Department of Botany, University of Dhaka

Curriculum for PhD Courses in Botany
(Session 2022-2023 Onward)

In the Department of Botany, there are 8 different specialized laboratories, where students are conducting research on various aspects of basic and applied Botany to obtain PhD degree. Students of MS degree from any public University, except National University will be able to register with the recommendation of respective supervisor following Dhaka University admission guidelines. Students obtained their MS degree from the other than Dhaka, Rajshahi, Chittagong and Jahangirnagar University will have to take 12 credits (two theoretical courses 4 credits each and one viva voce, 4 credits) as selected by the supervisor from the courses offered. An excerpt of the PhD syllabus is given below:

Theoretical Courses	**Credits**
BOT 701: Environmental Microbiology	4
BOT 702: Environmental Biotechnology	4
BOT 703: Applied Hydrobiology	4
BOT 704: Aquatic Plant Biology	4
BOT 705: Advanced Plant Taxonomy: Principles, Practices and Application	4
BOT 706: Applied Plant Taxonomy and Conservation	4
BOT 707: Terrestrial Ecosystem	4
BOT 708: Plant Molecular Ecology	4
BOT 709: Ecosystem Ecology	4
BOT 710: Plant Stress Physiology	4
BOT 711: Advanced Plant Physiology and Nutrition	4
BOT 712: Plant Cytogenetics	4
BOT 713: Chromosome Banding: Techniques and Application	4
BOT 714: Advanced Genomics, Proteomics and Bioinformatics	4
BOT 715: Plant Biotechnology and Bioinformatics	4
BOT 716: Marine and Environmental Sciences	4
BOT. 717: Applied and Molecular Phycology	4
BOT 730: Viva Voce	4

DETAIL SYLLABUS FOR PhD COURSES

Theory

BOT 701: Environmental Microbiology Credit hour: 4

Course description:

Environmental Microbiology and Biotechnology is a theoretical course out of the courses offered for the Ph.D. degree in Botany program. This course is structured in a way that the students develop clear understanding of the concept of Environmental microbiology, microbial habitats, isolation of microbial populations from environmental samples, interactions of microorganisms in the environment, Activities of microorganisms in environments, their biotechnological application for degradation organic and metal pollutant. Students also understand the reason for damage and ways of management of the environment through proper application of potential microorganisms. Furthermore, stress was also given some of the applied aspects like the discovery and application of novel microbes and their products to benefit human health and welfare.

Course objectives

- To understand environmental microbiology and its scope
- To identify different types of microorganisms in the environment
- To describe nucleic acid-based method for analysis of microbes
- To describe the non-culturable microorganisms in the environment
- To identify biosensor in detection of environmental and clinical pollutants
- To describe the role of microorganisms for decomposition of organic pollutants
- To describe the mechanisms of microbial metal resistance and detoxification
- To describe the remediation of metal contaminated environmental sites
- To describe the application of microbes for human health and welfare

Course contents

Units	Contents	No. of Lectures
1. Microorganisms in the environment	Terrestrial environments: microorganisms in surface and subsurface environments; Aeromicrobiology – aeromicrobiological pathway, collection of bioaerosols, microbial survival in the air, extra and intramural aeromicrobiology, bioaerosol control; aquatic and extreme environments: microbial habitats in the aquatic environment, freshwater environments, brackish water, marine water, subterranean water; environmental determinants that govern extreme environments.	12
2. Environmental sample collection and processing	Soils and sediments: sampling strategies and methods for surface and subsurface soils, sample processing and storage; water: sampling strategies and method for water, processing of water sample for microbial analysis, detection of microbial populations; approaches to enrich and isolate microbes having catabolic properties; detection of microorganisms on fomites.	8
3. Nucleic acid-based methods of analysis	Structure and complementarity of nucleic acids; obtaining nucleic acids from the environment, extracting community bacterial DNA from soil and water samples; nucleic acid-based methods: gene probes and probing, PCR, RT-PCR, recombinant DNA techniques, restriction fragment length polymorphism analysis, temperature gradient gel electrophoresis, plasmid analysis, reporter genes.	10
4. Non-culturable microorganisms in the environment	Concept of viable but non-culturable cells (VBNC); present status of VBNC; molecular methods of detection and identification of VBNC.	4
5. Biosensors	Development of biosensors and their use; characteristics of biosensors; biochemical application of biosensors in detection of environmental and clinical pollutants.	4

6. Microorganisms and organic pollutants	Environmental law, biodegradation process, relationship between contaminant structure, toxicity, and biodegradability - genetic potential, bioavailability, contaminant structure and toxicity, factors affecting biodegradation: oxygen, organic matter content, nitrogen, temperature, pH, salinity, water activity.	10
7. Microorganisms and metal pollutants	Cause for concern, metals defined, sources of metals; metal bioavailability in the environment – metal chemistry, cation exchange capacity, redox potential and pH; metal toxicity effects on the microbial cell; mechanisms of microbial metal resistance and detoxification – general mechanism of metal resistance, metal-dependent mechanism of resistance; metal-microbial interactions; adverse effects of microbial metal transformations, benefits of metal-microbial interactions, methods of metal remediation, remediation of metal-contaminated soils and sediments, remediation of metal contaminated aquatic systems.	12

Unit wise learning outcome

Units	Learning outcomes
1.	• define environmental microbiology • describe the surface soil microorganisms • distinguish sub-surface soil microorganisms • explain the survival capacity of microorganisms in extreme environments • define aeromicrobiology • collection of bioaerosols • describe microbial survival in the air • control of bioaerosol • discuss the role of microorganism in the formation of biofilm • explain the role of microorganisms in the formation of microbial mat • describe the importance of microorganisms in the benthic site • describe the activities of microorganisms in estuaries • describe the distribution and role of microorganisms in the marine environments • describe environmental determinants that govern extreme environments
2.	• describe the methods of sampling from different environmental sites • describe the process of environmental samples • describe the storage mechanism of environmental samples • chemical analyses the environmental samples • microbiological analyses the environmental samples • bacterial total counts in the environmental samples • bacterial total counts in the environmental samples • describe isolation method of bacteria having catabolic properties
3.	• mention the structure and complementarity of nucleic acids • describe the procedure for isolation of nucleic acid from the environmental samples • describe the procedure for extracting community bacterial DNA from soil samples • describe the procedure for extracting community bacterial DNA from water samples • describe gene probes and probing, PCR, RT-PCR, recombinant DNA techniques, restriction fragment length polymorphism analysis • describe temperature gradient gel electrophoresis, plasmid analysis, reporter genes
4.	• define viable but non-culturable (VBNC) cells • describe present status of VBNC • describe the method of detection and identification of VBNC
5.	• describe development of biosensors and their use • mention the characteristics of biosensors • biochemical application of biosensors in detection of environmental pollutants

	• biochemical application of biosensors in detection of clinical pollutants
6.	• define environmental law • describe the application environmental low in control of environmental pollution • define biodegradation process • mention the role of microorganism in biodegradation • describe the relationship between contaminant structure, toxicity and bio-degradability • describe the factors affecting biodegradation • describe the factors affecting biodegradation – oxygen, organic matter content, nitrogen, temperature, pH, salinity, water activity
7.	• define metals • characterize metals • describe bioavailability of metal in the environment • explain the metal toxicity effects on the microbial cell • describe the mechanisms of microbial metal resistance and detoxification • describe methods for studying interactions between metal and microorganisms • explain adverse effects of microbial metal transformations • explain benefits of metal-microbial interactions • describe the methods of metal remediation • describe the remediation of metal-contaminated soils and sediments • describe the remediation of metal contaminated aquatic systems

Recommended Readings

Edwards C (Ed.). 1999. Methods in Biotechnology, Environmental Monitoring of Bacteria. Humana Press, Totowa, NJ.

Gibson TD (Ed.). 2002. Microbial Degradation of Organic Compounds. Marcel Dekker, Inc., NY.

Kirchman, DL (Ed.). 2008. Microbial Ecology of the Ocean. Wiley-Liss, Inc., NY.

Madigan MT, JM Martinko, PV Dunlap and DP Clark. 2021. Brock Biology of Microorganisms. Pearson Education, Inc., CA.

Mitchell R and Gu Ji-D (Ed.). 2010. Environmental Microbiology. Wiley-Liss, Inc., NY.

Overbeck J and Chróst RJ (Eds.). 1990. Aquatic Microbial Ecology: Biochemical and Molecular Approaches. Springer-Verlag, NY.

Pickup RW and Saunders JR (Eds.). 1996. Molecular Approaches to Environmental Microbiology. Ellis Horwood, NY

Instruction strategies and Learning experiences

- Lecture followed by group discussion
- Question answer
- Guided discussion
- Project discussion
- Demonstration

Assignment: Students will be given assignment on particular units

Assessment: Final examination will be taken after completing the lectures at the end of the year.

BOT 702: Environmental Biotechnology **Credit hour: 4**

Course description:

Environmental Biotechnology is a theoretical course out of the courses offered for the Ph.D. degree in Botany program. This course is structured in a way that the students develop clear understanding of the concept of Environmental biotechnology. Activities of microorganisms in the environments, their biotechnological application for treatment of the domestic wastes, industrial wastes, wastewater, and contaminated environmental sites. Students also understand the reason for damage and ways of detoxification hazardous contaminants present in the environment through proper application of potential microorganisms. Furthermore, stress was also

given some of the applied aspects like the discovery and application of novel microbes and their products to benefit human health and welfare.

Course objectives

- To identify indicator bacteria in the environment
- To describe the role of bacteria for decomposition of domestic and industrial wastes
- To describe the role of bacteria in nutrient recycling
- To describe the role of extracellular enzymes in aquatic ecosystems
- To characterize the environmental contaminants and their biodegradability
- To apply novel microbes for improvement of the contaminated environmental sites
- To describe the role of microorganisms in detoxification of hazardous chemicals
- To describe the application of microbes for human health and welfare

Course contents

Units	Contents	No. of Lectures
1. Indicator microorganisms	The concept of indicator organisms; total coliforms – the most probable number (MPN) test, the membrane filter (MF) test, the presence-absence (P-A) test; fecal coliforms; fecal *Streptococci*; *Clostridium perfringens*; Heterotrophic plate count; bacteriophage; standards and criteria for indicators.	8
2. Domestic wastes and waste treatment	Domestic wastewater; modern wastewater treatment – primary treatment, secondary treatment, tertiary treatment, removal of pathogen by sewage treatment processes, sludge processing, pathogen occurrence and fate of biosolids; land application of wastewater; wetlands and aquaculture systems.	8
3. Microorganisms in recycling	Transformations of nitrogen and nitrogen compounds: nitrogen fixation, proteolysis, ammonification, nitrification, nitrate reduction, denitrification; phosphorus in freshwater and marine environments, removal of phosphorus from wastewater.	12
4. Extracellular enzymatic interaction	Extracellular enzymes – their position relative to the cell in the environment; strategy of external vs. free enzymes; immobilization of enzyme activity; humic loading to fresh waters; regulation of enzyme activity in aquatic ecosystems.	8
5. Bioremediation	Characteristics of contaminants – organic compounds, mixture of organic compounds; biodegradability; contaminant availability for biodegradation – sorption to surfaces, formation of a nonaqueous phase; treatability studies; engineering strategies for bioremediation – site characterization, engineered *in situ* bioremediation, intrinsic *in situ* bioremediation and natural attenuation, *in situ* bio-barriers, *ex situ* bioremediation; bioremediation by addition of oxygen, nutrient and microbes; evaluating bioremediation.	12
6. Detoxification of hazardous chemicals	Factors causing molecular recalcitrance – molecular structure, environmental conditions, microorganism presence; synthetic organic chemicals, energy metabolism vs. co-metabolism, electron donor vs. electron acceptor; minimum substrate concentration (S_{min}); biodegradation of environmental contaminants – synthetic detergents, pesticides, hydrocarbons, chlorinated solvents and other halogenated aliphatic hydrocarbons, chlorinated aromatic hydrocarbons, explosives, fate of organic chemicals, inorganic elements.	12

Unit wise learning outcome

Units	Learning outcomes
1.	• define indicator organisms • define total coliforms • describe the enumeration and isolation mechanism of total coliforms in environmental samples

	• define fecal coliforms • describe the procedure for enumeration and isolation of fecal coliforms in environmental samples • define fecal streptococci • mention the presence of fecal streptococci in environmental samples • explain the *Clostridium perfringens* as pathogenic organism • describe the procedure of heterotrophic plate count (HPC) in environmental samples • mention standards and criteria for indicator organisms
2.	• define domestic wastewater • describe the modern wastewater treatment method • mention the removal process of pathogen through sewage treatment process • define sludge processing • mention the fate of biosolids • describe the application of treated wastewater in land, wetlands, and aquaculture systems
3.	• describe the mechanism of transformations of nitrogen and nitrogen compounds in nature • define nitrogen fixation • mention nitrogen fixing microorganisms • define proteolysis • discuss the role of microorganisms in proteolysis • define ammonification • describe the role of microorganisms in ammonification • define nitrification • describe the role of microorganisms in nitrification • define nitrate reduction • describe the role of microorganisms in nitrate deduction • define denitrification • describe the role of microorganisms in denitrification • mention the source of phosphorus in freshwater • mention the source of phosphorus in marine environments • describe the role of phosphorus in environments • describe the mechanism of removal of phosphorus from wastewater
4.	• describe extracellular enzymes in the environments • explain the strategy of external vs. free enzymes • discuss immobilization of enzyme activity • quantify the quantitative loading of humic in fresh waters • describe the regulation of enzyme activity in aquatic ecosystems
5.	• define organic compounds • mention the scope and characteristics of contaminants • define the mixture of organic compounds • describe the contaminant availability for biodegradation – sorption to surfaces, formation of a nonaqueous phase • define bioremediation • discuss the engineering strategies for bioremediation – site characterization • describe the engineered *in-situ* bioremediation, intrinsic *in situ* bioremediation and natural attenuation, *in-situ* bio-barriers • explain *ex-situ* bioremediation • describe the process of bioremediation by addition of oxygen, nutrient and novel microbes • explain the potentiality of bioremediation
6.	• mention the factors causing molecular recalcitrance • explain the role of microorganisms in molecular recalcitrans • detection of synthetic organic chemicals • differentiate between energy metabolism vs. cometabolism • discuss electron donor vs. electron acceptor • Explain minimum substrate concentration (S_{min})

	• describe biodegradation of environmental contaminants - synthetic detergents, pesticides, hydrocarbons, chlorinated solvents and other halogenated aliphatic hydrocarbons, chlorinated aromatic hydrocarbons, explosives, fate of organic chemicals, inorganic elements

Recommended Readings

Chróst RJ (Ed.). 1991. Microbial Enzymes in Aquatic Environments. Springer-Verlag, NY.
Daniels A Vallero. 2015. Environmental Biotechnology: A Biosystems Approach. Academic Press, NY.
Evans GM and Furlong JC. 2010. Environmental Biotechnology: Theory and Application. John Wiley & Sons Ltd., West Sussex, England.
Gibson TD (Ed.). 2002. Microbial Degradation of Organic Compounds. Marcel Dekker, Inc., NY.
Kirchman, DL (Ed.). 2008. Microbial Ecology of the Ocean. Wiley-Liss, Inc., NY.
Pelczar MJ, ECS Chan and NR Krieg. 1993. Microbiology, Concepts and Application. McGraw-Hill, Inc., NY.
Rittmann BE and PL McCarty. 2020. Environmental Biotechnology: Principles and Applications. McGraw-Hill Companies, Inc. NY.

Instruction strategies and Learning experiences

- Lecture followed by group discussion
- Question answer
- Guided discussion
- Project discussion
- Demonstration

Assignment: Students will be given assignment on particular units
Assessment: Final examination will be taken after completing the lectures at the end of the year.

BOT 703: Applied Hydrobiology **Credit hour: 4**

Course description:
This course comprehensive knowledge on applied hydrobotany and applied knowledge of aquatic ecosystems. Students shall get insight into the essential functions and processes of chemical/physical and biotic system components, as well as their interactions and impacts of climate change, conservation of freshwater ecosystems and restoration ecology. Modern thoughts on hydrobiology the key concepts concerning various aquatic flora and fauna and water quality problems in relation to their uses and sustainability; practical methods and techniques for the biotechnological application of aquatic plants; use of paleolimnological data for the reconstruction of the past environment; development of research methodology with special emphasis on hydrobiolological aspects, the key concepts concerning health issues associated with aquatic flora and fauna and applied hydrobiological researches in Bangladesh and its status in relation to other countries.

Course objectives

- Modern thoughts on applied hydrobiology
- Aquatic plant resources, uses, management, ecology, their interactions with environment
- Pollution study, bioremediation, wastewater treatment and recycling
- Biotechnological application of aquatic resources
- Climate change impact analysis, remote sensing and GIS application.
- Conservation measures, paleolimnology study and research methodology study.

Course contents

Units	Contents	No. of Lectures
1.	Aquatic plant resources: Bio-prospecting-definition and concept, bio-prospecting of aquatic plants, economic importance of aquatic plants in fisheries and aquaculture.	**6**
2.	Microbial bioremediation of degraded water and various pollutants, Industrial and domestic wastewater characteristic. Conventional and advanced treatment methods for wastewater, wastewater recycling.	**4**
3.	Phytoremediation of degraded water and various pollutants.	**4**
4.	Probiotics, Bioreactors, Biosensors, Bio-fertilizers.	**4**
5.	Biotechnological approaches for bio-energy and bio-fuels.	**4**
6.	Production of single cell protein, microbial enzymes and biomolecules. Aquatic plant	**4**

	production systems: Ornamental aquatic plants and seaweeds	
7.	Molecular tools for biotechnological applications, culture-independent technique	**4**
8.	Application of remote sensing and GIS in aquatic resources, Global warming and climate change- impact on biodiversity, Role of GIS technology in monitoring global climate change. Role of phytoplankton density in GIS based Potential Fishing Zone advisory generation.	**4**
9.	Algae as a source of food and value added compounds – pigments, biofuels, fine chemicals and pharmaceutical drugs.	**4**
10.	Aquatic weed management. Harmful algae and their management. Impacts of algal blooms on fisheries, bio-control of algal blooms, bio-manipulation, top-down cascading effects.	**4**
11.	Management of aquatic plant resources, methods for increasing productivity of water bodies through thermal energy and artificial upwelling, artificial sea ranching, plants as FAD's. Utilization of aquatic plants for environmental management, Algae and angiosperm plants as bio-indicators.	**6**
12.	Paleolimnology, definition, role in the construction of historical past and development of lake ecosystems. Use of paleolimnological data for the reconstruction of the past environment.	**4**
13.	Conservation measures for aquatic plant resources - marine parks, biosphere reserves, International conventions for conservation of aquatic ecosystems, Ramsar convention, Lake conservation programs, Conservation and applications of polar algal resources.	**4**
14.	Research design, sampling techniques, collection and documentation, presentation, analysis and interpretation of data.	**4**

Unit wise learning outcome

Units	Learning Outcome
1.	• Concepts of aquatic plant resources • Bio-prospecting-definition and concept • Bio-prospecting of aquatic plants • Economic importance of aquatic plants in fisheries and aquaculture
2.	• Microbial bioremediation of degraded water and various pollutants • Industrial and domestic wastewater characteristic • Conventional and advanced treatment methods for wastewater, wastewater recycling
3.	• Phytoremediation of degraded water and various pollutants
4.	• Concepts of Probiotics, Bioreactors, Biosensors, Bio-fertilizers
5.	• Biotechnological approaches for bio-energy and bio-fuels
6.	• Production of single cell protein • Microbial enzymes and biomolecules • Aquatic plant production systems: Ornamental aquatic plants and seaweed
7.	• Molecular tools for biotechnological applications • culture-independent technique
8.	• Application of remote sensing and GIS in aquatic resources • Global warming and climate change- impact on biodiversity • Role of GIS technology in monitoring global climate change • Role of phytoplankton density in GIS based Potential Fishing Zone advisory generation
9.	• Algae as a source of food and value added compounds – pigments, biofuels • Fine chemicals and pharmaceutical drugs
10.	• Aquatic weed management • Harmful algae and their management • Impacts of algal blooms on fisheries, bio-control of algal blooms, bio-manipulation, top-down cascading effects
11.	• Management of aquatic plant resources • Methods for increasing productivity of water bodies through thermal energy and artificial upwelling, artificial sea ranching, plants as FAD's • Utilization of aquatic plants for environmental management, Algae and angiosperm plants as bio-indicators
12.	• Paleolimnology, definition, role in the construction of historical past and development of lake

	ecosystems • Use of paleolimnological data for the reconstruction of the past environment
13.	• Conservation measures for aquatic plant resources - marine parks, biosphere reserves, • International conventions for conservation of aquatic ecosystems • Ramsar convention, Lake conservation programs • Conservation and applications of polar algal resources
14.	• Research design • Sampling techniques • Collection and documentation • Presentation, analysis and interpretation of data

Recommended Readings

Aderson RA 2008. Algal cultural technique. Phycological Soc. America, Elsevier/Acad. Press

Alfasane MA, Akhtar A, Lopa NS and Rahman M. 2023. Introduction to Biomass- Biomass-Based Supercapacitors: Design, Fabrication and Sustainability, *In*: Aziz MA and Shah SS (Eds.), Wiley Publication.

Alfasane MA. 2022. Phycology, Limnology and Hydrobiological Researches in Bangladesh: History and achievement of Phycology, Hydrobiology and Nanotechnology. *In*: Saha ML, Khondker M, Shamsi S and Rahman MO (eds.) BOTANY: Addressing the challenges and opportunities for the 21st Century, Dhaka University Centennial Special Book, SRL printing press, Dhaka.

Barsanti I and P Gualtieri 2006. Algae: Anatomy, Biochemistry and biotechnology CRC, N.Y.

Bold HC and Wynne MJ 1985. Introduction to the algae- structure and reproduction, Prentice-Hall, Inc., Englewood Cliffs, New Jersey

Gustafsson O, Manukyan L, Gustafsson S, Tummala GK, Zaman S, Begum A, Alfasane MA, Rabbani KSE and Mihranyan A. 2019. Scalable and Sustainable Total Pathogen Removal Filter Paper for Point-of-Use Drinking Water Purification in Bangladesh. ACS Sustainable Chemistry & Engineering, **7**, 17, 14373-14383.

Hashem MA and Alfasane MA 2011. Cyanobacteria. *In*: Misbahuddin, M. and Khandaker, S (eds.). Drinking water contaminants in Bangladesh: Focuses on arsenic, fluoride, pesticides, manganese and cyanobacteria. United Kingdom, LAP LAMBERT Academic Publishing, U.K.

Islam AKMN 1976. Contribution to the study of the marine algae of Bangladesh. Bibliotheca Phycologica**19**: 1-253

Lee RE 2008. Phycology, Cambridge University Press, U.K.

Mia MM, Islam S, Alfasane MA, Nayem SMA, Awal A, Shah SS, Dafalla HDM, Aziz MA and Ahammad AJS 2023. *Sargassum coriifolium* seaweed derived sub-micro sphere carbon for simultaneous electrochemical detection of hydroquinone and catechol: Mechanistic and kinetic studies, Materials chemistry and Physics 309, 128439.

Shah SS, Alfasane MA, Bakare IA, Aziz, MA and Yamani ZH. 2020. Polyaniline and heteroatoms–enriched carbon derived from *Pithophora polymorpha* composite for high performance supercapacitor. J. Energy Storage, 30, 101562.

Stewart WDP 1974. Algal physiology and biochemistry, University of California Press, USA.

Aderson RA 2008. Algal cultural technique. Phycological Soc. America, Elsevier/Acad. Press

Alfasane MA, M Khondker and ZNT Begum 2011. Ecology of some selected wetland macrophytes of Bangladesh: Focuses on four wetland macrophytes. United Kingdom, LAP LAMBERT Academic Publishing, ISBN: 978-3846533178, 172 pp

Nishat A, Z Hussain, MK Roy and A Karim (eds.) 1993. Fresh water wetlands in Bangladesh: Issues and approaches for Management. IUCN, Gland, Switzerland. xii + 283 pp.

Tyagi R 2010. Textbook of Hydrobiology. Discovery publishing house, ISBN 13: 9788183565578, 181 pp.

Instruction strategies and Learning experiences

- Lecture followed by group discussion
- Question answer
- Guided discussion
- Project discussion
- Demonstration

Assignment: Students will be given assignment on particular units

Assessment: Final examination will be taken after completing the lectures at the end of the year.

BOT 704: Aquatic Plant Biology Credit hour: 4

Course description:
Survey of wetlands, aquatic plant diversity, with an emphasis on algae and angiosperms. Topics include plant identification, seaweed diversity, ecology, physiology, reproduction, and dispersal of aquatic plants. Economically important and invasive plant species will be discussed. The major aims included of the topics are (i) Introduce the concept of taxonomy and biodiversity of aquatic plants (ii) To provide information on the theory and practice of aquatic plant biology. (iii) Current status of aquatic plant resources of Bangladesh and impact of environmental factors on aquatic plant resources. This core course encompasses of various aquatic ecosystems and aspects on the biology of aquatic organisms, Fresh water, estuarine and marine plankton, productivity and impact on fisheries; Seaweeds and seagrasses, diversity, distribution and its uses; Estuaries and characteristics in Bangladesh.

Course objectives

- Modern thoughts of wetlands and aquatic plant resources.
- Plankton, their roles, trophic status and benthic organisms.
- Aquatic angiosperms and coastal ecosystems of Bangladesh.
- Seaweeds of Bangladesh.
- Dynamics of aquatic resources and pollution of aquatic ecosystems and their control.
- Impact of environmental factors on aquatic plant resources

Course contents

Units	Contents	No. of Lectures
1.	Wetlands and aquatic plant resources- Definition and concept, species diversity of aquatic plants. Wetland concepts, classification and socio economic importance.	**6**
2.	Physical and chemical factors that operating biological community of aquatic habitats, circulation of water in the epilimnion and hypolimnion; Composition, kinetics of nutrients, flow of energy in the aquatic ecosystem.	**6**
3.	Plankton- Life history, important plankters, predator-prey relationship, interrelationships between phytoplankton and zooplankton.	**4**
4.	Role of plankters in food chain, trophic level and food-webs.	**4**
5.	Characterization of benthic habitats; Benthic resources; Role of benthos in bio-turbation and reclamation.	**4**
6.	Current status of aquatic angiosperms taxonomic research in Bangladesh, Endangered and endemic species of Bangladesh.	**6**
7.	Estuary concept, Characteristics, Buoyancy input as freshwater; biodiversity, mangrove, mudflat, sea-grass ecosystems.	**6**
8.	Physical, chemical and biological dynamics in estuarine and coastal ecosystems of Bangladesh.	**4**
9.	Species diversity, distribution and standing biomass of sublittoral seaweeds of the St. Martin's Island, Bangladesh.	**4**
10.	Dynamics of aquatic virus, bacteria, fungi and lichen, role of different microbes in the decomposition processes.	**4**
11.	Pollution of aquatic ecosystems by acid rain, where and how acid rain occurs, effect of acid rain and its control.	**6**
12.	Impact of environmental factors on aquatic plant resources - Environmental flow, industrial pollution, aqua-cultural practices, irrigation and drainage, habitat fragmentation and habitat degradation, bio-invasion, pesticide uses and its impact on aquatic plants .	**6**

Unit wise learning outcome

Units	Learning Outcomes
1.	• Concepts of wetlands and aquatic plant resources • Classification and socio economic importance
2.	• Physical and chemical factors that operating biological community of aquatic habitats • Circulation of water in the epilimnion and hypolimnion • Composition, kinetics of nutrients, flow of energy in the aquatic ecosystem
3.	• Plankton- Life history, important plankters, predator-prey relationship

	• Interrelationships between phytoplankton and zooplankton
4.	• Role of plankters in food chain • Trophic level and food-webs
5.	• Characterization of benthic habitats • Benthic resources • Role of benthos in bio-turbation and reclamation.
6.	• Current status of aquatic angiosperms taxonomic research in Bangladesh • Endangered and endemic species of Bangladesh
7.	• Estuary concept, Characteristics, Buoyancy input as freshwater • Biodiversity, mangrove, mudflat, sea-grass ecosystems
8.	• Physical, chemical and biological dynamics in estuarine and coastal ecosystems of Bangladesh.
9.	• Species diversity, distribution and standing biomass of sublittoral seaweeds of the St. Martin's Island, Bangladesh
10.	• Dynamics of aquatic virus, bacteria, fungi and lichen • Role of different microbes in the decomposition processes
11.	• Pollution of aquatic ecosystems by acid rain, where and how acid rain occurs, effect of acid rain and its control
12.	• Impact of environmental factors on aquatic plant resources • Environmental flow, industrial pollution, aqua-cultural practices, irrigation and drainage • Habitat fragmentation and habitat degradation, bio-invasion, pesticide uses and its impact on aquatic plants

Recommended Readings

Alfasane MA and Hassan MA 2021. *In*: Baruscotti DA, Saroldi S, Antonello G, Rivolta AM, Pandeli G, Basso G and Baruscotti A (eds.) *Utricularia rosettifolia* Alfasane& Hassan sp. nov. (Lentibulariaceae) - A new species from Bangladesh. Italian Carnivorous Plant Society-AssociazioneItaliana Piante Carnivore- AIPC MAGAZINE 62 Giugno, **16**(2): 1-30.

Alfasane MA, Bhuiyan R, Jolly J, and Islam S 2019b. *Azolla microphylla* Kaulf. (Salviniaceae): A new pteridophytic record for Bangladesh. Bangladesh J. Plant Taxon.**26**(2): 325-327

Alfasane MA, Hoque, FP, Hassan MA, Khan, MSM. 2023. *Elodea Canadensis* Michx. (Hydrocharitaceae)- A new angiospermic record for Bangladesh. Bangladesh J. Plant Taxon. **30**(2): 195-200.

Alfasane MA, Khondker M and Begum ZNT 2011. Ecology of some selected wetland macrophytes of Bangladesh: Focuses on four wetland macrophytes. United Kingdom, LAP LAMBERT Academic Publishing, ISBN: 978-3846533178, 172 pp

Alfasane MA, Ullah MS and Khondker M 2013. Limnology of lake Rainkhyongkain of Bangladesh with a new record of *Marchantia polymorpha* L. var. *aquatic* Nees. Bangladesh J. Bot. **42**(2): 223-229.

Aziz A and Alfasane MA 2020. New records of seaweeds from southeastern coasts of Cox's Bazar district, Bangladesh. Bangladesh J. Plant Taxon. **27**(2): 335–343.

Aziz A, Kabir S and Alfasane MA 2023. Seaweed flora of the St. Martin's Reef, Bangladesh. Bangladesh J. Plant Taxon. **30**(1): 153-163.

Aziz A, Towhidy S and Alfasane MA 2015. Sublittoral seaweed flora of the St. Martin's Island, Bangladesh. Bangladesh J. Bot. **44**(2): 223-236.

Aziz A, Towhidy S and Alfasane MA. 2022. Species diversity, distribution and standing biomass of sublittoral seaweeds of the St. Martin's Island, Bangladesh. Bangladesh J. Plant Taxon. **29**(1): 13-29.

Aziz, A. and Alfasane, M.A. 2023. New records of seaweeds from the St. Martin's Reef, Bangladesh. II. Bangladesh J. Plant Taxon. **30**(2): 249-254.

Dodson S 2005. Introduction to Limnology. Mc-Graw Hill, Boston. 400 pp.

Islam AKM Nazrul, Haque AE, Maniruzzaman, Jamali T, Haque T, Alfasane MA, Nahar N, Jahan N, Sultana S, Kumar TS, 2019. Species Distribution in Different Ecological Zones and Conservation Strategy of Halophytes of Sundarbans Mangrove Forest of Bangladesh,*In*: Gul B., Böer B., Khan M A., Clüsener-Godt M., Hameed A. (eds) Tasks for Vegetation Science-49, Sabkha Ecosystems, vol VI: Asia/Pacific, pp 479-495. Springer Nature Switzerland, DOI: https://doi.org/10.1007/978-3-030-04417-630.

Khondker M 1994. Limnology. Mawla Brothers. Dhaka. 464 pp.

Moss B 1980. Ecology of Freshwaters. Blackewll Sc. Publ. Oxford. 331 pp.

Nishat A, Hussain Z; Roy MK and Karim A (eds) 1993. Freshwater wetlands in Bangladesh: Issues and approaches for Management. IUCN, Gland, Switzerland. Xii+283 pp .

Reynolds CS 1984. The ecology of freshwater phytoplankton. Cambridge Univ. Press, London.pp. 384 pp.
Tilzer MM and Khondker M (eds), 1993. Hypertrophic and Polluted Freshwater Ecosystems: Ecological Bases for Water Resource Management. Department of Botany, University of Dhaka. 229 pp.
Wetzel RG 2001. Limnology, Lake and river ecosystems. 3rd edn. Academic Press. San Diego. 1006 pp.

Instruction strategies and Learning experiences

- Lecture followed by group discussion
- Question answer
- Guided discussion
- Project discussion
- Demonstration

Assignment: Students will be given assignment on particular units
Assessment: Final examination will be taken after completing the lectures at the end of the year.

BOT 705: Advanced Plant Taxonomy: Principles, Practices and Application Credit hour: 4

Course description:

Advanced Plant Taxonomy delves into the intricate world of plant classification, providing a comprehensive understanding of principles, practices, and modern applications. The course begins with an introduction outlining its structure, fundamental principles, and current concepts, setting the stage for in-depth exploration. Students will delve into the scientific naming of plants, understanding the various forms of scientific names, the hierarchical concept of taxa ranks, and the citation of authorities. Practical skills in plant naming will be honed through comparison methods, utilization of keys, and expert guidance. Flora and vegetation studies will be explored, elucidating objectives, standard inclusions, and planning aids, along with techniques for floral summary and documentation, including floristic spectral analysis. Students will gain proficiency in data accumulation and analysis techniques, including organization, presentation, and documentation, utilizing various tools. The course will also delve into the history, objectives, and functions of botanic gardens and arboreta. Advancements in molecular taxonomy, including DNA-based markers and barcoding, will be explored, along with their applications in complementing traditional taxonomy and enhancing drug design methodologies. Through an interdisciplinary approach, students will grasp the nexus between plant taxonomy and drug design, including structure-based drug design, molecular docking, and molecular dynamics simulations

Course Objectives

- Familiarize with the principles and concepts underlying plant taxonomy and enable to understand and apply scientific naming conventions effectively
- Develop practical skills in plant identification through various methods
- Explore the significance of flora and vegetation studies in botanical research
- Provide insights into taxonomic data accumulation, analysis, and documentation techniques
- Introduce the history, functions, and importance of botanic gardens and arboreta
- Understand the fundamentals and applied aspects of molecular taxonomy and DNA barcoding
- Explore the application of plant taxonomy in drug design endeavor and related fields.

Course Contents

Units	Contents	No. of Lectures
1. Introduction to the course	Outline of the course; Principles; Current Concepts	4
2. The scientific naming of plants	Forms of scientific names; Concept of ranks of taxa; Names of taxa; Citation of authorities; Publication; Typification; Priority and limitation of priority; Double citation; Names of cultivated plants; Names of sexual hybrids; Retention, choice and rejection of names and epithets; Names and Nyms	8
3. The practical naming of plants	Naming by comparison; Naming by means of keys - Bracketed key, Indented key, Use of keys, Good points in keys, Faults and limitations of keys, Short cuts and checks; Naming by an expert	6
4. Formation of	General information; Commemorative epithets; Descriptive epithets;	6

specific epithets and Meaning of Specific epithets	Names of plant parts; Prefixes and suffixes	
5. Flora and Vegetation	Objectives of flora and vegetation study; Standard inclusions in flora and vegetation study; Reconnaissance and planning aids for flora and vegetation study; Floral summary; Documentation; Floristic spectral analysis	6
6. Data accumulation and analysis	Introduction; Organization; Data accumulation; Data presentation and documentation; Drawings; Chromatographic data; Polygonal graphs and histograms; Hybrid index	6
7. Botanic gardens and Arboreta	Introduction; Basic objectives; History; Organization and development; Functions of the botanic garden	4
8. Molecular Taxonomy	DNA Taxonomy; PCR based DNA markers - SSR, ISSR, RAPD, RFLP; Nuclear gene - Internal Transcribed Spacers (ITS); Chloroplast genes - *rbcL*, *matK*	6
9. DNA Barcoding	Taxonomy in a new perspective; Components of a DNA barcoding project; Power of DNA barcoding; How DNA barcoding complements taxonomy, molecular phylogenetics and population genetics; Application of DNA barcodes	8
10. Drug Design in relation to Plant Taxonomy	Introduction; Structure Based Drug Design (SBDD); Molecular Docking; Molecular Dynamics Simulations	6

Unit-wise learning outcomes

Units	Learning outcomes
1	• Gasp the fundamental principles underlying plant taxonomy, including the hierarchical classification system and nomenclature rules • Explore recent developments and trends in plant taxonomy, including advancements in molecular techniques and their impact on classification
2	• Learning and understanding the different formats used for scientific names, including binomial nomenclature, importance of valid publication for establishing scientific names and learn about the process of typification and its role in stabilizing nomenclature • Learn about naming conventions for cultivated plants and hybrids • Understand the criteria for retaining, choosing, or rejecting specific names and epithets. • Explore the significance of names and their relation to nomenclatural principles
3	• Learn to identify plants based on comparison with known specimens • Understand the use of taxonomic keys for plant identification • Evaluate the strengths and weaknesses of keys
4	• Understand the purpose and structure of specific epithets and learn about specific epithets that honor individuals or commemorate events • Recognize how specific epithets may refer to plant morphology • Learn about common prefixes and suffixes used in specific epithets • Analyze the meanings and significance of specific epithets in plant names
5	• Recognize the essential components of a flora and vegetation study • Learn about tools and techniques for conducting reconnaissance and planning flora studies • Be able to summarize and document floral data effectively • Understand the concept and application of floristic spectral analysis in vegetation studies
6	• Understand the importance of proper organization in data accumulation processes • Develop skills in effective data accumulation techniques and demonstrate proficiency in presenting and documenting botanical data accurately • Gain practical experience in creating botanical drawings, principles and applications of chromatographic data, Interpret and create polygonal graphs and histograms to analyze botanical data effectively
7	• Comprehend the historical significance and evolution of botanic gardens and arboreta • Identify the basic objectives of botanic gardens, including conservation, education, and research • Understand and explore the diverse functions of botanic gardens, including plant

	conservation, public education, and scientific research
8	• Understand the principles and applications of DNA taxonomy in plant classification • Identify and explain the role of PCR-based DNA markers such as SSR, ISSR, RAPD, and RFLP in molecular systematics • Analyze the significance of nuclear genes, particularly Internal Transcribed Spacers (ITS), in plant molecular systematics • Explore the utility of chloroplast genes such as *rbcL* and *matK* in species delimitation and phylogenetic studies
9	• Identify the key components of a DNA barcoding project, including sample collection, DNA extraction, and sequencing • Understand the potential of DNA barcoding in revolutionizing taxonomy, molecular phylogenetics, and population genetics • Analyze how DNA barcoding complements traditional taxonomy and contributes to a deeper understanding of biodiversity • Explore practical applications of DNA barcodes in species identification, conservation, and forensic botany
10	• Understand the fundamentals of structure-based drug design (SBDD) and its relevance to plant taxonomy • Explore the techniques of molecular docking in drug discovery using plant-derived compounds • Gain insights into molecular dynamics simulations and their role in understanding the interactions between plant compounds and drug targets • Understand how to unveil potential drug candidates from phytochemicals

Recommended Readings

Ahmed, S.S., Suchana, S. Sultana, N. and Rahman, M.O. 2023. Unveiling cervical cancer therapeutics from *Abrus precatorius* and *Aphanamixis polystachya*: Insights from molecular docking, dynamics simulation, MM/GBSA and DFT analyses. South African Journal of Botany 163: 561-579. (Elsevier).

Ahmed, S.S., Rahman, M.O., Alqahtani, A.S. Sultana, N., Almarfadi, O.M., Ali, M.A. and Lee, J. 2023. Anticancer potential of phytochemicals from *Oroxylum indicum* targeting Lactate Dehydrogenase A through bioinformatic approach. *Toxicology Reports* 10: 56-75. (Elsevier)

Hooker, J.D. 1872-1897. Flora of British India. Vols. 1-7. L Reeve & Co. Ltd. England.

Hebert, P.D.N. and Gregory, T.R. 2005. The Promise of DNA Barcoding for Taxonomy. Systematic Biology 54(5): 852–859.

Jeffrey, C. 1986. An Introduction to plant taxonomy. 2nd edn. Cambridge Univ. Press.

Khan, M.S. (ed.). 1973-2002. Flora of Bangladesh. Fasciole 1-51 BNH, BARC, Dhaka.

Khan, M.S. 1991. The vegetation of Bangladesh. In: Plant life of South Asia (Ali SI and Gaffar A Eds), pp. 185-192.

Mendie, L.E. and Hemalatha, S. 2022. Molecular docking of phytochemicals targeting GFRs as therapeutic sites for cancer: An *in silico* study. Appl. Biochem. Biotech. 194(1): 215-231.

Meng, X.Y., Zhang, H.X., Mezei, M. and Cui, M. 2011. Molecular docking: A powerful approach for structure-based drug discovery. Curr. Comp. Drug Des. 7(2): 146-157.

Prain, D. 1981 (Reprinted), Bengal Plants, Vols. 1&2. Bishen Singh Mahendra Pal Singh, Dehradun, Inida.

Radford, A.E., W.C. Dic Dickson, J.R. Masey & C.R. Bell. 1974. Vascular Plant Systematic. Harper & Raw Publishers NY.

Rahman, M.O. 2022. Plant Systematics and its Application. In: Saha, M.L., Khondker, M.Z., Shamsi, S. and Rahman, M.O. (Eds), Botany – Addressing the Challenges and Opportunities for the 21st Century. Department of Botany, University of Dhaka.

Rahman, M.O. and Ahmed, S.S. 2023. Anti-angiogenic potential of natural bioactive phytochemicals from *Helicteres isora* targeting VEGFR 2 to fight cancer via molecular docking and molecular dynamics simulation. Journal of Biomolecular Structure and Dynamics 41(15): 7447-7462. (Taylor & Francis).

Rahman, M.O., Ahmed, S.S., Alqahtani, A.S., Cakilcioğlu, U. and Akbar, M.A. 2023. Insight into novel inhibitors from *Sterculia urens* against Cholera via pharmacoinformatics, molecular dynamics and quantum mechanics approaches. Journal of Biomolecular Structure and Dynamics, pp. 1-22 (Taylor & Francis).

Stace, C.A. 1989. Plant Taxonomy & Biosystematics, 2nd Edward Annold London.

Simpson, M.G. 2019. Plant Systematics, Third Edition. Academic Press, London, New York. 761 pp.

Singh, G. 2010. Plant Systematics. Third edition. Science Publishers, Enfield, NH, USA, 702 pp.
Stuessy, T.F. 2009. Plant Taxonomy – The Systematic Evaluation of Comparative Data. (Ed. 2), Columbia University Press, New York.
Vijayan, K. and Tsou, C.H. 2010. DNA barcoding in plants: taxonomy in a new perspective. Current Science 99 (11): 1530-1541.

Instruction strategies and Learning experiences

- Lecture followed by group discussion
- Question answer
- Guided discussion
- Project discussion
- Demonstration

Assignment: Students will be given assignment on particular units
Assessment: Final examination will be taken after completing the lectures at the end of the year.

BOT 706: Applied Plant Taxonomy and Conservation Credit hour: 4

Course description:

The course on applied plant taxonomy and conservation initially covers an introduction, scopes, and applications of the subject. To solve taxonomic problems, the course includes anatomical and chemical features of plants. A number of other topics related to this course are also included here, including research methodologies, reproductive biology, habitats and environmental relationships of plants, taxonomy in biodiversity conservation, propagation modes, applied taxonomy, and plant taxonomy in practices. All topics are very relevant to the course, and after taking this course, students will be well equipped to apply taxonomic knowledge to biodiversity conservation and sustainable plant resource management.

Course Objectives

- To provide the basic knowledge of reproductive biology, plant anatomy, and plant chemistry that helps to solve the complexity of identification.
- To establish the needs of plant taxonomy in biodiversity conservation.
- To provide basic strategies to undertake and conduct research projects in taxonomy.
- to give basic strategies for the publications.
- To provide tools for plant conservation programs.
- To show the ways in which taxonomy can apply to real-life problem solutions.

Course contents

Unit	Course contents	No. of Lectures
1. Introduction	Introduction to the subject, scopes and applications.	**4**
2. Research methodologies	Research methodologies, data collection, data analysis, data presentation, report preparation and research project development.	**6**
3. Reproductive Biology	Reproductive Biology: Population growth, size, density and carrying capacity; out breeding systems, asexual reproduction, in breeding systems, reproductive biology in relation to systematics; study methods; pollination types, mechanisms, vectors, isolation and speciation.	**6**
4. Anatomical features in taxonomy	Anatomical evidence in Taxonomy: Leaf anatomy; stomata, trichomes; petiole anatomy foliar venation; stem anatomy; stelar anatomy.	**4**
5. Chemical features in Taxonomy	The application of natural products chemistry to taxonomy and phylogeny: Steps to be followed in the solution of a chemotaxonomic problem; some natural products used in chemotaxonomic correlations; chromatography - basics and definitions; chemotaxonomy through protein analysis.	**6**
6. Habitats and environment relationships of plants	Habitats; Environmental relationships; biotic, abiotic factors; spatial relations, temporal relations, adaptive features. Life forms, diaspores types, fidelity, vitality, leaf size, developmental responses, heterotrophy.	**6**

7. Taxonomy and biodiversity	Why taxonomy matters in biodiversity conservation? Introduction to biodiversity conservation; importance and threats to biodiversity; biodiversity conservation strategies examples from Bangladesh; International laws and convention to Biodiversity and position of Bangladesh; The IUCN Red List Categories and threatened plants of Bangladesh.	**8**
8. Propagation modes	Introduction to plant propagation, Modes of plant propagation; asexual propagation and sexual propagation; role of propagation in conservation.	**6**
9. Applied Taxonomy	Plant taxonomy in human services; environmental impacts assessment and biodiversity management; steps of assessment; biodiversity restoration steps and monitoring plan; Development of botanical garden based on plant taxonomic knowledge and *ex situ* conservation sites.	**10**
10. Plant taxonomy in practices	Plant taxonomy in practices, floristic research, new to science, floristic richness, abundance, diversity, dominance, uses and origin of flora.	**4**

Unit-wise learning outcome

Unit	Course Contents
1. Introduction	Students will be acquainted with subject, opportunities and rea world applications.
2. Research methodologies	Students will be learned the project development procedures and to be an independent researcher
3. Reproductive Biology	Students will be learned the biology of higher plants and the processes of speciation
4. Anatomical features in taxonomy	Students will be learned how to use anatomical features to solve taxonomic problems
5. Chemical features in Taxonomy	Students will be learned how to use chemical features of plants to solve taxonomic problems.
6. Habitats and environment relationships of plants	Students will be learned plants and environment interactions and effects of environment on plants life**.**
7. Taxonomy and biodiversity	Students will be learned how plant taxonomy helps in biodiversity conservation programs and also how to make threatened plant list of IUCN.
8. Propagation modes	Students will be learned the strategies of plant conservation.
9. Applied Taxonomy	Students will be learned how taxonomy knowledge can be applied in the development programs and garden establishment.
10. Plant taxonomy in practices	Students will be learned how to establish new species to science and also be learned to determine the abundance and origin of plants in nature.

Recommended Readings

Arthur J. Eames, Laurence H. Mac-Daniels. 1950. An Introduction to Plant Anatomy. American Midland Naturalist, Vol. 43, No. 1 (Jan., 1950), p. 254.

Burkill, I.H. 1965. Chapters on the history of Botany in India. Govt. of India Press, Delhi. Charles B. Beck. 2005. An Introduction to Plant Structure and Development, University of Michigan, Ann Arbor, Hardback.

Cronquist, A. 1989. The evolution and classification of flowering plants. Houghton, Millin Co. Mass, USA

Hunter, M.L. 1996. Fundamentals of conservation biology, Blackwell Science Publishers.

Khan, M.S. 1991. Angiosperms. (In: (Islam, A.K.M. Nurul ed.) Two Centuries of plant studies in Bangladesh and Adjacent Regions. Asiatic Soc. Bangladesh, Dhaka.

Khan, M.S., Rahman, M.M. and Ali, M.R. 2001. Red Data Book of vascular plants of Bangladesh, Bangladesh National Herbarium, Dhaka.

Meffe, G. R. and Carroll, C.R. 1997. Principles of conservation biology (Second edn.) Sinauer Associates Inc. Publishers, Sunderland, Massachusetts.

Prain, D. 1903. Bengal plants. Vols. 1-2, Calcutta.

Radford, A.E., W.C. Dickson, J.R. Masey, C.R. Bell & Vascular Plant Systematic. Harper & Raw Publishers NY.

Stace, C.A. 1989. Plant Taxonomy & Biosystematics, 2nd Edward Ann.

Krebs 1981. Ecological methodology Plant propagation: principles and practices, 2nd edition 1968. Hudson

Hartman, Dale E. Kester. Cement Sustainability Initiative (CSI); Biodiversity Management Plan (BMP) Guidance; WBCSD (file:///C:/Users/Acer/Desktop/file.pdf) Biodiversity management plan (file:///C:/Users/Acer/Downloads/Biodiversity%20Management%20Plan.pdf).

IUCN Guidelines for planning and monitoring corporate biodiversity performance chrome-extension: //efaidnbmnnnibp-cajpcglclefindmkaj/https://portals.iucn.org/library/sites/library/files/documents/2021-009-En.pdf

Guidelines for Environmental Impact Assessments in International Development Cooperation July 1998, SIDA(chromeextension://efaidnbmnnnibpcajpcglclefindmkaj/https://ec.europa.eu/echo/files/evaluation/watsan2005/annex_files/SIDA/SIDA%201%20-%20Environmental%20impact%20assessments.pdf)

ESS6: Biodiversity Conservation and Sustainable Management of Living Natural Resources (chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://documents1.worldbank.org/curated/en/924371530217086973/ESF-Guidance-Note-6-Biodiversity-Conservation-English.pdf).

Planning and Implementing Botanic Garden Design Projects https://www.researchgate.net/publication/304659438_Planning_ and_Implementing_Botanic Garden Design Projects.

Instruction strategies and Learning experiences

- Lecture followed by group discussion
- Question answer
- Guided discussion
- Project discussion
- Demonstration

Assignment: Students will be given assignment on particular units
Assessment: Final examination will be taken after completing the lectures at the end of the year.

BOT 707: Terrestrial Ecosystem — Credit hour: 4

Course description:

Earth's ecosystem is being exploited by human activities that have increased more in the last half-century than in the entire planet history. In managing Earth resource, ecosystem approach is fundamental because it addresses the interactions linking biotic systems with the physical systems. In many ways, numerous direct and indirect factors including human activities are affecting the global environment. Sixth major extinction on Earth event is advent due to our actions. Our activities are radically modifying the interactions among forest, fields, streams and oceans. Understanding the temporal and spatial patterns of ecosystem processes, mechanisms by which terrestrial ecosystems function, water, energy and cycling of carbon and nutrients and role of organisms of these processes through trophic interactions, environmental effects and disturbance are of prime importance.

Course objectives

The course is intended to provide the conceptual advanced understanding to the

- Control over of terrestrial ecosystem processes, functions, their sensitivity to environmental and biotic changes
- Water and energy budget, and plant and ecosystem carbon budget
- The nutrient use efficiency, decomposition and trophic dynamics
- The ecosystem services, and management

Course contents

Units	Contents	No. of Lectures
1	**The ecosystem concept:** Overview of Ecosystem Ecology, history of Ecosystem Ecology, ecosystem processes and constrains, control over ecosystem processes, human induced ecosystem changes, resilience and threshold changes, degradation of ecosystem services	05
2	**Geology, Soils and Sediments:** Control over soil formation and losses, soil properties and ecosystem functioning.	05
3	**Water and Energy Balance:** Surface energy balance, partitioning of absorbed radiation, overview of ecosystem water budgets, water input to ecosystems, water	06

	movement within ecosystems, water losses from ecosystems.	
4	**Carbon inputs to Ecosystem:** Overview, living on the edge, terrestrial gross primary productivity (GPP), canopy processes. leaf area, satellite-based estimates of GPP.	05
5	**Plant Carbon Budget:** Terrestrial net primary productivity (NPP), physiological, environmental and species control over NPP, allocation of NPP, allocation responses to multiple resources, diurnal and seasonal cycles of allocation, global distribution of biomass and NPP.	07
6	**Decomposition and Ecosystem Carbon Budget:** Overview, litter fragmentation, chemical alteration, temporal and spatial heterogeneity of decomposition, factors controlling decomposition.	05
7	**Plant Nutrient Use:** Terrestrial, lakes, rivers and ocean ecosystems, nutrient supply, movement and mass flow, nutrient use, nutrient loss from plants.	05
8	**Trophic and temporal dynamics:** Control over energy flow through ecosystems, trophic effects on nutrient cycling, ecological efficiencies, ecosystem resilience and changes, conceptual framework of disturbance, trophic dynamics	07
9	**Landscape heterogeneity and Ecosystem dynamics:** Concept, causes of spatial heterogeneity, patches interaction on the landscape, human land-use change, extrapolation to larger scale.	08
10	**Managing and sustaining Ecosystems:** Ecological dimension of sustainability, conceptual framework of ecosystem management, ecological principles to management, innovation and adaptive management, socio-economic contexts of ecosystem management, managing flow of ecosystem services.	07

Unit wise Learning outcome

Units	Learning outcome
1	Students would have a clear idea on the conceptual framework about the link between organisms and their physical environment within an Earth-System context.
2	This chapter provides the background ideas on factors regulating soil and sediment properties that most strongly influences ecosystems
3	Students would be able to describe ecosystem energy budget and other control overs different cycles and their sensitivity to environmental and biotic changes
4	Students would be able to explain the controls over carbon input to ecosystems that drive most biological processes.
5	Students would be able to understand and describe the balance between carbon input and losses that govern the carbon balance of plants.
6	Students would have a clear understanding on the key control over decomposition and carbon balance of ecosystems.
7	Students would be able to describe the factors that regulate nutrient cycling through vegetation.
8	Students will have the concept of control over the trophic dynamics that govern the movement of carbon, nutrients and energy among individuals and ecosystem processes adjusting temporal variations.
9	Students would have to concept of major causes and consequences of landscape heterogeneity that determines the regional consequences guiding the individual ecosystems.
10	Earth's ecosystems are influenced by anthropogenic activities. Students will be able to summarizes the principles by which ecological properties can be sustained to meet the needs of ecosystems and society.

Recommended Readings

Alster CJ, Allison SD and Treseder KK 2020. Carbon budgets for soil and plants respond to long-term warming in an Alaskan boreal forest. Biogeochemistry. 150: 345-353.

Brady NC and Weil RR 2008. The Nature and Properties of Soils. 14th Edition. Pearson Education Inc. Upper Saddle Riv.er, NJ.

Buss W, Yeates K, Rohling EJ and Borevitz J 2021. Enhancing natural cycles in agro-ecosystems to boost plant carbon capture and soil storage. Oxford Open Climate Change.: kgab006. doi: 10.1093/oxfclm/kgab006

Barbour MG, Burk JH, Pitts WD, Gilliam FS and Schwartz MW 1998. Terrestrial Plant Ecology. 3rd Edition. The Benjamin/Cummings Publishing Company

Chapin FS III, Kofinas GP and Folke C 2009. Principles of Ecosystem Stewardship: Resilience Based Natural Resource Management in a Changing World. Springer, New York.

Chapin, FS III, Matson, PA and Vitousek PM 2011. Principles of Terrestrial Ecosystem Ecology, 2nd Edition, Springer, New York.

Clark WC and Dicken NM 2003. Sustainability science: The emerging research program. Proceedings of the National Academy of Sciences, USA 100:8059-8061.

Jenny H 1941. Factors of Soil Formation. Mc Graw-Hill, New York.

Kimberly AW 2019. Essential of Landscape Ecology. Oxford Academic.

Lindeman RL 1942. The trophic-dynamic aspects of ecology. Ecology 23:399-418.

MEA (Millennium Ecosystem Assessment) 2005. Ecosystem and Ecological Well-being: Synthesis. Island Press, Washington.

Oke TR 1987. Boundary Layer Climate, 2nd Edition, Methuen, London.

Steffen WL, Sanderson A, Tyson PD, Jager J and Matson PA 2004. Global Change and Earth System: A Planet under Pressure. Springer-Verlag, New York.

Vitousek PM 2004. Nutrient cycling and Limitation: Hawai'i as a Model System. Princeton University Press, Princeton.

Instruction strategies and Learning experiences

- Lecture followed by group discussion
- Question answer
- Guided discussion
- Project discussion
- Demonstration

Assignment: Students will be given assignment on particular units
Assessment: Final examination will be taken after completing the lectures at the end of the year.

BOT 708: Plant Molecular Ecology — Credit hour: 4

Course description:

This course aims to teach students potentials of molecular data in addressing ecological issues. By studying this course students will be able to answer classical ecological questions by using molecular approaches. Students will be introduced with molecular methods for characterizing individuals, populations and species genetically.

Course objectives

- Introduce students with molecular methods and markers useful to address ecological questions such as identification and phylogeny of individuals and species and retrace historical patterns of dispersal and distribution of organisms
- Teach students how to apply molecular methods in biodiversity conservation, wildlife forensics, sustainable agriculture, and mitigation of global climate change and environmental pollution
- Enhance knowledge of the students about the molecular mechanisms of adaptation of plants

Course contents

Unit	Contents	Lecture
1. Introduction to molecular ecology	Definition, Scope and Emergence of molecular ecology	6
2. Molecular markers in Ecology	Inheritance pattern, Kinds and features of molecular markers used in ecology	8
3. Molecular markers	Methodology, application and data interpretation of RAPD, AFLP and microsatellites.	6
4. Phylogenetics	Definition of phylogenetics, Types of phylogenetic tree, Methods for constructing phylogenetic tree	6
5. Population ecology	Definition and types of population, Quantifying genetic diversity, Factors influencing genetic diversity, Quantifying gene flow, Factors influencing gene flow	8
6. Community and ecosystem genomics	Relationships between genetic variation and ecosystem functions	8

7. Legume-rhizobia symbiosis	Molecular interactions between partners, Host specificity in rhizobia	6
8. Applied molecular ecology	Application of molecular ecology in the context of wildlife forensics, agriculture and global climate change	6
9. Conservation biology	Importance of biodiversity conservation, Methods of conserving biodiversity	6

Unit-wise learning outcomes

Unit	Unit-wise learning outcomes
1. Introduction to molecular ecology	Gain knowledge about the importance of and scope of molecular ecology; historical development of molecular ecology
2. Molecular markers in Ecology	Gain knowledge about the inheritance patterns; use of molecular markers
3. Molecular markers	Learn how to solve ecological questions by using molecular markers
4. Phylogenetics	Learn how to construct phylogenetic trees, how to examine phylogenetic relationships among organisms
5. Population ecology	Learn the fundamentals of population genetics in relation to biodiversity conservation
6. Community and ecosystem genomics	Learn ecological aspects of genomics and application of genomics in solving ecological questions
7. Legume-rhizobia symbiosis	Understand about the interactions between legume and rhizobia and its applied aspects
8. Applied molecular ecology	Understand the application of molecular ecological methods
9. Conservation biology	Know the importance of conserving biodiversity, threats to biodiversity, ecosystem services, and learn methods for conserving genetic diversity

Recommended Readings

Baker AJ 2000. Molecular Methods in Ecology. Blackwell Science.

Beebee T and G Rowe. 2008. An Introduction to Molecular Ecology. 2nd Edition. Oxford University Press, Oxford.

Dresler-Nurmi A, DP Fewer, LA Räsänen and K Lindström 2009. The diversity and evolution of rhizobia. Microbiology Monograph. 8: 3-41.

Freeland JR. 2005. Molecular Ecology. John Wiley & Sons, Ltd. England.

Freeland JR and SD Petersen 2011. Molecular Ecology. 2nd Edition. John Wiley & Sons, Ltd. England.

Hoelzel AR and GA Dove. 1991. Molecular Genetic Ecology. IRL, Oxford.

Wardle DA 2002. Communities and Ecosystems. Princeton University Press.

Weaver RF 2005. Molecular Biology. McGraw-Hill.

Instruction strategies and Learning experiences

- Lecture followed by group discussion
- Question answer
- Guided discussion
- Project discussion
- Demonstration

Assignment: Students will be given assignment on particular units

Assessment: Final examination will be taken after completing the lectures at the end of the year.

BOT 709: Ecosystem Ecology **Credit hour: 4**

Course description:

This course aims to explore the structure, function, development and dynamics of terrestrial ecosystems with a focus on the exchange of energy and nutrient between biotic and abiotic components of the biosphere. Course is designed to develop graduates with up to date knowledge on ecosystem ecology so that they can contribute in achieving sustainable goal (SDGs).

Course objectives

- Gain knowledge on structure, functions and diversity of ecosystems and its scopes.
- Explain the factors including global warming that governs the ecosystems.
- Understand major ecosystem processes such as biogeochemical cycles, plant productivity and decomposition, trophic dynamics and nutrient cycling.
- Explain ecosystem services and threats to ecosystem services.
- Understand the genetic diversity and genomics in relation to adaptation of plants.

Course contents

Unit	Contents	No. of Lectures
1. Introduction to ecosystem ecology	Definition; Scopes; Ecosystem concept & fundamentals	6
2. Ecosystem diversity	Defining ecosystem diversity; Major ecosystems of the world & Ecosystem diversity in Bangladesh	8
3. Ecosystem controls	Definition of ecosystem control, Factors regulating ecosystem; Spatial and temporal heterogeneity in ecosystems	6
4. Carbon budget and ecosystem	Global carbon cycle; Role of ecosystem on global carbon cycle; Soil organic carbon pools	6
4. Ecosystem processes	Ecosystem functions; Factors influencing ecosystem functions; Diversity versus ecosystem functions	6
6. Ecosystem change	Ecosystem stability; Factors driving ecosystem change; Interactions between human and natural systems; Regime shifts, Resilience and biodiversity in ecosystem management	8
7. Ecosystem genomics:	Gene and genome functions in the natural environment; Ecosystem genomics; Mechanisms of adaptation; Forest ecosystem genomics and adaptation	6
8. Ecosystem services	Concepts; Identifying ecosystem services; Biodiversity and ecosystem services; Valuing ecosystem services; Ecosystem condition and sustainable use; Case studies on identifying ecosystem services of major forests and water bodies in Bangladesh	8
9. Trophic dynamics	Energy and nutrient flow, food chain, food web, aboveground and belowground food webs, top-down and bottom-up regulation of food web, ecological pyramids	6

Unit-wise learning outcomes

Unit	Unit-wise learning outcomes
1. Introduction to ecosystem ecology	Gain knowledge about the fundamentals of ecosystem ecology and its scopes
2. Ecosystem diversity	Learn ecosystem diversity at global and regional scale
3. Ecosystem controls	Understand the regulating factors of ecosystems heterogeneity at spatial and temporal scales
4. Carbon budget and ecosystem	Know factors influencing carbon budget and the role of ecosystem on global C budget
4. Ecosystem processes	Learn about the ecosystem drivers and also will gain knowledge about the factors that influence ecosystem function
6. Ecosystem change	Understand ecosystem stability and the factors that influence ecosystem stability and know the management of ecosystem conservation
7. Ecosystem genomics:	Learn genetic diversity of ecosystems and its relevance in forest adaptation and management

8. Ecosystem services	Learn about ecosystem services and its sustainable management
9. Trophic dynamics	Learn trophic structure of ecosystem and its regulation

Recommended Readings

Bruenig EF 1989. Ecosystems of the World. Ecotoxicology and Climate,. (Eds.) Bourdeau P, Haines JA, Klein W and Krishna Murti CRK. John Wiley & Sons Ltd.

Dronova I 2017. Environmental heterogeneity as a bridge between ecosystem service and visual quality objectives in management, planning and design. Landscape and Urban Planning 163: 90–106.

Folke C, S Carpenter, B Walker, M Scheffer, T Elmqvist, L Gunderson and CS Holling 2004. Regime Shifts, Resilience, and Biodiversity in Ecosystem Management. Annu. Reviews on Ecology and Evolutionary Systematics 35: 557–581.

Hossain MZ, Anawar HM and Chaudhary DR (eds) 2023. Climate Change and legumes: Stress mitigation for sustainability and food security. CRC Press (Taylor & Francis Group), USA. p 253.

Hossain MZ 2022. Methods for Ecological Studies. Ariban PublicatinTech, Qeensland, Australia. p 306.

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Schwartz MW, CA Brigham, JD Hoeksema, KG Lyons, MH Mills and PJ van Mantgem 2000. Linking biodiversity to ecosystem function: implications for conservation ecology. Oecologia 122: 297–305.

Taylor G, J Turok, O Savolainen and B Ziegenhagen 2011. Forest ecosystem genomics and adaptation. Tree Genetics & Genomes 7: 869–875.

Wardle DA 2000. Communities and Ecosystems: Linking aboveground and belowground components. Princeton University Press, Princeton and Oxford.

Instruction strategies and Learning experiences

- Lecture followed by group discussion
- Question answer
- Guided discussion
- Project discussion
- Demonstration

Assignment: Students will be given assignment on particular units

Assessment: Final examination will be taken after completing the lectures at the end of the year.

BOT 710: Plant Stress Physiology Credit hour: 4

Course description:

Plant Physiology is an interdisciplinary field which incorporates elements of biology, chemistry, physics and environmental science. Students in Plant Stress Physiology get to engage in research in areas such as plant development, metabolism and responses to biotic and abiotic stresses. A PhD in Plant Stress Physiology is a research-oriented degree that typically takes 4 years to complete. The course has been meticulously designed to enlighten the students about key concepts regarding various adverse effects of abiotic stresses on metabolism and other physiological processes that regulate growth and productivity of plants. Students will acquire knowledge of some advanced principles of plant physiological processes through this course, with particular attention to driving forces of ions, plant cell wall, metabolism of storage carbohydrates, biosynthesis of plant growth regulators, plant stresses, signaling hormones, signal perception and transduction, and mechanisms of adaptation of plants to adverse chemical soil conditions. Research in Plant Stress Physiology has significant implications for addressing global challenges such as food security, climate change and environmental sustainability. Students in this field can make a significant contribution to society by conducting research that has practical applications and can lead to real-world solutions.

Course objectives

- To have a comprehensive understanding of how plants work. Understanding transport of ions and function relationships, and interactions with the environment, is a vital strategy for comprehending fundamental concepts of plant physiology. This in turn relates greatly to understand the function of whole plant;

- To recognize and describe how plants respond to their environment;
- To introduce plant stress physiology tools by running different types of experiments, formulating and testing hypotheses, processing, analyzing, presenting results, and preparing a thesis paper.
- Moreover, students will have the ability to analyze the mechanisms of stress resistance which plants have developed to cope with stress conditions in order to prevent injury and maintain life functions.
- Successful completion of this course will end with an introduction to the interactions of plants with their environment and stress-adaptation.

Course content

Units	Course content	No. of Lectures
1. Driving forces and transport of ions across membranes	(a) Electrochemical potential as driving forces of ions; (b) The Nernst potential and the detection of active transport; (c) Consumption of ions in metabolism; (d) The role of calcium in controlling membrane permeability; and (e) Conductance and electrical resistance of membranes.	**8**
2. Plant Cell Wall	(a) Structure, biochemistry and biosynthesis; (b) Interactions between cell wall and plant-microbe; and (c) Plant cell wall as a renewable material resource.	**6**
3. Metabolism of Storage Carbohydrate	Metabolism and biosynthesis of (a) sucrose, (b) starch and (c) fructan.	**6**
4. Plant Growth Regulators:	Biosynthesis of (a) auxin, (b) gibberellin, (c) cytokinin, (d) ethylene and (e) abscisic acid.	**8**
5. Environmental Stresses:	(a) Types and causes of plant stresses; (b) Plant responses to abiotic stress; (c) Oxidative stress, production and dual role of ROS; and (d) Signaling pathways in response to abiotic stress conditions.	**8**
6. Signaling hormones:	(a) Types of stress hormones (abscisic acid, salisyclic acid, jasmonic acid and brassinosteroid); (b) Chemistry; and (c) Role as main mediators in stress improvement.	**8**
7. Signal Perception and Transduction:	(a) General aspects; (b) Routes of signal perception, transduction, and response in plants; (c) Membrane Potential as a Receptor; (d) Signal perception at the plasma membrane (receptor kinases, G-protein-coupled receptors, ion channel-linked receptors); (e) Signal transduction and amplification via second messengers; and (f) Significance of second messengers in signal transduction;	**8**
8. Adaptation of plants to adverse chemical soil conditions:	Plant responses and mechanisms of adaptation under (a) acid mineral soils; (b) waterlogged soils; (c) saline soils; and (d) alkaline soils.	**8**

Unit wise learning outcome

Units	Learning outcomes
1	• Impart knowledge about driving forces of ions; explain electrochemical potential as driving forces of ions, the Nernst potential and consumption of ions in metabolism; state the role of calcium in controlling membrane permeability and conductance and electrical resistance of membranes.
2	• Elucidate conception of plant cell wall; comprehend and integrate between cell wall and plant-microbe; discern cell wall as a renewable material resource.
3	• Procure knowledge on metabolism and biosynthesis of different carbohydrates.
4	• Outline the biosynthesis of different hormones in plants.
5	• Extensive knowledge on plant stresses and ROS; recognize different types of ROS; describe their chemistry, site, dual role and signaling pathways in response to stress conditions.
6	• Cognizance of stress hormones; list different types of stress hormones with molecular formulae and structures; state roles of these hormones in stress improvement.
7	• Explicit concept of signal perception, transduction, and response in plants; emphasize second messengers in signal transduction.

8	• Clarify the concept of plant responses and mechanisms of adaptation under various stressed soils.

Recommended Readings

Nelson DL and MM Cox 2015. Lehninger Principles of Biochemistry (7th Ed.), Freeman and Company, N.Y.

Bhatla SC and Lal MA 2018. Plant Physiology, Development and Metabolism, Springer Nature, Singapore.

Taiz L. and E. Zeiger 2010. Plant Physiology (5th Ed.). Sinauer Associates Inc., Massachusetts, USA.

Hopkins WG and NPA Hüner 2009. Introduction to Plant Physiology (4th Ed.), John Wiley and Son, Inc.

Hasanuzzaman M, M Fujita, H Oku and MT Islam 2019. Plant Tolerance to Environmental Stress, CRC press, Taylor and Francis group, UK.

Clarkson D.T. 1980. Ion Transport and Cell Structure in Plants. McGraw Hill, V.S.H.

Marschner H. 1995. Inorganic Nutrition of Higher Plants. Academic Press, New York.

Pareek A, Sopory SK, Bohnert HJ and Govindjee 2010. Abiotic Stress Adaptation in Plants, Springer, Netherlands.

Instruction strategies and Learning experiences

- Lecture followed by group discussion
- Question answer
- Guided discussion
- Project discussion
- Demonstration

Assignment: Students will be given assignment on particular units

Assessment: Final examination will be taken after completing the lectures at the end of the year.

BOT 711: Advanced Plant Physiology and Nutrition — Credit hour: 4

Course description:

PhD students in Plant Physiology typically begin their studies with a strong foundation in biology, chemistry and physics. As a result, PhD students in this field gain a broad perspective on the complex processes underlying Plant Physiology. This course imparts basic knowledge about different aspects of ion transport, physiological and biochemical processes, as well as their applications in agricultural research. Through this course students will comprehend some advanced concepts of plant physiological phenomena with special reference to compartmentation and other complications in higher plants regarding ion transport, links between cellular metabolism and ion transport, distribution and redistribution of ions, mechanism of sieve tubes transport, metabolic potential of phloem, coenzymes, rhizosphere and radioactivity. They use technologies to conduct experiments, collect and analyze data and make new discoveries. Under the supervision of a faculty advisor, independent research is covered in the syllabus.

Course objectives

- Integrate and synthesize scientific information on the physiology of plants;
- Comprehend transport of ions, function relationships and environmental interactions;
- Grasp the physiological, biochemical and nutritional concepts which underlie plant adaptations to their environment;
- learn to develop critical thinking, problem-solving, and communication skills that are valuable in both academia and industry;
- Perform scientific research on globally relevant problems in plant sciences and contribute this knowledge to their discipline.

Course contents

Units	Contents	No. of Lectures
1. Ion transport in higher plants: The chemical approach:	a) Metabolism (a) Compartmentation and other complications in higher plants; (b) Ionic composition of intracellular compartments; (c) Transmembrane potentials in cells of higher plants.	**8**
2. Links between cellular metabolism and ion transport:	(a) Energy flow and ATP production in photosynthesis; (b) Energy flow in respiration; (c) Dependance of ion pumping on ATP and electron flow; and (d) Charge separation and ion transport.	**6**

3. Distribution and redistribution of ions:	(a) Extraction of ions from xylem; (b) Delivery of ions and solutes within leaves; (c) Movement of ions and solutes within leaves; (d) Export of ions from leaves; and (e) Redistribution of ions in relation to physiological process.	**8**
4. The hypothesis of the mechanism of sieve tubes transport:	(a) Passive mechanisms; and (b) Active mechanisms.	**6**
5. Metabolic energy and transport of carbohydrate:	(a) The metabolic potential of phloem; and (b) The effect of localized application of low temperature, metabolic inhibitors and anoxia on transport.	**8**
6. Coenzymes:	(a) Chemical nature; (b) Important coenzymes (ATP, NAD, FAD, CoA, vitamins); and (c) Mode of action and role.	**8**
7. The soil-root interface (rhizophere) in relation to mineral nutrition:	(a) Ion concentration in the rhizosphere; (b) Rhizosphere pH and redox potential; (c) Rhizodeposition and root exudates; (d) Noninfecting rhizosphere microorganisms; and (e) Mycorrhizas.	**8**
8. Basic concept in isotopic studies:	(a) Radioactivity; (b) Artificial radioactivity; (c) Isotopic techniques for tracer studies; and (d) Health physics; and (e) Use of isotopes.	**8**

4. Unit wise learning outcome

Unit No.	Learning outcomes
1	• Comprehensible knowledge on compartmentation and other complications in higher plants, ionic composition of intracellular compartments, and transmembrane potentials in cells.
2	• Clarify the concept of energy flow and ATP production in photosynthesis and respiration; deeper understanding of ion pumping on ATP and electron flow.
3	• Perceive the conception of extraction of ions from xylem, distribution and redistribution of ions in relation to physiological process.
4	• Interpret the active and passive mechanism through sieve tubes transport.
5	• Illuminate the concept of metabolic potentiality of phloem; describe the effect of localized application of different factors on transport of carbohydrate.
6	• Define coenzymes; list some important coenzymes; elucidate chemical nature and mode of action and role of coenzymes.
7	• Perceive the conception of rhizosphere; integrate the soil-root interface.
8	• Acquire knowledge of isotope and radioactivity.

Recommended Readings

Nelson DL and Cox MM 2015. Lehninger Principles of Biochemistry (7th Ed.), Freeman and Company, N.Y.
Bhatla SC and Lal MA 2018. Plant Physiology, Development and Metabolism, Springer Nature, Singapore.
Taiz L and Zeiger E 2010. Plant Physiology (5th Ed.). Sinauer Associates Inc., Massachusetts, USA.
Hopkins WG and Hüner NPA 2009. Introduction to Plant Physiology (4th Ed.), John Wiley and Son, Inc.
Clarkson DT 1980. Ion Transport and Cell Structure in Plants. McGraw Hill, V.S.H.
Epstein E 1982. Mineral Nutrition of Plants. Principle and Perspective. John Wiley and Sons, New York.
Hewitt EJ and Smith TA 1974. Plant Mineral Nutrition. The English University Press, London.
Marschner H 1995. Inorganic Nutrition of Higher Plants. Academic Press, New York.

Instruction strategies and Learning experiences

- Lecture followed by group discussion
- Question answer
- Guided discussion
- Project discussion
- Demonstration

Assignment: Students will be given assignment on particular units
Assessment: Final examination will be taken after completing the lectures at the end of the year.

BOT 712: Plant Cytogenetics Credit hour: 4

Course description:
This is a basic course in PhD program in Botany. It will be very helpful to the students for developing clear knowledge about structure and composition of chromosomes, smear technique for plant chromosomes, karyotyping and sorting of plant chromosomes by flow cytometry, genetic control of meiosis, the chromosomal basis of sex determination in plants and chromosomal aberrations in cell and tissue culture.

Course objectives

- Students will acquire knowledge about structure and composition of chromosomes.
- get clear idea about the smear technique for plant chromosomes, karyotyping and sorting of plant chromosomes by flow cytometry, genetic control of meiosis, the chromosomal basis of sex determination in plants
- Explain the reason of chromosomal aberrations in cell and tissue culture

Course contents

Unit No.	Contents	No. of Lecturers
1	Structure and composition of chromosomes: (a) Constituents of chromosome- DNA, RNA, histones, inorganic ions. (b) Assembly of chromosomal constituents into chromosomes- nucleosome, solenoids, higher order packing of chromosome fibres. (c) Distribution of chromosomal constitutions along chromosomes. (d) Changes during chromosome condensation.	5
2	Smear technique for plant chromosomes: (a) Chromosome preparation from the root. (b) Chromosome preparation from cell suspension and callus, (i) Suspension culture of celery (*Apium graveolens*), (ii) Callus culture of *Brassica carinata.* (c) Chromosome preparation from flower. (d) Chromosome preparation from Shoot	5
3	Karyotyping and sorting of plant chromosomes by flow cytometry: (a) Protocol 1, (i) Accumulation of mitotic metaphase, (ii) Analysis of the degree of the metaphase synchrony. (b) Protocol 2, (i) Suspension of plant chromosome, (ii) Alignment of flow cytometer for chromosome analysis and sorting. (c) Protocol 3, (i) Univariate flow karyotyping and sorting of plant chromosomes, (ii) Bivariate flow karyotyping and chromosome sorting. (d) Protocol 4, (i) Physical mapping of DNA sequences using PCR, (ii) Two- step sorting, (iii) Reagents and solutions. (e) Protocol 5, (i) Karyotype analysis by pachytene chromosomes, (ii) Karyotype analysis by flow cytometry, (iii) Karyotype analysis by image analysis.	10
4	Genetic control of meiosis: (a) Synaptic mutants- (i) Distribution of synaptic mutants, (ii) Origin of synaptic mutants (iii) Cytological behavior of synaptic mutants, (iv) Synaptic Mutants and recondensation. (v) Factors influencing pairing in Synaptic Mutants, (b) Genetic Control of recondensation, (c) Genes responsible for chromosome disjunction, (d) Other meiotic mutants, (e) Role of heterochromatin in chromosome pairing, (f) Diploid-like meiosis in allopolyploids - The 5-B system in wheat (2n = 6x = 42), (g) Haploidy- (i) Mechanism of chromosome elimination, (ii) Genetics of chromosomes elimination, (iii) Haploid-initiator gene in Barley. (h) Male sterility- (i) Classification of male sterility, (ii) Mechanism of male sterility.	10
5	The Chromosomal basis of sex determination in plants: (a) System of sex determination- (i) Male heterogametic (female XX; male XY; X-Y system), (ii) Male heterogametic (female XX; male XO; X-O system), (iii) Male heterogametic (but with one extra chromosome), (iv) Female heterogametic (female XX (ZW); male XX (ZZ) (Z-W System), (v) Compound chromosomes (interchanges among X, Y, and autosomes), (b) Determination of heterogametic sex in plants- (i) Cytological identification. (ii) Sex linkage inheritance. (iii) Crosses between dioecious and monoecious *Bryonia* species. (iv) Competition tests in pollination, (v) Self-pollination of plants that are normally unisexual, (vi) Crosses between diploids and autotetraploids, (c) Sex ratio among progeny of primary trisomics, (d) Sex expression. (e) The evolution of dioecism, (f) Evolution of sex chromosomes.	15
6	Chromosomal aberrations in cell and tissue culture: (a) Introduction, (b) Chromosomal aberrations in callus - (i) Media composition, (ii) Age of callus, (iii) Nature of callus (Morphogenic vs. Nonmorphogenic), (iv) Kind of media (solid vs.	15

	liquid), (c) Mechanism of chromosomal aberrations in culture, (d) Chromosomal aberrations in regenerated plants: (a) Diploid vs. polyploid species - (i) Potato (*Solanum tuberosum*), (ii) Wheat (*Triticum aestivum*), (iii) Triticale (2n = 6x = 42), (b) Age of callus. (c) Source of explant materials, (d) Culture conditions, (e) Chromosomal aberrations in haploid callus and their regenerants. (f) Chromosomal aberrations in somatic hybrids - (i) Stable somatic hybrids, (ii) Partially stable somatic hybrids, (iii) Unstable somatic hybrids, (iv) Chromosomal aberrations in transgenenic crops, Genetic background of the explant, Cytological basis of gene silencing.	

Unit wise learning outcome

Unit No.	Learning outcomes
1	Students will get overview idea about structure and composition of chromosomes
2	Students will learn about smear technique for plant chromosomes
3	Students will acquire knowledge about karyotyping and sorting of plant chromosomes by flow cytometry
4	Get knowledge about genetic control of meiosis
5	Gather knowledge about the chromosomal basis of sex determination in plants.
6	Students will acquire knowledge about chromosomal aberrations in cell and tissue culture.

Recommended Readings

Akhtaruzzaman M 2008. Kosh Bangshagatibiddaya. (3rd Edn.). Bangla Academy, Dhaka.

Schwaszacher T and P Heslop-Harrison 2000. Practical *in situ* hybridization. Springer-Verlag New York, Inc. 70010-7858 abd BIOS Scientific Publishers Ltd.

Singh Ram J 2003. Plant Cytogenetics. CRC Press, London.

Sumner AT 1990. Chromosome banding. Unwin Hyman, London.

Instruction strategies and Learning experiences

- Lecture followed by group discussion
- Question answer
- Guided discussion
- Project discussion
- Demonstration

Assignment: Students will be given assignment on particular units
Assessment: Final examination will be taken after completing the lectures at the end of the year.

BOT 713: Chromosome Banding: Techniques and Application Credit hour: 4

Course description

This is a basic course in PhD program in Botany. It will be very helpful to the students for developing clear knowledge about genome organization in the light of chromosome banding, chromosome banding polymorphism, heteromorphism and variants, banding with nucleases, banding demonstrated by immunocytochemical methods, Fluorescence *in situ* Hybridization (FISH), Genomic *in situ* Hybridization (GISH) and total DNA extraction of plant genomic DNA.

Course objectives

a) Students will acquire knowledge about genome organization in the light of chromosome banding.
b) get clear idea about chromosome banding polymorphism, heteromorphism and variants, banding with nucleases, banding demonstrated by immunocytochemical methods
c) Explain the Fluorescence in situ Hybridization (FISH), Genomic in situ Hybridization (GISH) and total DNA extraction of plant genomic DNA.

Course contents

Unit No.	Contents	No. of Lecturers
1	Genome organization in the light of chromosome banding - (a) heterochromatic bands, (b) euchromatic bands, (c) molecular correlations with euchromatic banding,	5

	(d) structural correlations with euchromatic banding.	
2	Chromosome banding polymorphism, heteromorphism and variants - (a) Mechanism of formation heteromorphism. (b) Quantitative assessment of heteromorphic bands. (c) Heteromorphism in plants. (d) Human chromosome heteromorphism (chromosome No 1, 3, 4, 6, 9, 16, Y chromosome).	10
3	Banding with nucleases- (a) Digestion of chromosomes with non-specific nucleases, (b) Digestion of chromosomes with restriction endonucleases, (c) (i) Banding pattern produced by restriction endonucleases with conventional staining, (ii) Restriction enzyme/ nick translation, (iii) Studies on the mechanism of action of restriction endonucleases on chromosomes.	10
4	Banding demonstrated by immunocytochemical methods- (a) Antibodies to the four unsubstituted bases of DNA, (b) Anti-5-methylcytosine, (c) Antibodies to single and double-stranded DNA. (d) Antibodies to histone, (e) Antibodies to non-histone chromosomal proteins.	10
5	Fluorescence *in situ* Hybridization (FISH) - (a) Chromosome preparation, (i) Collection, pretreatment, and fixation of root, (ii) Preparation of buffer, (iii) Enzyme solution, (iv) Preparation of slides. (b) Fluorescence *in situ* Hybridization procedure - (i) Prehybridization method, (ii) Hybridization, (iii) Observation and photography, (c) Genomic *in situ* Hybridization (GISH), (d) Multicolor genomic *in situ* Hybridization (McGISH), (e) Primed *in situ* (PRINS) DNA labeling.	10
6	Total DNA extraction - plant genomic DNA: (a) Solutions, (b) Procedure, (c) Determination of nuclear DNA content of plants by flow cytometry - (i) Stock solutions, (ii) Final solutions, (iii) Procedure, (iv) Flow cytometry after DAPI staining, (v) Flow cytometry after propidium iodide (P1) staining, (vi) Materials for flow cytometry, (vii) Fluorescent staining of nuclear DNA, (viii) Cell cycle in higher plants, (ix) Nuclear DNA content and the cell cycle, (x) Determination of nuclear genome size, (xi) Resolution of DNA content histograms, (xii) Instrument calibration, xiii) Determination of ploidy in plants by flow cytometry, (xix) Identification of interspecific hybrids.	15

Unit wise learning outcome

Unit No.	Learning outcomes
1	Students will get overview idea about genome organization in the light of chromosome banding
2	Students will learn about chromosome banding polymorphism
3	Students will acquire knowledge about heteromorphism and variants, banding with nucleases
4	Get knowledge about banding demonstrated by immunocytochemical methods
5	Gather knowledge about the Fluorescence *in situ* Hybridization (FISH), Genomic *in situ* Hybridization (GISH)
6	Students will acquire knowledge about total DNA extraction of plant genomic DNA.

Recommended Readings

Akhtaruzzaman M 2008. Kosh Bangshagatibiddaya. (3rd Edn.). Bangla Academy, Dhaka.

Schwaszacher T and P Heslop-Harrison 2000. Practical *in situ* hybridization. Springer-Verlag New York, Inc. 70010-7858 abd BIOS Scientific Publishers Ltd.

Singh Ram J 2003. Plant Cytogenetics. CRC Press, London.

Sumner AT 1990. Chromosome banding. Unwin Hyman, London.

Instruction strategies and Learning experiences

- Lecture followed by group discussion
- Question answer
- Guided discussion
- Project discussion
- Demonstration

Assignment: Students will be given assignment on particular units

Assessment: Final examination will be taken after completing the lectures at the end of the year.

BOT 714: Advanced Genomics, Proteomics and Bioinformatics Credit hour: 4

Course description:

This course is structured in a way to provide genome function. Students will also get the detailed knowledge about mechanism of eukaryotic DNA replication as well as transcription and translation. Moreover, transcriptomics, Proteomics and regulation of gene expression will also be discussed.

Course objectives

- Acquisition of advanced knowledge about gene and gene functioning.
- Learn the basic principles and molecular mechanism of DNA replication, transcription and translation in eukaryotic systems.
- To know the various bioinformatics data bases.
- Learn the sequence analysis using bioinformatics tools.
- Understand necessity of drug design using bioinformatics tools.

Course contents

Unit	Contents	No. of Lectures
1. Introduction to Molecular Genetics	Overview of classical genetics, Molecular basis of inheritance, Structure and function of DNA, RNA, and proteins, Overview of Central dogma of molecular biology.	**8**
2. Eukaryotic DNA Replication	Mechanism- initiation, elongation and termination, telomere maintenance, regulation of eukaryotic genome replication.	**5**
3. Transcription in Eukaryotes	Mechanism- initiation, elongation and termination; Processing and transport of eukaryotic RNA.	**5**
4. Translation in Eukaryotes	Mechanism- initiation, elongation and termination; Role of tRNA and ribosome in protein synthesis, Post translational processing of protein, Protein degradation.	**6**
5. Regulation of Gene Expression	Overview of Regulation of Gene Expression; Mechanism- Prokaryotic Gene Regulation, Eukaryotic Gene Regulation.	**4**
6. Recombinant DNA Technology and Gene Cloning	The Basic Principles, Restriction enzymes and DNA cloning, Plasmids, vectors, and cloning strategies, DNA libraries and genomic DNA cloning.	**8**
7. Basic Techniques	Gel electrophoresis, 2-D gel electrophoresis, ion exchange chromatography, gel filtration chromatography, Affinity chromatography, radioactive and non-radioactive tracers, Southern analysis, Northern analysis, Western analysis, Expressed sequenced tag (EST) analysis, Microarray analysis, Polymerase chain reaction (PCR), RT-PCR, qRT-PCR, Genome editing.	**8**
8. Good laboratory practice	Introduction, Compliance, Documentation, Standard Operating Procedures (SOPs), Personnel Training, Facilities and Equipment, Quality Assurance (QA), Study Conduct, Data Integrity, Reporting and Archiving.	**4**
9. Proteomics	Mass-spectrometry, Peptide Sequencing, Functional annotation of Protein sequences. Protein Structure and Folding Determinations. Homology Modelling of Protein. Molecular Docking and Virtual Screening. ADMET analysis. Networking and signalling pathway analysis, Gene therapy and medical applications.	**4**
10. Sequencing Genes, Genomes and Proteomes	Methodologies for DNA sequencing- Sanger sequencing techniques and Next Generation Sequencing (NGS) techniques, Assembly of contiguous DNA sequences, Determining the function of unknown genes, Benefits of genome sequencing.	**8**

Unit wise learning outcome

Unit No.	Learning outcomes
1	• Students will learn basic principles and application of the advanced molecular tools for studying gene functions.

2	• Know the basic mechanism of eukaryotic DNA replication and will be able to differentiate with mechanism operating in prokaryotic cells
3	• Know the Eukaryotic RNA polymerases and their promoters, general transcription factors in eukaryotes, post transcriptional processing of RNA and transport of mature RNA from nucleus to the cytoplasm.
4	• Learn the mechanism of initiation of translation in eukaryotes, eukaryotic initiation factors, eukaryotic translation control.
5	• Get fundamental ideas about the mechanism of regulation of eukaryotic gene expression.
6	• Learn the principles and application of recombinant DNA Technology and Gene Cloning.
7	• Know the principles and methods of different Sequencing methodologies applied to sequence genes and genomes
8	• Learn the good laboratory practice and management
9	• Know the applications of gene manipulation techniques and relevant ethical considerations
10	• Get fundamental ideas about the mechanism of peptide sequencing, and structure prediction followed by molecular docking towards drug development

Recommended Readings

Brown TA 2007. Genomes 3. Garland Science Publishing, USA.

Primrose SB, Twyman RM 2006. Principles of Gene Manipulation and Genomics. Blackwell Publishing, USA.

Klug WS, Cummings MR, Spencer CA and Palladino MA 2009. Concepts of Genetics (9th edition). Pearsons International Edition

Watson JD, Michael L, Baker TA, Gann A and Bell SP 2007. Molecular Biology of Gene. Benjamin-Cummings Pub Co

Weaver RF 2005. Molecular Biology. Mcgraw-Hill International edition

Lewin B 2012. Genes XI. Prentice Hall

Lesk AM 2010. Introduction to Bioinformatics 3rd edition, Oxford University Press

Instruction strategies and Learning experiences

- Lecture followed by group discussion
- Question answer
- Guided discussion
- Project discussion
- Demonstration

Assignment: Students will be given assignment on particular units
Assessment: Final examination will be taken after completing the lectures at the end of the year.

BOT 715: Plant Biotechnology and Bioinformatics Credit hour: 4

Course description

Plant biotechnology and genetic engineering offer new tools to meet these and other agricultural needs. Molecular biologists now know how to transfer foreign genes into plant cells. They are doing on a molecular level what plant breeders have been doing with whole plants for centuries: combining genes in new ways to create improved crops. Working with single genes, rather than whole plants, offers several advantages. One advantage is specificity. In a sexual cross, the entire genomes of two plants are combined even though the breeder may be trying to transfer a trait controlled by a single gene. It takes repeated back crosses to eliminate the extraneous genes and thus many years to create an improved variety. Using molecular techniques, a gene can be snipped from one plant and spliced into another in a single experiment. Genetic engineering opens up a new source of genetic variability that can be used in crop improvement. Breeders can work only with plants that are cross-fertile. By contrast, genetic engineering offers the promise of selecting valuable traits from any organism. For instance, insect resistant cotton as well as fruit and shoot borer resistant brinjal have been developed and commercialized taking a gene from a soil bacteria, *Bacillus thuringiensis.* Another approach might be the transfer of genes which will make crops tolerant to biotic and abiotic stresses.

This course has been designed to offer an in depth knowledge on the recent developments and applications of genetic engineering, the strategies and various methods needed for developing transgenic plants. Course contents also covers modern bioinformatics tools, genome editing concept and biosafety aspects as well as importance Intellectual Property Rights (IPR) in genetic engineering research. Both theoretical presentations and practical laboratory demonstrations will allow students to gain experience in different basic and applied

concepts and methods of plant genetic engineering, trials of genetically modified crops in contained, confined and open field conditions. Students will also compare the benefits and potential risks of genetically modified crops (GM crops).

Course objectives

- To provide basic principles and historical background of plant genetic engineering and tissue culture.
- To provide information on Genetic transformation methods.
- To provide lesson on vectors and promoters needed for genetic engineering.
- To learn methods of characterization of transgenic plants using molecular techniques.
- To learn methods of gene modifications.
- To Provide detail knowledge in Bioinformatics.
- To describe methods for Contained, Confined and Open field trials of biotech crops.
- To provide knowledge on the requirements of biosafety for transgenic research.
- To familiarize the importance of bioinformatics and Intellectual Property Rights.

Course contents

Units	Contents	No. of Lectures
1. Plant tissue culture and Biotechnology	Totipotency of plant cells, organogenesis, somatic embryogenesis, somaclonal variation, recalcitrant plants, micropropagation and applications, disease free plants, protoplast culture and fusion with reference to cybrids and cytoplasmic male sterility, anther culture and applications for breeding, Plant tissue culture as a basis for genetic engineering.	4
2. Cloning and vectors for Plant Transformation	Principles of cloning, vectors, codon optimization, Recombinant DNA technology, Gateway and GoldenGate cloning strategies, Modular cloning (MoClo), *In silico* Vector construction, in-vitro transcription and translation, T-DNA and transposon tagging.	8
3. Plant transformation technology and applications	Crown Gall to *Agrobacterium* Insertion sites, Gene transfer methods in plants; transgene stability and gene silencing, Use of constitutive, tissue specific and stress specific promoters, Chloroplast Transformation and its advantages, molecular assessment of transgenic status and inheritance of transgenes, Fundamental analysis of DNA sequence.	4
4. Genomics for plant improvement	Introduction to science of omics, functional genomics-expression analysis using microarrays, transposon tagging and Insertional mutagenesis - methods and significance, TILLING and EcoTILLING, Diversity Array Technology, transcriptomics.	4
5. Biotechnological strategies for plant improvement:	Overexpression and Directed modification of genomes, gene expression, suppression, RNAi strategies, TALEN and VIGS, genome editing (CRISPR, Prime editing and Base editing).	6
6. Biotechnological manipulation of important traits	Strategies for engineering abiotic (drought, salinity, flooding, temperature, etc.) and biotic (insect pest, fungal, viral and bacterial diseases, weeds, etc.) stresses, quality improvement (protein, essential amino acids, vitamins, minerals nutrients, etc.), herbicide resistance in plants.	6
7. Genome sequencing in plants	Principles and Techniques; Illumina sequencing, Applications of sequence information in plant genome analyses; Comparative genomics, Detection of Single Nucleotide Polymorphism; DARTseq, GBS (genotyping by sequencing) and other third generation sequencing platforms, GEBVs (Genomics estimated breeding values), Role of transcriptomics, proteomics and metabolomics in linking genome and phenome.	8
8. Introduction to Bioinformatics	Bioinformatics and computational biology, Use of nucleic acid and protein data banks - NCBI, EMBL, DDBJ, SWISSPORT, phylogenetic analysis, Profile searches of databases, revealing protein motifs, 3D structural comparisons, predictions and modeling. Candidate drug designing by molecular docking.	4

9. Networks in Bioinformatics	Communication networks, Biological networks (Protein interaction networks, Gene regulation networks), Databases and search tools for biological network analysis, Genomic circuits: in single genes, Complex integrated Genomic circuits, modeling whole genome circuits: Genomics vs. Proteomics.	4
10. Genomic platforms for genome-wide analysis	Gene family identification, cis regulatory motif analysis, Comparative/Synteny mapping, in silico expression analysis, Gene ontology (GO) analysis, GWAS (Genome-wide association studies).	4
11. Regulatory system for Plant Biotechnology	Biosafety and risk assessment issues, regulatory framework, National biosafety policies and law, The Cartagena protocol on biosafety, General principles for the laboratory and environmental biosafety, gene flow in natural and artificial ecologies, sources of gene escape, tolerance of target organisms, creation of superweeds/superviruses etc, ecological aspects of GMOs and impact on biodiversity; Monitoring strategies and methods for detecting transgenics; contained, confined and open field trials of transgenic plants.	2
12. Global status of Biotech crops	Status of commercially available GMOs, Intellectual properties, copyrights, trademarks, trade secret, patents, geographical indications, etc.; Protection of plant variety and farmers right act; Implications of intellectual property rights on the commercialization of biotechnology products.	4

Unit wise learning outcome

Units	Learning Outcomes
1	• Will be able to know why plant tissue culture is the integral part of genetic engineering.
2	• Will be able to know vectors, mechanism of gene cloning, strategy for cloning and their role.
3	• students will know about the vectors needed for indirect methods of genetic transformation. Will know about different direct methods of genetic transformation including their advantages and disadvantages. Students will be able to know the biology of *Agrobacterium*. They will compare the functionality of Ti- and Ri-plasmids, mechanisms of T-DNA transfer, etc.
4	• Will know about the omics, mutagenesis and expression analysis.
5	• know the gene manipulation, genome editing mechanism, types and role of genetic manipulation in molecular science.
6	• students will be able to know the concepts and applications of plant genetic engineering towards developing crops tolerant to biotic and abiotic stresses as well as with enhanced nutritional qualities.
7	• Students will be able to understand various methods of genome analysis, compare the methods as well as they will familiar with the use of genome sequencing.
8	• Students will know the developmental background of bioinformatics including its importance in biotechnology research. They will also know how to search the databases for gene sequences, etc.
9	• Will be familiar with genomic networks, network analysis and modeling.
10	• Will be able to know about gene family, association studies with expression and GO analysis.
11	• Will know the importance of biosafety for transgenic research and the functions of various biosafety regulatory committees as mentioned in the Bangladesh Biosafety Guidelines. Will know the steps for releasing the genetically modified crops including contained, confined and open field trials as well as the precautionary principles needed to follow during these trials.
12	• Will be able to know the importance of Intellectual Property Rights (IPR) for biotechnology research. They will also know the forms of IPR protection and how to protect the Rights of individual inventions

Recommended Readings

Plant Tissue Culture: Application and Limitation by S. S. Bhojwani and M. K. .Razdan, Elsevier Publication
An Introduction to Plant Tissue Culture by M. K. Razdan, Oxford & IBH Publishing Co. Pvt. Ltd.

Plant Biotechnology: The genetic manipulation of plants by Adrian Slater, NigelScott, and Mark Fowler, Oxford University Press

From Genes to Clones: Introduction to gene technology, by Ernst-L Winnacker, VCH Publication, Germany

Principles of Gene Manipulation: An Introduction to genetic Engineering (6th Edition) by R.W. Old and S.B. Primrose, Blackwell Publication

Genes IX by Benjamin Lewin, Oxford University Press, U.K.

Introduction to Bioinformatics by Stephen A Krawetz and David D. Womble, Humana Press.

Bioinformatics: Sequence and Genome Analysis by David W. Mount, Cold Spring Harbor Laboratory Press

Lehninger, A. L., D. L. Nelson and M. M. Cox 2000: Principles of Biochemistry. CBS Publishers and Distributors, New Delhi.

Beier, F.K., Crespi, R.S. and Straus, T. Biotechnology and Patent protection-Oxford and IBH Publishing Co. New Delhi.

Instruction strategies and Learning experiences

- Lecture followed by group discussion
- Question answer
- Guided discussion
- Project discussion
- Demonstration

Assignment: Students will be given assignment on particular units

Assessment: Final examination will be taken after completing the lectures at the end of the year.

BOT 716: Marine and Environmental Sciences **Credit hour**: 4

Course description

Marine and Environmental Sciences is a course offered for PhD students in the Department of Botany. Marine and Environmental Sciences explore the diversity of coastal marine habitats and ecosystems and the tools scientists use to study them, with an emphasis on topics related to human impacts and environmental health. We know that the Earth is unique within our solar system for a number of reasons. Its marine ecosystem covers a large portion of biosphere, over 71% (360 million km^2) of Earth's surface with an average depth of 4 km. So, Marine potential is massive. Marine Environment is highly diverse. Marine ecosystems are hot spots for the diversity of flora and fauna. But, total biodiversity including plankton, algae, seaweeds, sea grasses, flowering plants, salt marsh plants, mangroves etc. are still unknown. This course introduces the concepts of marine resources and management of marine environments, its complex interactions between flora and fauna. This course is structured in a way that students will be able to acquire knowledge about marine ecology, its structure, different factors affecting marine environment, plankton and its composition, role and distribution of seaweeds, phytogeography of sea weeds, importance and huge commercial benefits from it, estuarine ecology, Sundarbans and its threat and reclamation.

Since marine environments are being damaged due to coral bleaching and several anthropogenic activities like fishing, pollution, habitat alteration, introduction of exotic species and climate change, the environment of these areas are drastically undergoing degradation, so inhabiting organisms could possibly become extinct in near future. So, this course will give the students a clear understanding how marine environment and marine resources act as balancing factors of the earth and how and why we are to take care of it.

Course objectives

- To know about marine ecology including life habitat, populations and interactions among organisms and surrounding environment including physical, chemical factors that affect the ability of organisms to survive and reproduce.
- To gather knowledge on the diversity of marine phytoplankton, their classification, productivity, seasonal variation, adaptation and importance.
- To explore seaweeds and uses of seaweeds as foods and feeds, know their enormous importance; apply different methods for the cultivation and production of different industrial and pharmaceutical useful products.
- To gather knowledge on estuarine ecology, Sundarbans and its reclamation
- Production of biofuel from algae, extraction of phycocolloids from marine resources

- Sea grass, salt marshes, reefs, marls and stromatoliths, toxic algae and human health
- Impact of humans on marine environment
- Marine environment a balancing factor of the earth
- The course is suitable to equip students with knowledge and solution to our marine ecosystem problems.
- Identify the major marine resources that beneficial to human livelihood and how to sustain
- the resources for future generations.
- Define the present level of exploitation of marine resources and how pollution affected the
- resources.
- Acquaint the principles of sustainable management of marine and environmental resources
- and healthy product to human.
- Impart knowledge on the policy and management of the resources and on the conservation aspects.

Course contents

Units	content	No. of Lectures
1	Marine and Environmental Sciences: General aspects , Introduction to Marine Resources • Defining marine resources • Type of marine resources • Marine resources use overview and history • Human association with marine resources , The importance of marine biological diversity • The Oceanic Environment: the Oceans and Seas, Marine plants and their habitats, Marine ecology: (a) physical (light, temperature, waves and current, circulation, density etc.) and (b) Chemical (nutrient elements, pH, salinity, oxygen, Carbon cycle, etc.) properties of seawater. (c) Horizontal and vertical zonations of seas and oceans.	**8**
2	Marine phytoplankton: Classification and diversity and adaptation of phytoplankton, Food chain and energy transfer, productivity of phytoplankton and biomass and seasonal variation/distribution of plankton.	**8**
3	Seaweeds: Introduction to the seaweeds, general morphology, seaweeds and their occurrences, diversity and importance of seaweeds, edible seaweeds, factors (Oceanic currents, temperature, surf, waves etc.) affecting seaweed distribution, biomass and phytogeography of seaweeds.	**8**
4	Sea grasses: characteristics, evolution and distribution, adaptations. Salt marshes: introduction, geographic distribution, adaptations	**4**
5	Estuarine ecology: introduction, evolution and biogeographic distribution, biodiversity of mangroves, Sundarbans: geo-ecological status, its flora nd fauna, salinity effects on it, formation and causes of degradation of Sundarbans and its reclamation, services of Sundarbans, management of estuarine ecology	**8**
6	Marine environment a balancing factor of the earth: Role of phytoplankton and seaweeds (Carbon sink, Cleanser of the atmosphere, cooling of the Earth, etc.).	**4**
7	Formation, morphology and fossil records of reef, marls and stromatoliths, marine plants of coral reefs	**4**
8	Blooms and their impact on aquatic biota and human being	**4**
9	Marine biotechnology: Algal industry, status of seaweed cultivation, production and utilization in different countries of the world (e. g., China, Japan, Korea etc.) and in Bangladesh. Seaweed culture in the coastal area of Bangladesh. (a) Seaweed farming model, cultivation of nori, kelp etc. (b) Biofuel production from algae (c) Extraction of phycocolloids and uses as food and industrial and pharmaceutical products.	**4**
10	The Impact of Humans on the Marine Environment: Modification and destruction of habitats, pollution, threatened and endangered species, conserving and enhancing the environment. Protecting marine resources • Marine protected areas	**4**
11	Pollution of Marine Resources • Type of marine pollution	**4**

	• Effect of marine pollution on marine resources • Prevention and control of pollution and marine resources degradation • Current cases on marine pollution	

Unit wise learning outcome

Units	Learning outcomes
1	• Define and understand Marine and Environmental Sciences • the concept and type of marine resources and marine resources management • Different factors including different chemical and physical properties of Oceans and seas • Horizontal and vertical zonations of Oceans and seas
2	• Know about the diversity of phytoplankton • Importance of phytoplankton, classification and adaptation • How different factors affects biomass of phytoplankton • Seasonal variation of plankton
3	Concept on Seaweeds • Morphology, diversity and importance of seaweeds • Factors affecting seaweed distribution • Biomass of seaweeds • Phytogeography of seaweeds
4	• Sea grasses: characteristics, evolution and distribution, adaptations. • Salt marshes: introduction, geographic distribution, adaptations
5	• Estuarine ecology: introduction, evolution and biogeographic distribution, biodiversity of mangroves • Estuarine Ecology and its importance • Sundarbans: geo-ecological status, its flora and fauna, salinity effects on it, formation and causes of degradation of Sundarbans and its reclamation, services of Sundarbans, management of estuarine ecology
6	• How a marine environment acts as a balancing factor of the earth • Role of phytoplankton and seaweeds • Carbon sink, cleanser of the atmosphere, cooling of the earth.
7	• Formation, morphology and fossil records of Reef, marls and stromatolites, • Marine plants of coral reefs
8	• Blooms and their impact on aquatic biota and human being.
9	• Seaweeds identification, cultivation and processing • Identify phycocolloids, their production and uses • Methods of Marine biotechnology • Potentiality of extraction of biofuels from algae • Seaweeds use as food, industrial and pharmaceuticals products
10	• Destruction of marine habitats, pollution, • Threatened and endangered species, • Conserving and enhancing the environment. • Integrate the connection between human activity and the current issues related to marine resources.
11	• Pollution and marine resource management. Interpret the management of marine resources available and the interaction between biotic and abiotic factors without affecting the carrying capacity of the ocean. Demonstrate the relevant ideas or models to overcome the problems of marine resource.

Recommended Readings

Abel D C and McConnell 2010. Environmental oceanography: topic analysis. Jones & Bartlett Publ., London

Anon. 2016. Adaptive Trials on Seaweed Cultivation, BARC, Farmgate, Dhaka.

Bhuiyan, M. A. H. 2023; Clarification of current understanding of the genus *Pyramimonas*. DU 100 Years Celebration Book. Chapter 2, Volume 2: 11-32. University of Dhaka.

Bhuiyan, M. A. H. 2022. Assessment of Coastal and Marine Biodiversity Resources and Ecosystems to Implement the Blue Economy Action Plan. Chapter 3. Seaweeds / Algae and Seagrass Resources of the Bay of Bengal, 116-150. Ministry of Environment. Government of the Peoples' Republic of Bangladesh.

Bhuiyan, M. A. H. 2022. Advancements and Potential of Molecular and Applied Phycology in BOTANY: Addressing the challenges and Opportunities for the 21st Century, Centennial Special Book, Chapter 5.3: 162-196. Department of Botany, University of Dhaka, Bangladesh.

Bold HC and Wynne MJ 1985. Introduction of the Algae. Prentice-Hall, New Jersey, USA

Castro P and ME Huber 2003. Marine Biology. McGraw Hill. N.Y.

Dawes CJ 1998. Marine Botany. Willey and Sons, NY.

Innovative Methods of Marine Ecosystem Restoration 2013. Goreau T. J. and Trench R. K. CRC Press. Taylor and Francis Group, 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL 33487-2742.London, New York.

Introduction to Marine Biology 2006. Karleskint Jr G., Turner R. and Small Jr. J. W. Thomson Higher Education. 10 Davis Drive, Belmont, CA 94002-3098, USA.

Introduction to the Physical and biological Oceanography of Shelf Seas. Simpson J. H. and Sharples J. 2012. Cambridge University Press, The Edinburgh Building, Cambridge CB2 8RU, UK.

Lee RE. 2008. Phycology. Cambridge Univ. Press, Cambridge.

Lehman, R.L. (2013) Marine Plants of the Texas Coast. Texas A & M University Press. College Station, TX. ISNB: 978-1-62349-016-4.

Levinto J 2009. Marine biology: function, biodiversity and ecology. Oxford Univ. Press, Oxford.

Marine Algae 2015. Pereira L. and Neto J. M. CRC Press. Taylor and Francis Group, 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL 33487-2742. London. Newyork

Marine Biology 2009. Levinton J. S. Oxford University Press, Inc., 198 Madison Avenue, New York, New York 10016, USA.

Khondker, M; Bhuiyan, M. A. H. and Bashar, M. A. 2023. Towards an appraisal of Biodiversity in Bangladesh. *J. biodivers. conserv. bioresour. manag.* **9**(1), 79-100. DOI: https://doi.org/10.3329/jbcbm.v9i1.66634

Speight M and P Henderson 2010. Marine ecology. Wiley-Blackwell, Sussex.

Instruction strategies

- Lecture followed by group discussion
- Question answer
- Guided discussion
- Project discussion
- Demonstration
-Field visit to important marine and estuarine environments.

Assignment: Students will be given assignment on particular units

Assessment: Final examination will be taken after completing the lectures at the end of the year.

BOT. 717**: Applied and Molecular Phycology** **Credit hours:** 04

Course description

Molecular and Applied Phycology provides students with the opportunity to develop their specialist knowledge in modern molecular and applied level of phycology. Identification of algae used to be confined to the light microscope, resulting in some inaccuracies. Accurate identification can only be achieved by careful observation of features and structures at both the light and electron microscope level. Nowadays, molecular analyses along with light and electron microscopy techniques make the identification of organisms more reliable than before.

A series of lectures and practical sessions cover key themes in molecular and applied phycology including identification of algae with light and electron microscopy along with molecular bases, different characters considers for the identification, algal diversity and relationships on the basis of molecules, origin, endosymbiosis and diversification of algae, phylogeny and molecular evolution of algae, study of phytoplankton, the most important part of algae and the aquatic ecosystems, algal culturing methods and their application, algal incredible uses in industrial and technological sites.Laboratory sessions allow students to gain

experience in isolation, culture, and sub-culturing techniques of algae, preparation of media for marine and freshwater algae, DNA extraction and PCR techniques of algae, techniques of electron microscopy, preparation of phylogenetic trees by different methods and cultivation of algae, produce different commercially important foods, industrial and pharmaceuticals products. The Molecular and Applied Phycologyaims to equip graduates with knowledge of advanced phycological researches that understanding, practical, research, professional and transferable skills to enable them to undertake further postgraduate training (i.e. Ph. D. level) and/or employment within academic research and in industrial settings at home and abroad.

Course objectives

- To gather advanced knowledge inmolecular and applied phycology.
- To know about the importance of algae with special reference to itsindustrial and technological applications.
- Uses of electron microscopy and molecular evidence for the identification and applications of algae
- To know different characters considered for proper identification of macro algae and micro algae
- To know the origin of algae, symbiosis, algal diversity and relationships with each other
- Obtain knowledge in phylogeny and molecular evolution
- Phytoplanktons, their, and role in oceans and seas, primary production, food chain and factors affecting phytoplankton population and abundance
- Methods of algae including collection, isolation, cultivation, purification and preservation
- Algal biochemical taxonomy and biochemical compunds
- The course is suitable to equip students with the advanced knowledge in molecular and applied level of phycology.

Course contents

Units	content	No. of Lectures
1	**Introduction:** Introduction and application of molecular concept in the algal identification and uses. Identification of algae including light, electron microscopy [Transmission Electron Microscopy(TEM) and Scanning Electron Microscopy (SEM)] and molecular bases, limitations and advantages of identifying algae with light microscope, advantages of identifying algae with electron microscope and molecular bases, processes of DNA extraction, sequencing, PCR, electrophoresis, electron microscopy (TEM and SEM) and primer selection / preparation for algae.	**8**
2	**Identification of Algae:** Characters considered for the identification of algae- structure & ultra-structure of cell, cell coverings, flagella and flagellar apparatus, pigments, chloroplast, nucleus, nuclear division and cell division, mitochondria, pyrenoid and its numbers and positions, the transition region, the basal body, the basal apparatus, micro tubular roots, micro body, cytoskeleton microtubules, molecular characters - e.g. Ribosomal DNA, Rubisco.	**4**
3	**Algal diversity and relationships**: the diversity and importance of algal species, Molecular phylogenetic approaches, molecular markers for phylogeny construction, Phylogenetic trees - acquiring and aligning the sequences, major methods for making phylogenetic trees (e.g. maximum likelihood (ML), Bayesian inference of trees with Mr. Bayes, etc.), Reconstructing ancestral DNA sequences, application of phylogeny.	**4**
4	**Endosymbiosis and diversification of eukaryotic algae**: Origin of eukaryotic algae, Fossil evidence for early events in the diversification of eukaryotic algae, Molecular evidence bearing on the origin of eukaryotic cells and mitochondria, Origin of plastids, Endosymbiosis in the modern world, Prokaryotic endosymbionts, primary, secondary and tertiary endosymbiosis, nucleomorphs as evidence of secondary endosymbiosis.	**6**
5	**Phylogeny and molecular evolution of algae**: The nature and origin of green algae and land plants. Green lineage relationships- (a) Morphology, Ultra-structure, and Molecules, (b) Phylogeny of the Green Lineage. Green algal evolution: Insights from Genes and Genomes- (**I**) Organelle Genome Evolution, (**II**) Role of Prasinophytes in the evolution of algae, Ecology and Molecular Evolution of Oceanic Picoplanktonic Prasinophytes, (**III**) Genomic insights into Evolution of Complexity in Volvocine Green algae, (**IV**) Genetic code and the translation apparatus in green Seaweeds, ((**V**)) Molecular evolution in the Streptophyta and the origin of Land plant. Spread of green genes in other eukaryotes.	**8**

6	**Phytoplankton and the aquatic ecosystems:** Food webs in the oceans, The physical environment, The Chemical environment, Growth and external nutrient supply and uptake, Growth processes of phytoplankton populations, Phytoplankton and global climate change, UV radiation effects on phytoplankton (metabolism and development; motility, orientation and vertical distribution, protective strategies), Loss in biomass production and effects on food web, Change in species composition.	**6**
7	**Methods of algae:** Algal Methods of collection, Isolation, cultivation, purification, and preservation of macro and microalgae. Automated isolation techniques for microalgae, Different culture media- for fresh and marine water algae, their composition, selection of medium for optimum growth of algae.	**6**
8	**Algae in industrial uses:** Macro and Microalgae as good sources of sustainable Human foods and nutrients, Feeds, Food supplements, Stabilizing agents, promising and exciting source of Bio-fuels, Cosmetics, Beta-carotene, Phycocolloids and Gelling agents (Alginates, Carrageenans, Agars, Algal Cellulose etc.), Antibiotics and medicines in pharmaceutical industries, Chemical dyes and coloring agents in textile, leather and brewing industries, their Extraction processes and uses, Use of algae as organic fertilizer	**6**
9	**Technological Applications of Algae:** Algae as research tools, Algal genomics and proteomics, Algae as environmental monitors, Algae in bioassays, Alage as paleoecological indicators, Uses of algae in aquaculture, Algae in space research, Genetic engineering of algae, Algae as pollution controlling agent, Uses of algae in wastewater treatment, the role of algae in land reclamation, algae as cleaners of the world, Algal toxins.	**8**
10	**Algal Biochemistry: Biochemical Taxonomy, Cell wall and intercellular region polysaccharides, Cytoplasmic organelles, plastids, chlorophylls, carotenoids and biliproteins,storage products, Nucleic acids, Nitrogen fixation and asssimilation,** Bioactive phenolic compounds in seaweeds, seaweeds as a source of bioactive proteins, peptides and amino acids, Lipid and fatty acid profile of major seaweeds, Minerals in edible seaweeds.	**4**

Unit-wise Learning Outcomes

Unit	Learning Outcomes
01	▪ Algal research from ancient to present time ▪ Identification of algae with scanning and transmission electron microscopy ▪ Identification of algae with molecular bases ▪ Processes of DNA extraction, sequencing, PCR, electrophoresis, and primer selection/preparation
02	▪ Structure and ultra-structure of cell useful for the identification of algae ▪ Important characters such as cell coverings, flagella, pigments, chloroplast, nucleus, mitochondria, pyrenoid, transition region, basal body, basal apparatus, microtubular roots, microbody, cytoskeleton microtubules ▪ Ribosomal DNA and Rubisco
03	▪ The diversity and relationships of algal species ▪ Molecular phylogenetic approaches ▪ Acquiring and aligning the sequences for making phylogenetic trees ▪ Construction of different types of phylogenetic trees ▪ Application of phylogeny
04	▪ Endosymbiosis and diversification of eukaryotic algae ▪ Origin of eukaryotic algae and fossil and molecular evidence of it ▪ Origin of plastids, mitochondria ▪ Endosymbiosis in the modern world
05	▪ The nature and origin of green algae and land plants ▪ Green lineage relationships

	▪ Green algal evolution ▪ Molecular evolution in the streptophytes ▪ The spread of green genes in other eukaryotes
06	▪ Phytoplankton and their role in food webs in oceans and seas ▪ The Physical and chemical environment that affects the growth, distribution, and abundance in oceans and seas ▪ The relationship between phytoplankton and global climate change, ▪ Loss in biomass production and effects on food web ▪ Changes in species composition of phytoplankton
07	▪ Algal methods of collection, isolation, cultivation, and purification ▪ Preservation of micro and macro algae ▪ Composition and preparation of Different culture media for algal growth ▪ Selection of medium for optimum growth
08	▪ Algal uses as foods, feeds, food supplements, stabilizing agents, cosmetics, Beta-carotene etc. ▪ Extraction of phycocolloids such as alginates, carrageenans, agar etc. ▪ Production of antibiotics and medicines in Pharmaceutical industries, ▪ Chemical dyes and coloring agents in textile, leather and brewing industries, their extraction processes and uses ▪ Use of algae as organic fertilizer
09	▪ Algae as research tools such as in space research, genetic engineering etc. ▪ Algal genomics and proteomics ▪ Algae in bioassay ▪ Algae as cleaners of the world ▪ Role of algae in land reclamation
10	▪ Biochemical compounds in algae ▪ Nitrogen fixation and assimilation ▪ Bioactive phenolic compounds ▪ bioactive proteins, peptides and amino acids ▪ Lipid and fatty acid profile ▪ Minerals in edible seaweeds

Recommended Readings

Andersen RA 2005. Algal culturing techniques. Phycological Society of America. Elsvier Academic Press. Burlington, MA 01803, USA.

Berner T 1993. Ultra structure of Microalgae. CRC Press, Inc., 2000 Corporate Blvd., N.W., Boca Raton, Florida 33431, U.S.A.

Bhuiyan, M. A. H., Faria, D.G., Horiguchi, T., Sym, S. D. and Suda, S. 2015. Taxonomy and phylogeny of *Pyramimonas vacuolata* sp. nov. (Pyramimonadales, Chlorophyta). *Phycologia*, **54**: 323-332. DOI: 10.2216/15-004.1, U.S.A.

Bhuiyan, M. A. H. 2022. Advancements and Potential of Molecular and Applied Phycology in BOTANY: Addressing the challenges and Opportunities for the 21st Century, Centennial Special Book, Chapter 5.3: 162-196. Department of Botany, University of Dhaka, Bangladesh.

Bhuiyan, M. A. H. 2023; Clarification of current understanding of the genus *Pyramimonas*. DU 100 Years Celebration Book. Chapter 2, Volume 2: 11-32. University of Dhaka.

Bhuiyan, M. A. H. 2022. Variation, diversity, and phylogenetic relationships among strains of *Pyramimonas* Schmarda from Ryukyu Islands, Japan. Biosystematics and Bioresources. Chapter 3. Pages. 53-66 Editors : Debabrata Maity and Krishnendu Acharya. A publication by MESSRS BISHEN SINGH MAHENDRA PAL SINGH, Dehra Dun, INDIA.

Chaudhary BR and Agrawal SB 2009. Cytology, genetics and molecular biology of algae. SPB Press. ISBN-13: 978-9051031263, The University of California, U.S.A.

Graham, L. E., Graham, J.M.and Wilcox, L.W. 2009. Algae. Pearson Education Inc. Sansome St. Sanfrancisco, CA 9411, USA.

Hall BG 2008. Phylogenetic Trees Made Easy: A How –To Manual, Third Edition. Sinauer Associates, Inc., 23 Plumtree Road, Sunderland, MA 01375 U.S.A.

Leliaert, F., Smith, D. R., Moreau, H., Herron, M. D., Verbruggen, H., Delwiche, C. F. and Clerck, O.D. 2012. Phylogeny and molecular evolution of the green algae. Critical Reviews in Plant Sciences 31: 1-46. DOI: 10.1080/07352689.2011.615705.

Piganeau G 2012. Genomic Insights into the Biology of Algae, Volume 64. Advances in Botanical Research. ISBN: 9780123944115. Academic Press.

Qiagen 2008. Sample and Assay Technologies. Qiaquick Spin Handbook. 28159 Avenue Stanford, Valencia, CA 91355, U.S.A.

Qiagen 2000. D Neasy Plant Mini Kit and D Neasy Plant Maxi Kit Handbook. 28159 Avenue Stanford, Valencia, CA 91355, U.S.A.

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Round FE and Chapman DJ 1993. Progress in Phycological Research. Volume 9. ISBN: 0-948737-19-0. Biopress Ltd. The Orchard, Clanage Road, Bristol, BS3 2JX, England.

Smith GM 1950. The freshwater algae of the United States, McGraw-Hill Book Company, New York, U.S.A.

Stewart, W. D. P. 1974. Algal Physiology and Biochemistry. Botanical monographs. Volume 10. Blackwell Scientific Publication, 3 Notingham Street, London W1, 9 Forest road, Edinburgh, P.O. Box 9, North Balwyn, Victoria, Australia.

Sym SD and Pienaar RN 1993. The Class Prasinophyceae. In: progress in Phycological Research, Biopress, Bristol, UK.

Suda, S., Bhuiyan, M. A. H., and Faria, D.G. 2013. Genetic diversity of the genus *Pyramimonas* from Ryukyu Archipelago, Japan (Chlorophyceae, Pyramimonadales). *Journal of Marine Science and Technology*, **21**: 285- 296. DOI: 10.6119/JMST-013-1220-16. Taiwan.

Instructional strategies/ Learning experiences

- Lecture followed by group discussion
- Question-answer
- Guided discussion
- Project discussion
- Demonstration

Assignment: Assignment on particular unit will given to the students.

Assessment: Final examination will be taken after completing the lectures at the end of the year.

BOT 730: Viva Voce **Credit hour: 4**