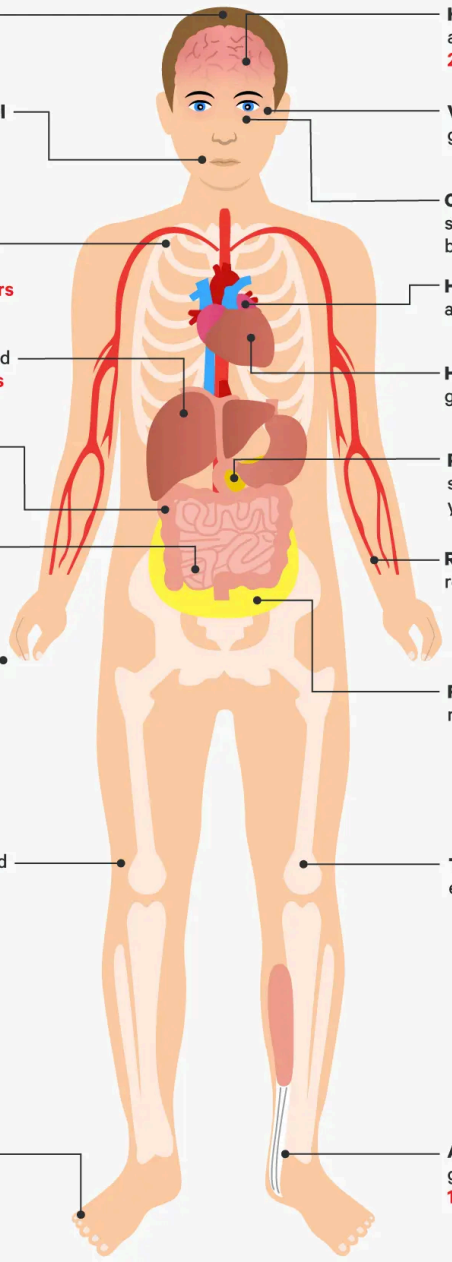
Chapter 9: The Cell Cycle

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



Head hair grows **0.35 mm/day**

Wisdom tooth enamel stops growing when you're **12 years old**

Intercostal skeletal muscle cells are replaced every **15 years**

Liver cells are replaced every **300 to 500 days**

Intestinal epithelial cells are replaced every **5 days**

Internal intestinal cells are replaced every **16 years**

Fingernails grow **0.1 mm/day**

Skin cells are replaced every **39 days**

Toenails grow **1 mm/month**

Hippocampal neurons are replaced every **20 to 30 years**

Visual cortex stops growing when **you're born**

Cerebellum grey matter stops growing when you're between **2.5 and 3 years old**

Heart endothelial cells are replaced every **6 years**

Heart muscle cells stop growing at **10 years old**

Pancreatic beta cells stop growing when you're **30 years old**

Red blood cells are replaced every **120 days**

Fat storage cells are replaced every **10 years**

The skeleton is replaced every **10 years**

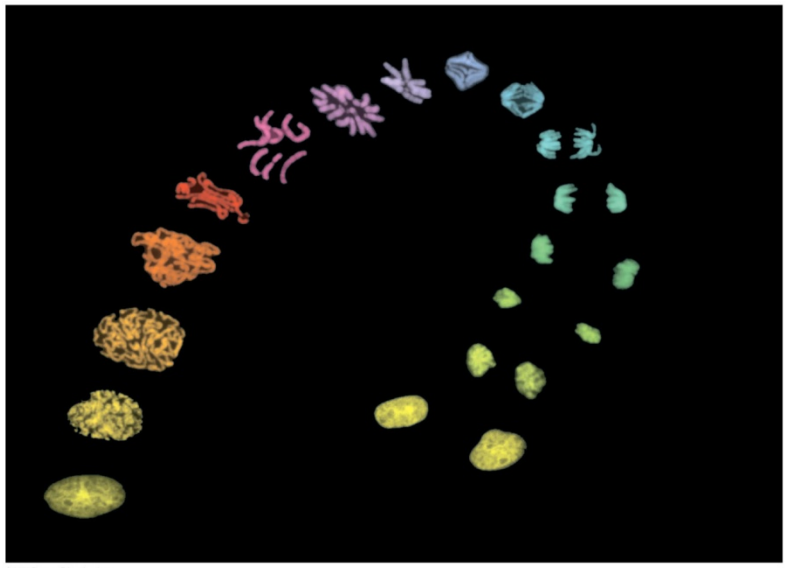
Achilles tendon stops growing when you're **17 years old**

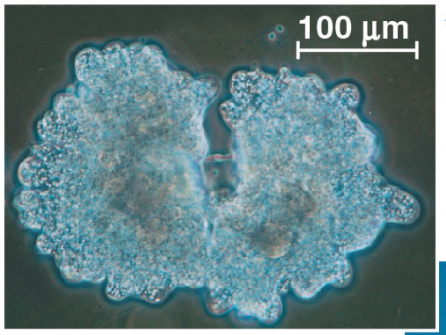
SOURCES: Journal of Investigative Dermatology, Journal of Biological Chemistry, New York Times, Nature, PBS, American Academy of Dermatology, Textbook of Clinical Pediatrics, FASEB Journal, Journal of Clinical Endocrinology & Metabolism

TECH INSIDER

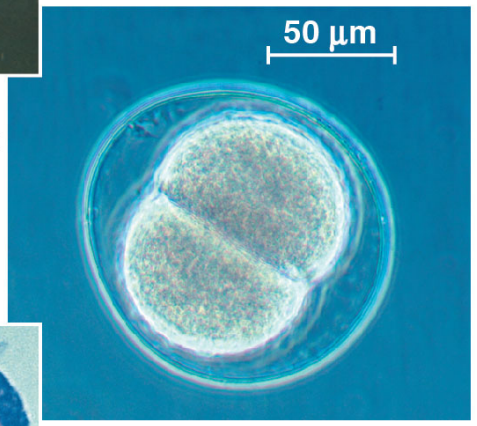
Cell Cycle: life of a cell from its formation until it divides into two cells

Functions of Cell Division: Reproduction, Growth and Tissue Repair

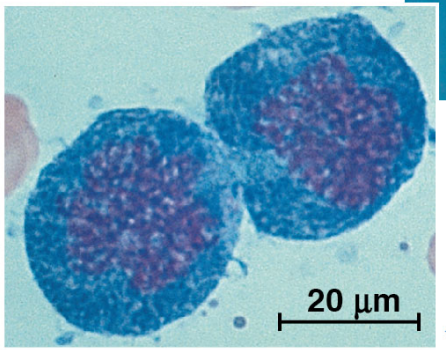




◀ (a) Reproduction



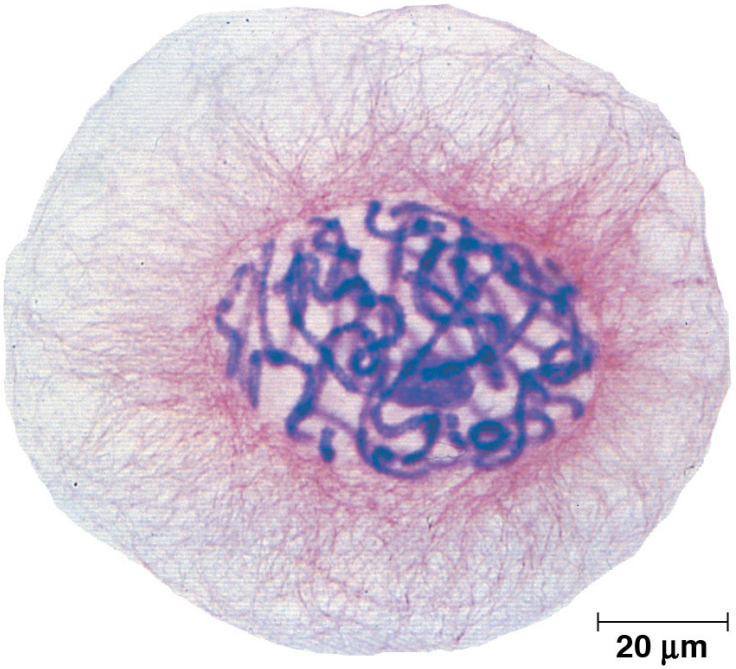
▶ (b) Growth and development



◀ (c) Tissue renewal

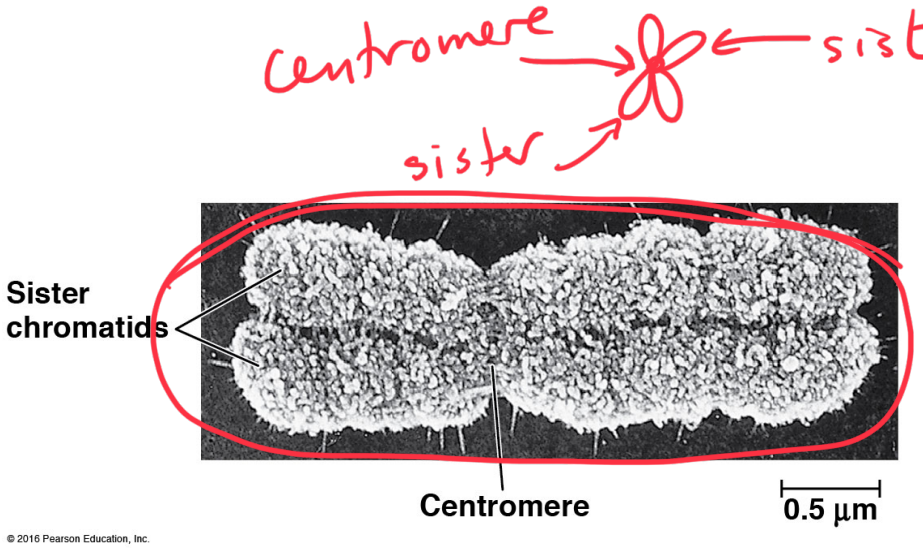
Genome = all of a cell's genetic info (DNA)

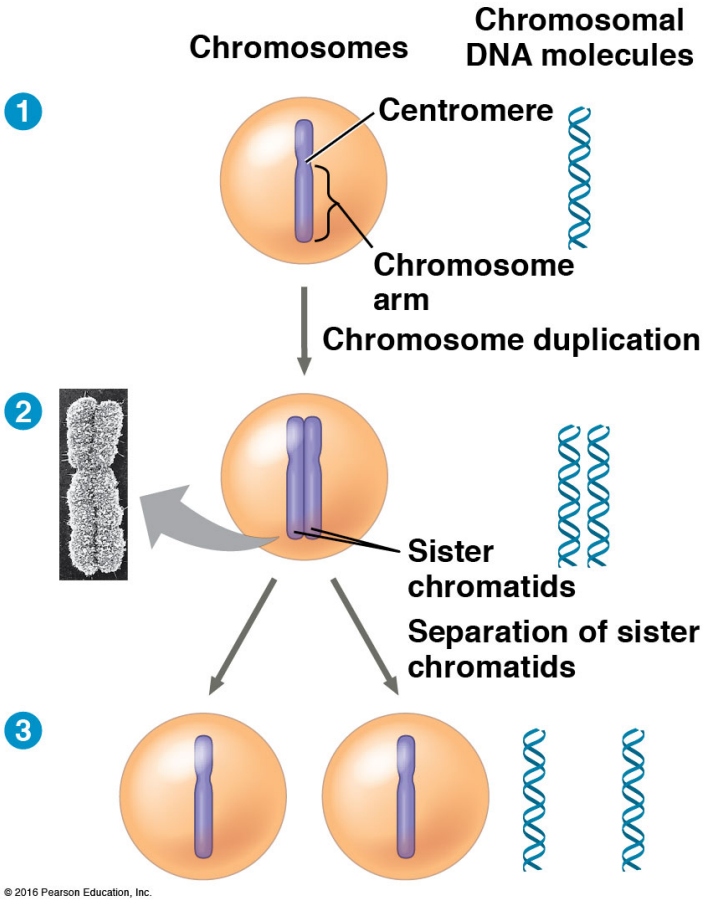
- Prokaryote: single, circular chromosome
- Eukaryote: more than one linear chromosomes
  - Eg. Human:46 chromosomes, mouse: 40, fruit fly: 8



Each chromosome must be duplicated (replicated) before cell division

- Duplicated chromosome = 2 sister chromatids attached by a centromere





Somatic Cells

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

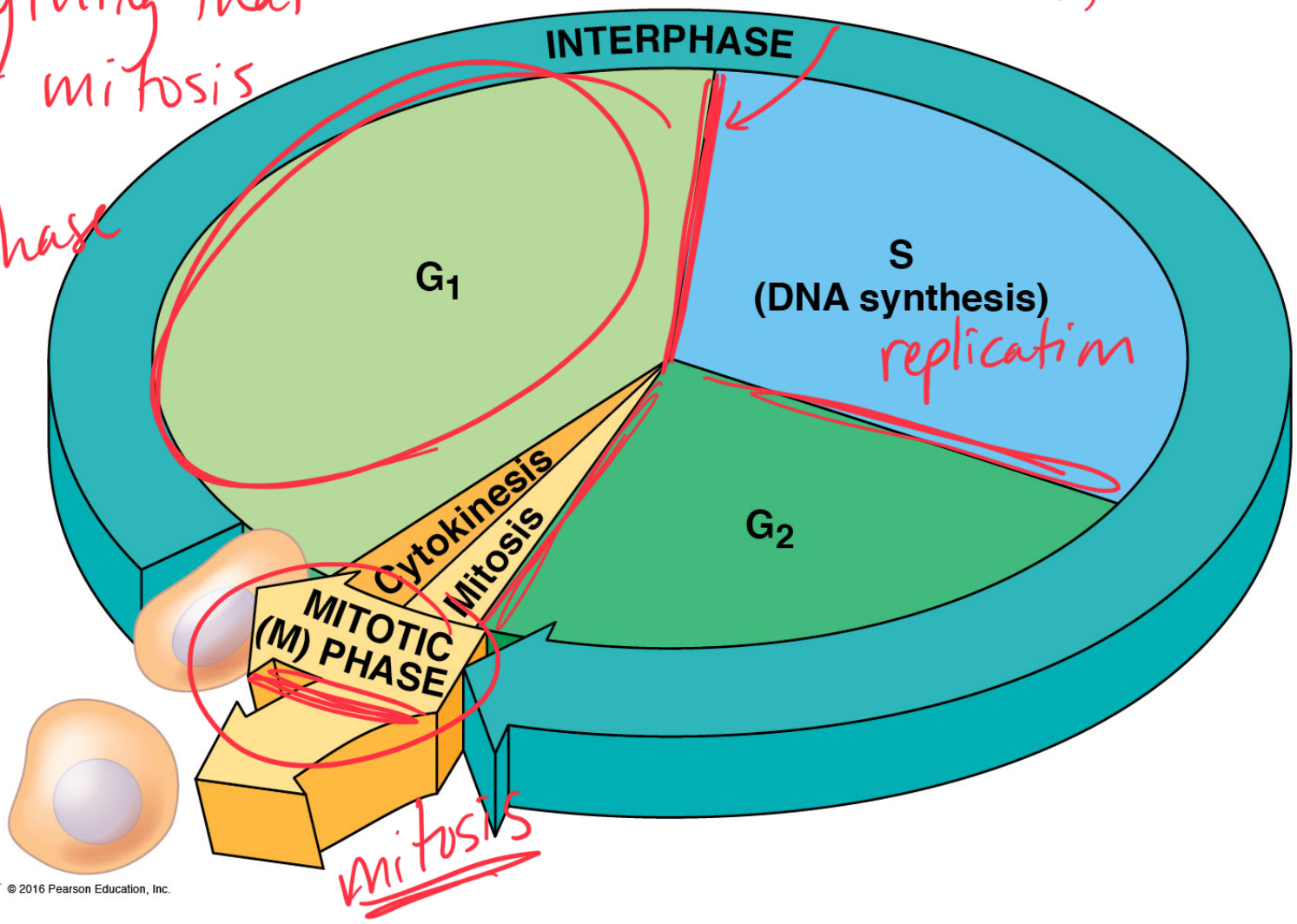
Gametes

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

Phases of the Cell Cycle

Understand the idea

Everything that isn't mitosis is interphase



Phases of the Cell Cycle

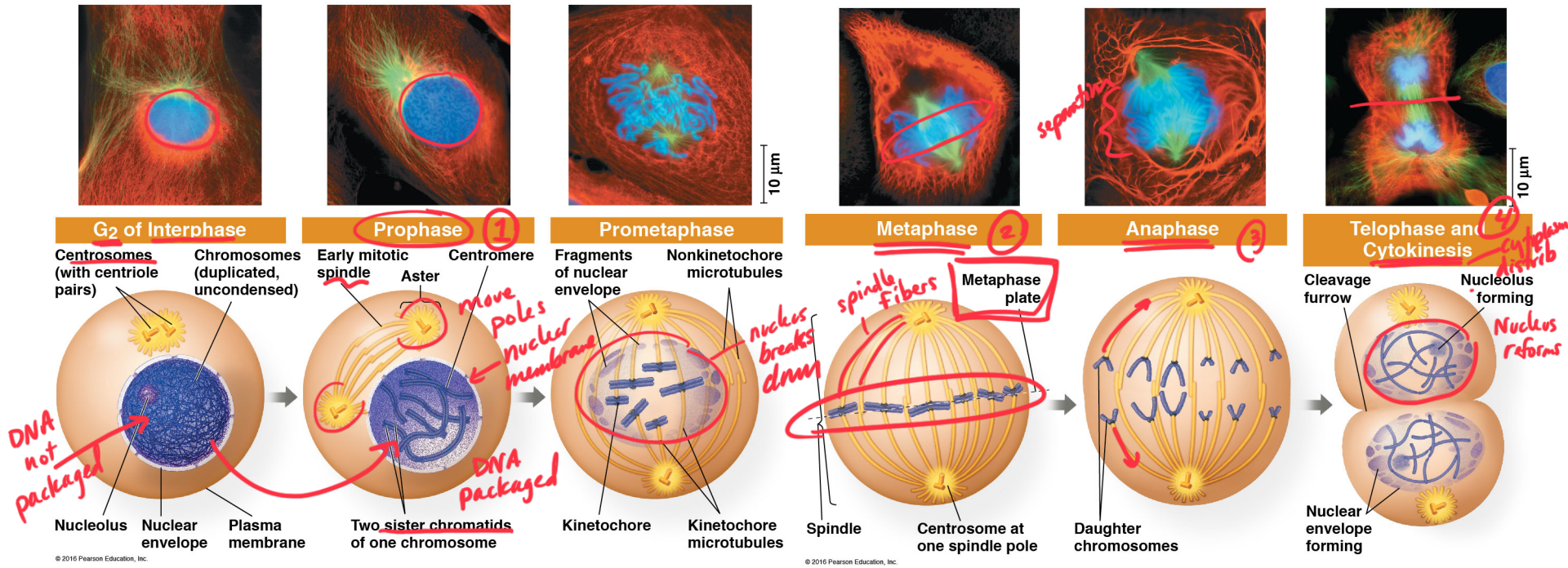
- The *mitotic* phase alternates with *interphase*:

  G_1 → S → G_2 → mitosis → cytokinesis

- Interphase (90% of cell cycle)
- G_1 Phase: cell grows and carries out normal functions
- S Phase: duplicates chromosomes (DNA replication)
- G_2 Phase: prepares for cell division
- M Phase (mitotic)
- Mitosis: nucleus divides
- Cytokinesis: cytoplasm divides

Mitosis: Prophase → Metaphase → Anaphase → Telophase

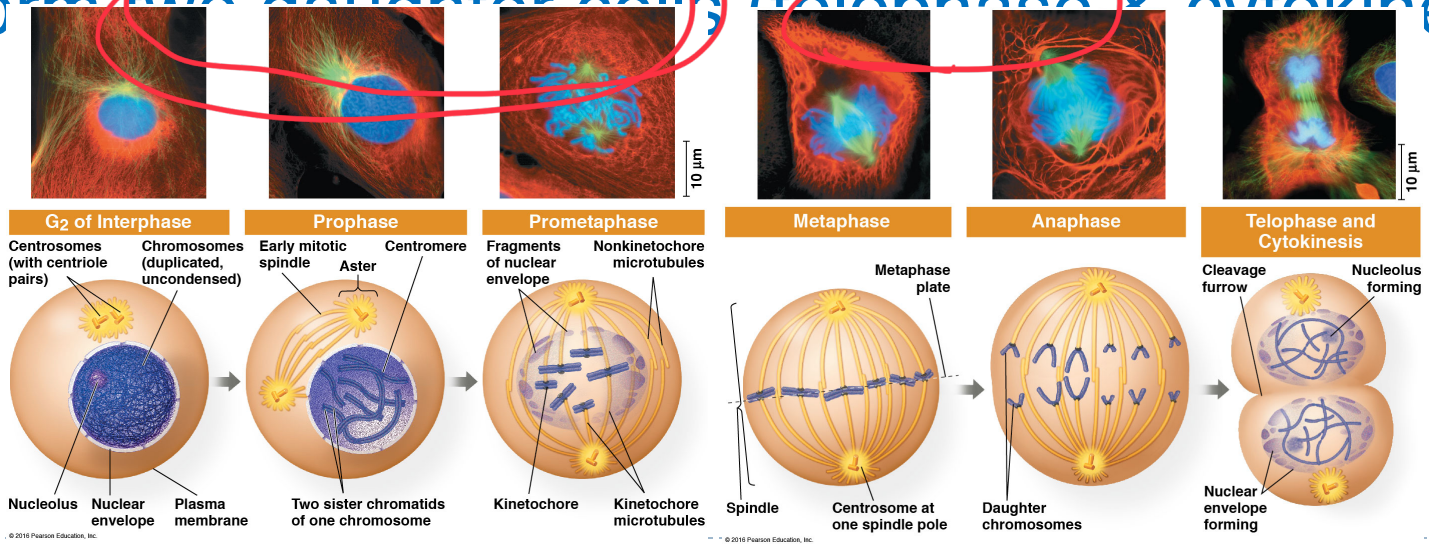
PMAT



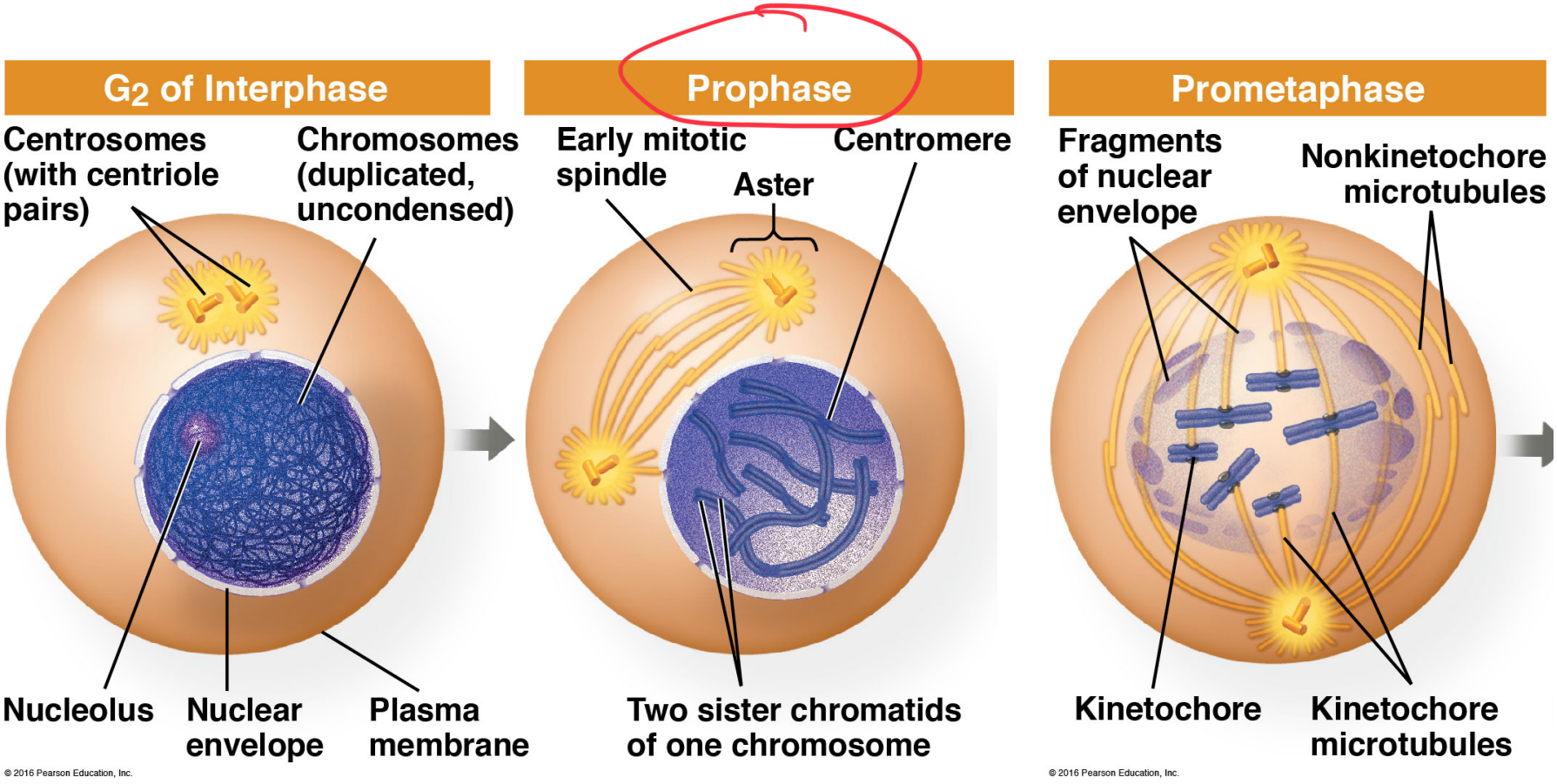
Mitosis

Good Summary

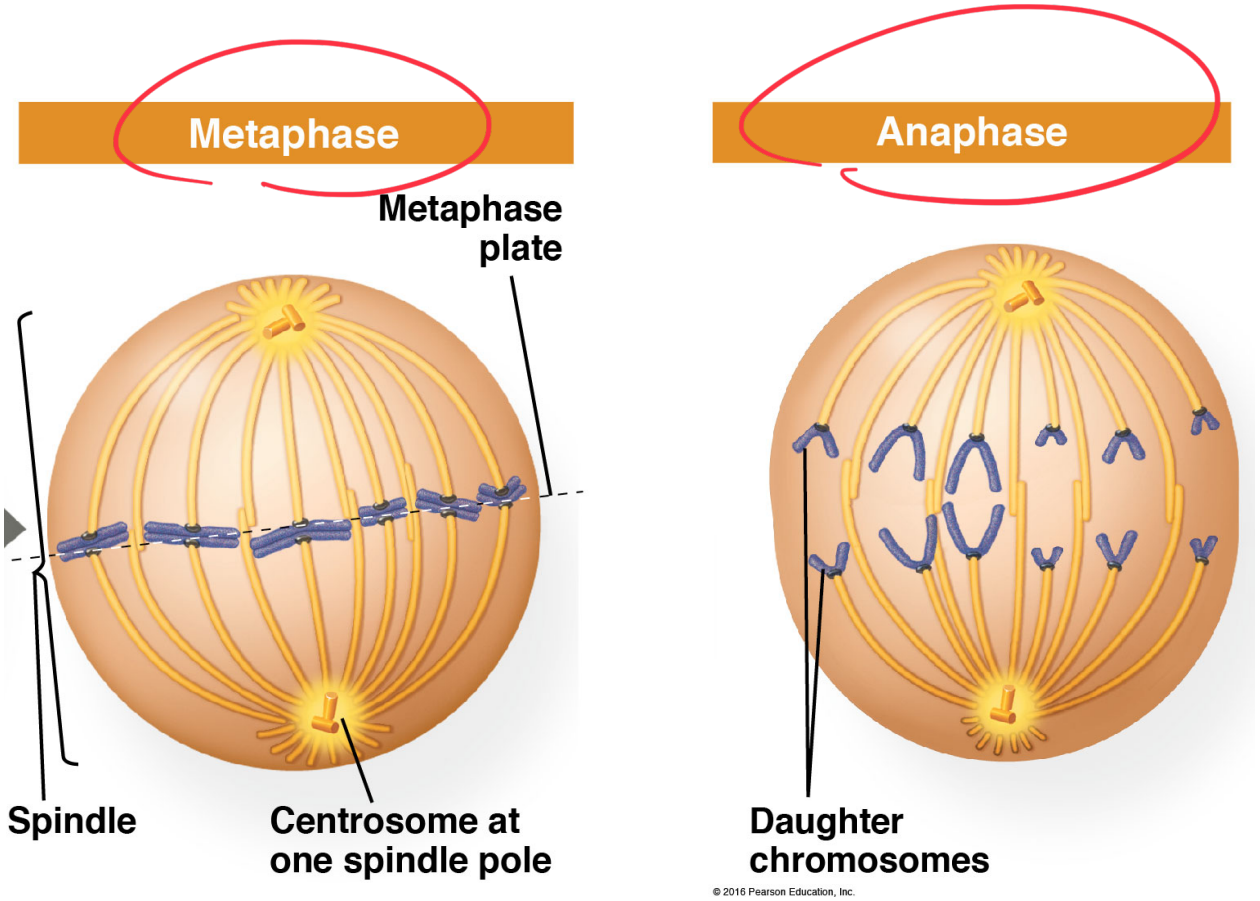
- Continuous process with observable structural features:
  - Chromosomes become visible (prophase)
  - Alignment at the equator (metaphase)
  - Separation of sister chromatids (anaphase)
  - Form two daughter cells (telophase & cytokinesis)



Prophase & Prometaphase



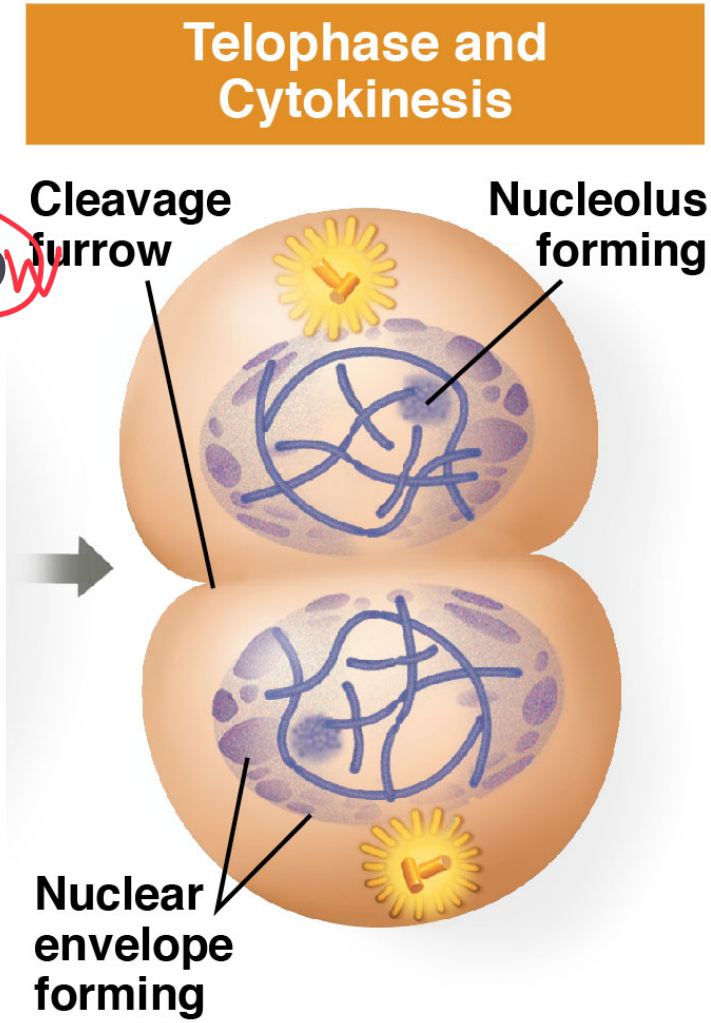
Metaphase & Anaphase



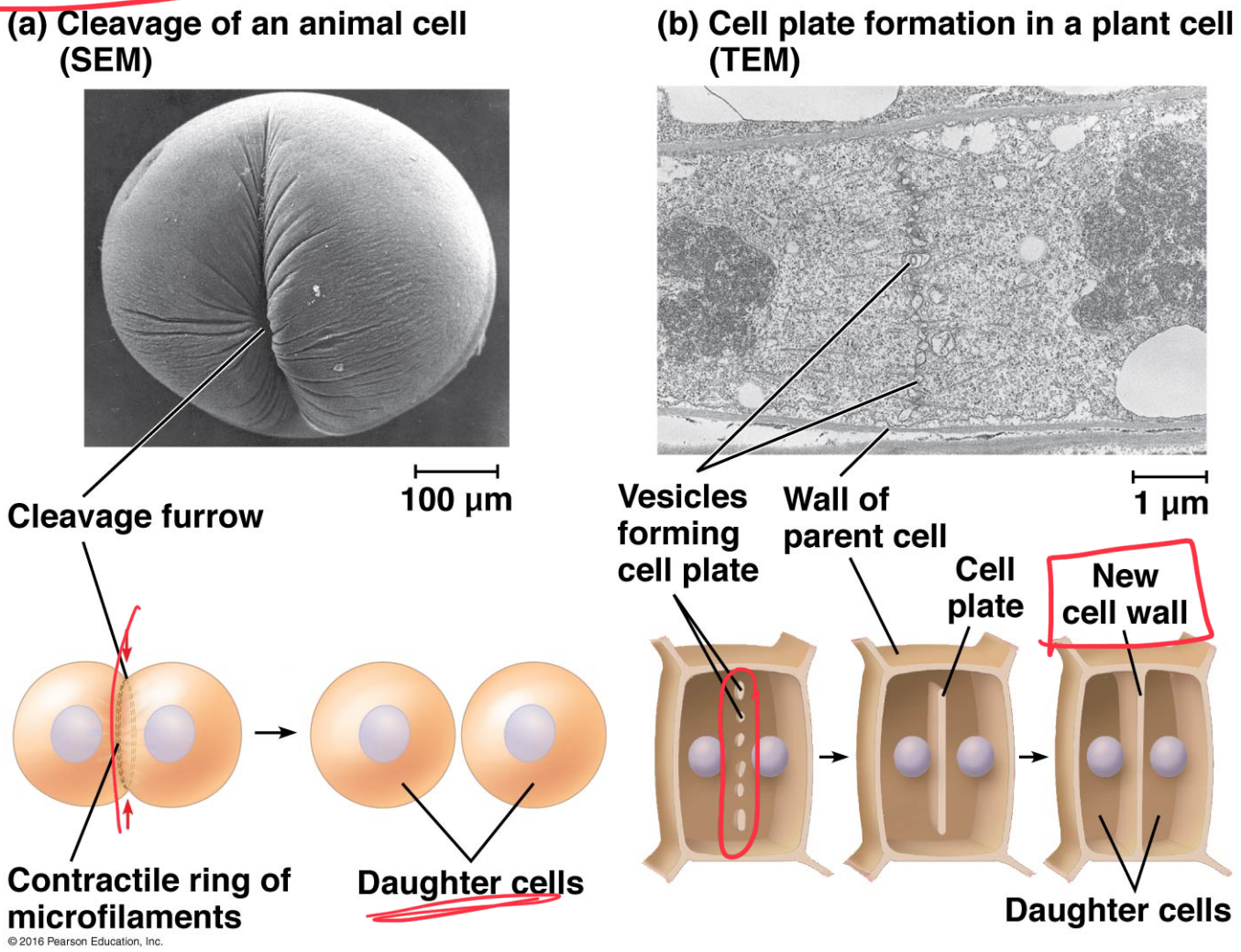
Telophase & Cytokinesis

Cytokinesis

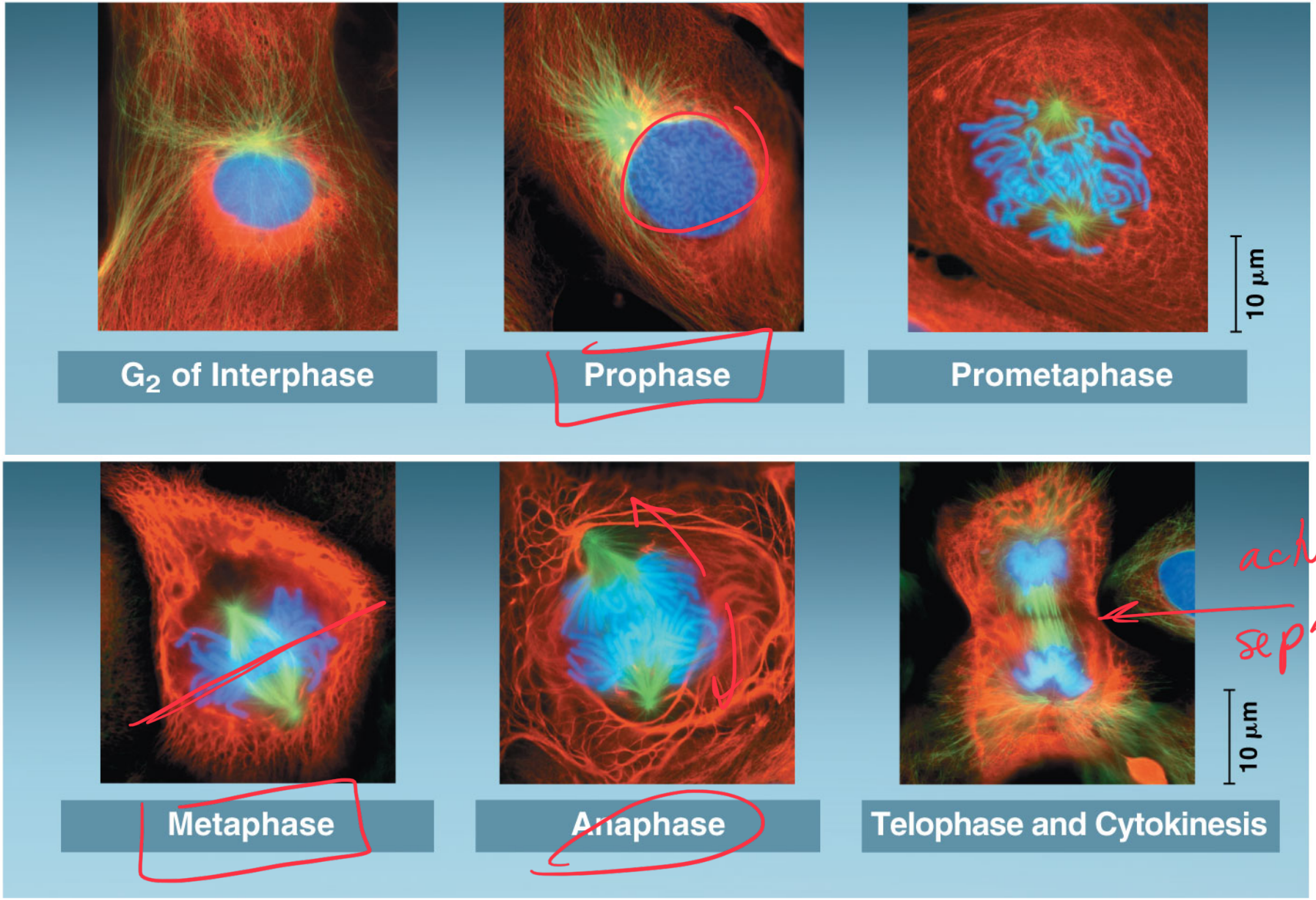
- Cytoplasm of cell divided
- ***Animal Cells***: cleavage furrow
- ***Plant Cells***: cell plate forms



Cytokinesis in Animal vs. Plant Cells

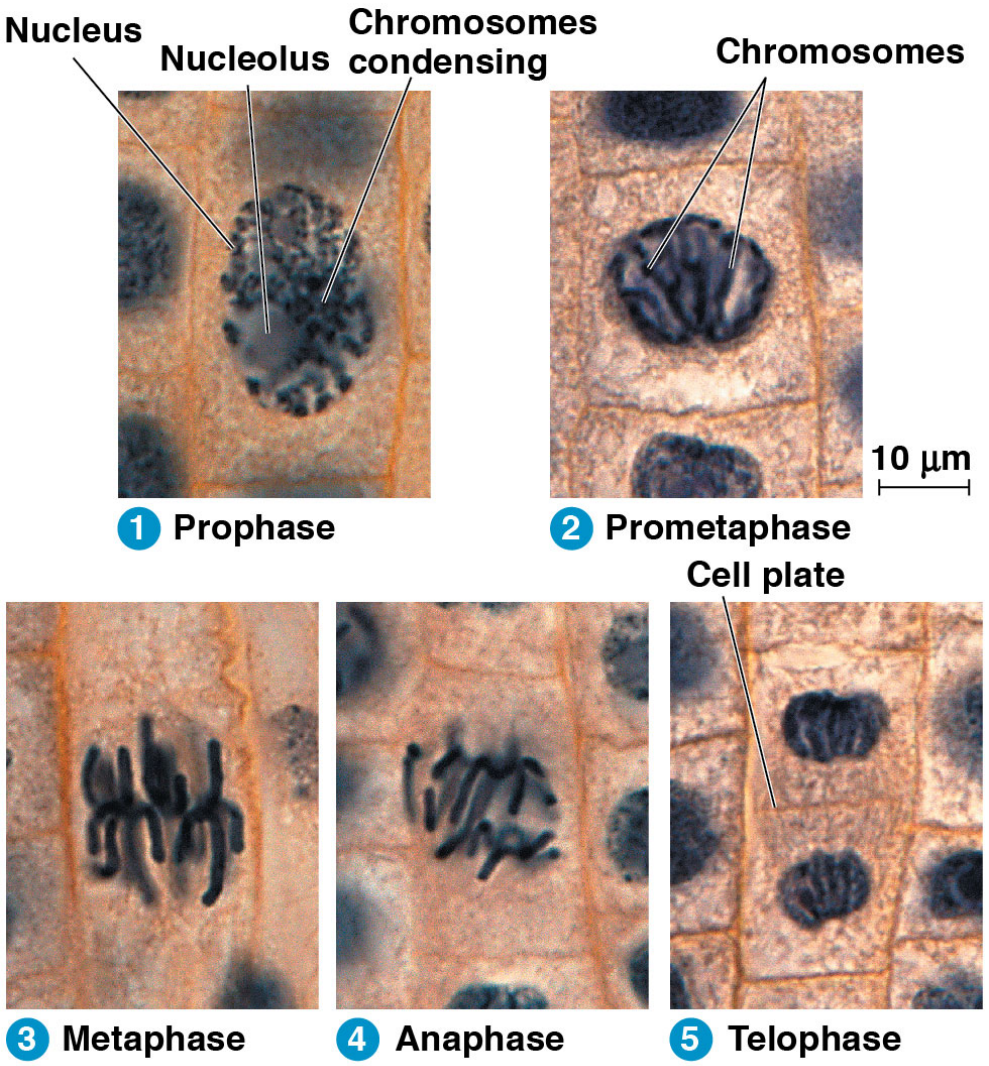


Animal Cell Division

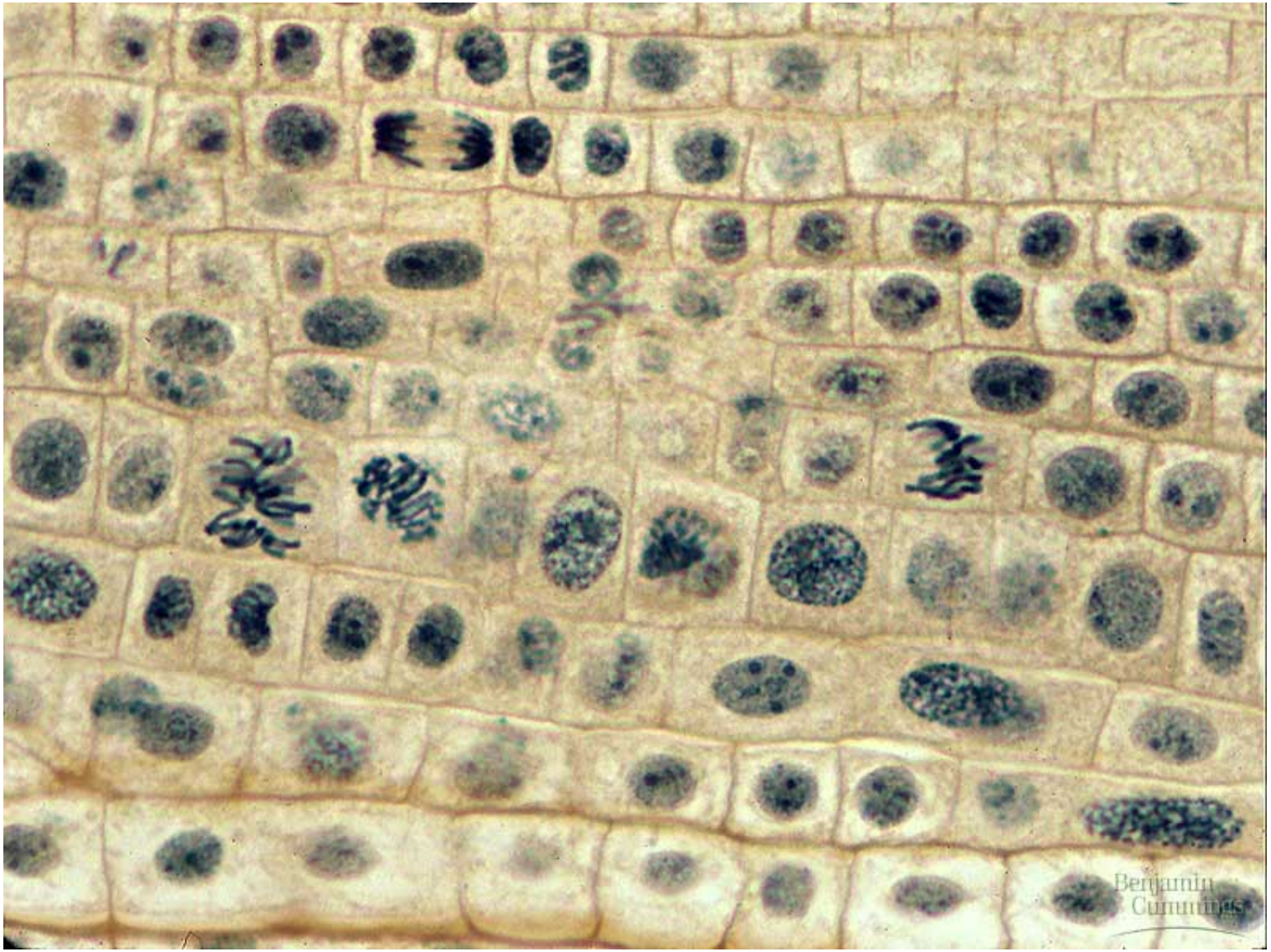


Plant Cell Division

Look at



Which phases of the cell cycle can you identify?



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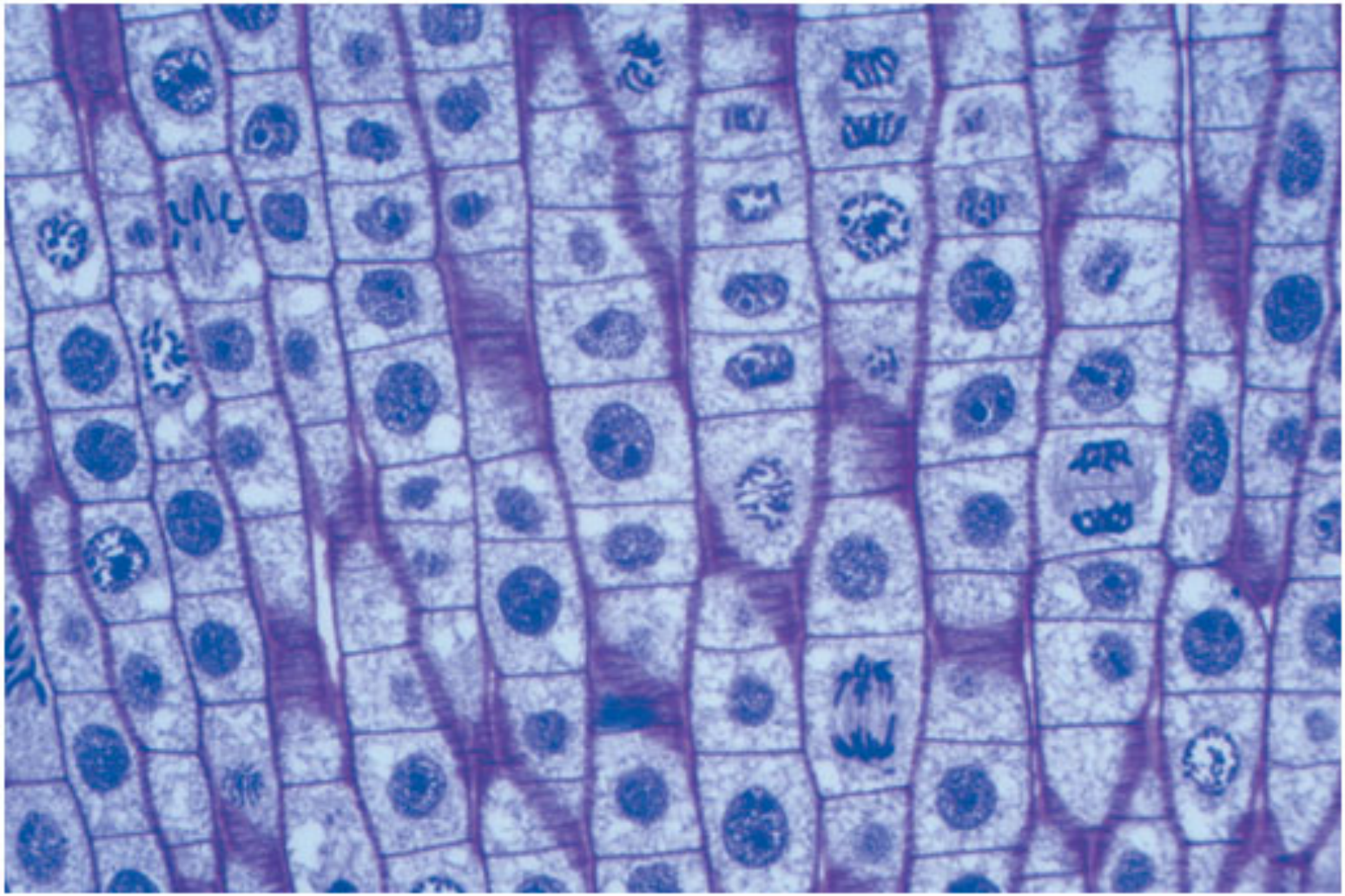
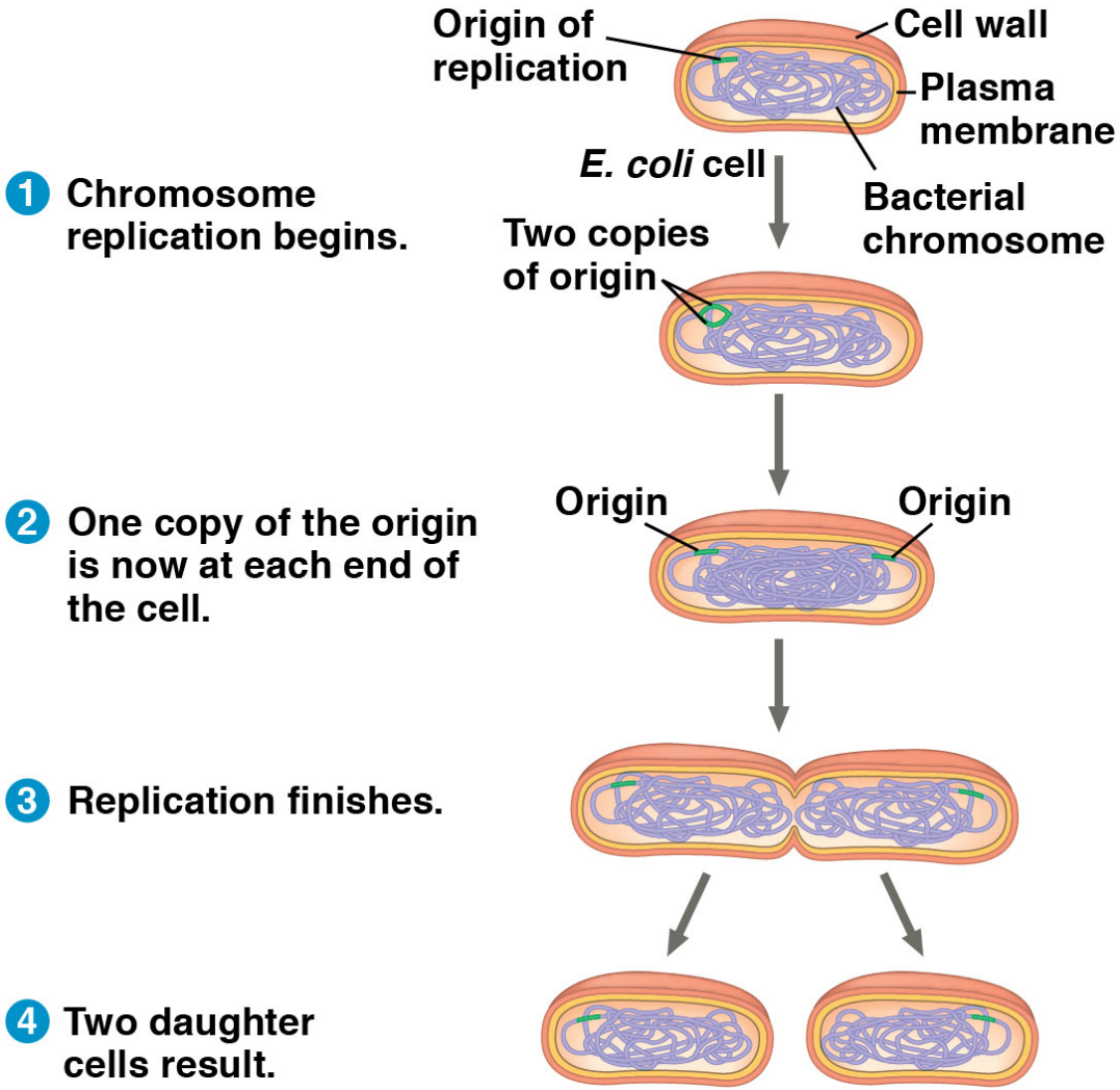
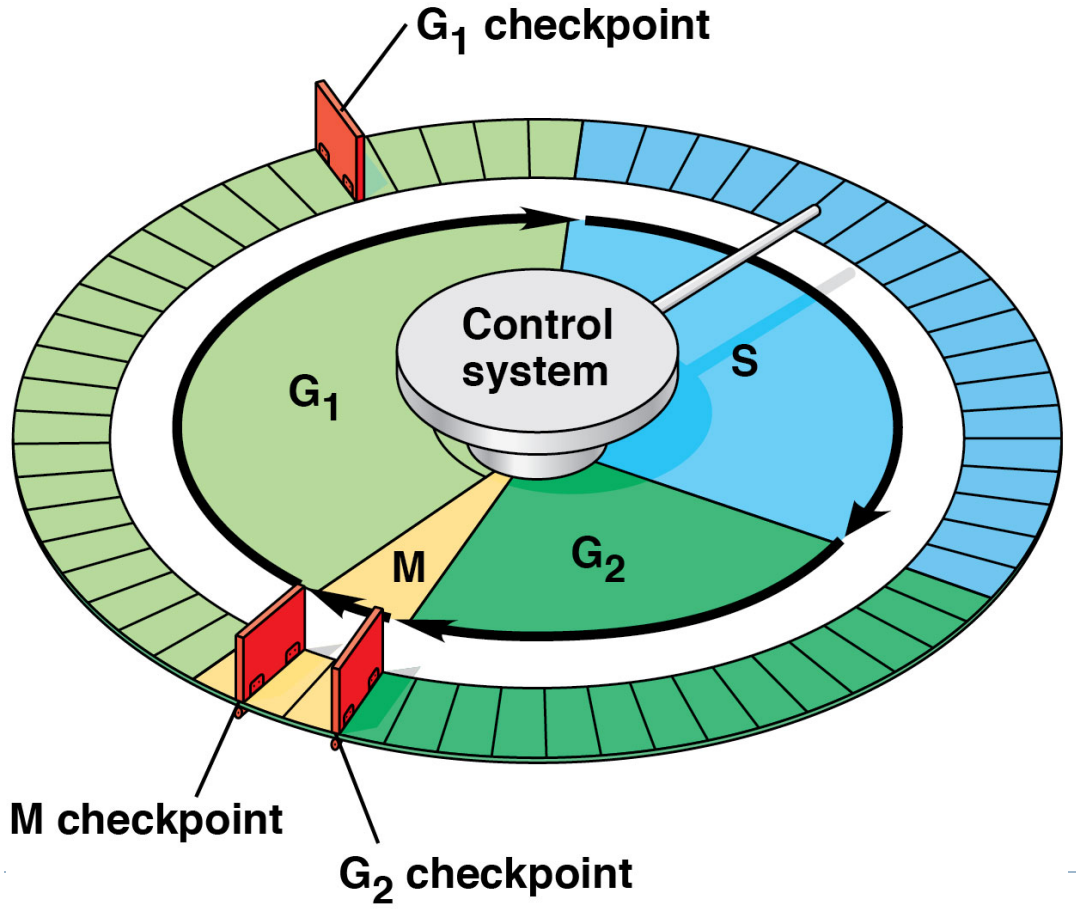


Bacterial cells divide by Binary Fission



Cell Cycle Control System

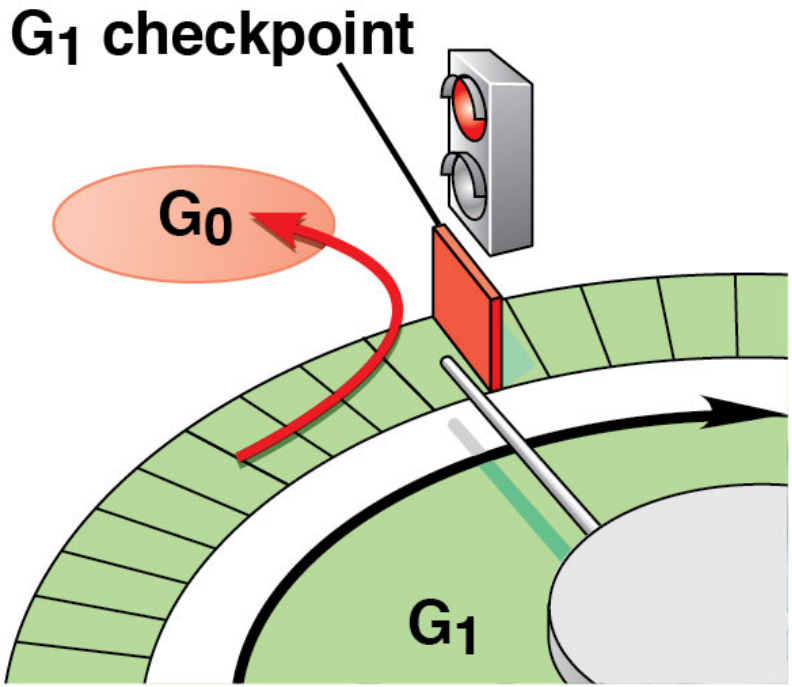
- **Checkpoint** = control point where **stop**/**go** signals regulate the cell cycle



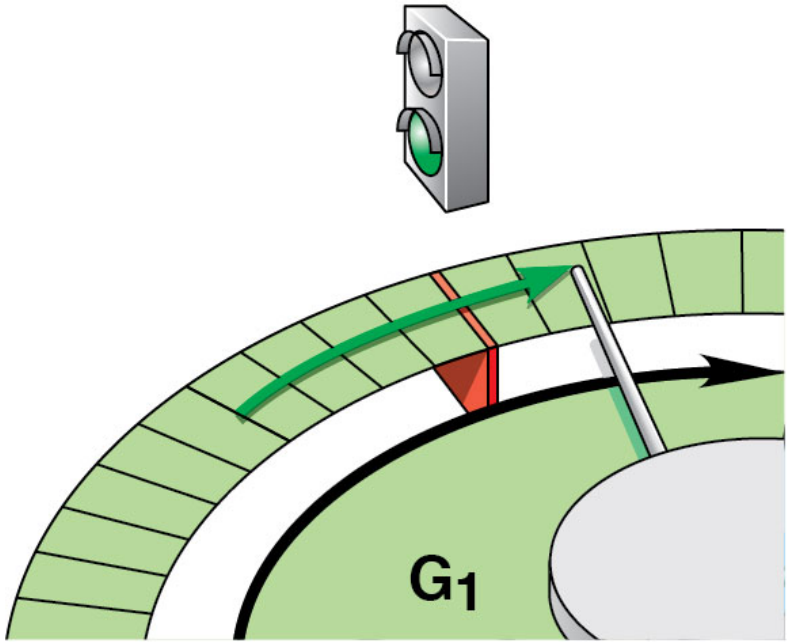
Major Checkpoints

1. G_1 checkpoint (Most important!)
   - Controlled by cell size, growth factors, environment
   - "Go" → completes whole cell cycle
   - "Stop" → cell enters nondividing state (G_0 Phase)
     - Nerve, muscle cells stay at G_0; liver cells called back from G_0
2. G_2 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_1 Checkpoint



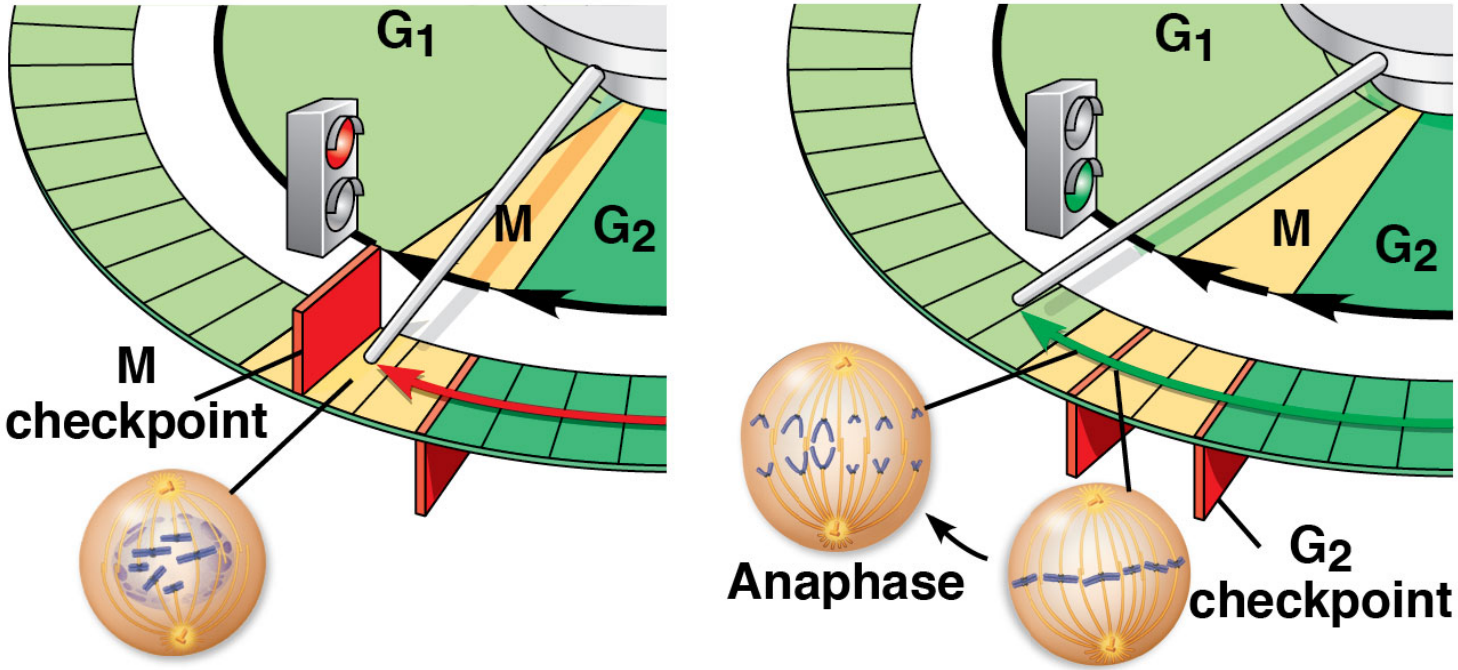
Without go-ahead signal, cell enters G_0.



With go-ahead signal, cell continues cell cycle.

(a) G_1 checkpoint

M Checkpoint



Prometaphase

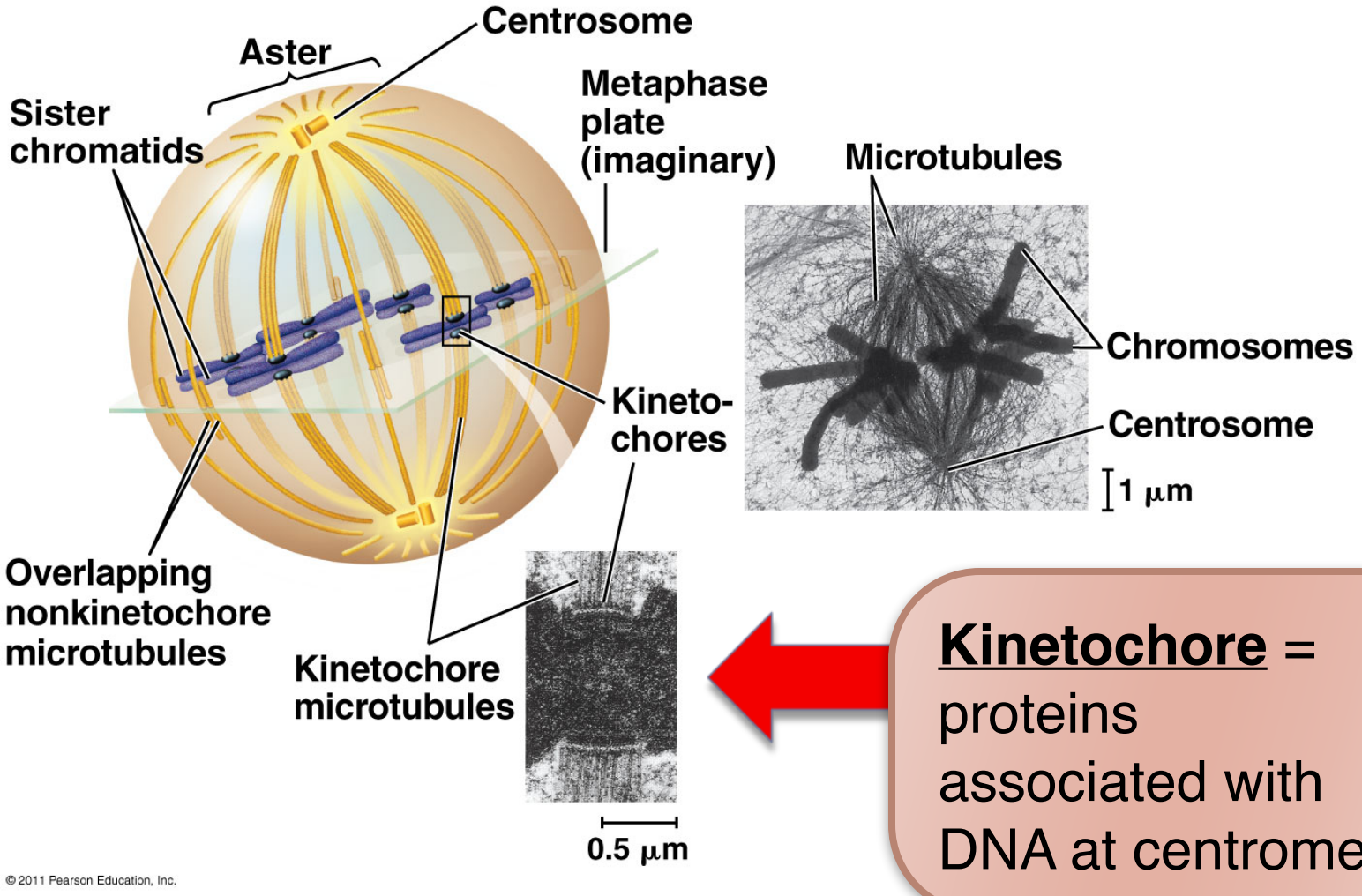
Without full chromosome attachment, stop signal is received.

Metaphase

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

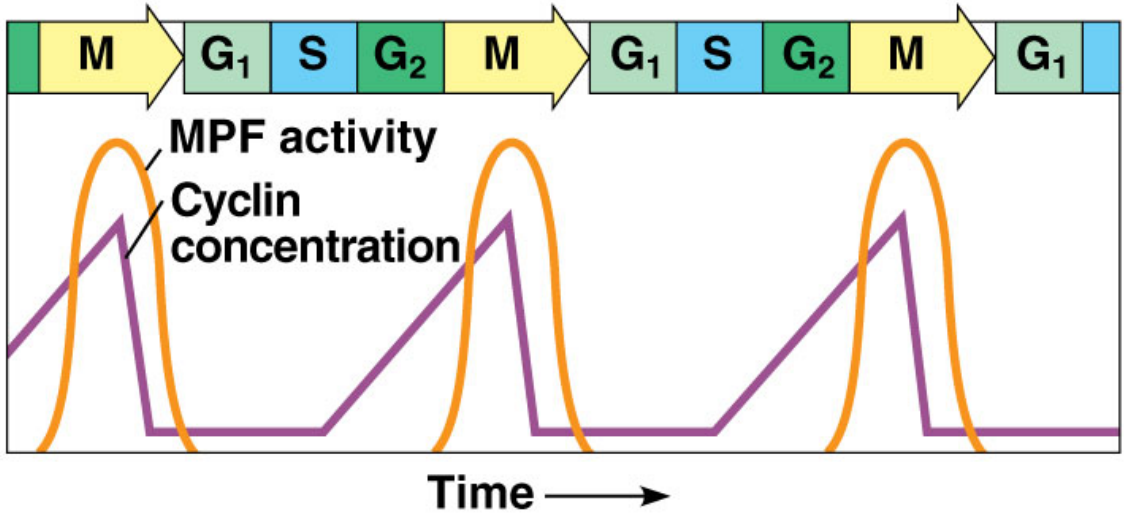
(b) M checkpoint

M-spindle Checkpoint: Mitotic spindle at metaphase



Kinetochore = proteins associated with DNA at centromere

Internal Regulatory Molecules



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

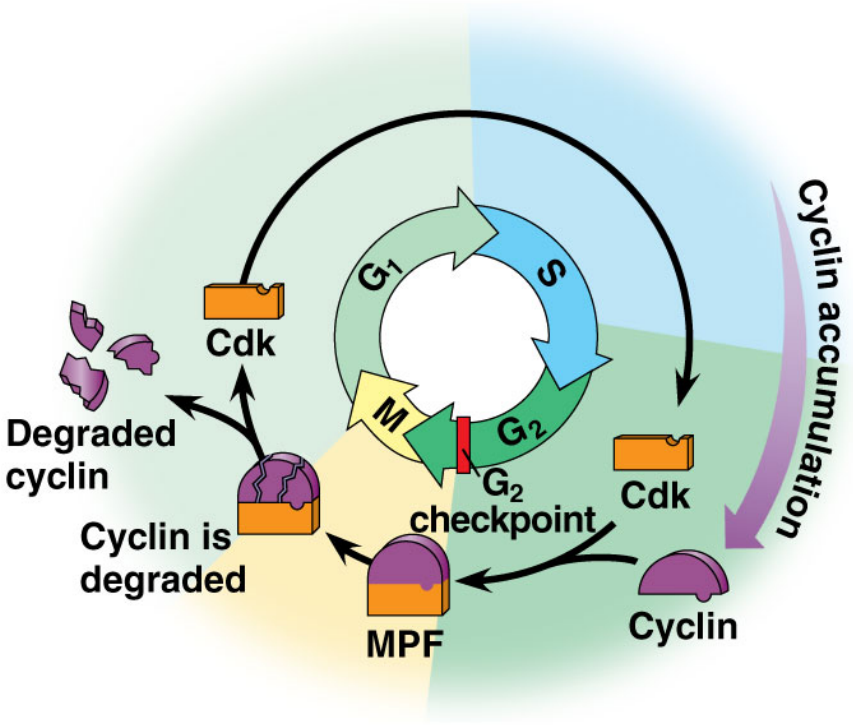
- **Kinases** (cyclin-dependent kinase, **Cdk**): protein enzyme controls cell cycle; active when connected to **cyclin**

- **Cyclins**: proteins which attach to kinases to activate them; levels fluctuate in the cell cycle

Internal Regulatory Molecules

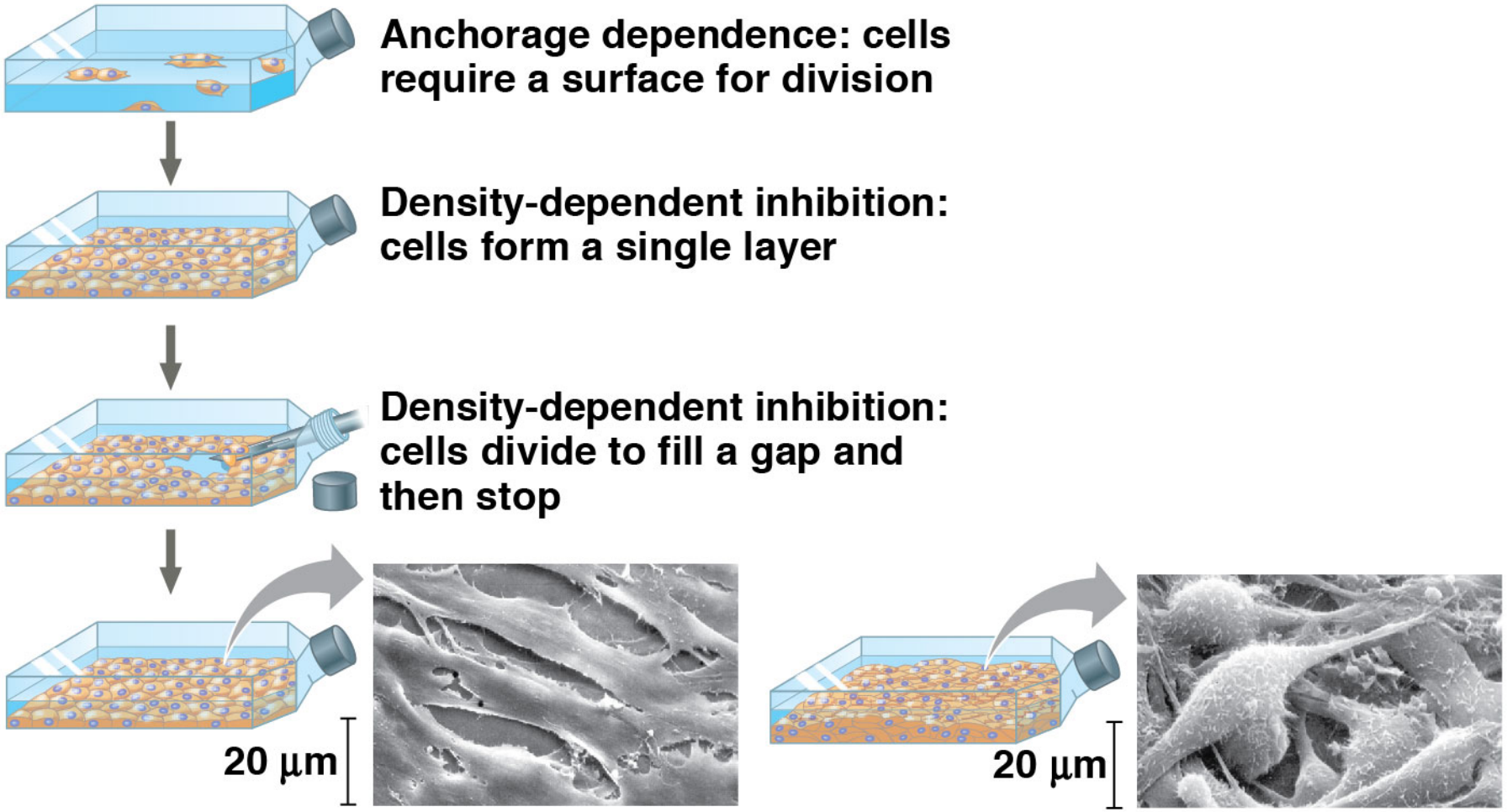
MPF = maturation-promoting factor

- 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



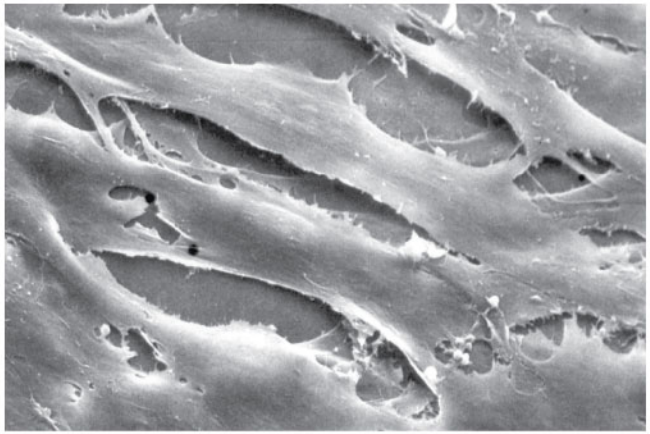
External Regulatory Factors

- 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

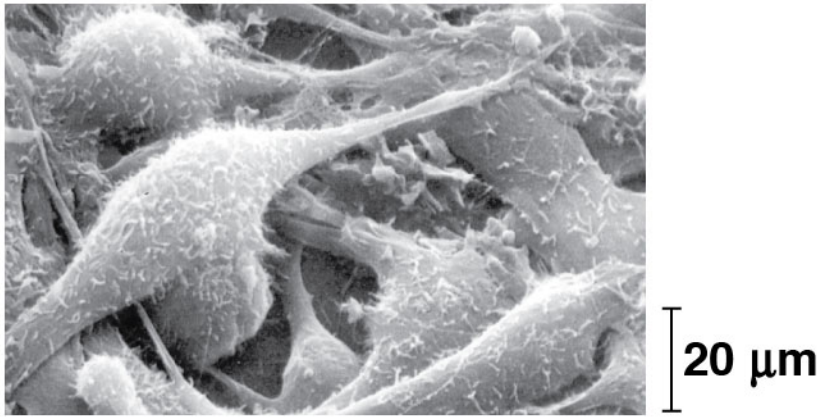
Cancer Cells

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

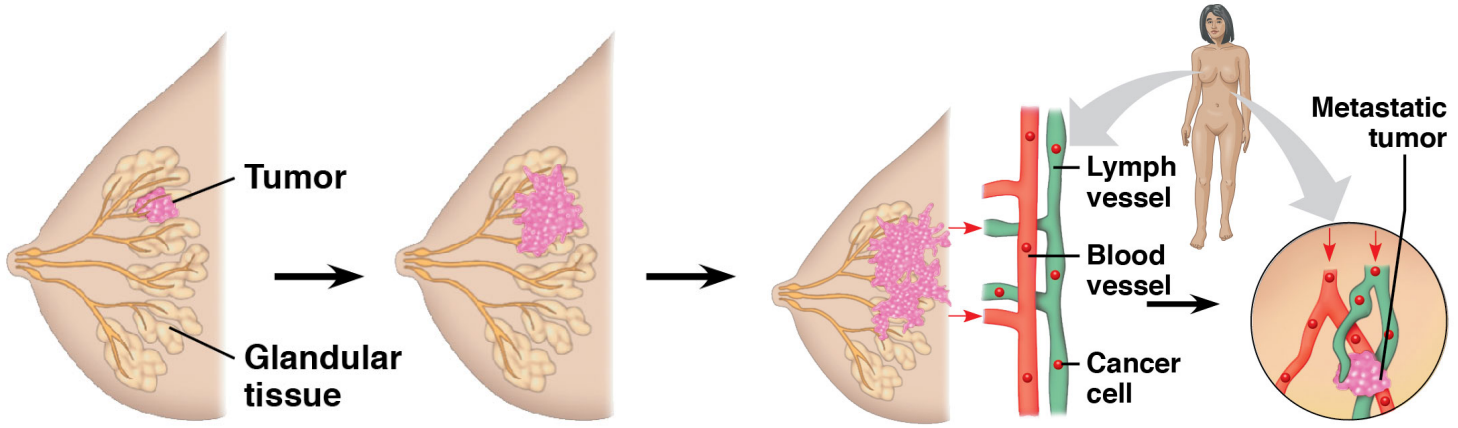


(b) Cancer cells

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



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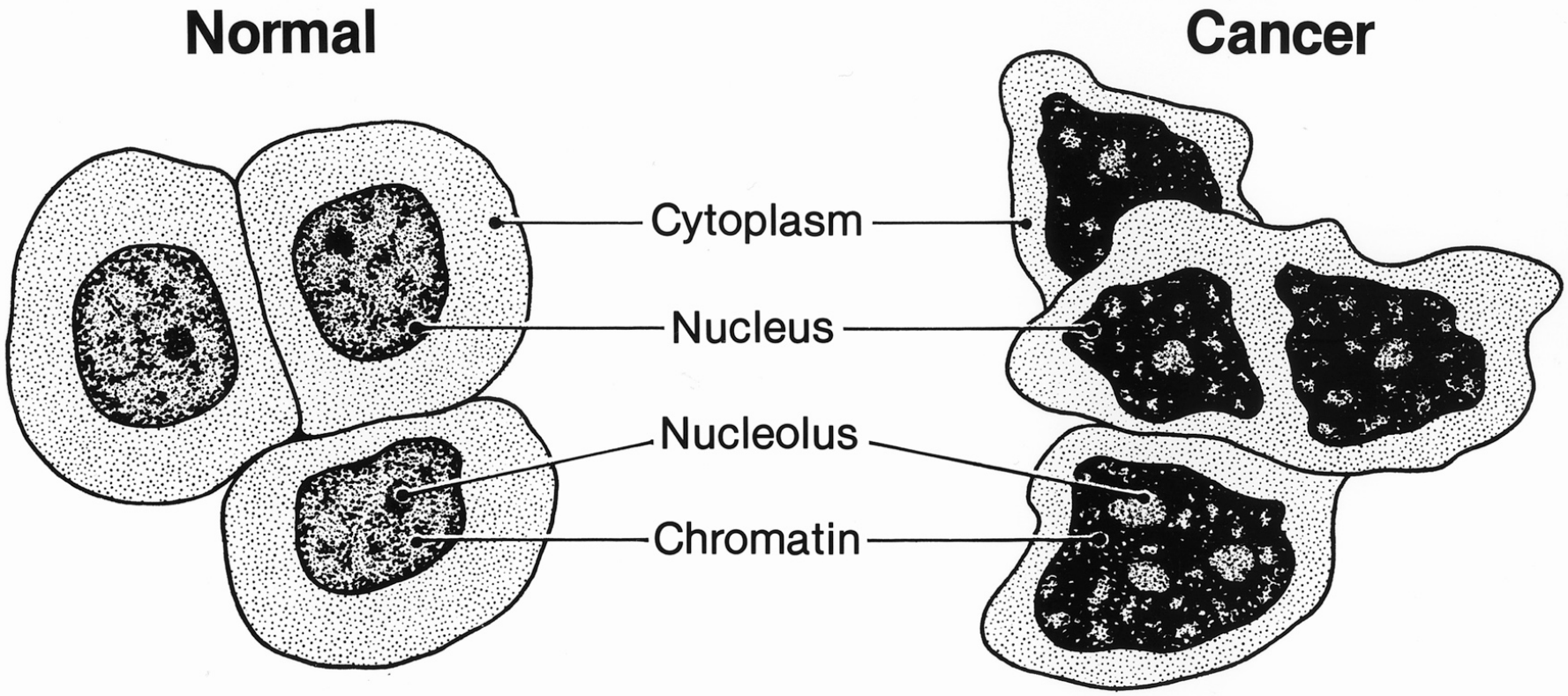
Normal and Cancer Cells

Structure



— Large cytoplasm
— Single nucleus
— Single nucleolus
— Fine chromatin

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

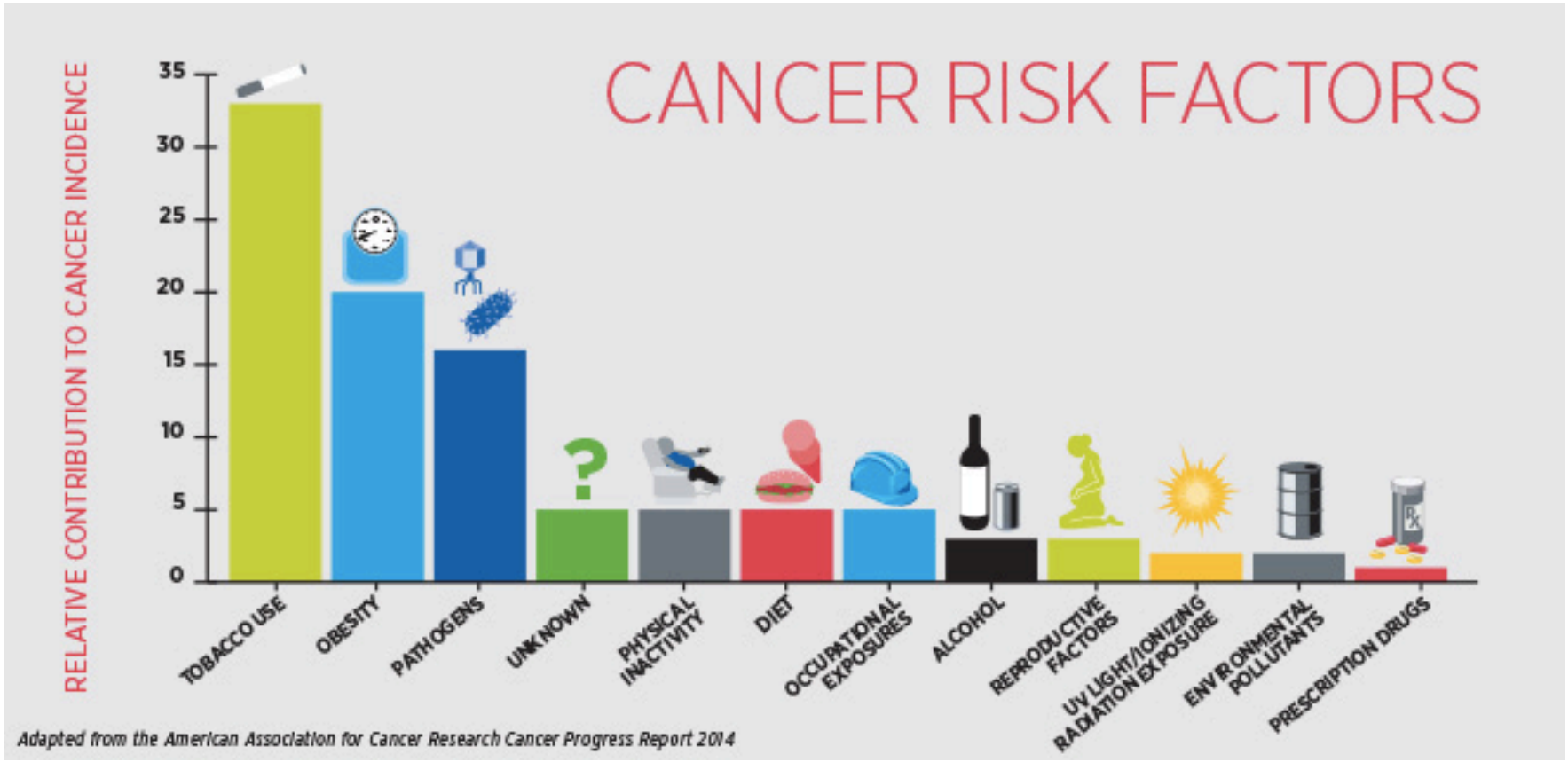
Cancer Cells

- 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:

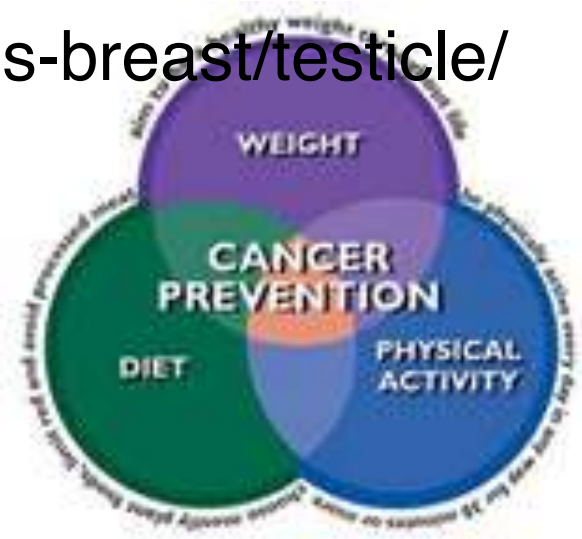
- Surgery, radiation, chemotherapy
- Personalized Medicine:
  - Breast Cancer: 20-25% tumors show high HER2 receptors → use Herceptin to block HER2 protein

Cancer Risk Factors



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

- Don't smoke, legal or illegal (includes hookahs, chew, 2nd-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
MAINTAIN A HEALTHY WEIGHT
MOVE MORE
EAT WELL
ENJOY A PLANT BASED DIET
10 CANCER PREVENTION RECOMMENDATIONS
REDUCE RED MEAT, AVOID PROCESSED MEAT
CUT DOWN ON ALCOHOL
EAT LESS SALT
AFTER TREATMENT, CANCER SURVIVORS SHOULD FOLLOW THE CANCER PREVENTION RECOMMENDATIONS
IF YOU CAN, BREASTFEED YOUR BABY
FOR CANCER PREVENTION DON'T USE SUPPLEMENTS
aicr.org
Blog
And always remember – do not smoke or chew tobacco.
CANCER PREVENTION
Together We Can

Summary of the Cell Cycle