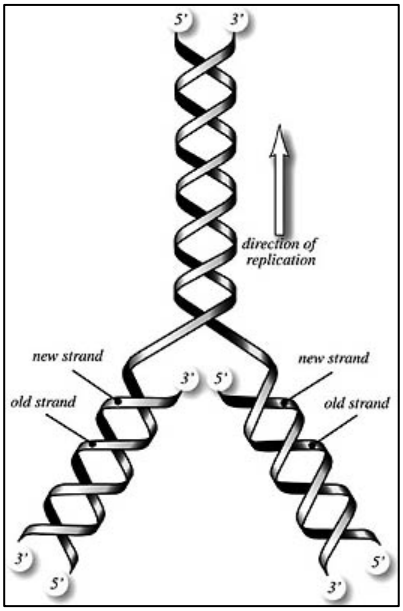
L # 3: DNA Replication, Cell Cycle, Mitosis, and Meiosis

DNA Replication

DNA replication is how cells make an exact copy of their DNA before dividing. It ensures that both new cells get the same genetic information.

Step-By-Step Of DNA Replication:

1. **Unwinding the Double Helix:**
   - The two strands of DNA separate like unzipping a zipper. This is done by an enzyme called **helicase**, which breaks the bonds between the base pairs.
2. **Building New Strands:**
   - Each separated strand serves as a template.
   - An enzyme called **DNA polymerase** adds new nucleotides (A, T, C, G) to the exposed bases, following the pairing rules:
     - A pairs with T.
     - C pairs with G.
3. **Completion:**
   - The result is two identical DNA molecules. Each has one original strand and one newly made strand, making the process **semi-conservative**.



Cell Cycle

The **cell cycle** is the series of organized, regulated events that a cell undergoes to grow, replicate its DNA, and divide into two daughter cells.

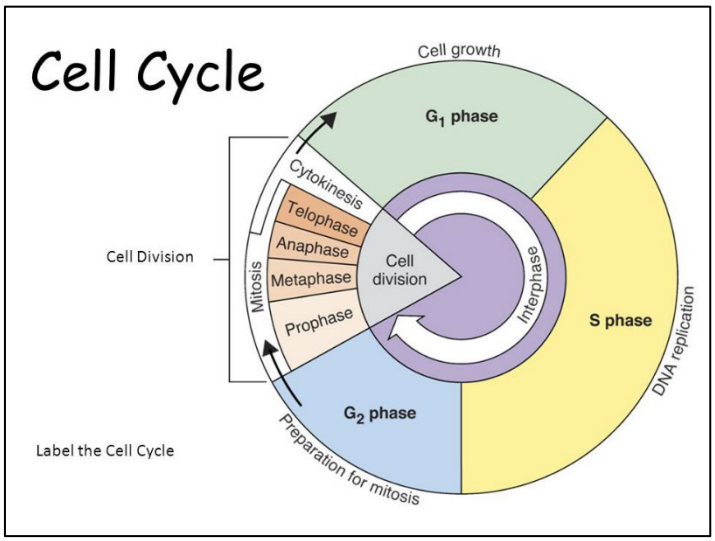
Why Do Cells Need the Cell Cycle?

1. **Growth and Development:** In multicellular organisms, the cell cycle supports the growth of tissues and organs during development.
2. **Tissue Repair and Regeneration:** Damaged or worn-out cells are replaced through cell division.
3. **Reproduction:** For single-celled organisms, the cell cycle enables asexual reproduction, while in multicellular organisms, specialized cell cycles (meiosis) produce gametes for sexual reproduction.
4. **Genomic Stability:** By tightly regulating DNA replication and division, the cell cycle prevents mutations and chromosomal abnormalities.

5. **Prevention of Disease:** Proper control of the cell cycle prevents unchecked proliferation, which can lead to cancer and other pathologies.

Phases of the Cell Cycle

The cell cycle consists of four distinct phases: **G1 (Gap 1), S (Synthesis), G2 (Gap 2), and M (Mitosis)**.



1. **G1 Phase:**
   - ➔ First gap phase where the cell grows and synthesizes proteins necessary for DNA replication.
2. **S Phase:**
   - ➔ DNA replication occurs, resulting in two identical sister chromatids for each chromosome.
3. **G2 Phase:**
   - ➔ Second gap phase where the cell continues to grow and prepare for mitosis.
   - ➔ The cell checks DNA for errors and repairs them.
4. **M Phase:**
   - ➔ Division phase, encompassing mitosis (nuclear division) and cytokinesis (cytoplasmic division).
5. **G0 Phase (Quiescence):**
   - ➔ Non-dividing phase where cells may enter temporarily or permanently (e.g., neurons).

Regulation of the Cell Cycle

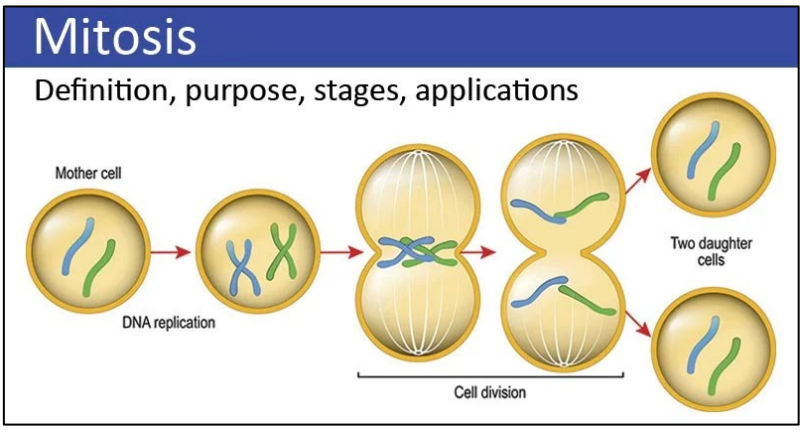
The cell cycle is tightly regulated by molecular checkpoints to ensure reliability in DNA replication and division. Dysregulation can lead to cancer or other pathologies.

1. **Cyclins and Cyclin-Dependent Kinases (CDKs):**
   - Cyclins are regulatory proteins that activate CDKs.
2. **Key Checkpoints:**
   - **G1/S Checkpoint:** Ensures the cell is ready for DNA synthesis.
   - **G2/M Checkpoint:** Verifies DNA integrity before mitosis.
   - **Spindle Assembly Checkpoint (Metaphase-Anaphase Transition):** Ensures proper chromosome alignment and attachment to spindle fibers.
3. **Tumor Suppressors and Oncogenes:**

- Proteins like **p53** and **Rb** act as tumor suppressors.
- Mutations in these proteins can lead to unregulated cell division.

Mitosis: Stages and Mechanisms

Mitosis ensures equal distribution of genetic material into two daughter cells. It occurs in somatic cells and comprises several stages:



1. **Prophase:**
   - Chromatin condenses into visible chromosomes.
   - Nuclear envelope disassembles, and spindle fibers form.
2. **Metaphase:**
   - Chromosomes align at the metaphase plate.
   - Microtubules attach to centromeres.
3. **Anaphase:**
   - Sister chromatids separate and move toward opposite poles.
4. **Telophase:**
   - Chromatids arrive at poles, and nuclear envelopes reform.
   - Chromosomes decondense into chromatin.
5. **Cytokinesis:**
   - Cytoplasm divides, forming two genetically identical daughter cells.

Meiosis: Stages and Mechanisms

Meiosis is a specialized cell division that reduces chromosome number by half, producing gametes (sperm and ova).

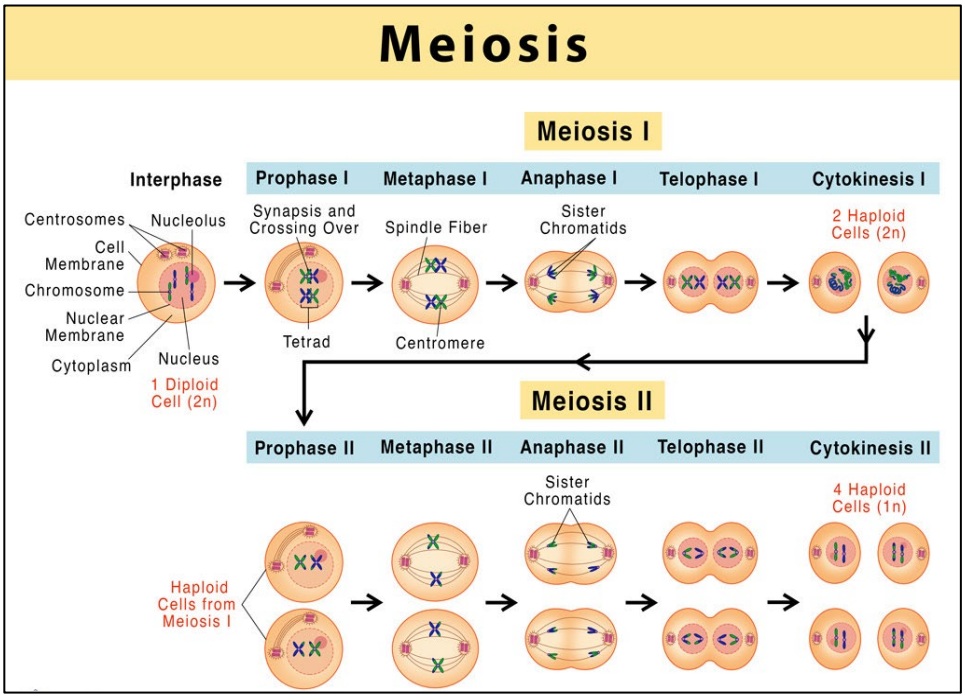
Meiosis I: Reductional Division

1. **Prophase I:**
   - Chromosomes condense, and homologous chromosomes pair (synapsis).
   - Genetic recombination occurs via crossing over at chiasmata.
2. **Metaphase I:**
   - Homologous pairs align at the metaphase plate.
3. **Anaphase I:**
   - Homologous chromosomes separate, moving to opposite poles.

4. **Telophase I and Cytokinesis:**
    - Two haploid cells are formed.

Meiosis II: Equational Division

1. **Prophase II:**
    - Spindle apparatus reforms.
2. **Metaphase II:**
    - Chromosomes align individually at the metaphase plate.
3. **Anaphase II:**
    - Sister chromatids separate and move to opposite poles.
4. **Telophase II and Cytokinesis:**
    - Four genetically unique haploid cells are formed.



Review questions L3

DNA Replication

1. What is the purpose of DNA replication in a cell?
2. Explain the role of helicase during DNA replication.
3. How does DNA polymerase ensure accuracy in base pairing?
4. Why is DNA replication described as "semi-conservative"?

Cell Cycle

1. List and briefly describe the four main phases of the cell cycle.
2. What is the significance of the G0 phase, and give an example of a cell type that enters this phase permanently?
3. How does the cell cycle contribute to genomic stability? *Hint: through Checkpoints and from there carry on your answer*

Mitosis

1. List the stages of mitosis in the correct order and briefly describe what occurs in each stage.

Meiosis

1. Differentiate between meiosis I and meiosis II in terms of their outcomes.