

# Chapter 9: The Cell Cycle

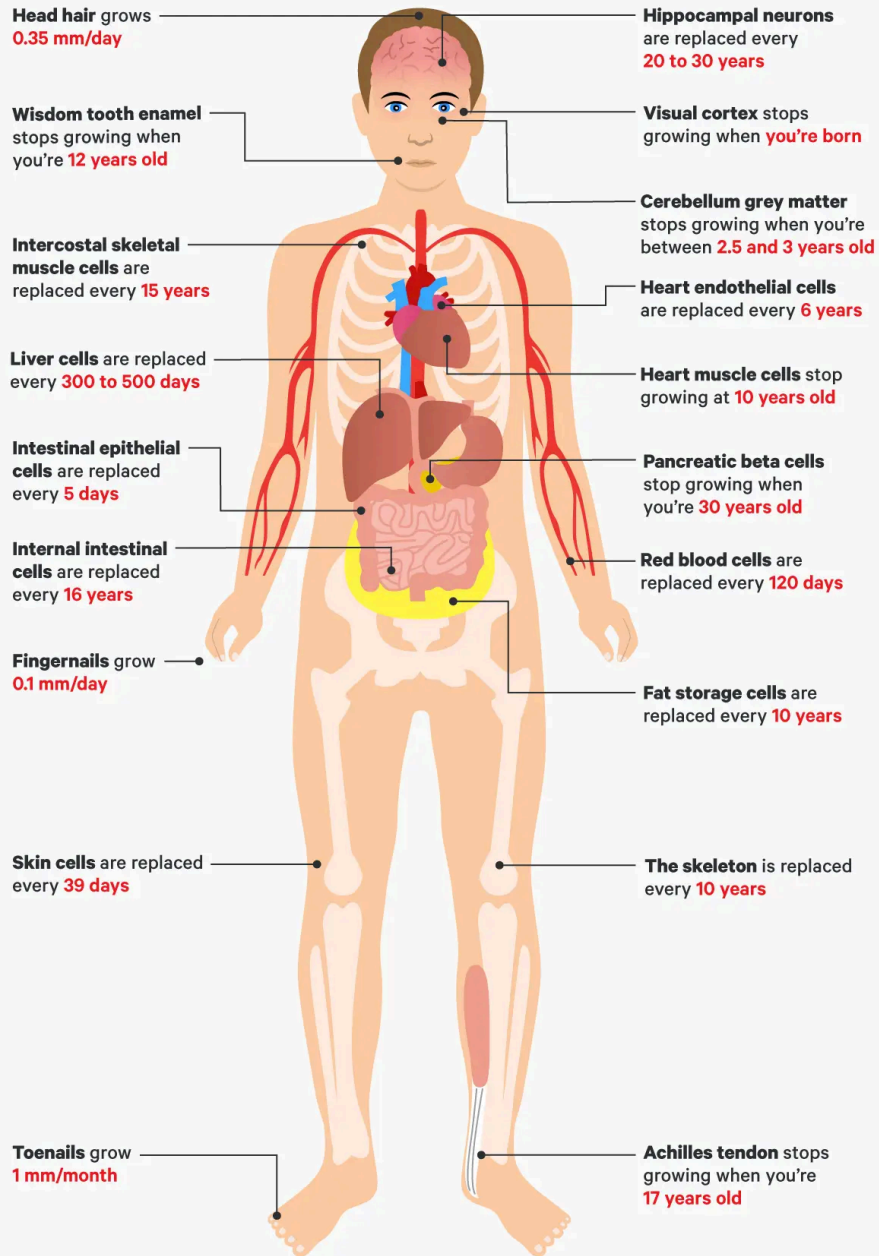
# What you must know:

---

- ▶ The structure of the replicated chromosome.
- ▶ The events that occur in interphase of the cell cycle (G1, S, G2).
- ▶ The role of cyclins and cyclin-dependent kinases in the regulation of the cell cycle.
- ▶ Ways in which the normal cell cycle is disrupted to cause cancer or halted in certain specialized cells.
- ▶ The features of mitosis that result in the production of genetically identical daughter cells including replication, alignment of chromosomes (metaphase), and separation of chromosomes (anaphase).



# THE AVERAGE LIFE OF YOUR CELLS

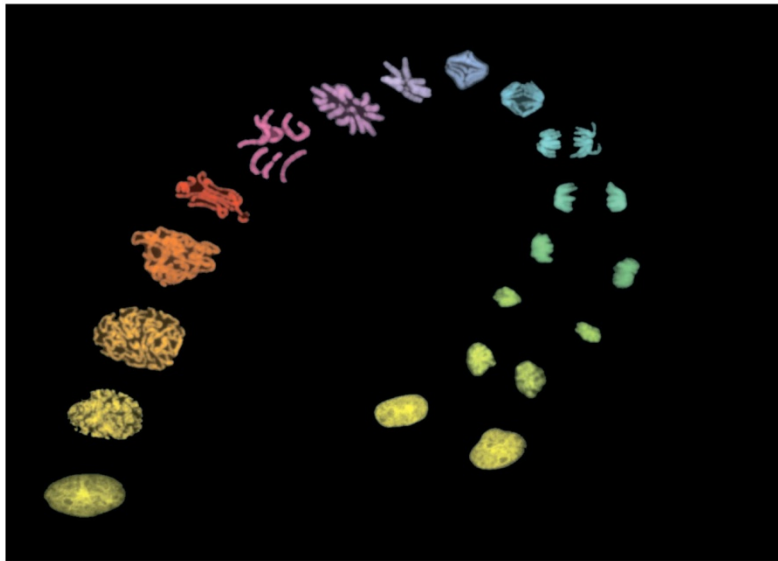


**Cell Cycle**: life of a cell from its formation until it divides into two cells

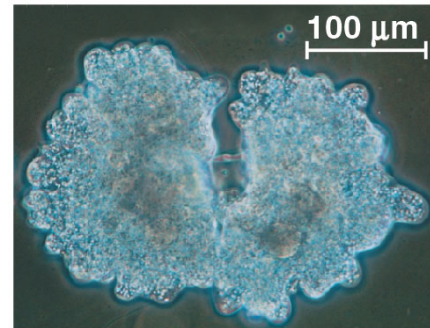
---

## **Functions of Cell**

**Division**: Reproduction, Growth and Tissue Repair

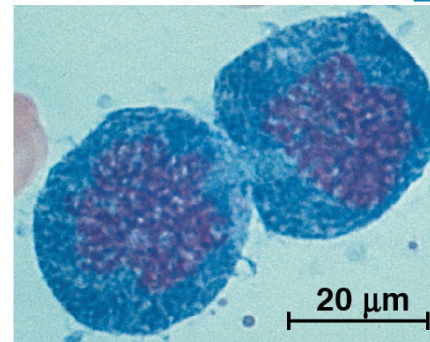
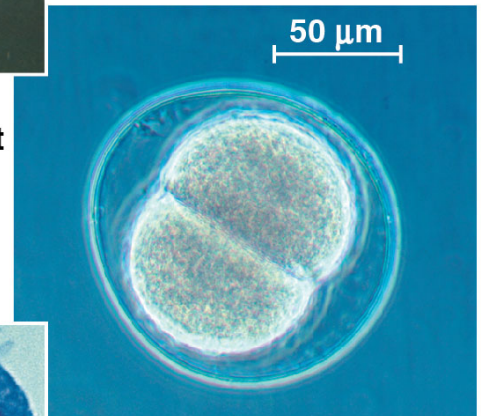


© 2011 Pearson Education, Inc.



◀ (a) Reproduction

▶ (b) Growth and development



◀ (c) Tissue renewal

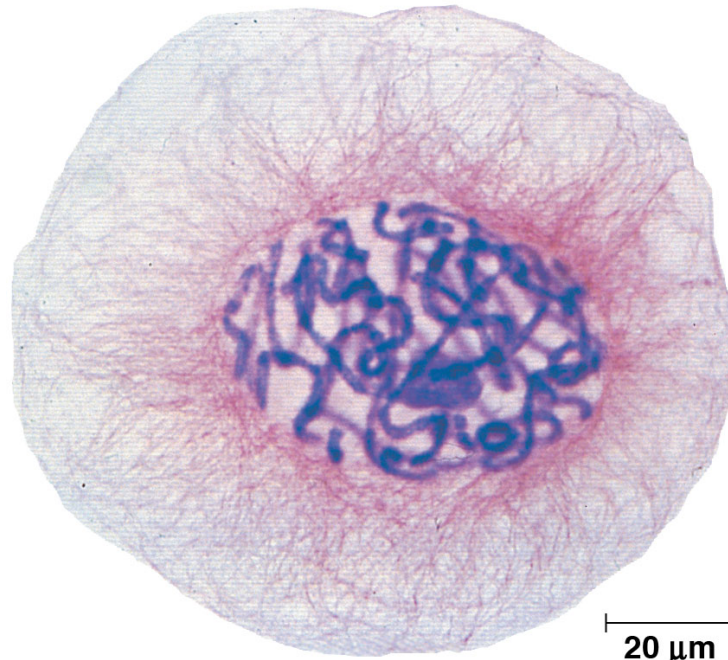
© 2016 Pearson Education, Inc.



**Genome** = all of a cell's genetic info (DNA)

---

- ▶ Prokaryote: single, circular chromosome
- ▶ Eukaryote: more than one linear chromosomes
  - ▶ Eg. Human: 46 chromosomes, mouse: 40, fruit fly: 8

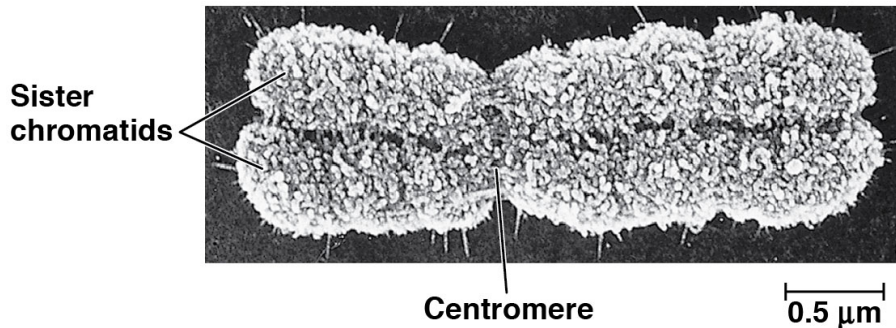


© 2016 Pearson Education, Inc.

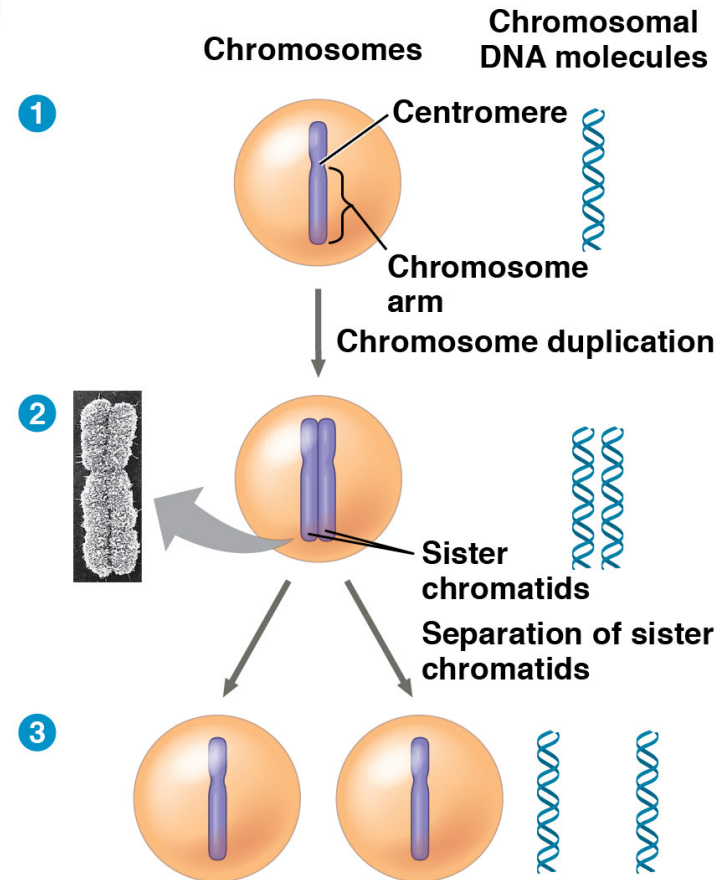


# Each chromosome must be duplicated (replicated) before cell division

- ▶ Duplicated chromosome = 2 sister chromatids attached by a centromere



© 2016 Pearson Education, Inc.



© 2016 Pearson Education, Inc.

---

## Somatic Cells

- ▶ Body cells
- ▶ Diploid ( $2n$ ): 2 of each type of chromosome
- ▶ Divide by mitosis
  
- ▶ Humans:  $2n = 46$

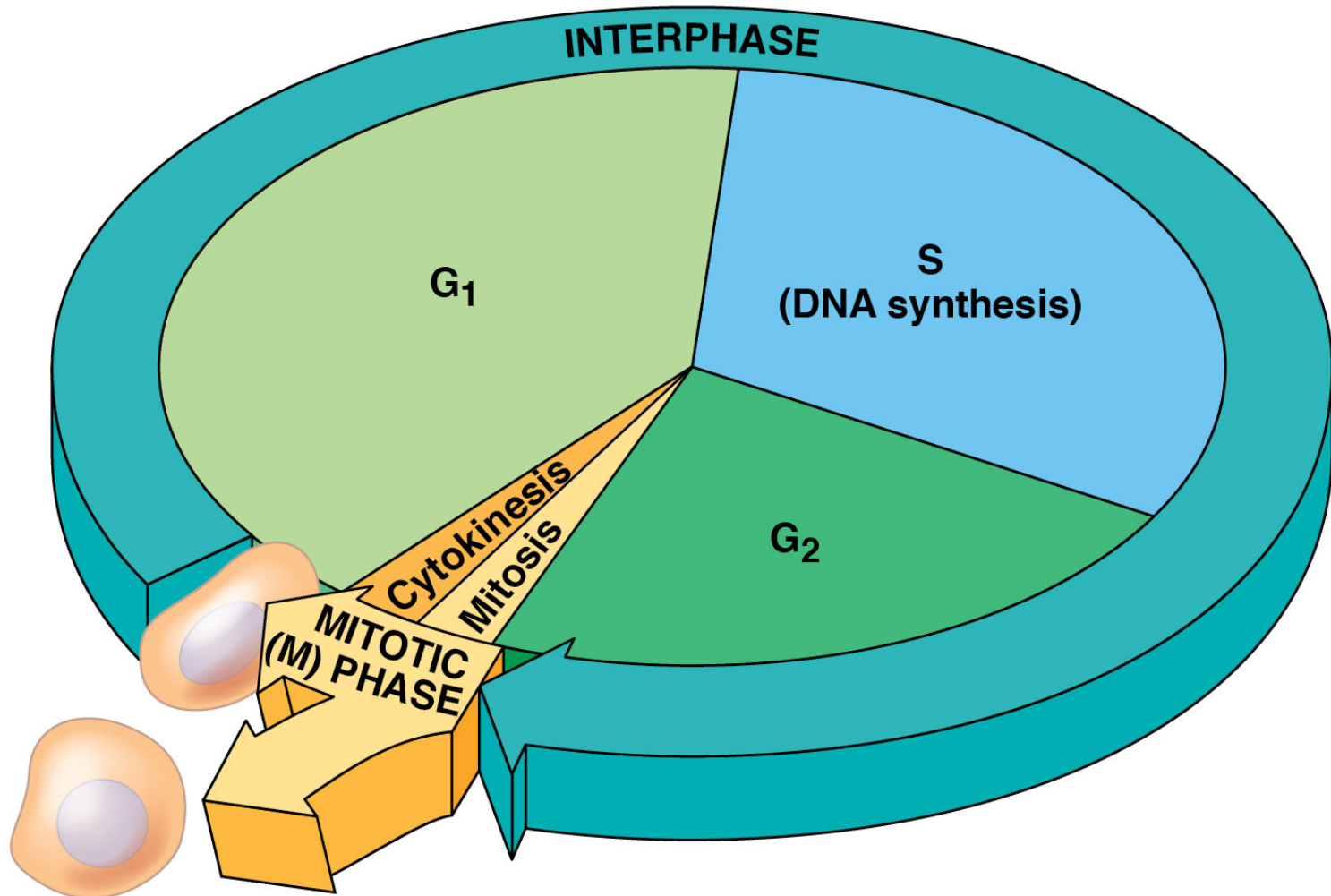
## Gametes

- ▶ Sex cells (sperm/egg)
- ▶ Haploid ( $n$ ): 1 of each type of chromosome
- ▶ Divide by meiosis
  
- ▶ Humans:  $n = 23$



# Phases of the Cell Cycle

---





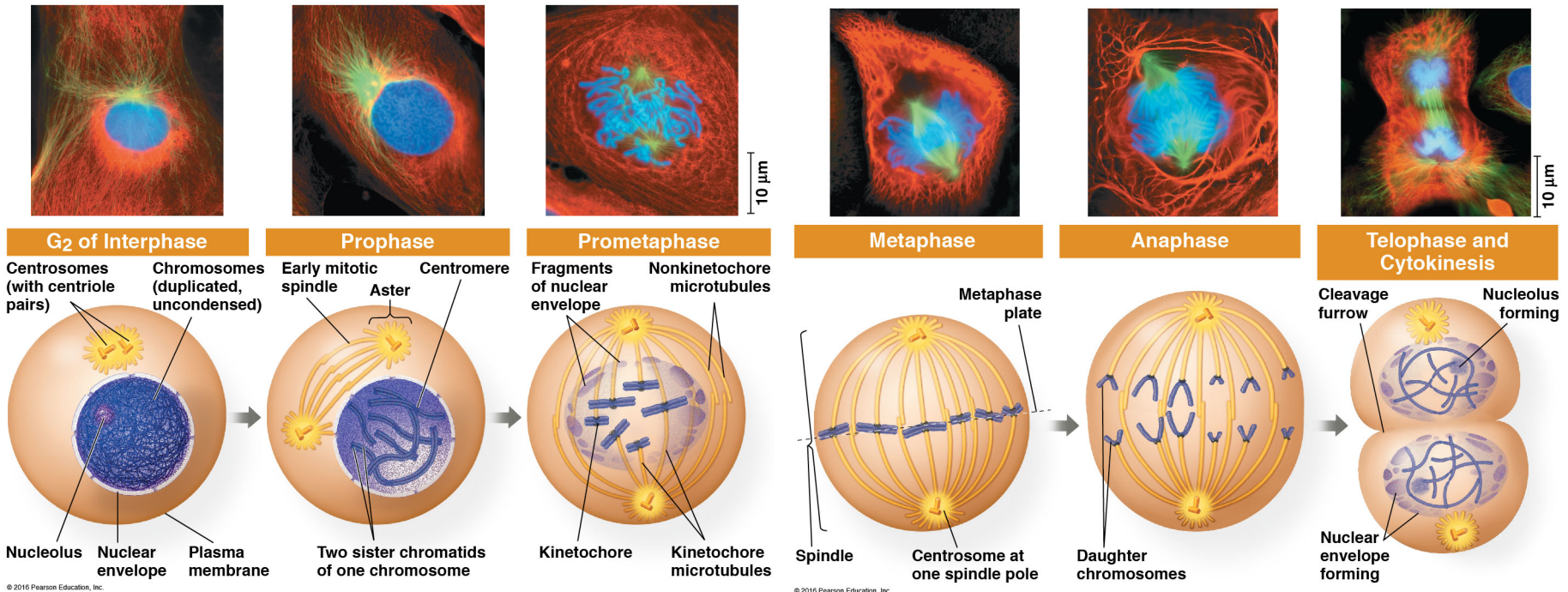
# Phases of the Cell Cycle

---

- ▶ The *mitotic* phase alternates with *interphase*:  
 $G_1 \rightarrow S \rightarrow G_2 \rightarrow \text{mitosis} \rightarrow \text{cytokinesis}$
- ▶ Interphase (90% of cell cycle)
- ▶ **G<sub>1</sub> Phase**: cell grows and carries out normal functions
- ▶ **S Phase**: duplicates chromosomes (DNA replication)
- ▶ **G<sub>2</sub> Phase**: prepares for cell division
- ▶ M Phase (mitotic)
- ▶ **Mitosis**: nucleus divides
- ▶ **Cytokinesis**: cytoplasm divides

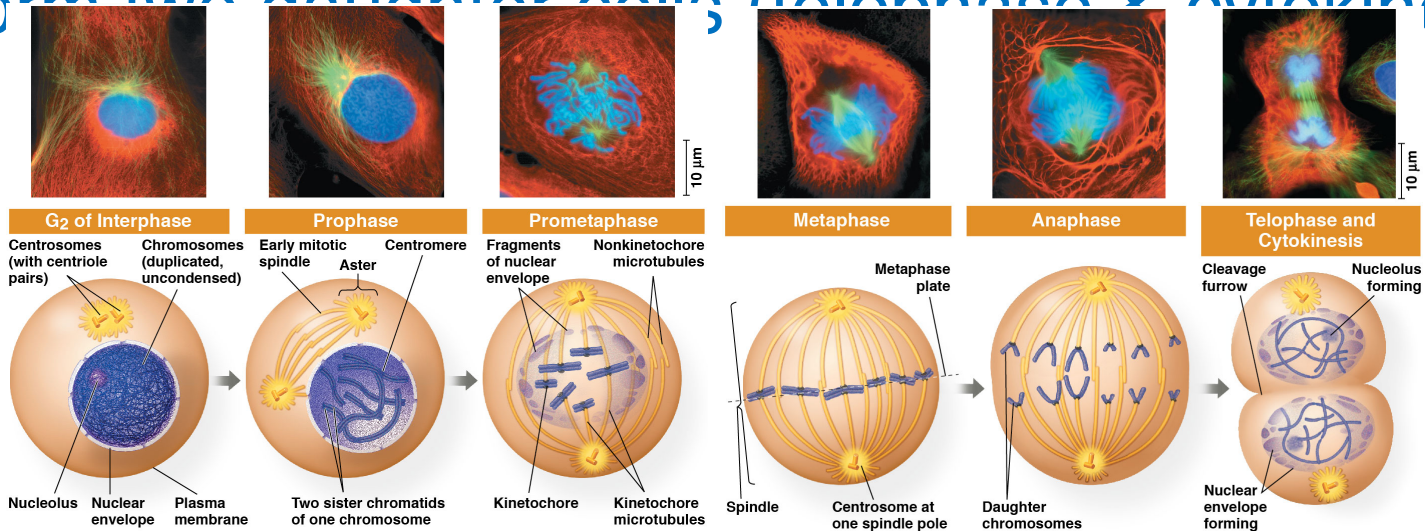


# Mitosis: Prophase → Metaphase → Anaphase → Telophase

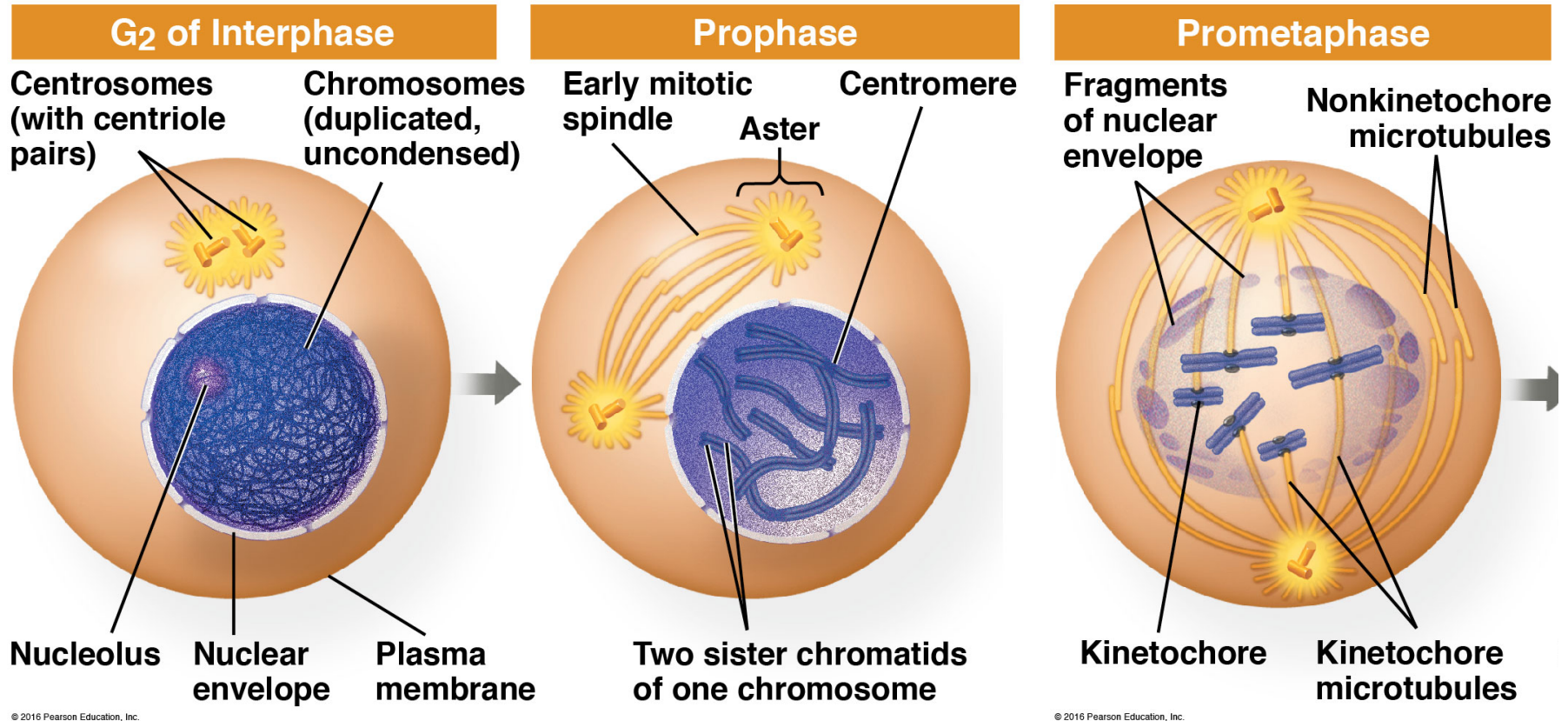


# Mitosis

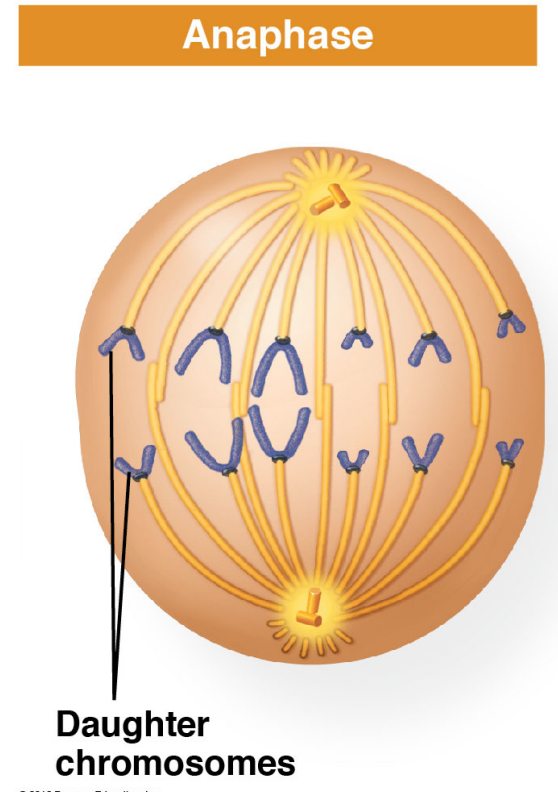
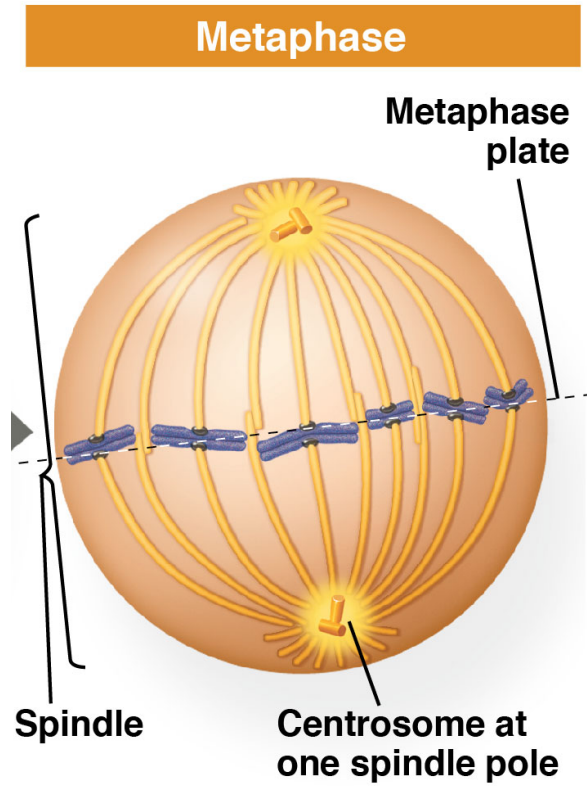
- ▶ Continuous process with observable structural features:
  - ▶ Chromosomes become visible (prophase)
  - ▶ Alignment at the equator (metaphase)
  - ▶ Separation of sister chromatids (anaphase)
  - ▶ Form two daughter cells (telophase & cytokinesis)



# Prophase & Prometaphase



# Metaphase & Anaphase

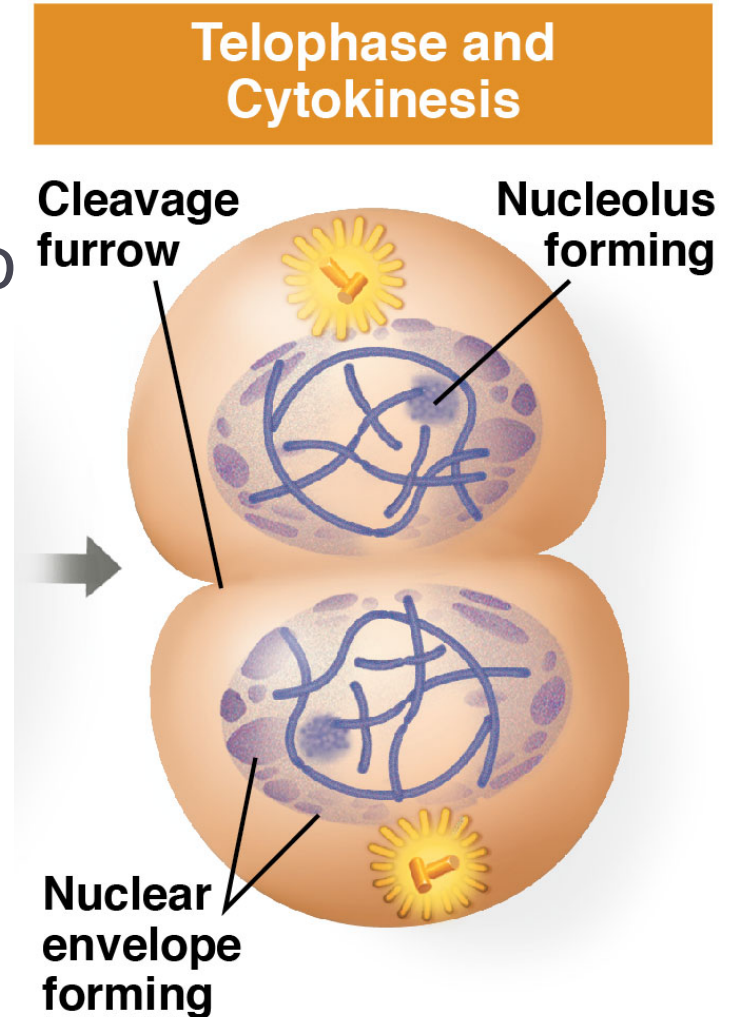


© 2016 Pearson Education, Inc.

# Telophase & Cytokinesis

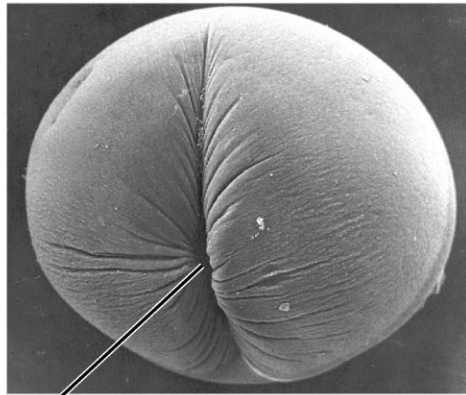
## Cytokinesis

- ▶ Cytoplasm of cell divided
- ▶ **Animal Cells:** cleavage furro
- ▶ **Plant Cells:** cell plate forms



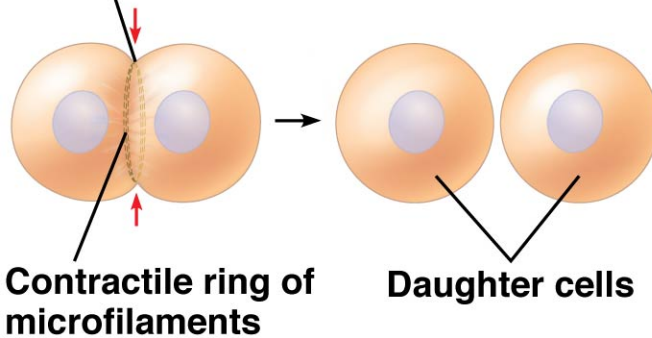
# Cytokinesis in Animal vs. Plant Cells

(a) Cleavage of an animal cell (SEM)



100  $\mu\text{m}$

Cleavage furrow

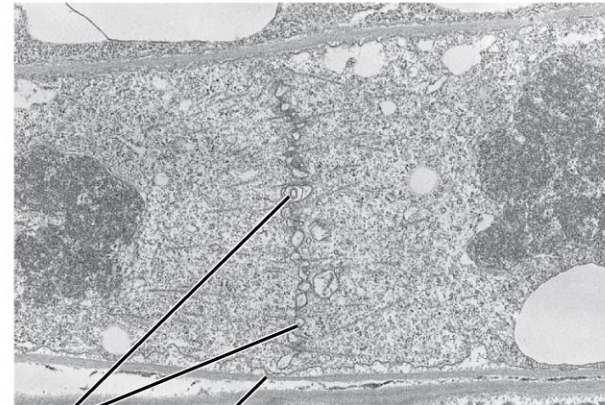


Contractile ring of microfilaments

Daughter cells

© 2016 Pearson Education, Inc.

(b) Cell plate formation in a plant cell (TEM)



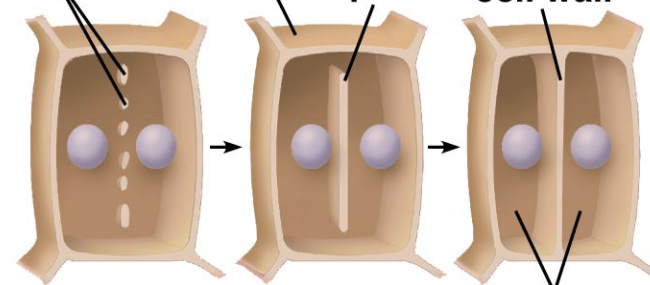
1  $\mu\text{m}$

Vesicles forming cell plate

Wall of parent cell

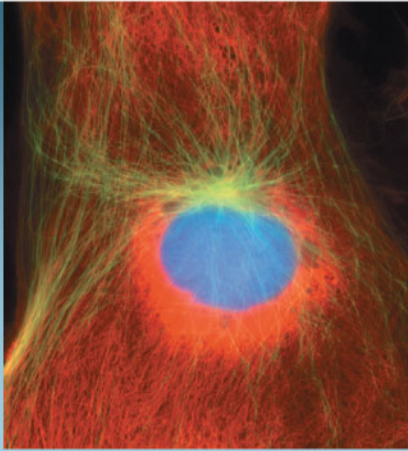
Cell plate

New cell wall

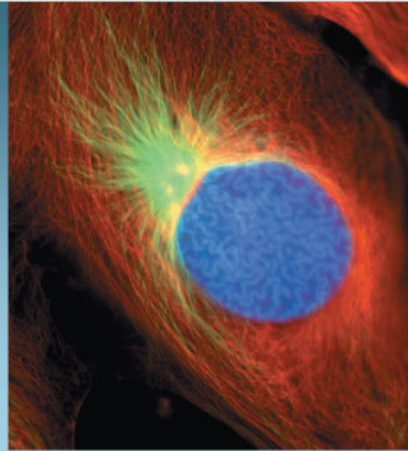


Daughter cells

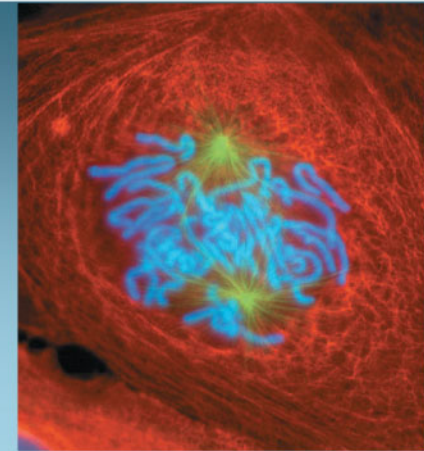
# Animal Cell Division



**G<sub>2</sub> of Interphase**

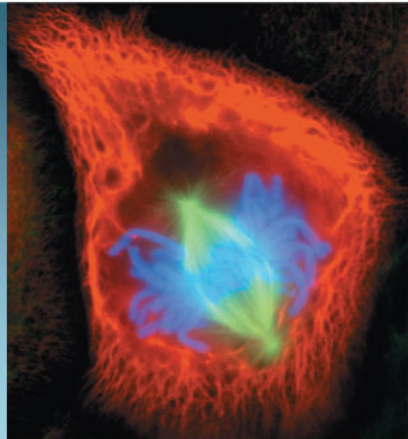


**Prophase**

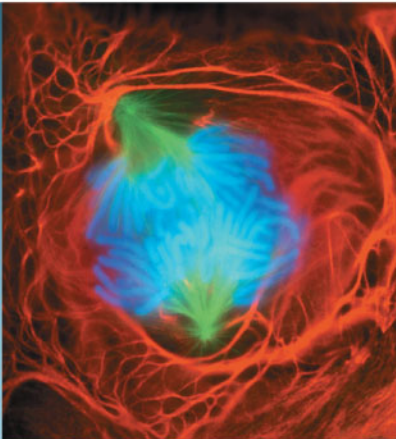


**Prometaphase**

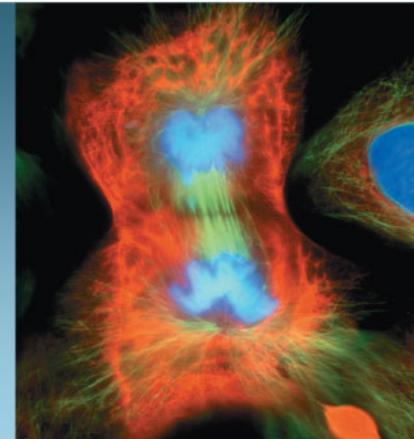
10  $\mu$ m



**Metaphase**



**Anaphase**

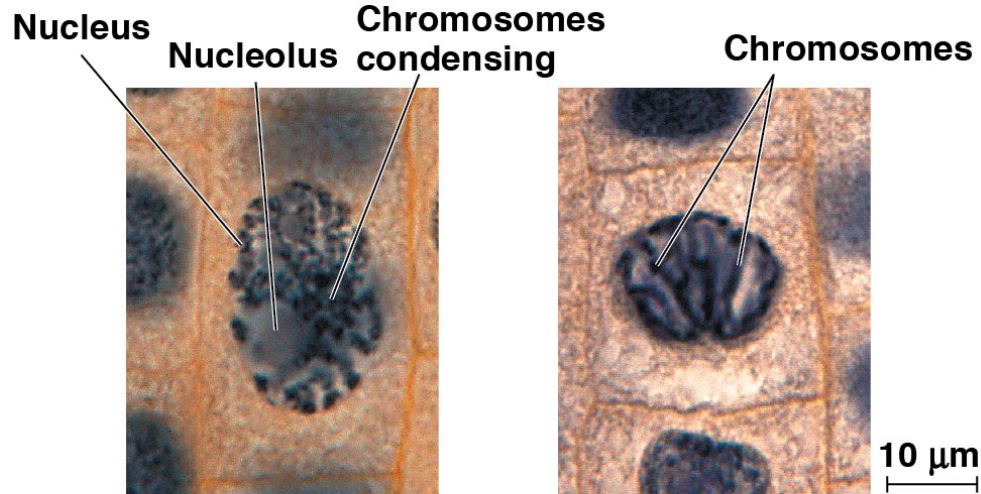


**Telophase and Cytokinesis**

10  $\mu$ m



# Plant Cell Division



**1** Prophase

**2** Prometaphase

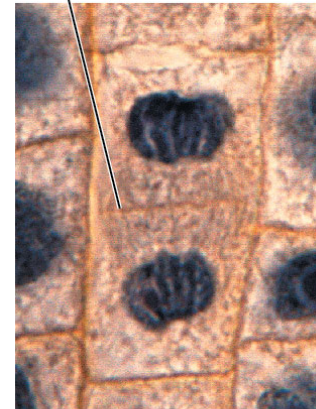
Cell plate



**3** Metaphase

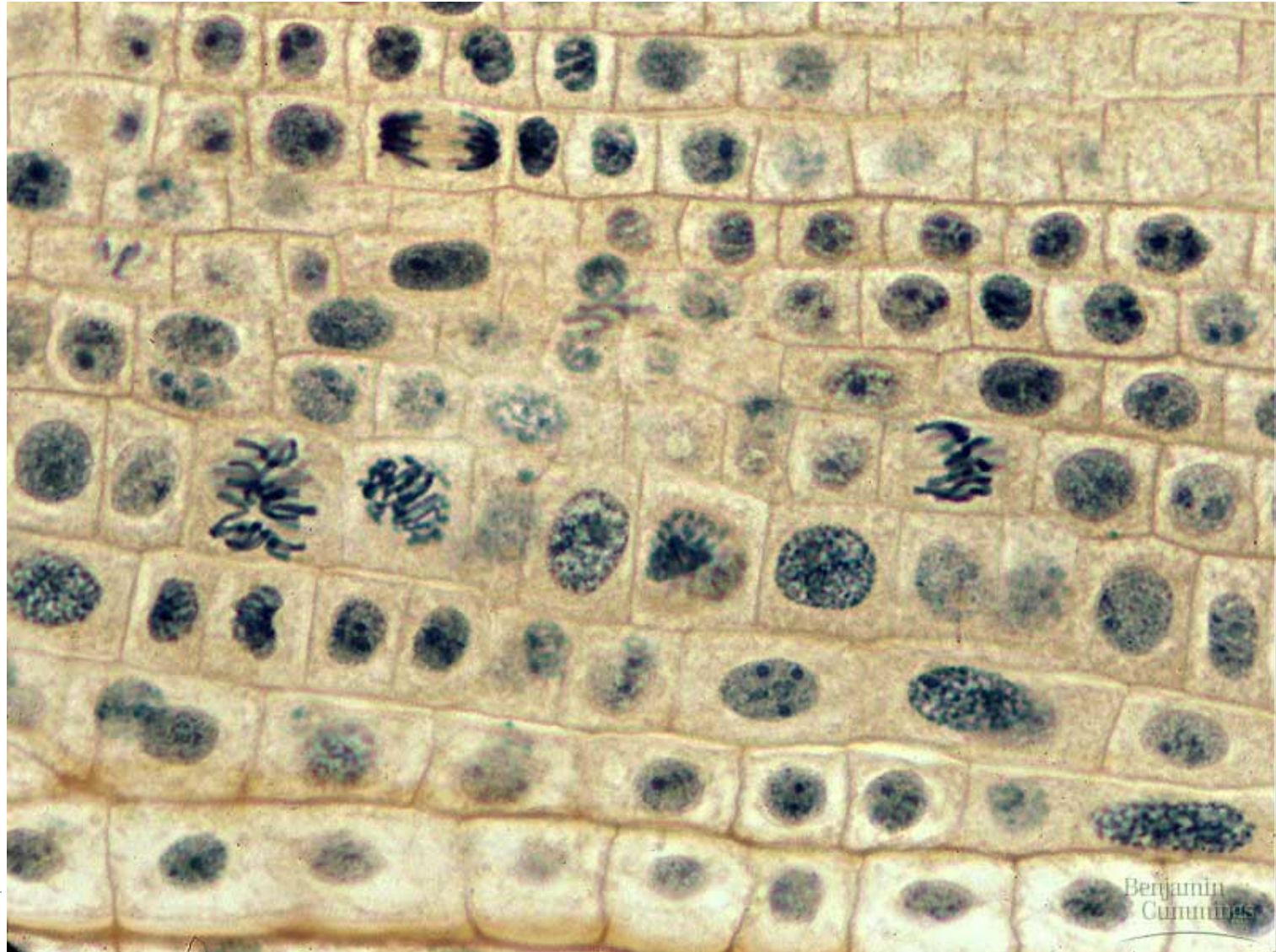


**4** Anaphase



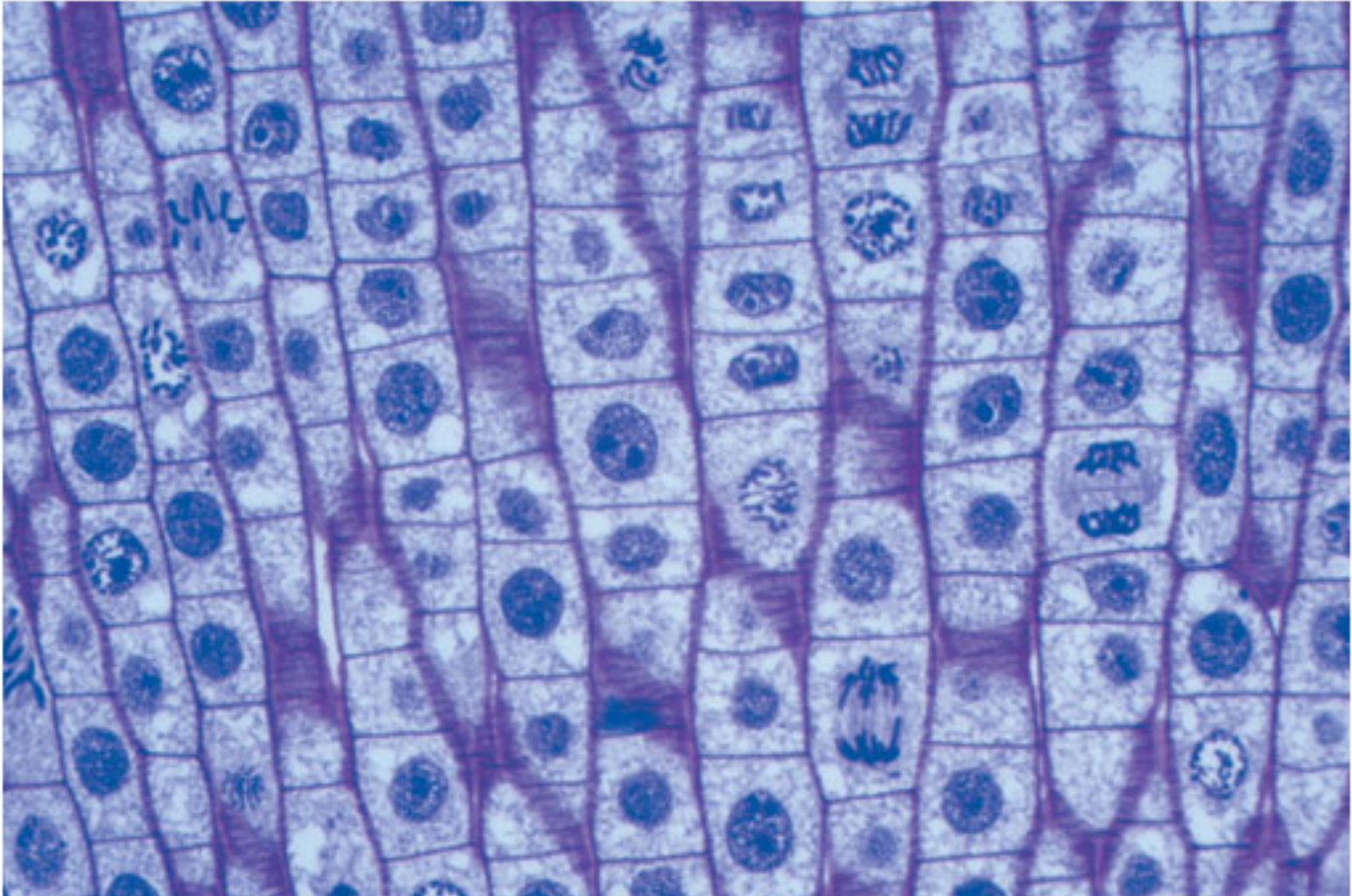
**5** Telophase

Which phases of the cell cycle can you identify?

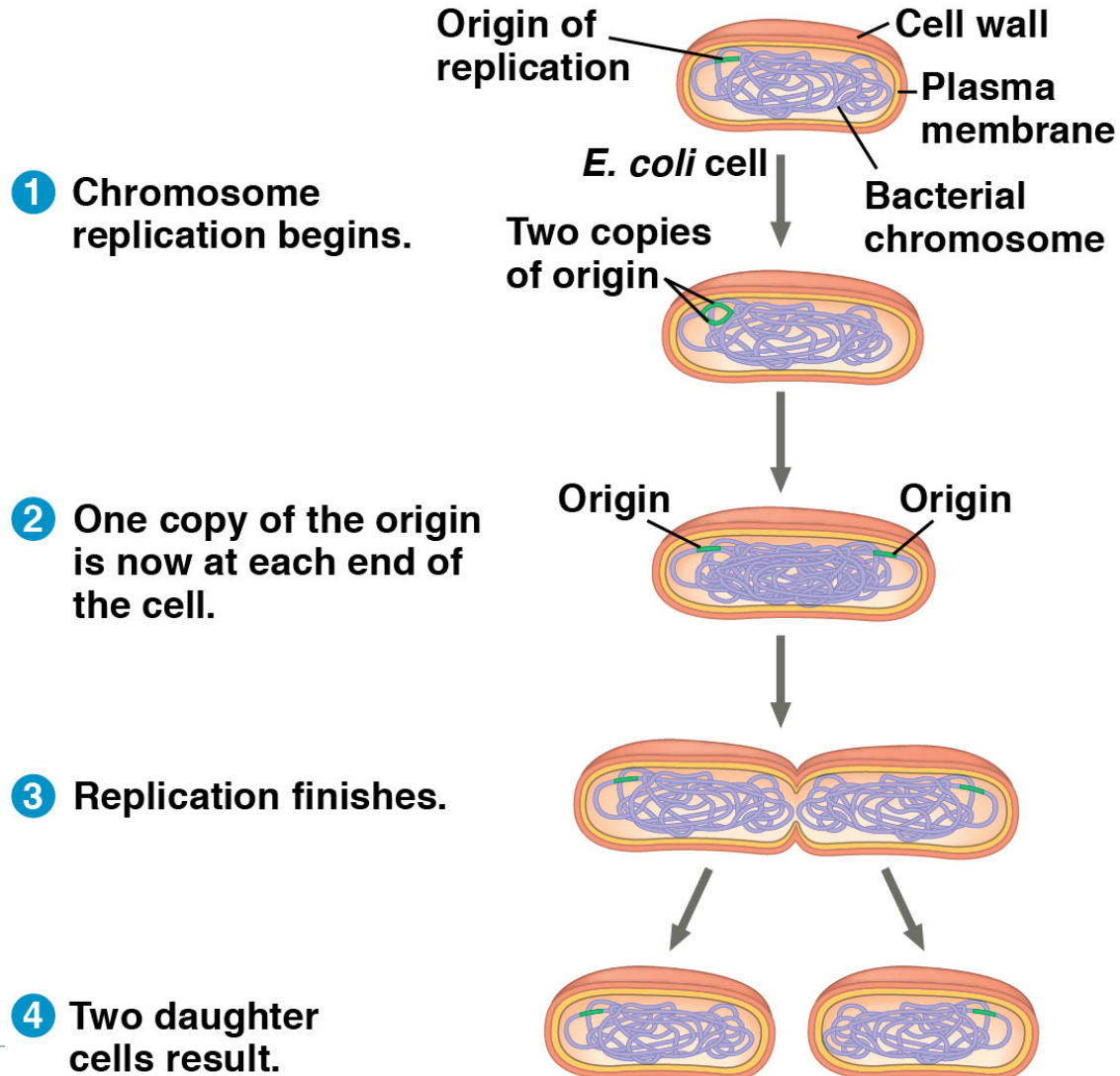


Which phases of the cell cycle can you identify?

---

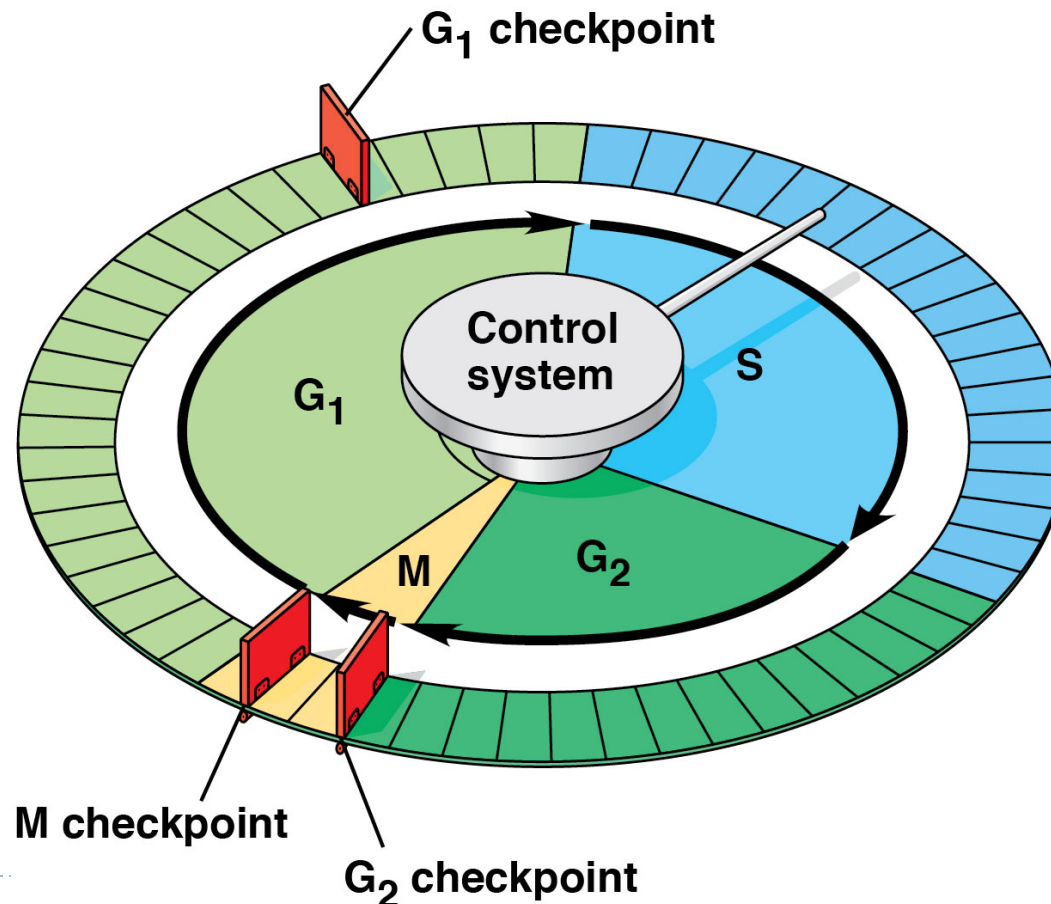


# Bacterial cells divide by **Binary Fission**



# Cell Cycle Control System

- ▶ **Checkpoint** = control point where **stop/go** signals regulate the cell cycle



# Major Checkpoints

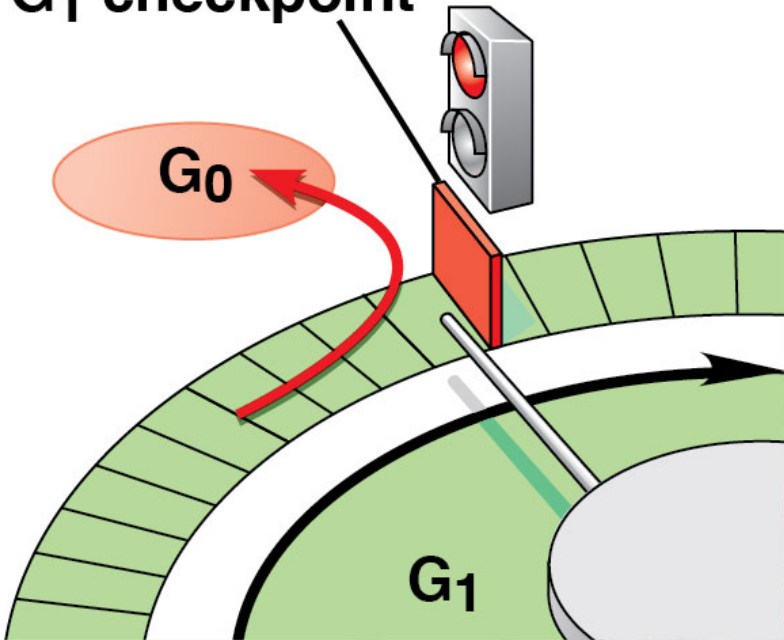
---

1. **G<sub>1</sub> checkpoint** (Most important!)
  - ▶ Controlled by cell size, growth factors, environment
  - ▶ “Go” → completes whole cell cycle
  - ▶ “Stop” → cell enters nondividing state (G<sub>0</sub> Phase)
    - ▶ Nerve, muscle cells stay at G<sub>0</sub>; liver cells called back from G<sub>0</sub>
2. **G<sub>2</sub> checkpoint**
  - ▶ Controlled by DNA replication completion, DNA mutations, cell size
3. **M-spindle (Metaphase) checkpoint**
  - ▶ Check spindle fiber (microtubule) attachment to chromosomes at kinetochores (anchor sites)



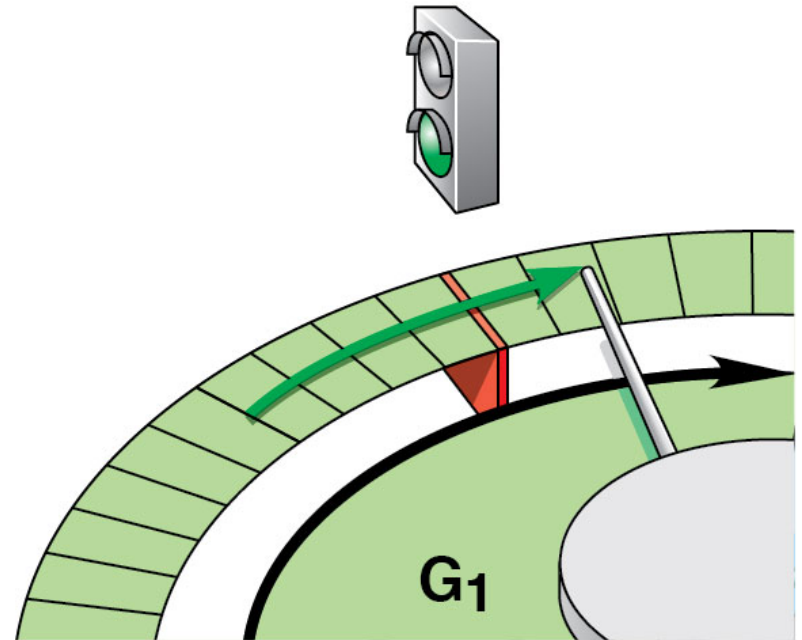
# G<sub>1</sub> Checkpoint

G<sub>1</sub> checkpoint



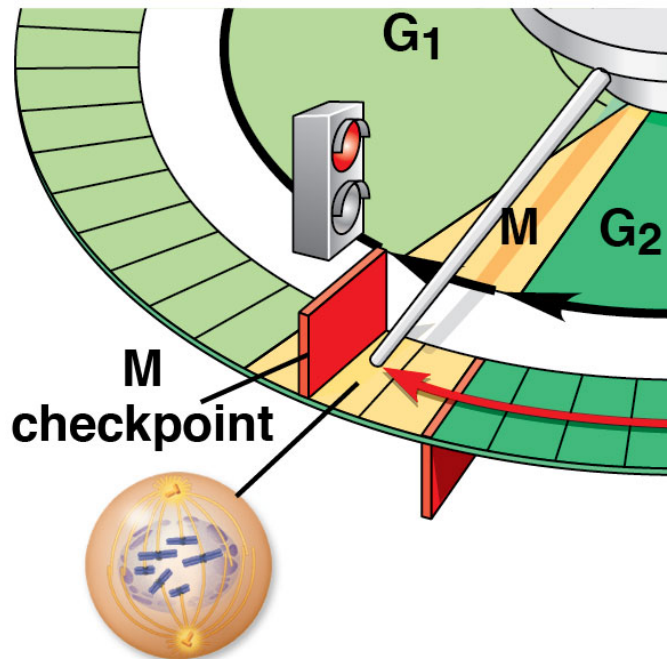
Without go-ahead signal, cell enters G<sub>0</sub>.

(a) G<sub>1</sub> checkpoint



With go-ahead signal, cell continues cell cycle.

# M Checkpoint

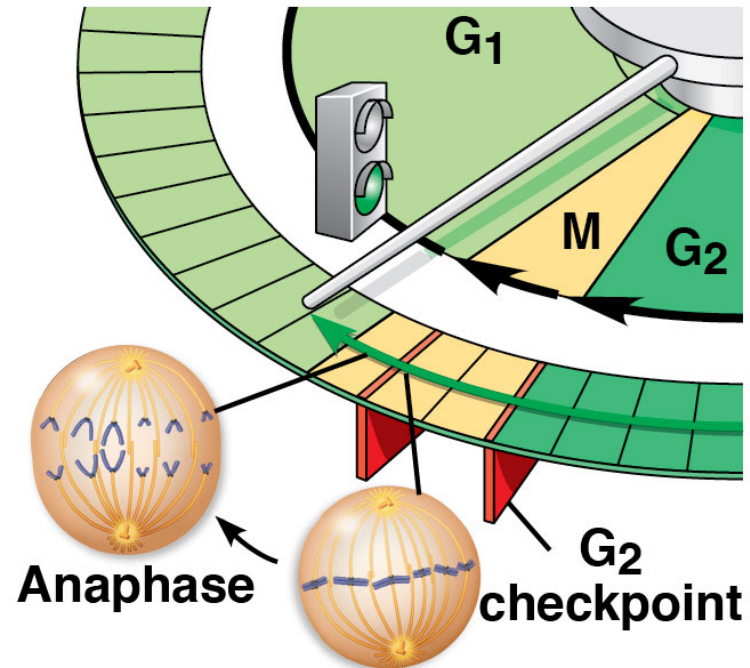


## Prometaphase

Without full chromosome attachment, stop signal is received.

## (b) M checkpoint

© 2016 Pearson Education, Inc.



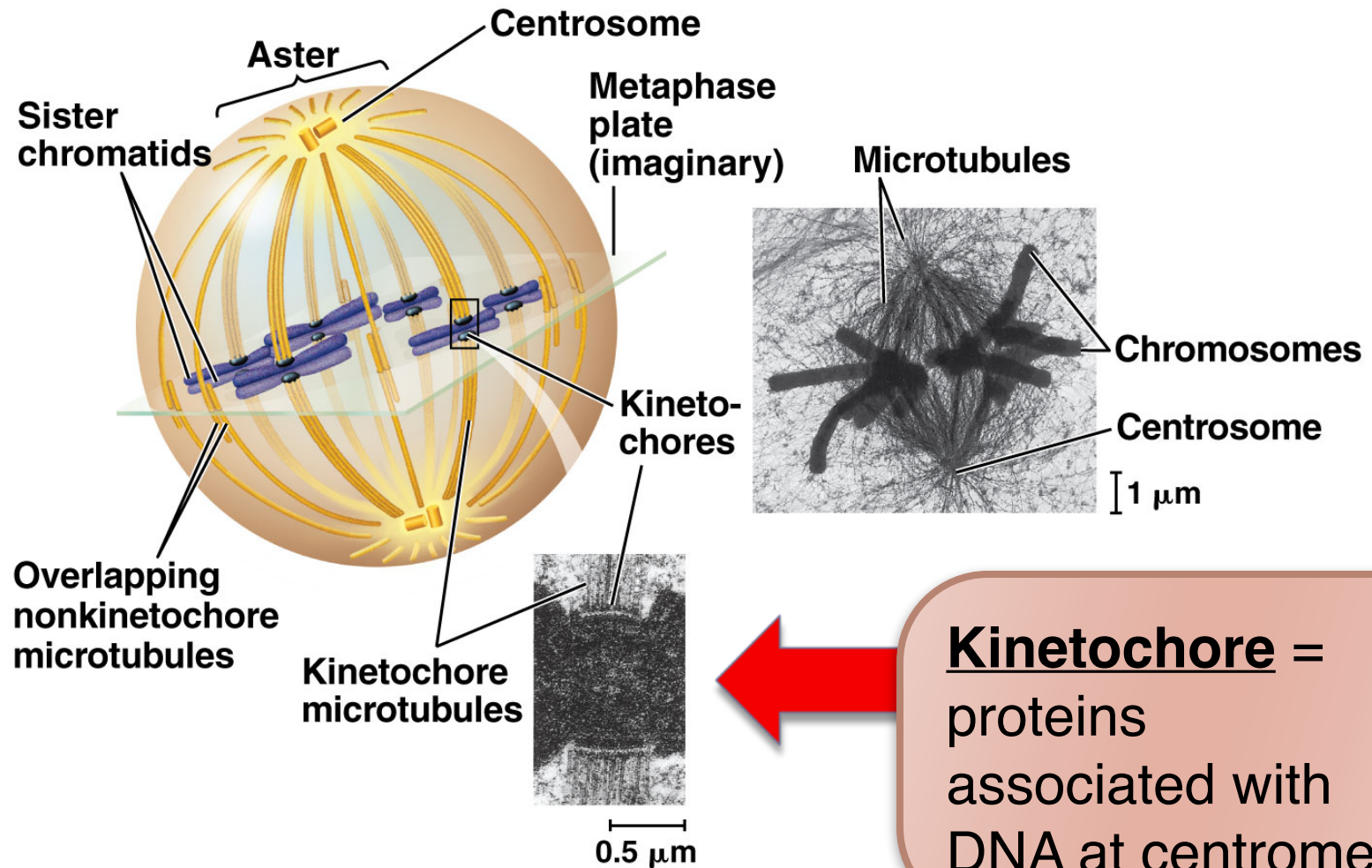
## Metaphase

With full chromosome attachment, go-ahead signal is received.

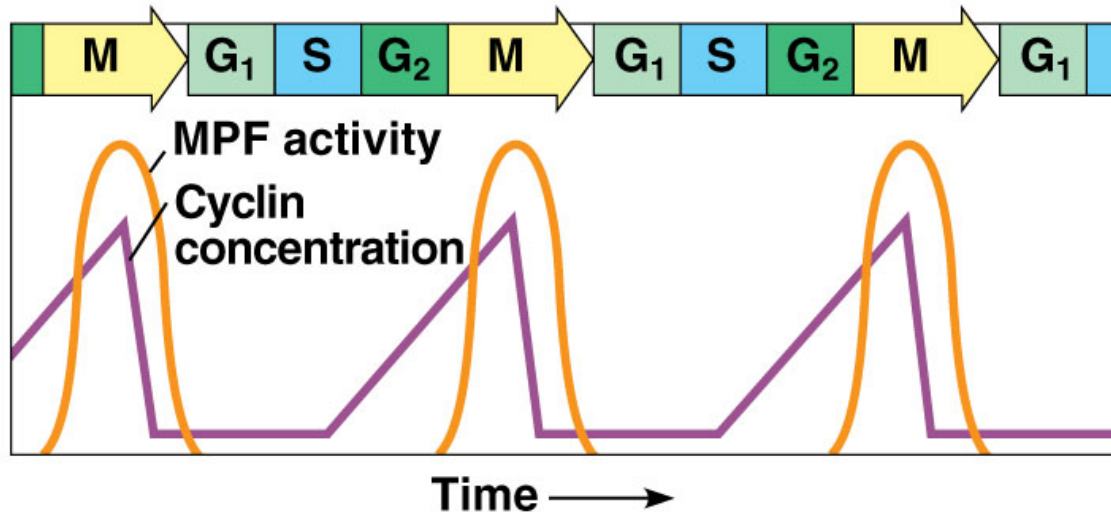




# M-spindle Checkpoint: Mitotic spindle at metaphase



# Internal Regulatory Molecules



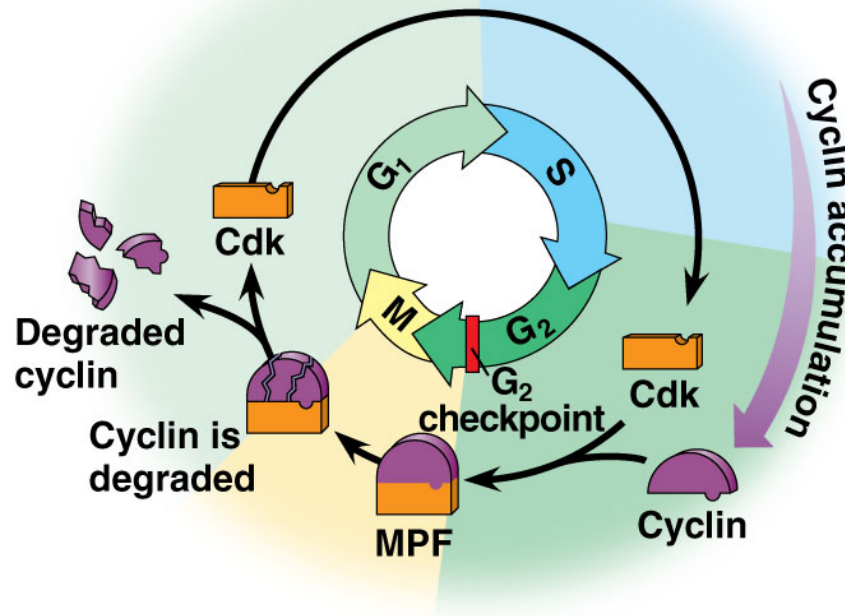
(a) Fluctuation of MPF activity and cyclin concentration during the cell cycle

- **Kinases** (cyclin-dependent kinase, **Cdk**): protein enzyme controls cell cycle; active when connected to **cyclin**
- **Cyclins**: proteins which attach to kinases to activate them; levels fluctuate in the cell cycle

# Internal Regulatory Molecules

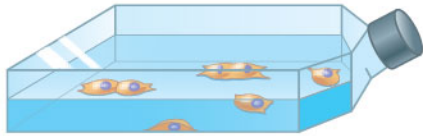
**MPF** = maturation-promoting factor

- specific **cyclin-Cdk complex** which allows cells to pass  $G_2$  and go to M phase

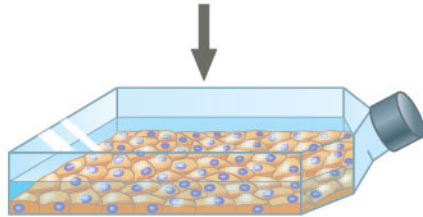


(b) Molecular mechanisms that help regulate the cell cycle

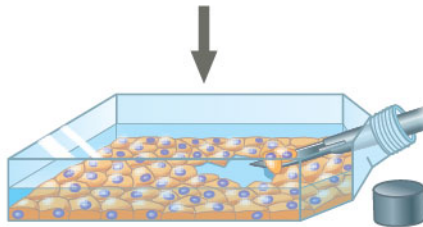
# External Regulatory Factors



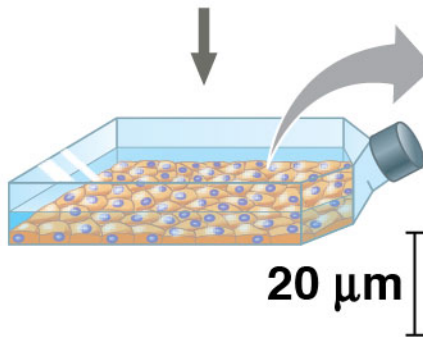
**Anchorage dependence: cells require a surface for division**



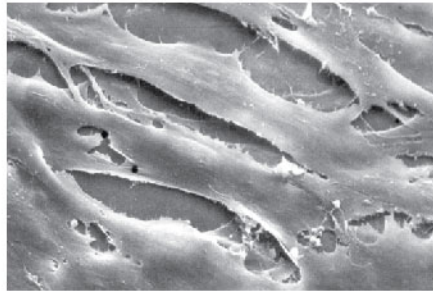
**Density-dependent inhibition: cells form a single layer**



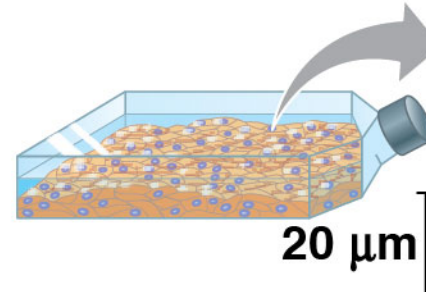
**Density-dependent inhibition: cells divide to fill a gap and then stop**



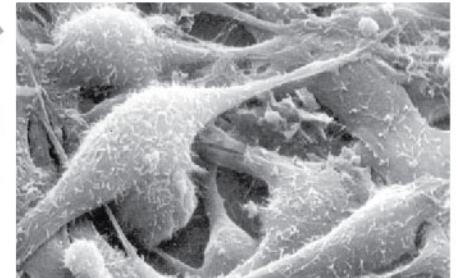
20 µm



**(a) Normal mammalian cells**



20 µm



**(b) Cancer cells**

# External Regulatory Factors

---

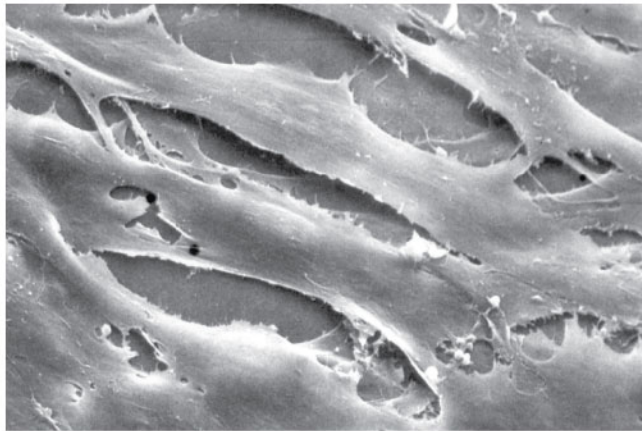
- ▶ Growth Factor: proteins released by other cells to stimulate cell division
- ▶ Density-Dependent Inhibition: crowded cells normally stop dividing; cell-surface protein binds to adjoining cell to inhibit growth
- ▶ Anchorage Dependence: cells must be attached to another cell or ECM (extracellular matrix) to divide



# Cancer Cells

Cancer: Disorder in which cells lose the ability to control growth by not responding to regulation.

- ▶ multistep process of about 5-7 genetic changes (for a human) for a cell to transform
- ▶ loses anchorage dependency and density-dependency regulation



**(a) Normal mammalian cells**

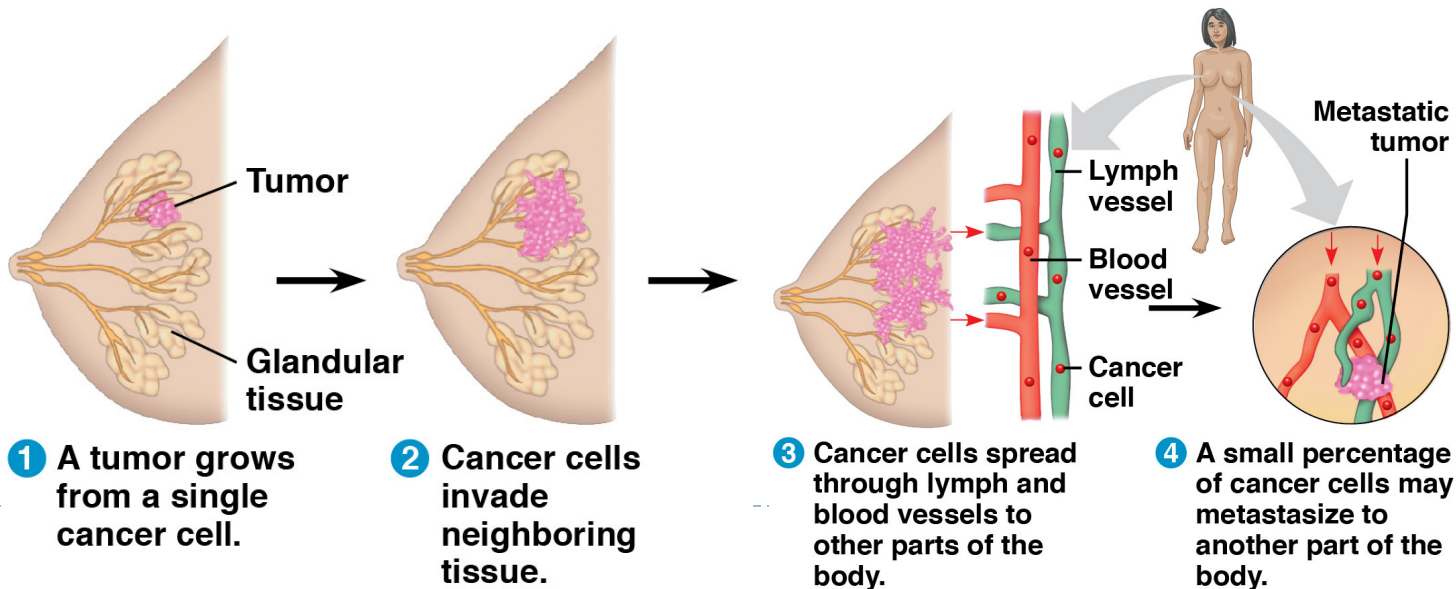


**(b) Cancer cells**

**Transformation:** Process that converts a normal cell to a cancer cell

**Tumors** = mass of abnormal cells

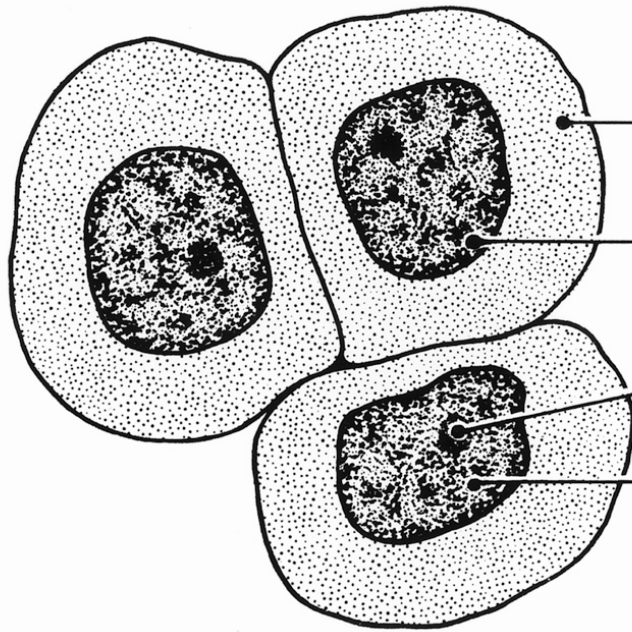
- ▶ **Benign tumor:** lump of cells remain at original site
- ▶ **Malignant tumor:** invasive - impairs functions of 1+ organs (called cancer)
- ▶ **Metastasis:** cells separate from tumor and travel to other parts of body



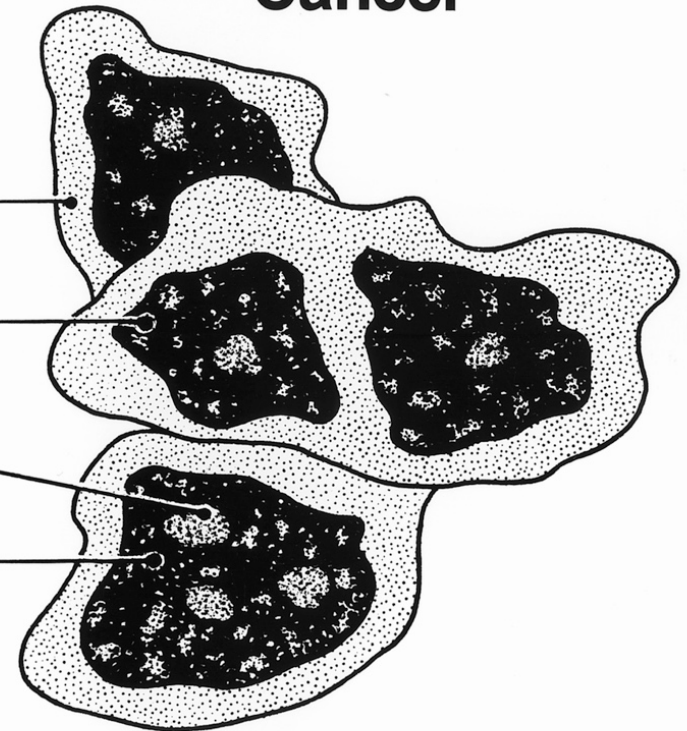
# Normal and Cancer Cells Structure

---

## Normal



## Cancer



Cytoplasm

Nucleus

Nucleolus

Chromatin

- Large cytoplasm
- Single nucleus
- Single nucleolus
- Fine chromatin

- Small cytoplasm
- Multiple nuclei
- Multiple and large nucleoli
- Coarse chromatin



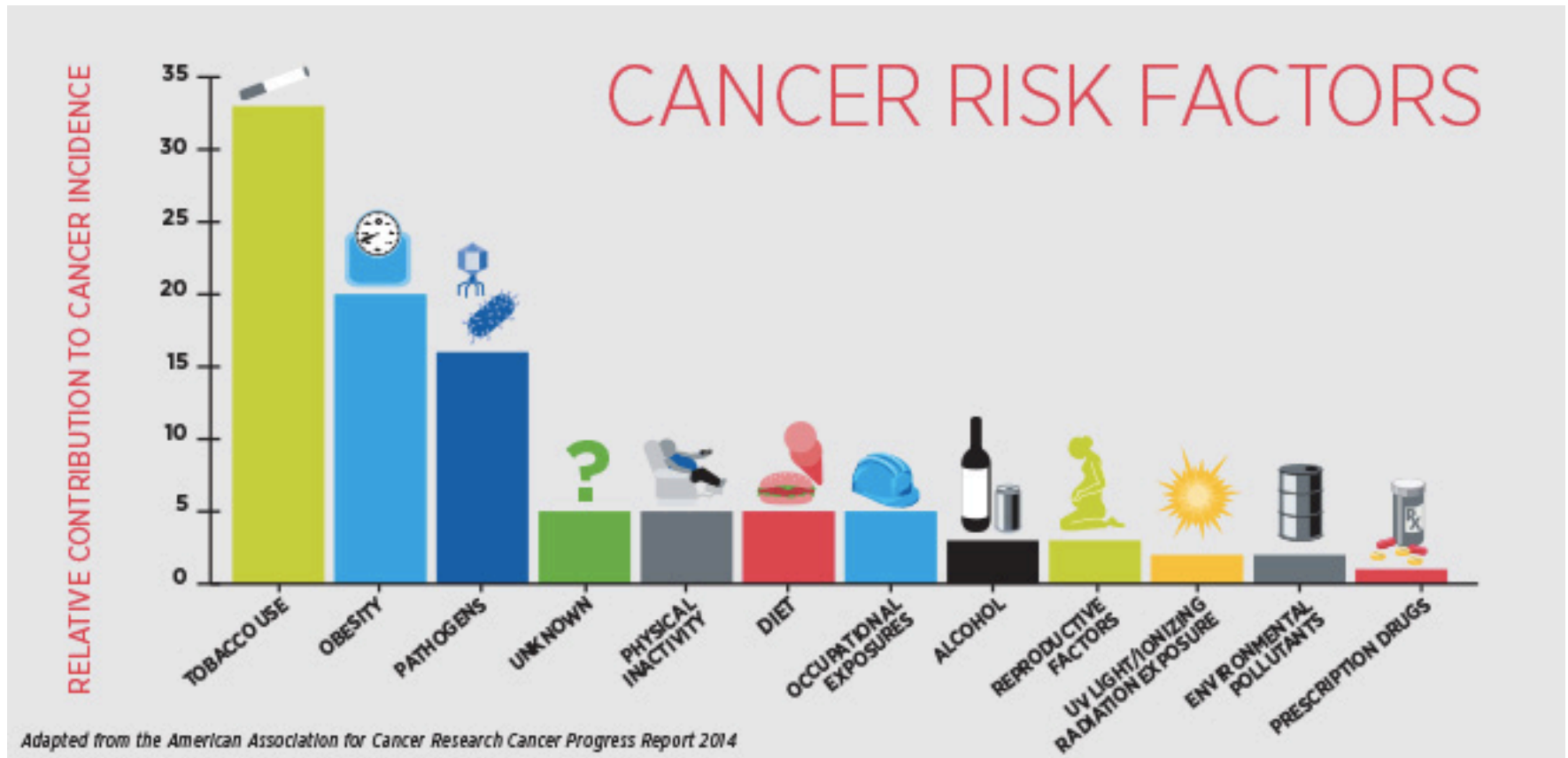
# Cancer Cells

- ▶ Some have abnormal #'s of chromosomes
- ▶ Metabolism disabled
- ▶ Lose attachment to ECM → spread to other tissues
- ▶ Signaling molecules cause blood vessels to grow toward tumor

## Treatment:

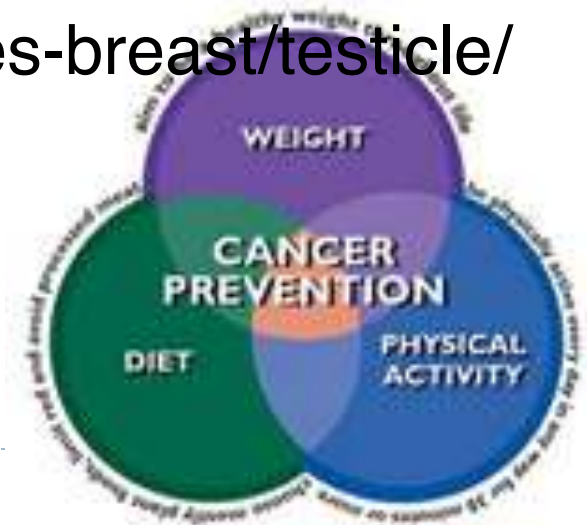
- ▶ Surgery, radiation, chemotherapy
- ▶ Personalized Medicine:
  - ▶ Breast Cancer: 20-25% tumors show high HER2 receptors → use Herceptin to block HER2 protein

# Cancer Risk Factors



Anyone can get cancer but there are ways to **minimize** risk:

- ▶ Don't smoke, legal or illegal (includes hookahs, chew, 2<sup>nd</sup>-hand smoke)
- ▶ Use sun protection
- ▶ Exercise and keep weight at ideal level
- ▶ Eat 5-7 servings of fruit and veggies **a day**
- ▶ Use screening/preventative measures-breast/testicle/mole checks
- ▶ Practice abstinence or use condoms
- ▶ Vaccines (eg. HPV)





 American Institute for Cancer Research

**10 CANCER PREVENTION RECOMMENDATIONS**

 <b>MAINTAIN A HEALTHY WEIGHT</b>	 <b>MOVE MORE</b>	 <b>EAT WELL</b>	 <b>ENJOY A PLANT BASED DIET</b>
 <b>REDUCE RED MEAT, AVOID PROCESSED MEAT</b>	 <b>CUT DOWN ON ALCOHOL</b>	 <b>EAT LESS SALT</b>	
 <b>AFTER TREATMENT, CANCER SURVIVORS SHOULD FOLLOW THE CANCER PREVENTION RECOMMENDATIONS</b>	 <b>IF YOU CAN, BREASTFEED YOUR BABY</b>	 <b>FOR CANCER PREVENTION DON'T USE SUPPLEMENTS</b>	 <b>aicr.org</b> f     Bleg

*And always remember – do not smoke or chew tobacco.*

**CANCER PREVENTION**  
Together We Can™

# Summary of the Cell Cycle

