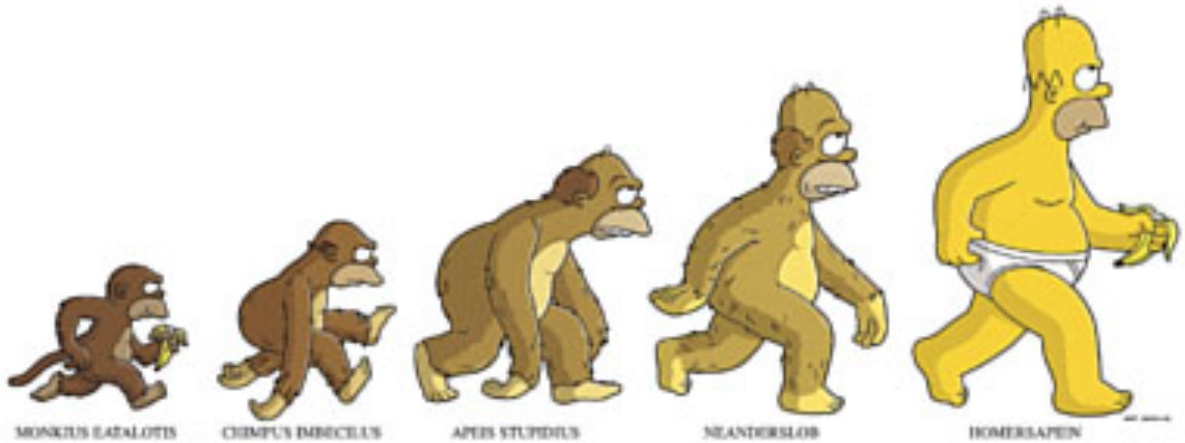
Cell Division

Biology 30i

Jon Paul Cooper



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Cell Division
I) Introduction

Cell Division

I) Introduction

- nucleic acids are biological chemicals that direct the growth and development of every organism.
  - there are two types:
    - RNA (ribonucleic acid)
    - DNA (deoxyribonucleic acid)

Cell Division

I) Introduction

- there are two types:
  - RNA (ribonucleic acid)
  - DNA (deoxyribonucleic acid)
- DNA is the main component of genes in all cells
  - each gene contains instructions for making RNA
    - RNA contains instructions for making proteins.
- proteins make up the structures of a cell and controls how it functions.

Cell Division

I) Introduction

- RNA contains instructions for making proteins.
- proteins make up the structures of a cell and controls how it functions.
- the majority of organism have no true nucleus
  - we call these organisms “prokaryotes”

    “pro” meaning before

    “karyon” meaning nucleus
  - the prokaryotes are divided into two domains:
    - Bacteria
    - Archaea

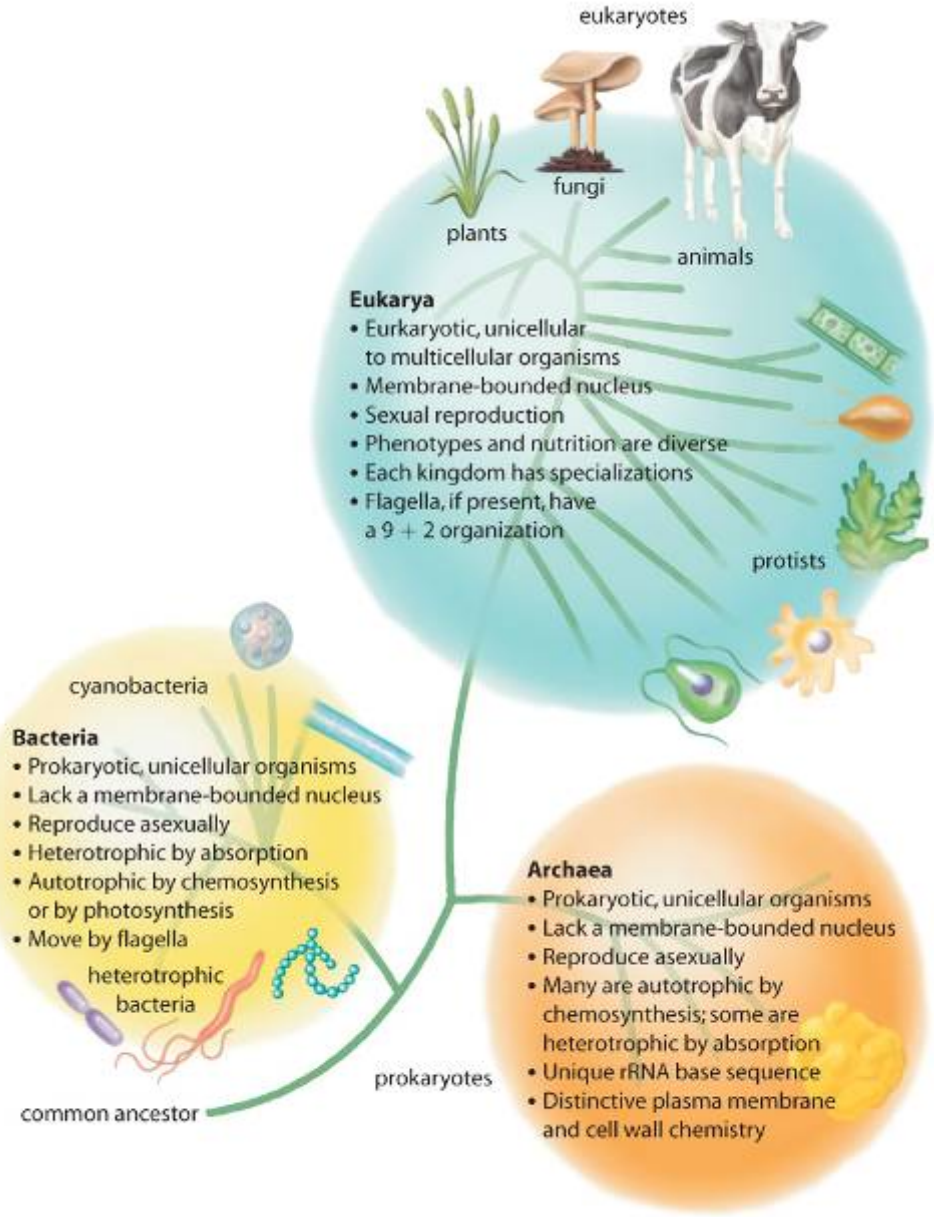

Figure P7.1 Two of the three domains of life contain prokaryotic organisms. The remaining domain contains eukaryotic organisms, including humans.

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Cell Division

I) Introduction

- we call these organisms “prokaryotes”

  “pro” meaning before

  “karyon” meaning nucleus
- the proakaryotes are divided into two domains:
  - Bacteria
  - Archaea
- organisms with a true nucleus are called eukaryotes

  “eu” meaning true

  “karyon” meaning nucleus
  - eukaryotic cells have organelles that are specialized to perform tasks much like cells of the human body are differentiated to perform tasks.

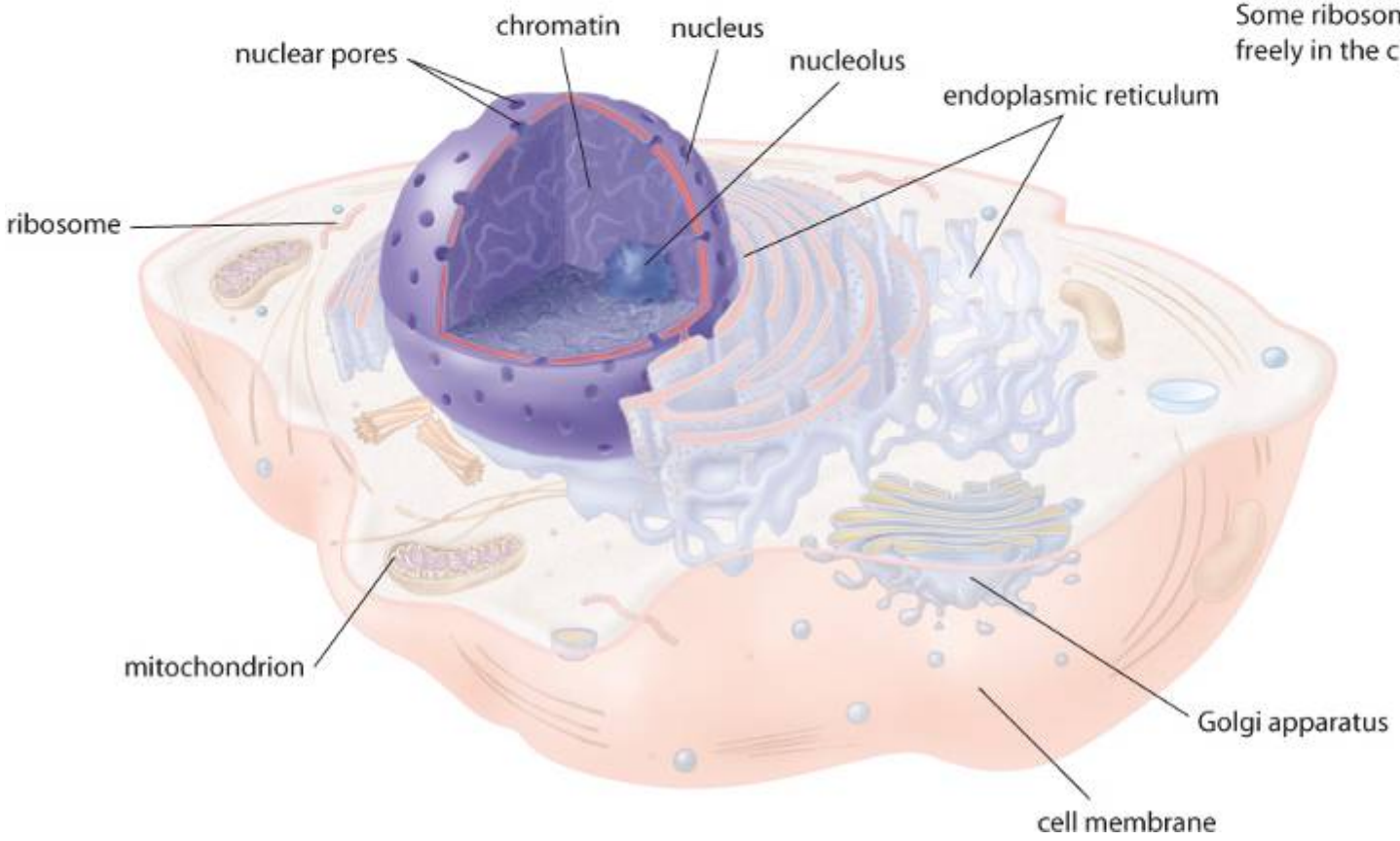

Figure P7.2 The cell nucleus and related structures. Continuous with the outer membrane of the nuclear envelope is a system of flattened membrane-bound sacs, the endoplasmic reticulum, studded with protein-synthesizing ribosomes. Some ribosomes also float freely in the cytoplasm.

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Cell Division

I) Introduction

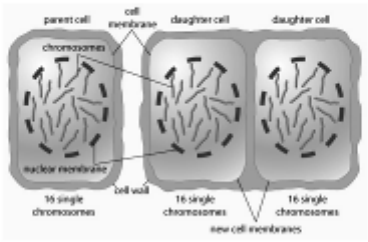
Cell Division Activity

CHAPTER 16 | HANDOUT

Launch Lab: Cell Division

BLM 16.0

Purpose: How are these new, genetically identical cells produced?



Procedure

1. The diagrams show onion root-tip cells before and after the cells have divided to form new cel
   The tip of an onion root-tip is an active growing region. The cells in this region are actively dividing to produce new cells.
2. Study the diagrams. Compare the number and characteristics of the chromosomes in the paren cell to the number of chromosomes in the two daughter cells.

Analysis

1. What do you notice about the number of chromosomes in the parent cell compared to the num of chromosomes in the two daughter cells?

2. What do you notice about the characteristics of each chromosome in the three cells?

CHAPTER 16 | HANDOUT

Launch Lab: Cell Division (cont'd)

BLM 16.0.3

3. How do you think it is possible to start with 16 chromosomes in the parent cell and end up with 16 chromosomes in each of the two daughter cells?

4. A somatic cell in humans contains 46 chromosomes. If this cell divides, how many chromosomes do you think will appear in the two new daughter cells?

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Cell Division
II) The Cell Cycle

Cell Division
II) The Cell Cycle

A) Introduction

"growth comes about by the addition of new cells, not the ever increasing size of just one cell"

- as cells grow in size the volume of its cytoplasm increases at a faster rate than the surface area of plasma membrane
  - the cell absorbs nutrients and excretes wastes through its plasma membrane.
  - if the cell continues to grow the plasma membrane will be too small to meet the cells metabolic needs (cell can only be a certain maximum size)

Cell Division

II) The Cell Cycle

- the cell absorbs nutrients and excretes wastes through its plasma membrane.
- if the cell continues to grow the plasma membrane will be too small to meet the cells metabolic needs (cell can only be a certain maximum size)
- remember that cells need to keep a large surface area to volume ratio

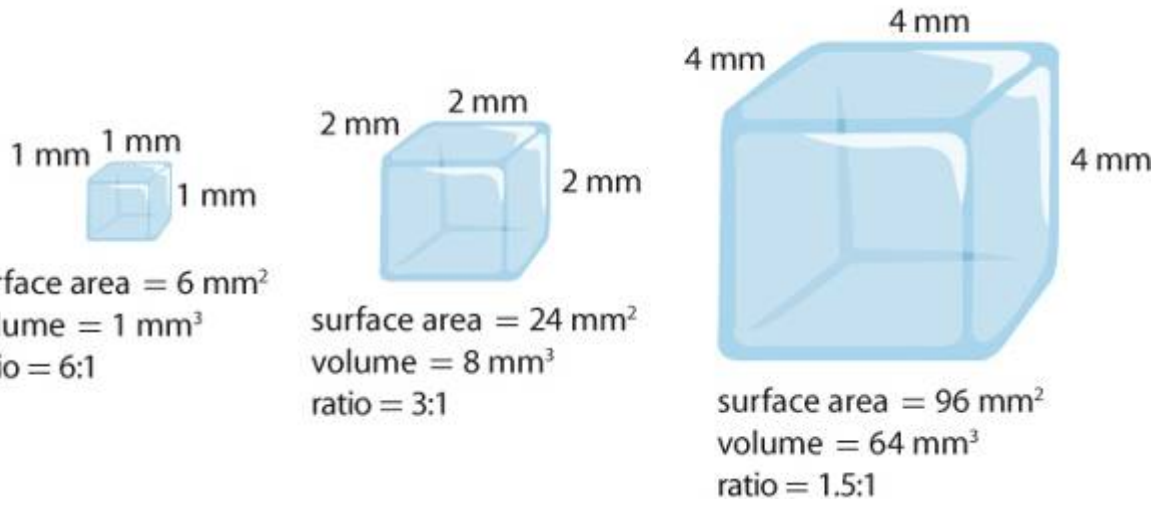


Figure 16.1 The ratio of surface area to volume is a key factor that limits cell size. In these model cells, an increase in the length of the cell from 1 mm to 4 mm causes the ratio of surface area to volume to decrease from 6:1 to 1.5:1.

Cell Division
II) The Cell Cycle

B) Cell Division and the Cell Cycle

- the life cycle of the cell is called the cell cycle.
- body cells are called somatic cells (all cells other than gametes)
  - somatic cells have varying cell cycles.

    ex. blood and skin cells are replaced frequently

    nerve cells divide infrequently or not at all
- a single cell cycle is defined as the sequence of events from one cell division to the next.

Cell Division
II) The Cell Cycle

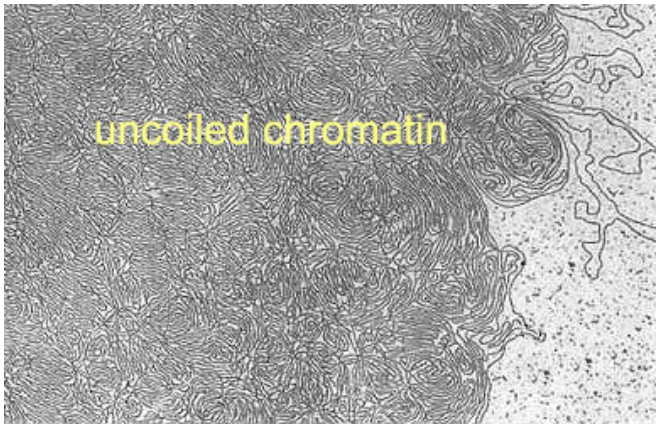
- somatic cells have varying cell cycles.
  - ex. blood and skin cells are replaced frequently
    nerve cells divide infrequently or not at all
- a single cell cycle is defined as the sequence of events from one cell division to the next.
- the central feature of the cell cycle is the way that genetic material is duplicated and then passed from the original cell (the parent cell) to each new cell (daughter cell)
  - the process is possible because of the highly organized genetic material within the cell.

Cell Division
II) The Cell Cycle

- the central feature of the cell cycle is the way that genetic material is duplicated and then passed from the original cell (the parent cell) to each new cell (daughter cell)
  - the process is possible because of the highly organized genetic material within the cell.
- the genetic information of a cell is contained in the DNA.
  - a chromosome
    - is a length of DNA and its associated proteins.
    - is found in the nucleus.
  - there is about 3 meters of DNA in a single human cell.
    - the diameter of a nucleus is only about 5 μm
      (this like stuffing 150 m of string into a lunch box)

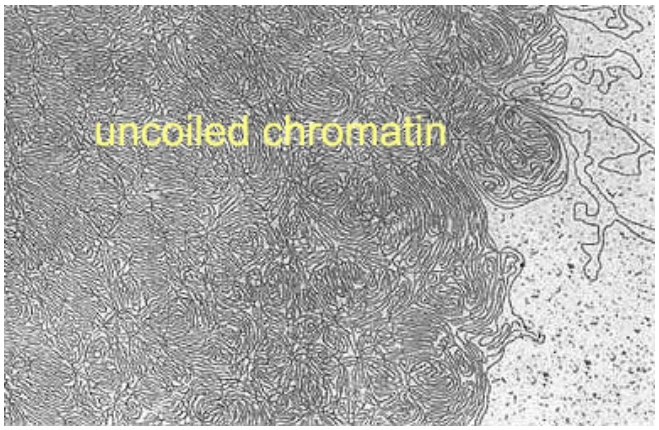
Cell Division
II) The Cell Cycle

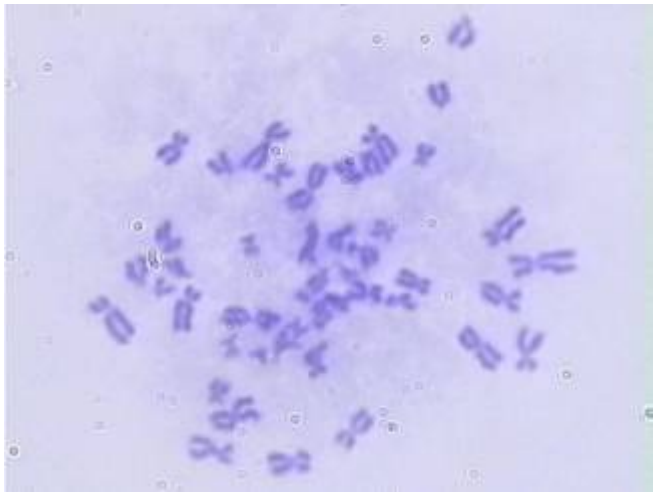
- there is about 3 meters of DNA in a single human cell.
  - the diameter of a nucleus is only about 5 μm
    (this like stuffing 150 m of string into a lunch box)
- a highly organized arrangement of proteins, called histones, and DNA compact the genetic material inside the nucleus.
  - for the majority of a cell's life genetic material appears as a mass of long, intertwined strands known as chromatin.



Cell Division
II) The Cell Cycle

- for the majority of a cell's life genetic material appears as a mass of long, intertwined strands known as chromatin.
- as genetic material is reorganized during the process of cellular division, the threads of chromatin condense and become distinct chromosomes.
  - the "pinched in" region in the chromosome is a specialized region called a centromere.





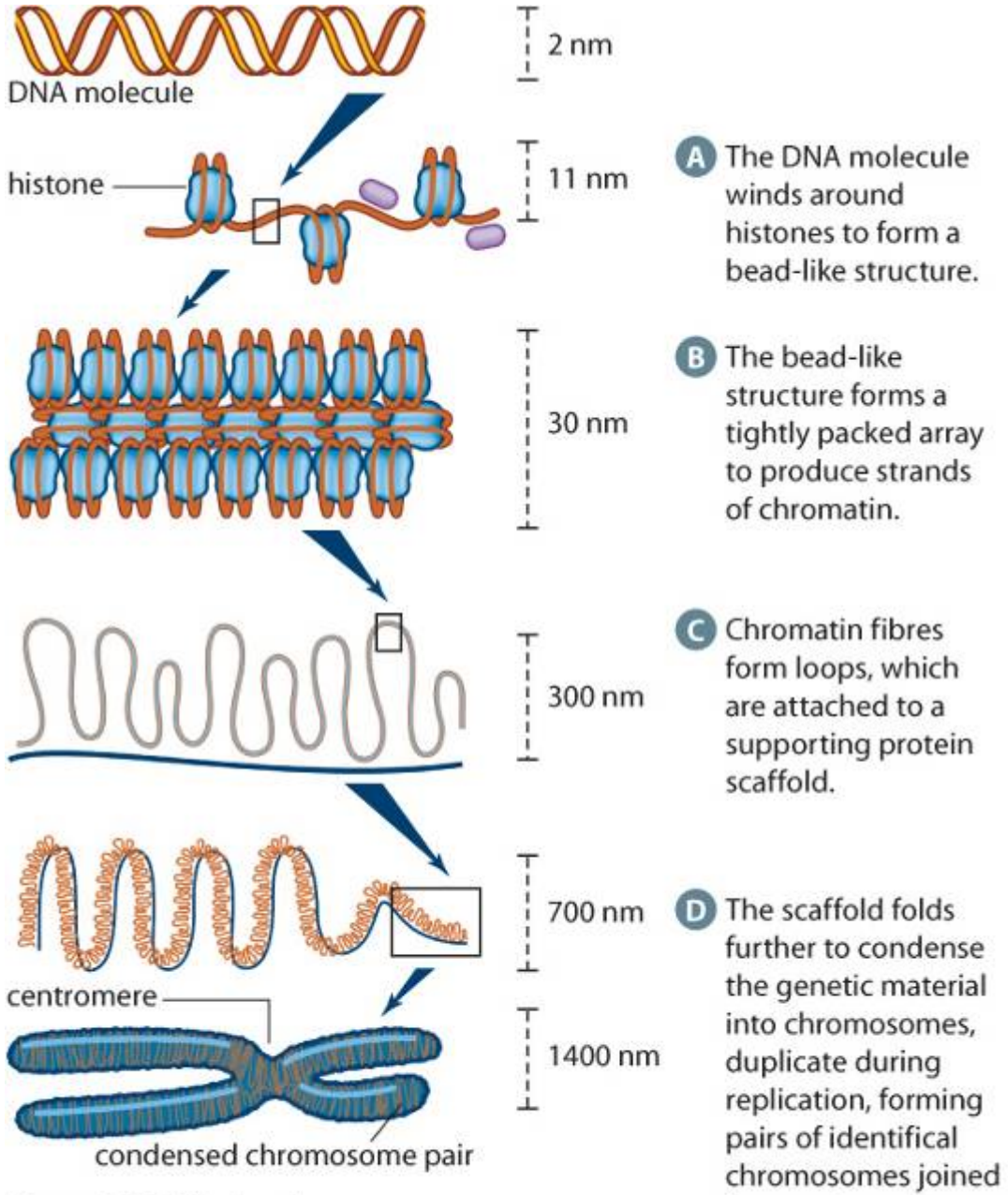
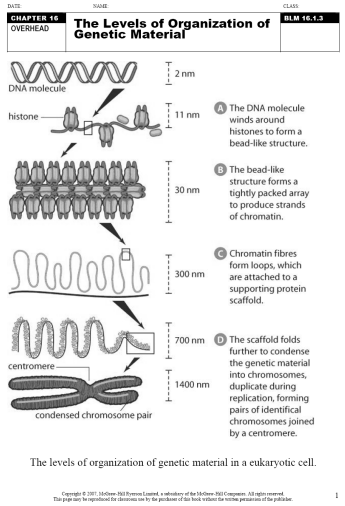


Figure 16.2 The levels of organization of genetic material in a eukaryotic cell

- as genetic material is reorganized during the process of cellular division, the threads of chromatin condense and become distinct chromosomes.
  - the "pinched in" region in the chromosome is a specialized region called a centromere.



The levels of organization of genetic material in a eukaryotic cell.

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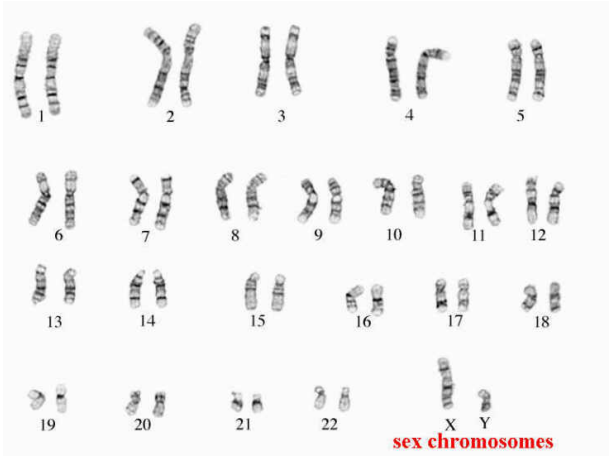
Cell Division
II) The Cell Cycle

- the number of individual chromosome numbers varies from species to species.
  - human somatic cells have 46 chromosomes
    - these 46 chromosomes can be organized into 22 pairs of homologous (similar in appearance) chromosomes
    - each somatic cell has two sex chromosomes

      xx ~ female (homologous pair)

      xy ~ male (pair)



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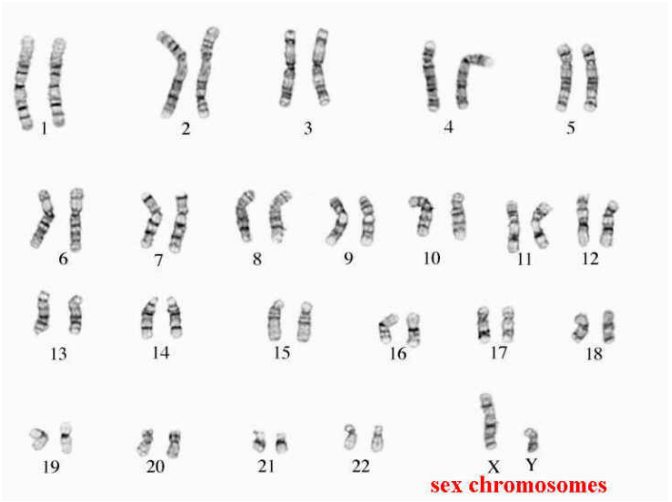
Cell Division
II) The Cell Cycle

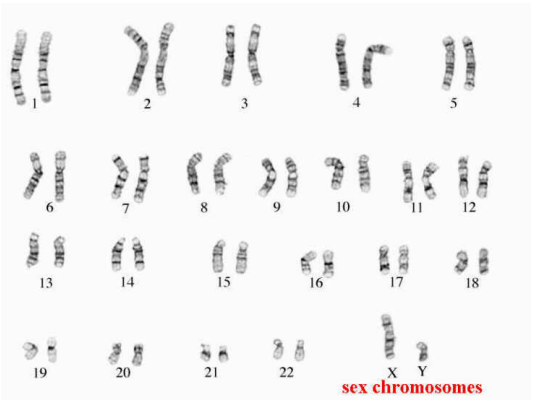


- each somatic cell has two sex chromosomes
  - xx ~ female (homologous pair)
  - xy ~ male (pair)

- homologous chromosomes
  - carry the same genes at the same location (locus)

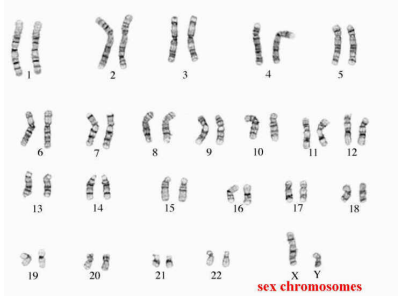
    (genes are areas of DNA that contain specific genetic information)
  - not identical to each other.
    - they carry different forms, or alleles, of the same gene

Cell Division
II) The Cell Cycle



- homologous chromosomes
  - carry the same genes at the same location (locus)
    (genes are areas of DNA that contain specific genetic information)
  - not identical to each other.
    - they carry different forms, or alleles, of the same gene
- a cell that contains pairs of homologous chromosomes is said to be diploid (Greek for “double”)
  - the diploid number in humans is 46 or 23 pair.
- a cell that contains unpaired chromosomes is said to be haploid (Greek for “single”)
  - human gametes are haploid.

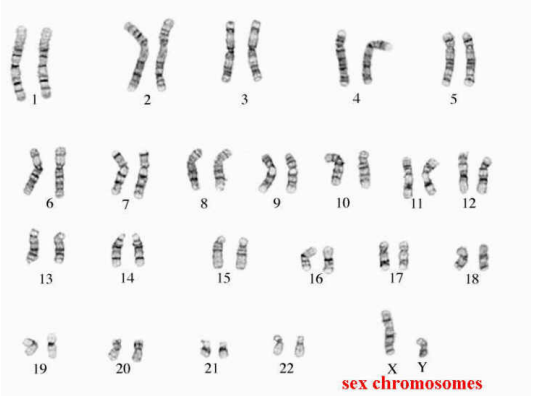
Cell Division
II) The Cell Cycle



- a cell that contains unpaired chromosomes is said to be haploid (Greek for "single")
  - human gametes are haploid.
  - diploid human cells are described as 2n=46 ("2n" meaning diploid)
  - haploid human cells are described as n = 23 ("n" meaning haploid)
    - in corn plants n = 10
    - in fruit flies n = 4
    - In the Ophioglossum fern upto 2n = 1400
    - in a hermit crab 2n = 254

Cell Division

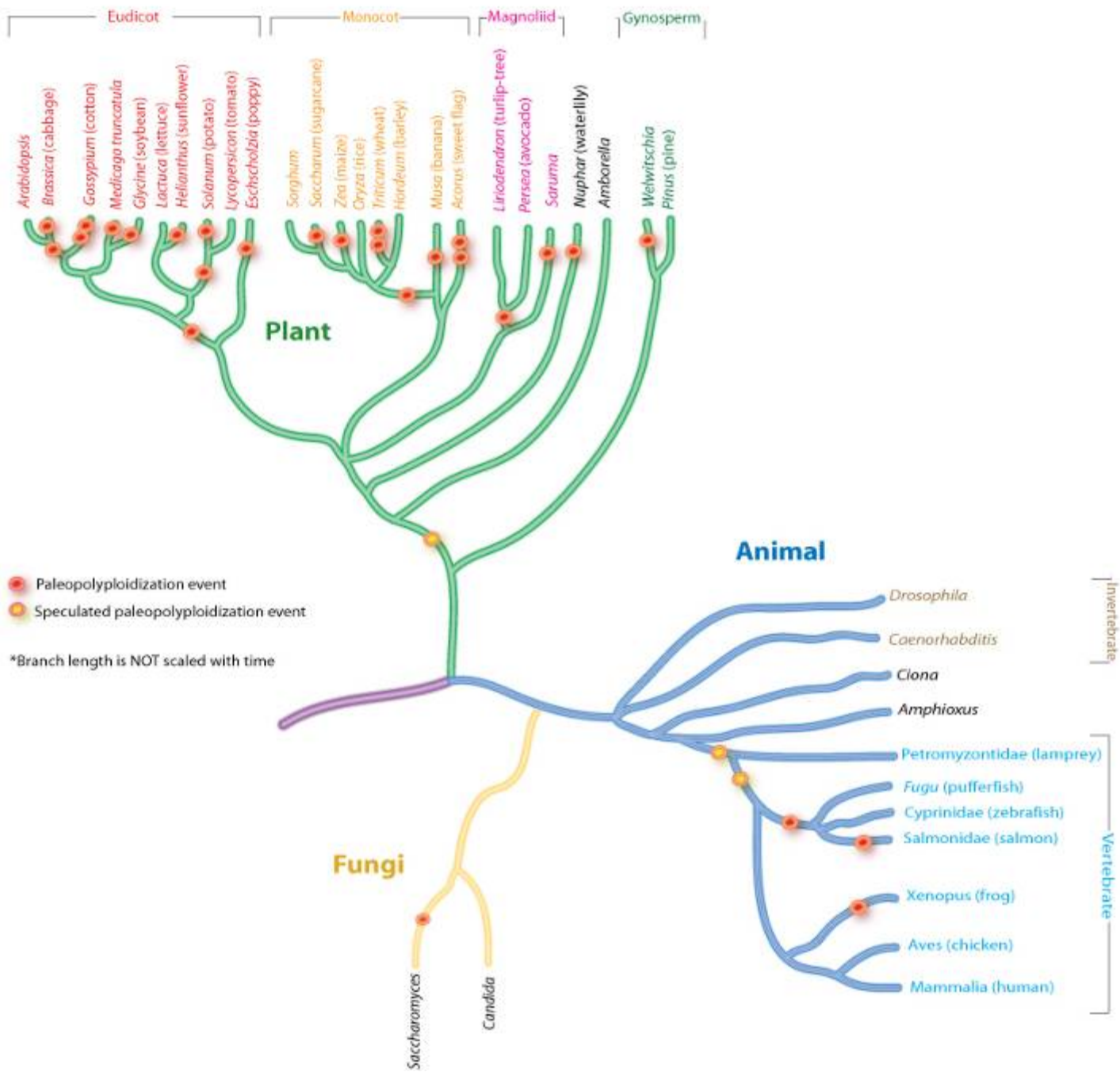
II) The Cell Cycle

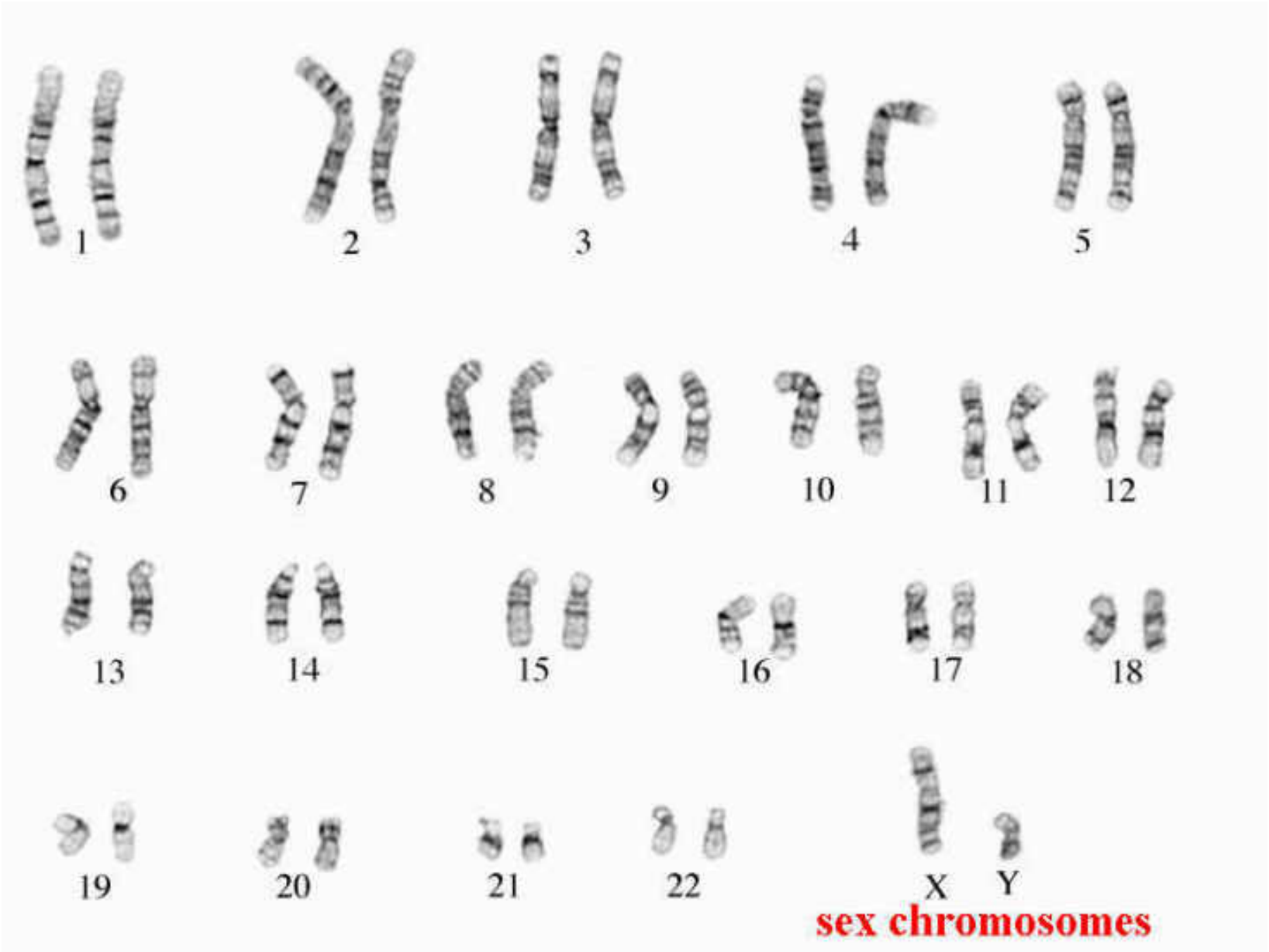


- in corn plants n = 10
- in fruit lies n = 4
- In the Ophioglossum fern upto 2n = 1400
- in a hermit crab 2n = 254

- some organisms are polypoid
  - have sets of more than two homologous chromosomes.
    - some plants are tetraploid (4n), triploid (3n) and even octoploid (8n)
- the particular set of chromosomes that an individual has is called the karyotype.
  - the human karyotype is made up of 22 pairs of autosomes (non sex chromosomes) and one pair of sex chromosomes.

Known Paleopolyploidy in Eukaryotes

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21
22
X
Y
sex chromosomes

Cell Division

II) The Cell Cycle

B) Stages of The Cell Cycle

Cell Division

II) The Cell Cycle

B) Stages of the Cell Cycle

- the cell cycle takes place in phases that occur one after the other without stopping.
- the phases of the cell cycle:
  - S phase
  - G2 phase
  - Mitosis and Cytokinesis
  - G1 phase

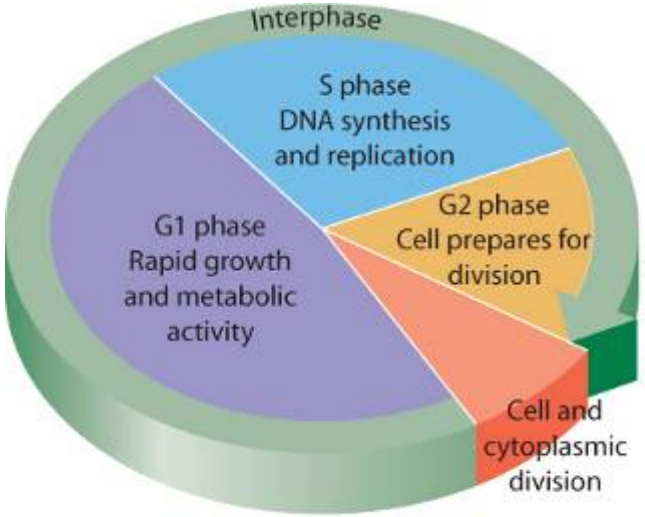

Figure 16.5
The cell cycle. Interphase, the stage of growth and metabolic activity, occupies most of the cell cycle. The division stage involves the reproduction of the nucleus and the division of the cell contents.

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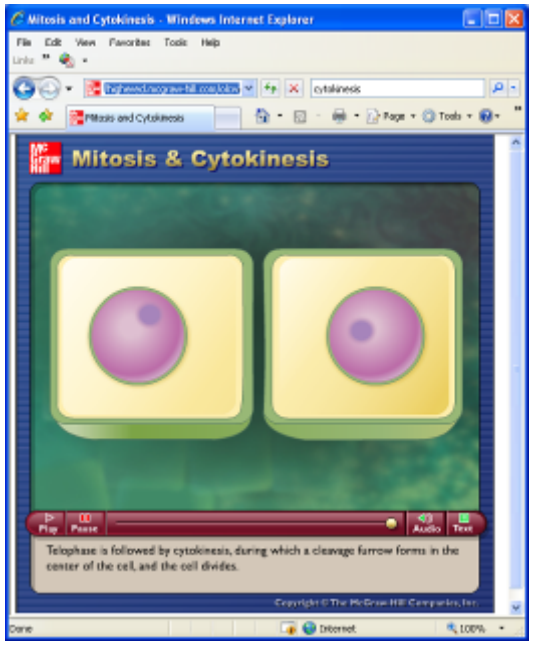
Cell Division

II) The Cell Cycle

- **the phases of the cell cycle:**
  - **S phase**
  - **G2 phase**
  - **Mitosis and Cytokinesis**
  - **G1 phase**
- the cell cycle can be divided into two parts
  - Division Phase
    - the components of the cytoplasm and the nucleus of the parent cell are divided to give rise to two identical daughter cells.
      - mitosis is the segregation of the copied material
      - cytokinesis is the splitting of the parent cell into two daughter cells.
      - small part of the cell cycle



Cell Division
II) The Cell Cycle

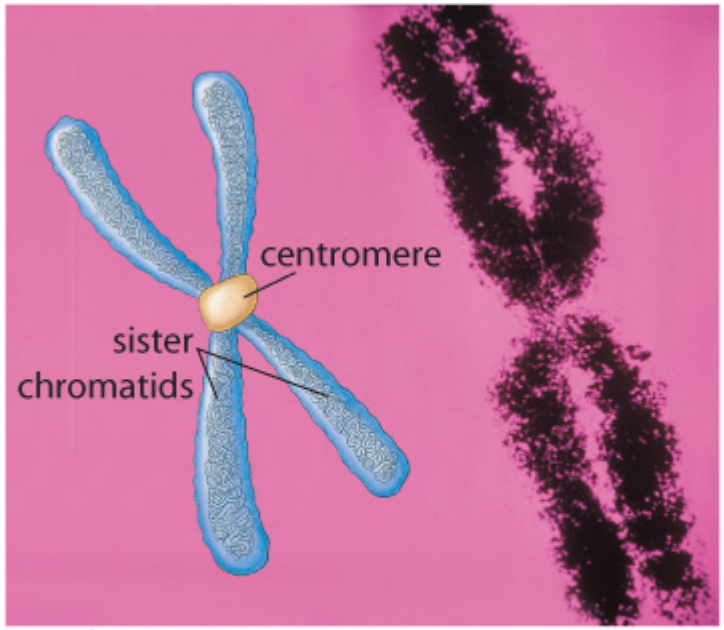
- cytokinesis is the splilting of the parent cell into two daughter cells.
- small part of the cell cycle

- Interphase
  - encompasses the majority of the cell cycle
    - G1 Phase
      - first called the Gap 1 phase because early on no one knew what was happening.
      - now call Growth 1 phase because of the rapid growth that occurs during it.
    - S Phase
      - synthesis phase
      - phase where DNA is replicated

        ~ two identical chromosomes, called sister chromatids are joined at the centromere.

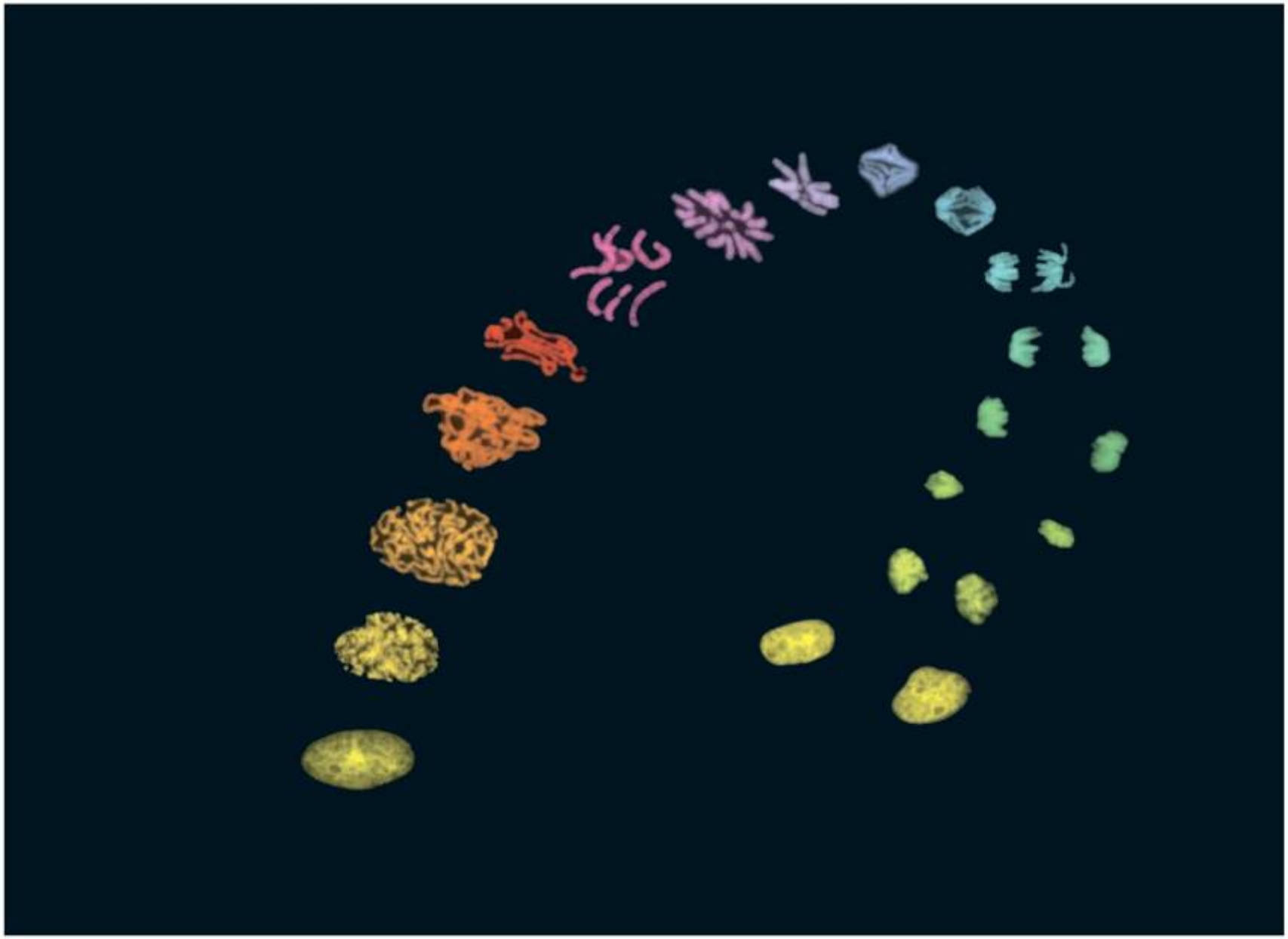
Cell Division
II) The Cell Cycle

- S Phase
  - synthesis phase
  - phase where DNA is replicated
    ~ two identical chromosomes, called sister chromatids are joined at the centromere.
- G2 Phase
  - Gap 2 or Growth 2 phase
  - time for the cell to rebuild its reserves of energy and make proteins for cell division



Magnification: 67 534 ×

Figure 16.6 During the S phase of the cell cycle, each chromosome is copied. The resulting sister chromatids are held together at the centromere.



Cell Division

II) The Cell Cycle

C) Mitosis

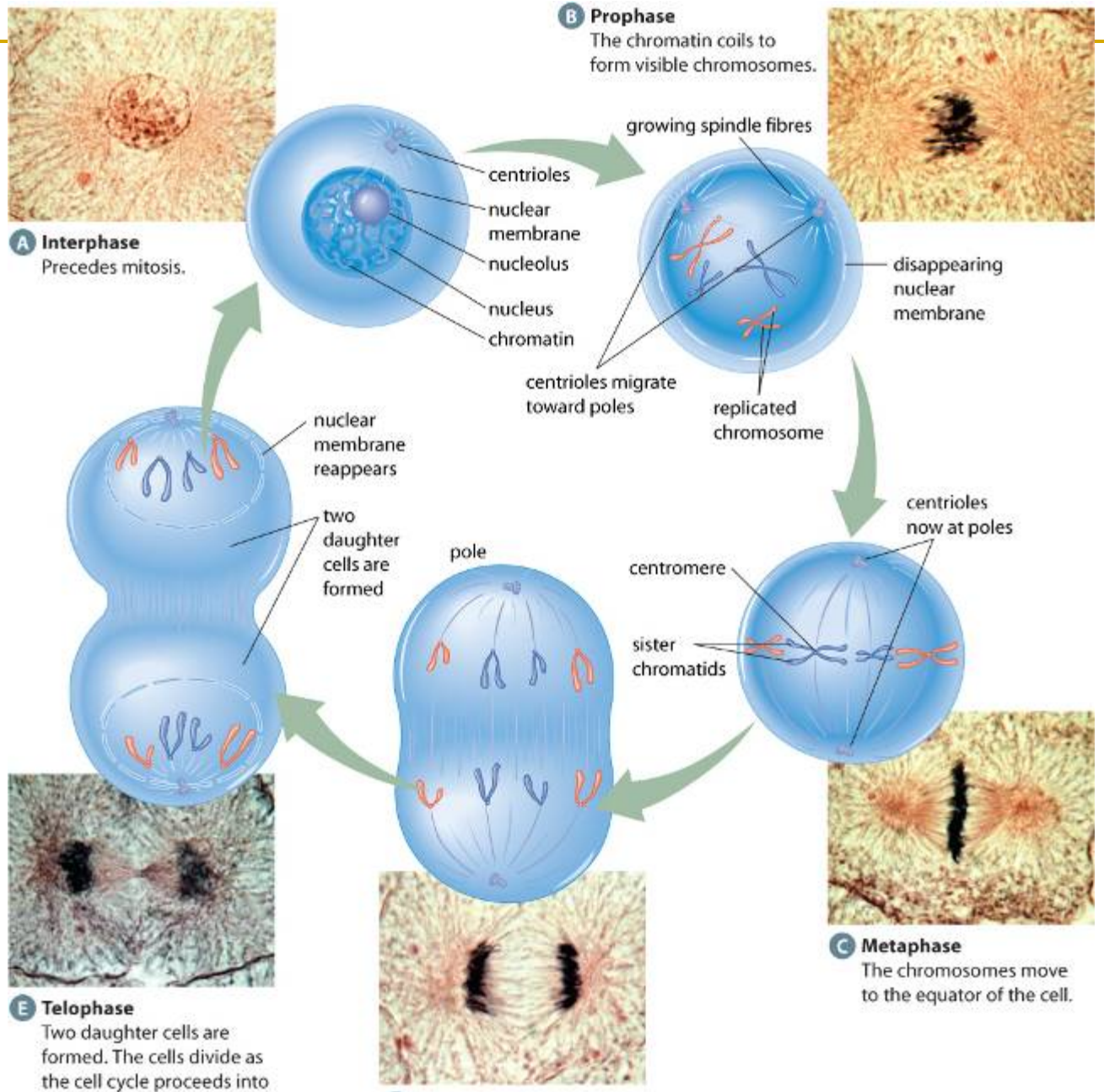
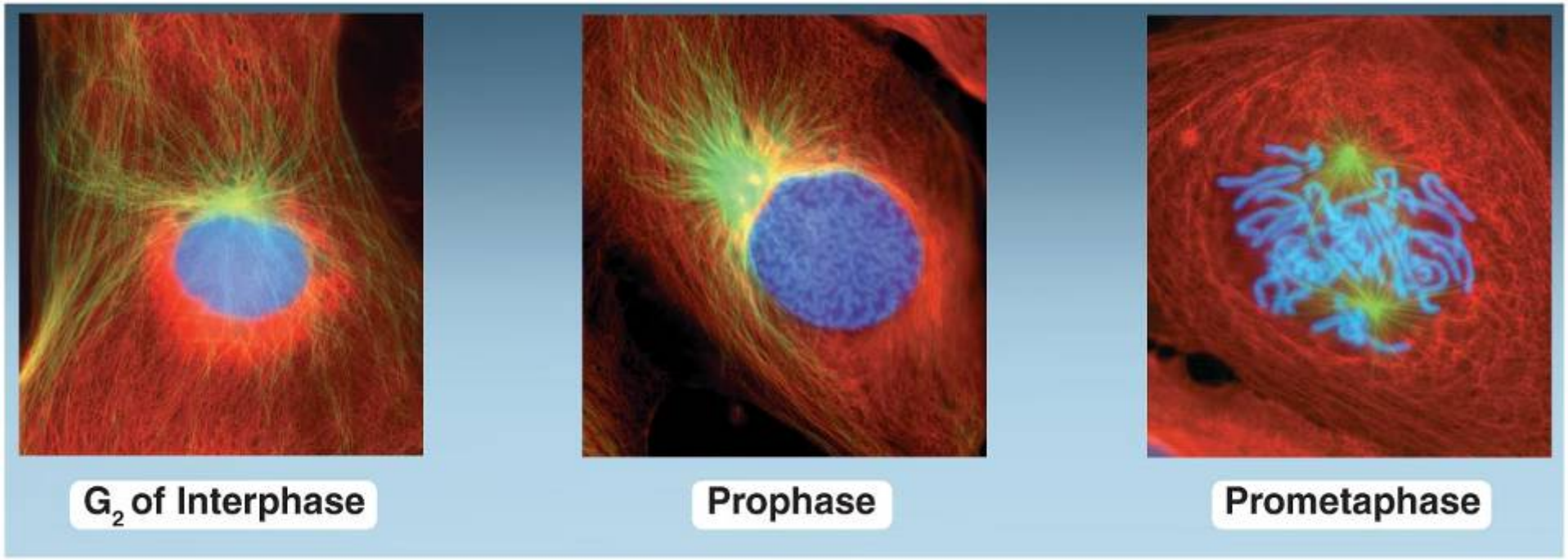
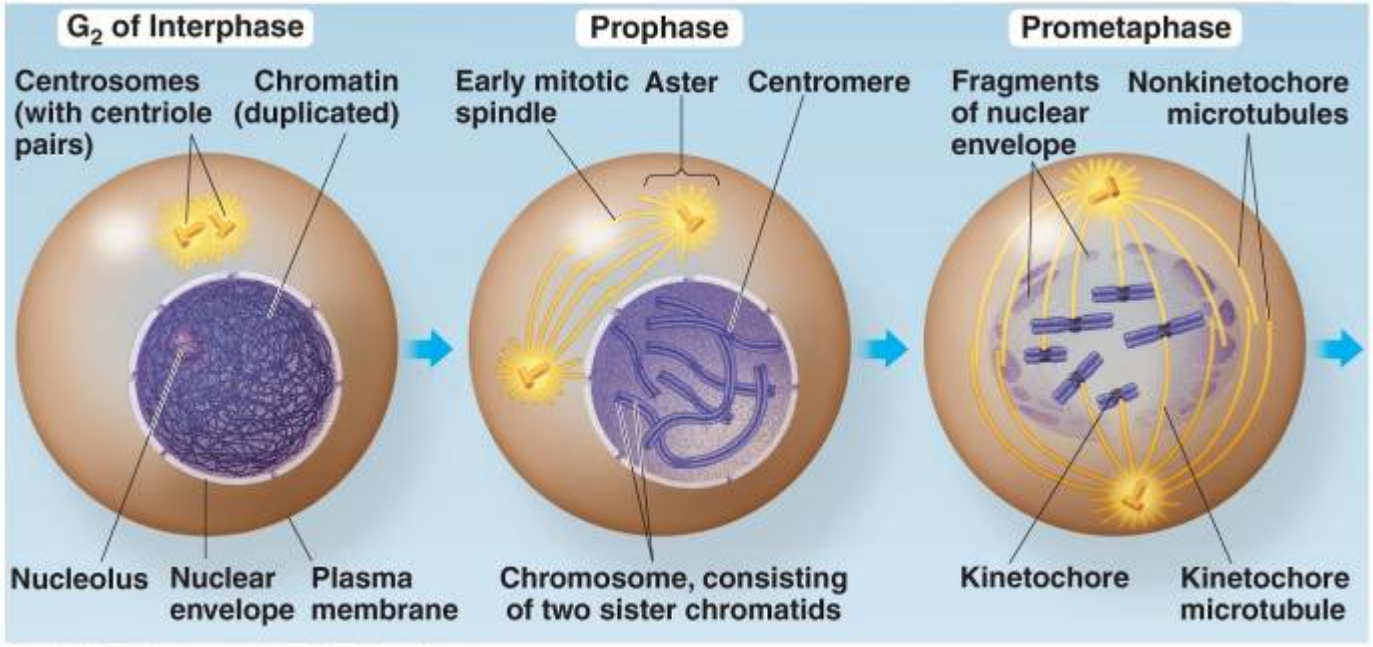
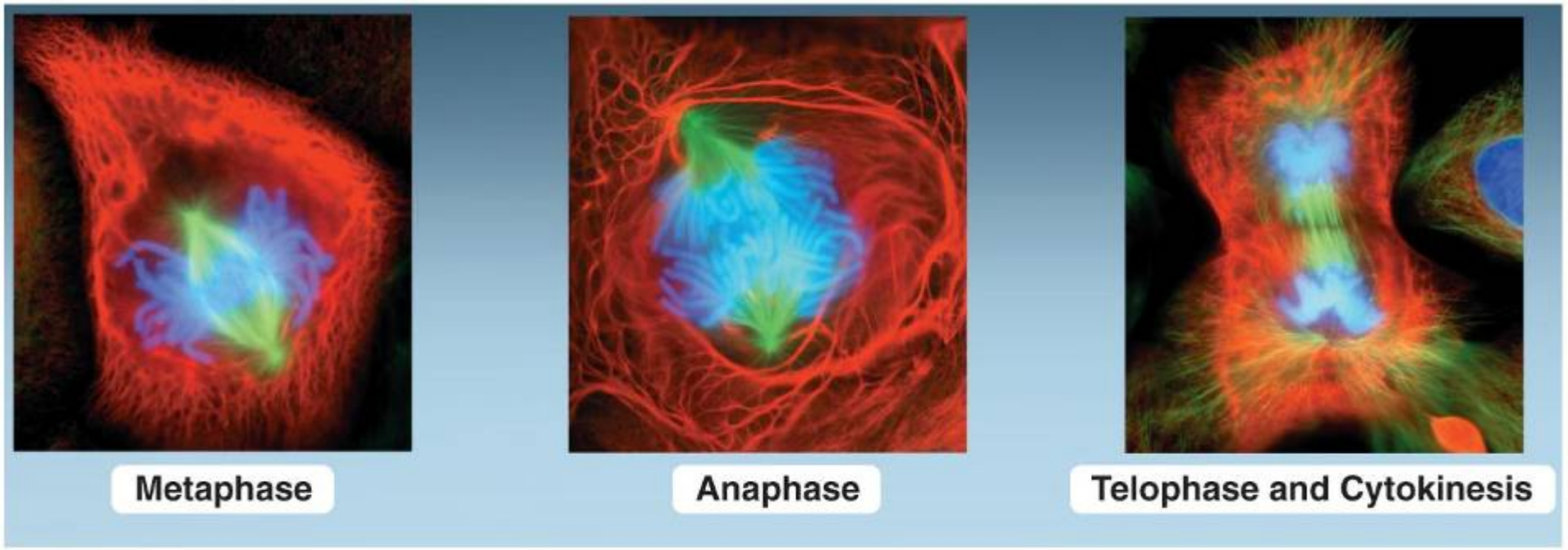
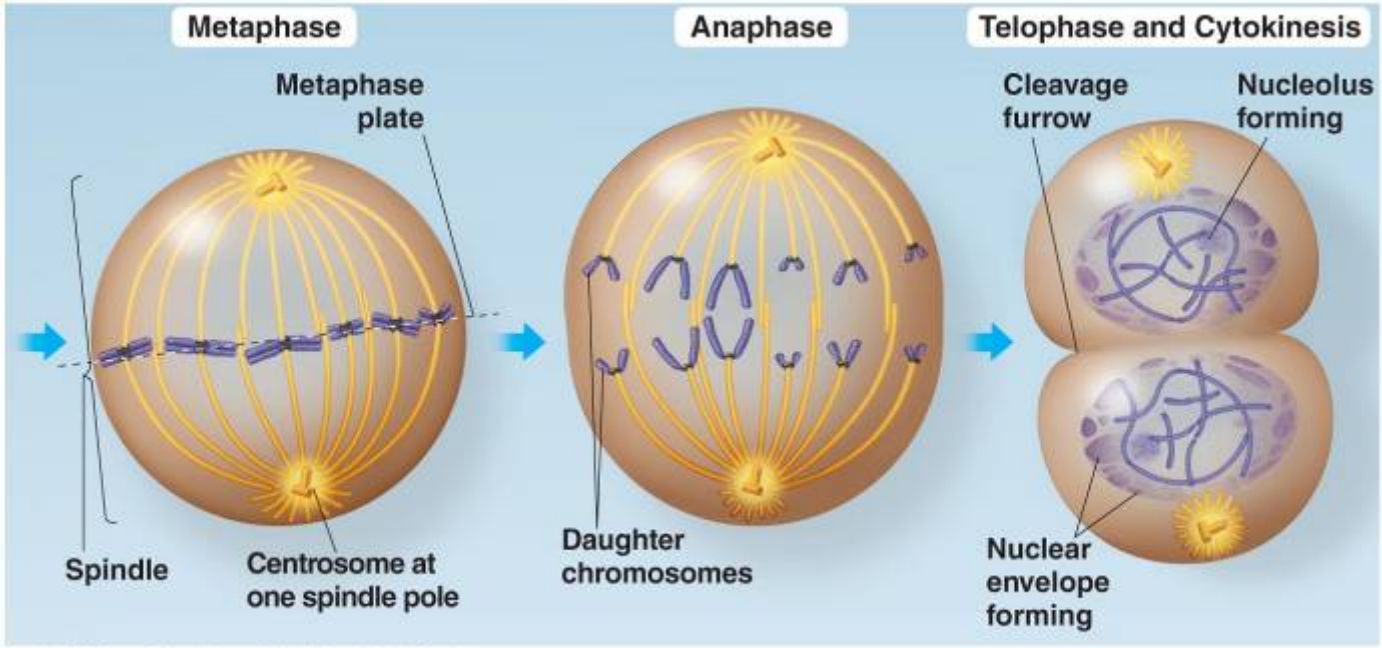


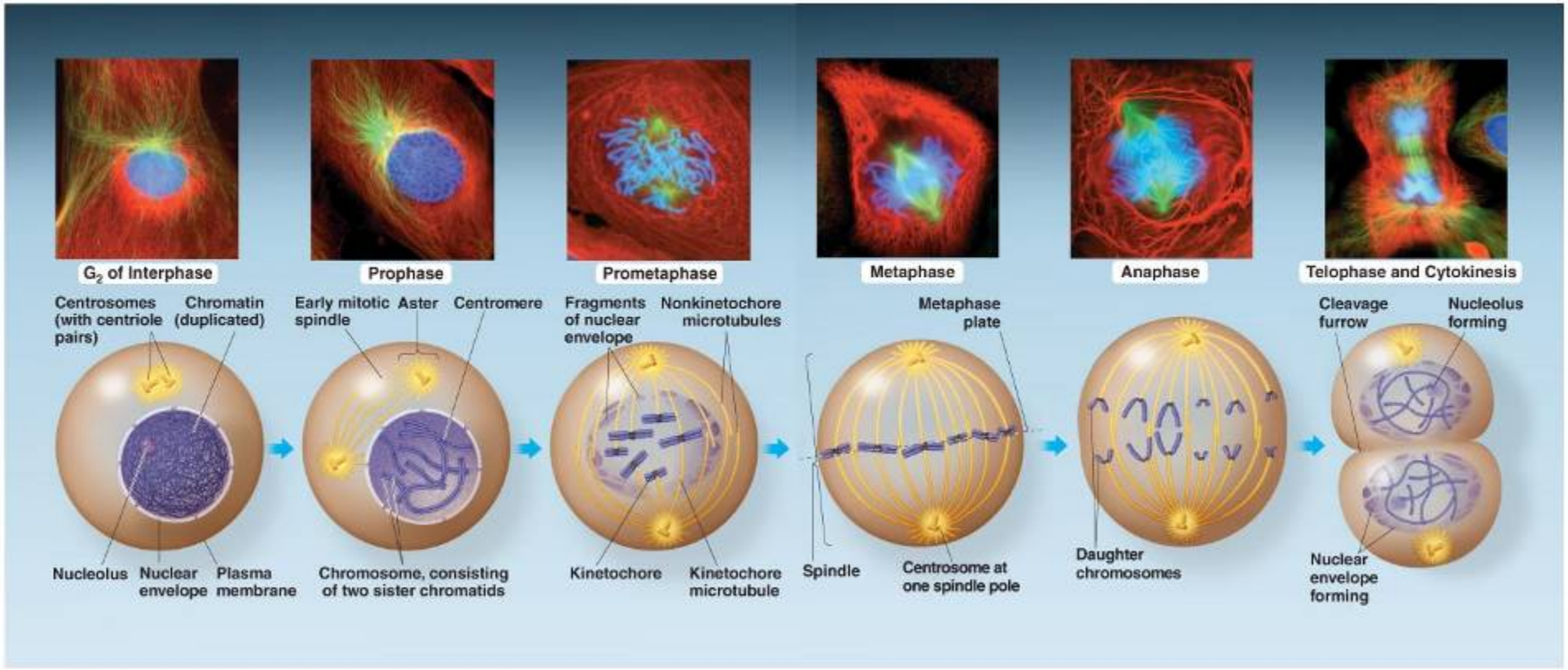
Figure 16.8 These illustrations and micrographs show what happens inside a cell during interphase **(A)** and mitotic cell division **(B** to **E)**.











Cell Division
II) The Cell Cycle

C) Mitosis

- there are four main stages to mitosis
  - Prophase
  - Metaphase
  - Anaphase
  - Telophase
  - Cytokinesis (splitting of the cell)

Cell Division
II) The Cell Cycle

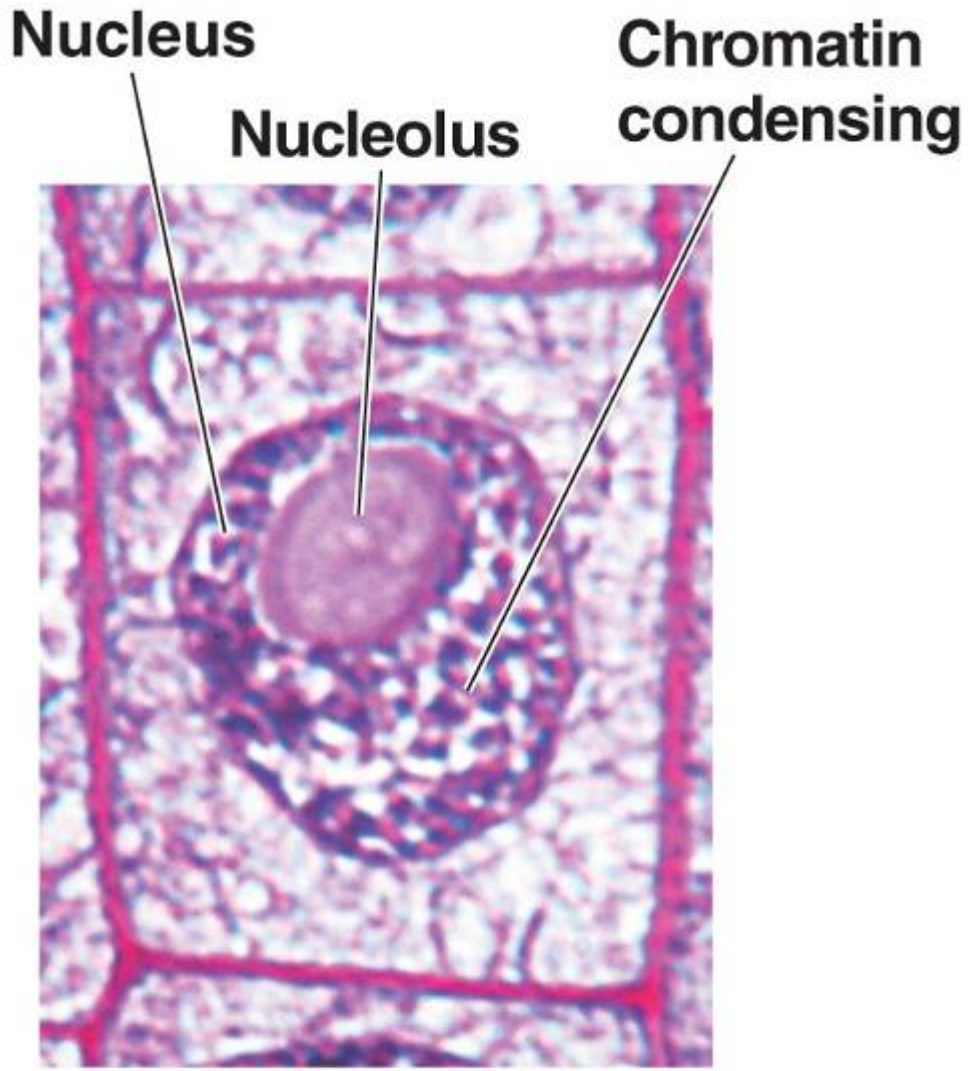
- Prophase
  - the first phase of mitosis
  - chromosomes become visible
  - centrioles migrate to opposite poles of the cell
    - centrioles are small protein bodies found in the cytoplasm of animal cells that provides a site for spindle fibers to attach to.
    - spindle fibres are protein structures that guide the movement of chromosomes during cell division.
    - collectively centrioles and spindle fibres make up the spindle apparatus.

Cell Division

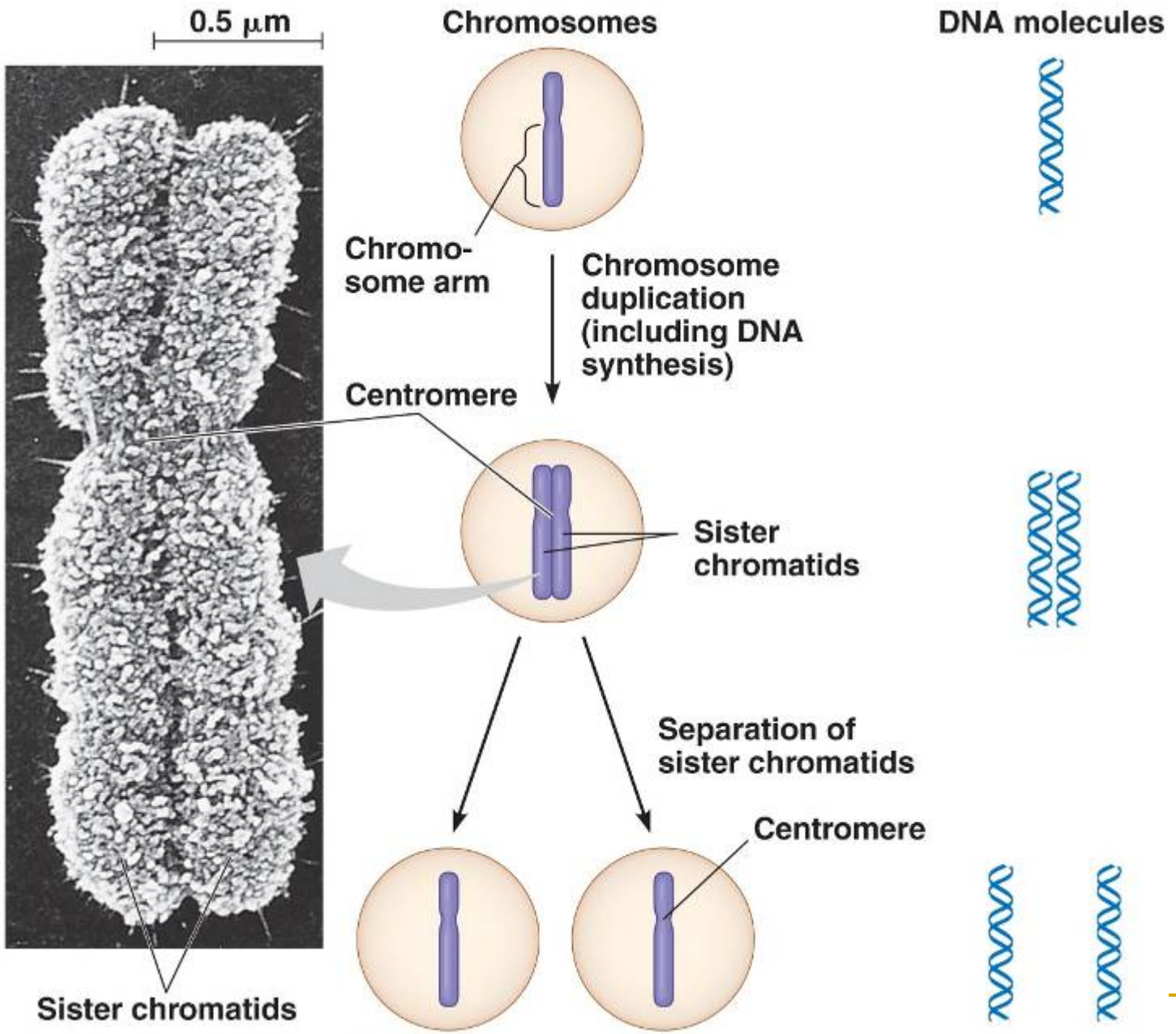
II) The Cell Cycle

- spindle fibres are protein structures that guide the movement of chromosomes during cell division.
- collectively centrioles and spindle fibres make up the spindle apparatus.
- most plant cells lack centrioles but have spindle fibres

- the centromere joining two chromatids anchor the chromosomes to the spindle fibers.
- nuclear membrane appears to fade.



1 Prophase



Cell Division
II) The Cell Cycle

- the centromere joining two chromatids anchor the chromosomes to the spindle fibers.
- nuclear membrane appears to fade.

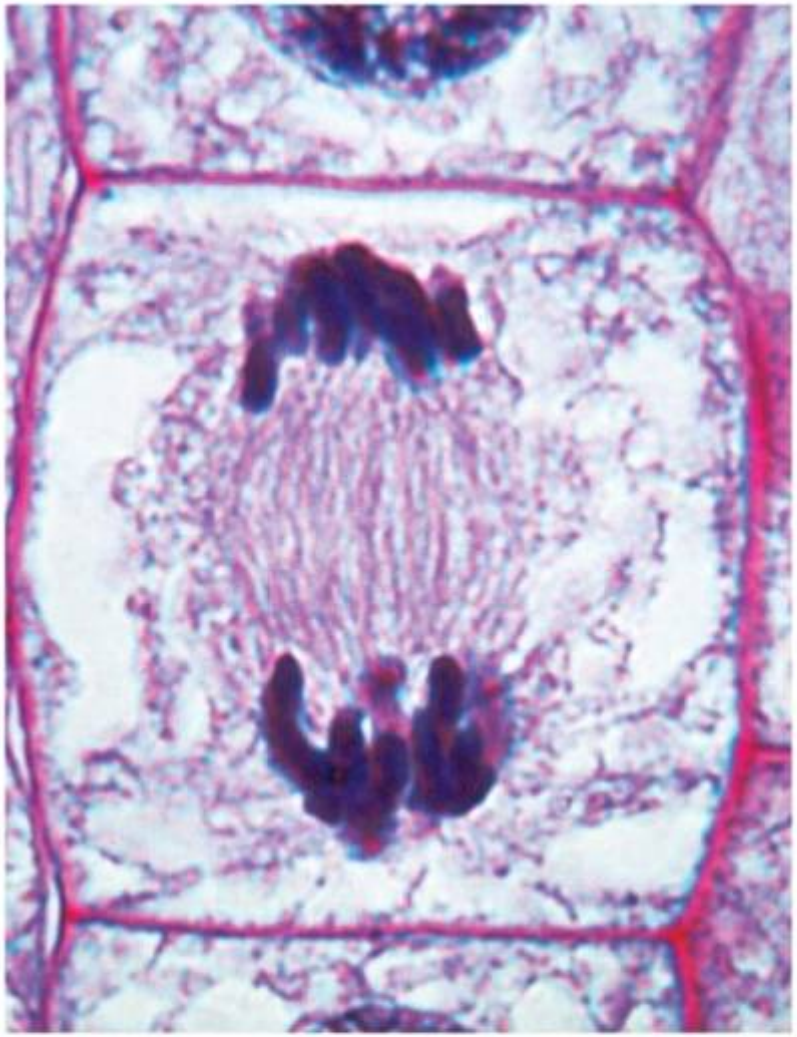
- Metaphase
  - Second phase of mitosis
  - Chromosomes composed of sister chromatids move toward the centre of the cell (the equatorial plate)
  - Chromosomes are dark filaments attached to spindle fibers (most visible at this stage)
  - Chromatids can become intertwined

3 Metaphase

Cell Division
II) The Cell Cycle

- Chromosomes are dark filaments attached to spindle fibers (most visible at this stage)
- Chromatids can become intertwined

- Anaphase
  - Third phase of mitosis
  - The centromeres divide
    - The sister chromatids, now called chromosomes, move to opposite poles.
  - The same number and same type of chromosomes will be found at each pole.



4 Anaphase

Cell Division
II) The Cell Cycle

- The sister chromatids, now called chromosomes, move to opposite poles.
- The same number and same type of chromosomes will be found at each pole.

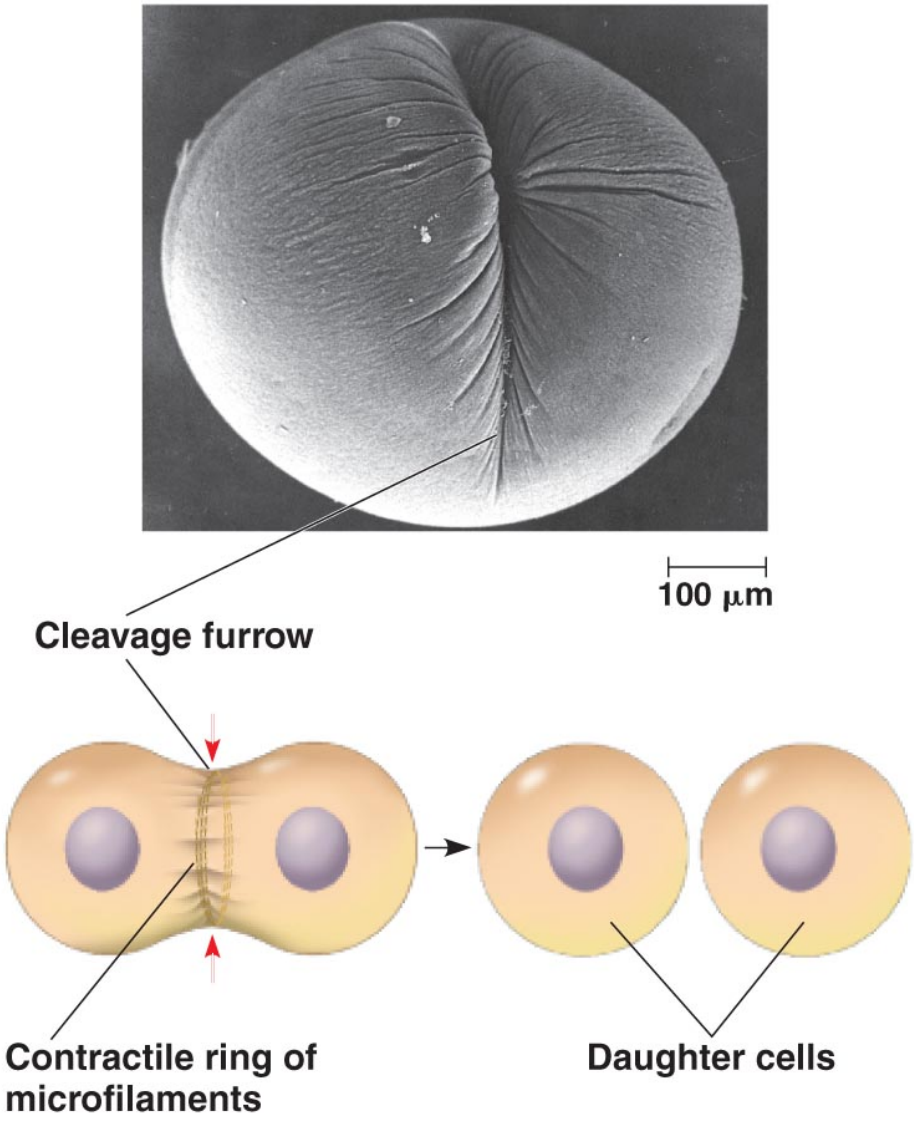
- Telophase
  - the last phase of mitosis
  - the chromosomes reach the opposite poles of the cell.
  - spindle fibers dissolve and a nuclear membrane forms around each mass of chromatin

5 Telophase

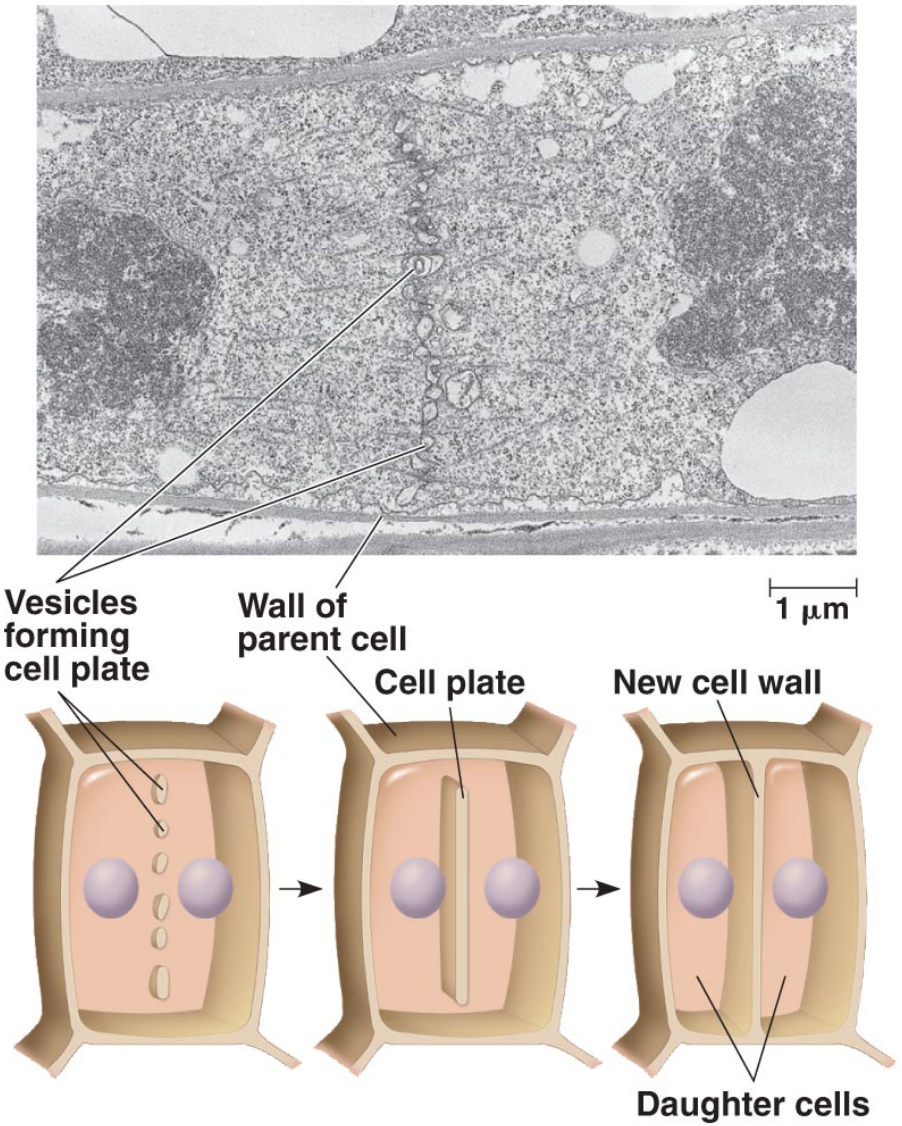
Cell Division
II) The Cell Cycle

- The chromosomes reach the opposite poles of the cell and length.
- Spindle fibers dissolve and a nuclear membrane forms around each mass of chromatin

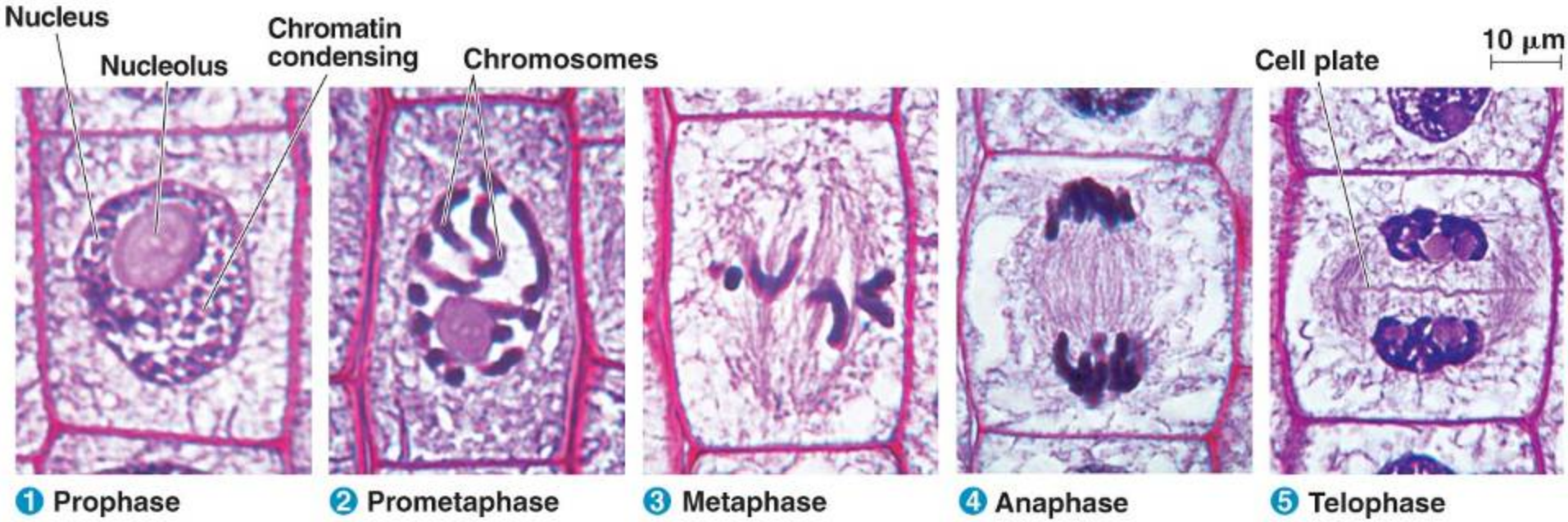
- Cytokinesis
  - the division of the cytoplasm
    - in an animal cell a furrow develops, pinching off the cell into two pairs.
    - in plant cells a cell plate will develop into a new cell wall.

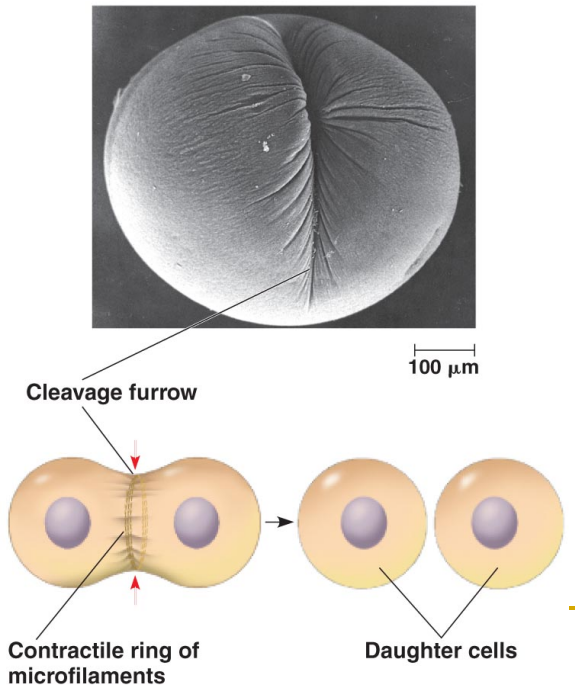


(a) Cleavage of an animal cell (SEM)

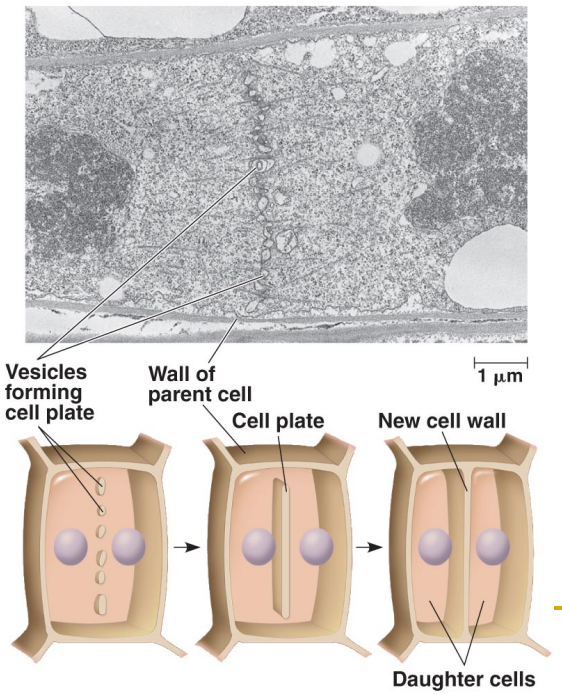


(b) Cell plate formation in a plant cell (TEM)





(a) Cleavage of an animal cell (SEM)



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

Cell Division
II) The Cell Cycle

- The division of the cytoplasm
  - In an animal cell a furrow develops, pinching off the cell into two pairs.
  - In plant cells a cell plate will develop into a new cell wall.

- The Cell Clock
  - cells have a biological clock that regulates the number of cell divisions

    Example) Heart Cells
    - normally can undergo mitosis approximately 50 times.
    - if you freeze the cells in liquid nitrogen after 10 division they will divide 40 more times when thawed.
      - this proves that there is some sort of “cell clock”

Cell Division

II) The Cell Cycle

- normally can undergo mitosis approximately 50 times.
- if you cytogenetically free the cells after 10 division they will divide 40 more times when thawed.
  - this proves that there is some sort of "cell clock"

- usually more specialized cells (neurons, excretory) divide less than nonspeciallized (skin, stomach lining)
- two types of cells divide endlessly
  - sperm producing spermatogonia
  - cancer cells
- the biological clock is turned on after cells differentiate.

Cell Division

II) The Cell Cycle

D) Cloning

Cell Division
II) The Cell Cycle

Cloning 411

- cellular differentiation
  - is the process by which a less specialized cell becomes a more specialized cell type.
  - occurs numerous times as the organism changes from a single zygote to a complex system of tissues and cell types.
  - a common process in adults as well: adult stem cells divide and create fully-differentiated daughter cells during tissue repair and during normal cell turnover.

Cell Division

II) The Cell Cycle

- occurs numerous times as the organism changes from a single zygote to a complex system of tissues and cell types.
- a common process in adults as well: adult stem cells divide and create fully-differentiated daughter cells during tissue repair and during normal cell turnover.
- causes a cells size, shape, polarity, metabolic activity, and responsiveness to signals to change dramatically.
- these changes are largely due to highly-controlled modifications in gene expression.
  - different cells can have very different physical characteristics despite having the same genome.

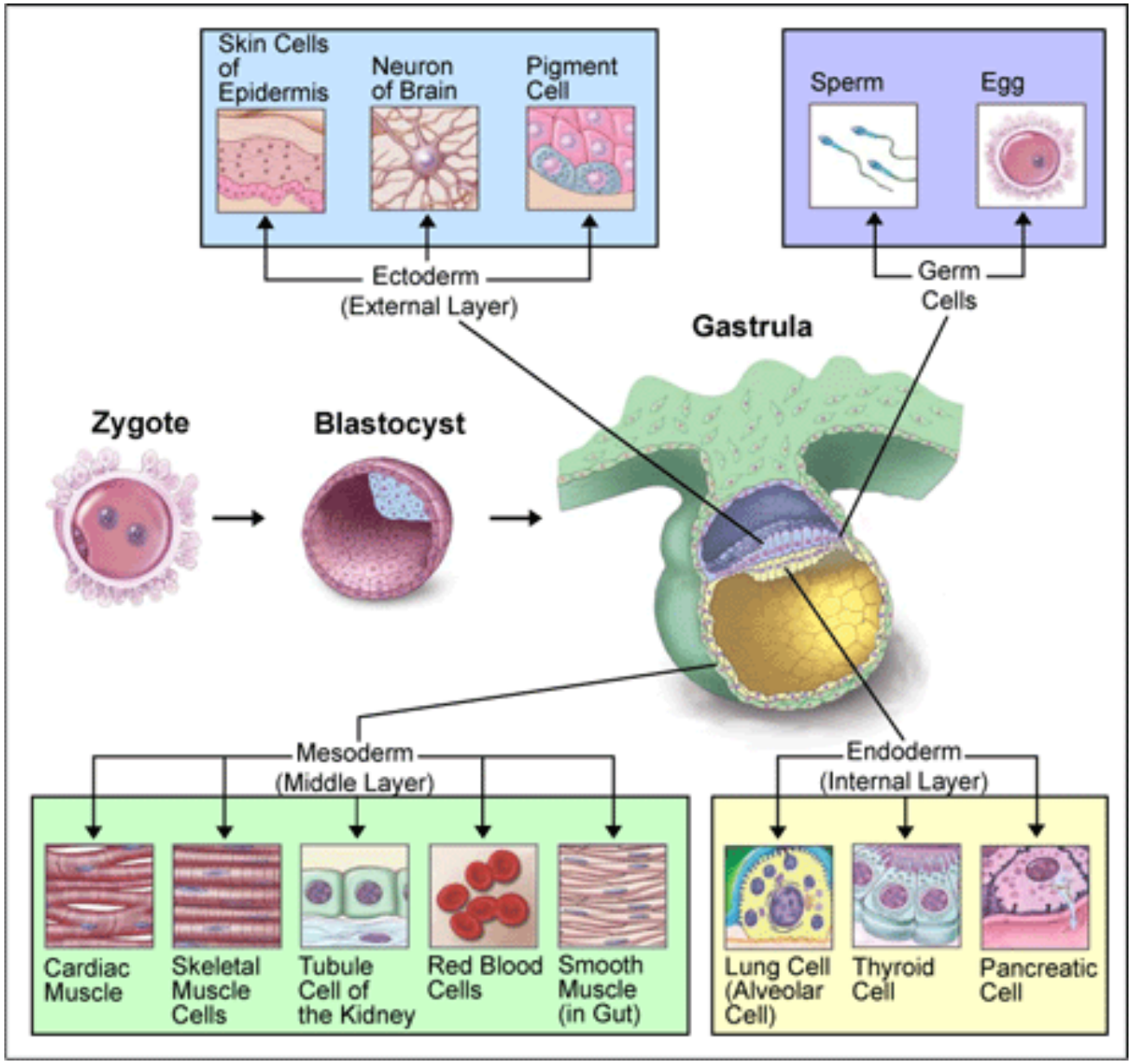
Cell Division
II) The Cell Cycle

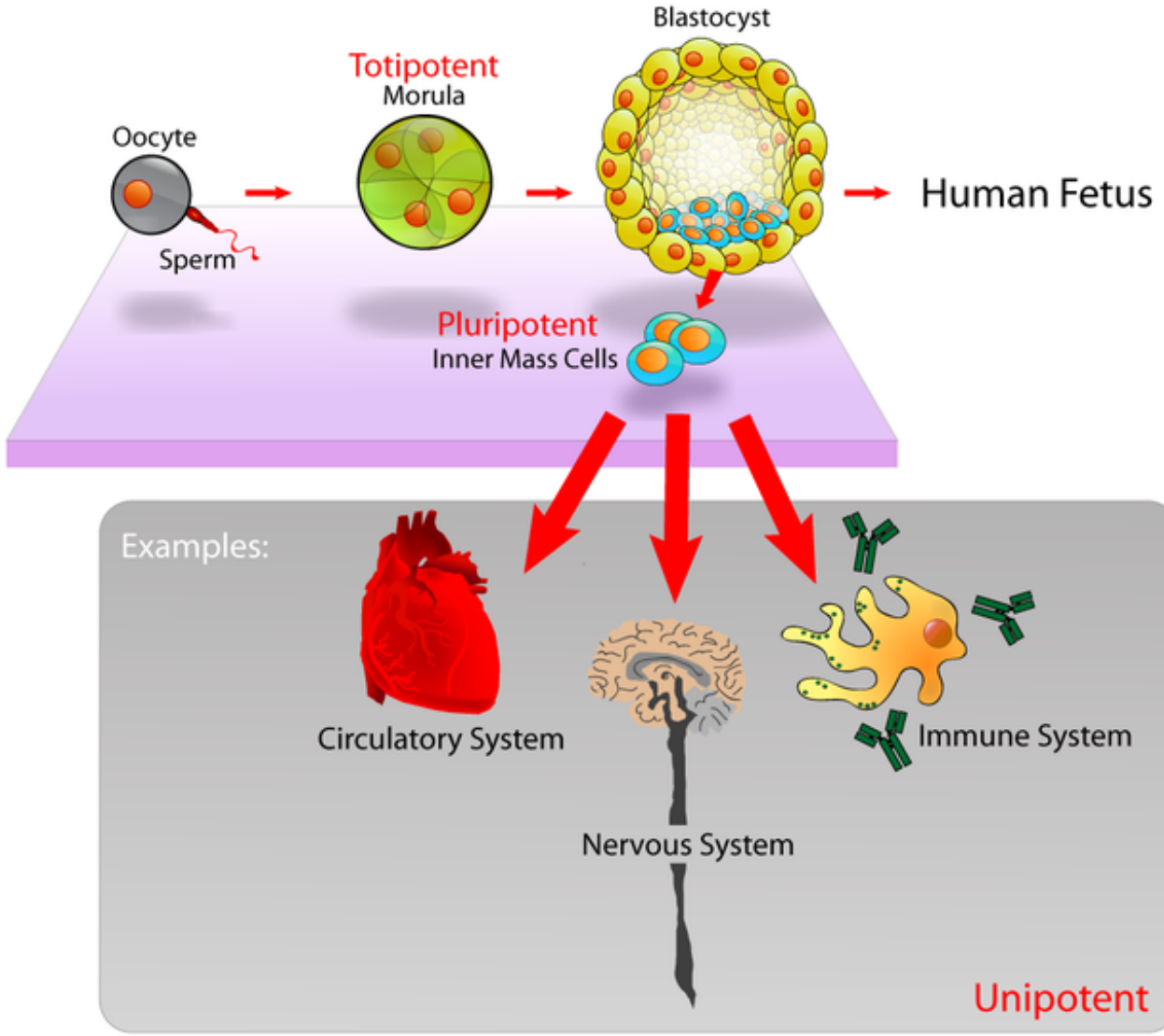
- these changes are largely due to highly-controlled modifications in gene expression.
  - different cells can have very different physical characteristics despite having the same genome.

- a cell that is able to differentiate into many cell types is known as pluripotent.
  - called stem cells in animals
  - called meristematic cells in higher plants

Cell Division
II) The Cell Cycle

- a cell that is able to differentiate into many cell types is known as ***pluripotent***.
  - called **stem cells** in animals
  - called **meristematic cells** in higher plants.
  - a cell that is able to differentiate into all cell types is known as totipotent.
    - in mammals, only the zygote and early embryonic cells are totipotent, while in plants (and in animals), many differentiated cells can become totipotent with simple laboratory techniques.


Skin Cells of Epidermis
Neuron of Brain
Pigment Cell
Sperm
Egg
Ectoderm (External Layer)
Germ Cells
Gastrula
Zygote
Blastocyst
Mesoderm (Middle Layer)
Endoderm (Internal Layer)
Cardiac Muscle
Skeletal Muscle Cells
Tubule Cell of the Kidney
Red Blood Cells
Smooth Muscle (in Gut)
Lung Cell (Alveolar Cell)
Thyroid Cell
Pancreatic Cell


Blastocyst
Totipotent
Morula
Oocyte
Sperm
Human Fetus
Pluripotent
Inner Mass Cells
Examples:
Circulatory System
Nervous System
Immune System
Unipotent

Cell Division
II) The Cell Cycle

What is Cloning?

- cloning is the process of forming identical offspring from a single cell or tissue of a parent organism.
  - both the clone and the parent have identical or near identical DNA (random mutations occur)
  - does not result in variation of traits
- considered a form of asexual reproduction
  - clones occur naturally

    example)
    - Hydra undergoing mitosis during the process of budding

Cell Division

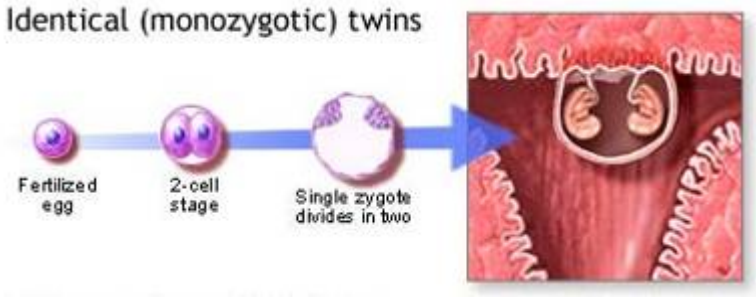
II) The Cell Cycle

example)

- Hydra undergoing mitosis during the process of budding

- Runner of a strawberry plant

- Monozygotic twins (zygote undergoes mitosis and splits into two)

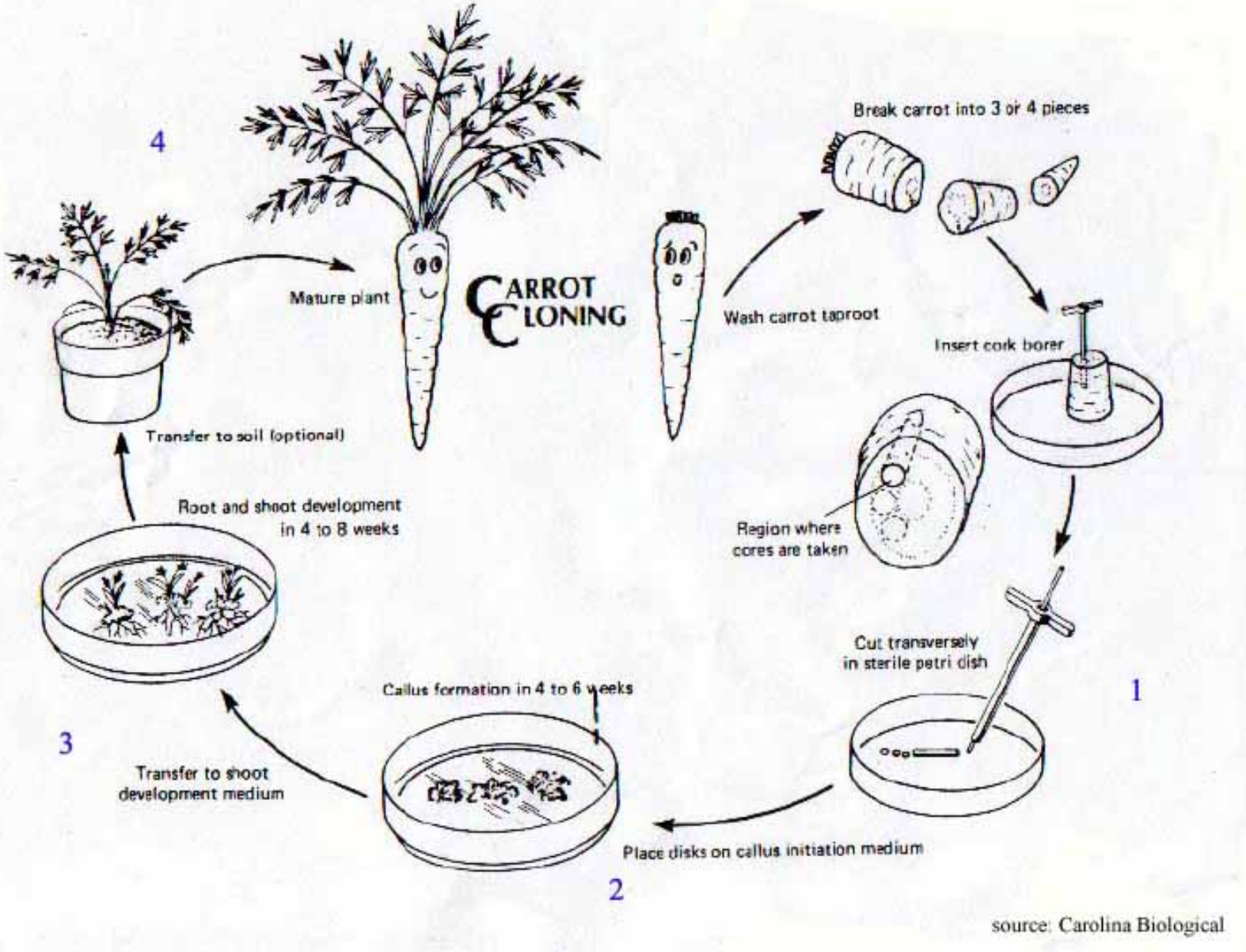


Cell Division

II) The Cell Cycle

- Hydra undergoing mitosis during the process of budding
- Runner of a strawberry plant
- Monozygotic twins (zygote undergoes mitosis and splits into two)

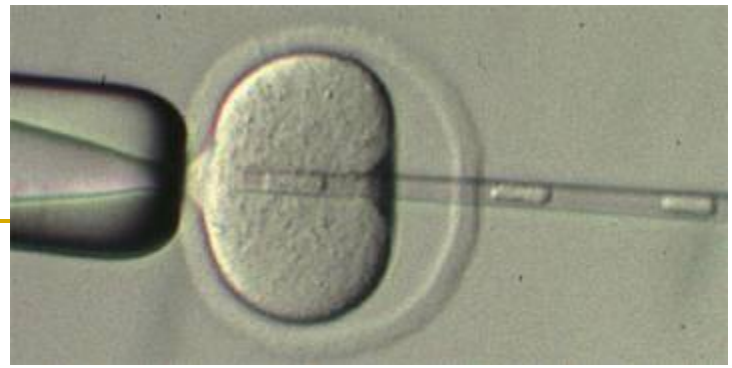
- Plant Cloning
  - In 1958 Fredrick Stewart produced a carrot plant from a single carrot cell
    - now cloning is widespread in the agriculture/horticulture industries.
      - it is desirable (profitable) to have plants of predictable characteristics
        - Easy to clone plants: carrots, tobacco, lettuce
        - Hard to clone plants: grasses, legumes.


CARROT CLONING
Break carrot into 3 or 4 pieces
Wash carrot taproot
Insert cork borer
Region where cores are taken
Cut transversely in sterile petri dish
1
Place disks on callus initiation medium
2
Callus formation in 4 to 6 weeks
Transfer to shoot development medium
3
Root and shoot development in 4 to 8 weeks
Transfer to soil (optional)
4
Mature plant
source: Carolina Biological

Cell Division
II) The Cell Cycle

- Easy to clone plants: carrots, tobacco, lettuce
- Hard to clone plants: grasses, legumes.

- Animal Cloning
  - Robert Biggs and Thomas King
    - investigated nuclear transplants in frogs.
    - first to clone a frog.



Cell Division
II) The Cell Cycle

- *Animal Cloning*
  - *Robert Biggs and Thomas King*
    - *investigated nuclear transplants in frogs.*
    - *first to clone a frog*
- the cloning of the sheep "Dolly" by Dr. Ian Wilmut's team was the first to clone an animal using adult cells.
  - the nucleus of an udder cell of an adult sheep was placed in the enucleated egg cell from another sheep.
    - the egg developed in a Petri dish until an early embryo stage.
      - then the egg was placed into the womb of another sheep.

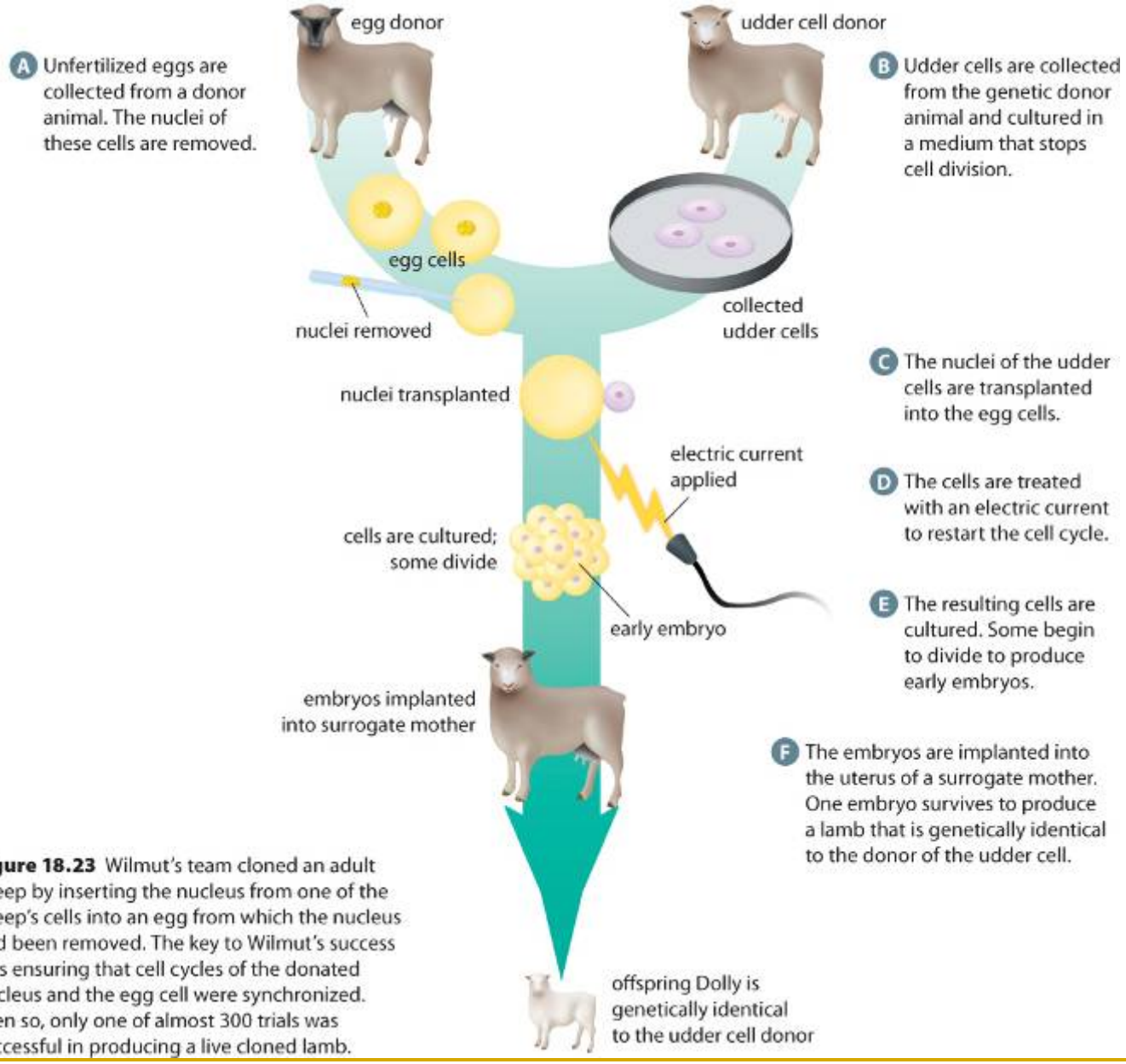


Figure 18.23 Wilmut's team cloned an adult sheep by inserting the nucleus from one of the sheep's cells into an egg from which the nucleus had been removed. The key to Wilmut's success was ensuring that cell cycles of the donated nucleus and the egg cell were synchronized. Even so, only one of almost 300 trials was successful in producing a live cloned lamb.

Cell Division
II) The Cell Cycle

- the egg developed in a Petri dish until an ealry embyro stage.
  - then the egg was placed into the womb of another sheep.

- DNA donor: adult Finn Dorsett Sheep
- Egg donor: Poll Dorsett Sheep
- Womb provider: a third sheep
- Clone: Dolly was a clone of the adult Finn Dorsett Sheep