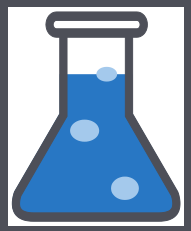
Go to the "Slide Show" shade above

Click on "Play from Beginning"

Chapter 10
Cell Reproduction
Mitosis

Lesson Objectives



By the end of this lesson, you should be able to:

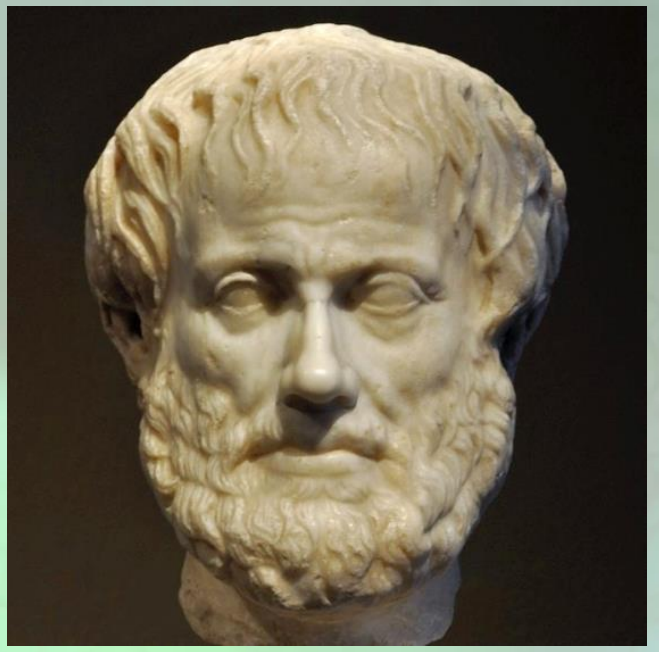
- ❑ Discuss the biological process of asexual cell division, called mitosis.
- ❑ Review the theory of spontaneous generation and how it was disproved.
- ❑ Review the Theory of Biogenesis.
- ❑ Investigate the process of DNA replication.
- ❑ Learn how DNA is packaged in the cell at various stages.
- ❑ Discuss the events of the cell cycle.
- **Science Practice: Mitosis in Onion Root Tip Cells**

Introduction

- **Biogenesis:**
  - The idea that life can only come from other life forms.
  - Every cell originates from another existing cell that is just like it.
- All cells are derived from pre-existing cells.
- New cells are produced for growth and to replace damaged or old cells.

Spontaneous Generation

- **ABIOGENESIS:** Belief that **life** can arise from **nonliving** materials … a major premise of gradualistic evolution.
- Proposed by **Aristotle.**
- Taught from 800 B.C. until 1700s (almost 2000 years).
- Carolus Linnaeus, who is usually regarded as the founder of modern taxonomy promoted spontaneous generation.



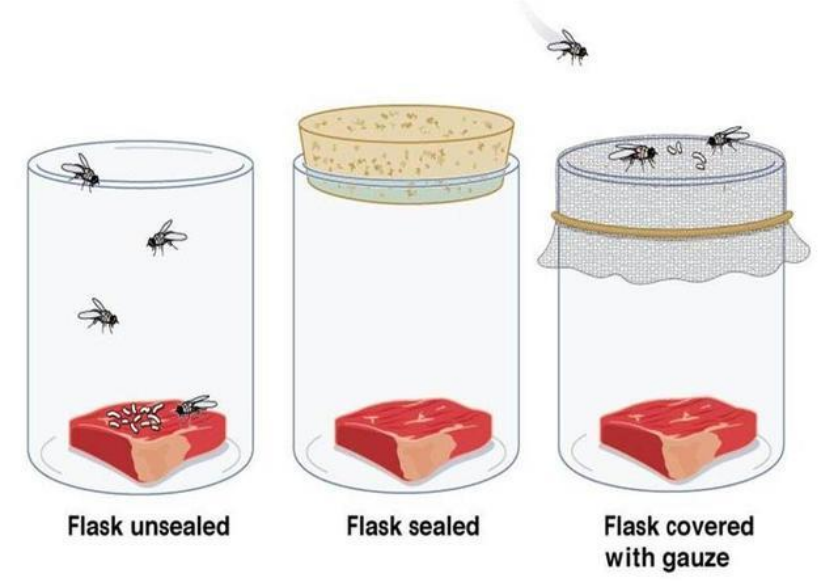
Spontaneous Generation

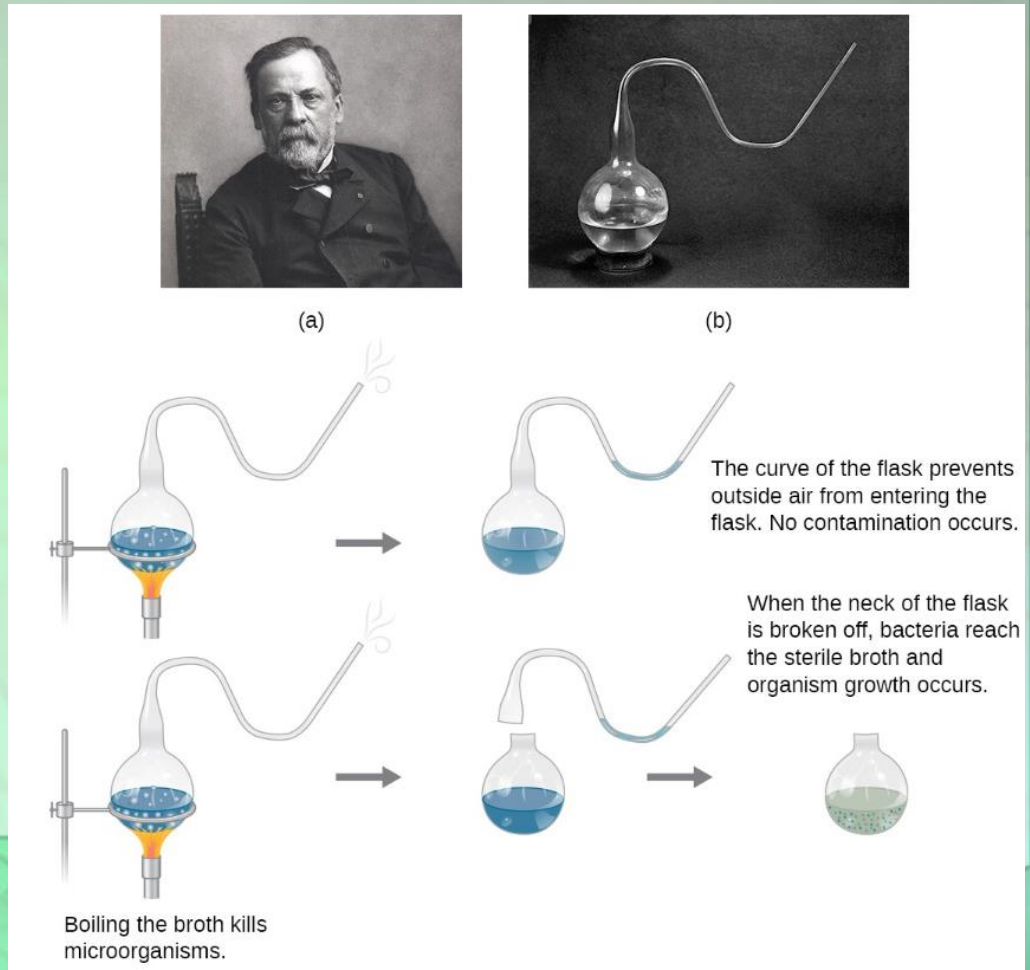
John Needham

- ✓ Used poor experimentation and stated that spontaneous generation exists.
- ✓ In England, John Needham conducted an experiment in which he placed a broth, or gravy, into a bottle, heated the bottle to kill anything inside, then sealed it.
- ✓ Days later, he reported the presence of life in the broth and announced that life had been created from nonlife.
- ✓ In actuality, he did not heat it long enough to kill all the microbes.

Disproving Spontaneous Generation

- ✓ 1668, **Francesco Redi** tested the meat maggot theory.
- ✓ **Louis Pasteur** tested his idea of microorganisms.
- ✓ Abiogenesis was thoroughly **disproven** by **Pasteur** in the mid 1800's.





Spontaneous Generation

How does this square with Evolutionary Theory?

- ✓ It suggests that life originated out of the **primordial soup** as a result of a **big bang.**
- ✓ Sir Fred Hoyle calculated that the possibility of this happening on its own was **slim to none.**

The previously agnostic scientist Sir Fred Hoyle was driven to become a creationist of sorts when he tried to calculate the probability of such a chance assemblage.

"Precious little in the way of biochemical evolution could have happened on the earth. If one counts the number of trial assemblies of amino acid that are needed to give rise to the enzymes, the probability of their discovery by random shufflings turns out to be less than 1 in 1040,000."

Morris, Henry M. (2002-05-31). The Biblical Basis for Modern Science (Kindle Locations 4963-4967). Master Books. Kindle Edition.

Spontaneous Generation

How does this square with Evolutionary Theory?

- ✓ God created "ex nihilo" (out of nothing).
- ✓ God created all organisms "After its Kind"?

Then God said, "Let the earth sprout vegetation, plants yielding seed, and fruit trees on the earth bearing fruit after their kind with seed in them"; and it was so. Genesis 1:11

God created the great sea monsters and every living creature that moves, with which the waters swarmed after their kind, and every winged bird after its kind; and God saw that it was good. Genesis 1:21

And God said, "Let the land produce living creatures according to their kinds: the livestock, the creatures that move along the ground, and the wild animals, each according to its kind." And it was so.

God made the beasts of the earth after their kind, and the cattle after their kind, and everything that creeps on the ground after its kind; and God saw that it was good. Genesis 1:24-25

Spontaneous Generation

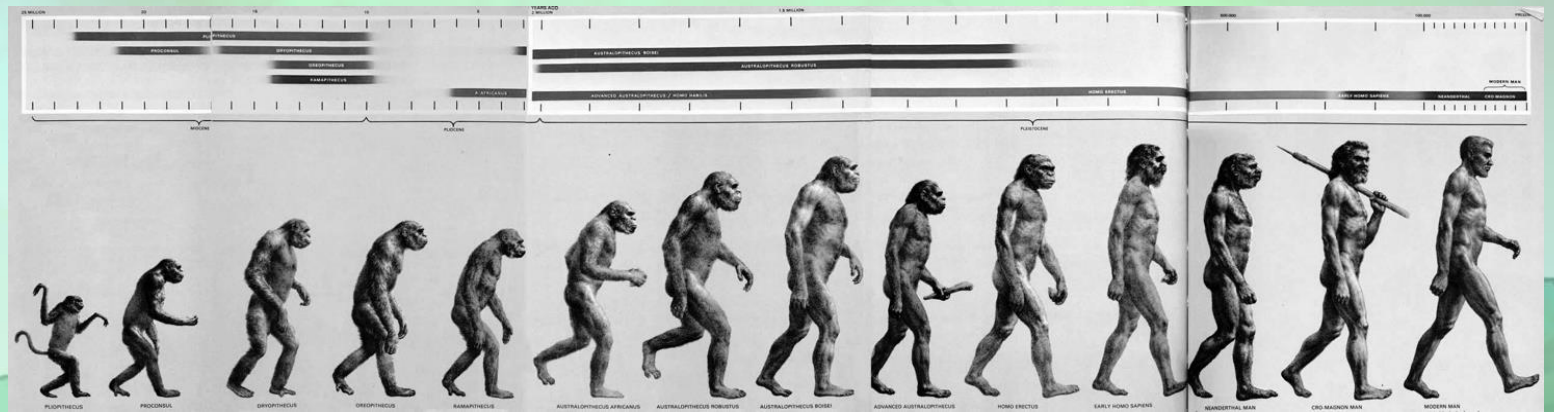
How does this square with Evolutionary Theory?

- ✓ What about transitional fossils?

Stephen Jay Gould of Harvard was perhaps the leading representative of this modern school of paleontologists. He made the following admission:

"All paleontologists know that the fossil record contains precious little in the way of intermediate forms; transitions between major groups are characteristically abrupt."

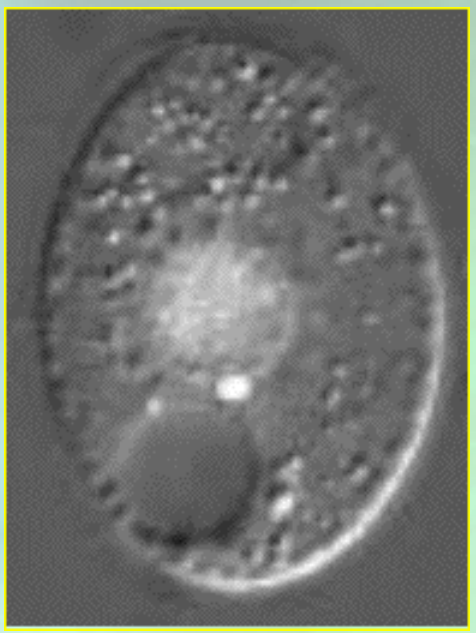
- Morris, Henry M. (2002-05-31). The Biblical Basis for Modern Science (Kindle Locations 7180-7183). Master Books. Kindle Edition.



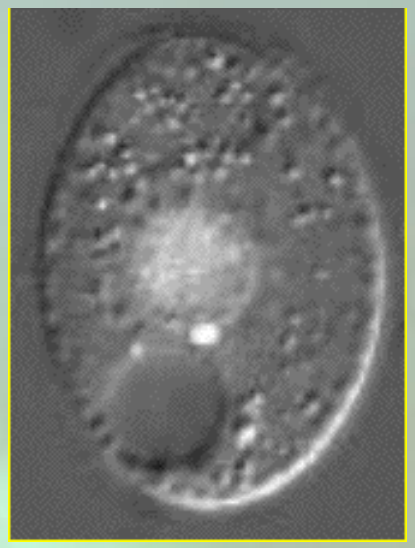
Cell Division plays many Important Roles in the Lives of Organisms

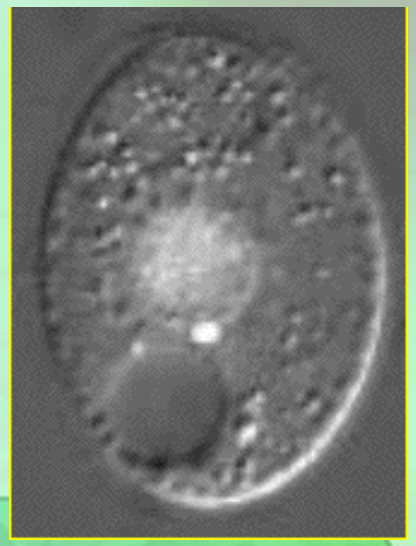
- The ability of organisms to **reproduce their own kind** is a key characteristic of life.
- **Cell Division**
  - is reproduction at the cellular level
  - produces **two "daughter" cells** that are genetically identical to each other and the original "parent" cell
  - requires the **duplication of chromosomes**, the structures that contain most of the cell's DNA
  - sorts new sets of chromosomes into the resulting pair of daughter cells.

Identical Daughter Cells



Parent Cell





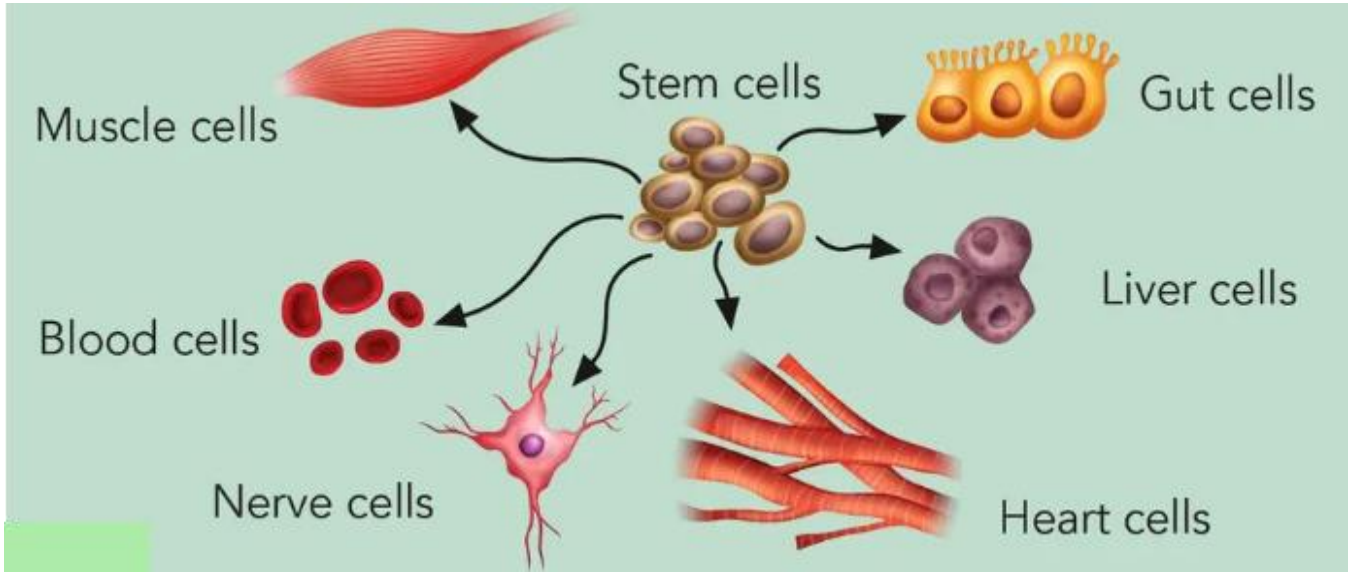
Two identical daughter cells

Cell Division plays many Important Roles in the Lives of Organisms

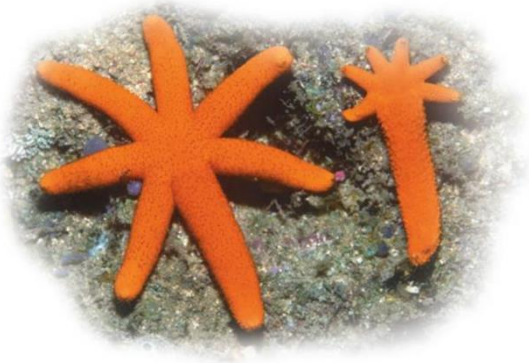
- Living organisms **reproduce** by two methods:
  - **Asexual Reproduction**
    - produces offspring that are **identical to the original cell or organism.**
    - involves inheritance of all genes from one parent.
  - **Sexual Reproduction**
    - produces offspring that are **similar to the parents but show variations in traits.**
    - involves inheritance of unique sets of genes from two parents.

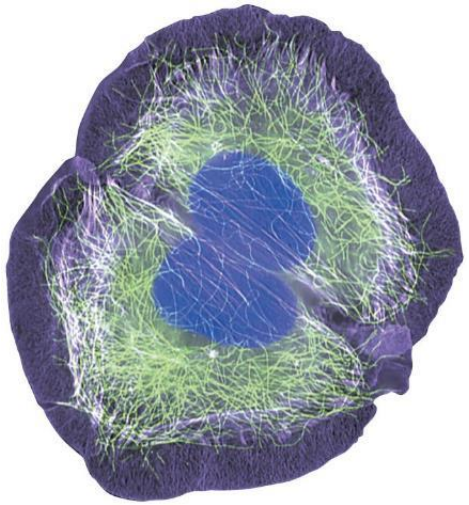
Cell Division plays many Important Roles in the Lives of Organisms

- **Cell Division** is used for:
  - reproduction of single-celled organisms.
  - growth of multicellular organisms from a fertilized egg into an adult.
  - repair and replacement of cells.
  - production of sperm and eggs.



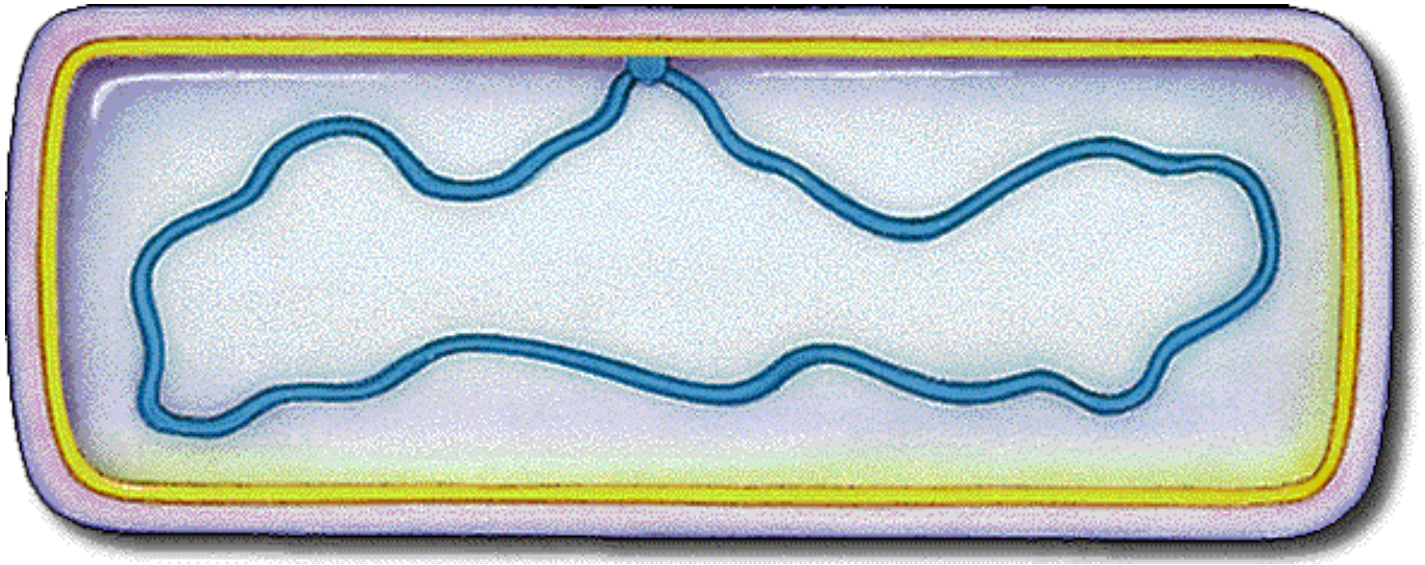
Cell Division plays many Important Roles in the Lives of Organisms





PROKARYOTES Reproduce by Binary Fission

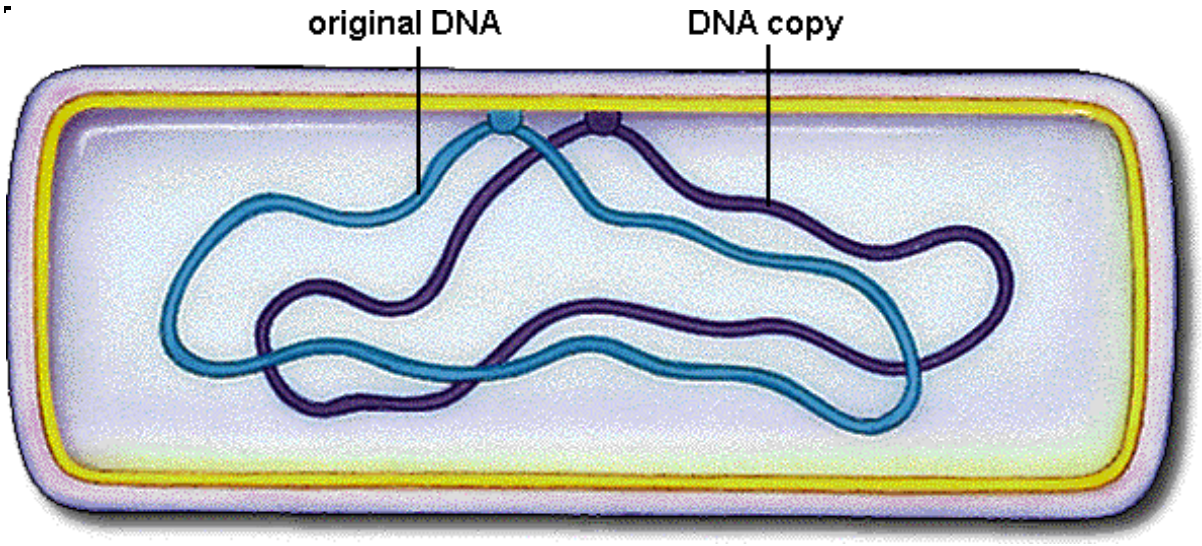
- **Prokaryotes** (single-celled bacteria and archaea) reproduce by **Binary Fission** (“dividing in half”).
- The chromosome of a prokaryote is typically
  - a **single circular DNA molecule** associated with proteins.
  - much smaller than those of eukaryotes.



Prokaryotes Reproduce by Binary Fission

Binary Fission of a **prokaryote** occurs in three stages:

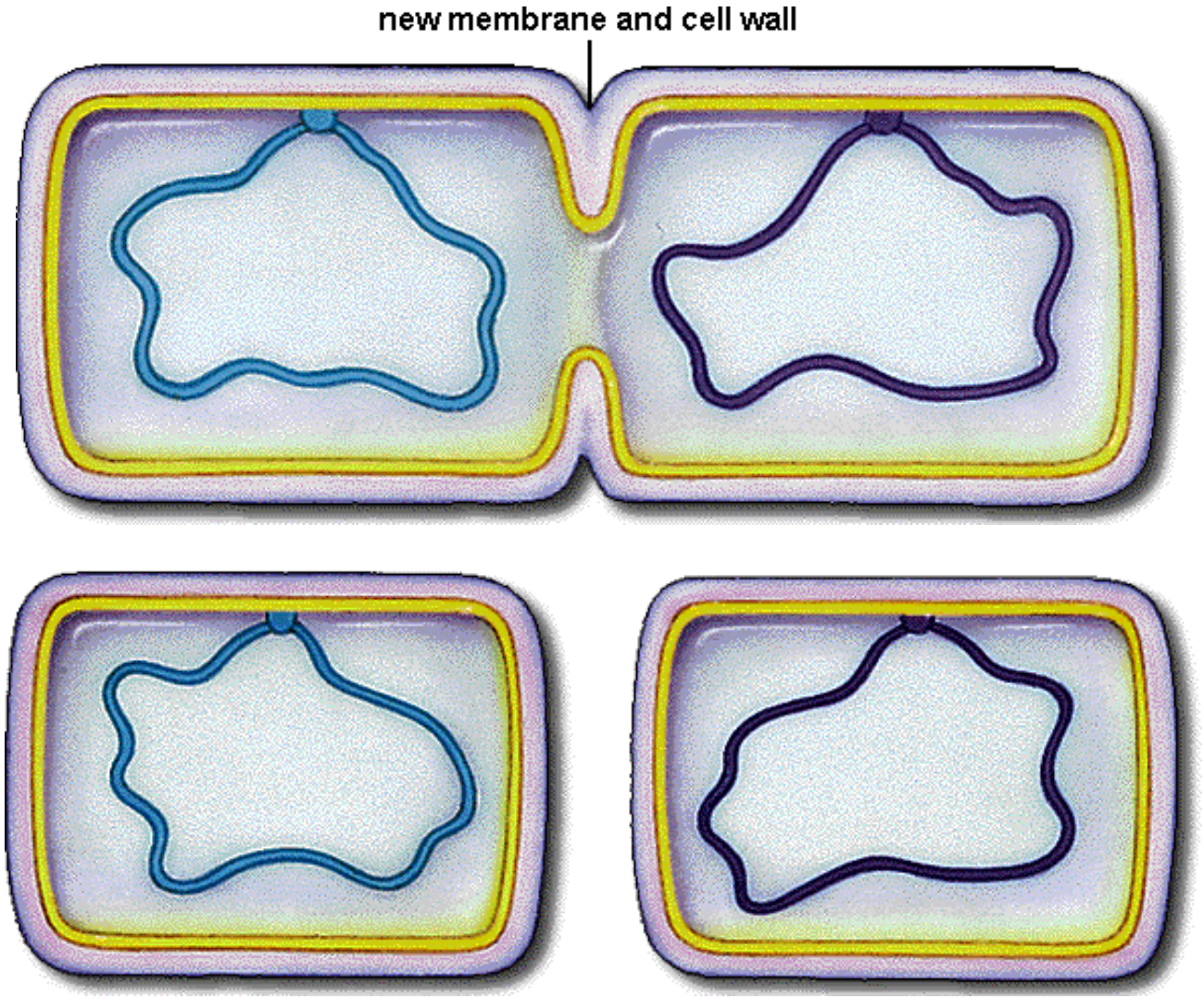
1. Duplication of the chromosome and separation of the copies.

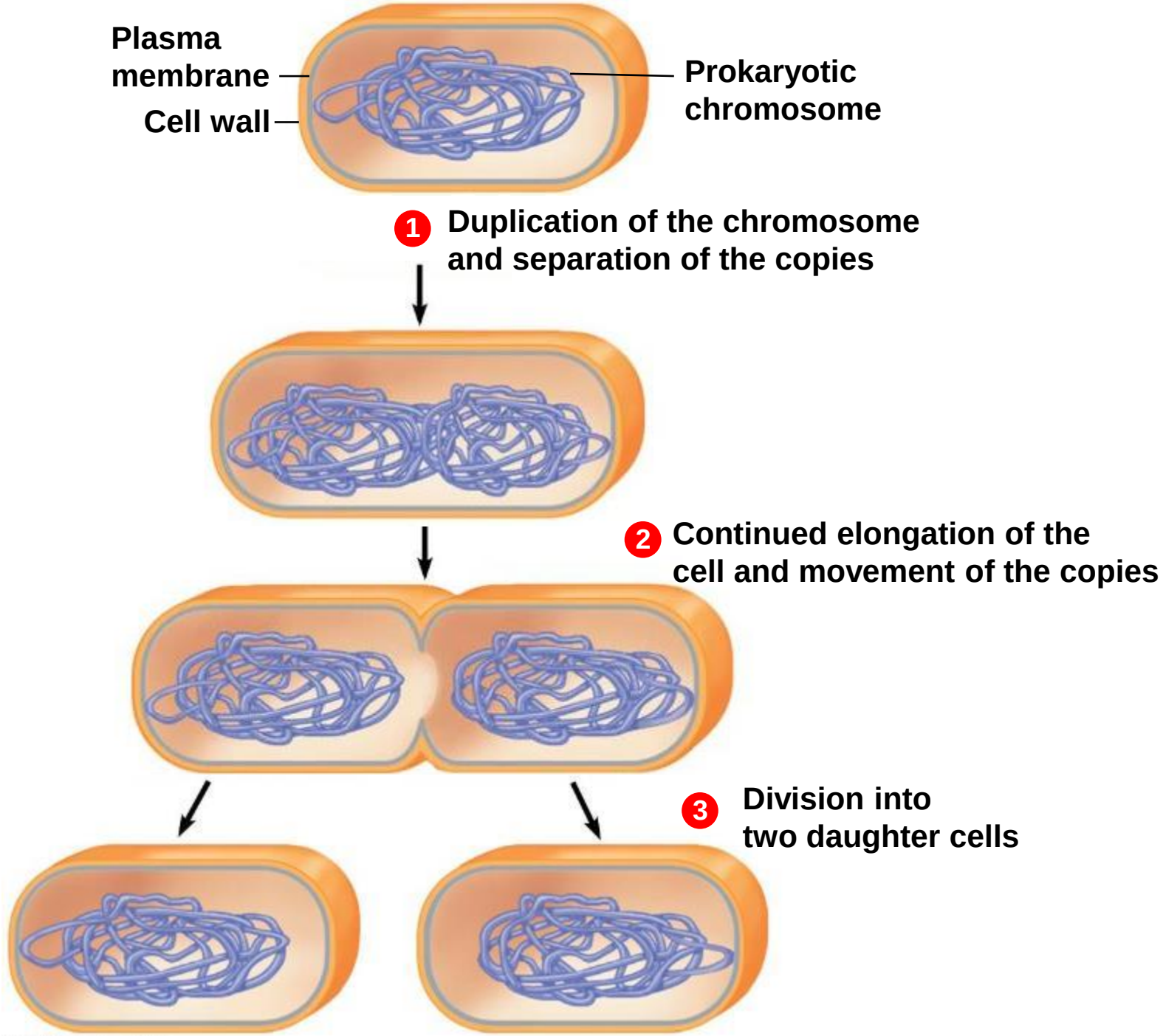


2. Continued elongation of the cell and movement of the copies.
3. Division into two daughter cells.

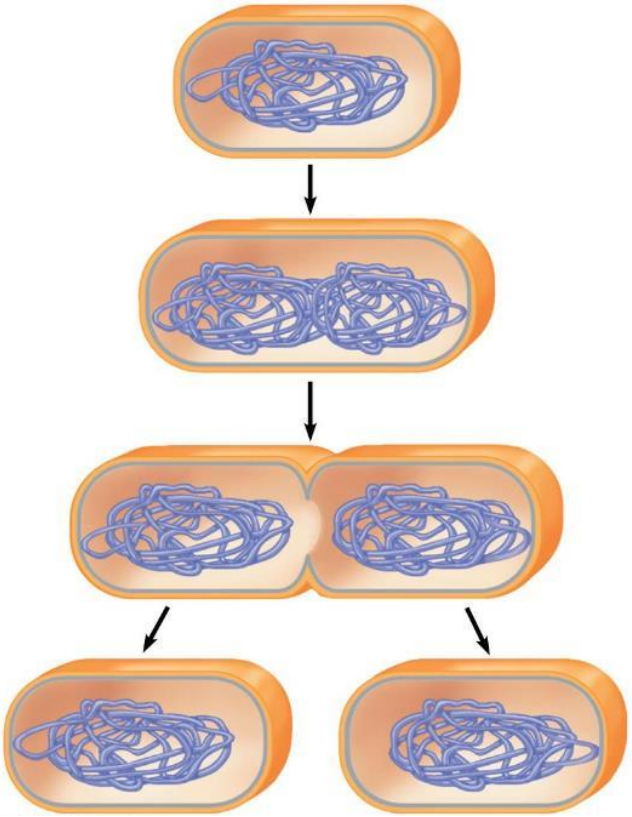
Prokaryotes Reproduce by Binary Fission

3. Division into two daughter cells.




Plasma membrane
Cell wall
Prokaryotic chromosome
1
Duplication of the chromosome and separation of the copies
2
Continued elongation of the cell and movement of the copies
3
Division into two daughter cells

Prokaryotes Reproduce by Binary Fission

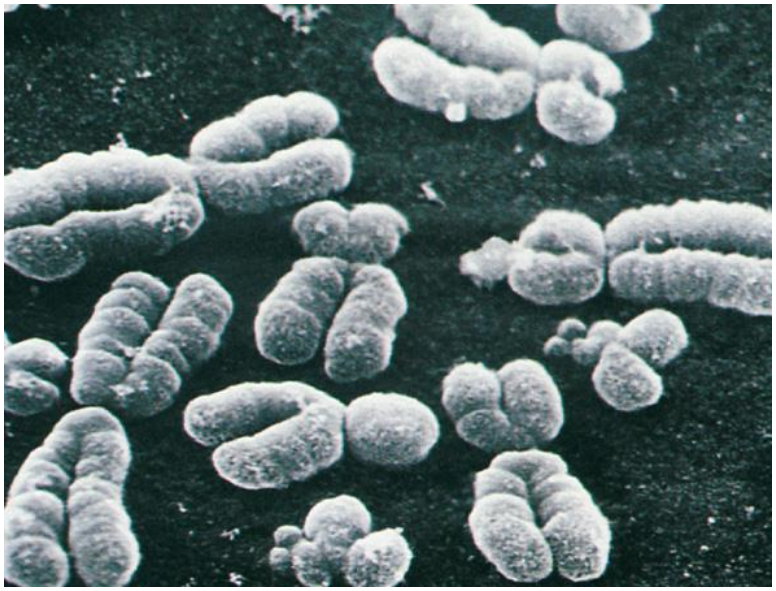


http://somup.com/c3fl0nOqmy

Binary Fission (1:18)

The Large, Complex Chromosomes of EUKARYOTES Duplicate with Each Cell Division

- **Eukaryotic Cells**
  - are more **complex and larger** than prokaryotic cells.
  - have **more genes.**
  - store most of their genes on **multiple chromosomes** within the nucleus.



The Large, Complex Chromosomes of EUKARYOTES Duplicate with Each Cell Division

- **Each** eukaryotic **species** has a **characteristic number of chromosomes** in each cell nucleus.
- **Human Body Cells have 46 chromosomes or 23 identical pairs of chromosomes.**

Species	*Parascaris equorum*	*Oryza sativa*	*Homo sapiens*	*Pan troglodytes*	*Canis familiaris*
Chromosome #	4	24	46	48	78
Common Name	 Roundworm	 Rice	 Human	 Chimpanzee	 Dog

Eukaryotic Chromosomes

- ✓ Each **chromosome** is composed of a **single DNA molecule** tightly coiled around proteins called **Histones.**

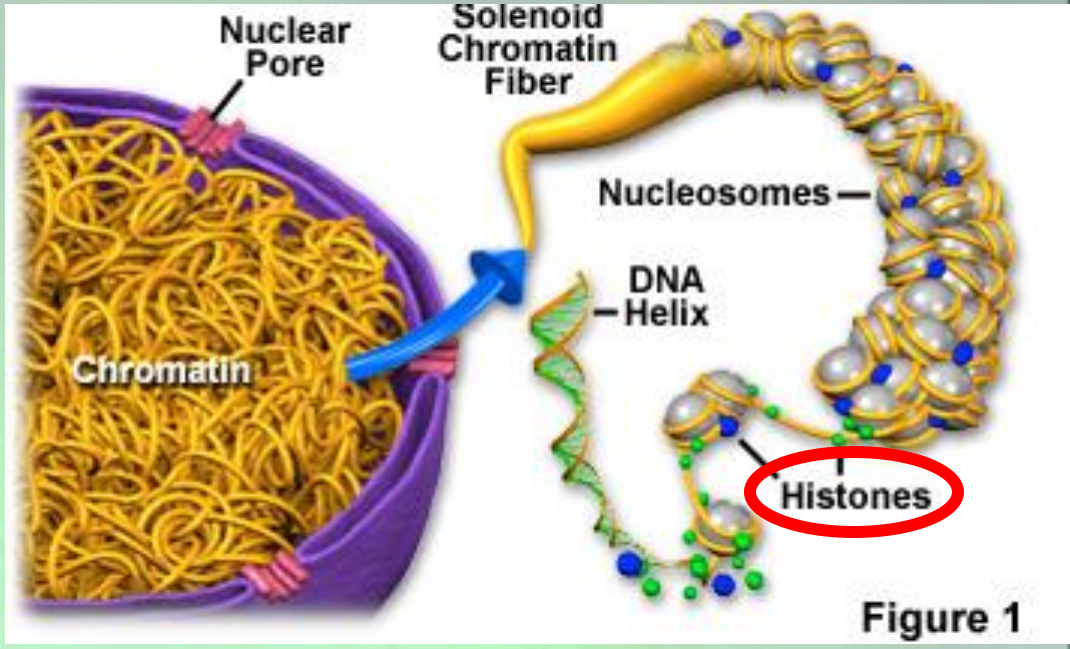
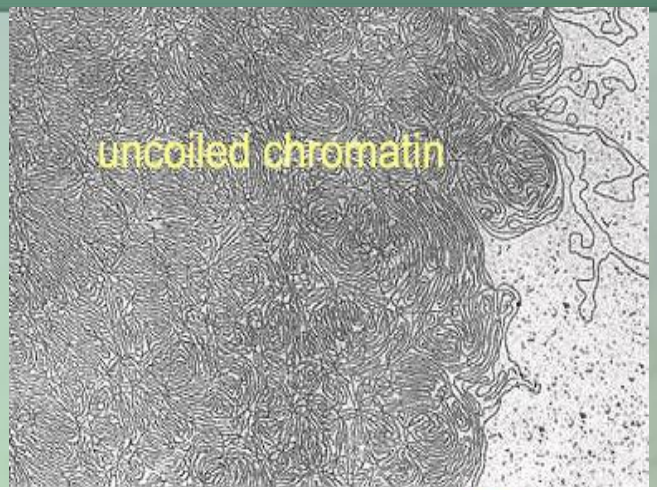
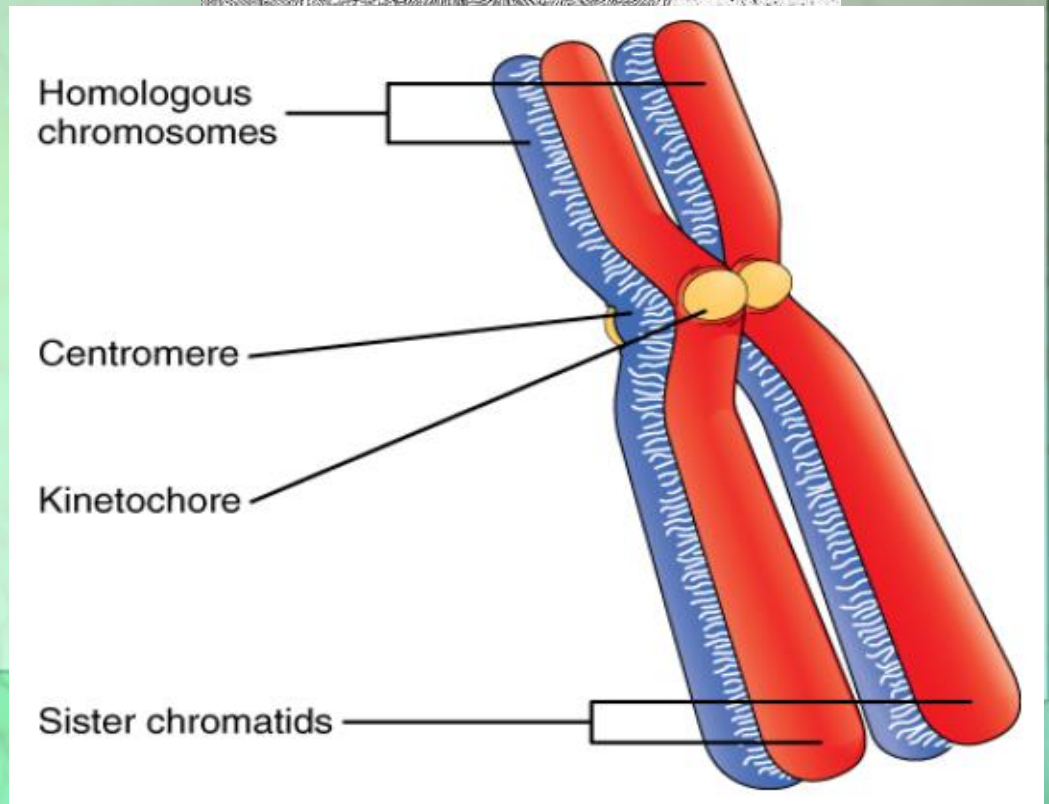


Figure 1

Eukaryotic Chromosomes

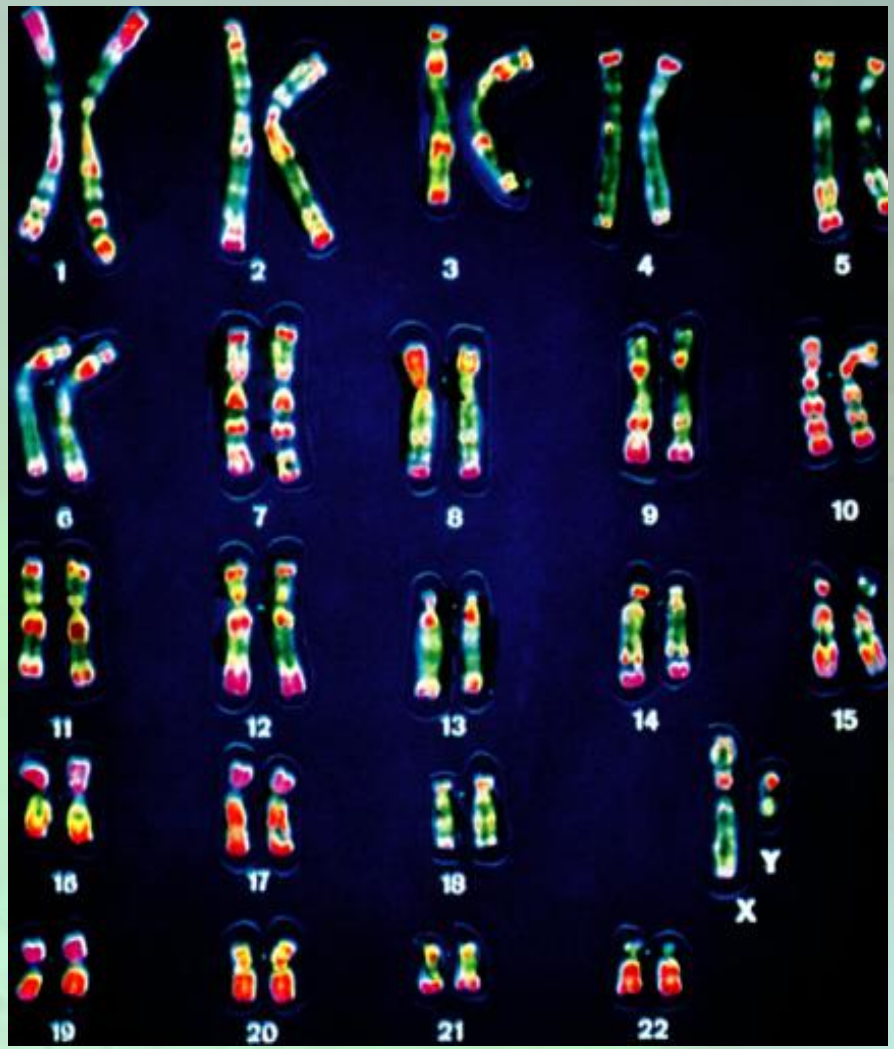
- ✓ Chromosomes cannot be seen when cells are not dividing and are called **Chromatin.**
- ✓ To prepare for division, the **Chromatin** becomes
  - highly **compact**
  - **visible** with a microscope.





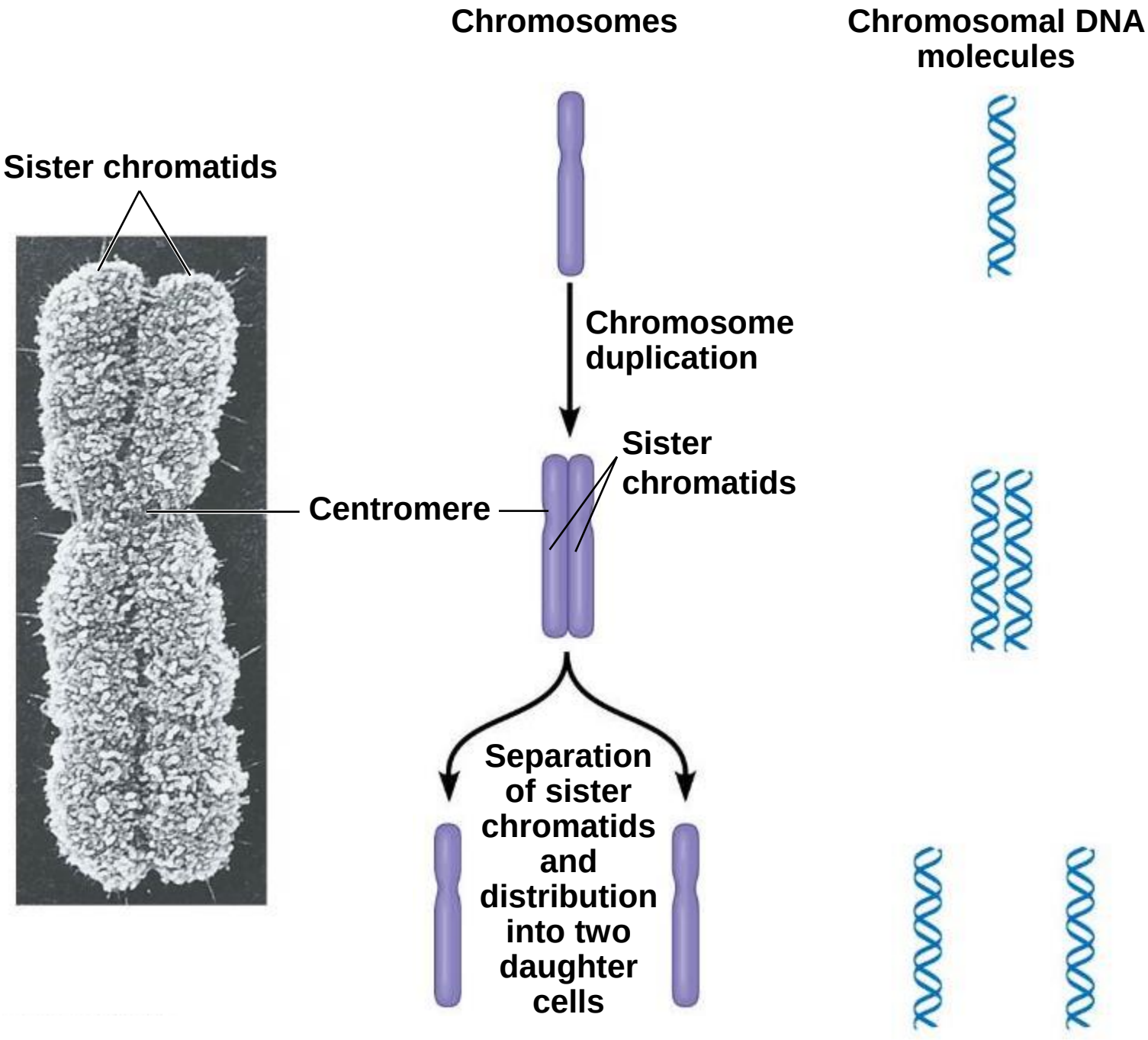
Human Karyotype

- ✓ A picture of the **chromosomes** from a **Human Cell** arranged in pairs by size.



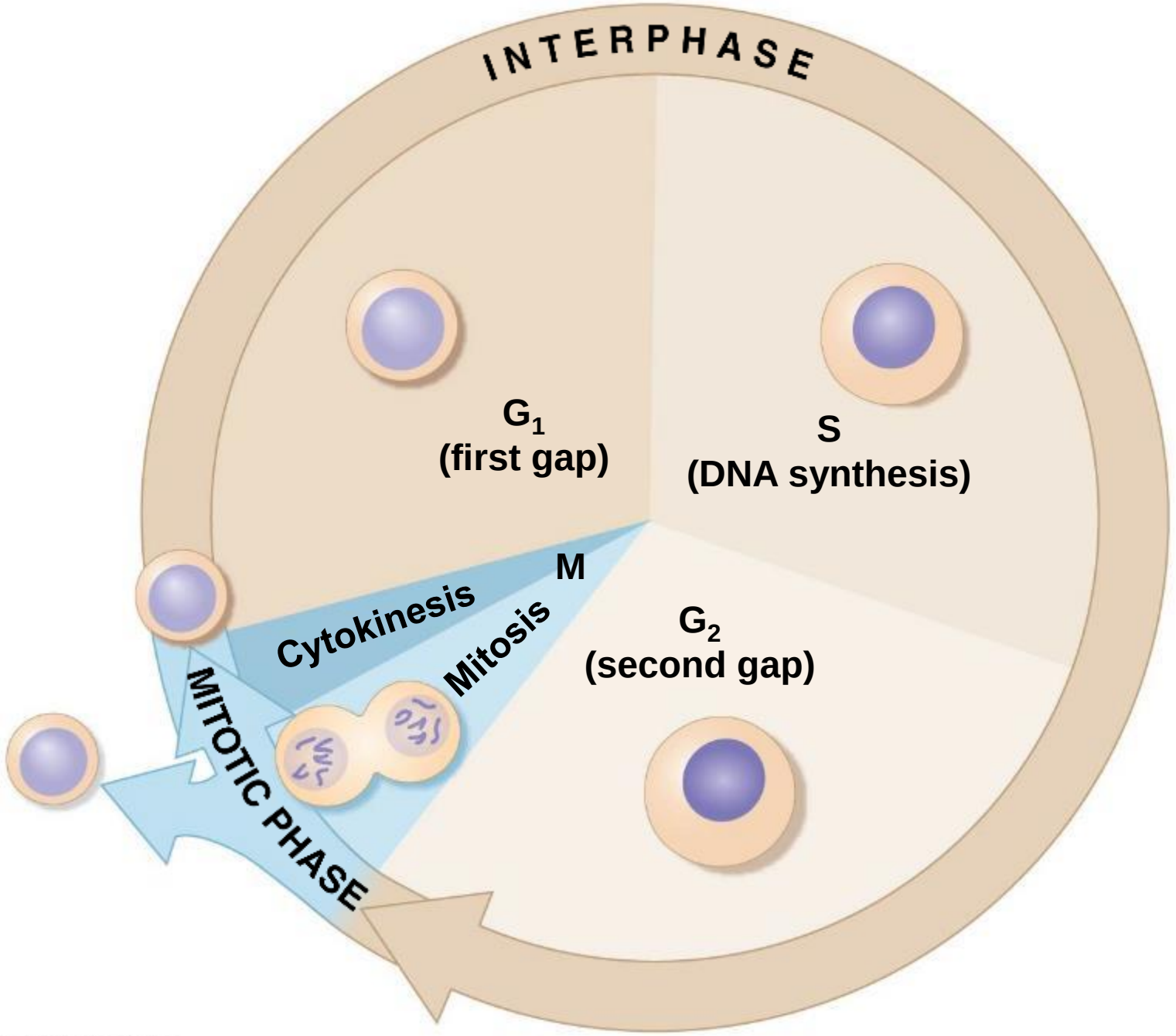
The Large, Complex Chromosomes of Eukaryotes Duplicate with Each Cell Division

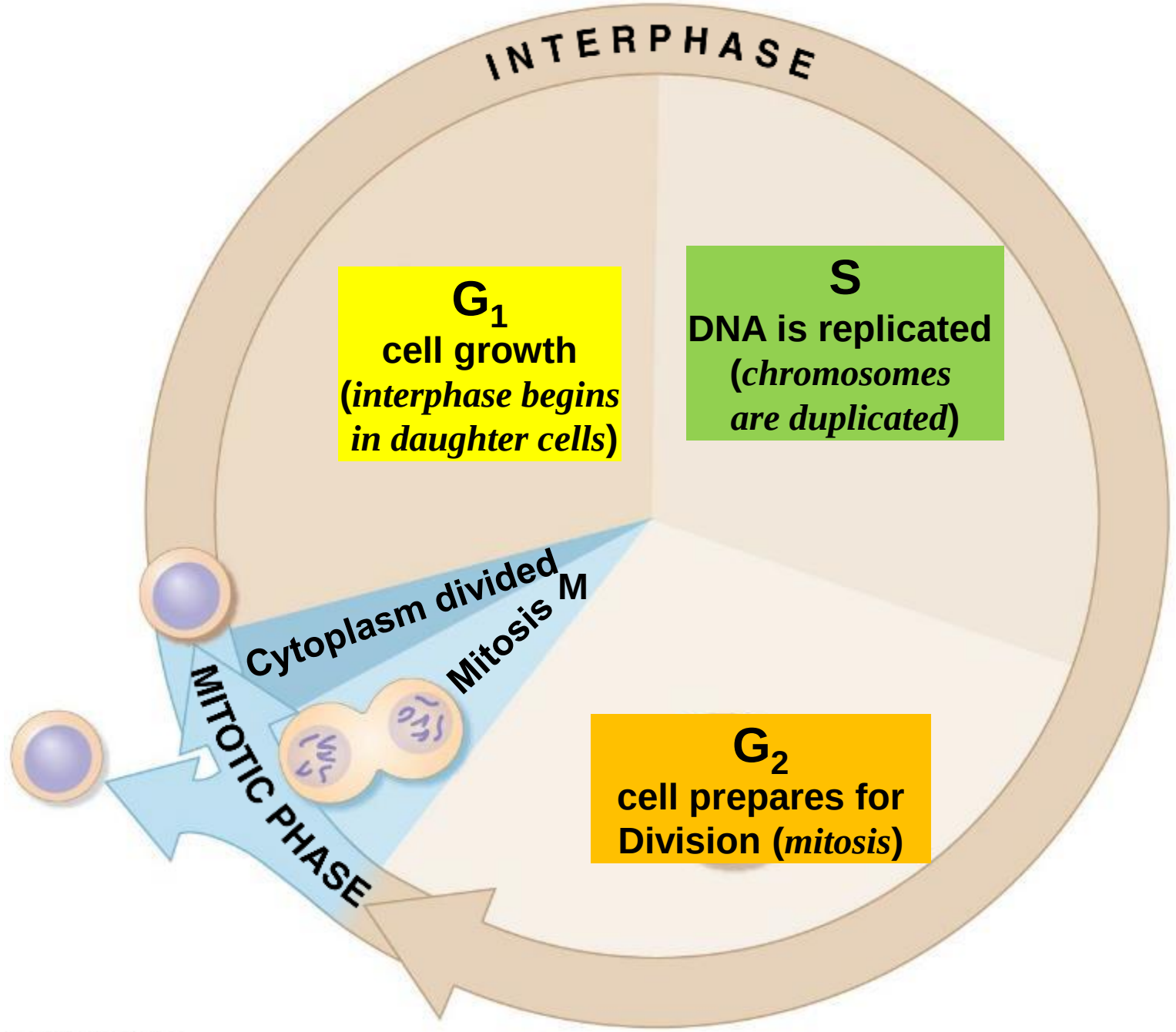
- **Before** a eukaryotic cell begins to divide, it **duplicates all of its Chromosomes**, resulting in two copies called **Sister Chromatids**.
- The sister chromatids are joined together along their lengths and are cinched especially tightly at a narrowed "waist" called the **Centromere**.
- When a **cell divides**, the **Sister Chromatids**:
  - separate from each other and
  - sort into separate daughter cells.


Chromosomes
Chromosomal DNA molecules
Sister chromatids
Chromosome duplication
Sister chromatids
Centromere
Separation of sister chromatids and distribution into two daughter cells

The Cell Cycle includes Growing and Division Phases

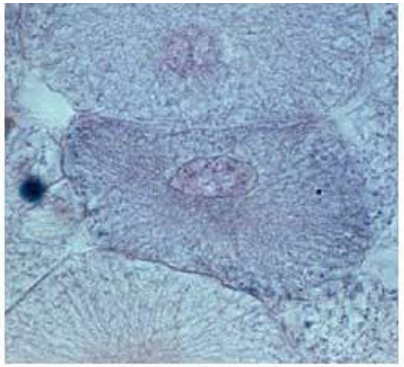
- The **Cell Cycle** is an ordered sequence of events that extends from the **time a cell is first formed** from a dividing parent cell until **its own division**.
- The **Cell Cycle** consists of two stages, characterized as follows:
  1. **Interphase**: duplication of cell contents
     - **G_1** — growth, increase in cytoplasm
     - **S** — duplication of chromosomes
     - **G_2** — growth, preparation for division
  2. **Mitotic Phase**: division
     - **Mitosis**—division of the nucleus
     - **Cytokinesis**—division of cytoplasm

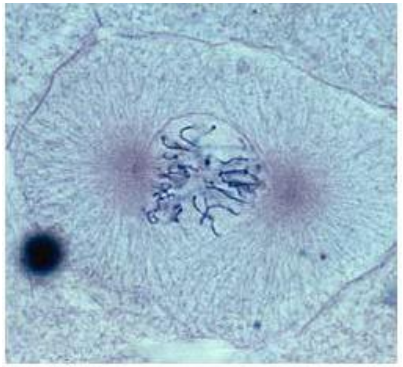

INTERPHASE
G1
(first gap)
S
(DNA synthesis)
M
Cytokinesis
Mitosis
G2
(second gap)
MITOTIC PHASE

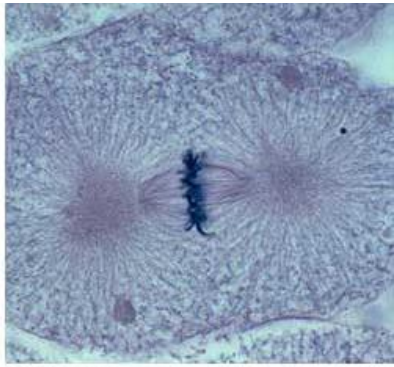

INTERPHASE
G1
cell growth
(interphase begins
in daughter cells)
S
DNA is replicated
(chromosomes
are duplicated)
Cytoplasm divided
Mitosis M
MITOTIC PHASE
G2
cell prepares for
Division (mitosis)

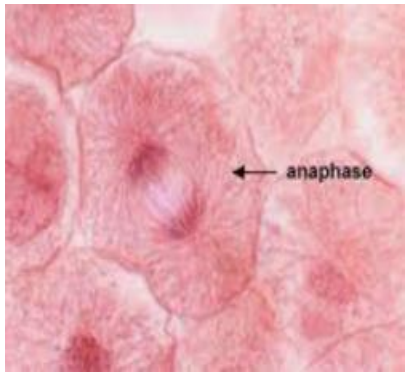
Cell Division is a Continuum of Dynamic Changes

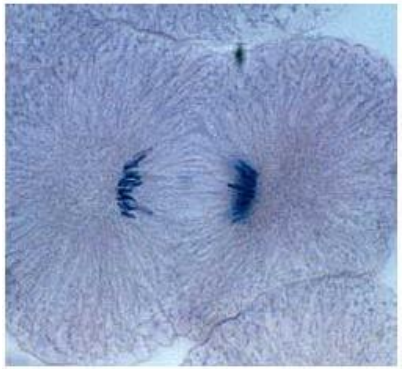
- **Mitosis** follows interphase and progresses through a series of stages:
  - **Prophase**
  - **Metaphase**
  - **Anaphase**
  - **Telophase**
- **Cytokinesis**

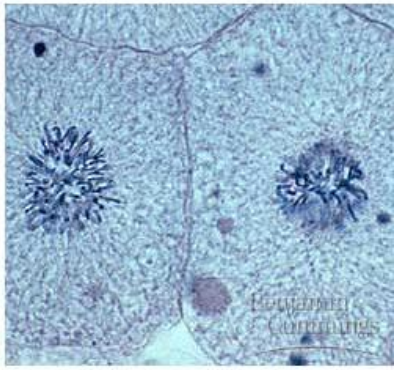

Interphase


Prophase


Metaphase



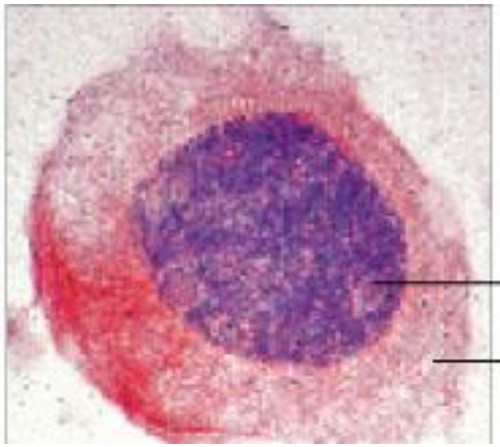

Early Telophase


Late Telophase

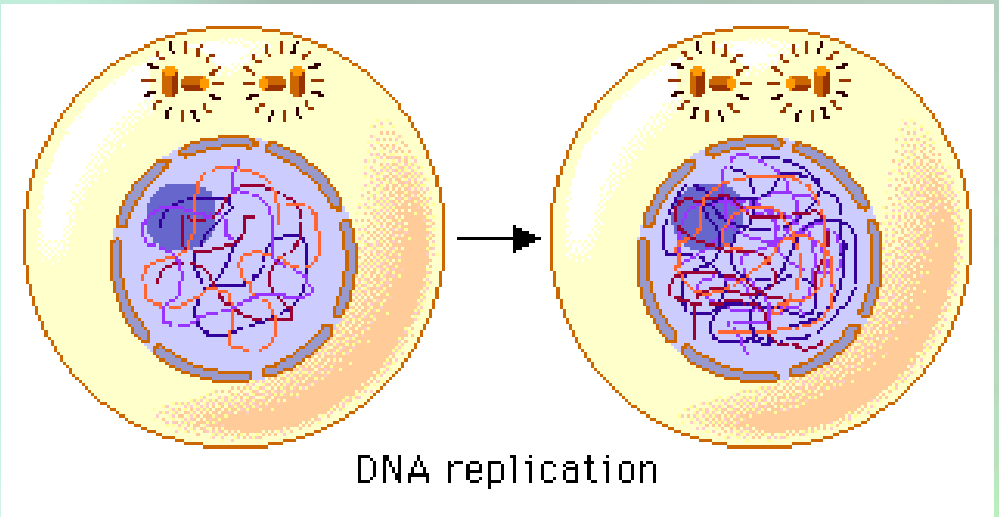
Cell Division is a Continuum of Dynamic Changes

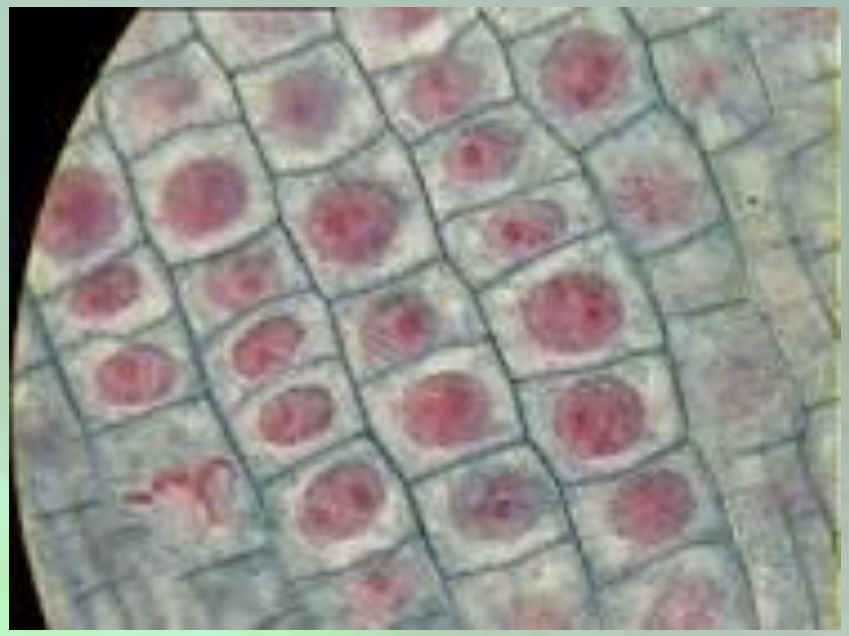
- **INTERPHASE**
  - The cytoplasmic contents double.
  - **Centrioles** appear [*in animal cells*].
  - Chromosomes duplicate in the nucleus during the **S Phase.**

A CELL AT INTERPHASE:



What's Happening during Interphase?

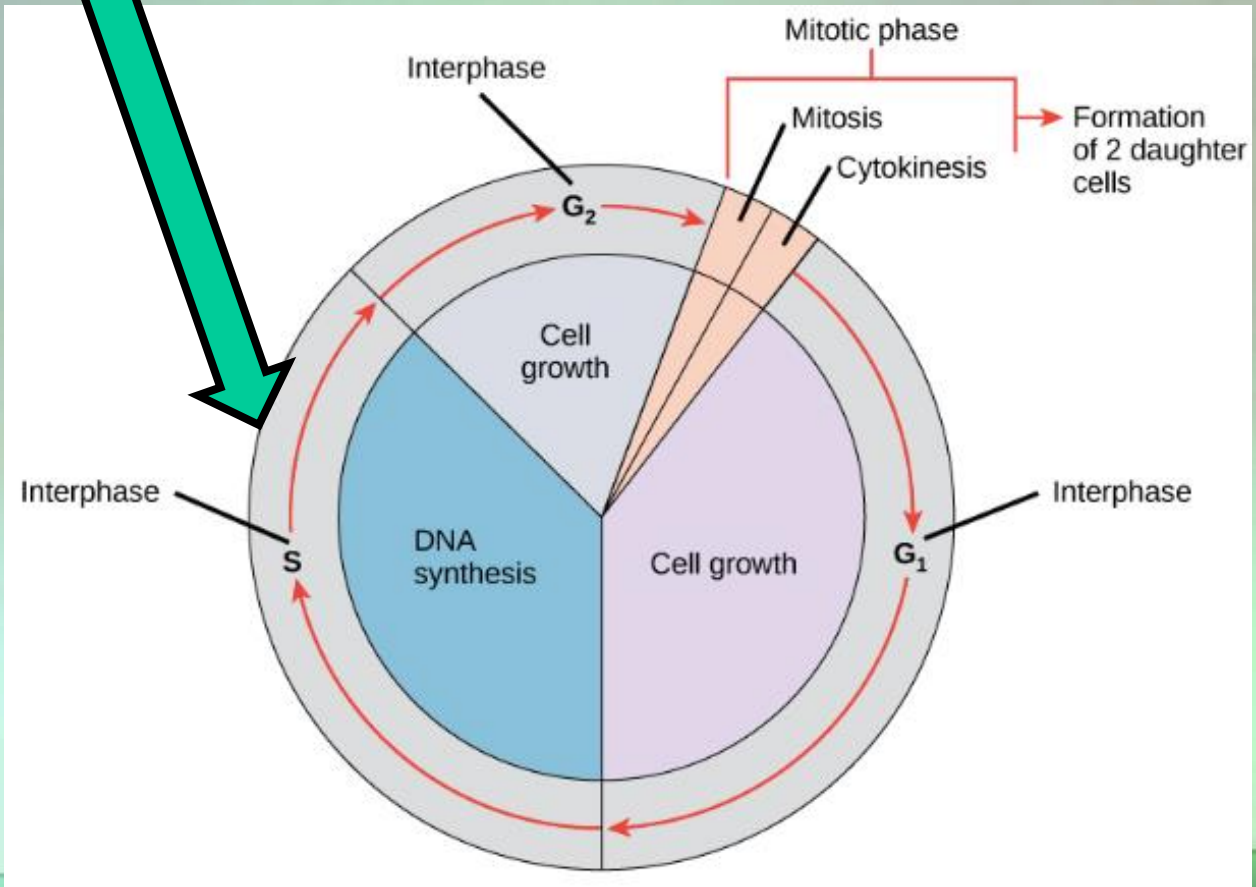




Interphase accounts for 90% of the time of the cell cycle.

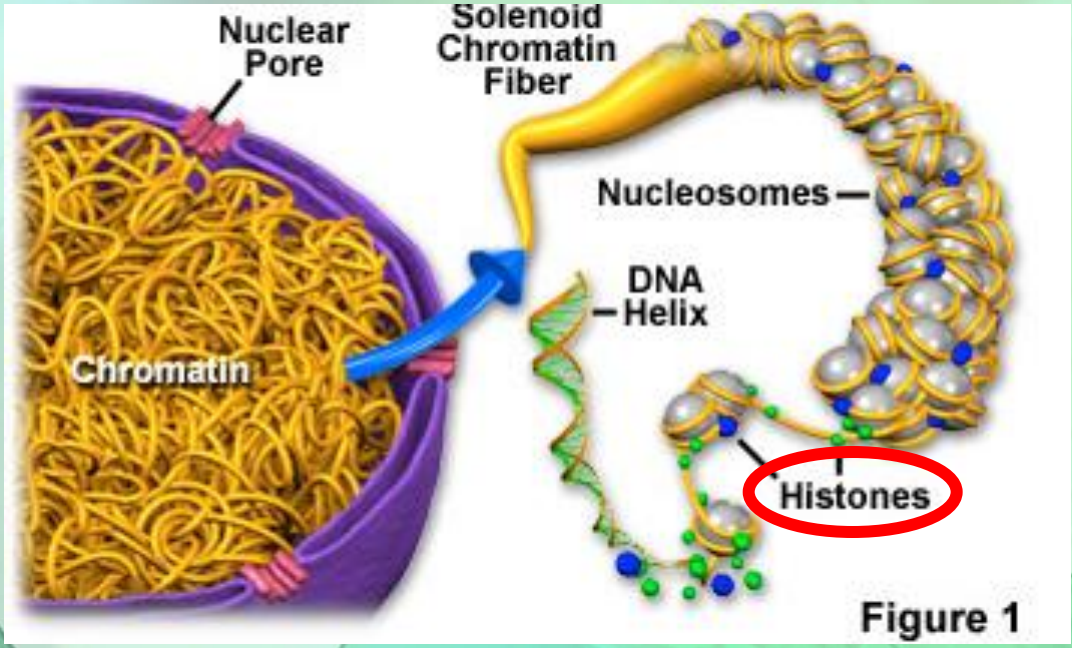
Interphase

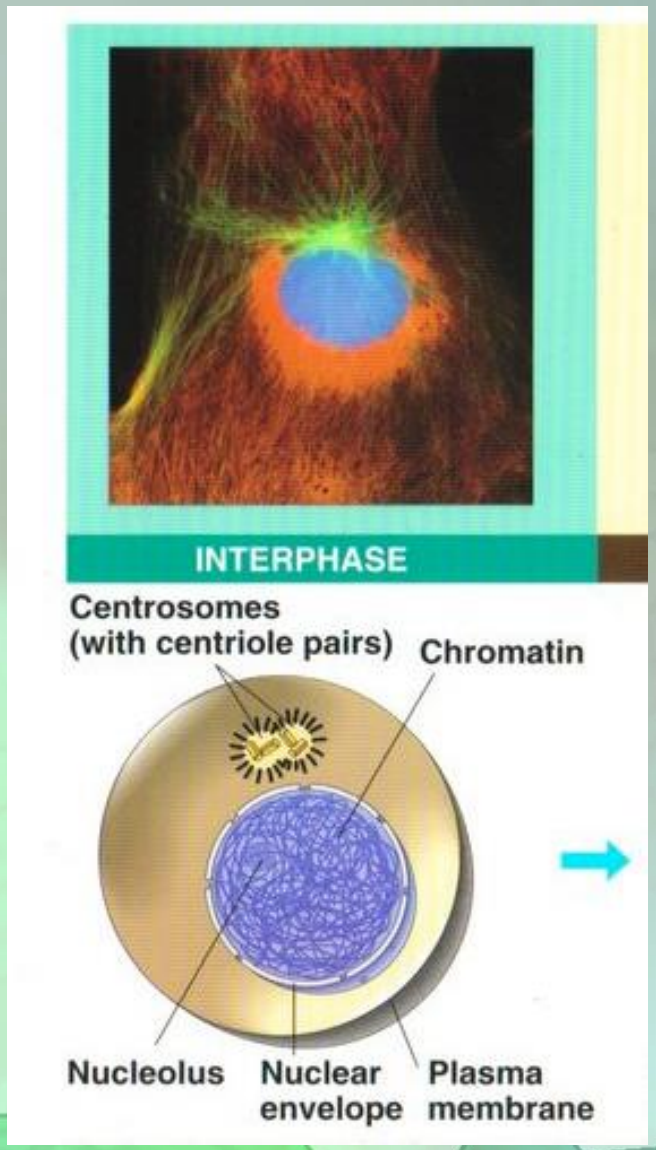
- **DNA Replication occurs during the S Phase of the cell cycle.**



Interphase

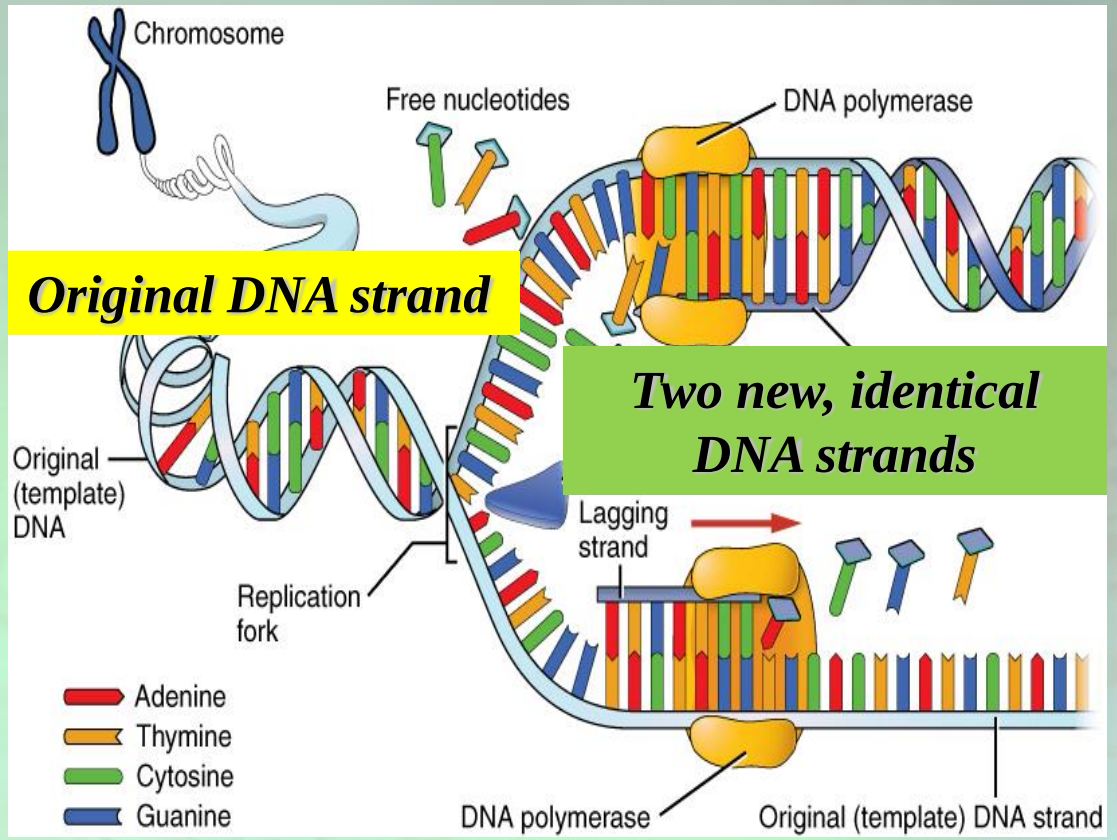
- Chromatin becomes condensed by wrapping around proteins called Histones.





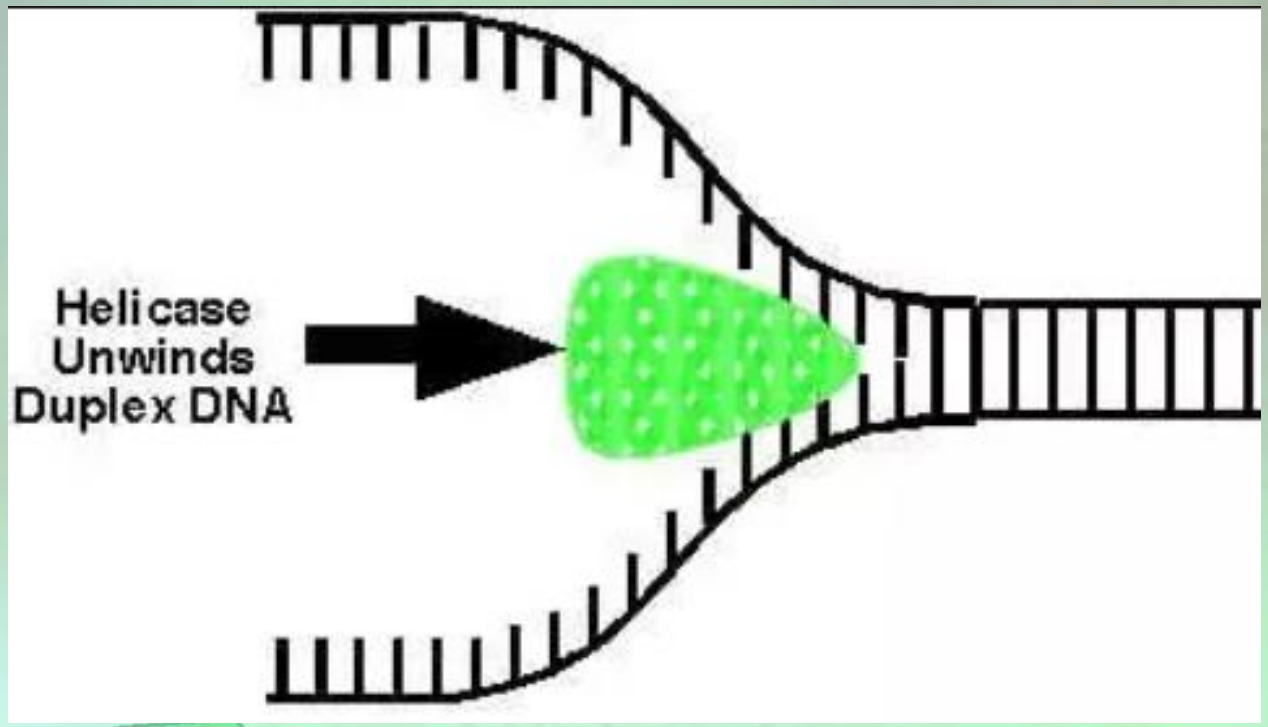
Interphase: DNA Replication

- ✓ DNA is copied or replicated before cell division.
- ✓ Each new cell will then have an identical copy of the DNA.



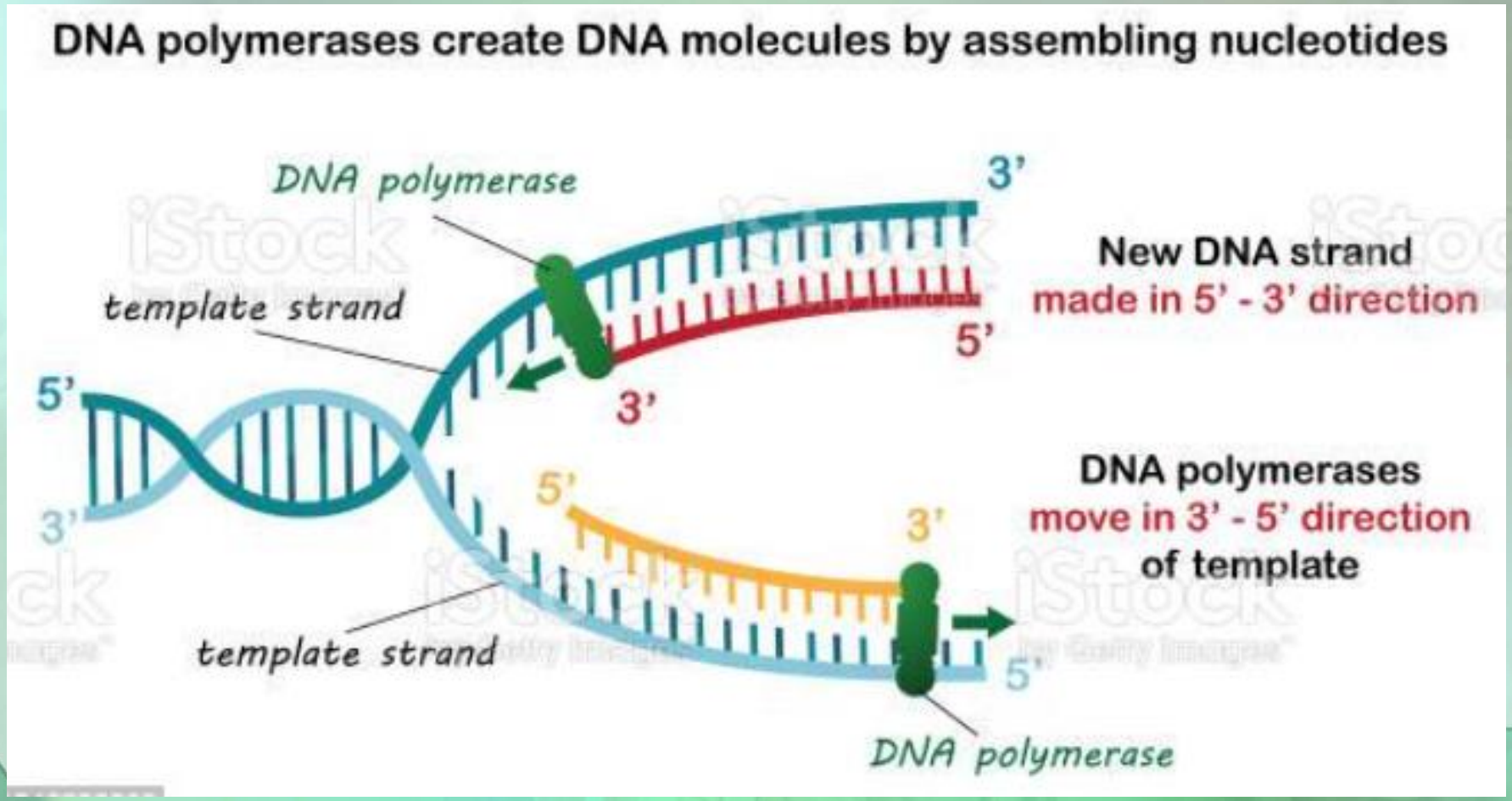
DNA Replication

- ✓ Enzyme **"Helicase"** binds to the DNA at the replication origin and begins to **"unzip"** it by **breaking** the hydrogen bonds between the complementary bases of DNA.



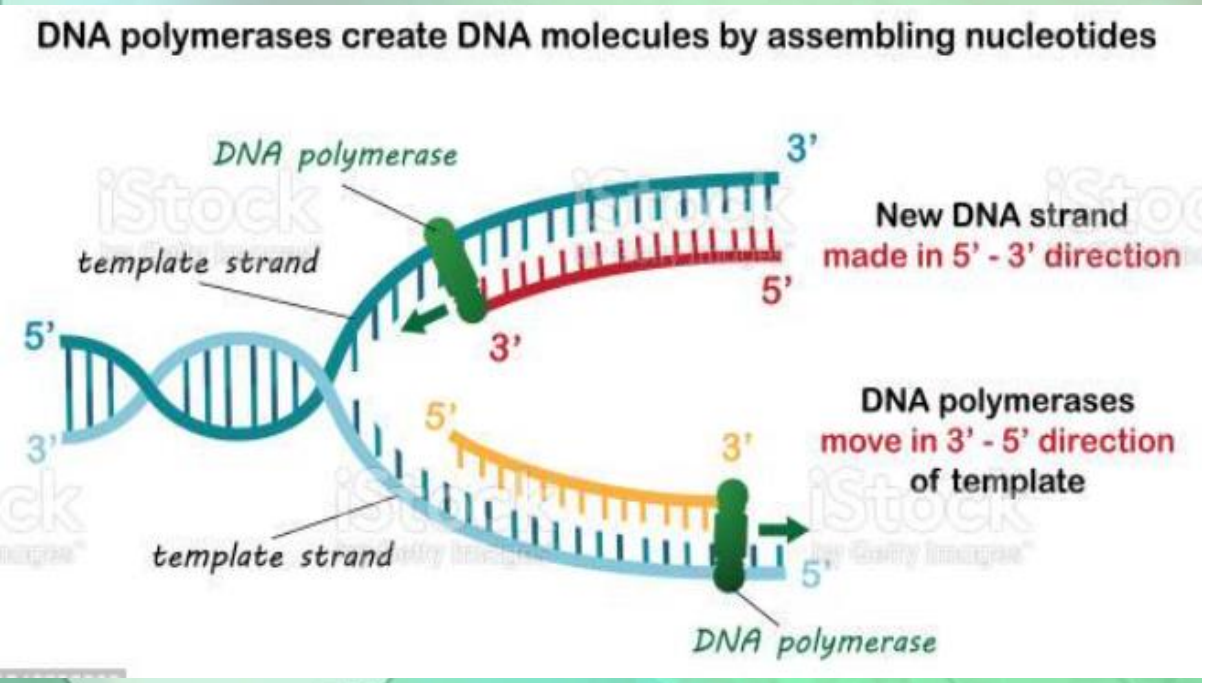
DNA Replication

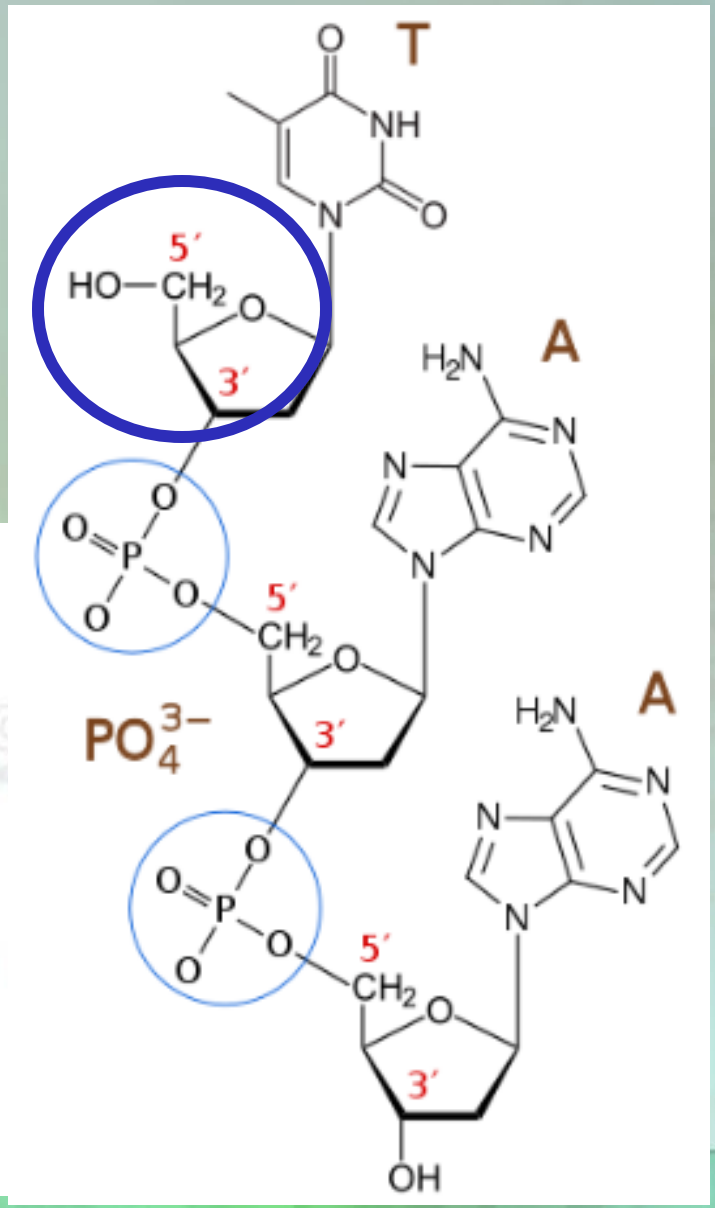
- ✓ **"DNA Polymerase"** binds to the unzipped DNA and begins linking **new nucleotides** across from the parent strand, forming a **complementary daughter strand.**



DNA Replication

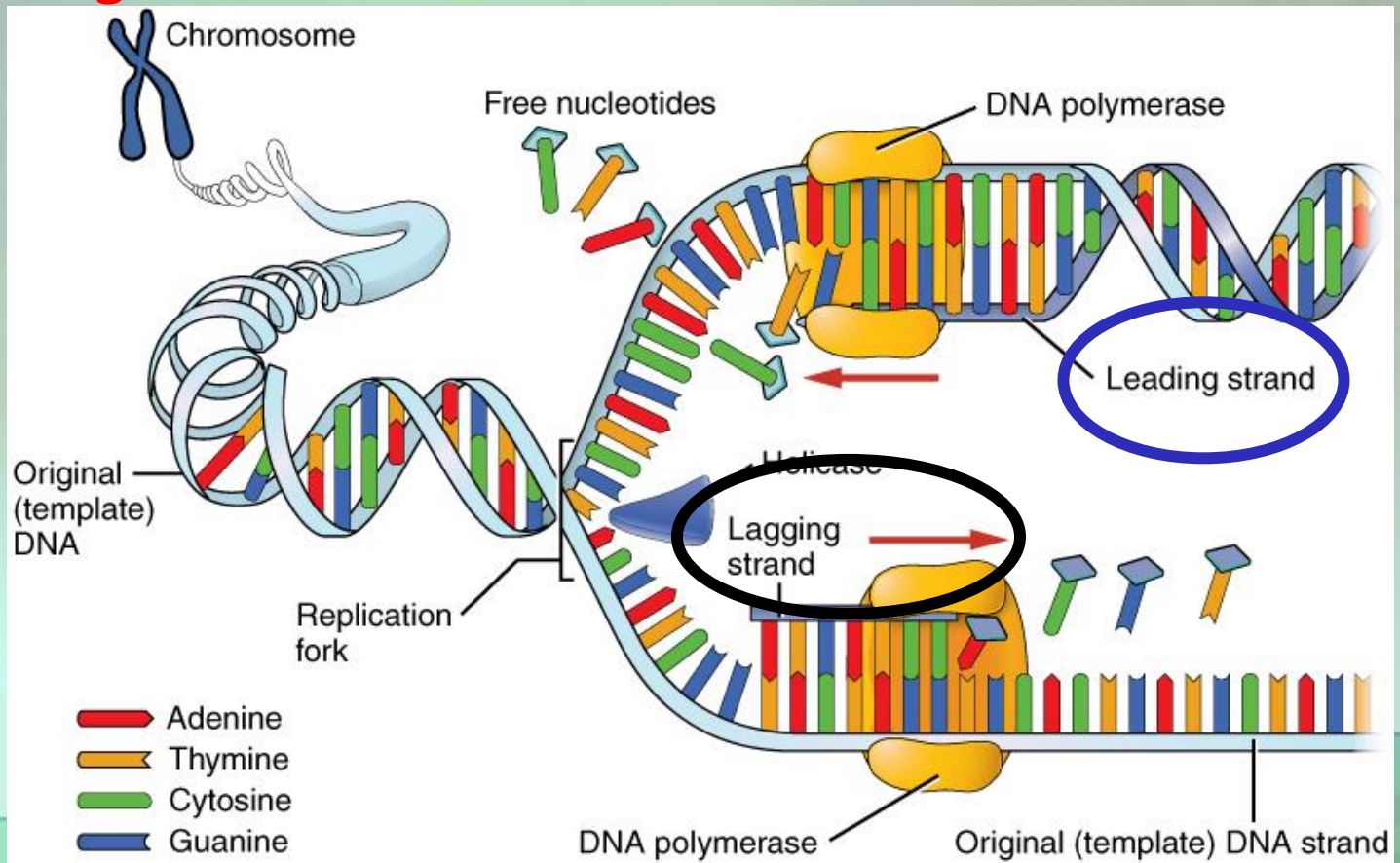
- ✓ **"DNA Polymerase"** binds to the unzipped DNA and begins linking **new nucleotides** across from the parent strand, forming a **complementary daughter strand.**





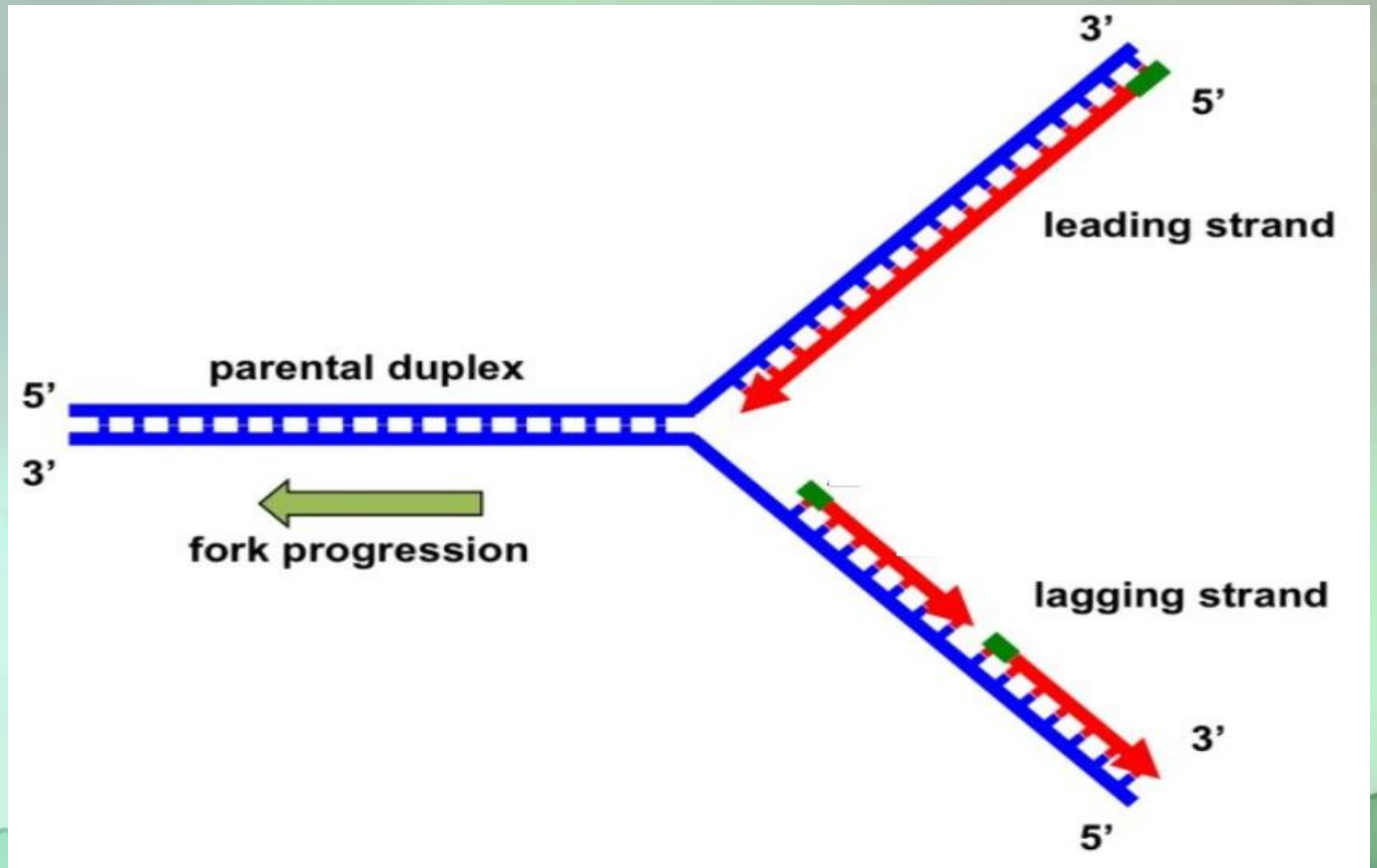
DNA Replication

- ✓ **Parent strand** is separated into
  - ✓ the **LEADING strand** and
  - ✓ the **LAGGING strand**, both serving as **templates** for the **daughter strand** to be made.



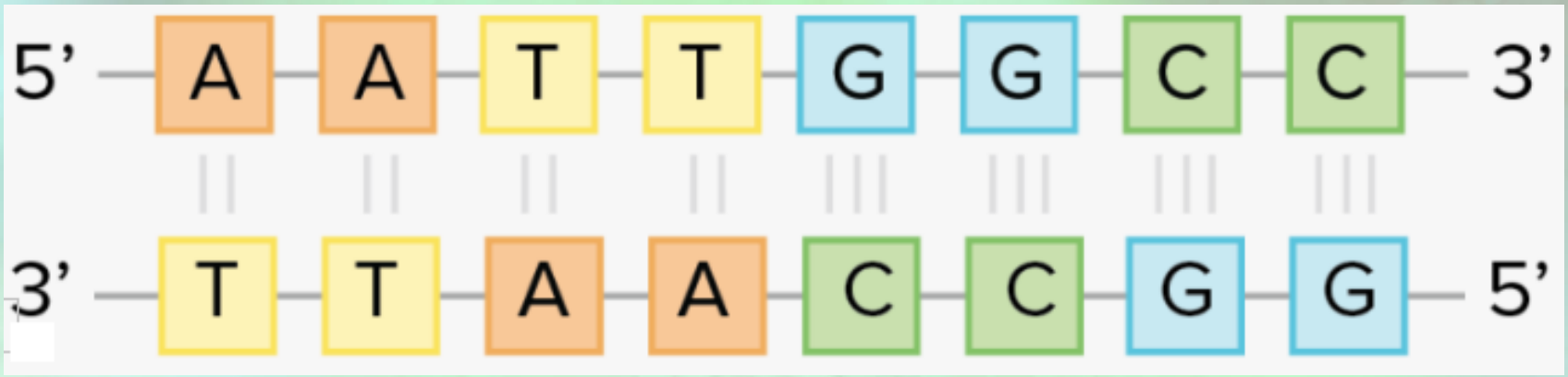
DNA Replication

- ✓ This process occurs simultaneously on both parent strands, but in **opposite directions.**
- ✓ **Each replicated copy of DNA is composed of one parent strand and one daughter strand.**

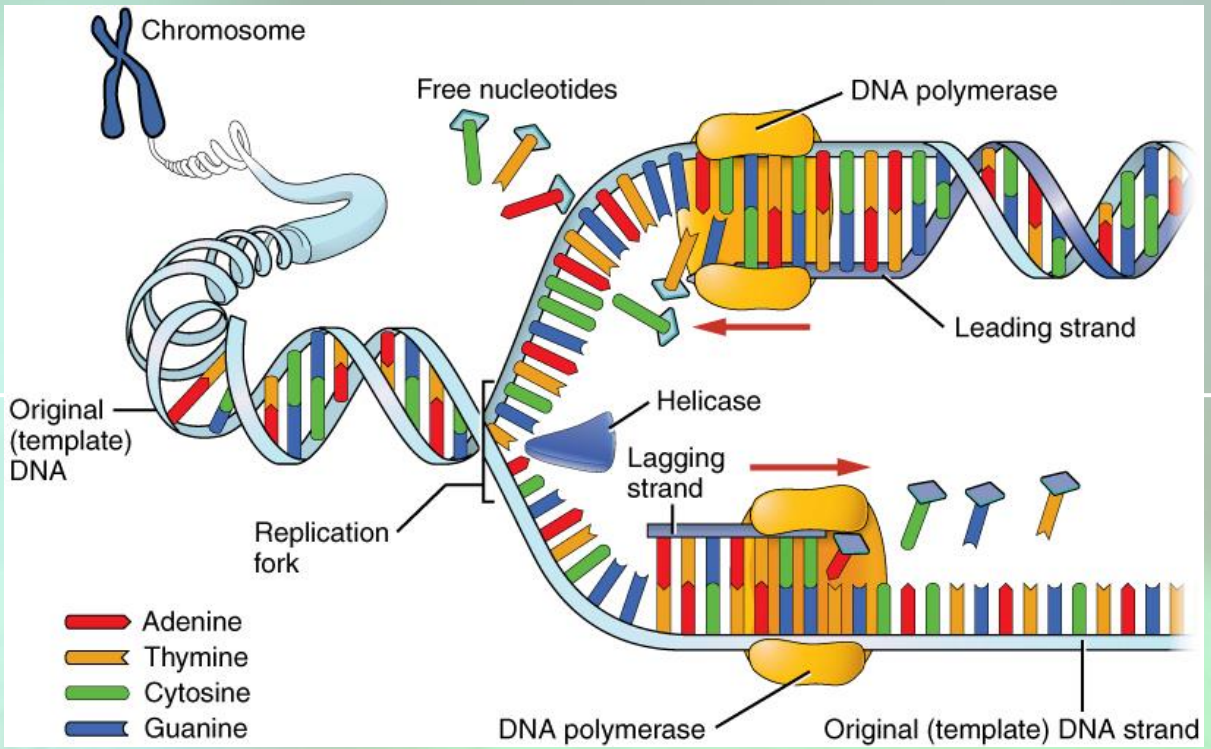


DNA Replication

- ✓ The nitrogenous bases of DNA always align the same.
- ✓ **Adenine = Thymine** [2 hydrogen bonds]
- ✓ **Guanine ≡ Cytosine** [3 hydrogen bonds]



DNA Replication



http://somup.com/c3fl0hOqmJ (2:08) **DNA Replication Animation**

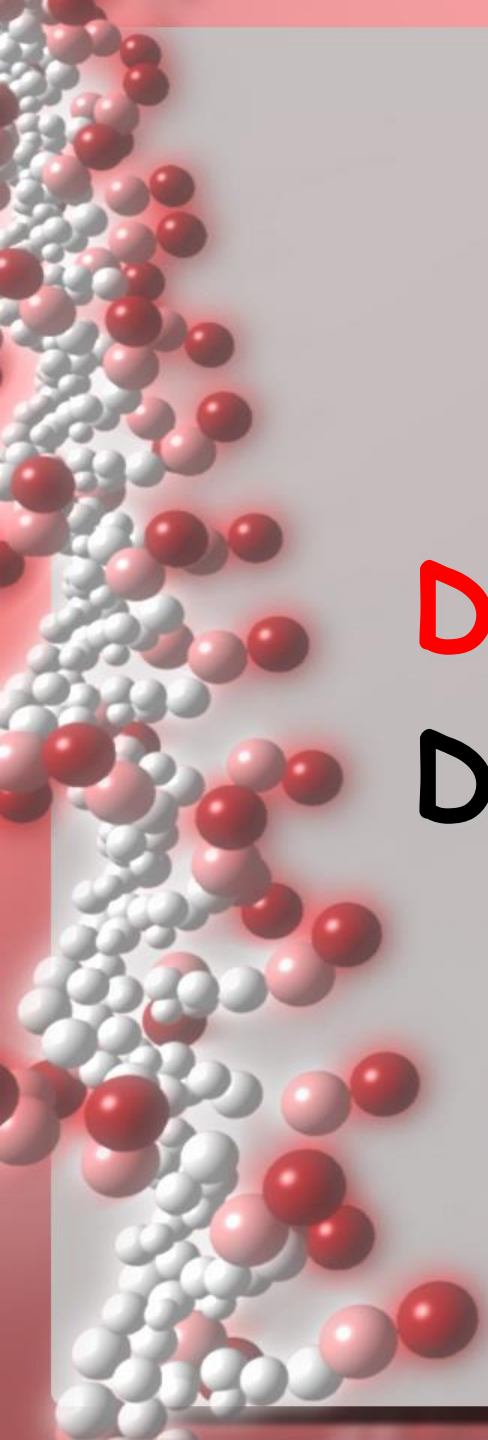
http://somup.com/c3fl0wOqHP (5:46) **DNA Replication (Mitosis)**

Question:

QUICK CHECK

- What would be the complementary DNA strand for the following DNA sequence?

DNA -CGTATG-



QUICK CHECK

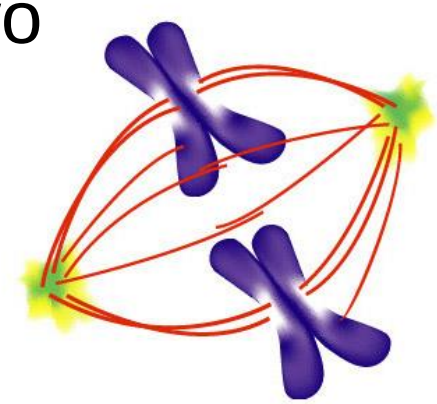
Answer:

DNA -CGTATG-

DNA -GCATAC-

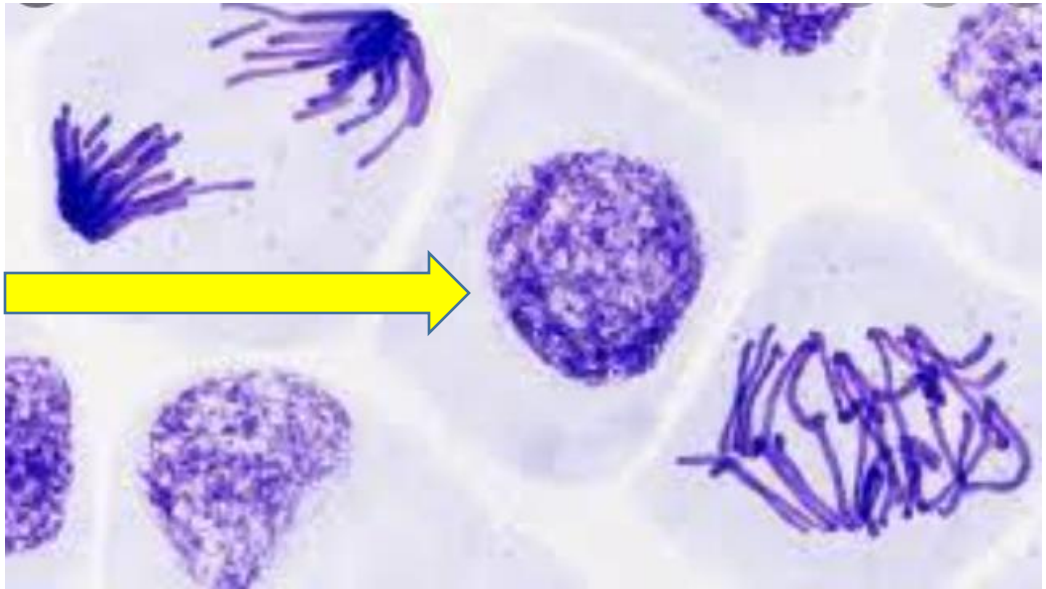
Cell Division is a Continuum of Dynamic Changes

- A **Mitotic Spindle**
  - is required to divide the chromosomes
  - guides the separation of the two sets of daughter chromosomes, and
  - is composed of **Microtubules** and associated proteins
- **Spindle Microtubules** emerge from two **Centrioles**



Cell Division is a Continuum of Dynamic Changes

- **PROPHASE**
  - In the **nucleus**, **chromosomes** become more tightly **coiled** and **folded**.
  - In the **cytoplasm**, the **mitotic spindle** begins to form as microtubules rapidly grow out from the **centrioles**.



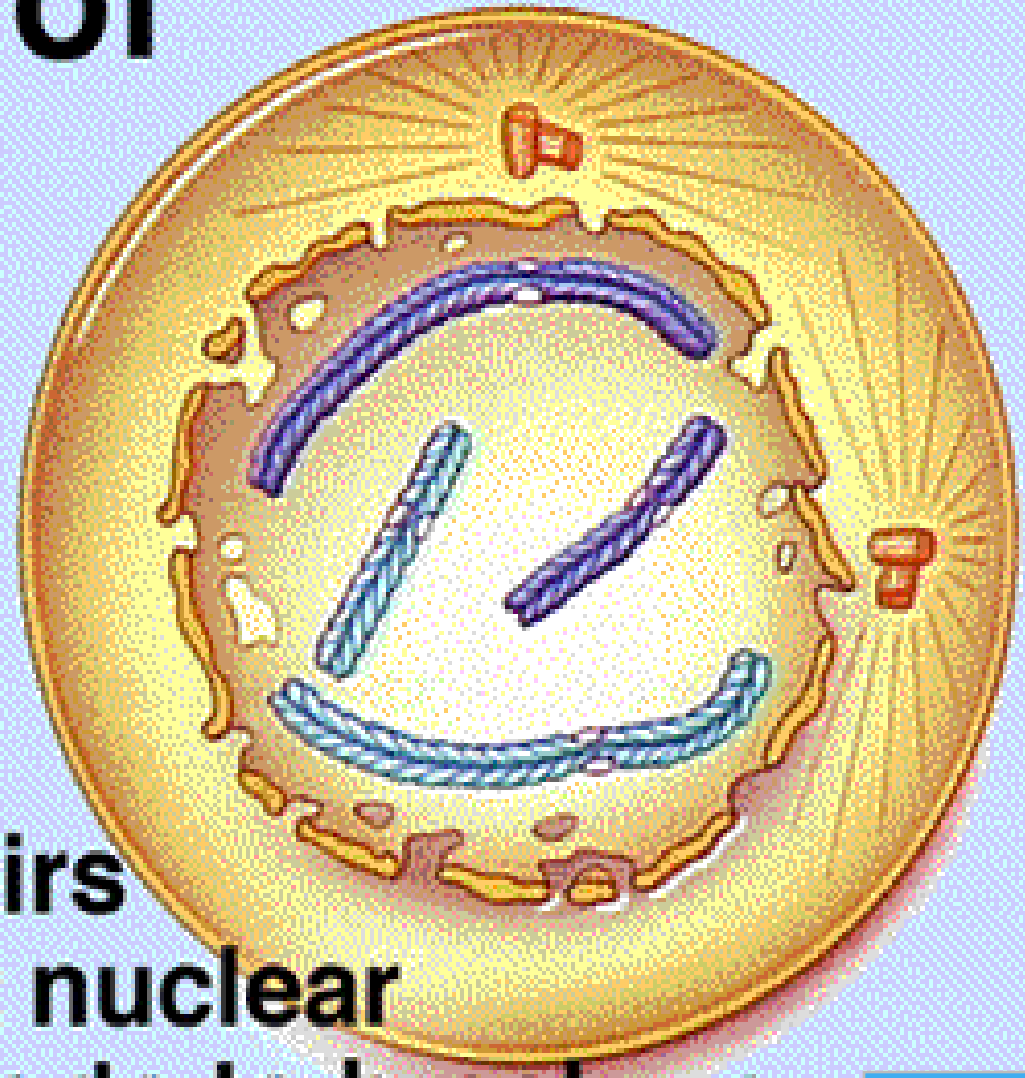
Stages of Mitosis

Early Prophase

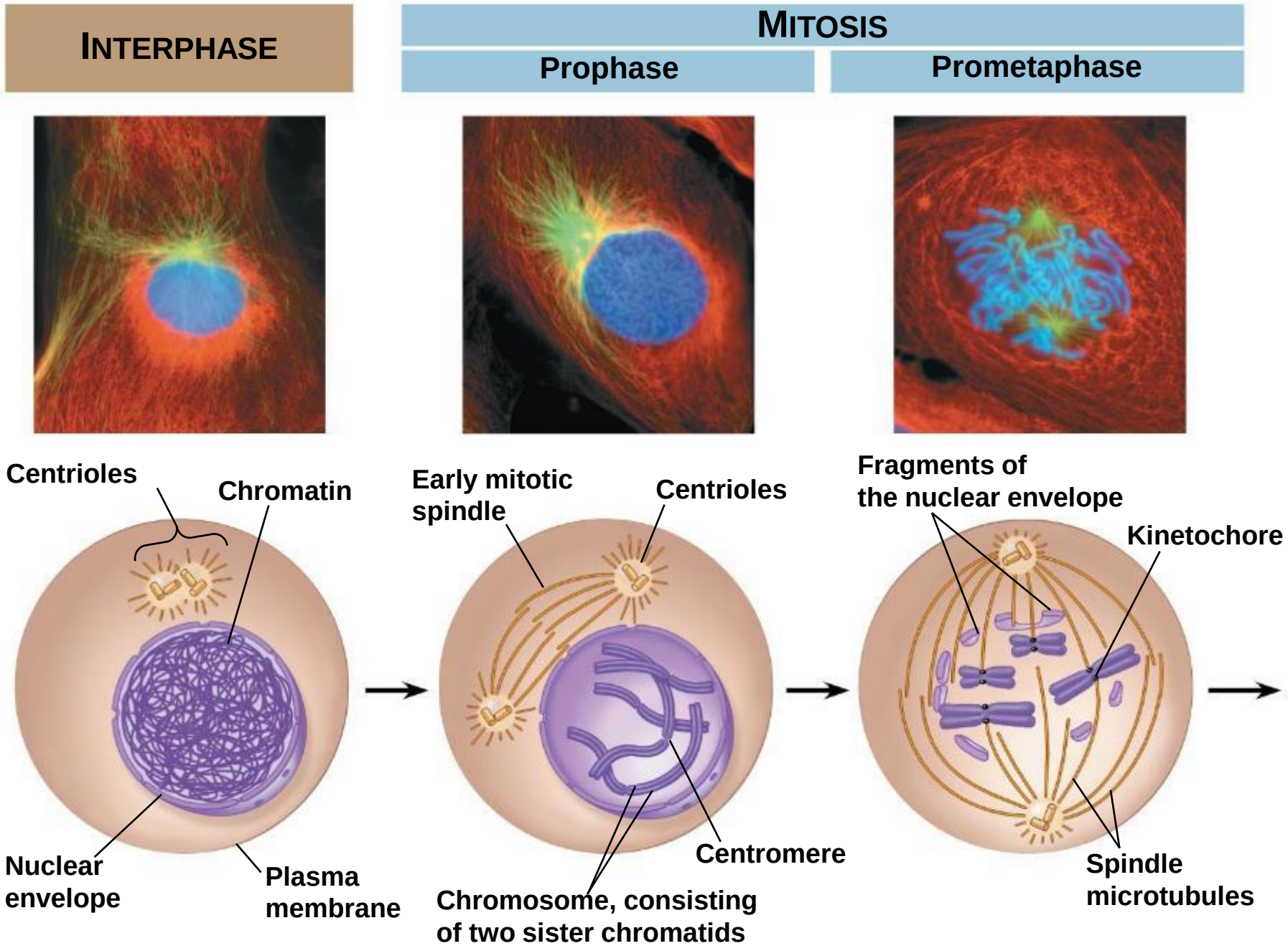
DNA begins to condense.

Stages of Mitosis

Late Prophase

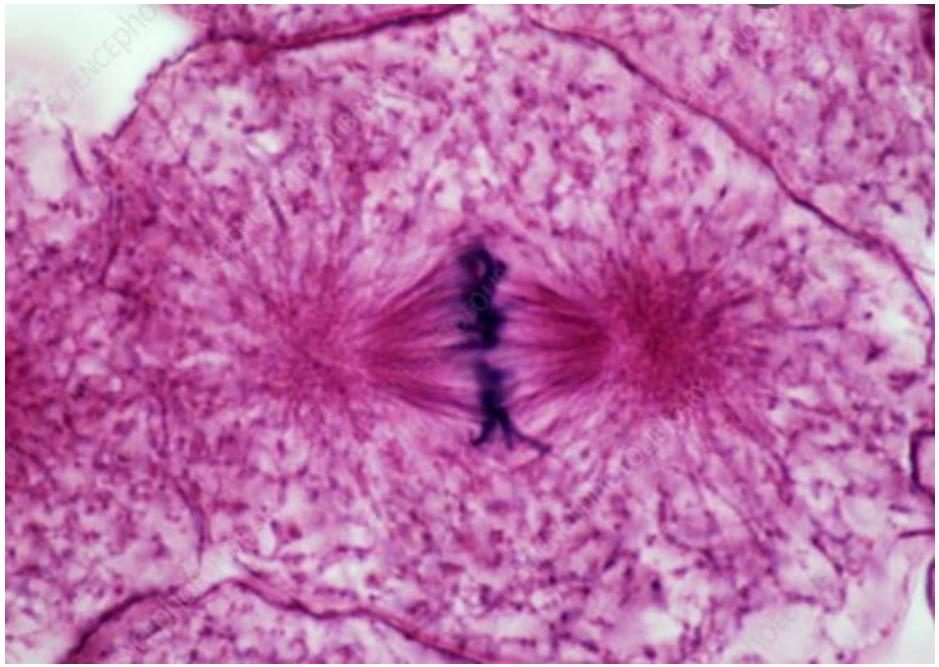


Centriole pairs move apart; nuclear envelope starts to break up.


INTERPHASE
MITOSIS
Prophase
Prometaphase
Centrioles
Chromatin
Nuclear envelope
Plasma membrane
Early mitotic spindle
Centrioles
Centromere
Chromosome, consisting of two sister chromatids
Fragments of the nuclear envelope
Kinetochore
Spindle microtubules

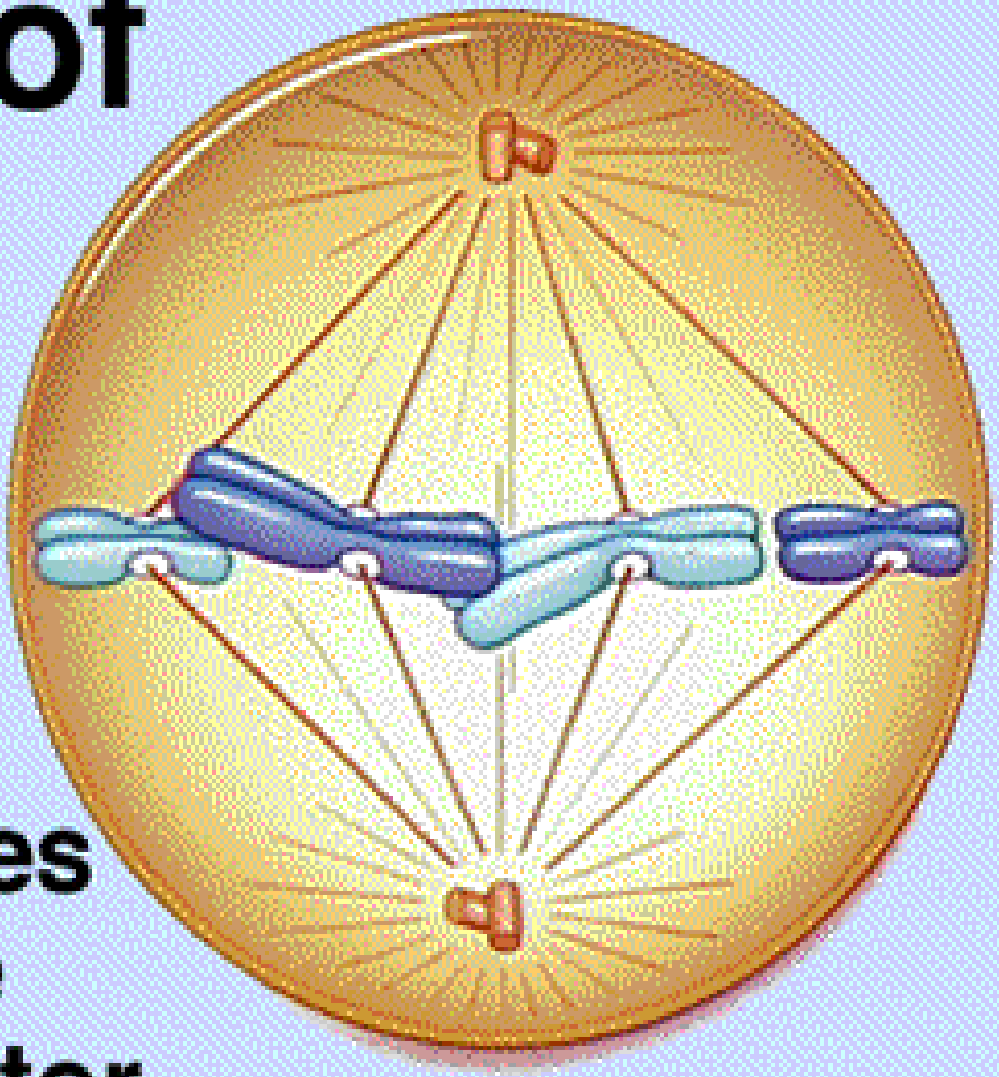
Cell Division is a Continuum of Dynamic Changes

- **METAPHASE**
  - The **mitotic spindle** is fully formed.
  - **Chromosomes align at the cell equator**.
  - **Sister Chromatids** are facing the opposite poles of the spindle.



Stages of Mitosis

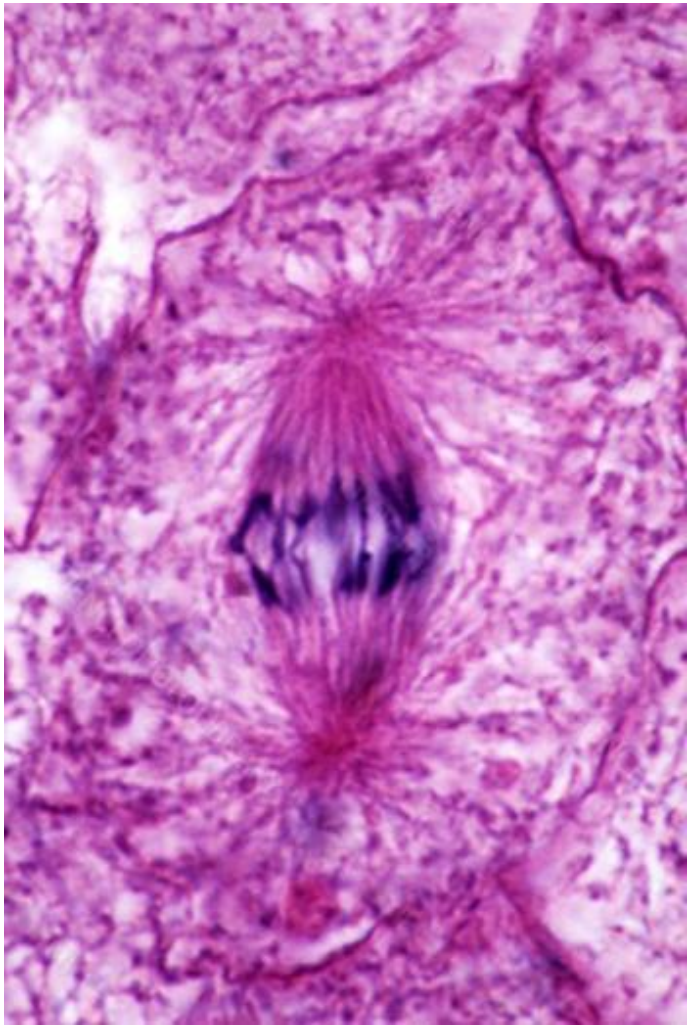
Metaphase



Chromosomes line up at the spindle equator.

Cell Division is a Continuum of Dynamic Changes

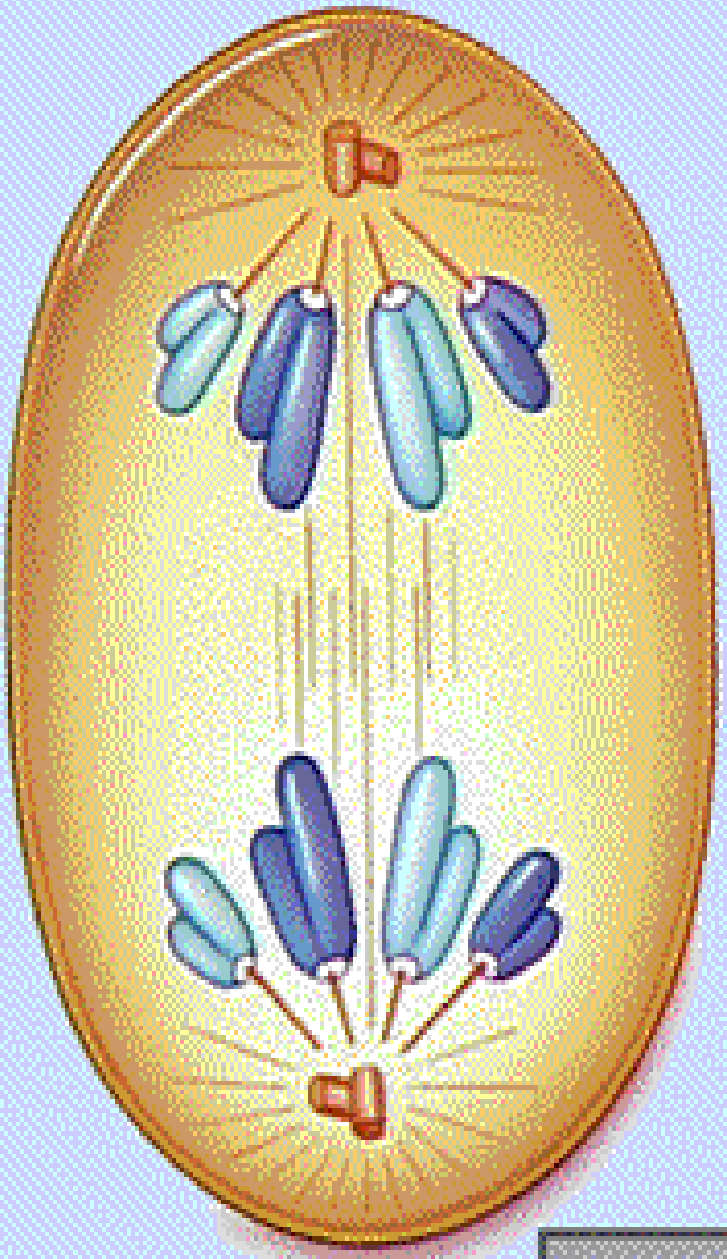
- **ANAPHASE**
  - **Sister Chromatids separate at the centromeres…**
  - **…and are moved to opposite poles of the cell** along the spindle microtubules.
  - At the end of anaphase, **the two ends of the cell have equal collections of chromosomes.**



Stages of Mitosis

Anaphase

Sister chromatids move apart.



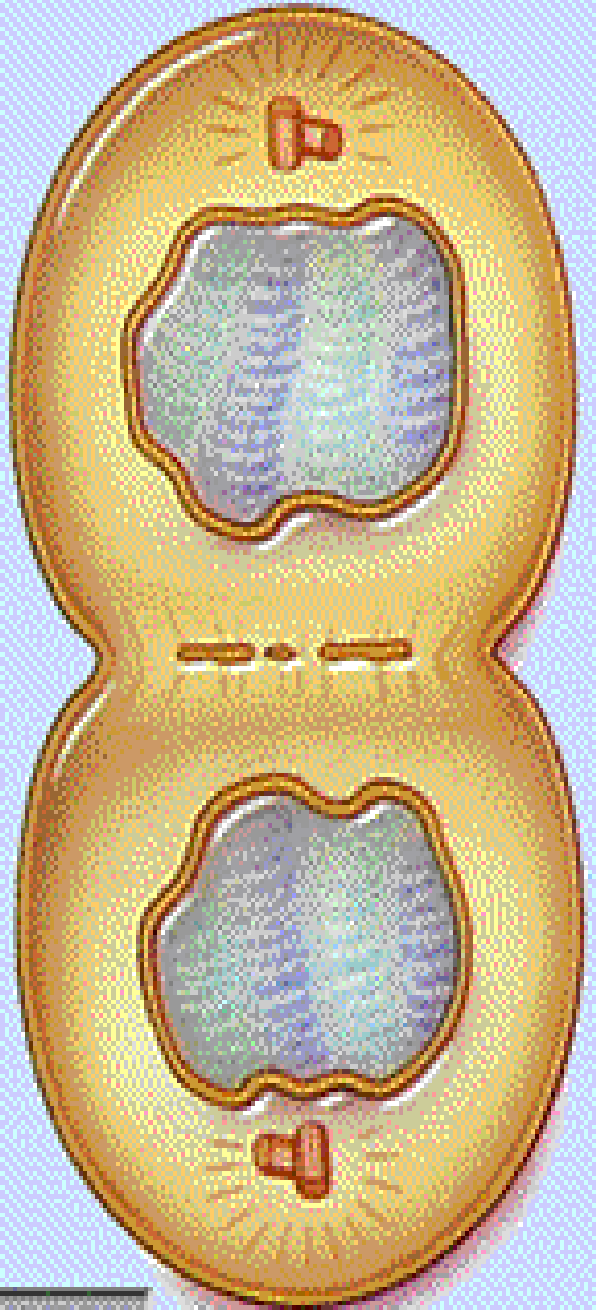
Cell Division is a Continuum of Dynamic Changes

- **TELOPHASE**
  - The **cell continues to elongate**.
  - The **nuclear envelope** forms around chromosomes at each pole, establishing daughter nuclei.
  - **Chromatin uncoils**.
  - The **mitotic spindle disappears**.

Stages of Mitosis

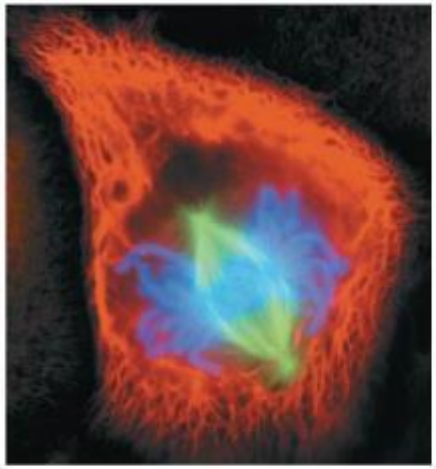
Telophase

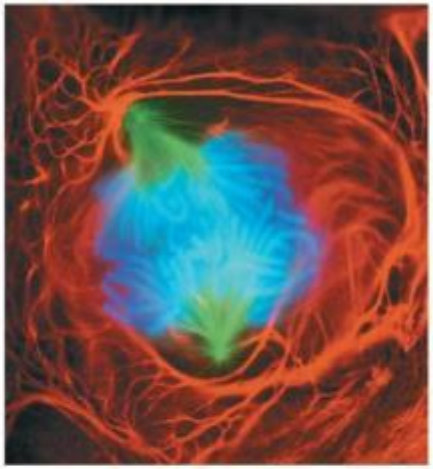
Cytoplasmic division occurs.

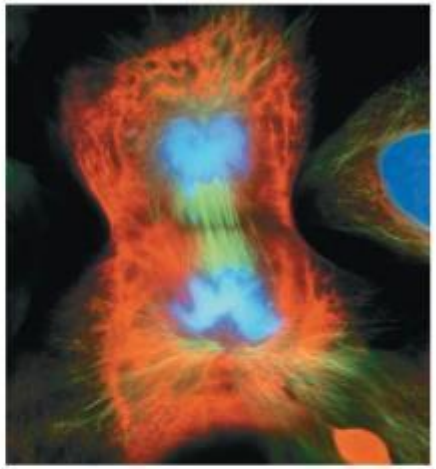


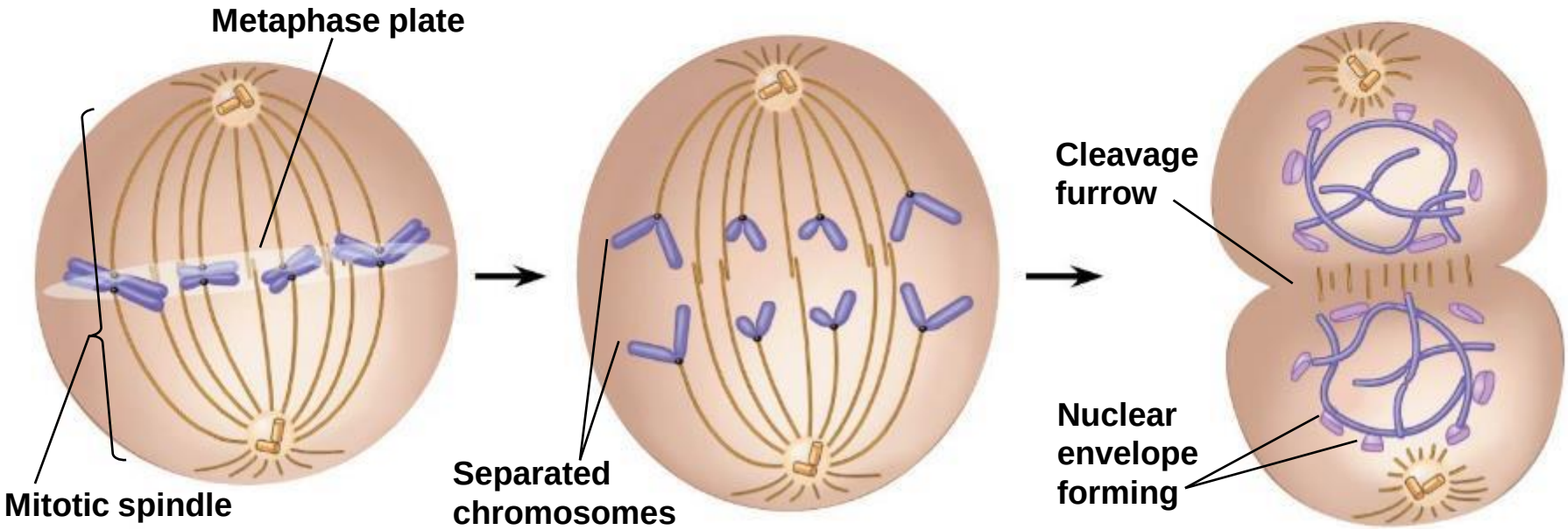
MITOSIS

Metaphase	Anaphase	Telophase and Cytokinesis





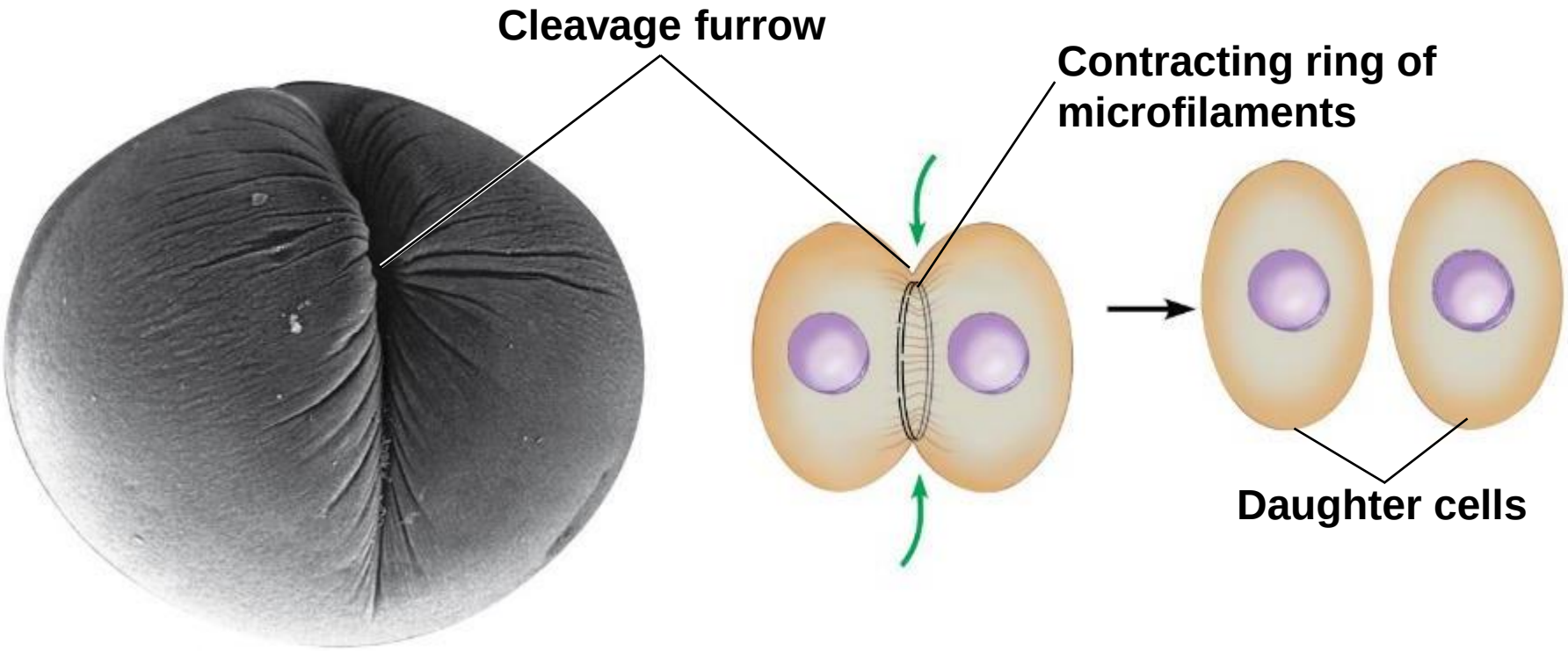




Cell Division is a Continuum of Dynamic Changes

- During **CYTOKINESIS**, the **cytoplasm is divided into separate cells**.
- **Cytokinesis usually occurs simultaneously with Telophase**.
- In **ANIMAL CELLS**, **cytokinesis** occurs as
  1. a **Cleavage Furrow** forms from a contracting ring of microfilaments.
  2. the **Cleavage Furrow** deepens to separate the contents into two cells.

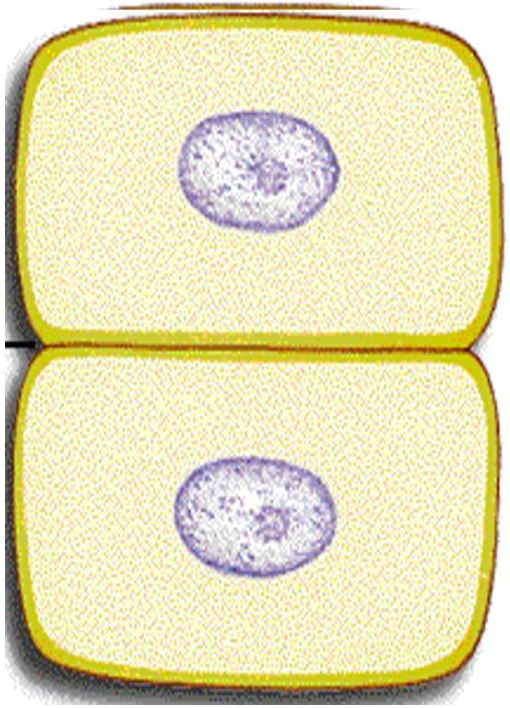
Cytokinesis



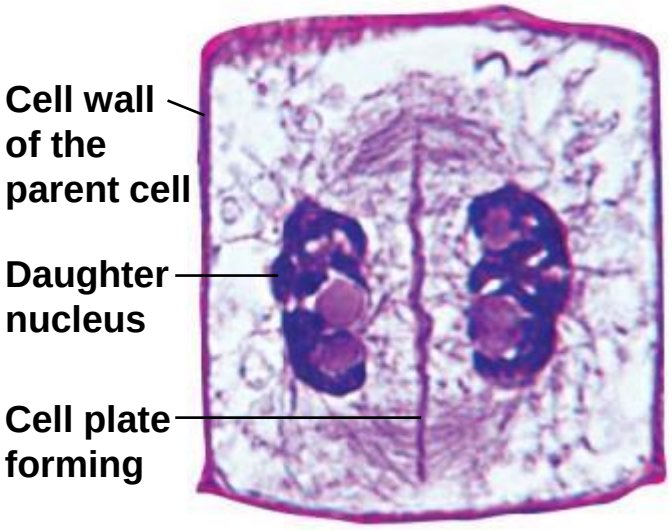
Cytokinesis differs for Plant and Animal Cells

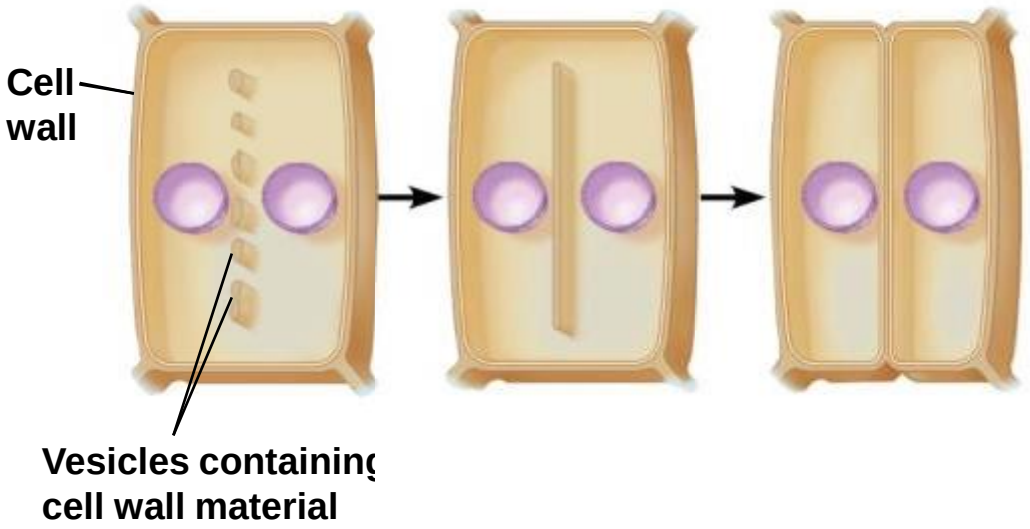
- In **PLANT CELLS**, **cytokinesis** occurs as

  1. a **Cell Plate** forms in the middle.
  2. the **Cell Plate** grows outward to reach the edges, dividing the contents into two cells.
  3. each cell now possesses a **plasma membrane** and **cell wall**.

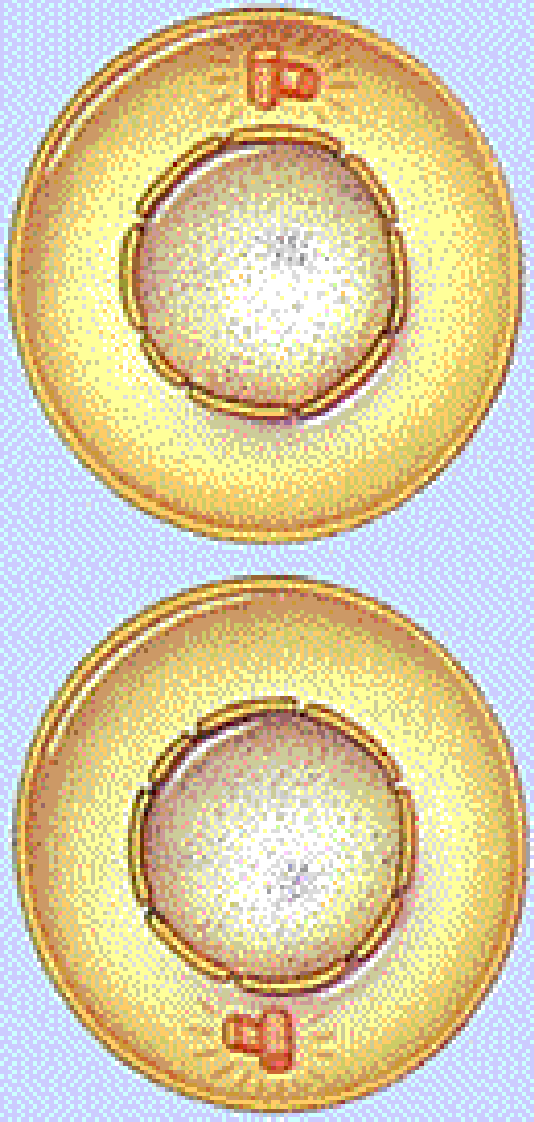


Cytokinesis in Plant Cells

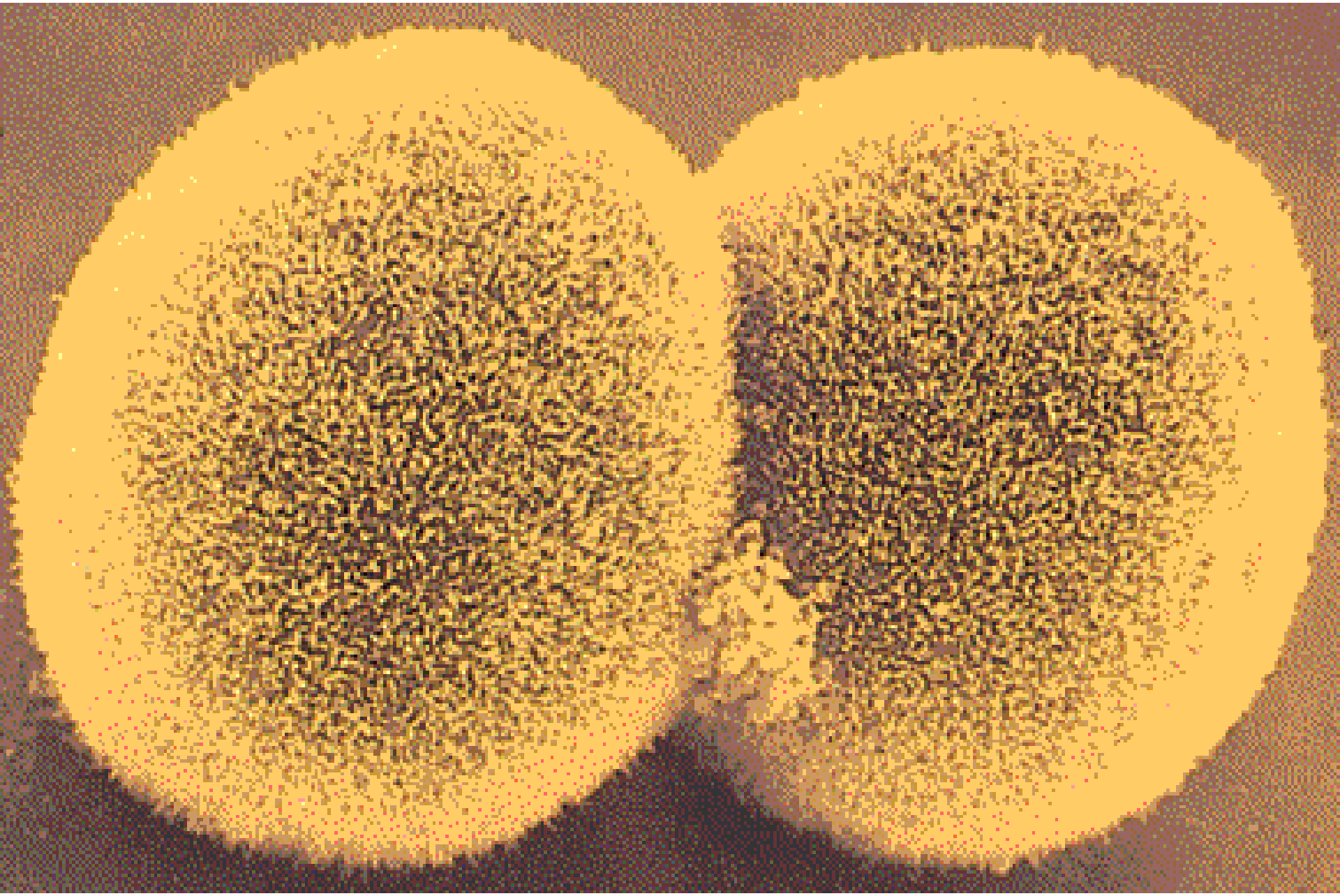




Interphase

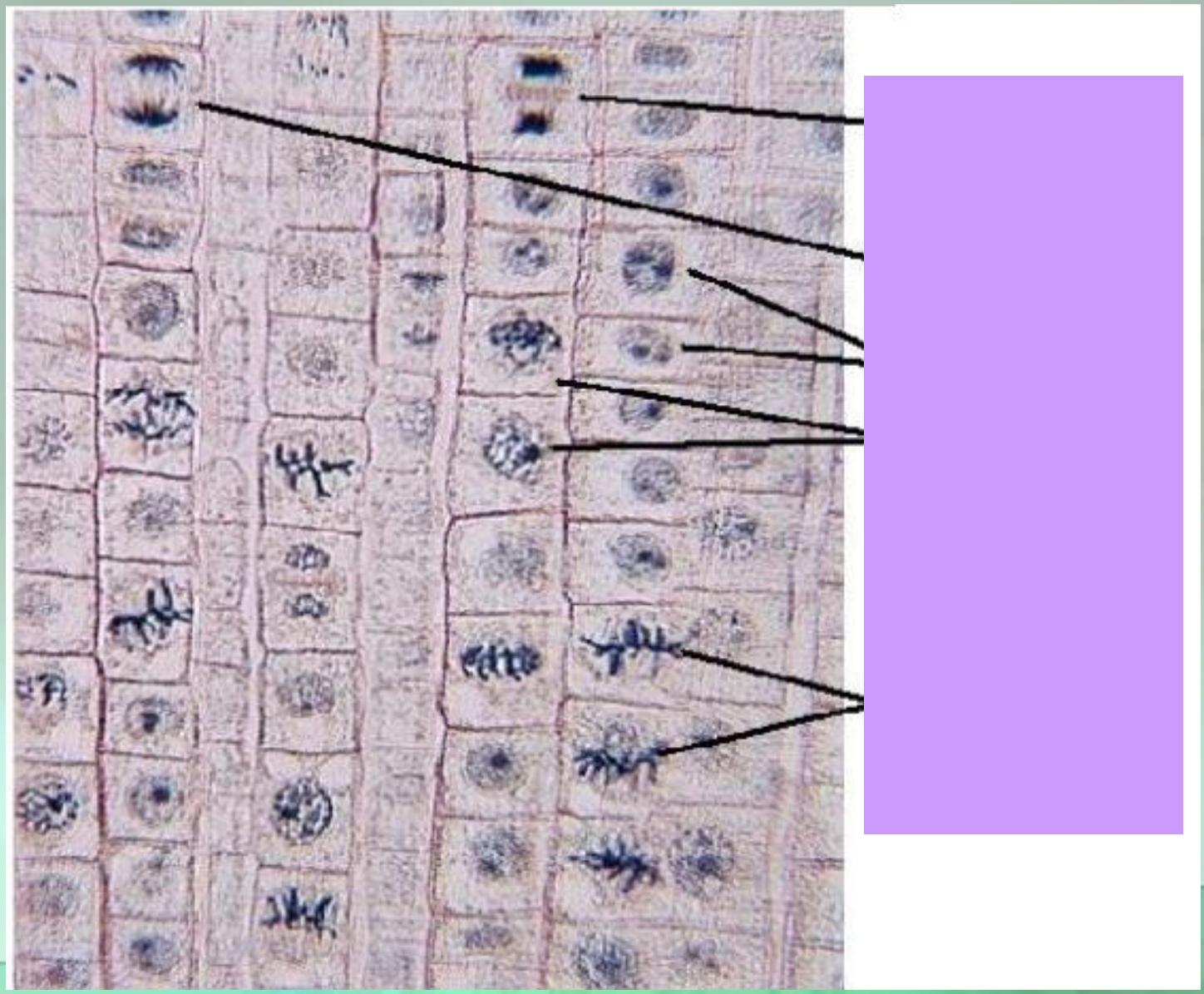


After mitosis, two diploid daughter cells have formed.



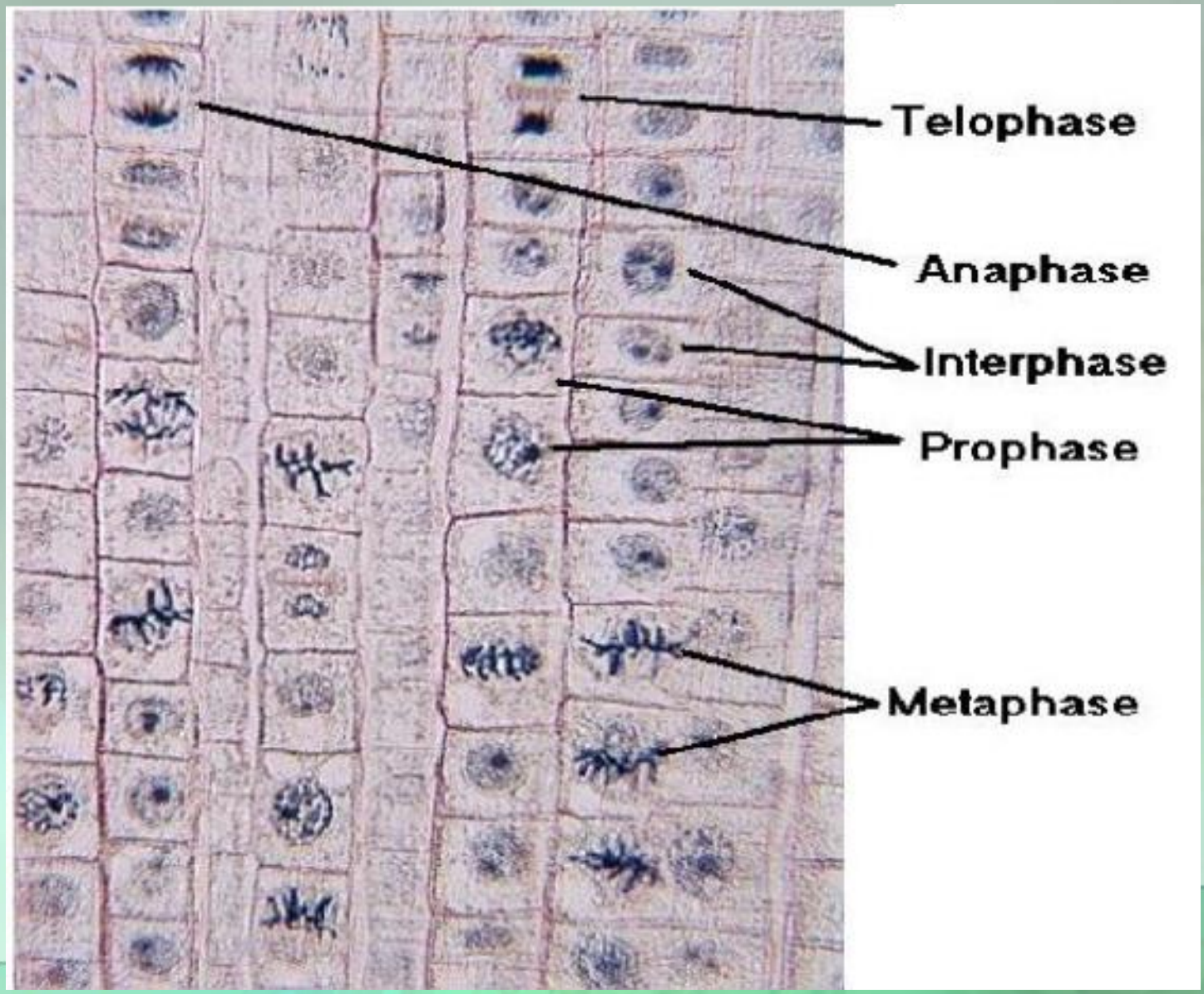
Locate Mitotic Stages

TRY IT



Locate Mitotic Stages

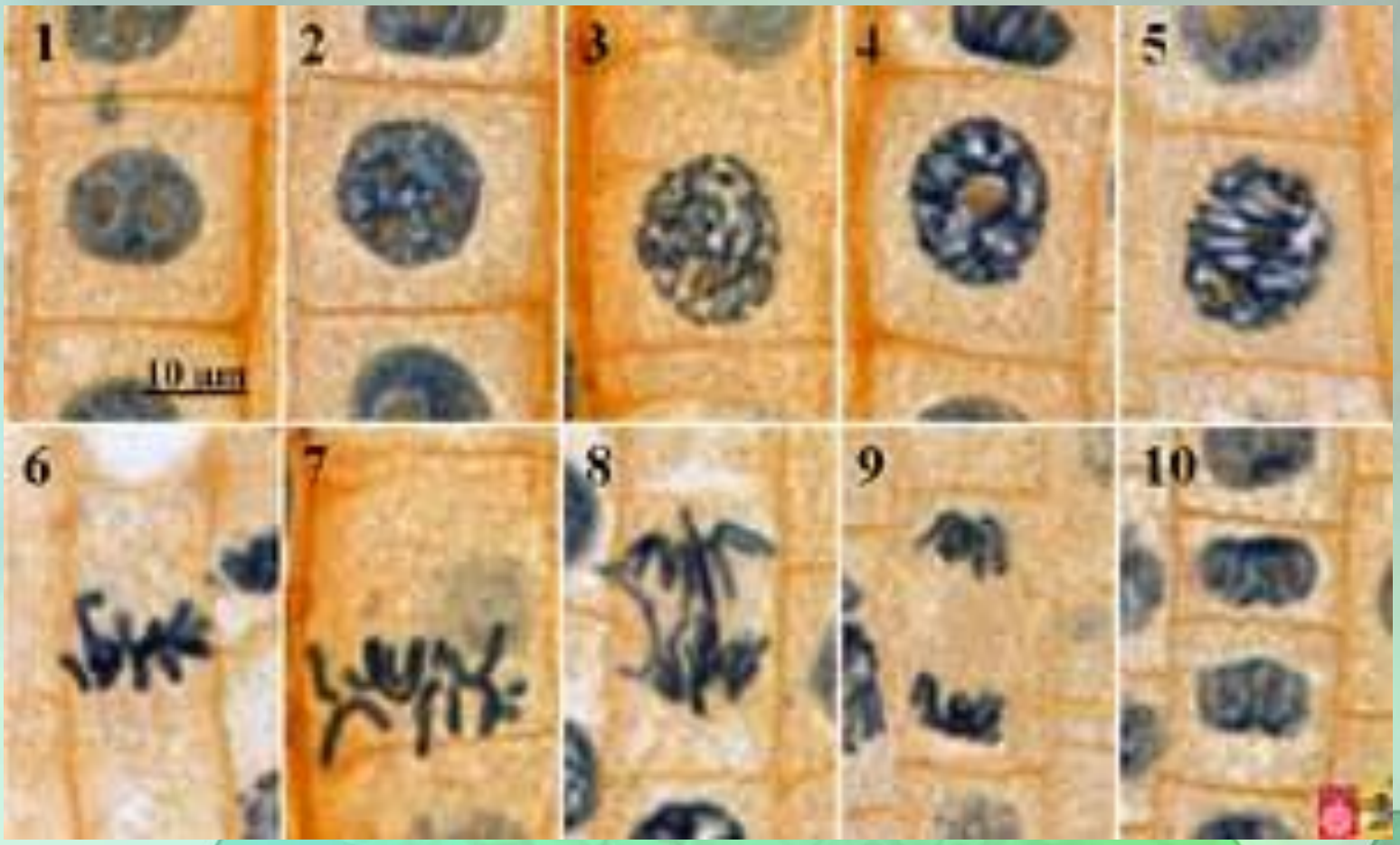
TRY IT



Mitosis in Onion Root Tips

TRY IT

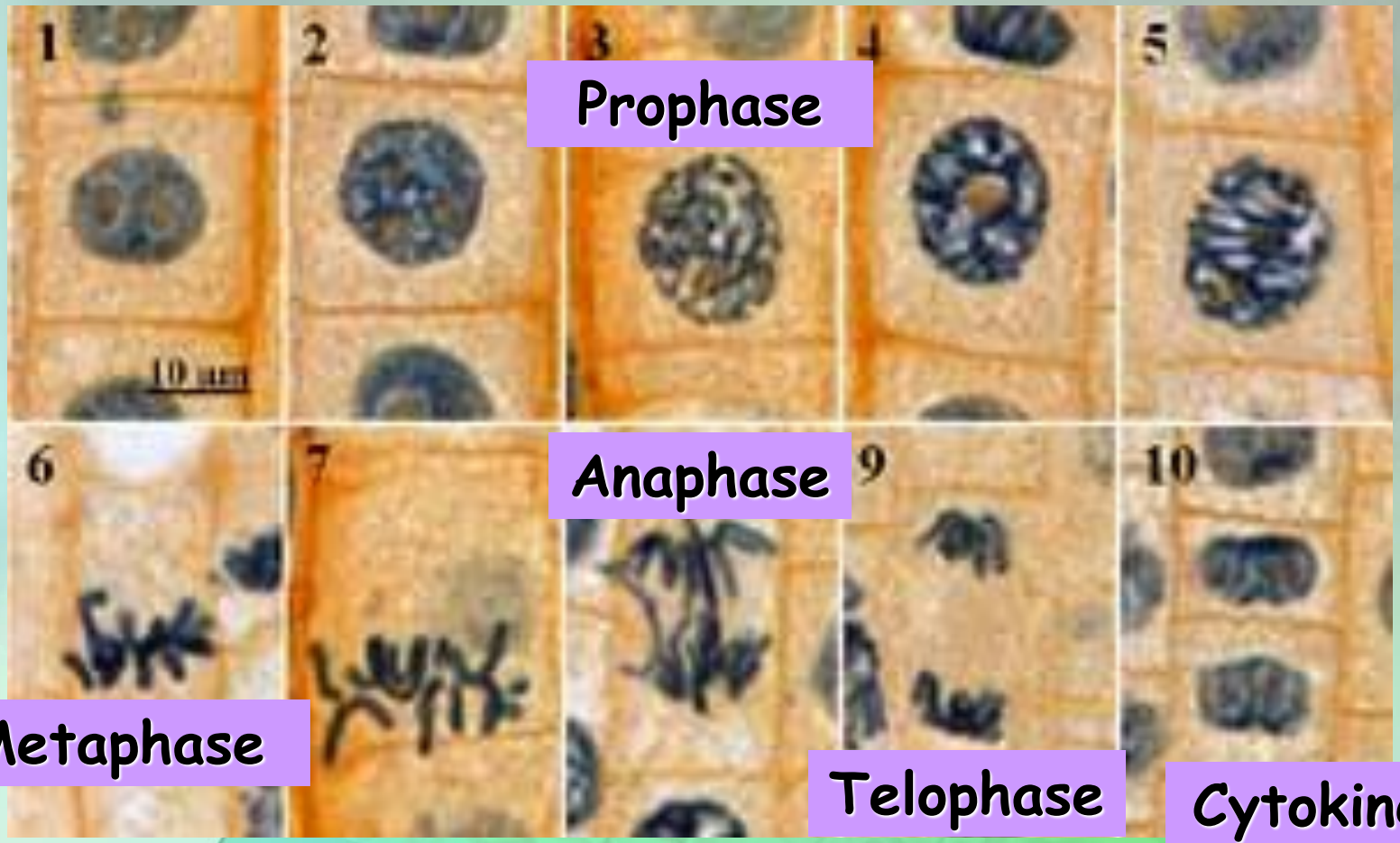
Do you see any stages of mitosis?



Mitosis in Onion Root Tips

TRY IT

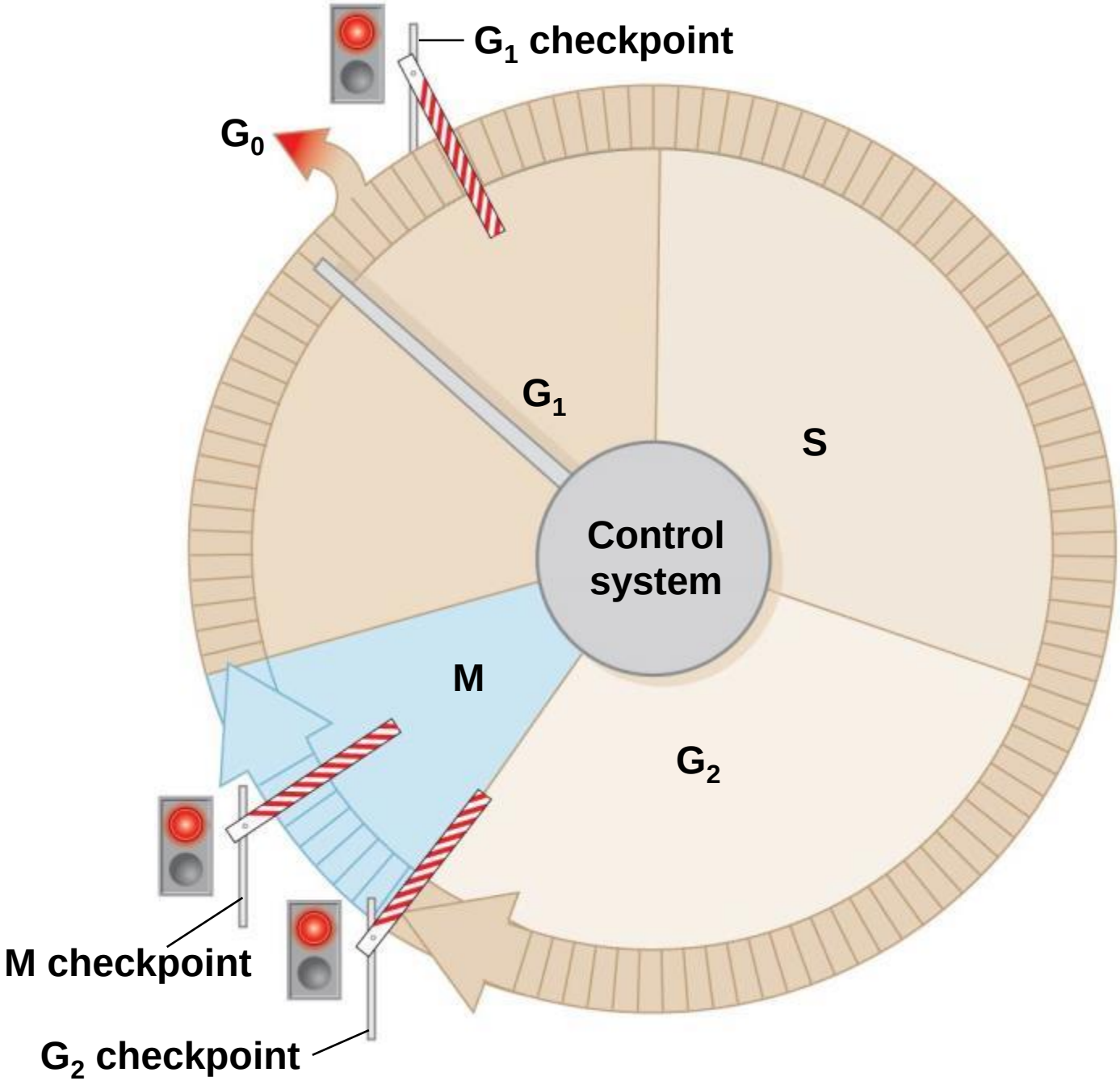
Do you see any stages of mitosis?



Growth Factors Signal the Cell Cycle Control System

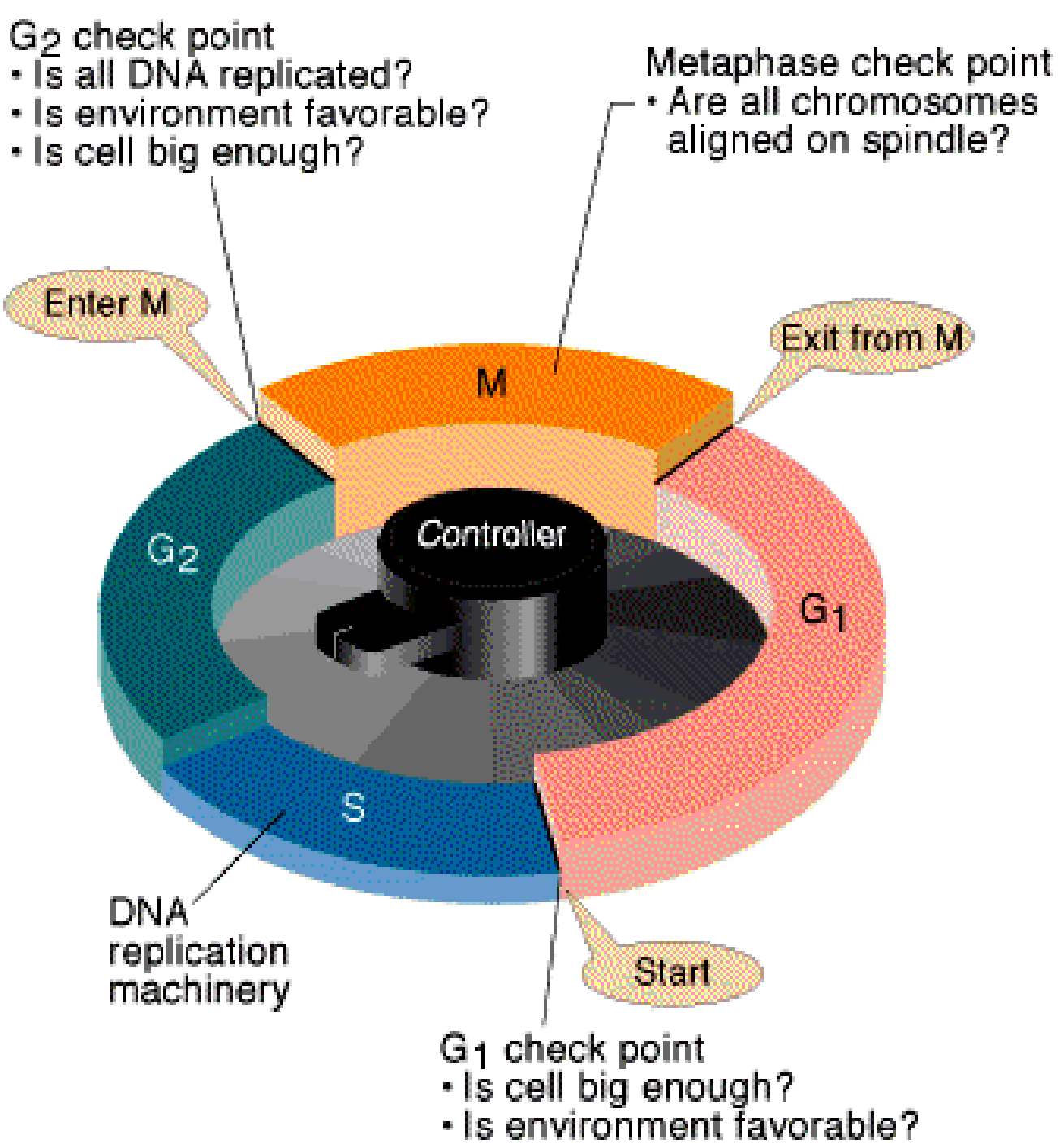
- The **CELL CYCLE CONTROL SYSTEM** is a **cycling set of molecules in the cell** that triggers and coordinates key events in the cell cycle.
- **CHECKPOINTS** in the cell cycle can
  - **stop** an event or
  - signal an event to **proceed.**

Figure 8.8a


G_1 checkpoint
G_0
G_1
S
Control system
M
G_2
M checkpoint
G_2 checkpoint

Growth Factors Signal the Cell Cycle Control System

- There are **Three Major Checkpoints** in the **Cell Cycle**:
  1. **G_1 Checkpoint**:
     - allows entry into the S phase or causes the cell to leave the cycle, entering a non-dividing **G_0 phase**.
  2. **G_2 Checkpoint**
     - Is all DNA replicated? Is environment favorable? Has the cell grown enough?
  3. **M Checkpoint**
     - **Are all chromosomes aligned on spindle?**

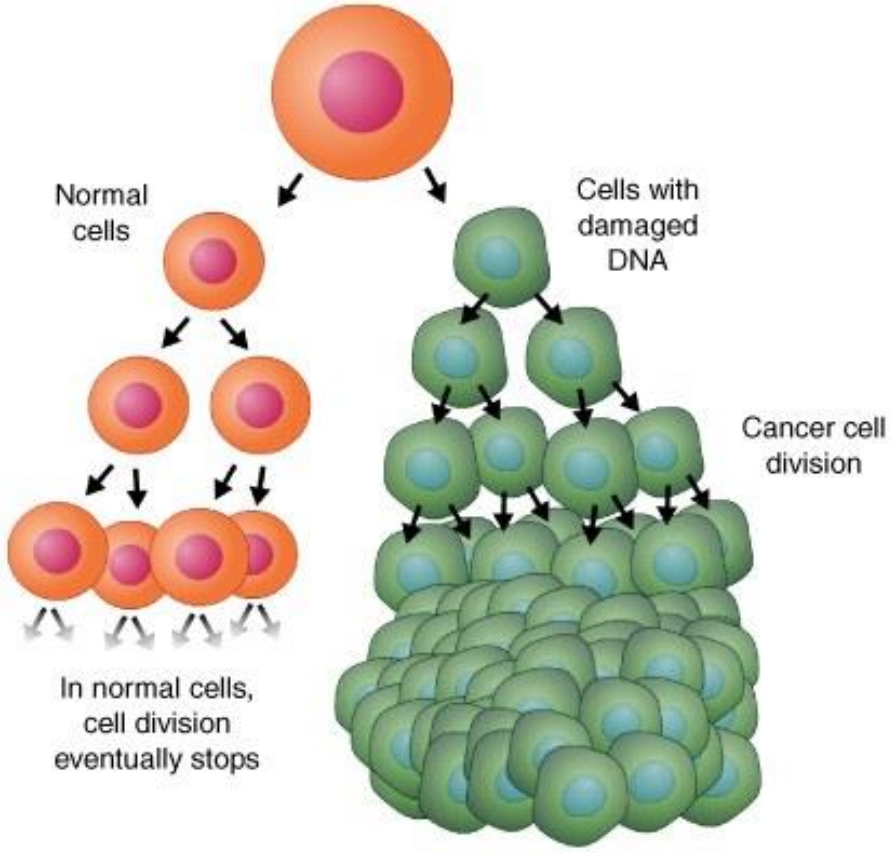

G2 check point
• Is all DNA replicated?
• Is environment favorable?
• Is cell big enough?
Metaphase check point
• Are all chromosomes aligned on spindle?
Enter M
Exit from M
M
Controller
G2
G1
S
DNA replication machinery
Start
G1 check point
• Is cell big enough?
• Is environment favorable?

Cancer?

- Unregulated mitosis
- Benign
- Malignant/ metastasis
- Source?

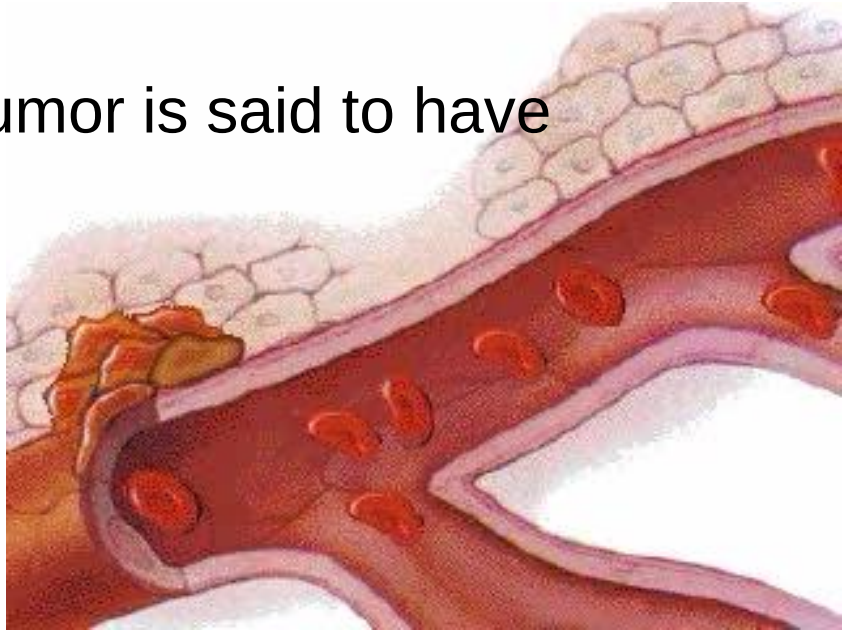
Growing out of control, Cancer Cells produce Malignant Tumors

- **CANCER** currently claims the lives of 20% of the people in the United States.
- **CANCER** cells **escape controls on the cell cycle**.
- **CANCER** cells **divide excessively** and **invade other tissues** of the body.

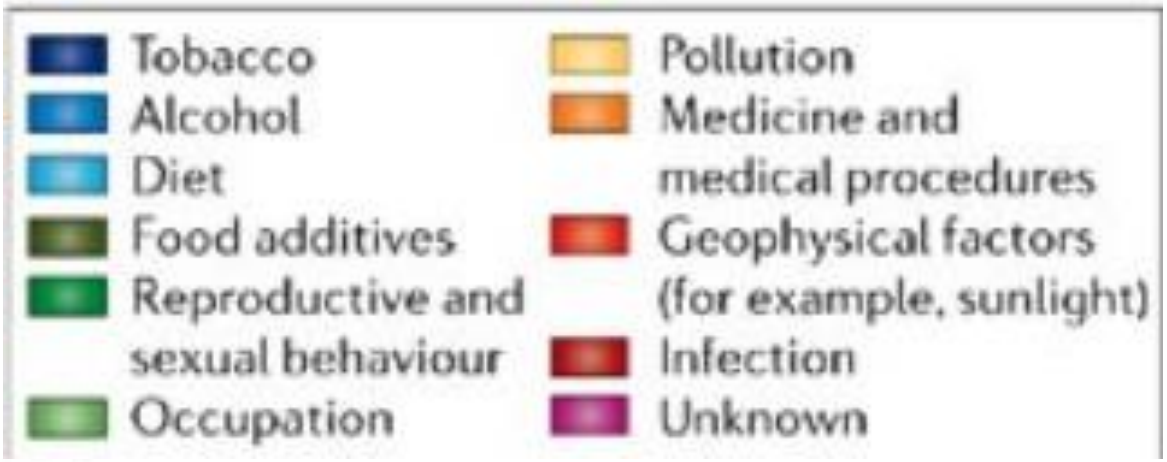


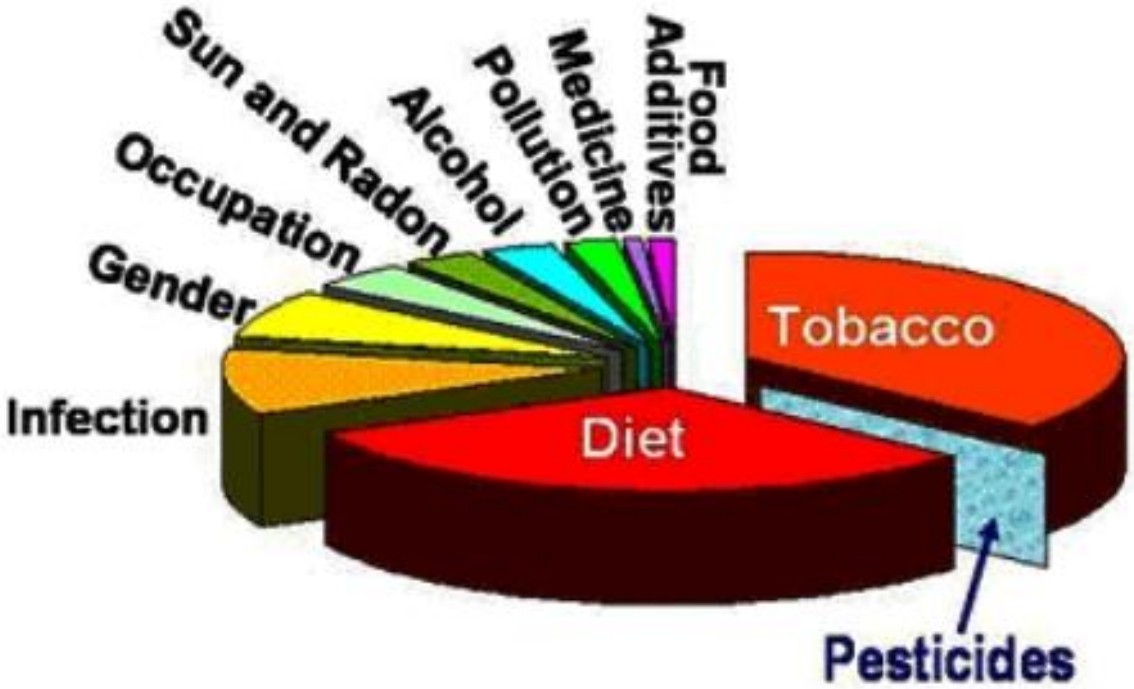
Growing out of control, Cancer Cells produce Malignant Tumors

- A **TUMOR** is a mass of abnormally growing cells within otherwise normal tissue.
  - **Benign Tumors** remain at the original site but may disrupt certain organs if they grow in size.
  - **Malignant Tumors** can spread to other locations in a process called **Metastasis**.
  - An individual with a malignant tumor is said to have **CANCER**.



Some Causes of Cancer

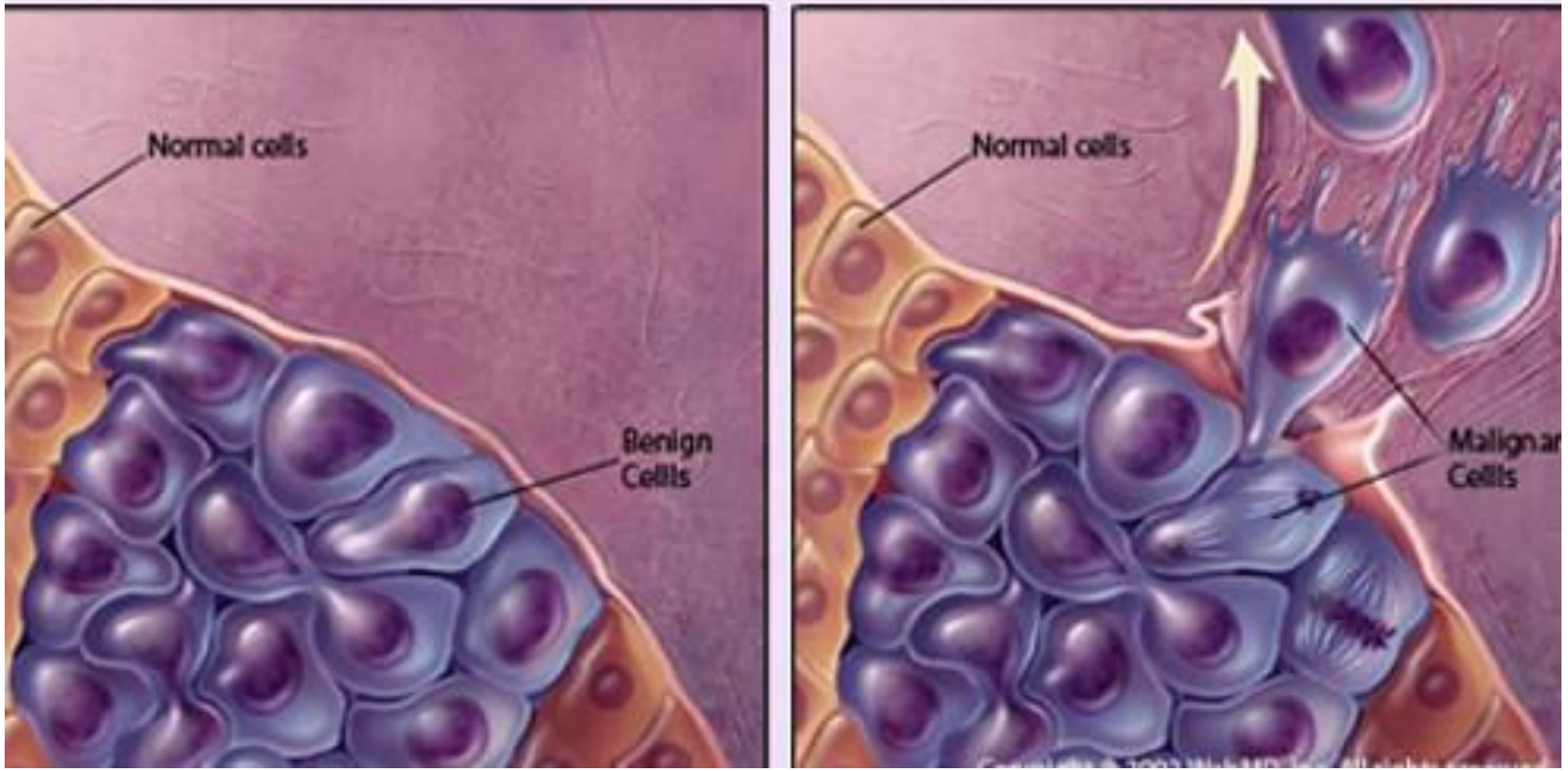




Benign vs. Malignant Tumors

Benign (not cancer) tumor cells grow only locally and cannot spread by invasion or metastasis

Malignant (cancer) cells invade neighboring tissues, enter blood vessels and metastasize to different sites



Growing out of control, Cancer Cells produce Malignant Tumors

- **Localized Tumors** can be
  - removed surgically and/or
  - treated with concentrated beams of high-energy radiation.
- **Metastatic Tumors** are treated with **Chemotherapy**.