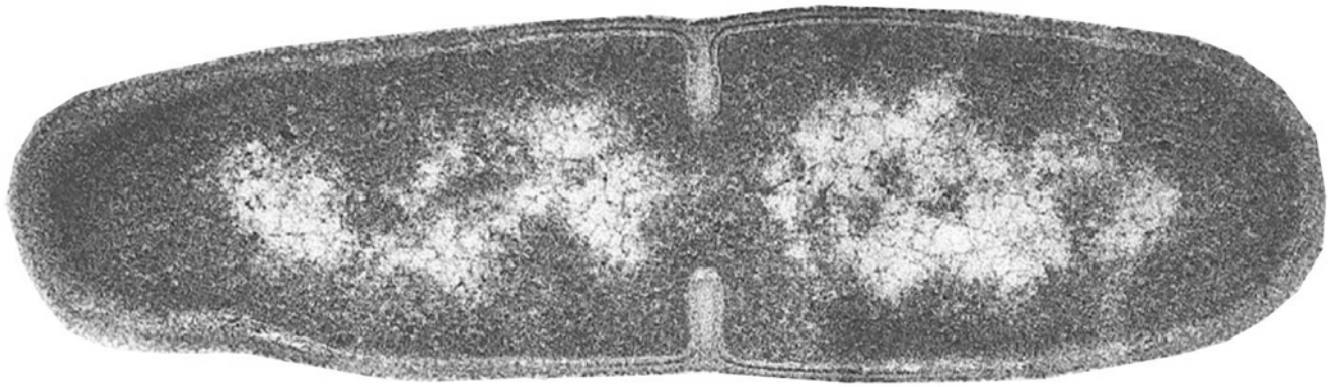
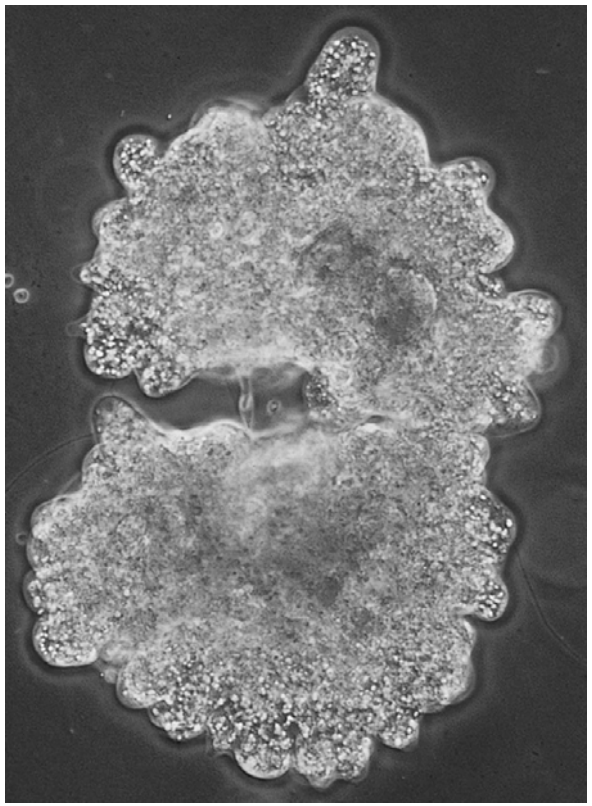
Cell cycle, mitosis & meiosis

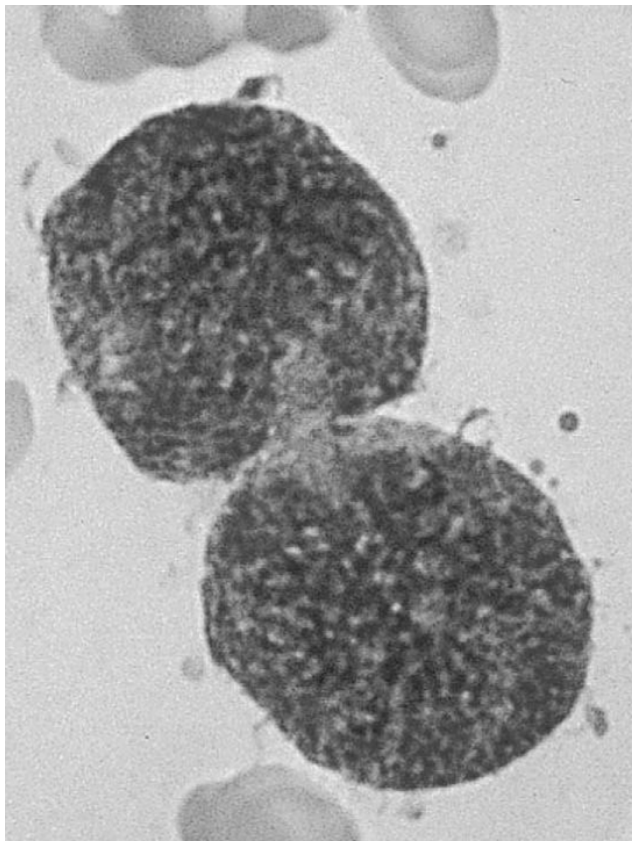
Chapter 6

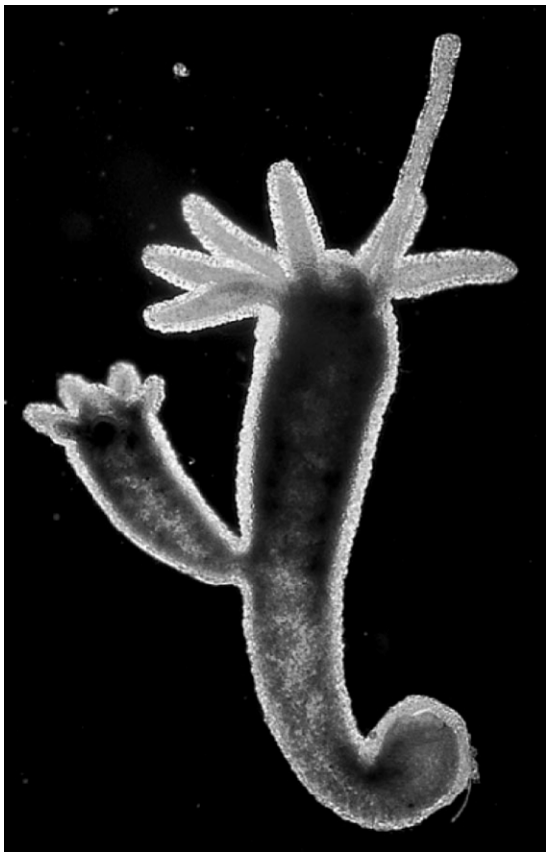
Why do cells divide?

Asexual reproduction

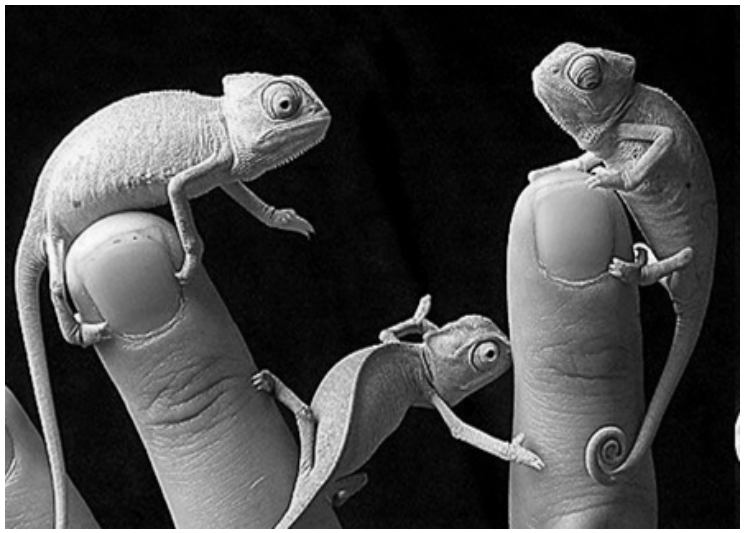




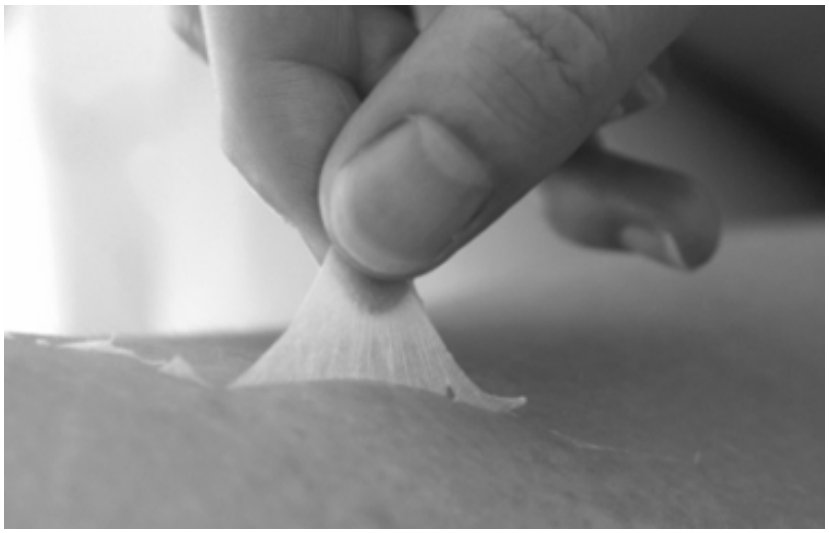




Growth

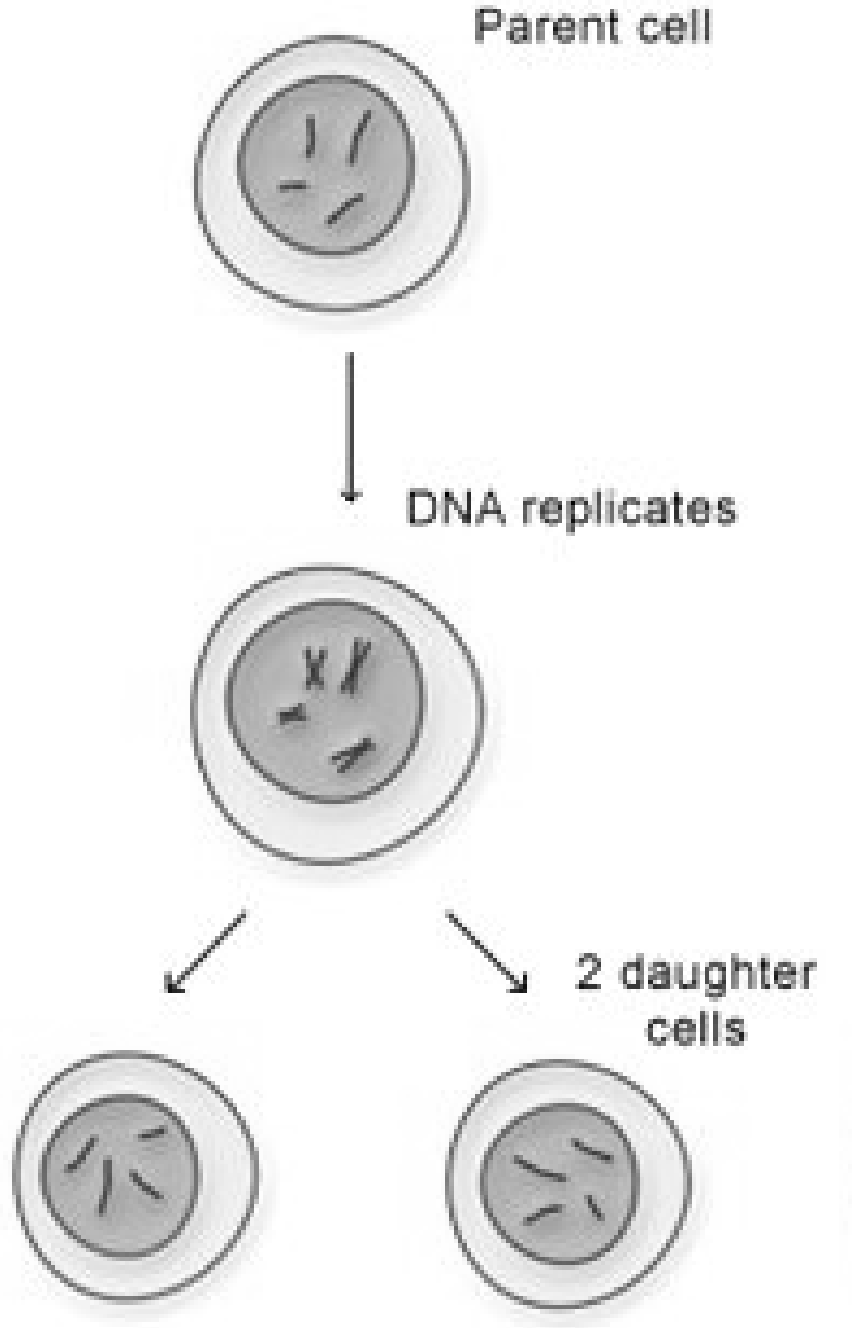


Replacement / repair



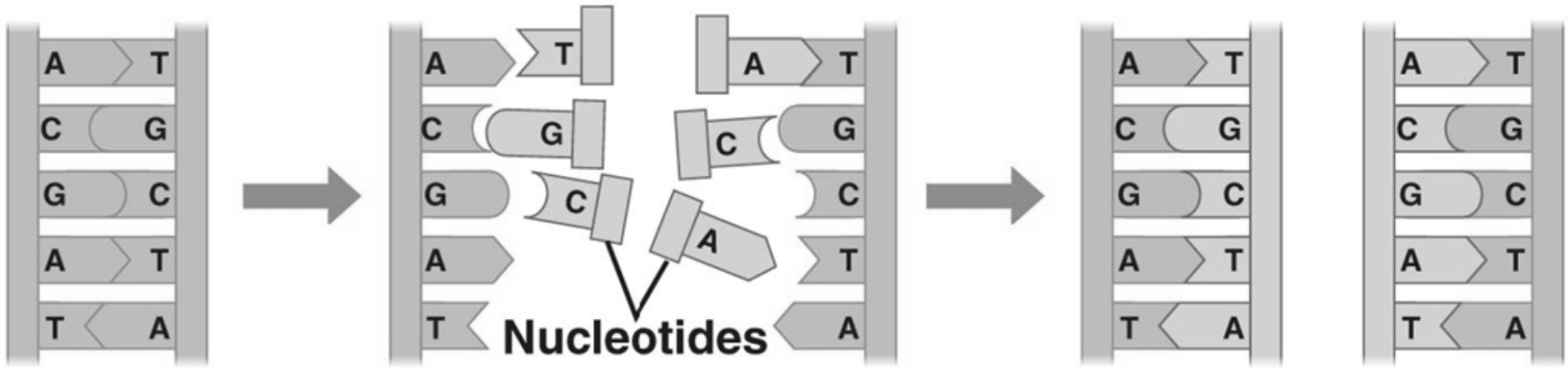
Cell division:

The big picture



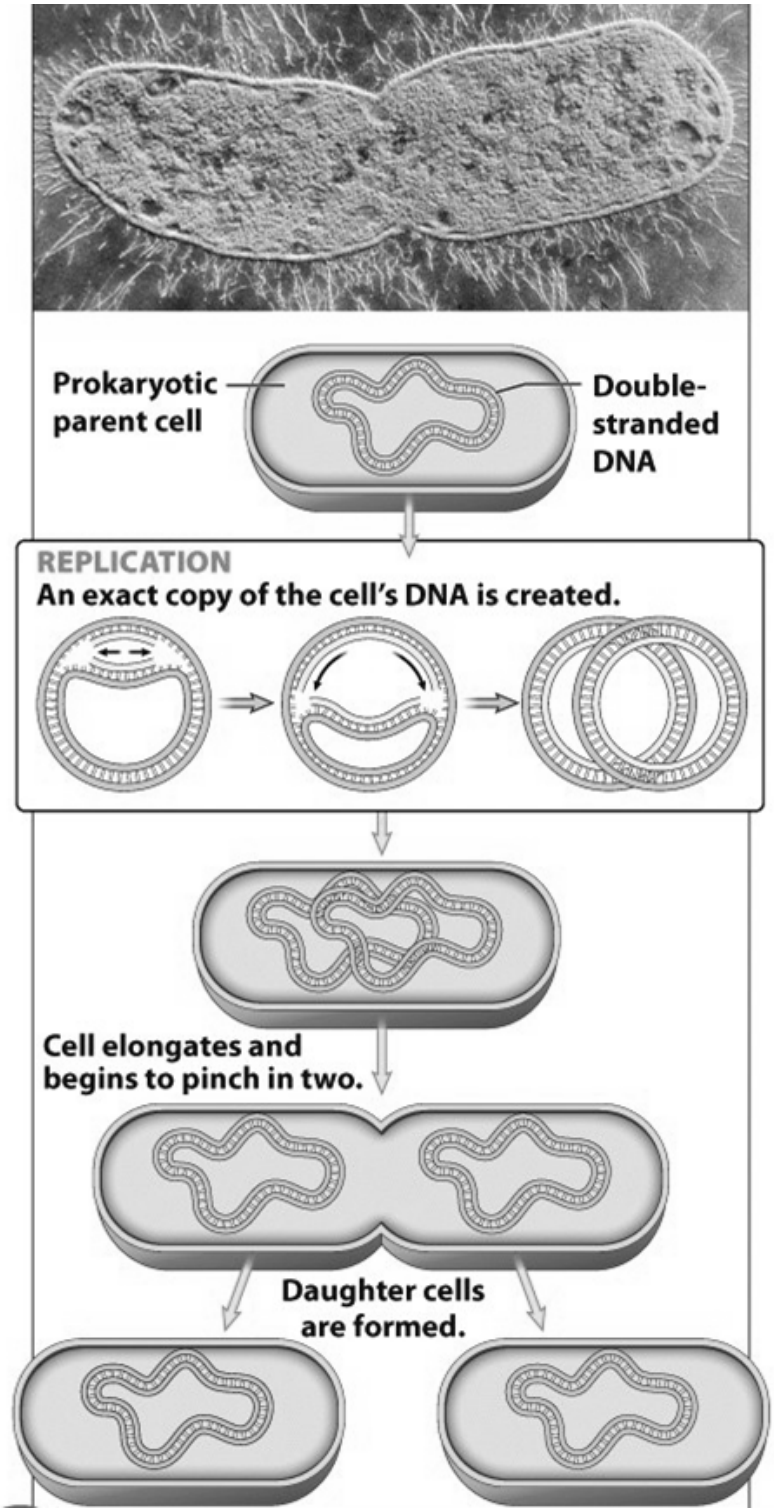
Before cells can divide, DNA needs to replicate

- Two steps
  - DNA strands separate
  - nucleotides bind to complimentary bases on each strand
- Result: two molecules of identical DNA

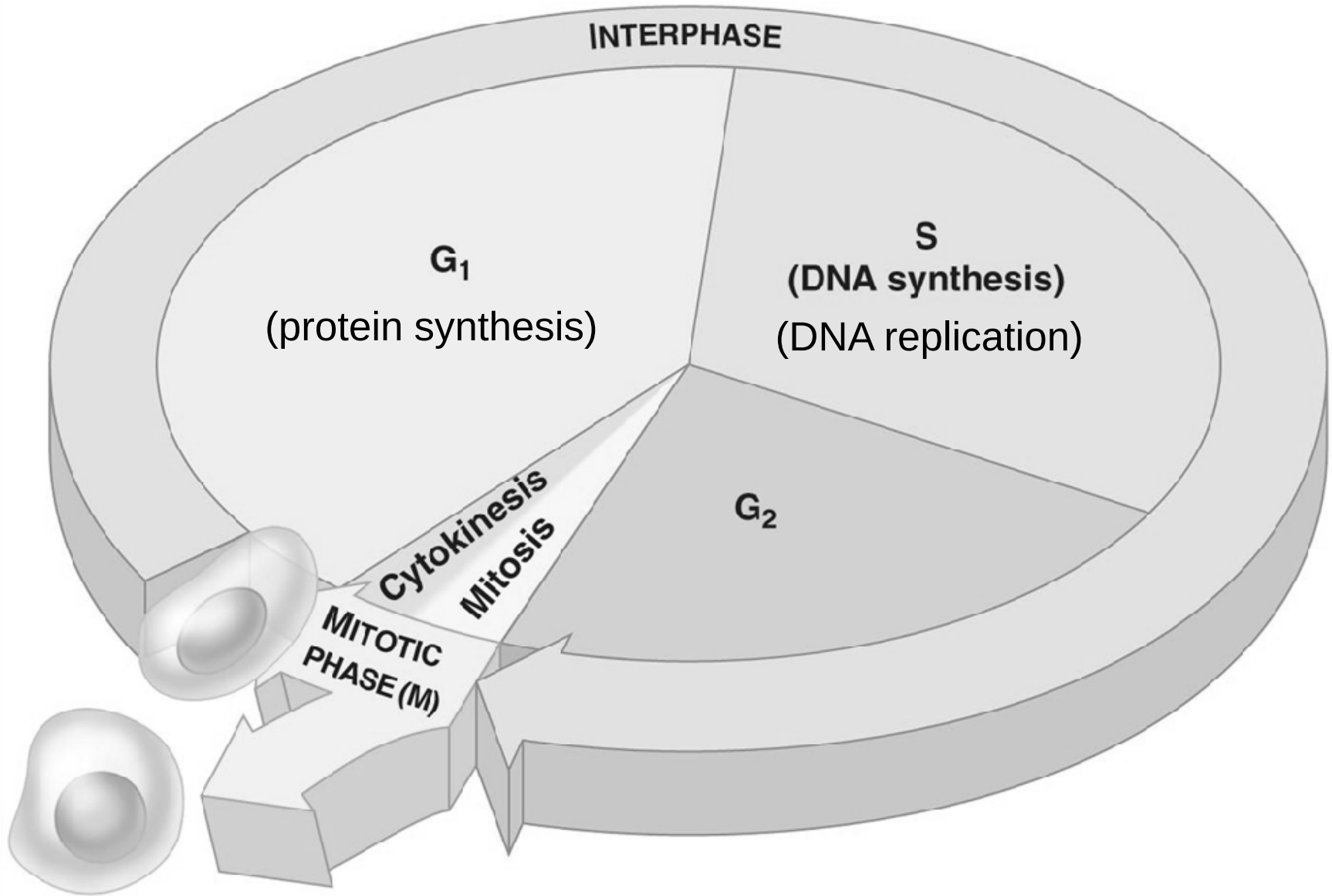


Cell division in prokaryotes

- Called <u>binary fission</u>
  - 1st DNA replicates
  - 2nd the original cell (the parent cell) pinches itself in two new cells (daughter cells)
  - result: two genetically identical cells; identical to each other & identical to the parent cell
  - Why does the DNA need to replicate first?



The eukaryotic cell cycle

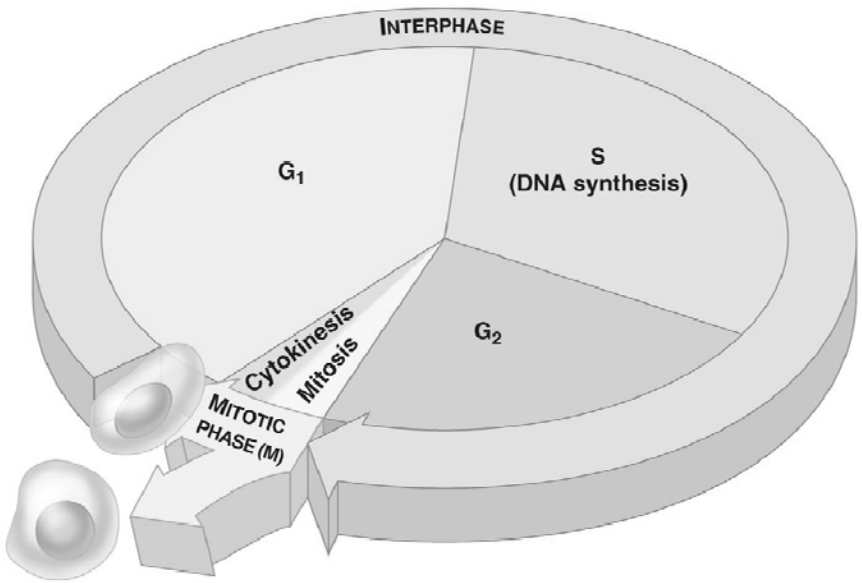


The cell cycle in words. . .

- Interphase
  - G_1
  - S
  - G_2
- Mitotic phase (division of the nucleus)
  - prophase
  - metaphase
  - anaphase
  - telophase
  - cytokinesis (division of the cytoplasm)

Interphase

- In the nucleus, DNA and associated proteins are a loose, diffuse mass called *chromatin*
- Why is it loose?

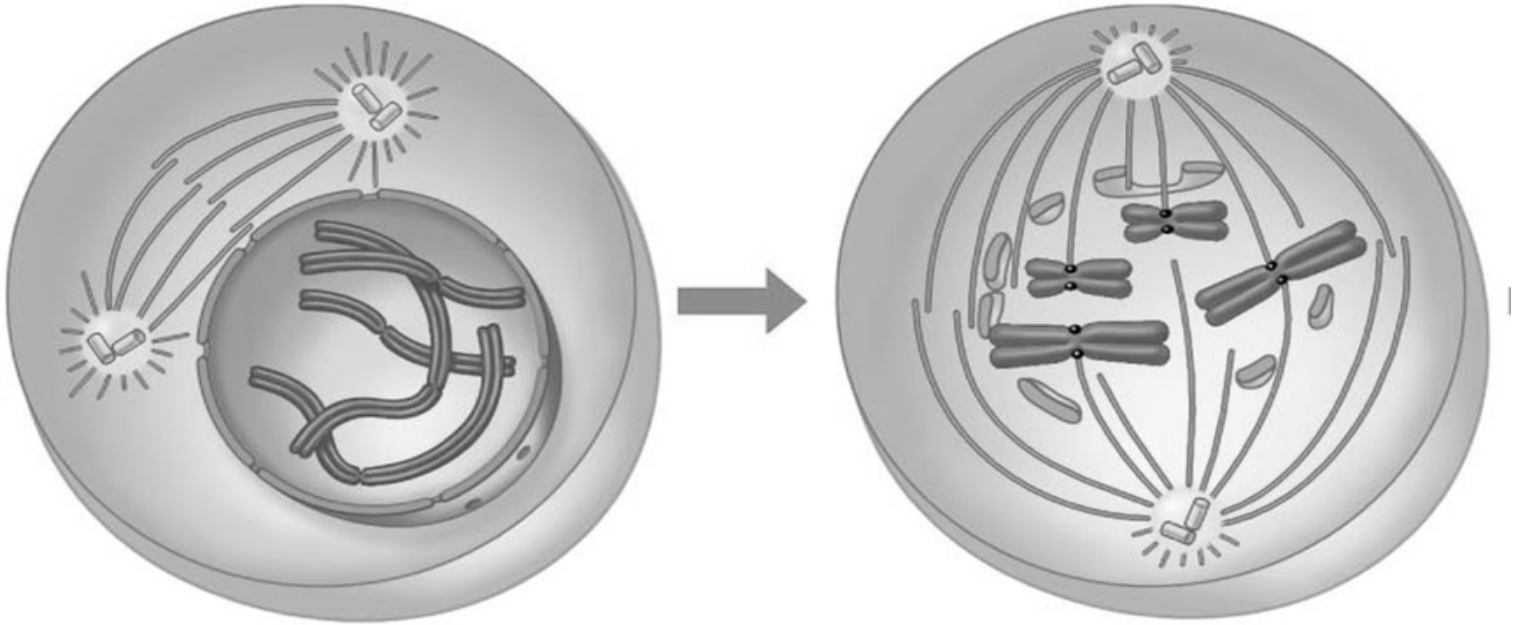


Mitotic phase

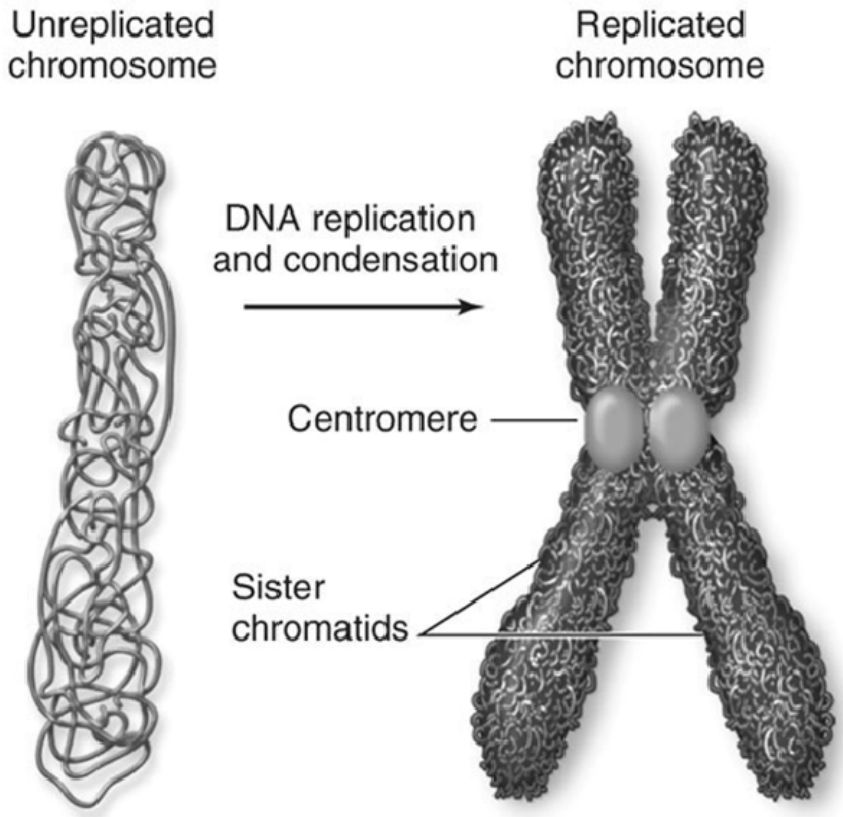
- Prophase
- Metaphase
- Anaphase
- Telophase
- Cytokinesis

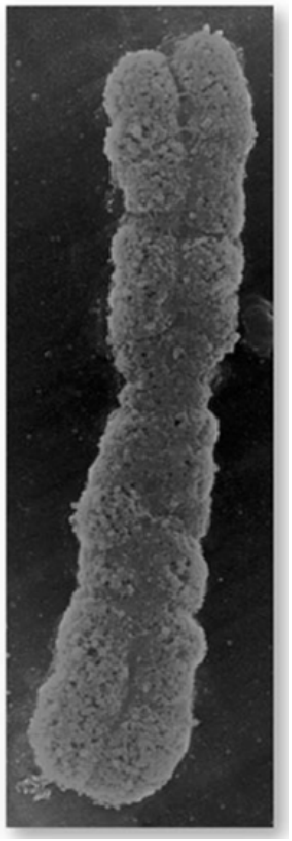
Prophase

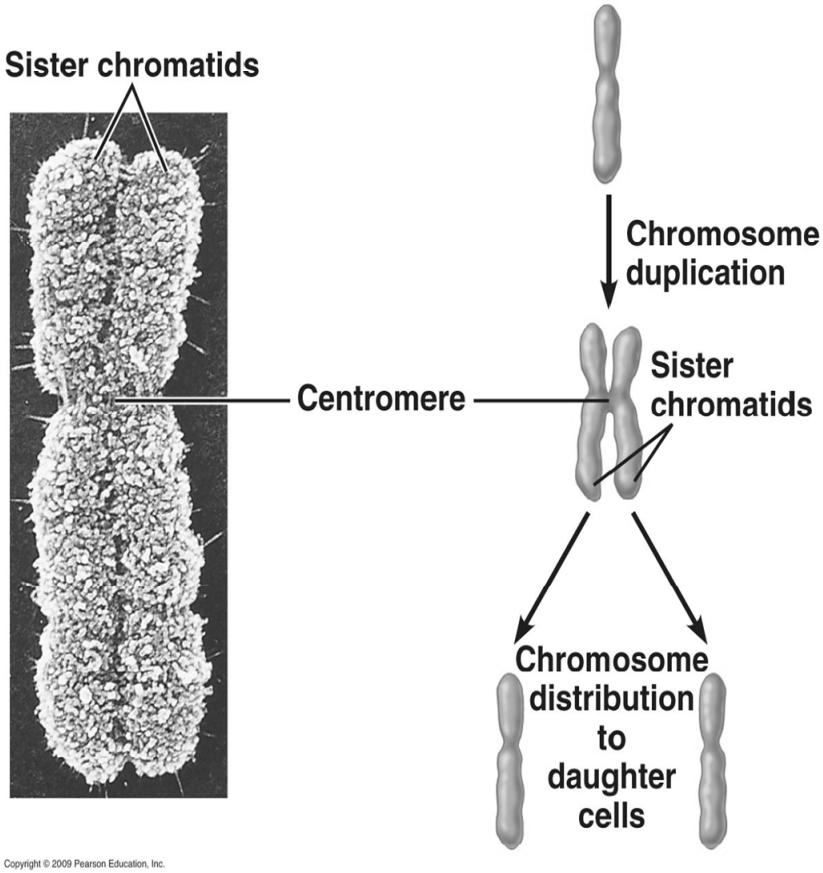
- Chromatin condenses to become chromosomes (*sister chromatids* are held together by a *centromere*)
- Spindle fibers begin to form
- Nuclear envelope starts to break apart



Sister chromatids are 2 identical copies of DNA held together by a *centromere*



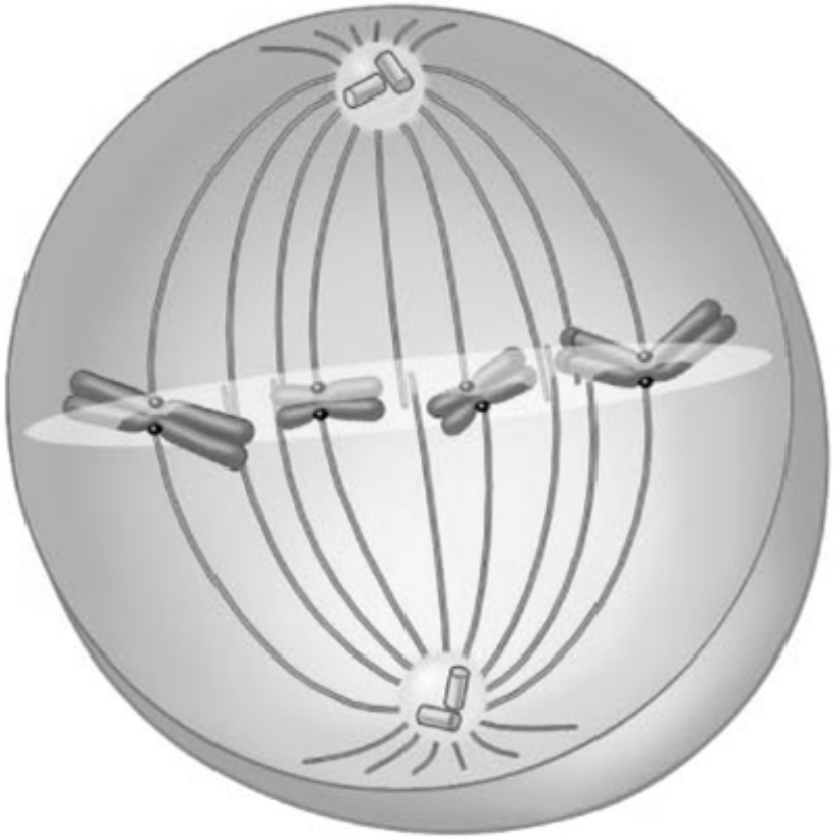




Metaphase

- Spindle fibers move sister chromatids to center of cell

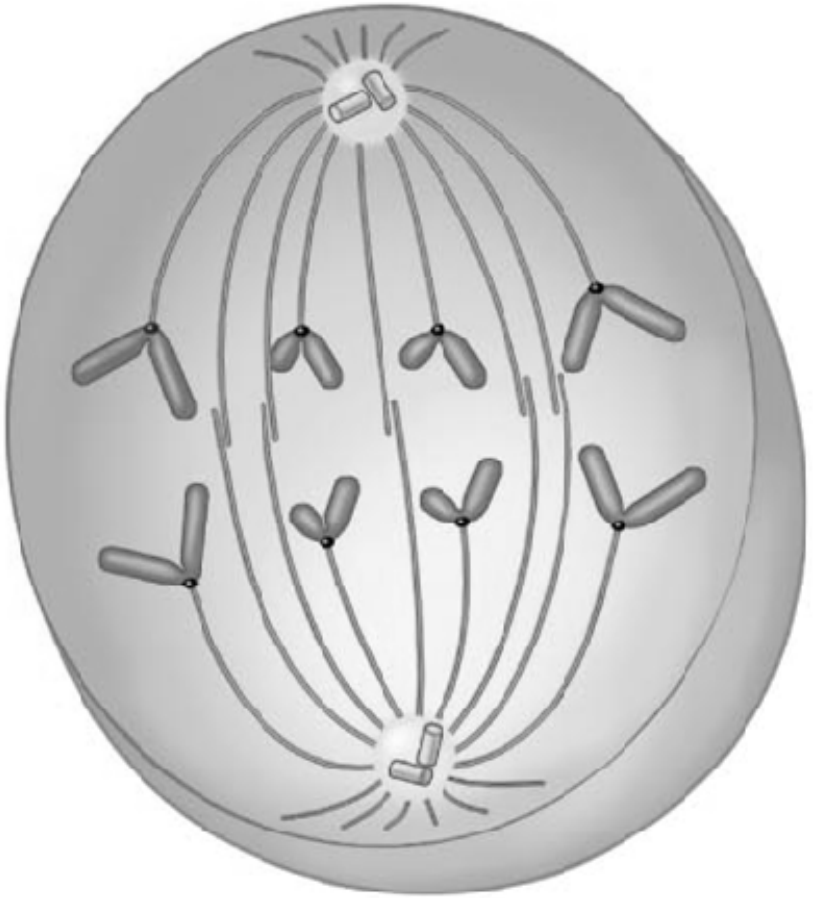
- (**M**etaphase: **M**eet in the **M**iddle)



Anaphase

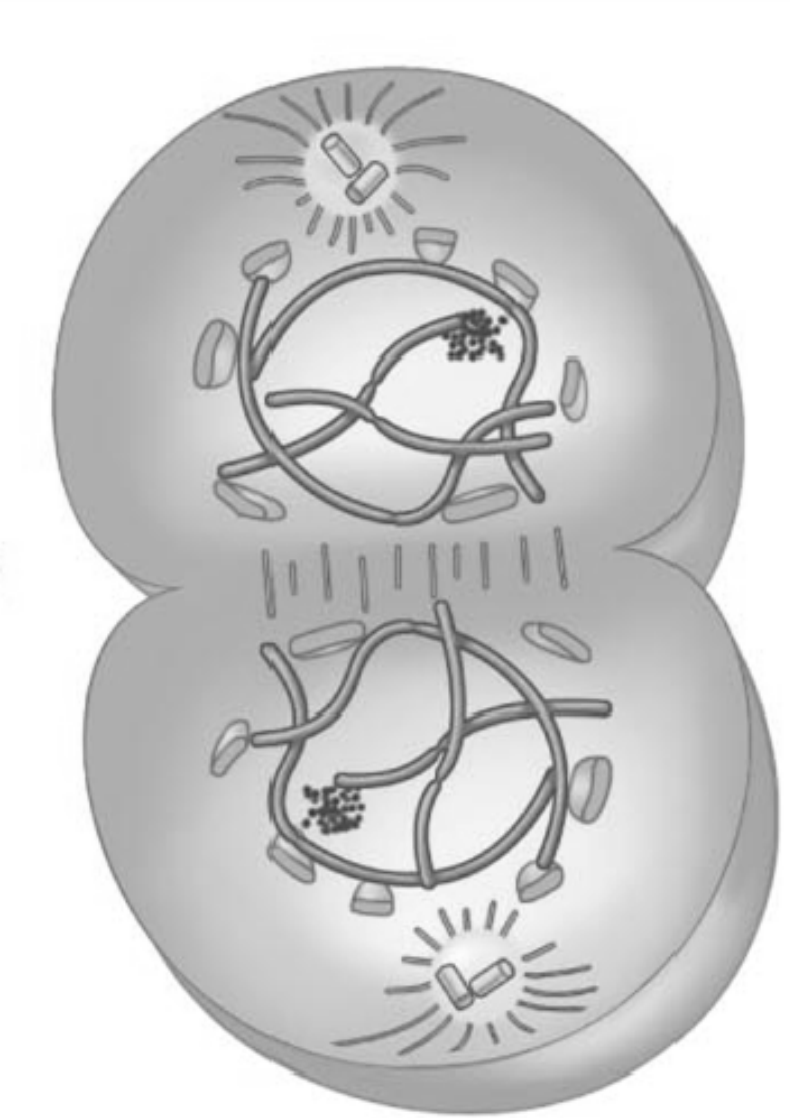
- Sister chromatids are pulled apart by spindle fibers and drawn to each pole of the cell

- (**A**naphase: **A** and **A**way)

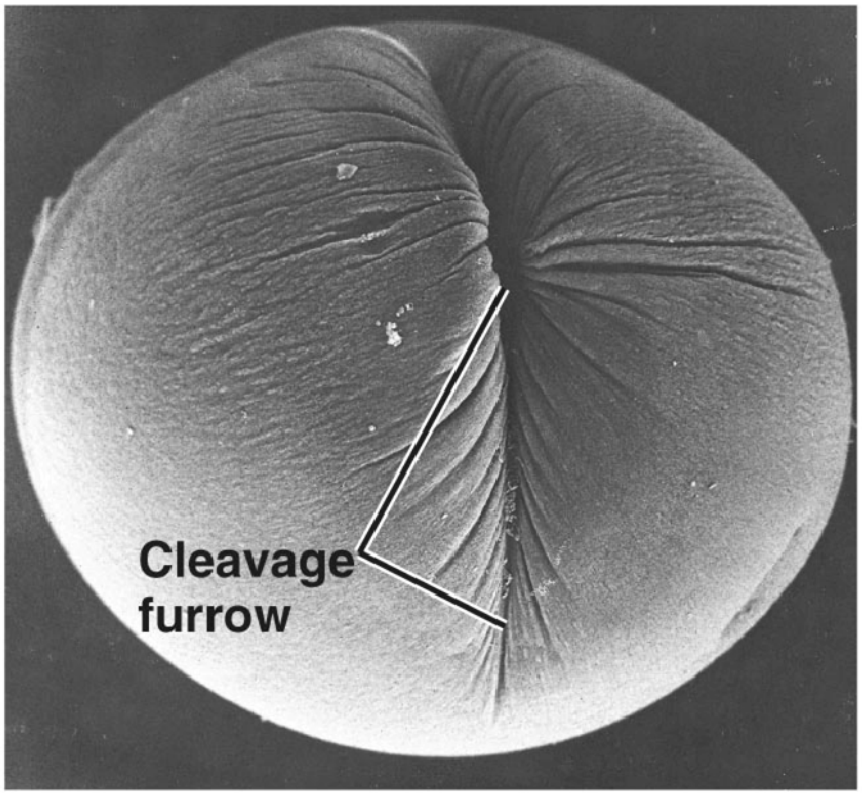


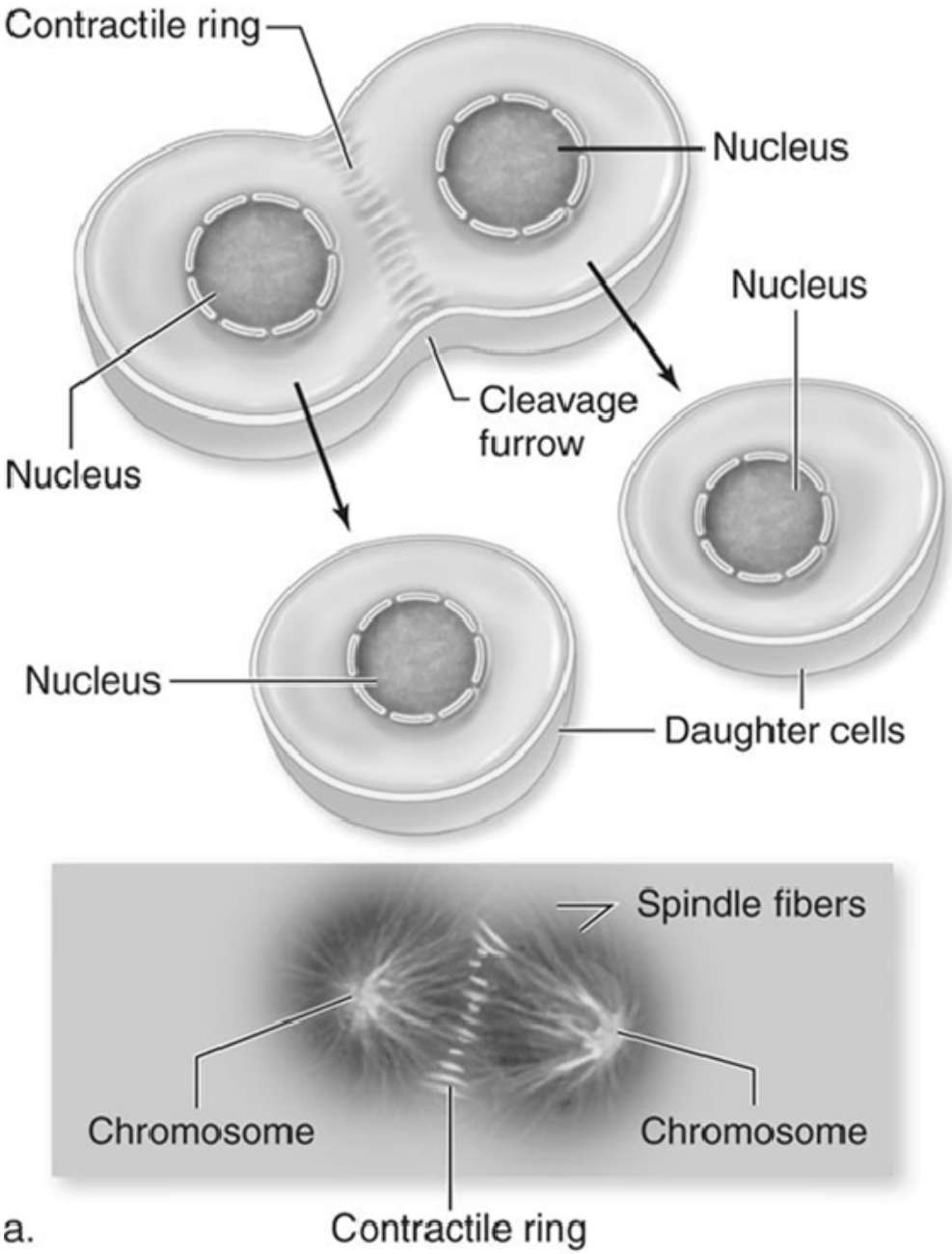
Telophase & cytokinesis

- Roughly the opposite of prophase
- Nuclear envelopes start to form
- Chromosomes begin to uncoil and loosen
- Spindle fibers shorten
- Cytoplasm & organelles divide (*cytokinesis*)

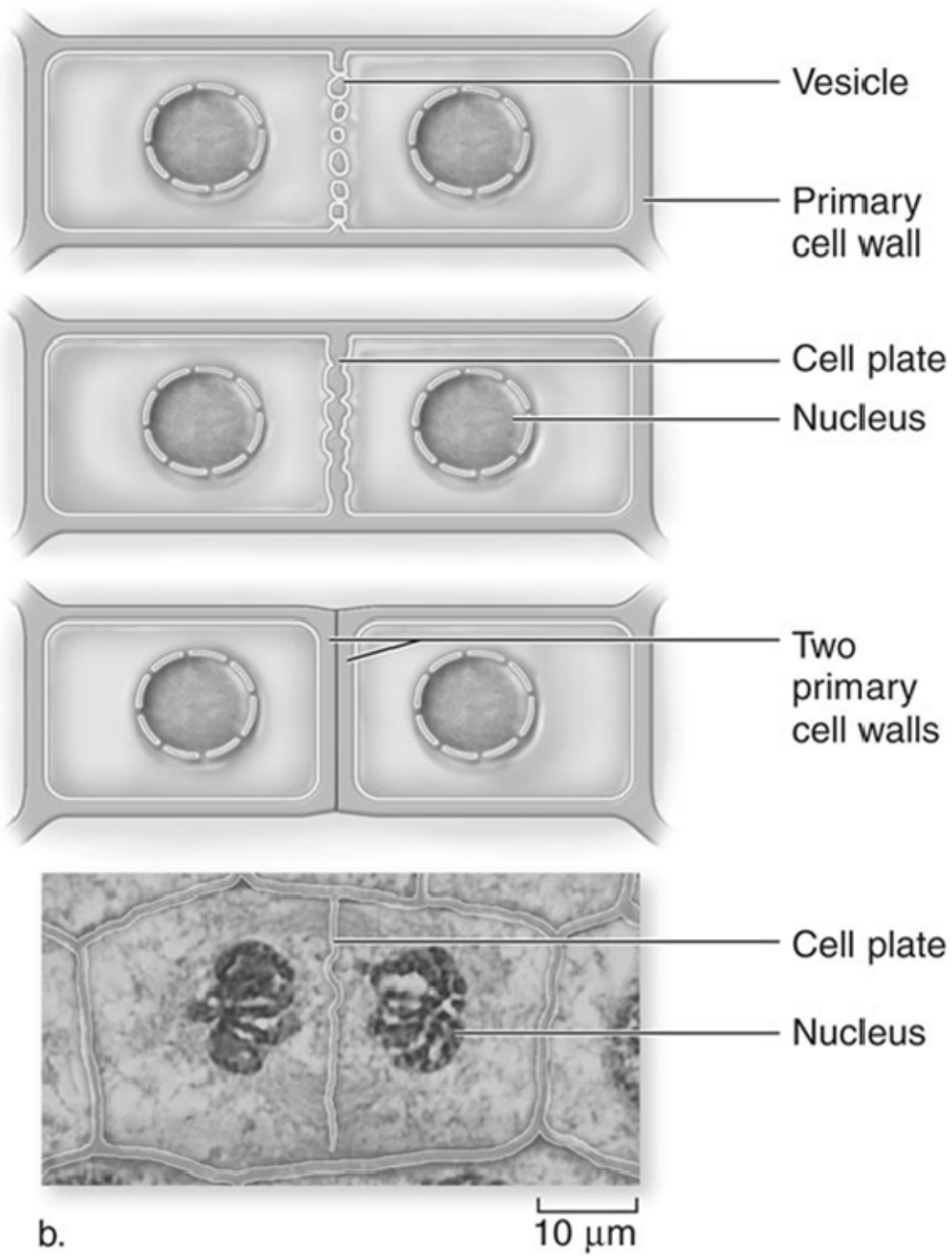


Cytokinesis in animal cells

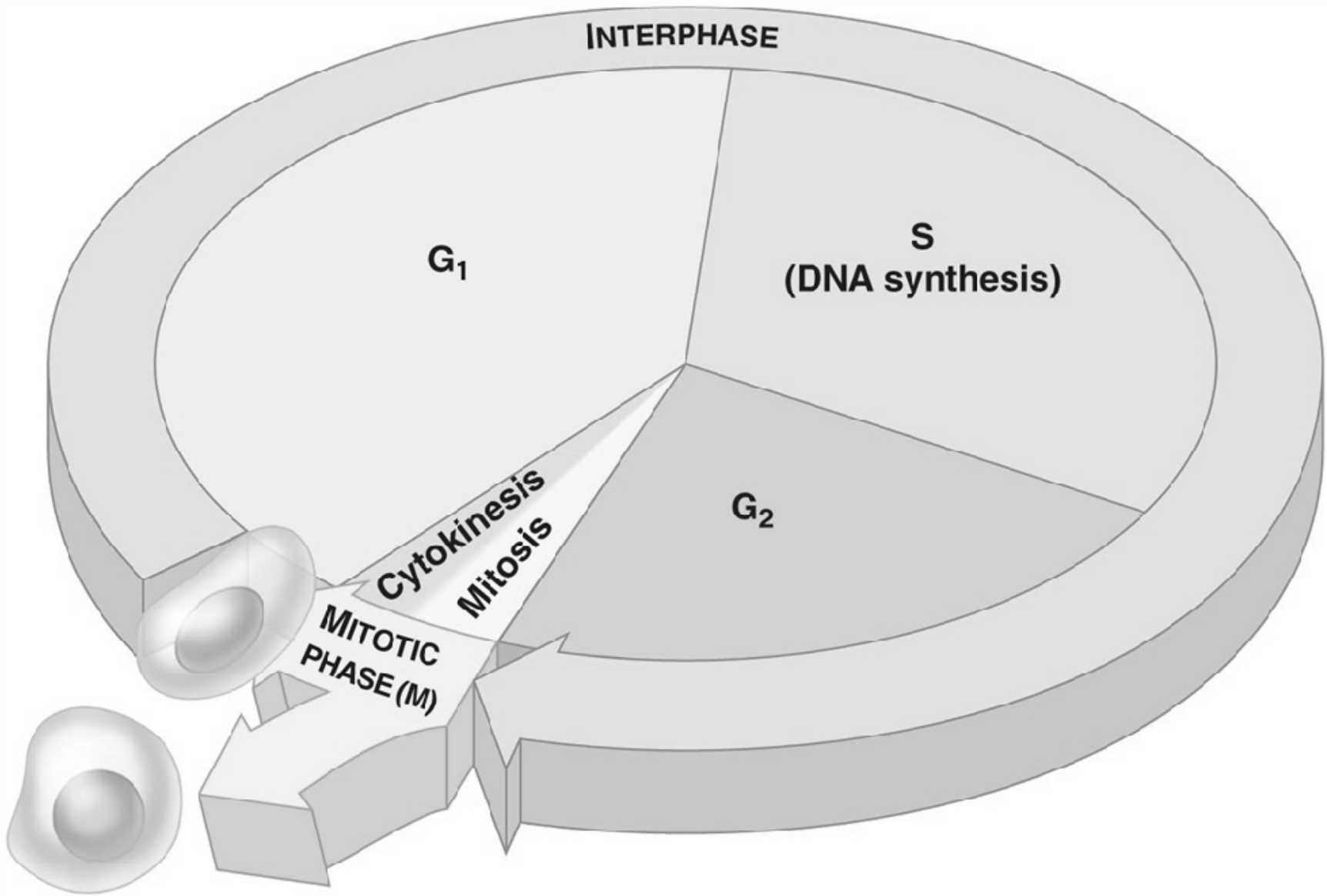




Cytokinesis in plant cells

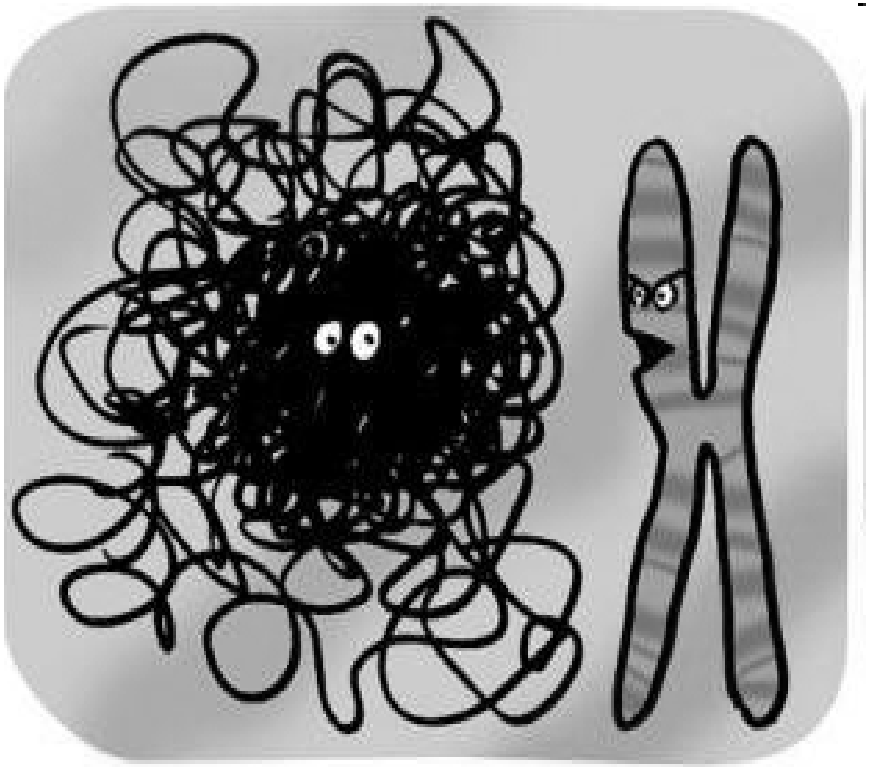


The eukaryotic cell cycle

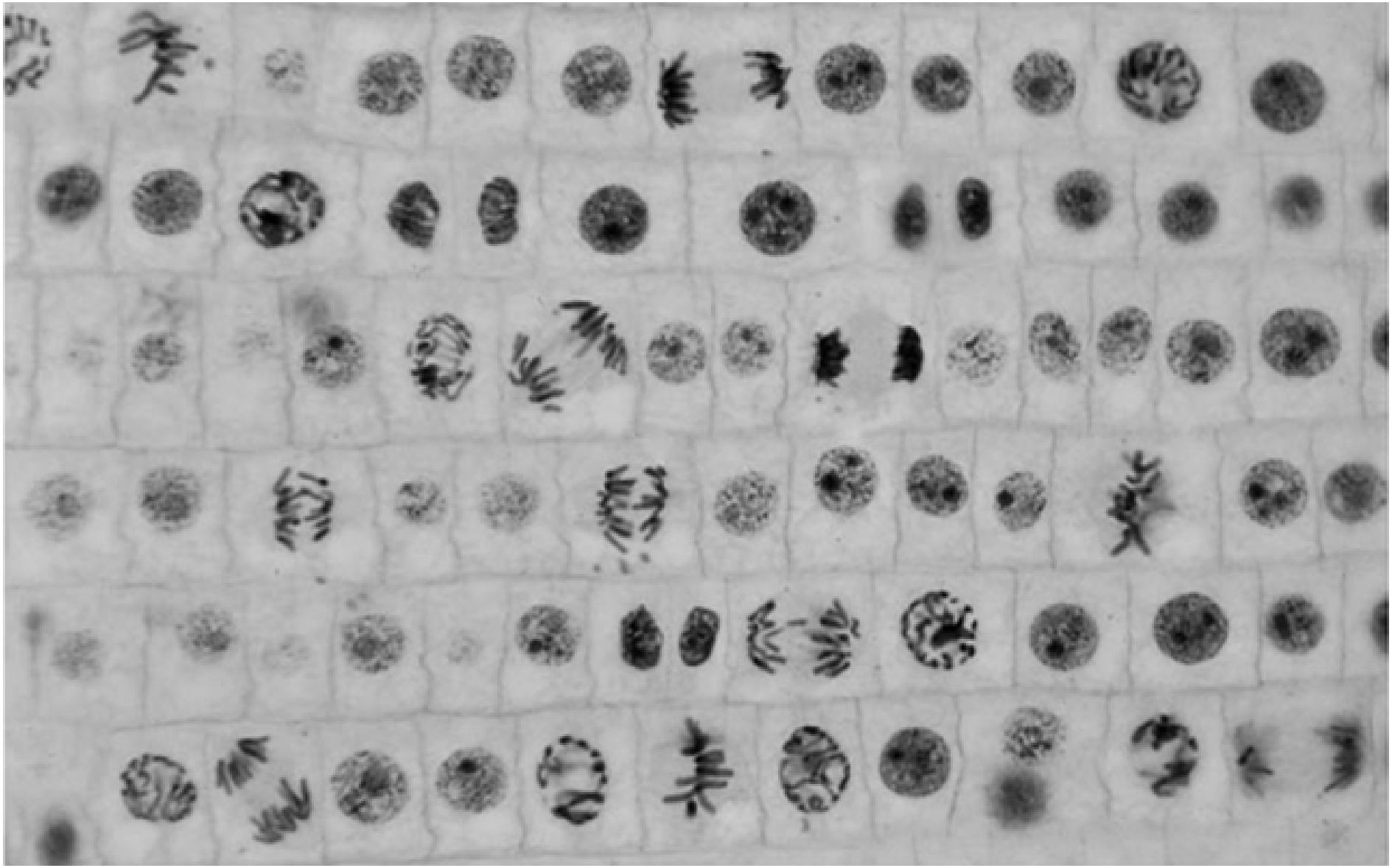


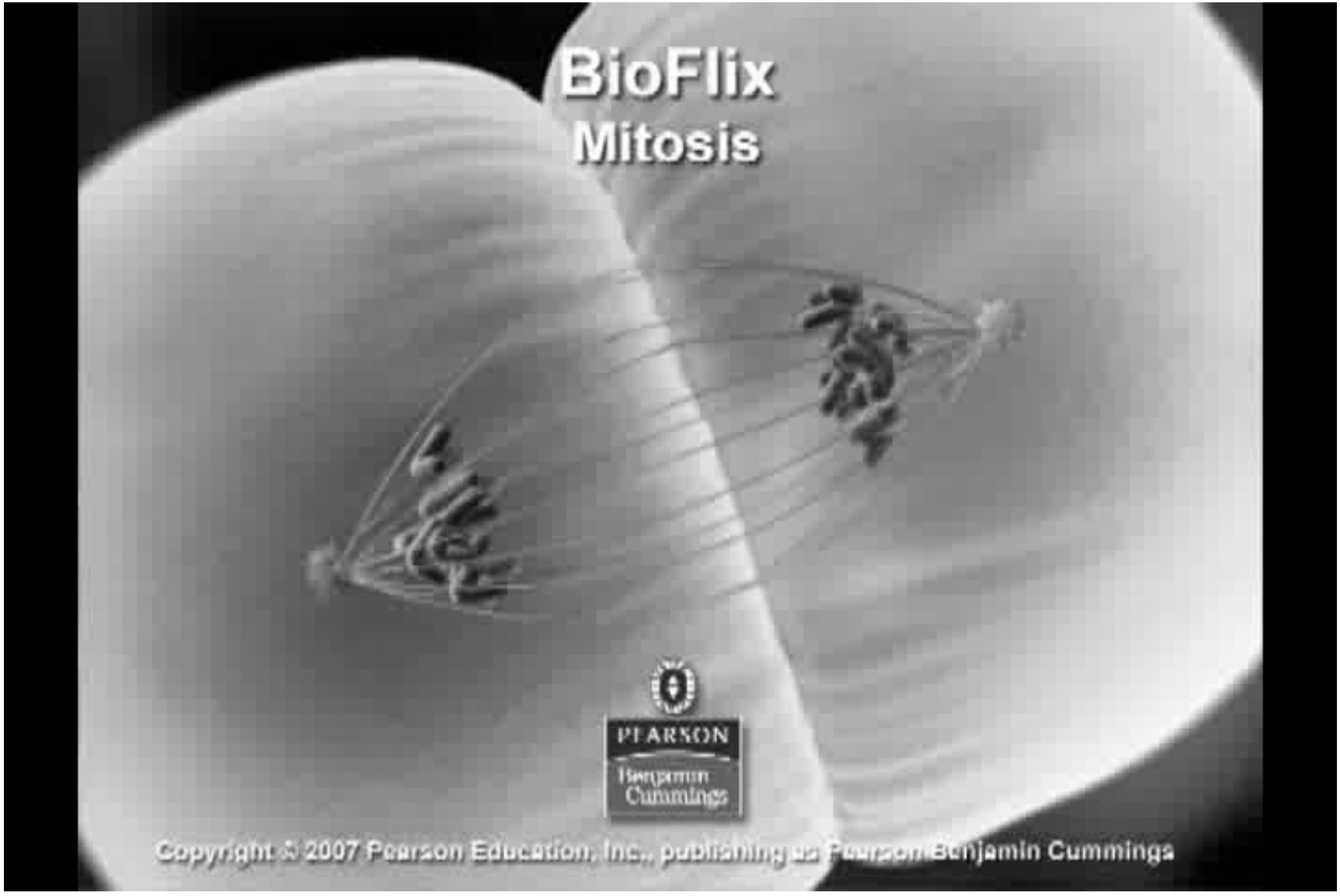
I pee on the mat, cee?!

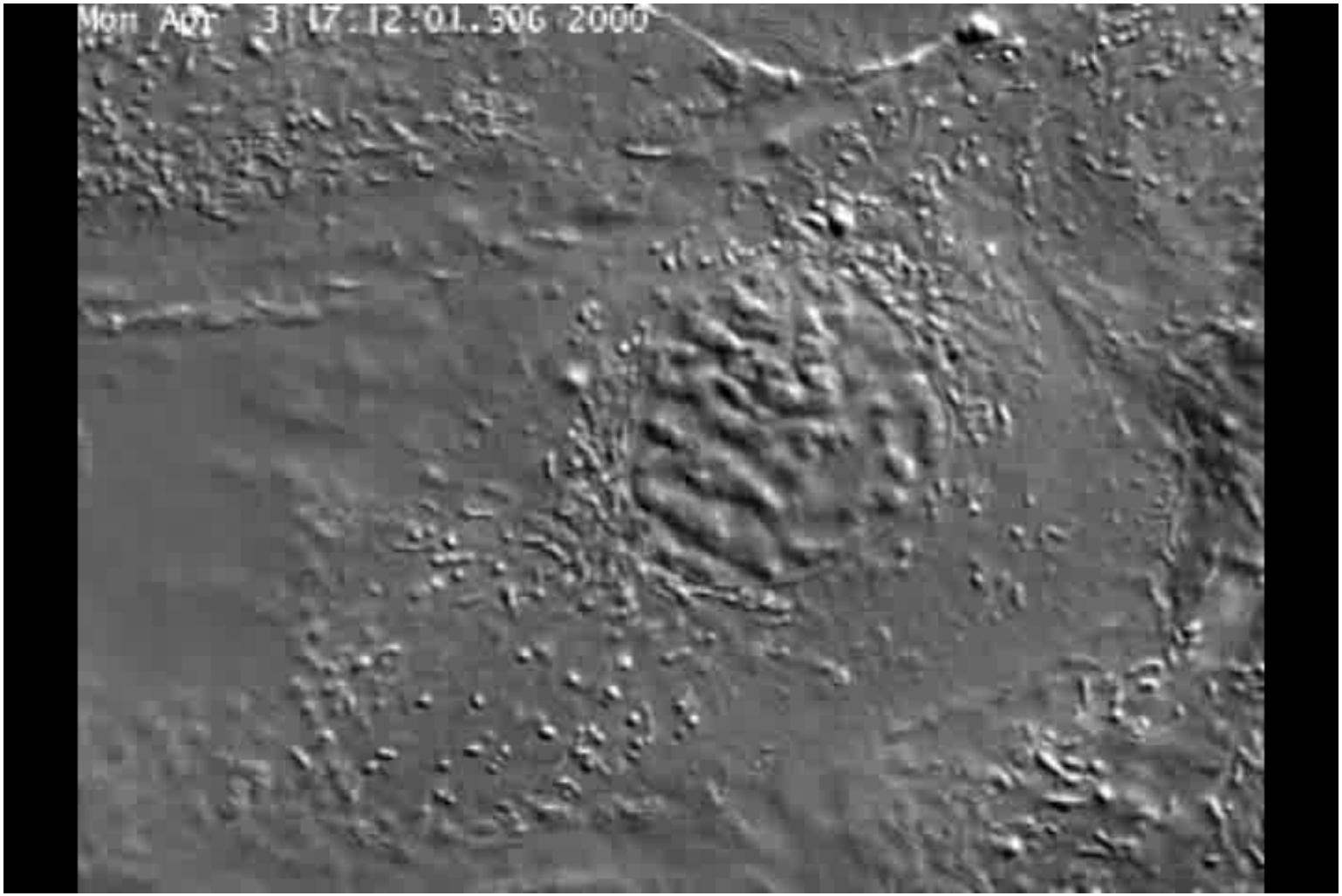
- I-PMAT-C
  - Interphase
  - Prophase
  - Metaphase
  - Anaphase
  - Telophase
  - Cytokinesis



Dude, mitosis starts in five minutes...
I can't believe you're not condensed yet.




BioFlix
Mitosis
PEARSON
Benjamin
Cummings
Copyright © 2007 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

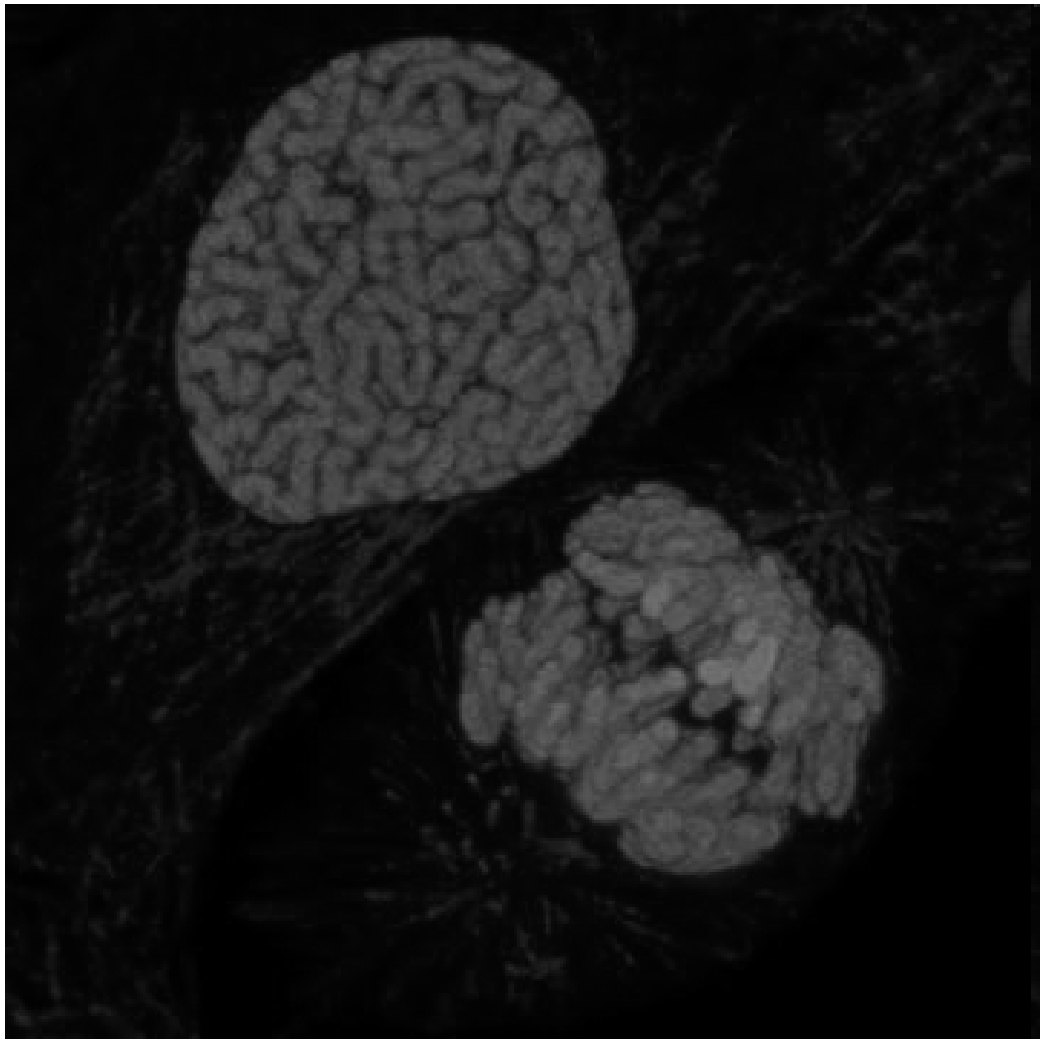

Mon Apr 3 17:12:01.306 2000

Let’s review so far. . .

- How many parent cells?
- How many daughter cells?
- How many times did the DNA replicate/duplicate/copy before division?
- How many mitotic divisions are there in each cycle?
- How many chromosomes in daughter cells?
- How are the daughter cells related to each other? Why?
- How are the daughter cells related to the parent cell? Why is this important?
- What is a sister chromatid? How are they related?

Influences on cell division

- Chemical factors
- Physical factors

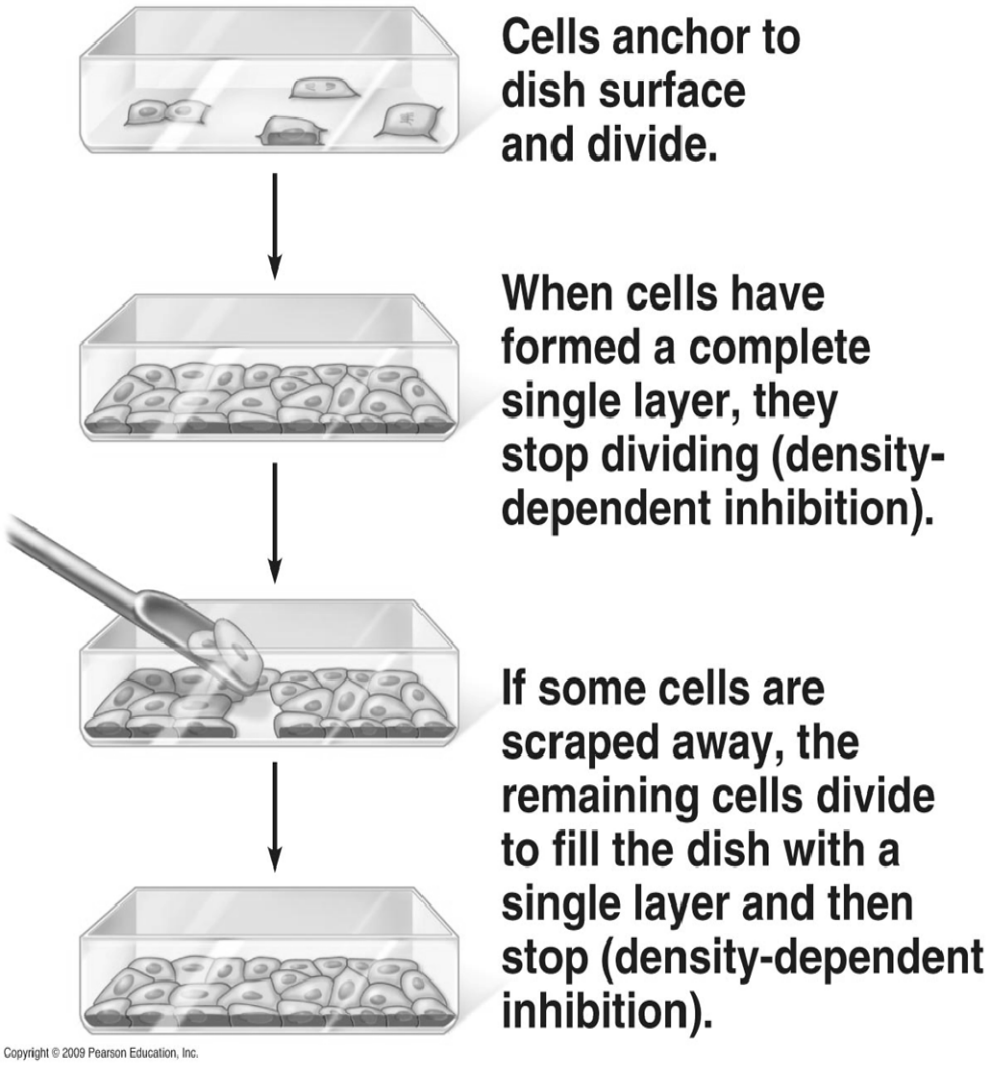


Chemical factors

- *Growth factors*; proteins that are released from one cell signaling another cell to divide
  - different cell types respond to different growth factors

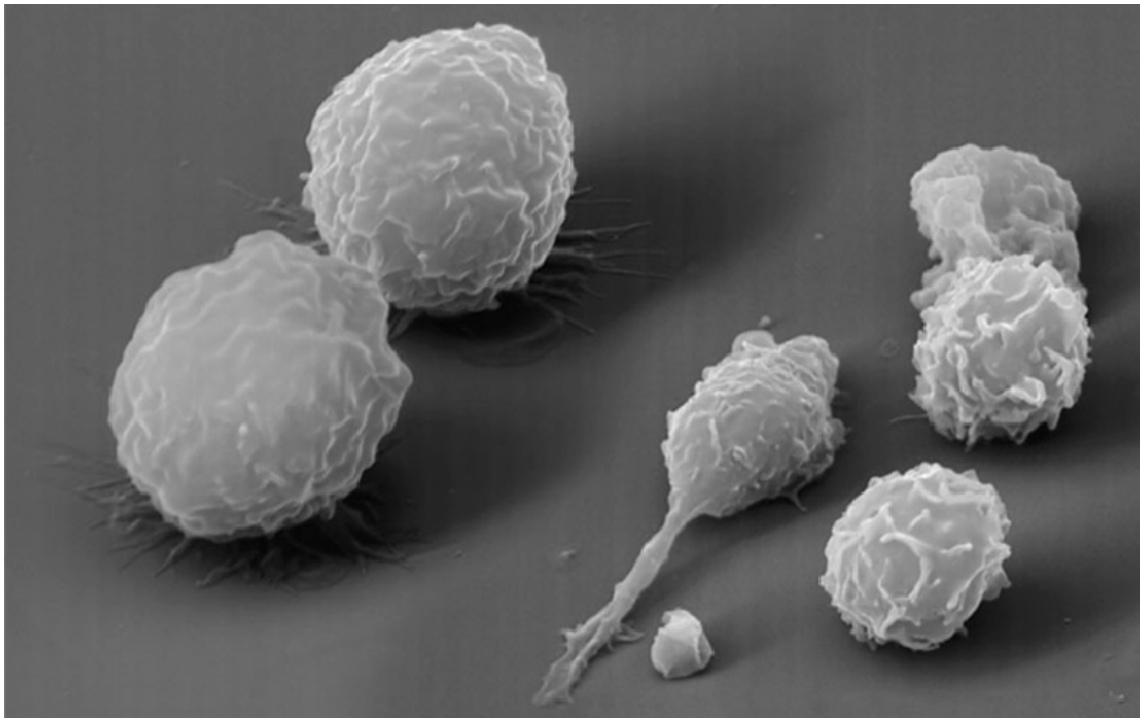
Physical factors

- Density-dependent inhibition
  - a condition where crowded cells stop dividing
- Anchorage dependence
  - cells must be in contact with a solid surface to divide



What happens when the cell cycle malfunctions?

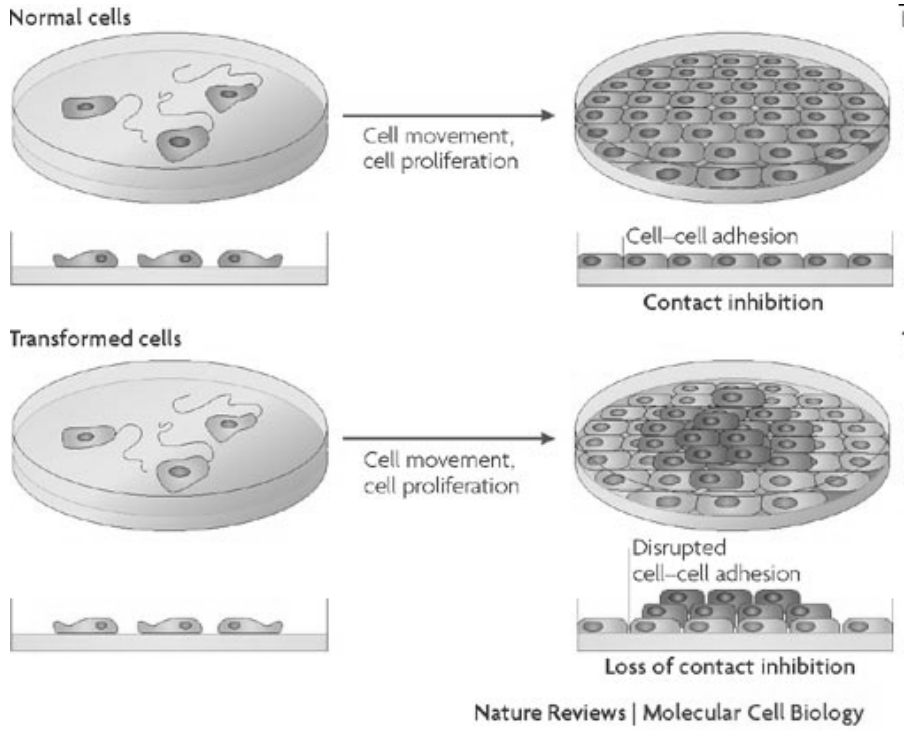
- Cancer
  - disease of cell cycle

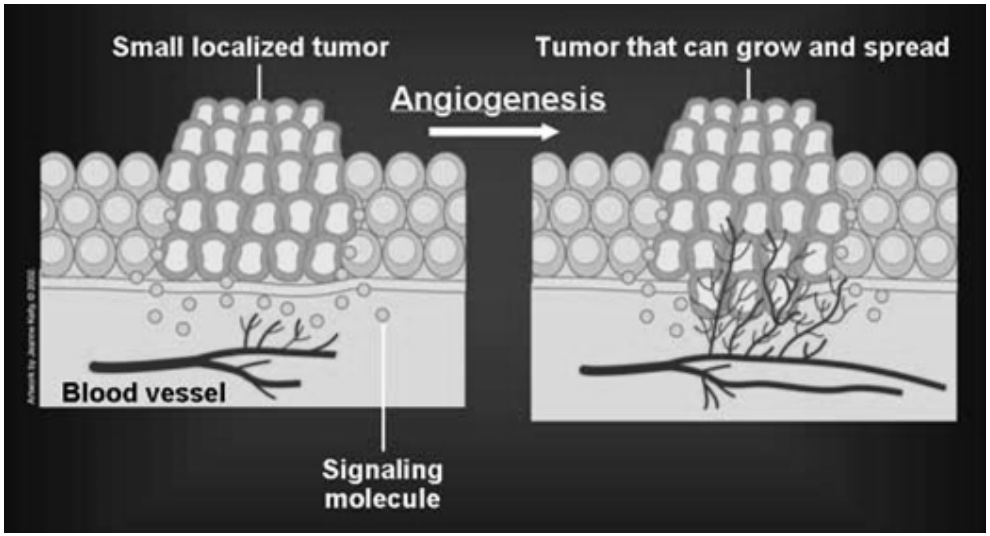


Cancerous leukemia cells (L) & normal marrow cells (R)

Cancer cells are not normal

- Larger & may have lost specialized features of parent cell
- Produce their own signals to divide
- Do not display growth inhibition
- No adhesion dependence
- Can stimulate the development of blood vessels
- Are essentially immortal (“HeLa” cells, 1951)

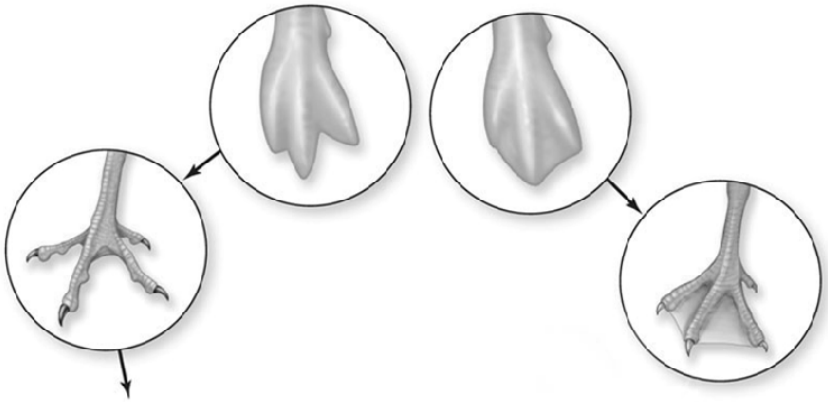




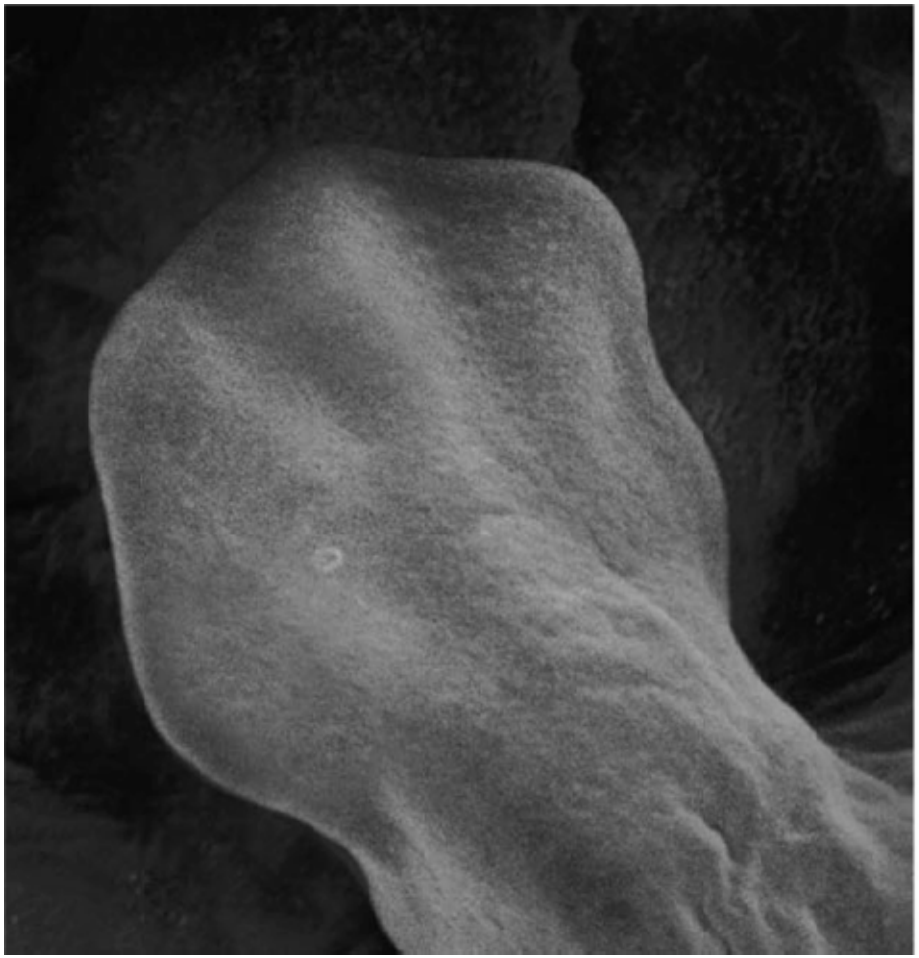
Cell death: part of the life

- Called *apoptosis*
- Part of the life of a cell (most cells divide ~50 times)
- Eliminates excess cells, especially during embryonic development
- Some research suggests it is the default option in cell cycle that needs to be overcome for mitosis to continue
  - for protection, ex. skin peel after sunburn

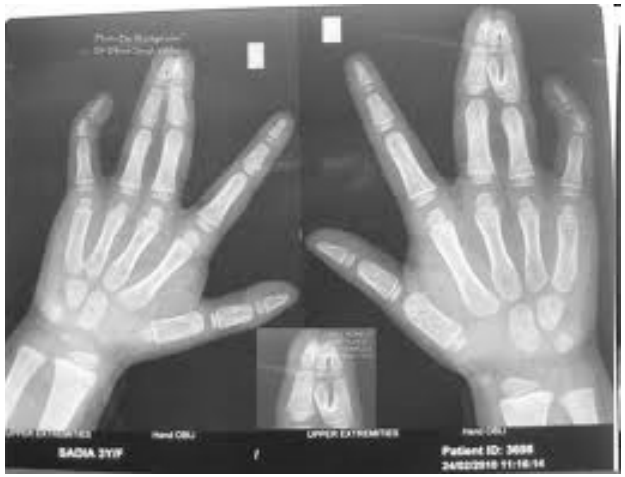
Apoptosis in development of digits



Apoptosis of human hand



Malfunction of apoptosis: syndactyly



Then what happens?

- After a cell's "death receptor" receives signal to die, apoptosis-specific enzymes begin to destroy the cell's proteins

- It's all over in about an hour and the immune system takes over, engulfing the remains (phagocytosis!!)

Quick mitosis summary

- Purpose
  - asexual reproduction
  - growth
  - replace and repair damaged cells
- Process
  - DNA replication
  - division of cell
- Products
  - 2 genetically identical daughter cells

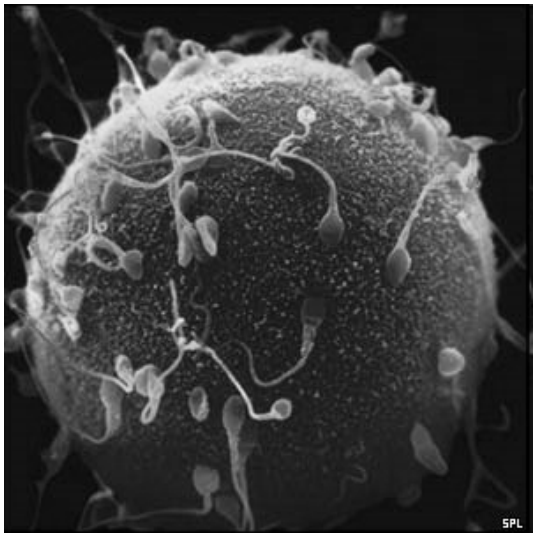
Asexual reproduction by mitosis

- Advantages
  - reproduce without a mate
  - can produce lots of offspring
  - all individuals can potentially reproduce

- Disadvantages
  - no genetic diversity

Sexual reproduction

- When two different parents contribute DNA to the offspring
- The offspring are the result of *fertilization*
  - the unification of two gametes (sperm & egg)
- Results in genetically unique offspring

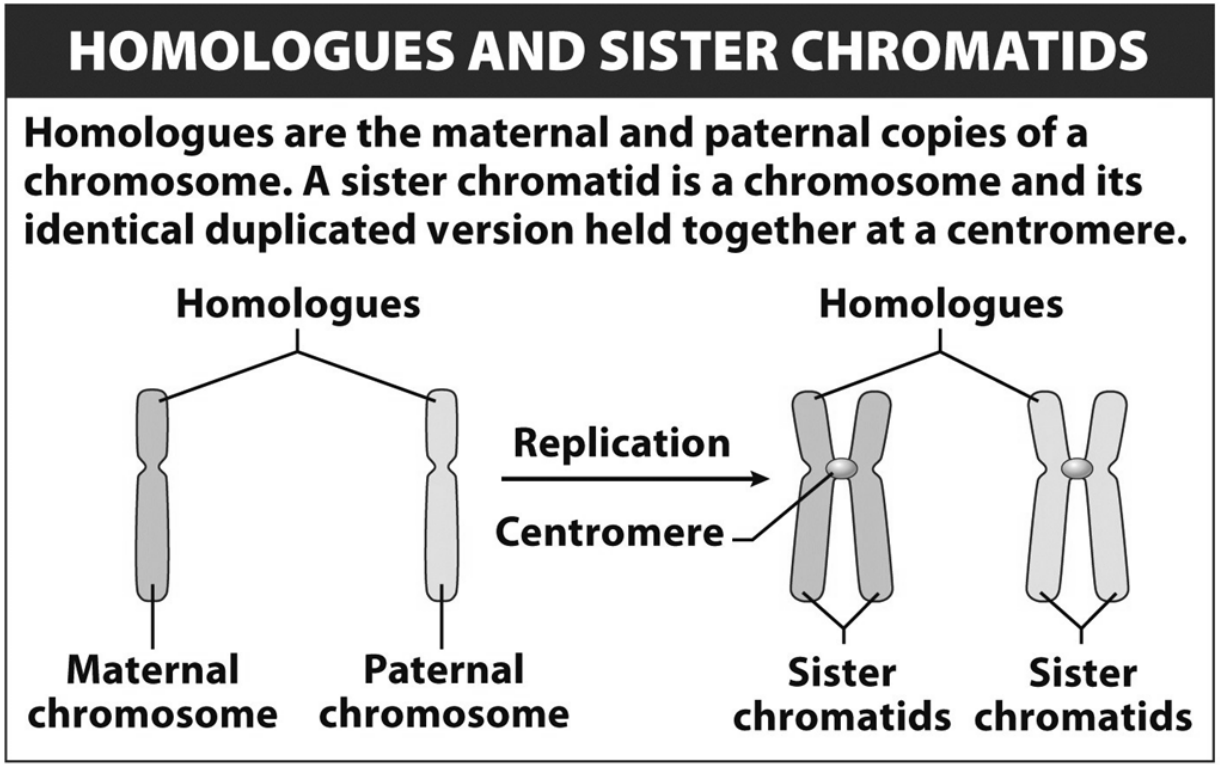


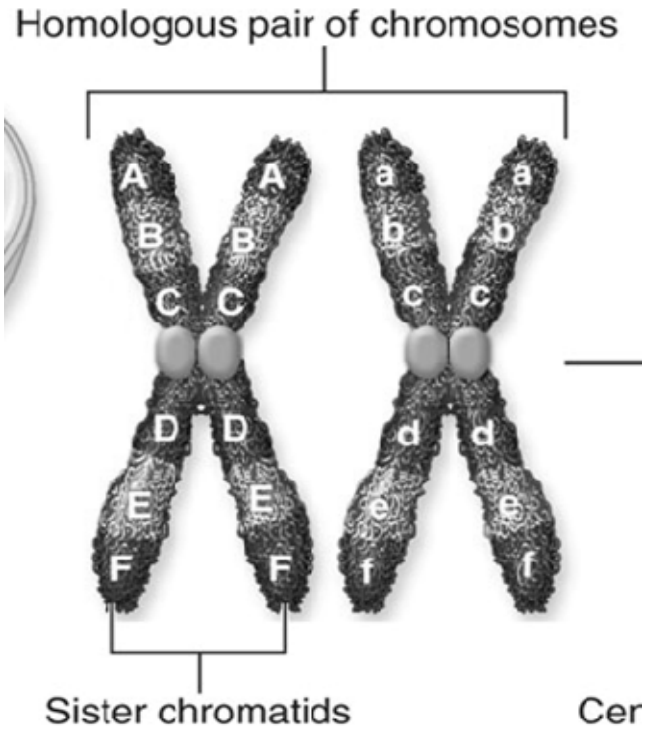
Meiosis: the production of gametes

- Meiosis is a special type of cell division that only produces gametes; takes place in ovaries & testes
- Gametes have only 1/2 the number of chromosomes as the rest of the cells in an organism (Why?)
- Diploid refers to cells that have 2 sets of chromosomes (all somatic cells)
  - humans have 2 sets of 23 chromosomes
- Haploid refers to cells that have 1 set of chromosomes (ONLY gametes)
- There are *two* cell divisions necessary in meiosis to produce *four* haploid daughter cells

Homologous chromosomes

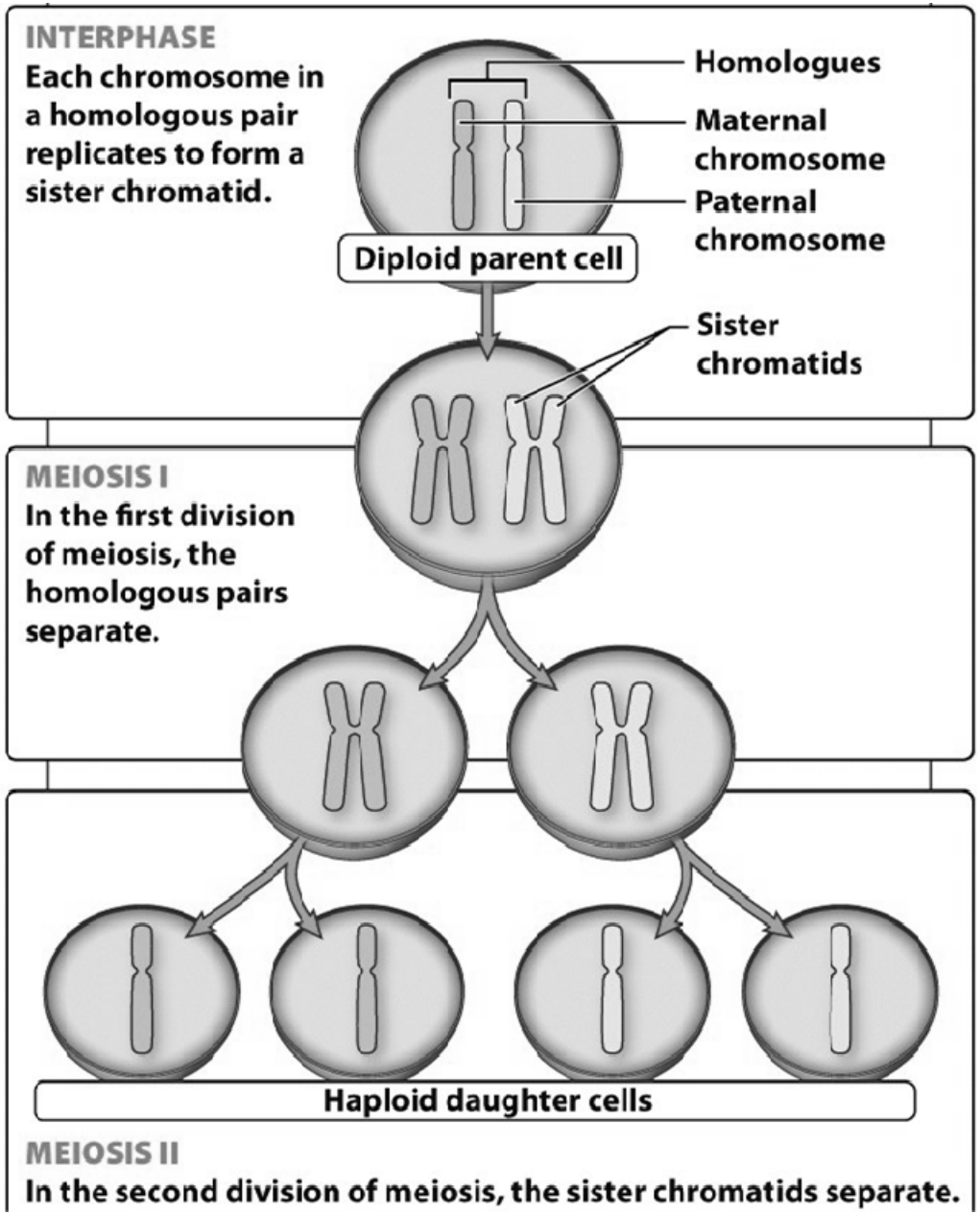
- The matching chromosomes of a pair, one from each parent, that carry the same genes, in the same order
- May have different *alleles* (versions) for each gene





Big picture of the two cell divisions

- Meiosis I
  - separation of homologous chromosomes
- Meiosis II
  - separation of sister chromatids



Interphase before meiosis I

- DNA replicates

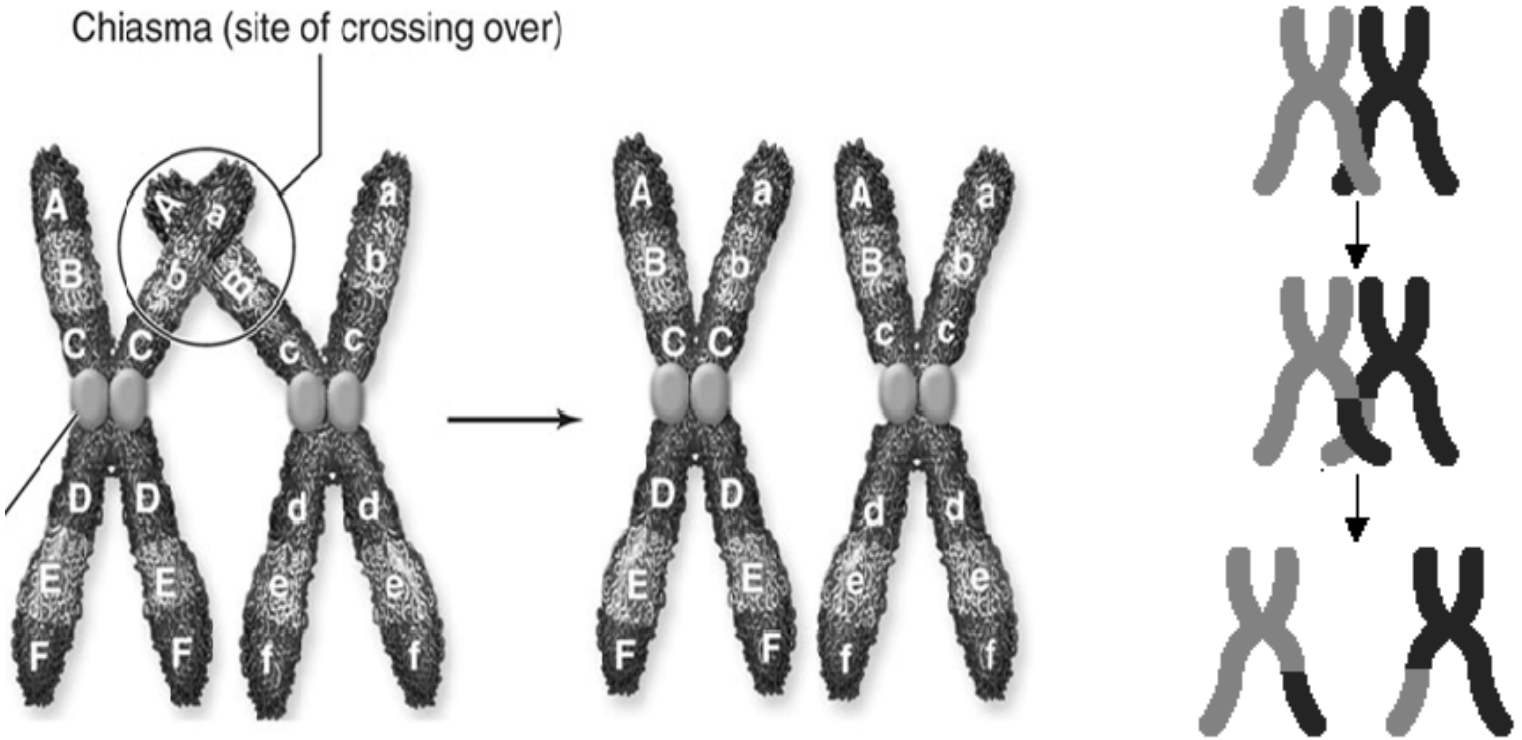
- **Cells that undergo meiosis do not have a cell cycle
  - gametes produced do not also go through meiosis; it's a one way street

Meiosis I: a lot happens!

- Prophase I
  - chromosomes condense
  - homologous chromosomes pair up & *crossing over* takes place
    - increases genetic diversity!
  - nuclear membrane disappears
  - spindle fibers form

Crossing over

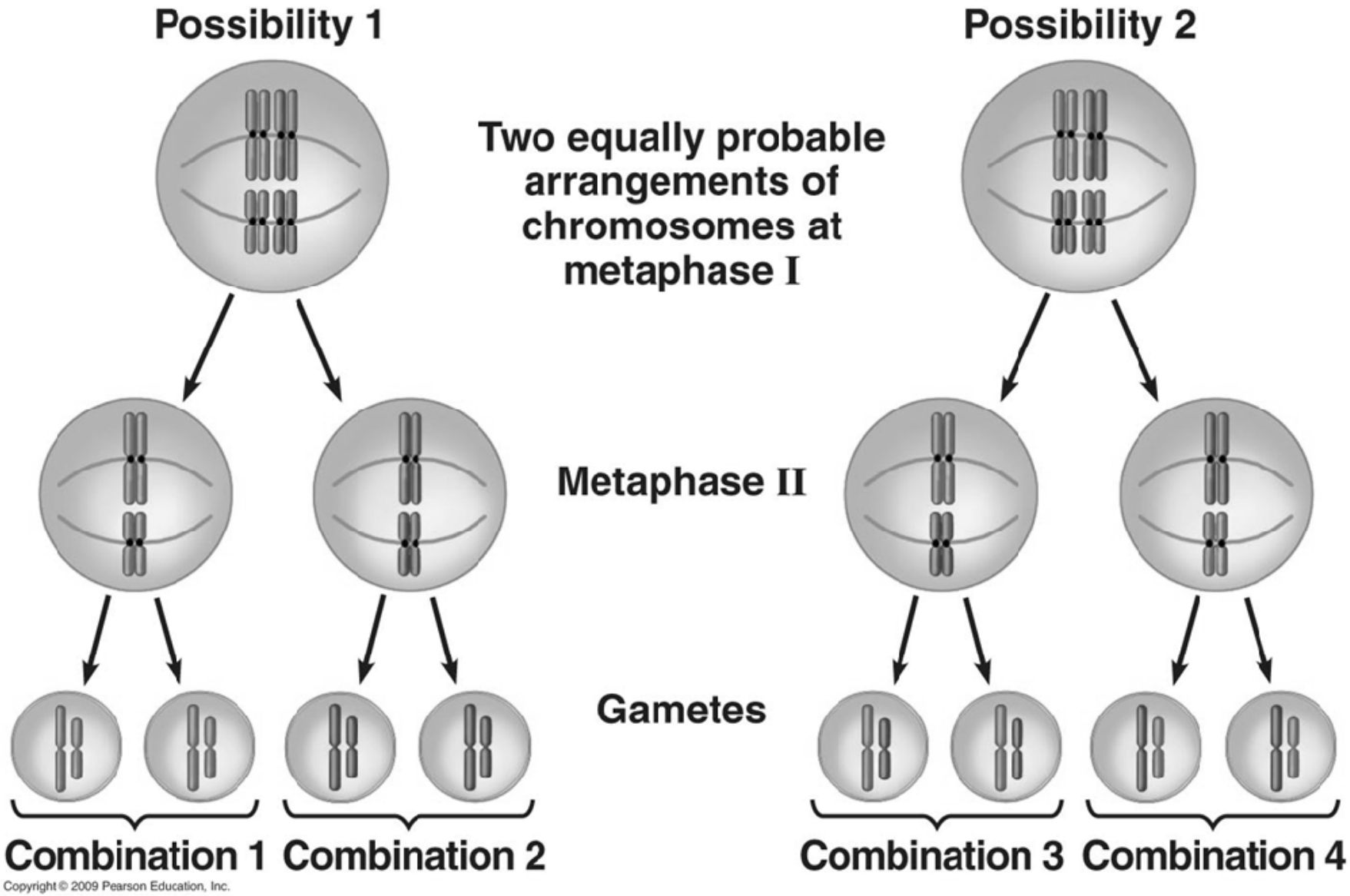
- The exchange of genes between homologous chromosomes
- Creates new combinations of alleles
- Occurs between non-sister chromatids. Why?



Meiosis I: a lot happens!

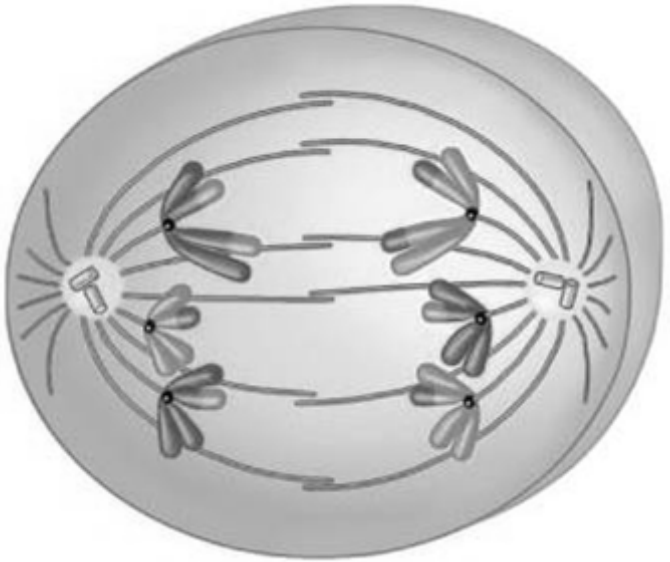
- Metaphase I
  - homologous pairs meet in the middle & independent orientation takes place
    - increases genetic diversity!

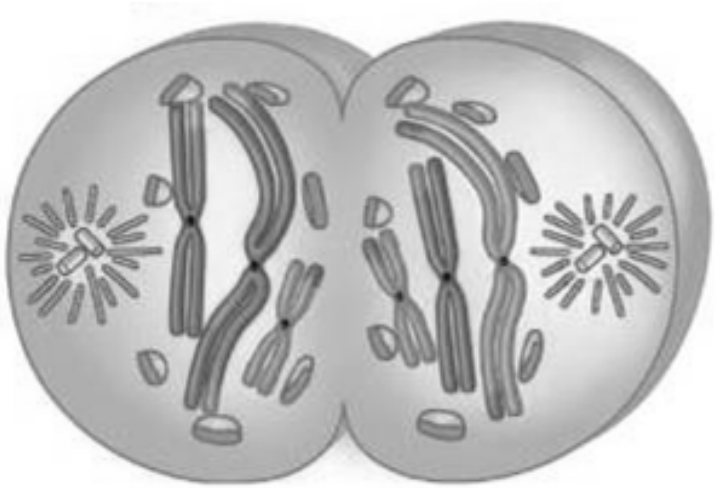
Independent assortment



Meiosis I: a lot happens

- Anaphase I
  - homologous chromosomes separate
- Telophase I & cytokinesis
  - nuclear membrane reforms & cytoplasm divides
  - 2 genetically unique, haploid daughter cells are produced





Meiosis II

- Basically the same as mitosis, but starting with a haploid cell
  - Prophase II
    - chromosomes condense (varies by species)
    - nuclear membrane disappears & spindles fibers form
  - Metaphase II
    - sister chromatids meet in the middle
  - Anaphase II
    - sister chromatids separate
  - Telophase II & cytokinesis
    - haploid daughter cells form (sperm or eggs)


BioFlix
Meiosis
PEARSON
Benjamin
Cummings
Copyright © 2007 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

Origins of genetic diversity

- Crossing over
  - mixes genes anywhere on chromosome (prophase I)
- Independent assortment
  - the way the homologous chromosomes meet in the middle (metaphase I)
- Fertilization
  - haploid sperm & haploid egg fuse to make diploid *zygote*

Sexual reproduction

- Advantages
  - genetic diversification (**This is a big one!! Why is genetic diversity important?)
- Disadvantages
  - requires a mate
    - may not be readily available
    - finding and keeping a mate is time consuming and expensive (resources)
  - not all individuals get to reproduce
  - not all offspring will be well adapted

Meiosis summary

- Purpose
  - reduce # of chromosomes from diploid to haploid (make gametes)
  - (Why do they have to be haploid?)
- Process
  - DNA replicates (when does this happen?)
  - division of cell
  - 2nd division of cell
- Product
  - 4 genetically unique, haploid daughter cells

Let's review (again). . .

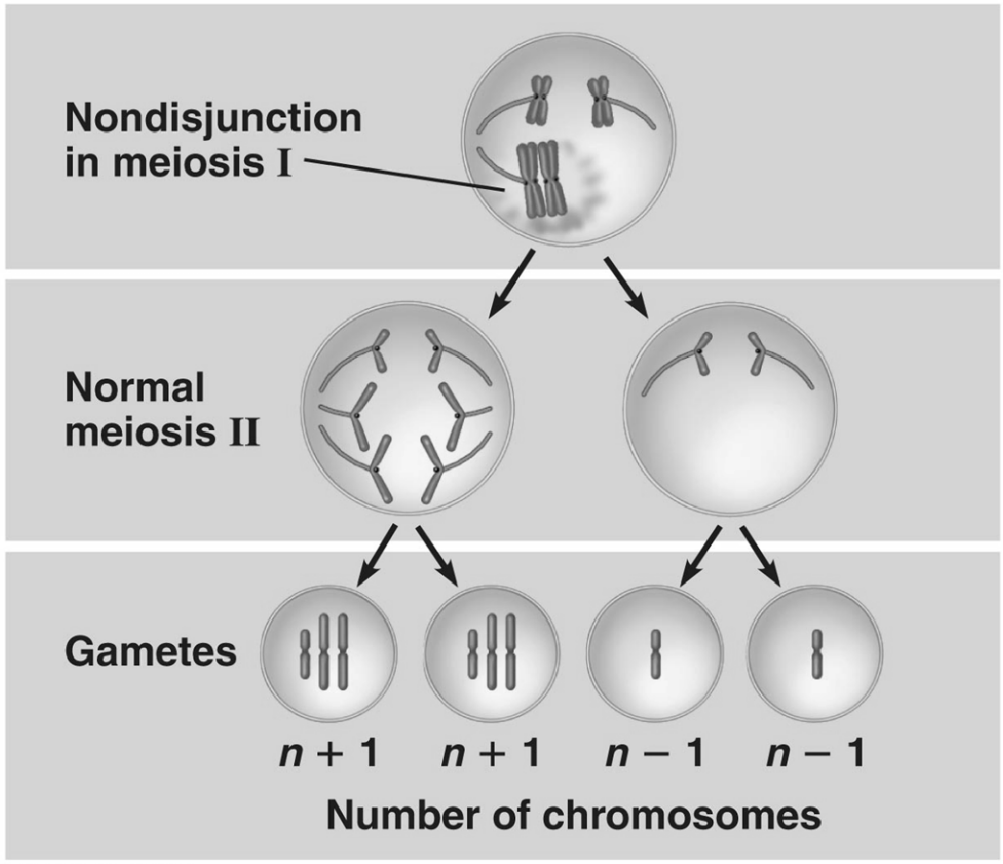
- How many parent cells in meiosis?
- How many daughter cells after meiosis?
- How many times did the DNA replicate/duplicate/copy before meiosis began?
- How many divisions are there?
- How many chromosomes in daughter cells?
- How are the daughter cells related to each other? Why?
- How are the daughter cells related to the parent cell? Why is this important?

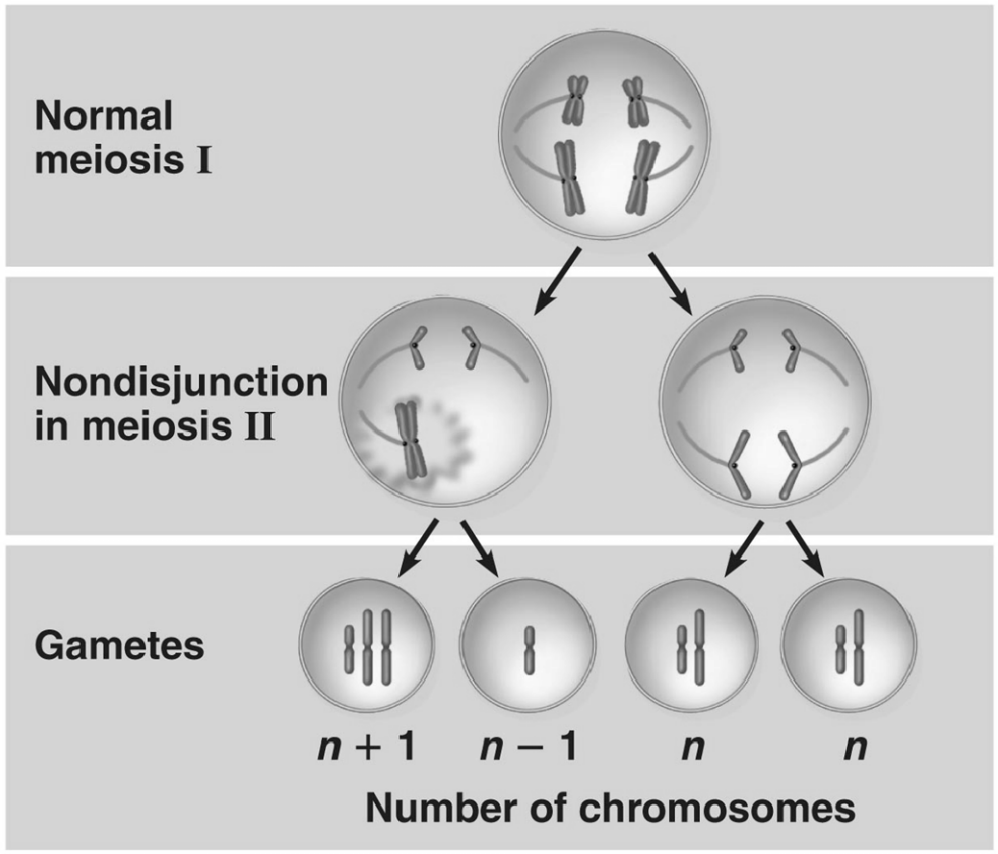
- What is the difference between sister chromatids & homologous chromosomes?
- What does diploid mean? What cells in humans are diploid?
- What does haploid mean? What cells in humans are haploid?
- Where does genetic diversity originate?

When meiosis goes wrong

- Non-disjunction: when members of a pair of chromosomes fail to separate
- Meiosis I
  - homologous chromosomes don't separate
- Meiosis II
  - sister chromatids don't separate
- Result: abnormal number of chromosomes in gamete (& then potentially in zygote)
- Unknown what causes non-disjunction

Non-disjunction



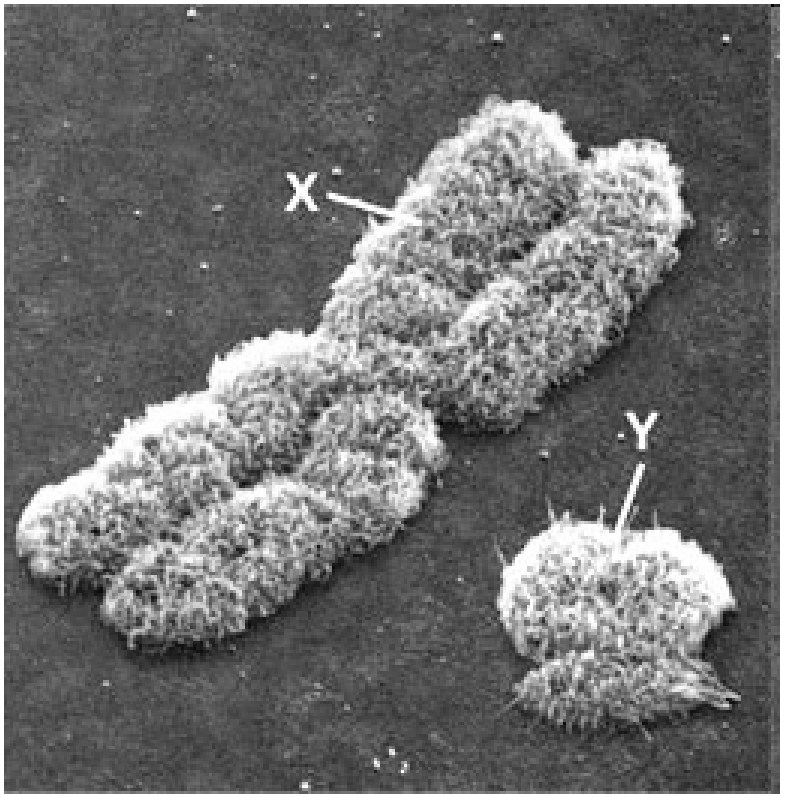


Non-disjunction of autosomal chromosomes

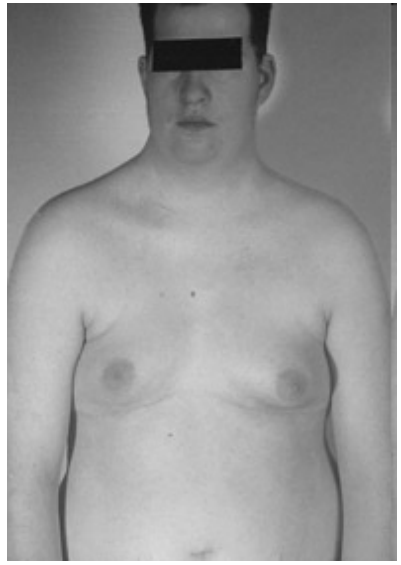
- Most result in spontaneous abortion (miscarriage) or death shortly after birth
- The exception: Trisomy 21(Down Syndrome)
  - 3 copies of chromosome 21
  - most common chromosomal number abnormality
    - this is slightly misleading. . .

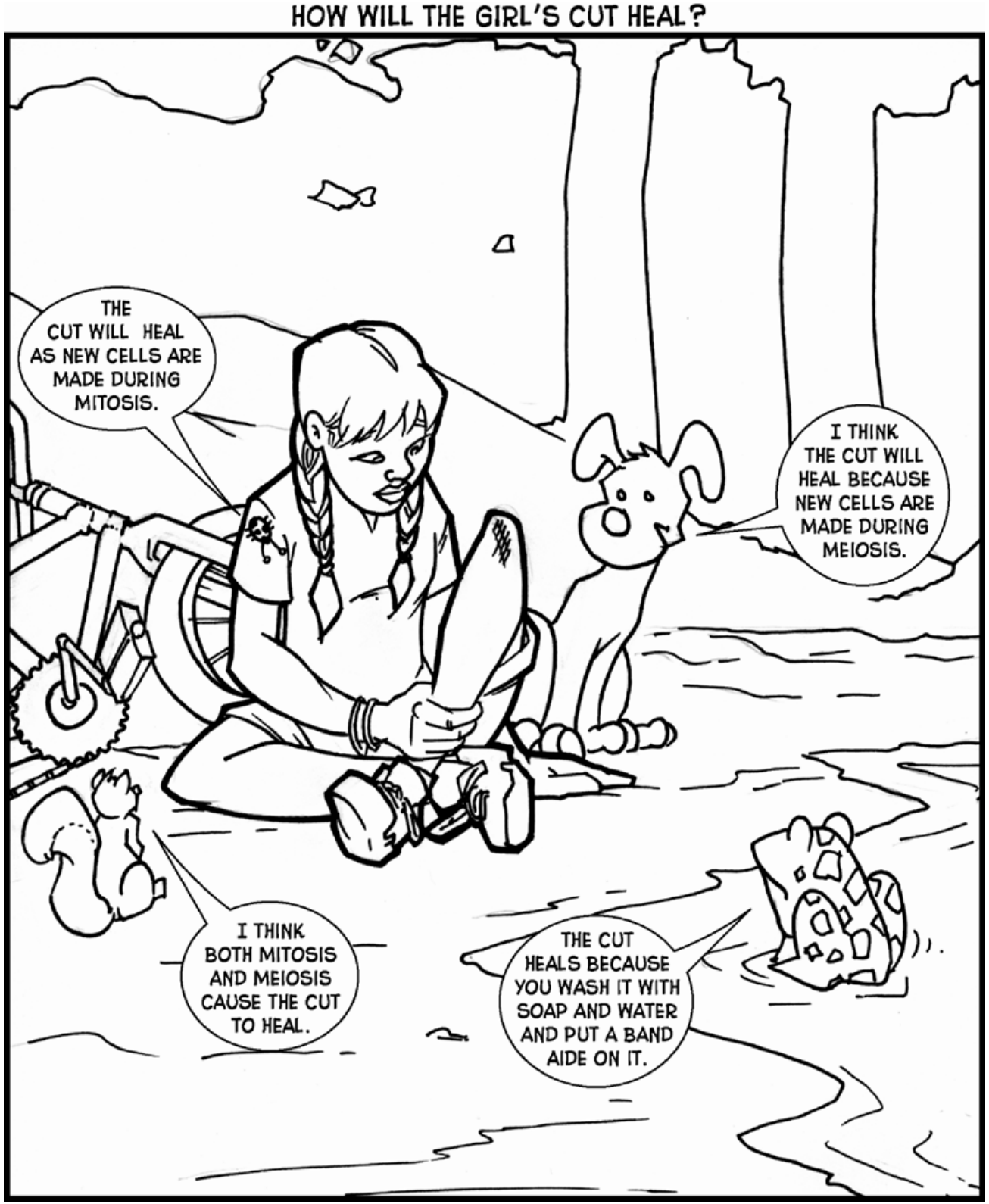
Non-disjunction of sex chromosomes

- Seems to upset the balance less than autosomal abnormalities
  - may be because Y chromosome carries relatively few genes
  - may be because in females, one X chromosome is randomly deactivated in each cell



Sex chromosomes	Syndrome	Characteristics
XXY (most common)	Klinefelter syndrome (male)	Underdeveloped testes, sterile; often includes breast enlargement & other female body characteristics; normal intelligence
XYY	none (normal male)	cannot be distinguished from XY male except by karyotype
XXX	none (normal female)	cannot be distinguished from XX female except by karyotype
XO (the only known case when having only 45 chromosomes is not fatal	Turner syndrome (female)	short in stature & often a web of skin b/w neck and shoulders; underdeveloped ovaries, sterile; poor development of secondary sex characteristics




HOW WILL THE GIRL'S CUT HEAL?
THE CUT WILL HEAL AS NEW CELLS ARE MADE DURING MITOSIS.
I THINK THE CUT WILL HEAL BECAUSE NEW CELLS ARE MADE DURING MEIOSIS.
I THINK BOTH MITOSIS AND MEIOSIS CAUSE THE CUT TO HEAL.
THE CUT HEALS BECAUSE YOU WASH IT WITH SOAP AND WATER AND PUT A BAND AIDE ON IT.