The Cell Cycle

You Must Know

* the structure of the duplicated chromosome
* the events that occur in the G1, S, and 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)

Most cell division results in genetically identical daughter cells

The cell cycle is the life of a cell from the time it is first formed from a dividing parent cell until its own division into two cells.

A cell’s endowment of DNA, its genetic material, is called its genome. Before the cell can divide, the cell’s genome must be copied

* All eukaryotic organisms have a characteristic number of chromosomes in their cell nuclei. As an example, human somatic cells (all body cells except gametes) have 46 chromosomes, which is the diploid chromosome number. Mitosis is the process by which somatic cells divide, forming daughter cells that contain the same chromosome number as the parent cell.
* Human gametes – sperm and egg cells – are haploid and have half the number of chromosomes as a diploid cell. Human gametes have 23 chromosomes. A special type of cell division called meiosis results in gametes

When the chromosomes are replicated, each duplicated chromosomes consist of two sister chromatids attached by a centromere

* The two sister chromatids have identical DNA sequences
* Later, in the process of cell division, the two sister chromatids will separate and move into two new cells. Once the sister chromatids separate, they are considered individual chromosomes
* Mitosis is the division of the cell’s nucleus. It may be followed by cytokinesis, which is the division of the cell’s cytoplasm. Where there was one cell, there are now two, each the genetic equivalent of the parent cell.

The mitotic phase alternates with interphase in the cell cycle

* The primary events of interphase, which is 90% of the cell cycle, follow
  + G1 – the cell grows while carrying out cell functions unique to its cell type
  + S phase – the cell continues to carry out its unique functions but does one other important process – it duplicates its chromosomes. This means it faithfully makes a copy of the DNA that makes up the cell’s chromosomes
  + G2 phase – period after chromosome duplication and just before mitosis. Cell continues to grow and carry out its functions during this time.
* Mitosis (focus on how each step contributes to the distribution of identical genetic info into 2 daughter cells)
  + Prophase
    - chromatin becomes more tightly coiled into discrete chromosomes
    - nucleoli disappear
    - mitotic spindle (made of microtubules extending from centrosomes) begins to form in cytoplasm
  + Prometaphase
    - nuclear envelope begins to fragment, allowing microtubules to attach to the chromosomes
    - the 2 chromatids of each chromosome are held together by the centromere. The centromere contains protein kinetochores on each chromatid, which is where the microtubules will attach
  + Metaphase
    - the microtubules move the chromosomes to the metaphase plate at the equator of the cell. microtubule complex is called the spindle
    - the centrioles have migrated to opposite poles in the cell, riding along the developing spindle
  + Anaphase
    - sister chromatids begin to separate, pulled apart by motor molecules interacting with kinetochore microtubules
    - the cell elongates, as the nonkinetochore microtubules ratchet apart, again with the help of motor molecules
    - by the end of anaphase, the opposite ends of the cell both contain complete and equal sets of chromosomes
  + Telophase
    - the nuclear envelopes re-form around the sets of chromosomes located at opposite ends of the cell
    - the chromatin fiber of the chromosomes becomes less condensed
    - cytokinesis begins, during which the cytoplasm of the cell is divided. In animal cells, a cleavage furrow forms that eventually divides the cytoplasm; in plant cells, a cell plate forms that divides the cytoplasm
    - prokaryotes replicate their genome by binary fission rather than mitosis

The eukaryotic cell cycle is regulated by a molecular control system

* the steps of the cycle are controlled by a cell cycle control system. This control system moves the cell through its stages by a series of checkpoints, during which molecular signals tell the cell either to continue dividing or to stop.
* the major cell cycle checkpoints include the g1 phase checkpoint, g2 phase checkpoint, and M phase checkpoint
* The G1 phase checkpoint seems to be most important. If the cell gets the go ahead signal at this checkpoint, it usually completes the whole cell cycle and divides. If it does not receive the go ahead signal, it enters a nondividing phase called G0 phase
* Most mature human cells remain in the G0 phase and never receive the molecular signal to divide (pass through the G1 checkpoint). Muscle and nerve cells never divide, but liver cells can respond to signals, moving from G0 back to the cell cycle at G1
* Kinases are the protein enzymes that control the cell cycle. They exist in the cells at all times but are active only when they are connected to the cyclin proteins. Thus, they are called cyclin-dependent kinases (Cdks). Specific kinases give the go ahead signals at the G1 and G2 checkpoints.
* As a specific example, cyclin molecules combine with the Cdk molecules, producing enough molecules of MPF to pass the G2 checkpoint and initiate the events of mitosis (MPF promotes mitosis – think of it as Mitosis Promoting Factor)
* How does the cell stop division? During anaphase, MPF switches itself off by starting a process that leads to the destruction of cyclin molecules. Without cyclin molecules Cdk molecules become inactive, bringing mitosis to a close.
* Normal cell division has two key characteristics
  + density dependent inhibition – the phenomenon in which crowded cells stop dividing.
  + anchorage dependency – normal cells must be attached to a substratum, like the extracellular matrix of a tissue, to divide
* Knowing the features of normal cell division is important because cancer cells exhibit neither density-dependent inhibition nor anchorage dependency.
  + Several important points about cancer
    - transformation is the process that converts a normal cell into a cancer cell
    - a tumor is a mass of abnormal cells within otherwise normal tissue. If the abnormal cells remain at the original site, the lump is called a benign tumor. A malignant tumor becomes invasive enough to impair the functions of one or more organs. An individual with a malignant tumor is said to have cancer.
    - metastasis occurs when cells separate from a malignant tumor and enter blood or lymph vessels and travel to other parts of the body.