Cell and Molecular Biology: An Introduction to Mitosis and Meiosis

Normal Cell Division

The nucleus regulates cell growth and reproduction, as well. The cell cycle consists of 4 discrete periods – coming shortly. Cell division occurs when the cells reproduce themselves. Somatic cell division (body cell division) occurs when a parent cell produces 2 identical daughter cells.

The division of the nuclear material is called mitosis; the cytoplasmic division is called cytokinesis. The daughter cells have the same number and the same kind of chromosomes (KROME uh somes) as does their parent cell.

Reproductive cells also undergo division of its/their nuclear material. This is called meiosis (my OH siss); cytokinesis (sigh to kunn EE siss) also occurs. When a parent cell divides by meiosis, haploid cells are formed. It is by this mechanism that spermatogenesis (spur ma toe GEN uh siss) occurs in the testes and oogenesis (oh oh GENN uh siss) in the ovaries.

There are two (2) successive nuclear divisions in meiosis: reduction division (meiosis I) and equatorial (or equational) division (meiosis II).

In terms of the reproductive cell divisions, the sex cells are called gametes (GAMM eets). In the female they are also called ova; in the male, sperm. Union/fusion of gametes is called fertilization and forms a zygote.

Somatic cells contain 46 chromosomes (2N), which are also equal to 23 pairs of chromosomes for ALL activities of the cell. In a sense, 23 chromosomes are duplicate. "N" or "n" describe the number of different chromosomes within the nucleus. Somatic cells contain 2 sets of each 20 chromosome. These cells are called diploid (DYE ploid) cells and are identified, as well, by 2N or 2n. In diploid cells, 2 chromosomes in a pair are called homologous chromosomes. Cells that contain 2N chromosomes contain 22 pairs that are autosomal (regulate the body) and 1 pair of sex chromosomes (X and X or X and Y for female and male, respectively). The chromosome number does NOT double in meiosis, rather, it halves producing haploid cells: N, n or 23 chromosomes.

Cell Reproduction

Mitosis and cytokinesis of somatic cells “runs” from approximately (varies by cell and by study) 1-2 hours in length up to more than 30 hours. Cell division occurs and the cells reproduce themselves.

Cell Cycle

The 4 Phases of Cell Growth and Reproduction (Mitosis) are summarized in the table, below, and in the following images.

G_1 phase	S phase	G_2 phase	Mitosis and cytokinesis
~ 8-10 hours in length	~ 6-9 hours in length	~ 2-6 hours in length	~ 1-2 hours in length
Growth phase	Synthesis phase	Growth phase	Cell division
Increased metabolism occurs; Gaps in DNA synthesis	Chromosomes replicated	Increased metabolism occurs; Gaps in DNA synthesis filled in	Cells reproduce
Cells that will NOT divide, again, are stopped in this phase, e.g., nerve cells	Once a cell is in this phase, it is committed to replicate	Cell volume increases about two-fold greater than it was in G1	
These first three phases are collectively known as Interphase. During these three phases, chromosomes replicate, centrosomes and centrioles replicate, RNA synthesis and protein synthesis increase. Once the chromosomes are capped off in interphase, they are ready to undergo division via either: mitosis (all cells in the human) or meiosis (only the immature sex cells in the human, i.e., spermatogonia and oogonia in the male and female, respectively).			

Between G_1 and S phase are four important stages: the "R" point, the G_0 phase, the re-entry point and the G_1/S checkpoint. These stages are summarized in the table below.

R point	G_0 phase	Re-entry point	G_1/S checkpoint	G_2/M checkpoint
Restriction point: is a decision point; cell decides to grow or quiesce [for later stimulation to regain entry into the growth cycle]	Cells that come here are not proliferative; are viable; have metabolic activity; quiescent; cancer cells avoid this stage	The point where previously quiescent cells are stimulated to leave G_0 and re-enter the cell cycle	A transition point; 1) to make certain enough time has passed since last mitosis, OR 2) cell is big enough to cause DNA synthesis, THEN go to S phase (uses a protein kinase)	This is another transition point where: 1) DNA synthesis is required to be completed and 2) When DNA repair is done in this stage, the cell goes on to mitosis (M phase) (again, uses a protein kinase for this function).

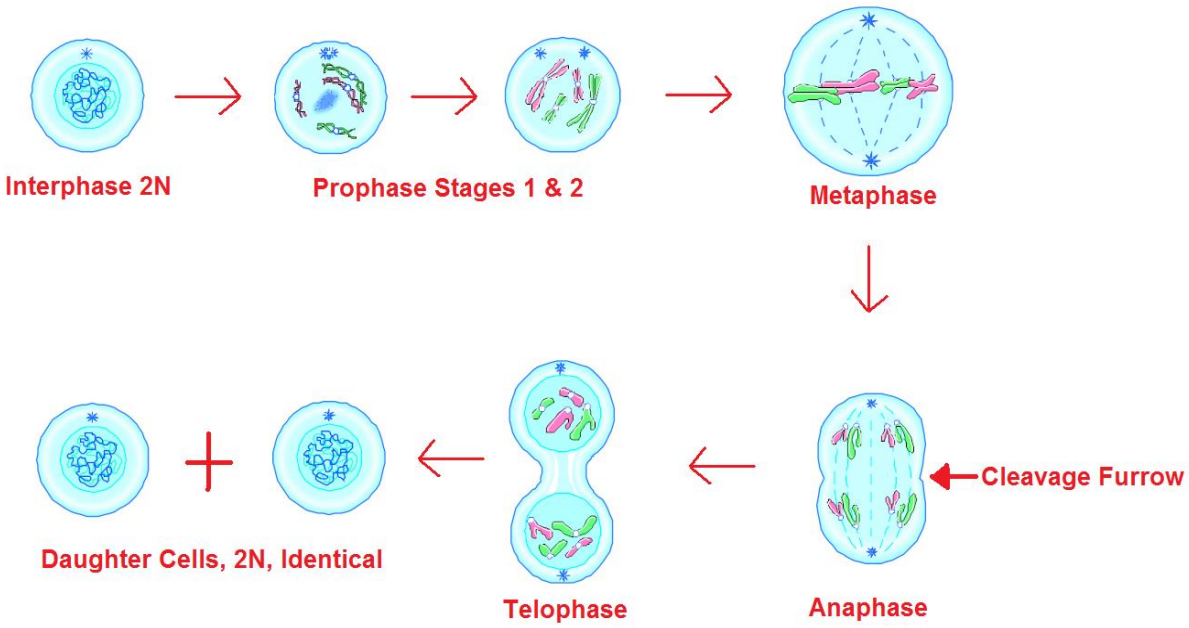
G_2/M checkpoint is between S phase and mitosis. This is another transition point in cell division where: 1) DNA synthesis is required to be completed and 2) When DNA repair is done in this stage, the cell goes on to mitosis (M phase) (again, uses a protein kinase for this function).

Remember from previous courses, e.g., high school biology, that there are four stages in mitosis: prophase (P), metaphase (M), anaphase (A) and telophase (T). The approximate time ratio in minutes for each stage is P: M: A: T -- 12: 1: 1: 6 – again, this varies by cell-type and study.

Mitosis vs Meiosis

Summary: Cells undergoing mitosis have daughter cells that are genetically identical with identical chromosomes (2N); Cells that undergo meiosis have daughter cells that are non-identical and have only half the number of chromosomes (N) of the parent cells (2N), Figure at right.

Mitosis



The graphic, above, illustrates an elementary version of mitosis by phase. Remember that Interphase is a combination of G_1, S and G_2 phases.

During Prophase, the nuclear membrane (envelope) is lost, the nucleolus is lost, organization of DNA is gained, centrioles move to the "poles" of the cell and the mitotic spindle forms with the chromosomes arranged parallel to the centrioles.

During Metaphase, the centrioles are aligned properly at each pole and the chromosomes are aligned perpendicular to the poles at the equator.

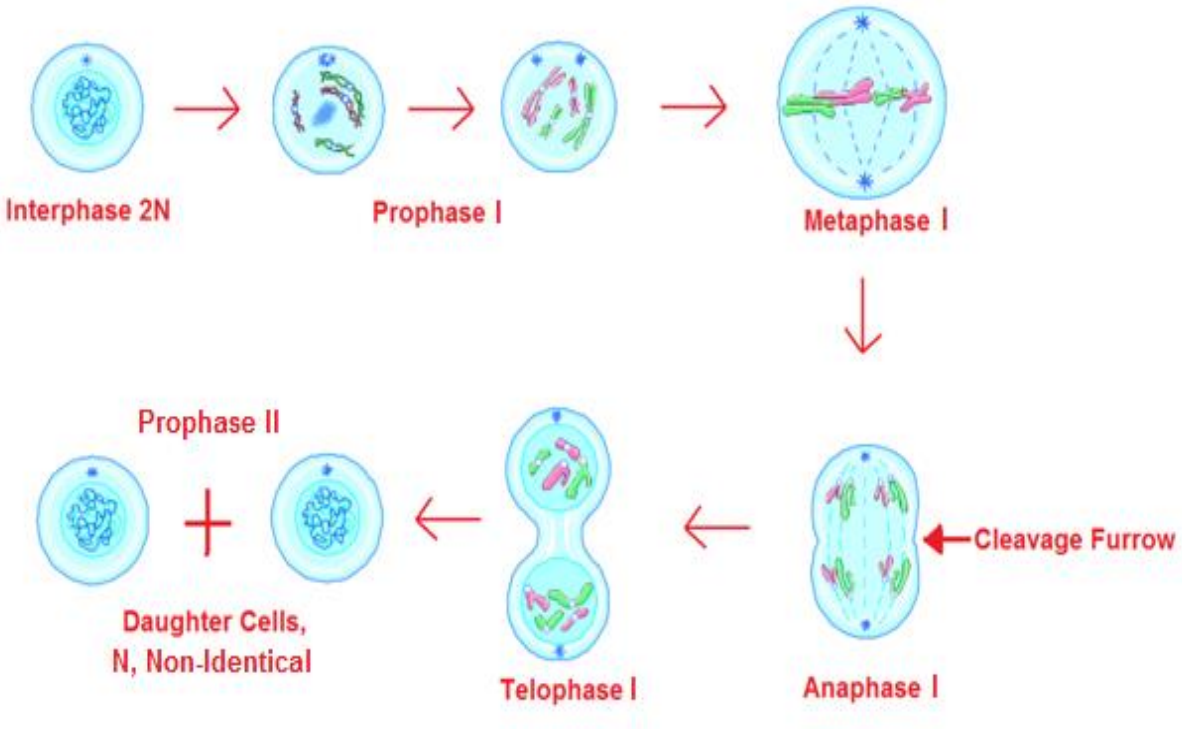
In Anaphase, the cleavage furrow is the first indicator of cytokinesis; chromosomes are pulled apart towards the poles.

Telophase, the last phase, completes cytokinesis and chromosome separation to form two identical daughter cells that are 2N, as was the mother cell. These new cells will undergo Interphase as necessary to continue the cell cycle.

Meiosis

We have to expand upon your fundamental knowledge of meiosis. As you learned in pre-req BIOL courses, there are two cycles of PMAT in meiosis: PMAT I and PMAT II. Prophase I is the stage we must expand. It consists of 7 distinct, more or less, stages: preleptotene, leptotene, zygotene, zygopachytene, pachytene, diplotene and diakinesis. The only stage with which you need be familiar is diakinesis. During diakinesis there is continued compaction of chromosomes; spindle fibers form; the nucleus loses its nuclear envelope; the cell then moves from prophase 1 into metaphase 1.

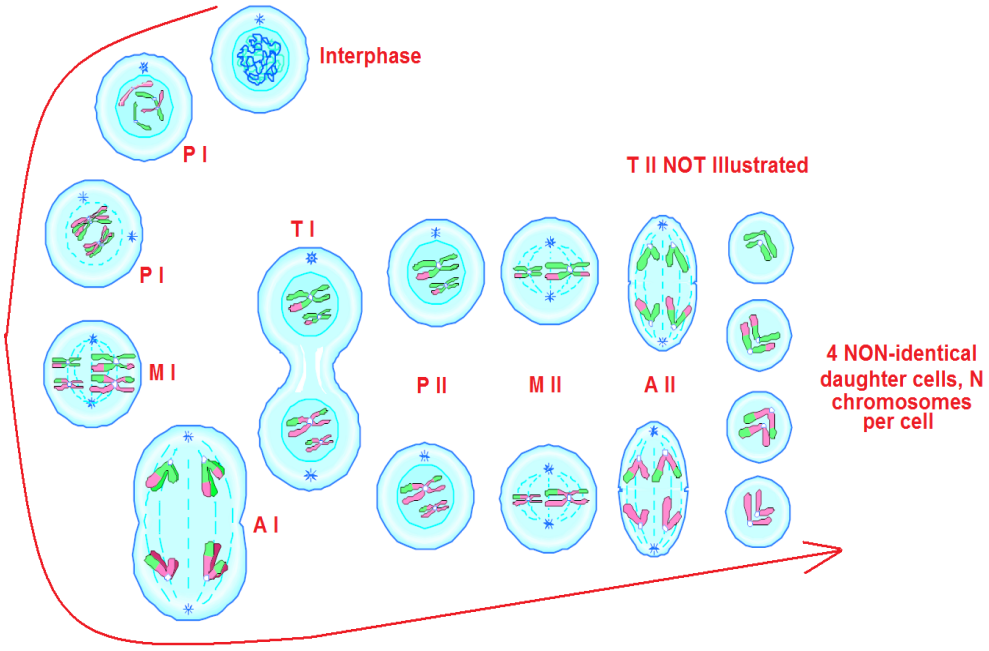
Meiosis I – Reduction Division



If the above diagram looks familiar, that's about right – there's not much difference between Meiosis I and MiTosis, with the exception that this stage of Meiosis reduces the chromosome number to half that of the parent cell (N from 2N). The idea of Meiosis I is to reduce the chromosome count to half of what it was.

Meiosis II -- Equatorial (Equational) Division

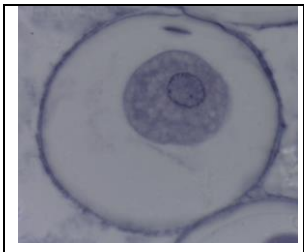
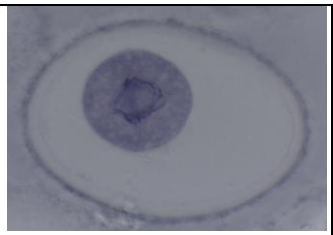
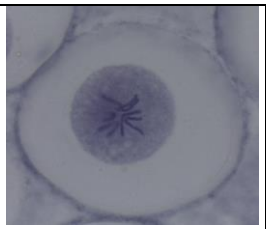
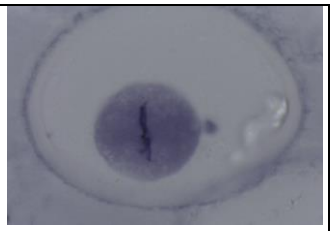
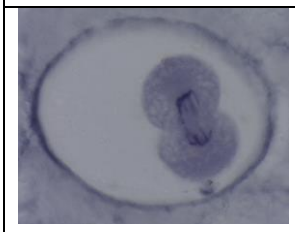
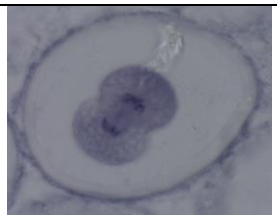
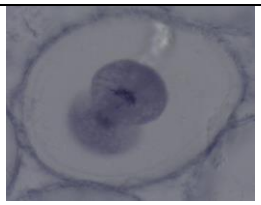
Meiosis II functions to double the number of daughter cells, yet maintain N numbers of chromosomes, Figure, below.



The figure above ties Meiosis I with Meiosis II (P = Prophase; M = Metaphase; A = Anaphase; T = Telophase; I = one; II = two). If you look carefully at the outcome, each of the four cells are unique.

Experimental

In the table, below, are captured images of ascarid eggs undergoing the various stages of mitosis. In the boxes below the pictures, write in the stage of mitosis the cells (nuclei) are undergoing.

Questions

1) What is a distinguishing visible feature of each stage of mitosis?

Prophase:

Metaphase:

Anaphase:

Telophase:

2) Using what you know about mitosis, would you agree that cancer is the disease of mitosis? Explain your answer.

3) The drawings A-E, below, show stages of mitosis in a plant cell:

Which of the above drawings A-E shows:

A) Interphase _____ (DNA is replicated)

B) Prophase _____ (chromosomes – 2 sister chromatids – shorten)

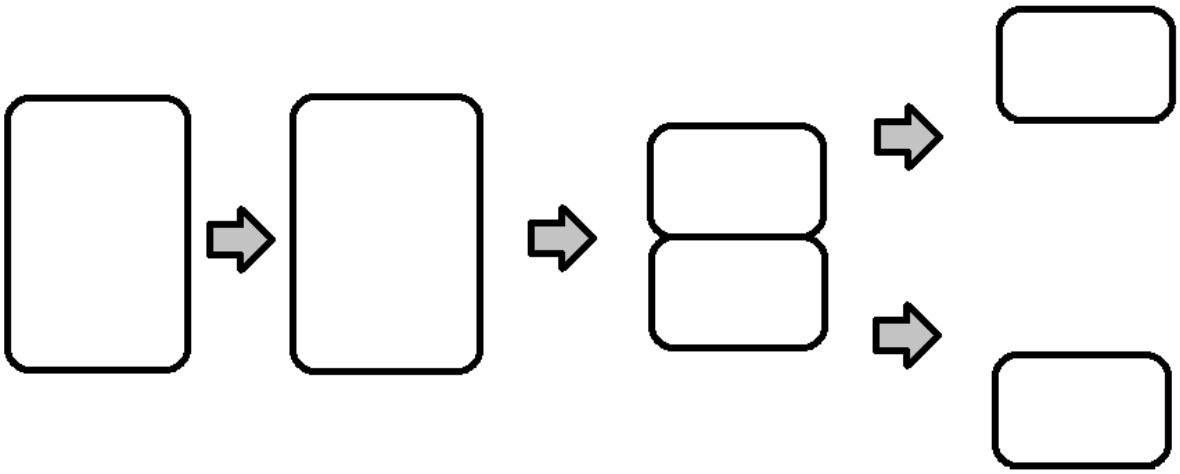
C) Metaphase _____ (sister chromatids line up)

D) Anaphase _____ (sister chromatids separate)

E) Telophase _____ (new nucleus forms at each end)

F) Cytokinesis _____ (cell contents divide between 2 daughter cells)

4) Using colored pencils or pens, illustrate how 2 chromosomes are passed from one parent cell to two daughter cells in mitosis:



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