# Chapter 13: Plant Growth and Development

## Comprehensive Study Notes

**Class 11 Biology - NCERT Based**

**EXAM SPRINT - Complete Coverage for NEET and Board Examinations**

## Introduction

Development is the sum of growth and differentiation. Plant development follows a precise and ordered succession of events from zygote to mature plant, producing complex body organization with roots, leaves, branches, flowers, fruits, and seeds.

### Key Questions Addressed:

- How do plant structures arise in orderly sequence?
- Why does vegetative phase precede flowering?
- How do cells from the same zygote develop different functions?
- What factors control developmental processes?

### Developmental Process Overview:

**Seed Germination → Growth → Differentiation → Maturation → Senescence → Death**

## 13.1 GROWTH

### Definition:

Growth is an **irreversible permanent increase in size** of an organ, its parts, or individual cells, accompanied by metabolic processes requiring energy.

### Examples:

- **Growth**: Leaf expansion
- **Non-growth**: Wood swelling in water (reversible)

## 13.1.1 Plant Growth Generally is Indeterminate

**Unique Features of Plant Growth:**

- **Unlimited Growth Capacity**: Throughout life due to meristems
- **Open Form of Growth**: New cells continuously added by meristematic activity
- **Self-perpetuating Meristems**: Divide and maintain growth capacity

**Types of Growth:**

**Primary Growth**:

- **Location**: Root and shoot apical meristems
- **Result**: Elongation along plant axis
- **Duration**: Throughout plant life

**Secondary Growth**:

- **Location**: Lateral meristems (vascular cambium, cork cambium)
- **Result**: Increase in girth/thickness
- **Plants**: Dicotyledons and gymnosperms
- **Timing**: Appears later in plant life

## 13.1.2 Growth is Measurable

**Measurement Parameters:**

- Fresh weight and dry weight
- Length, area, and volume
- Cell number

**Examples of Growth Measurements:**

- **Maize root**: 17,500 new cells per hour (growth by cell division)
- **Watermelon cells**: 3,50,000 times size increase (growth by cell enlargement)
- **Pollen tube**: Measured by length
- **Dorsiventral leaf**: Measured by surface area increase

### 13.1.3 Phases of Growth

Growth occurs in three distinct phases:

**1. Meristematic Phase:**

**Location**: Root and shoot apex **Characteristics**:

- Constantly dividing cells
- Rich in protoplasm
- Large, conspicuous nuclei
- Primary cell walls (thin, cellulosic)
- Abundant plasmodesmatal connections

**2. Elongation Phase:**

**Location**: Proximal to meristematic zone **Characteristics**:

- Increased vacuolation
- Cell enlargement

- New cell wall deposition

**3. Maturation Phase:**

**Location**: Most proximal to apex **Characteristics**:

- Cells attain maximal size
- Wall thickening
- Protoplasmic modifications
- Specialized cell types and tissues formed

### 13.1.4 Growth Rates

**Growth Rate**: Increased growth per unit time

**Types of Growth Patterns:**

**1. Arithmetic Growth:**

**Mechanism**: Only one daughter cell divides after mitosis, other differentiates **Pattern**: Linear growth curve **Example**: Root elongating at constant rate **Mathematical Expression**:

```
Lt = L0 + rt
Where:
Lt = length at time 't'
L0 = initial length
r = growth rate per unit time
```

**2. Geometric Growth:**

**Mechanism**: Both daughter cells retain division capacity **Pattern**: Sigmoid (S-curve) with three phases:

**Phases**:

1. **Lag Phase**: Slow initial growth
2. **Log/Exponential Phase**: Rapid exponential growth
3. **Stationary Phase**: Growth slows due to limited nutrients

**Mathematical Expression**:

$W1 = W0 \times e^{(rt)}$
Where:
W1 = final size
W0 = initial size
r = relative growth rate (efficiency index)
t = time
e = base of natural logarithms

**Growth Rate Comparisons:**

**Absolute Growth Rate**: Total growth per unit time **Relative Growth Rate**: Growth per unit time on common basis (per unit initial parameter)

### 13.1.5 Conditions for Growth

**Essential Requirements:**

1. **Water**:
   - Cell enlargement medium
   - Maintains turgidity for extension growth
   - Medium for enzymatic activities
2. **Oxygen**:
   - Releases metabolic energy

- Essential for growth activities

3. **Nutrients**:
   - Macro and microelements
   - Protoplasm synthesis
   - Energy source
4. **Optimum Temperature**:
   - Each plant has specific range
   - Deviation can be detrimental
5. **Environmental Signals**:
   - Light and gravity
   - Affect specific growth phases

## 13.2 DIFFERENTIATION, DEDIFFERENTIATION AND REDIFFERENTIATION

### Differentiation:

**Definition**: Process where cells mature to perform specific functions **Process**: Structural changes in cell walls and protoplasm **Example**: Tracheary element formation - cells lose protoplasm, develop strong lignocellulosic walls

### Dedifferentiation:

**Definition**: Differentiated cells regain capacity to divide under certain conditions **Examples**:

- Interfascicular cambium formation from parenchyma
- Cork cambium from differentiated cells
- Plant tissue culture callus formation

### Redifferentiation:

**Definition**: Dedifferentiated cells lose division capacity again and mature for specific functions
**Examples**: Secondary tissues in woody plants

### Open Differentiation:

- Cells from same meristem develop different structures
- Final cell structure determined by position
- **Examples**:
  - Root cap cells (away from apex)
  - Epidermal cells (at periphery)

## 13.3 DEVELOPMENT

### Definition:

Development includes all changes from seed germination to senescence, encompassing the entire life cycle.

### Sequence of Development:

**Cell Division → Plasmatic Growth → Expansion (Elongation) → Differentiation → Maturation → Senescence → Death**

### Plasticity in Development:

**Definition**: Ability to form different structures in response to environment or life phases

#### Examples of Plasticity:

1. **Heterophylly**: Different leaf shapes in same plant
   - **Juvenile vs Mature**: Cotton, coriander, larkspur

- **Environmental**: Buttercup (air vs water leaves)

### Development Control:

**Development = Growth + Differentiation**

**Controlling Factors:**

**Intrinsic (Internal)**:

- Genetic factors (intracellular)
- Chemical factors - Plant Growth Regulators (intercellular)

**Extrinsic (External)**:

- Light, temperature, water, oxygen, nutrition

## 13.4 PLANT GROWTH REGULATORS (PGRs)

### 13.4.1 Characteristics

**Chemical Composition:**

- **Indole compounds**: Indole-3-acetic acid (IAA)
- **Adenine derivatives**: Kinetin
- **Carotenoid derivatives**: Abscisic acid (ABA)
- **Terpenes**: Gibberellic acid ($GA_3$)
- **Gases**: Ethylene ($C_2H_4$)

**Alternative Names:**

Plant growth substances, plant hormones, phytohormones

**Classification by Function:**

**Group I - Growth Promoters**:

- **Functions**: Cell division, enlargement, pattern formation, flowering, fruiting
- **Examples**: Auxins, Gibberellins, Cytokinins

**Group II - Growth Inhibitors/Stress Responses**:

- **Functions**: Dormancy, abscission, stress responses
- **Examples**: Abscisic acid, Ethylene (mostly inhibitory)

### 13.4.2 The Discovery of Plant Growth Regulators

All five major PGR groups were discovered accidentally:

**1. Auxins - Charles Darwin (1880):**

- **Observation**: Coleoptile phototropism in canary grass
- **Conclusion**: Transmittable influence from coleoptile tip
- **Isolation**: F.W. Went from oat seedling coleoptile tips

**2. Gibberellins - E. Kurosawa (1926):**

- **Disease**: 'Bakanae' (foolish seedling) in rice
- **Cause**: Gibberella fujikuroi fungus
- **Discovery**: Active substances in sterile fungal filtrates

**3. Cytokinins - F. Skoog:**

- **Observation**: Tobacco stem callus proliferation
- **Requirement**: Auxin + supplements (coconut milk, yeast extract, DNA)

- **Isolation**: Miller et al. (1955) - crystallized kinetin

**4. Abscisic Acid (1960s):**

- **Sources**: Three independent research groups
- **Names**: Inhibitor-B, Abscission II, Dormin
- **Result**: All proved chemically identical - ABA

**5. Ethylene - H.H. Cousins (1910):**

- **Observation**: Volatile substance from ripe oranges
- **Effect**: Hastened banana ripening
- **Identification**: Gaseous ethylene

## 13.4.3 Physiological Effects of Plant Growth Regulators

### 13.4.3.1 Auxins

**Etymology**: Greek 'auxein' = to grow **First Source**: Human urine

**Natural Auxins:**

- **IAA**: Indole-3-acetic acid
- **IBA**: Indole butyric acid

**Synthetic Auxins:**

- **NAA**: Naphthalene acetic acid
- **2,4-D**: 2,4-dichlorophenoxyacetic acid

**Major Functions:**

**1. Root Initiation**:

- Promotes rooting in stem cuttings
- Widely used in plant propagation

**2. Flowering**:

- Promotes flowering (e.g., pineapples)

**3. Abscission Control**:

- Prevents early fruit and leaf drop
- Promotes abscission in mature organs

**4. Apical Dominance**:

- Growing apical bud inhibits lateral buds
- Decapitation promotes lateral bud growth
- **Applications**: Tea plantations, hedge-making

**5. Parthenocarpy**:

- Fruit development without fertilization
- **Example**: Seedless tomatoes

**6. Herbicidal Action**:

- 2,4-D kills dicot weeds
- Safe for mature monocots
- **Use**: Weed-free lawn preparation

**7. Other Effects**:

- Controls xylem differentiation

- Promotes cell division

#### 13.4.3.2 Gibberellins

**Diversity:**

- Over 100 gibberellins known ($GA_1$, $GA_2$, $GA_3$...)
- Found in fungi and higher plants
- $GA_3$ (Gibberellic acid) most studied
- All GAs are acidic

**Major Functions:**

**1. Axis Elongation**:

- Increases stem length
- **Example**: Grape stalk elongation

**2. Fruit Development**:

- Apple elongation and shape improvement
- Delays senescence
- Extended market period

**3. Industrial Applications**:

- **Brewing**: Speeds malting process
- **Sugarcane**: 20 tonnes per acre yield increase

**4. Reproductive Effects**:

- Hastens maturity in juvenile conifers

- Early seed production

**5. Bolting**:

- Promotes internode elongation before flowering
- **Examples**: Beet, cabbage, rosette plants

#### 13.4.3.3 Cytokinins

**Discovery**: Kinetin from autoclaved herring sperm DNA **Natural Form**: Zeatin (from corn kernels, coconut milk)

**Synthesis Locations:**

- Root apices
- Developing shoot buds
- Young fruits
- Regions of rapid cell division

**Major Functions:**

**1. Cell Division**:

- Specific effects on cytokinesis
- Promotes cell division activity

**2. Organ Development**:

- New leaf production
- Chloroplast development in leaves
- Lateral shoot growth
- Adventitious shoot formation

**3. Apical Dominance**:

- Overcomes apical dominance
- Promotes lateral bud growth

**4. Senescence Delay**:

- Nutrient mobilization
- Delays leaf senescence

#### 13.4.3.4 Ethylene

**Nature**: Simple gaseous PGR **Synthesis**: High amounts in senescent tissues and ripening fruits

**Major Functions:**

**1. Seedling Development**:

- Horizontal growth orientation
- Axis swelling
- Apical hook formation in dicots

**2. Senescence and Abscission**:

- Promotes organ senescence
- Accelerates leaf and flower abscission

**3. Fruit Ripening**:

- Highly effective ripening agent
- Enhances respiration rate
- **Respiratory Climacteric**: Rise in respiration during ripening

**4. Dormancy Breaking**:

- Breaks seed and bud dormancy
- **Examples**: Peanut germination, potato tuber sprouting

**5. Flooding Adaptation**:

- Rapid internode/petiole elongation
- Keeps leaves above water in deep water rice

**6. Root Development**:

- Promotes root growth
- Increases root hair formation
- Enhanced absorption surface

**7. Commercial Applications**:

- **Ethephon**: Synthetic ethylene source
- **Fruit Ripening**: Tomatoes, apples
- **Abscission**: Cotton, cherry, walnut thinning
- **Sex Expression**: Promotes female flowers in cucumbers

**13.4.3.5 Abscisic Acid (ABA)**

**Alternative Name**: Stress hormone

**Major Functions:**

**1. Growth Inhibition**:

- General plant growth inhibitor

- Inhibits plant metabolism

**2. Seed Development**:

- Inhibits seed germination
- Promotes seed dormancy
- Helps seeds withstand desiccation

**3. Stress Responses**:

- Stimulates stomatal closure
- Increases stress tolerance
- Response to water, salt, temperature stress

**4. Antagonistic Effects**:

- Often acts opposite to gibberellins
- Balances growth promotion

## PGR Interactions:

**Types of Interactions:**

- **Complementary**: Work together
- **Antagonistic**: Oppose each other
- **Individualistic**: Independent action
- **Synergistic**: Enhanced combined effect

**Examples of Multiple PGR Events:**

- Seed/bud dormancy
- Abscission

- Senescence
- Apical dominance

## NEET-Specific Important Points

### High-Yield Topics for NEET:

1. **Growth Patterns**:
   - Arithmetic vs geometric growth
   - Sigmoid curve phases
   - Mathematical expressions
2. **Growth Phases**:
   - Meristematic, elongation, maturation
   - Characteristics of each phase
3. **PGR Discovery and Functions**:
   - Historical discoveries
   - Major functions of each PGR
   - Commercial applications
4. **Differentiation Processes**:
   - Differentiation, dedifferentiation, redifferentiation
   - Examples and significance

### Common NEET Question Patterns:

1. **Identification Questions**:
   - PGR effects and applications
   - Growth phase characteristics

- Differentiation examples

2. **Function-Based Questions**:
   - Which PGR for specific function
   - Growth measurements
   - Developmental processes
3. **Application Questions**:
   - Commercial uses of PGRs
   - Agricultural applications
   - Practical examples

## Memory Aids and Mnemonics

### Five Major PGRs:

**"All Good Children Eat Apple"**

- **A**uxins
- **G**ibberellins
- **C**ytokinins
- **E**thylene
- **A**bscisic acid

### Auxin Functions:

**"RAPH Helps Plants"**

- **R**ooting
- **A**pical dominance
- **P**arthenocarpy

- **H**erbicide

### Growth Phases:

**"Many Elephants Migrate"**

- **M**eristematic
- **E**longation
- **M**aturation

### Gibberellin Effects:

**"Big Fruits Make Sales"**

- **B**olting
- **F**ruit elongation
- **M**alting process
- **S**tem elongation

## Practice Questions for NEET

### Multiple Choice Questions:

1. Which PGR is known as stress hormone? a) Auxin b) Gibberellin c) Cytokinin d) Abscisic acid
2. Apical dominance is caused by: a) Gibberellins b) Auxins c) Cytokinins d) Ethylene
3. Sigmoid growth curve is characteristic of: a) Arithmetic growth b) Geometric growth c) Linear growth d) Exponential growth

### Short Answer Questions:

1. Define differentiation, dedifferentiation, and redifferentiation with examples.
2. What is apical dominance? How is it commercially exploited?

3. Explain the phases of growth with their characteristics.

### Long Answer Questions:

1. Describe the discovery and physiological effects of auxins.
2. Compare arithmetic and geometric growth patterns with mathematical expressions.
3. Explain how plant growth regulators interact synergistically and antagonistically.

## Application-Based Questions for NEET:

**Which PGR would you use to:**

| Purpose | PGR | Explanation |
|---|---|---|
| Induce rooting in twig | Auxin | Promotes adventitious root formation |
| Quickly ripen fruit | Ethylene | Accelerates fruit ripening process |
| Delay leaf senescence | Cytokinin | Promotes nutrient mobilization |
| Induce axillary bud growth | Cytokinin | Overcomes apical dominance |
| 'Bolt' a rosette plant | Gibberellin | Promotes internode elongation |
| Immediate stomatal closure | Abscisic acid | Stress hormone response |

## Summary Table: PGR Overview

| PGR | Source | Major Functions | Commercial Uses |
|---|---|---|---|
| Auxins | Growing apices | Rooting, apical dominance | Plant propagation, herbicides |
| Gibberellins | Various tissues | Stem elongation, bolting | Brewing, sugarcane yield |
| Cytokinins | Root apices | Cell division, senescence delay | Tissue culture |
| Ethylene | Senescent tissues | Ripening, abscission | Fruit ripening, flower induction |
| Abscisic acid | Various tissues | Dormancy, stress response | Stress tolerance |

## Key Equations and Formulas:

1. **Arithmetic Growth**: Lt = L0 + rt
2. **Geometric Growth**: W1 = W0 × e^(rt)
3. **Relative Growth Rate**: (W1 - W0)/W0 × T
4. **Absolute Growth Rate**: (W1 - W0)/T

**EXAM SPRINT - Master Plant Growth and Development with focused study on PGR functions, growth patterns, and developmental processes. Understanding applications and interactions is key to NEET success.**

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*Source: NCERT Biology Class 11, Chapter 13 - Comprehensive coverage for NEET preparation*