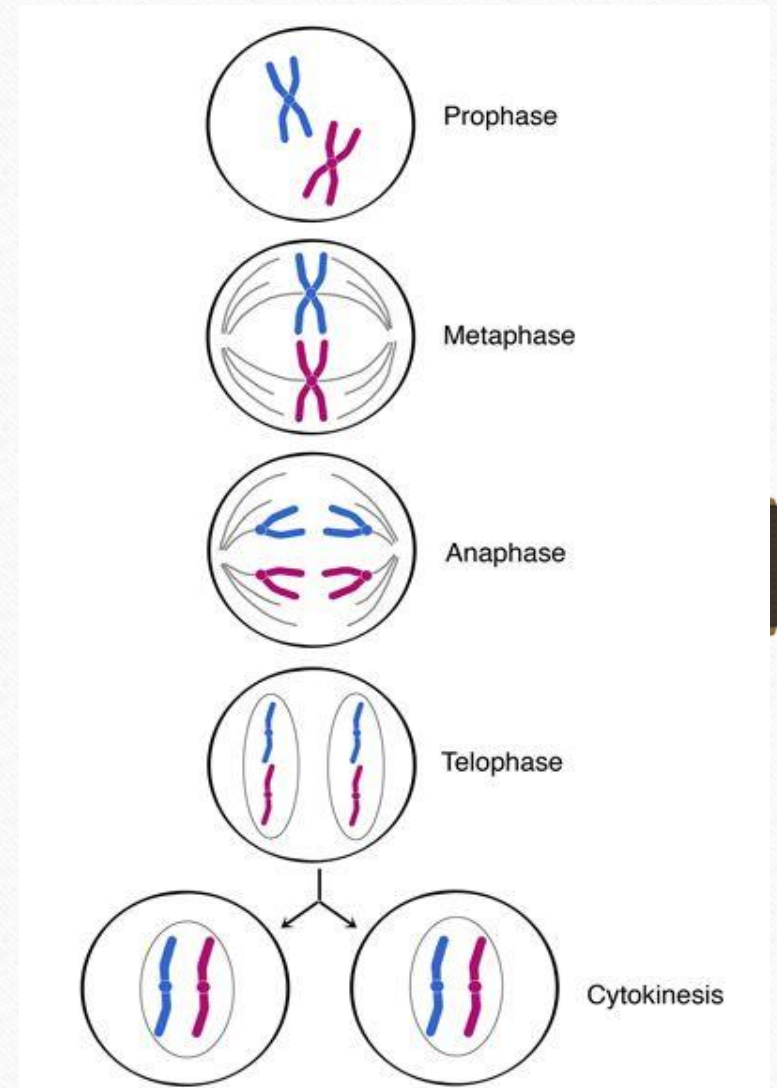
- The spindle microtubules contract to pull the sister chromatids apart splitting the centromeres.
- This splits the sister chromatids into chromosomes.
- Each identical chromosome is pulled to opposite poles.

## Telophase

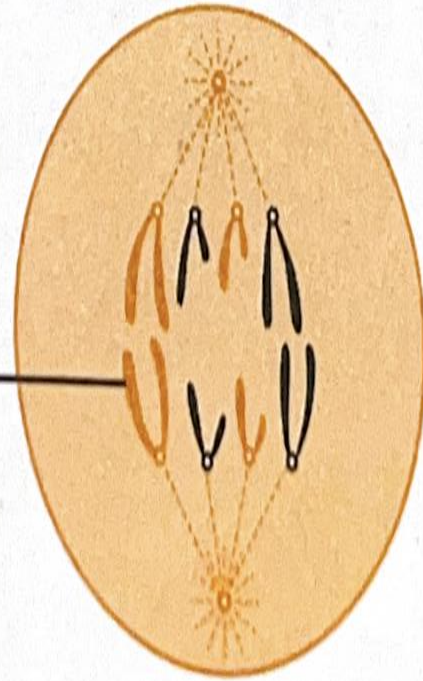
- The spindle microtubules break down.
- The chromosomes decondense and are no longer individually visible
- The nuclear membrane reforms.

*The cell then divides by cytokinesis to form two daughter cells with identical genetic nuclei.*

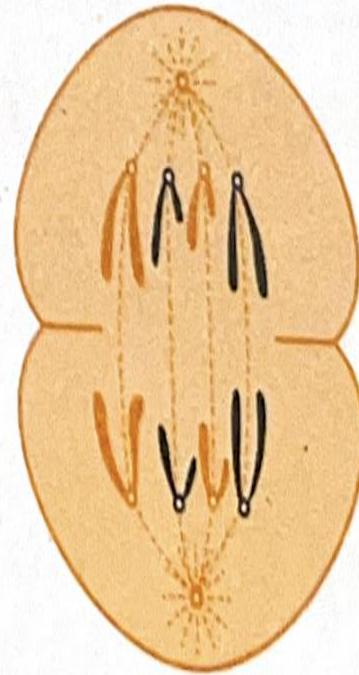
*Mitosis occurs in processes such as growth, embryonic development, tissue repair and asexual reproduction.*



chromosome



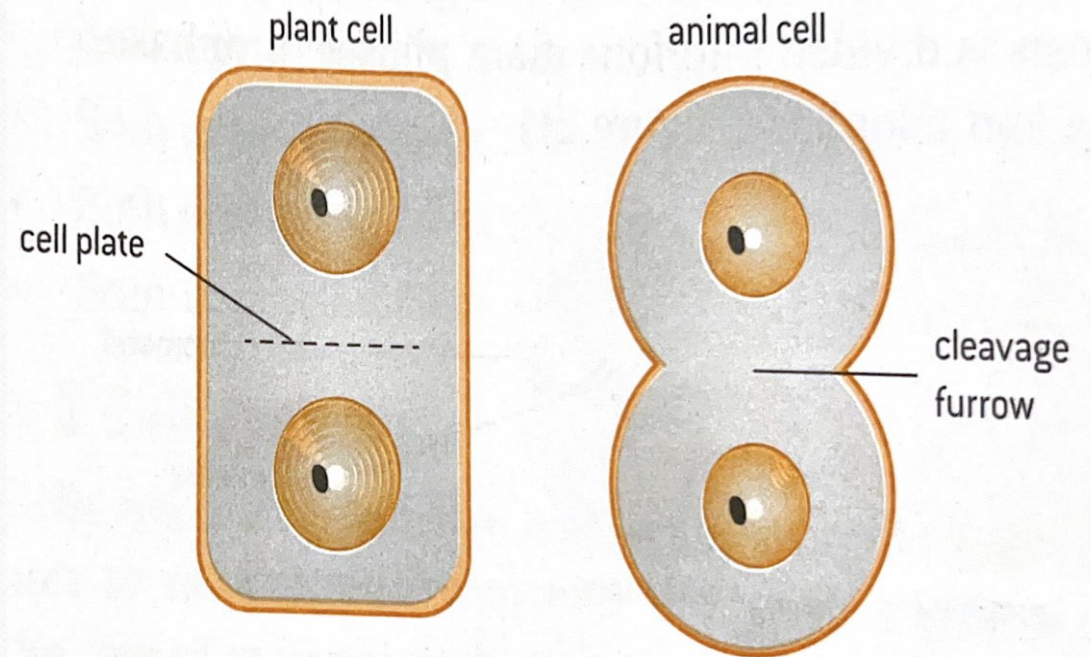
anaphase



telophase

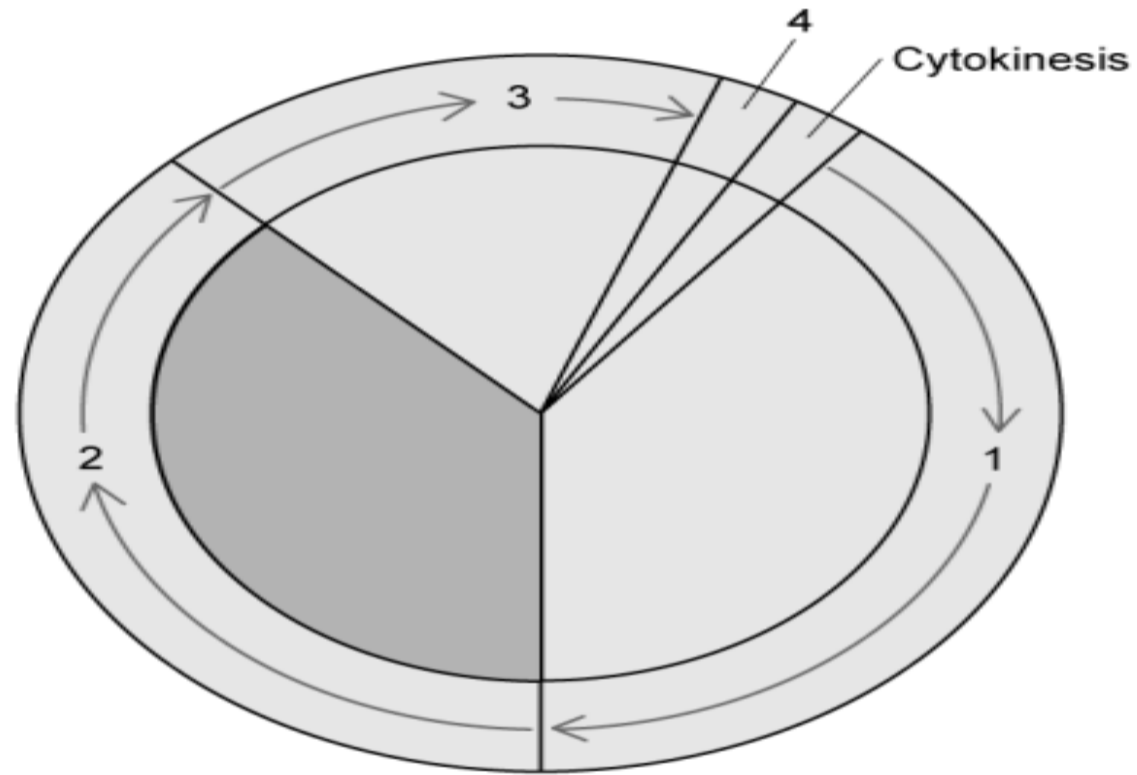
## Stage 3 - Cytokinesis

Cytokinesis is the last stage of the cell cycle during which the cytoplasm divides to develop two identical daughter cells. In plant cells, the cell wall forms a plate between the dividing cells. In animal cells, the cell pinches in the middle of the two dividing cells forming a cleavage furrow



**Figure 22.** Cytokinesis in plant and animal cells

1. The diagram below shows the different phases of the cell cycle.



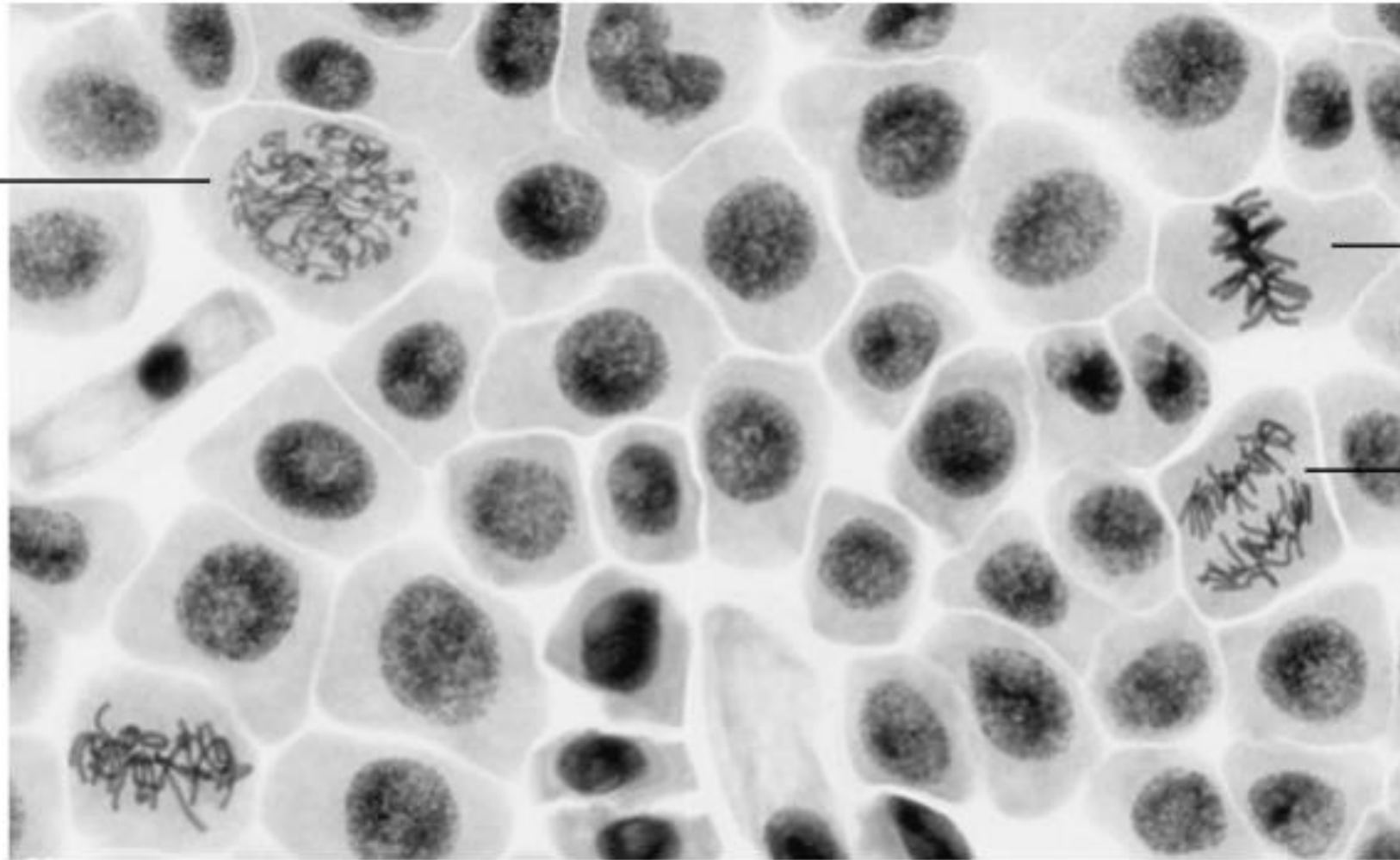
Which of the following rows correctly identifies the phases of the cell cycle?

	1	2	3	4
A.	Interphase: $G_1$	Interphase: $G_2$	Interphase: S	Nuclear division
B.	Mitosis	Interphase: $G_1$	Interphase: S	Interphase: $G_2$
C.	Interphase: $G_1$	Interphase: S	Interphase: $G_2$	Nuclear division
D.	Interphase: S	Interphase: $G_1$	Interphase: $G_2$	Mitosis

2. The micrograph below show cells that are in various stages of the cell cycle.

Prophase

P



Metaphase

Q

R

Anaphase


4. What properties does a human cell have just before it enters prophase?

	<b>Nuclear membrane present</b>	<b>Spindle present</b>	<b>Number of chromatids</b>
<b>A</b>	No	Yes	92
<b>B</b>	Yes	No	92
<b>C</b>	Yes	Yes	46
<b>D</b>	Yes	No	46

5. Each of the following events takes place during mitosis.

- 1 Chromosomes uncoil.
- 2 Chromatids move to opposite poles of the cell.
- 3 Centromeres divide.
- 4 Chromosomes line up along the equator of the spindle.
- 5 Two chromatids are joined by a centromere.

In which order do the events take place?

	<b>First</b>				<b>Last</b>
<b>A</b>	1	2	4	5	3
<b>B</b>	3	1	2	4	5
<b>C</b>	4	5	3	1	2
<b>D</b>	5	4	3	2	1



## Cell division in prokaryotes <https://www.youtube.com/watch?v=XICA-cdvSvU>

Most prokaryotic cells divide by binary fission. Binary fission is an asexual method that involves the splitting of the parent cell to produce two genetically identical cells (figure 24).

Binary fission involves the following steps:

1. DNA replication takes place in which the DNA strand and the plasmid are duplicated.
2. Each DNA copy separates and moves to an opposite direction.
3. The cell grows and elongates.
4. Cytokinesis: the cell membrane pinches in the middle to divide the cell into two identical daughter cells.

cytoplasm

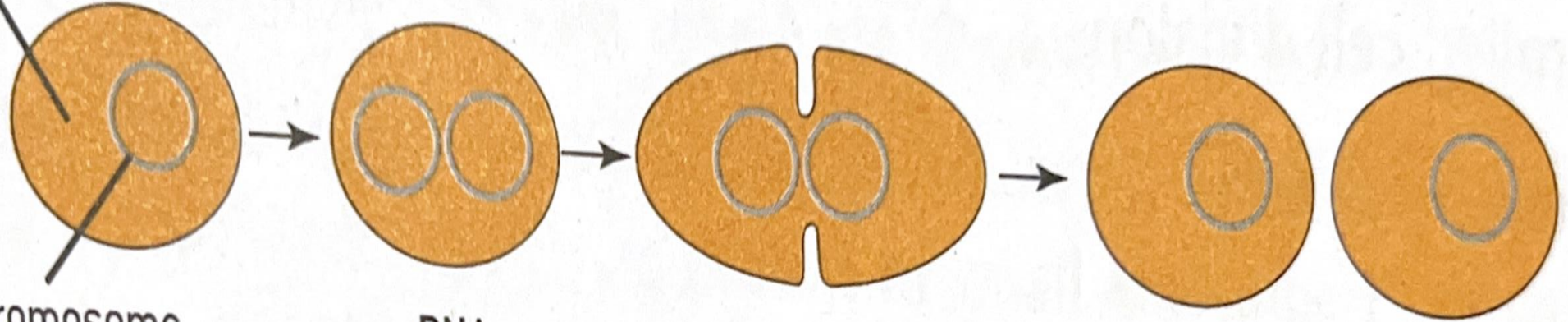
chromosome

DNA  
replication

cytokinesis

two identical  
daughter cells

**Figure 24.** Binary fission



**Mutations** <https://www.youtube.com/watch?v=MOtRqBs0jxE>

**Tumour formation** <https://www.youtube.com/watch?v=KMkmpitAH0>

Cell division is a controlled process in the body. **Tumours form because of uncontrolled cell division.** There are two types of tumours:

- **Benign tumours** which do not invade any body tissue. These tumours are usually inactive and harmless.
- **Malignant tumours** which are detached and carried in the bloodstream to other parts of the body. This will result in a secondary tumour or metastasis. These tumours are known as cancer because they are dangerous and life-threatening

**What causes tumour formation?**

The cell cycle is controlled by specific genes. If these genes mutate, the cell cycle is no longer controlled, and the cell will divide in an abnormal way. Mutation occurs because of several factors including smoking, high exposure to radiation such as X-rays and ultraviolet (UV) light, some viruses, and carcinogens such as benzene and asbestos.

Cancer cells result from rapid, uncontrolled cell division and therefore have a **shorter interphase** (when the cell carries out protein synthesis and grows). Mitosis takes a specific length of time, whereas the length of interphase varies depending on when the cell receives a signal to divide.

*Metastasis is the movement of cells from a primary tumour that are carried in the bloodstream and form secondary tumours in other parts of the body.*

**Stem cells** : <https://www.youtube.com/watch?v=fp5H3SslskQ>

Stem cells are undifferentiated cells that can divide and differentiate into many different types of cell. **Stem cells can be found in both plants and animals.**

**In plants**, stem cells are found in meristems (the tips of roots and shoots).

**In animals**, stem cells can be found in different places including embryos, some adult cells such as hematopoietic cells (in bone marrow) and cord blood cells. Stem cells can be used for the treatment of many diseases such as leukemia, lymphoma and diabetes.

**Table 7.** The ethical considerations about the use of the three types of stem cells

<b>Stem cells</b>	<b>Arguments for</b>	<b>Arguments against</b>
Embryonic stem cells	<ul style="list-style-type: none"><li>• Easy to obtain</li><li>• Pluripotent; can differentiate to many types of cells</li></ul>	<ul style="list-style-type: none"><li>• Involves the destruction of an embryo</li><li>• May result in tumour development</li></ul>
Adult stem cells	<ul style="list-style-type: none"><li>• Does not involve the destruction of an embryo</li><li>• Low chance of tumour development</li></ul>	<ul style="list-style-type: none"><li>• Limited differentiation</li><li>• Sometimes not easily obtained</li></ul>
Cord blood stem cells	<ul style="list-style-type: none"><li>• Easy to obtain</li><li>• Does not involve the destruction of an embryo</li><li>• Can differentiate to many types of cells</li><li>• Low chance of tumour development</li></ul>	<ul style="list-style-type: none"><li>• Must be obtained immediately after birth</li></ul>

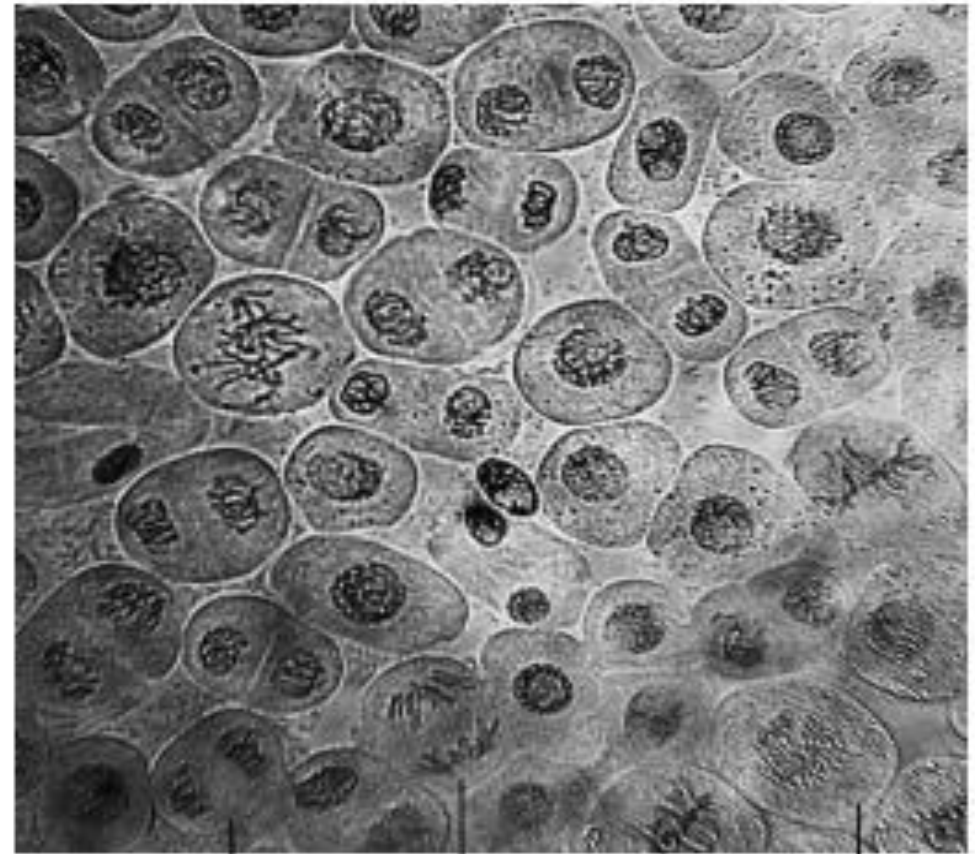
## MITOTIC INDEX

The **mitotic index** is the ratio between the number of cells in mitosis in a tissue and the total number of observed cells.

$$\text{Mitotic index} = \frac{\text{number of cells in mitosis}}{\text{total number of cells}}$$

Count the total number of cells in the micrograph and then count the number of cells in any of the four phases of mitosis. The mitotic index can then be calculated.

The mitotic index is used by doctors to predict how rapidly a tumour will grow and therefore what treatment is needed. A high index indicates a fast-growing tumour. One cell in each of the four stages of mitosis is identified right.



telophase

anaphase

metaphase

prophase

The table below shows the number of cells in different stages of mitosis in a sample from a garlic root tip.

Stage of mitotic cell cycle	Number of cells
Interphase	80
Prophase	11
Metaphase	2
Anaphase	4
Telophase	3

What is the mitotic index for this tissue?

- A** 0.20
- B** 20
- C** 0.80
- D** 4



The risk of developing a cancerous tumour is increased by exposure to which of the following?

	Ultraviolet light	Viruses	Carbon monoxide	X-rays
<b>A</b>	✓	✓	X	✓
<b>B</b>	✓	X	X	✓
<b>C</b>	X	✓	✓	X
<b>D</b>	✓	X	✓	X

Key: ✓ = increases risk, X = does not increase risk

Tumors are formed from uncontrolled cell division of cancer cells.

Which statement describes the difference between a normal cell and a cancer cell?

- A** Only cancer cells have mutated DNA.
- B** Cancer cells do not undergo cytokinesis.
- C** Cancer cells have a shorter interphase.
- D** Cancer cells do not have metaphase.