Chapter 10: Cell Cycle and Cell Division

Comprehensive Study Notes

Class 11 Biology - NCERT Based

EXAM SPRINT - Complete Coverage for NEET and Board Examinations

Introduction

All organisms, even the largest, start their life from a single cell. Growth and reproduction are fundamental characteristics of cells and all living organisms. All cells reproduce by dividing into two, with each parental cell giving rise to two daughter cells. These newly formed daughter cells can themselves grow and divide, allowing a single cell to form structures consisting of millions of cells.

10.1 CELL CYCLE

Definition

The cell cycle is the sequence of events by which a cell duplicates its genome, synthesizes other cellular constituents, and eventually divides into two daughter cells.

Key Features:

- Cell division, DNA replication, and cell growth must occur in a coordinated manner
- DNA synthesis occurs only during one specific stage
- Replicated chromosomes are distributed to daughter nuclei through complex events
- All processes are under genetic control

Duration and Variation:

- **Human cells in culture**: ~24 hours per cycle

- **Yeast**: ~90 minutes per cycle
- Duration varies between organisms and cell types

10.1.1 Phases of Cell Cycle

Two Basic Phases:

1. **Interphase** - Period of preparation for cell division
2. **M Phase (Mitosis phase)** - Actual cell division

Time Distribution:

- **M Phase**: ~1 hour (actual cell division)
- **Interphase**: >95% of cell cycle duration

Interphase Subdivisions:

G_1 Phase (Gap 1)

- **Duration**: Interval between mitosis and DNA replication initiation
- **Activities**:
  - Cell is metabolically active
  - Continuous growth occurs
  - **No DNA replication**
  - Organelle duplication

S Phase (Synthesis)

- **Key Process**: DNA synthesis/replication
- **DNA Content Change**: 2C → 4C (doubles)
- **Chromosome Number**: Remains same (2n)

- **Additional Events**:
  - In animal cells: Centriole duplication in cytoplasm

G_2 Phase (Gap 2)

- **Activities**:
  - Protein synthesis in preparation for mitosis
  - Continued cell growth
  - Cytoplasmic growth

G_0 Phase (Quiescent Stage)

- **Entry**: Some adult cells exit G_1 to enter inactive G_0
- **Characteristics**:
  - Cells remain metabolically active
  - No proliferation unless required
  - Examples: Heart cells
- **Function**: Replace cells lost due to injury or death

Cell Division Patterns:

- **Animals**: Mitotic division only in diploid somatic cells
- **Exception**: Male honey bees (haploid cells divide by mitosis)
- **Plants**: Both haploid and diploid cells can undergo mitosis

10.2 M PHASE (MITOSIS)

Characteristics:

- Most dramatic period of cell cycle

- Major reorganization of all cell components
- **Equational division**: Same chromosome number in parent and progeny
- Progressive process with no clear-cut boundaries between stages

Division Components:

- **Karyokinesis**: Nuclear division (4 stages)
- **Cytokinesis**: Cytoplasmic division

10.2.1 Prophase

Key Events:

1. **Chromosome Condensation**:
   - Chromosomal material becomes untangled
   - Compact mitotic chromosomes form
   - Each chromosome shows two chromatids attached at centromere
2. **Centrosome Movement**:
   - Duplicated centrosomes move to opposite poles
   - Each centrosome radiates microtubules (asters)
   - Asters + spindle fibers = mitotic apparatus
3. **Nuclear Envelope Breakdown**:
   - Golgi complex disappears
   - Endoplasmic reticulum disappears
   - Nucleolus disappears
   - Nuclear envelope disintegrates

10.2.2 Metaphase

Defining Features:

- Complete nuclear envelope disintegration
- Chromosomes spread throughout cytoplasm
- **Best stage for chromosome morphology study**

Chromosome Structure:

- Made of two sister chromatids
- Held together by centromere
- **Kinetochores**: Disc-shaped structures on centromere surface
- Attachment sites for spindle fibers

Chromosome Alignment:

- All chromosomes align at cell equator
- **Metaphase plate**: Plane of chromosome alignment
- Each chromatid connected to spindle fibers from opposite poles

10.2.3 Anaphase

Key Events:

1. **Centromere Division**: Simultaneous splitting of all centromeres
2. **Chromatid Separation**: Sister chromatids become daughter chromosomes
3. **Chromosome Movement**:
    - Migration toward opposite poles
    - Centromere leads, arms trail behind

10.2.4 Telophase

Characteristics:

1. **Chromosome Changes**:
   - Chromosomes reach respective poles
   - Decondensation occurs
   - Individual identity lost
2. **Nuclear Reformation**:
   - Nuclear envelope develops around chromosome clusters
   - Two daughter nuclei form
   - Nucleolus reappears
3. **Organelle Reformation**:
   - Golgi complex reforms
   - Endoplasmic reticulum reforms

10.2.5 Cytokinesis

Animal Cells:

- **Mechanism**: Furrow formation in plasma membrane
- **Process**: Furrow deepens and joins at center
- **Result**: Cytoplasm divides into two parts

Plant Cells:

- **Challenge**: Inextensible cell wall
- **Mechanism**: Cell wall formation from center outward
- **Process**:
  - Cell plate formation (precursor to middle lamella)

    - Grows outward to meet lateral walls
- **Organelle Distribution**: Mitochondria and plastids distributed between daughter cells

Special Cases:

- **Syncytium Formation**: Karyokinesis without cytokinesis
- **Example**: Liquid endosperm in coconut

10.3 Significance of Mitosis

Primary Functions:

1. **Growth:**

- Basis of multicellular organism growth
- Production of diploid daughter cells with identical genetic complement

2. **Cell Repair:**

- Continuous replacement of:
    - Epidermal cells
    - Gut lining cells
    - Blood cells

3. **Nucleo-cytoplasmic Ratio Maintenance:**

- Cell growth disturbs nucleus:cytoplasm ratio
- Division restores optimal ratio

4. **Plant Growth:**

- Continuous growth through meristematic tissues:

- Apical meristem
- Lateral cambium

Distribution:

- Usually restricted to diploid cells
- **Exceptions**: Some lower plants and social insects (haploid cells)

10.4 MEIOSIS

Definition and Purpose:

Specialized cell division that reduces chromosome number by half, producing haploid daughter cells (gametes) from diploid cells.

Key Features:

1. **Two sequential divisions**: Meiosis I and Meiosis II
2. **Single DNA replication cycle**
3. **Homologous chromosome pairing**
4. **Recombination between non-sister chromatids**
5. **Four haploid cells produced**

Biological Significance:

- Ensures haploid phase in sexual reproduction
- Fertilization restores diploid phase
- Occurs during gametogenesis

10.4.1 Meiosis I (Reductional Division)

Prophase I (Longest and Most Complex Phase)

Five Sub-stages:

1. Leptotene:

- Chromosomes become gradually visible
- Chromosome compaction begins

2. Zygotene:

- **Synapsis**: Homologous chromosome pairing
- **Synaptonemal complex**: Complex structure accompanying synapsis
- **Bivalent/Tetrad**: Paired homologous chromosomes

3. Pachytene:

- Four chromatids of each bivalent become distinct
- **Crossing over**: Exchange of genetic material between non-sister chromatids
- **Recombination nodules**: Sites where crossing over occurs
- **Recombinase**: Enzyme mediating crossing over

4. Diplotene:

- Synaptonemal complex dissolution
- Homologous chromosomes separate except at crossover sites
- **Chiasmata**: X-shaped structures at crossover sites
- Can last months/years in some vertebrate oocytes

5. Diakinesis:

- **Terminalization of chiasmata**
- Complete chromosome condensation
- Meiotic spindle assembly
- Nucleolus disappears
- Nuclear envelope breaks down

Metaphase I:

- Bivalent chromosomes align on equatorial plate
- Spindle microtubules attach to kinetochores of homologous chromosomes

Anaphase I:

- **Key difference from mitosis**: Homologous chromosomes separate
- Sister chromatids remain attached at centromeres

Telophase I:

- Nuclear membrane and nucleolus reappear
- Cytokinesis follows
- **Dyad formation**: Two cells formed
- Chromosomes may partially disperse but don't reach full interphase extension

Interkinesis:

- Short stage between meiosis I and II
- **No DNA replication**
- Much simpler than regular interphase

10.4.2 Meiosis II (Equational Division)

Characteristics:

- Resembles normal mitosis
- Initiated immediately after cytokinesis
- Operates on haploid cells

Stages:

Prophase II:

- Nuclear membrane disappears
- Chromosomes become compact again

Metaphase II:

- Chromosomes align at equator
- Spindle microtubules attach to sister chromatid kinetochores

Anaphase II:

- Centromere splitting
- Sister chromatids separate and move to opposite poles

Telophase II:

- Nuclear envelopes reform around chromosome groups
- Cytokinesis follows
- **Tetrad formation**: Four haploid daughter cells

10.5 Significance of Meiosis

1. **Chromosome Number Conservation:**

- Maintains species-specific chromosome number across generations
- Despite reduction division, restoration occurs through fertilization

2. **Genetic Variation:**

- Increases genetic variability through:
  - Independent assortment
  - Crossing over and recombination
- Essential for evolution

3. **Sexual Reproduction:**

- Enables formation of genetically diverse gametes
- Foundation of sexual reproduction in organisms

NEET-Specific Important Points

High-Yield Topics:

1. **Cell Cycle Phases:**

- Duration and activities of each phase
- DNA content changes (2C → 4C)
- Chromosome number consistency

2. **Mitosis vs Meiosis:**

- Purpose and outcomes
- Number of divisions
- Genetic variation

3. Chromosome Behavior:

- Condensation and movement patterns
- Difference in anaphase of mitosis vs meiosis I

4. Significance:

- Biological importance of each process
- Examples of where each occurs

Common NEET Question Patterns:

1. Process Identification:

- Recognize phases from descriptions
- Match events with phases
- Identify division types

2. Comparison Questions:

- Mitosis vs meiosis differences
- Animal vs plant cytokinesis
- Chromosome behavior patterns

3. Application Questions:

- Cell cycle regulation

- Cancer relation
- Genetic variation sources

Memory Aids and Mnemonics

Cell Cycle Phases:

"Good Students Make All"

- **G_1** (Gap 1)
- **S** (Synthesis)
- **M** (Mitosis)
- **All** (represents completion)

Mitosis Phases:

"Please Make All Tea"

- **P**rophase
- **M**etaphase
- **A**naphase
- **T**elophase

Meiosis I Prophase Substages:

"Lazy Zebras Play During Day"

- **L**eptotene
- **Z**ygotene
- **P**achytene

- **D**iplotene
- **D**iakinesis

Practice Questions for NEET

Multiple Choice Questions:

1. During which phase of the cell cycle does DNA replication occur? a) G_1 phase b) S phase c) G_2 phase d) M phase
2. The stage best suited for studying chromosome morphology is: a) Prophase b) Metaphase c) Anaphase d) Telophase
3. Crossing over occurs during: a) Leptotene b) Zygotene c) Pachytene d) Diplotene

Short Answer Questions:

1. Why is mitosis called equational division?
2. What is the significance of crossing over in meiosis?
3. Differentiate between cytokinesis in plant and animal cells.

Long Answer Questions:

1. Describe the various phases of meiosis I with diagrams.
2. Explain the significance of mitosis in multicellular organisms.
3. Compare and contrast mitosis and meiosis.

Summary Table: Cell Division Comparison

Feature	Mitosis	Meiosis
Purpose	Growth, repair	Gamete formation
Cell Type	Somatic cells	Germ cells
Number of Divisions	One	Two
DNA Replication	Once per division	Once for two divisions
Daughter Cells	2 diploid	4 haploid
Genetic Variation	None	High (crossing over)
Chromosome Pairing	No	Yes (synapsis)
Duration	Shorter	Longer

EXAM SPRINT - Master Cell Cycle and Division with focused study on phase identification, process comparison, and significance understanding. Regular practice with diagrams and comparison tables is key to NEET success.

Source: NCERT Biology Class 11, Chapter 10 - Comprehensive coverage for NEET preparation