

## OC 18

## Plants Physiology and Biochemistry

Code	OC 18
ECTS credits	6
Attendance time	6 Semester
Language of instruction	Ukrainian
Duration	1
Cycle	Each Summer Semester
Coordinator	Associate Professor, PhD, Andrii Schogolev
Instructor(s)	Associate Professor, PhD, Yuhno Yuliya
Allocation of study programmes	Biology
Recommended prerequisites	Cell biology; Structural Botany: Anatomy of Plants Chemistry; Physics; Botany: Thallobiontes; Biochemistry knowledge of the disciplines of natural science
Learning objectives	knowledge of the physiological and biochemical patterns of a plant organism functioning as a system of structures and functions, applied aspects of plant physiology and biochemistry; - knowledge of the place and role of plants in the biosphere and human life; - understanding of the fundamental importance of phytophysiology and biochemistry of plants in the formation of the overall system of ideas about living system functioning; - ability to apply theoretical knowledge and laboratory skills in the field of plant biology.
Syllabus	<p>Introduction to Plant Physiology and Biochemistry</p> <ul style="list-style-type: none"><li>• Introduction to plant physiology and biochemistry</li><li>• Evolution of plant physiological studies</li><li>• Methodological foundations and development of plant physiology</li><li>• Role of plant physiology in addressing global challenges</li></ul> <p>Chapter 1: Physiology of a Plant Cell. Photosynthesis. Respiration</p> <p>Topic 1: Plant Cell Structure and Function</p> <ul style="list-style-type: none"><li>• Plant cell as an elementary structural and functional unit</li></ul>

- Plant cell membranes, transport, and endomembrane system

#### Topic 2: Structural Organization of the Cell

- Nucleus, ribosomes, endoplasmic reticulum, Golgi apparatus
- Mitochondria, plastids, and microbodies
- Cytosol, cytoskeleton, and vacuole
- Functional interactions of cell organelles
- Plant cell as an osmotic system
- Cell regulatory systems and signal transduction mechanisms

#### Topic 3: Overview of Photosynthesis

- Photosynthesis as a biological process
- Photosynthetic apparatus and its structural organization

#### Topic 4: Pigment Systems and Excitation Energy Transfer

- Chlorophylls and carotenoids: properties and functions
- Phycobilins and chromatic adaptation

#### Topic 5: Primary Processes of Photosynthesis

- Antennas and reaction centers
- Electron transport chain and photophosphorylation

#### Topic 6: CO<sub>2</sub> Fixation and Calvin Cycle

- Calvin cycle and CO<sub>2</sub> assimilation
- C-4 and CAM pathways of CO<sub>2</sub> fixation
- Photorespiration and its significance

#### Topic 7: Transport of Assimilates in the Plant

- Intracellular transport: flows of metabolites into and out of the chloroplast
- Proximity transport of assimilates in the leaf, sieve tubes - organization and functioning, phloem loading mechanism
- Long-distance transport of assimilates: phloem sap composition, flow rate, long-distance transport mechanisms
- Concept of attracting centers and donor-acceptor relationships: direction and regulation of phloem flow
- Indicators characterizing the process of photosynthesis
- Ecology of photosynthesis: influence of light (intensity and spectral composition) on photosynthesis, light curves of photosynthesis, compensation point
- Effect on photosynthesis of carbon dioxide concentration, temperature, moisture supply, conditions of mineral nutrition
- Daily course of photosynthesis
- Genetic and ontogenetic features of photosynthesis
- Regulation of the photosynthesis process at its different levels of organization

- Photosynthesis and biological productivity of plant organisms
- Photosynthesis and harvest

#### Topic 8: Importance of Respiration in the Vital Activity of a Plant Organism

- Energy and plastic function of respiration
- Development of ideas about cellular respiration
- V.I. Palladina's theory about cellular plant respiration: the theory of "respiratory chromogens"
- Biochemistry of plant respiration: redox reactions, oxidoreductase enzymes, ways of substrate oxidation
- Glycolysis, fermentation, Krebs cycle, direct oxidation of glucose, pentose phosphate shunt, glyoxylate cycle
- Interrelationship of different pathways, their significance, and regulation
- Specificity of cellular respiration in plants: cyanide-resistant breathing, alternative terminal oxidase, non-mitochondrial electron transport chains
- Indicators characterizing the respiration process: respiratory control, respiratory coefficient, Pasteur effect
- Respiration as the central metabolic link: respiration for growth and support respiration
- Regulation of respiration
- Ecology of respiration: dependence on external and internal factors, effect of oxygen and carbon dioxide concentration, temperature, tissue water supply, mineral nutrition conditions on the respiratory process
- Ontogenetic changes, climacteric rise in respiration

#### Chapter 2: Water Exchange. Mineral Nutrition

##### Topic 9: The Value of Water in the Vital Activity of Plants

- General Characteristics of Water Exchange in Plant Organisms
  - Intake, transport, and allocation of water
  - Characterizing indicators of water exchange: water balance, water deficit
- Forms of Water in a Plant
  - Free, bound, homeostatic water, etc.
- Water Exchange of the Cell
  - Regularities of water absorption by the cell and mechanisms
  - Thermodynamic indicators determining the state of water: water activity, chemical potential, water potential
  - Transport of water through the cell: aquaporins, structure, and functions
  - Components of water potential: osmotic, hydrostatic, matrix, and gravity

##### Topic 10: Absorption and Allocation of Water

- Absorption of Water by a Plant
  - The root as the main organ of water intake
  - Root structure, radial (proximal) transport of water in the root
  - Root pressure: the bottom-end mover of water in the plant
  - Crying, guttation - physiological phenomena as manifestations of root pressure in the plant
  - Factors influencing water inflow into the root system
- Allocation of Water by the Plant
  - Transpiration: the upper-end engine of water in a plant
  - Physiological significance of transpiration and guttation
  - Quantitative indicators of transpiration: intensity, productivity, transpiration coefficient
  - Types of transpiration: respiratory, cuticular, peridermal
  - Structure of stomata, mechanisms of stomatal movements: potassium mechanism, osmotic, and hydrodynamic
  - Respiratory regulation of transpiration
  - External and internal factors influencing transpiration

#### Topic 11: Water Transport in Plants

- Water Transport Mechanisms
  - Transvacuolar, apoplastic, symplastic ways
  - Short and long-distance transport
  - Movement of water through vessels: forces of cohesion and adhesion
  - Interaction of upper (transpiration) and lower (root pressure) engines
- Water Potential Gradient and its Role
  - Water potential gradient as a driving force for water movement in the "soil-plant-atmosphere" system
- Ecology of Water Exchange in Plants
  - Peculiarities of water exchange in plants of different ecological groups (xerophytes, mesophytes, hygrophytes)
  - Adaptations of plants to water deficit

#### Topic 12: Plant Nutrition - Root and Aerial

- Basics of Plant Nutrition
  - Absorption of substances from the soil
  - Soil as a source of mineral elements
- Ion Absorption Mechanisms
  - Diffusion and adsorption processes in ion absorption
  - Role of cell walls in adsorption of mineral substances
  - Types of membrane transport: passive transfer and active transport of ions
  - Functions of H<sup>+</sup> - pump in a plant cell

- Plant ion channels and Porter systems (symport, antiport, uniport)

#### Topic 13: The Content of Mineral Elements in a Plant

- Macro- and Microelements
- Physiological role of individual elements: nitrogen, phosphorus, sulfur, calcium, potassium, and microelements
- Absorption, transport, assimilation, and metabolism of various elements

#### Topic 14: Extraction of Substances by the Root System of Plants

- Root System and Substance Extraction
  - Mechanisms of Substance Extraction by the Root System
  - Root Exudates and Their Role in Nutrient Acquisition
- Specialized Secretory Structures
  - Types and Functions of Specialized Secretory Structures in Plants
  - Role in Defense, Communication, and Mutualistic Relationships
- Mineral Nutrition: A Factor of Plant Productivity and Crop Quality
  - Importance of Mineral Nutrition in Plant Growth and Development
  - Impact on Yield, Quality, and Economic Value of Crops
  - Linkage to Overall Plant Health and Disease Resistance
- Physiological Basis of Fertilizer Application
  - Essential Nutrients and Their Functions in Plant Growth
  - Fertilizer Types and Composition
  - Nutrient Deficiencies and Toxicities: Symptoms and Remedies
  - Optimizing Fertilizer Application for Efficient Nutrient Uptake and Utilization
  - Sustainable Fertilization Practices for Environmental Health

#### Topic 15: Plant Growth

- Definition of the Concept of "Growth"
- General Patterns and Types of Growth in Plants
- Cellular Bases of Growth: Embryonic Phase, Stretching Phase, and Differentiation Phase
- Cell Growth Mechanisms: Stretching, "Acidic" Growth Phase, Role of Auxins
- Differentiation of Cells and Tissues: Competence, Determination, Totipotency
- Growth and Activity of Meristems
- Peculiarities of Plant Organ Growth
- Properties of Growth Processes: Correlativity, Polarity, Regeneration, Unevenness, Rhythmicity

- Growth in Plants and Environmental Influences: Temperature, Light, Soil and Air Humidity, Mineral Nutrition
- Photoreception as a Mechanism of Plant Morphogenesis Regulation

#### Topic 16: Mechanisms of Regulation of Growth Processes

- Hormonal System of Plants
- Concept of Phytohormone, Classification
- Growth-Stimulating Phytohormones: Auxins, Cytokinins, Gibberellins
- Growth-Inhibiting Phytohormones: Abscisic Acid (ABA) and Ethylene

#### Topic 17: Non-classical Phytohormones and Phytohormonal Signal Reception

- Non-classical Phytohormones: Brassinosteroids, Fusicoccin, Jasmonic Acid, Salicylic Acid, Oligosaccharins, Short Peptides
- Interaction Between Different Phytohormones
- Phytohormonal Signal Reception
- Concept of "Phytohormonal Balance"
- General Metabolic Pathways of Phytohormone Biosynthesis and Degradation
- Synthetic Regulators and Inhibitors of Growth (Herbicides, Retardants)

#### Topic 18: Movements of Plants and Plant Development

- Movement Mechanisms: Growth and Turgor
- Tropisms: Phototropism, Geotropism, Thermotropism, Hydrotropism, Electrotropism
- Hormonal Nature of Tropisms
- Nastic Movements and Nutations
- Seismonastic Movements of Plants
- Physiological Role of Movements

#### Topic 19: Physiology of Flowering and Plant Aging

- Physiology of Flowering: Stages and Theories
- Formation of Seeds and Fruits
- Physiology of Vegetative Reproduction of Plants
- Theories of Plant Aging

#### Topic 20: In Vitro Culture and Its Applications

- Cultures of Isolated Protoplasts, Cells, Tissues, Organs as Models for Study of Growth and Development Processes
- Practical Applications of In Vitro Culture in Modern Biotechnologies

### Topic 21: Stress, Adaptation, and Resilience in Plants

- General Concepts: Stress, Adaptation, Resilience
- Specific Stress Reaction of Plants
- Biochemistry of the Adaptation Process
- Mechanisms, Strategies, and Types of Plant Adaptations

### Topic 22: Plant Adaptations to Environmental Stress

- Drought Resistance of Plants
  - Types of Drought: Atmospheric and Soil Drought
  - Evolutionary Adaptations of Xerophyte Plants to Water Deficit
  - Physiological Adaptations of Mesophytes to Drought
- Extreme Temperatures and Plants
  - Effect of High Temperatures and Heat Resistance of Plants
  - Urgent Plant Adaptations
  - Heat Shock Proteins (HSPs): Synthesis, Groups, Functions as Molecular Chaperones
  - Effect of Low Positive Temperatures (Cold Resistance), Negative Temperatures (Frost Resistance), and Soil and Climatic Factors (Winter Resistance)
  - Hardening in Plants
- Salt Resistance of Plants
  - Halophytes: Classification and Evolutionary Adaptations to Soil Salinization
- Plants in Conditions of Hypoxia and Anoxia
- Higher Plants and Ultraviolet (UV) Radiation
  - Effects of UV Radiation on Plants
- Pollution and Harmful Gases
  - Toxic Effects of Harmful Gases on Plants
  - Formation of Resistance to Gases: Regulation of Intake, Maintenance of Intracellular Homeostasis, Detoxification of Produced Poisons
- Pollution by Heavy Metals
  - Toxicity of Heavy Metals to Higher Plants
  - Formation of Resistance to Heavy Metals: Cellular and Molecular Mechanisms
- Radiation and Plant Resistance
  - Plant Resistance to Radiation and Its Mechanisms

### Chapter 4: Basics of Plant Biochemistry

- Subject, Object, and Methods of Plant Biochemistry
  - Peculiarities of Plant Biochemical Processes
  - Importance of Plant Biochemistry and Its Connection with Other Biological Sciences
  - Practical Value of Plant Biochemistry
  - Static (Structural) and Dynamic (Metabolic) Biochemistry
  - Primary (General) and Secondary (Specialized) Metabolism

	<ul style="list-style-type: none"> <li>• Topic 23: Biochemical Organization of Plant Organism Structure <ul style="list-style-type: none"> <li>• General Characteristics of Carbohydrates: Functions, Classification, and Representatives</li> <li>• Structural Polysaccharides of Plant Cell Membranes</li> <li>• Biosynthesis and Breakdown of Carbohydrates: Sucrose, Starch, Cellulose, etc.</li> <li>• Proteinogenic and Non-Proteinogenic Amino Acids, Peptides, and Vegetable Proteins</li> <li>• General Characteristics and Classification of Lipids, Vegetable Oils, and Lipoids</li> <li>• Organic Acids of Plants: General Characteristics and Roles</li> </ul> </li> <li>• Topic 24: Substances of Secondary Origin <ul style="list-style-type: none"> <li>• Concept of "Substance of Secondary Origin"</li> <li>• Characteristics, Classification, and Importance of Substances of Secondary Metabolism</li> <li>• Phenolic Compounds: General Characteristics, Classification, and Functions</li> <li>• Flavonoids, Oligomeric Phenolic Compounds, Tannins, Lignin, and Their Synthesis</li> <li>• Isoprenoids, Essential Oils, Balsams, Resins, Steroids, Carotenoids, and Alkaloids</li> <li>• Glycosides: Classification, Structure, and Functions</li> </ul> </li> <li>• Topic 25: Generalization <ul style="list-style-type: none"> <li>• A Plant as a System of Structures and Functions</li> <li>• Levels of Structural and Functional Organization in a Plant: Cell - Tissue - Organ - Whole Organism</li> <li>• Mechanisms of Regulation of Life Processes at Different Structural and Functional Levels</li> <li>• External Factors as Regulators of Plant Life Processes</li> </ul> </li> </ul> <p>Interaction and Interdependence in the Functioning of Plant Structures and Processes</p>
Literature	Musiyenko M.M. Plant Physiology. Kyiv: Lybid, 2005. Hans-Walter Heldt, Fiona Heldt/ Plant Biochemistry Third edition. Elsevier Academic Press, - 2005. Plant Physiology /Edited By Philip Stewart, Sabine Globig. Published by Apple Academic Press, 2021
Teaching and learning methods	Lecture (4 WH), Laboratory (3 WH)
Workload	Classroom hours: 105 Individual study time: 105 <b>Total: 210</b>
Assessment	The assessment consists of written examination and preliminary graded study achievements



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Grading procedure	The module grade is the sum of preliminary study achievements and the examination grade
Basis for	Biology of Mineral Nutrition of Plants. Intracellular Signalling Systems and Mechanisms of Adaptation of Plants and Microorganisms. Ecophysiology of Plants and Microorganisms. Course project in specialty. Master's Thesis.