The Cell Cycle

- In this topic we will examine the cell cycle, the series of changes that a cell goes through from one division to the next.
- We will pay particular attention to how the genetic material is passed on from parent cell to daughter cells during the cell cycle.

Objective # 1

Compare the amount and organization of genetic material in prokaryotic cells with the amount and organization of genetic material in eukaryotic cells.

Objective 1

- An average eukaryotic cell has about 1,000 times more DNA then an average prokaryotic cell.
- Prokaryotes have a single, circular DNA molecule. It is sometimes called "naked" because the DNA is not combined with proteins.

Objective 1

- The DNA in a eukaryotic cell is organized into several linear chromosomes. Each chromosome normally contains one DNA molecule which is combined with special proteins called histones.

Objective 1

DNA	Prokaryotes	Eukaryotes
structure	single, naked, circular DNA molecule	many linear chromosomes, each made of 1 DNA molecule joined with protein
location	in an area of the cytoplasm called the nucleoid	inside a membrane-bound nucleus

Objective # 2

Describe the process of cell division in prokaryotic cells.

Objective 2

Prokaryotes use a type of cell division called binary fission:

1) First, the single, circular DNA molecule replicates, producing two identical copies of the original.
2) Next, the 2 DNA molecules move to opposite ends of the cell.

Objective 2

3) Finally, the cytoplasm divides in half, producing 2 daughter cells which each have one copy of the original DNA molecule. Therefore, the 2 new cells are genetically identical to each other and to the original cell:

Objective 2

Fission

Objective # 3

Describe the structure of both unduplicated and duplicated eukaryotic chromosomes; and distinguish between chromosome, chromatid, centromere, and chromatin.

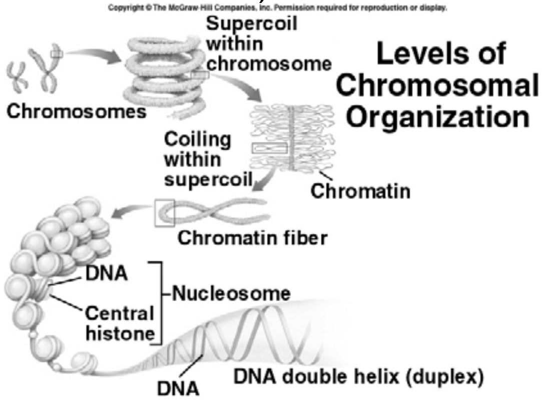
Objective 3

- Eukaryotic chromosomes are made of chromatin, a complex of DNA and protein.
- Each unduplicated chromosome contains one DNA molecule, which may be several inches long.

Objective 3

- How can such long molecules fit inside a microscopic nucleus?
  - ➢ Every 200 nucleotide pairs, the DNA wraps twice around a group of 8 histone proteins to form a nucleosome.
  - ➢ Higher order coiling and supercoiling also help condense and package the chromatin inside the nucleus:

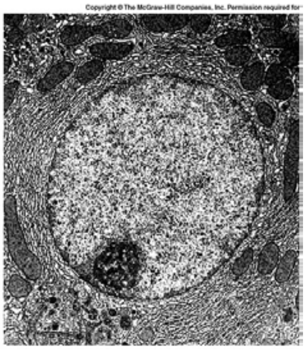
Objective 3



Objective 3

- For much of the cell cycle, most of the chromatin is loosely coiled.
- During this time, the individual chromosomes cannot be seen inside the nucleus.

Objective 3, Eukaryotic Nucleus

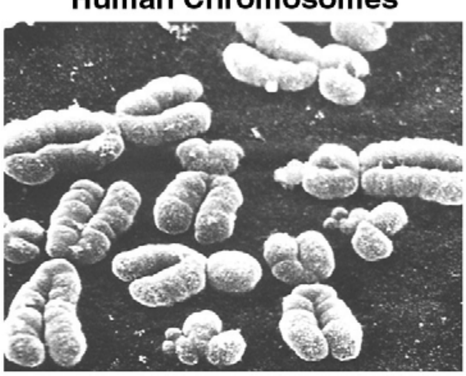


Objective 3

- Prior to cell division each chromosome duplicates itself.
- All the duplicated chromosomes then condense into short rod-like structures that can be seen and counted under the microscope:

Objective 3

Human Chromosomes

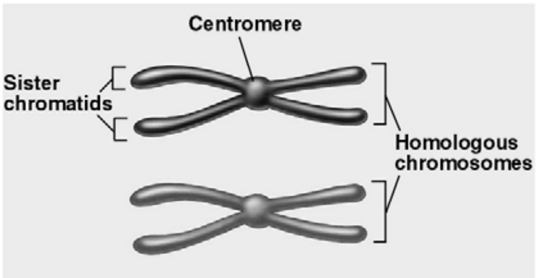


Objective 3

- Because of duplication, each condensed chromosome consists of 2 identical chromatids joined by a centromere.
- Each duplicated chromosome contains 2 identical DNA molecules (unless a mutation occurred during duplication), one in each chromatid:

Objective 3

Homologous Chromosomes and Sister Chromatids

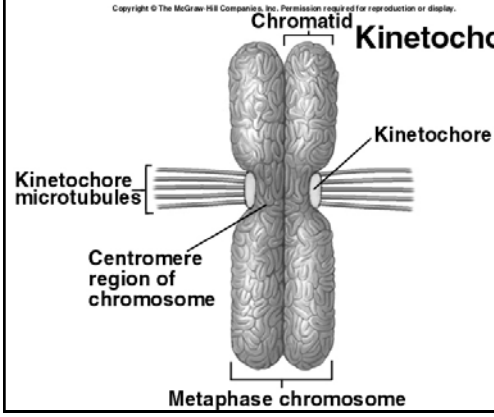


Objective 3

- The centromere is a constricted point on the chromosome containing a specific DNA sequence, to which is bound 2 discs of protein called kinetochores.
- Kinetochores serve as points of attachment for microtubules that move the chromosomes during cell division.

Objective 3

Kinetochores



Objective # 4

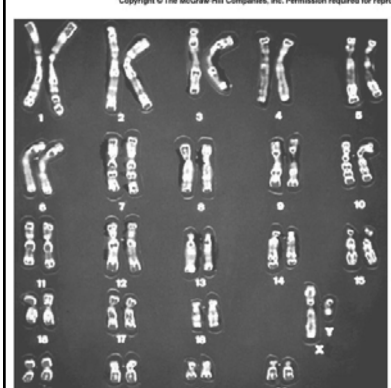
Explain what karyotypes are and how they are useful.

Objective 4

- The particular array of chromosomes in a eukaryotic cell is called its karyotype.
- To examine a karyotype, the chromosomes are photographed when they are highly condensed, then photos of the individual chromosomes are cut out and arranged in order of decreasing size:

Objective 4

A Human Karyotype



Objective 4

- Karyotypes are used to study the number and structure of the chromosomes present in a cell.
- They can also be used to detect chromosomal abnormalities that may be associated with specific genetic traits or defects.

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Objective # 5

Distinguish between a haploid cell and a diploid cell. Distinguish between identical chromosomes, homologous chromosomes, and non-homologous chromosomes.

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Objective 5

- In eukaryotes, every species requires a specific number of chromosomes to code for all the polypeptides produced by the organism. These chromosomes make up 1 complete set.
- Each chromosome in a set controls the production of a different group of polypeptides.

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Objective 5

- Cells that contain 1 complete set of chromosomes are called haploid.
- n or N represents the number of chromosomes in a haploid cell.
- Cells that contain 2 complete sets of chromosomes are called diploid.
- 2n or 2N represents the number of chromosomes in a diploid cell.

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Objective 5

- For example, 23 different chromosomes are needed to code for all the polypeptides produced by humans.
- Therefore, in humans:
  N=23
  2N = 46

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Objective 5

- We will use different shapes to represent the different chromosomes that make up a set, and different colors to represent different sets of chromosomes.

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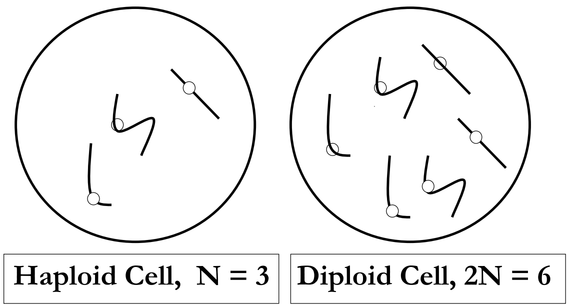
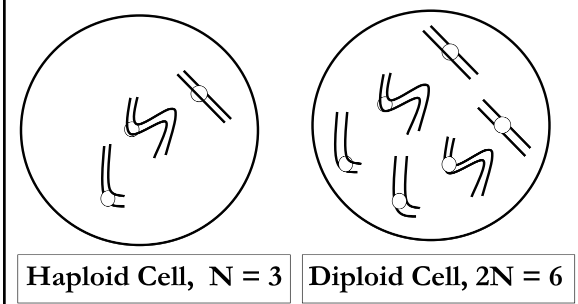
Objective 5

Unduplicated Chromosomes



Objective 5

Duplicated Chromosomes

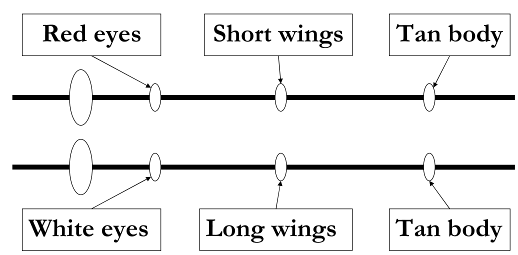


Objective 5

- In a diploid cell, the chromosomes occur in pairs. The 2 members of each pair are called homologous chromosomes or homologues.
- Under the microscope, homologous chromosomes look identical.
- In addition, because they code for the same polypeptides, they control the same traits.

Objective 5

- However, homologous chromosomes are not identical because they may code for different forms of each trait:



Objective 5

- Identical chromosomes:
  - Look the same under the microscope (have the same shape and color on our diagrams)
  - Control the same traits
  - Code for the same form of each trait
  - Common origin – both descended from the same original chromosome

Objective 5

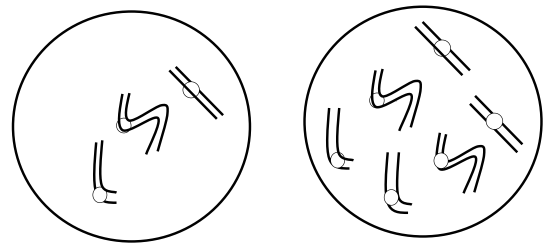
- Homologous chromosomes:
  - Look the same under the microscope (have the same shape but different colors on our diagrams)
  - Control the same traits
  - May code for different forms of each trait
  - Independent origin - each was inherited from a different parent

Objective 5

- Non-homologous chromosomes:
  - Look different under the microscope (have different shapes on our diagrams)
  - Control different traits

Objective 5

Duplicated Chromosomes



Haploid Cell, N = 3 | **Diploid Cell, 2N = 6**

Objective # 6

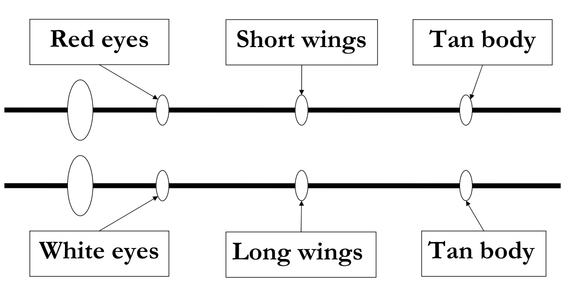
Define and be able to use the following terms correctly: gene, gene locus, and allele.

Objective 6

- Gene – a section of a DNA molecule that contains the code for making one polypeptide.
- Gene locus –the location of a gene along the length of a chromosome
- Alleles – genes that can occupy the same gene locus (on different chromosomes)

Objective 6

Homologous Chromosomes



Objective # 7

Identify the stages of the eukaryotic cell cycle, and describe the events of each stage.

Objective 7

- The cell cycle refers to the sequence of events that occur as a cell grows and divides. It is divided into 2 main stages:
  - Interphase – chromosomes are not visible. Involves cell growth and duplication of the genetic material.
  - Cell division – includes division of the duplicated chromosomes (mitosis) and division of the cytoplasm (cytokinesis).

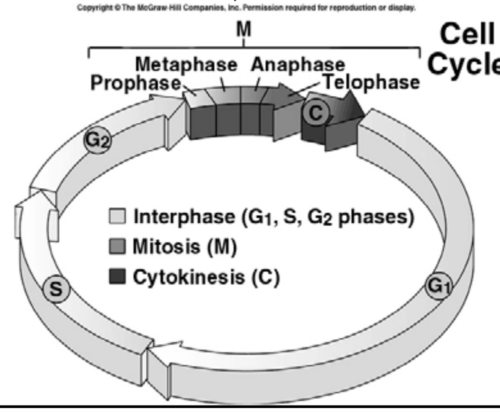
Objective 7

- Interphase is subdivided into 3 stages:
  - **G_1** is the primary growth phase of the cell cycle
  - **S** is when the cell synthesizes a copy of its chromosomes (DNA duplication).
  - **G_2** is the second growth phase, during which preparations are made for cell division.

Objective 7

- Mitosis is subdivided into 4 stages:
  - Prophase
  - Metaphase
  - Anaphase
  - Telophase

Objective 7



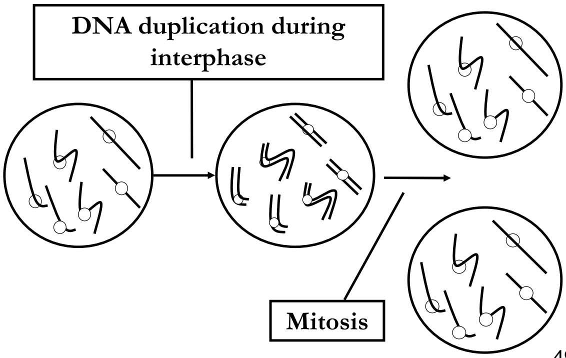
Objective # 8

List, describe, diagram, and identify the stages of mitosis.

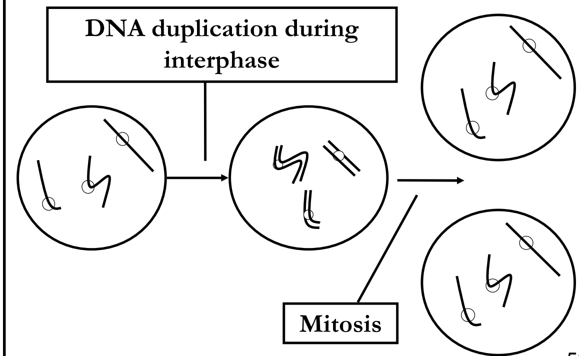
Objective 8

- Mitosis:
  - some haploid and some diploid cells may divide by mitosis.
  - each new cell receives one copy of every chromosome that was present in the original cell.
  - produces 2 new cells that are both genetically identical to the original cell.

Objective 8, Mitosis in a Diploid Cell (2N=6)



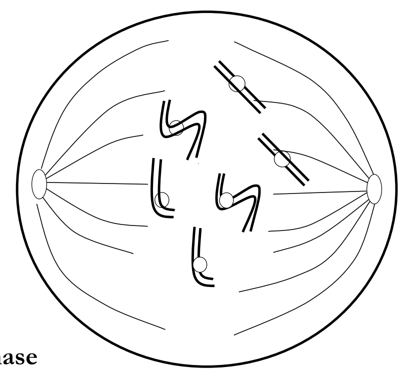
Objective 8, Mitosis in a Haploid Cell (N=3)



Objective 8, Stages of Mitosis

- Prophase:
  - nuclear membrane disintegrates
  - nucleolus disappears
  - duplicated chromosomes condense
  - mitotic spindle begins to form
  - kinetochores begin to mature and attach to mitotic spindle

Objective 8, Mitosis in a Diploid Cell (2N=6)

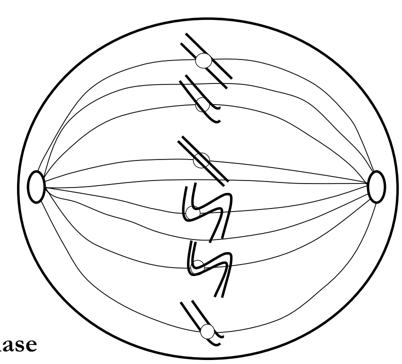


Prophase

Objective 8, Stages of Mitosis

- Metaphase:
  - kinetochores attach duplicated chromosomes to mitotic spindle
  - chromosomes line up, in single file, along metaphase plate at equator of cell

Objective 8, Mitosis in a Diploid Cell (2N=6)



Metaphase

Objective 8, Stages of Mitosis

- Anaphase:
  - centromeres split so that each duplicated chromosome becomes 2 identical, unduplicated chromosomes
  - kinetochore microtubules shorten, pulling identical chromosomes to opposite poles
  - polar microtubules elongate preparing cell for cytokinesis

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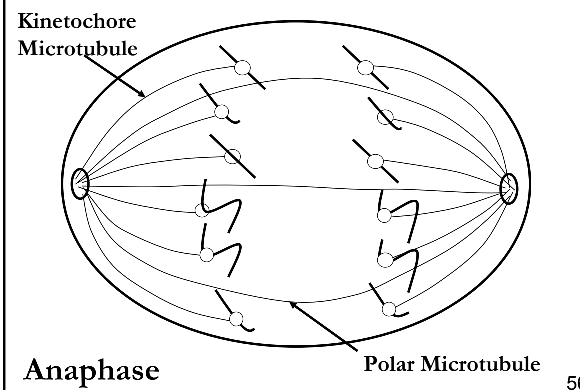
Objective 8, Mitosis in a Diploid Cell (2N=6)



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Objective 8, Stages of Mitosis

- Telophase:
  - chromosomes reach poles of cell
  - kinetochores disappear
  - polar microtubules continue to elongate, preparing cell for cytokinesis
  - nuclear membrane reforms
  - nucleolus reappears
  - chromosomes decondense

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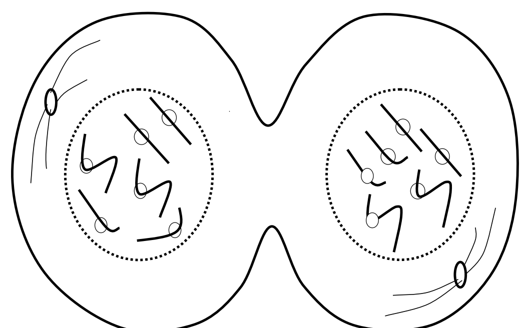
Objective 8, Mitosis in a Diploid Cell (2N=6)



Telophase

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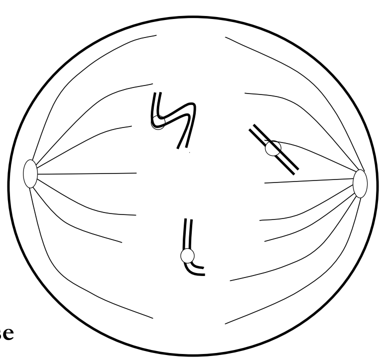
Objective 8, Mitosis in a Haploid Cell (N=3)



Prophase

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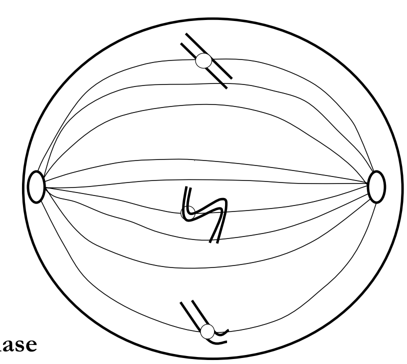
Objective 8, Mitosis in a Haploid Cell (N=3)



Metaphase

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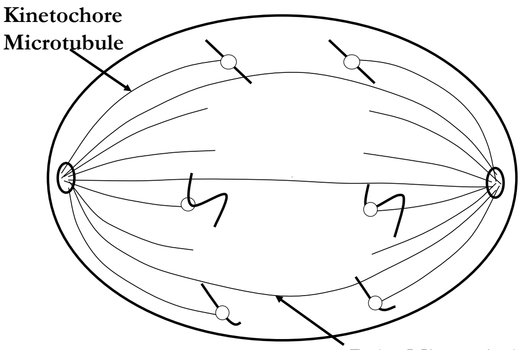
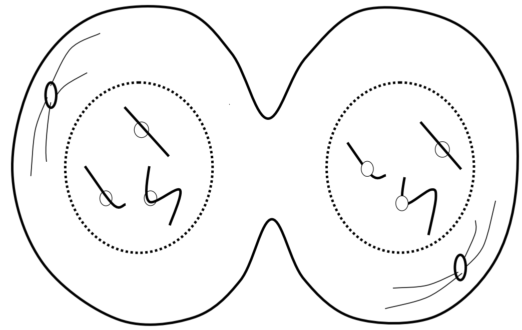
Objective 8, Mitosis in a Haploid Cell (N=3)



Anaphase

Objective 8, Mitosis in a Haploid Cell (N=3)



Telophase

Objective # 9

Describe the process of cytokinesis and distinguish between mitosis and cytokinesis.

Objective 9

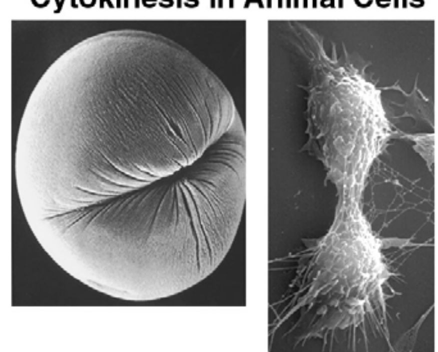
- Cytokinesis refers to division of the cytoplasm during cell division, while mitosis refers to division of the genetic material (chromosomes).
- Although cytokinesis generally follows mitosis, this isn't always the case.

Objective 9

- In animal cells and other eukaryotic cells that lack a cell wall, cytokinesis is achieved by means of a constricting belt of actin filaments.
- As the filaments slide past each other, they create a cleavage furrow which deepens and eventually pinches the cell in half:

Objective 9

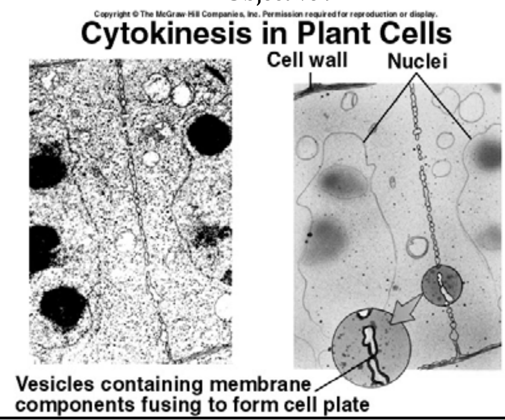
Cytokinesis in Animal Cells



Objective 9

- Plant cells possess a cell wall which is too rigid to be squeezed in half by actin filaments.
- Instead, a new cell membrane, called a cell plate, is assembled in the middle of the cell. As this expands outward, it effectively divides the cell in two.

Objective 9



Objective # 10

Explain what cancer is, and describe how cancer can result when control of the eukaryotic cell cycle breaks down.

Objective 10

- Cancer is the uncontrolled growth and division of cells.
- Most cancers result from mutations in one of two types of growth-regulating genes:
  - proto-oncogenes
  - tumor-suppressor genes

Objective 10

- Proto-oncogenes code for proteins involved in stimulating cell division.
- Mutated proto-oncogenes that stimulate a cell to divide when it shouldn't are called oncogenes (cancer-causing genes).

Objective 10

- Tumor-suppressor genes code for proteins involved in inhibiting cell division.
- Mutated tumor-suppressor genes that do not inhibit cell division when they should can also cause cancer.