

## Book Description

This book delves into the fascinating worlds of algae exploring their biology, ecology, and significance in various ecosystems and human applications. Algae Explore the diversity of algal forms, from microscopic phytoplankton to large seaweeds. Understand their classification, structure, life cycles, and ecological roles. Learn about their critical roles in decomposition, nutrient cycling, and symbiotic relationships. Understand the crucial roles of algae and fungi in ecosystems, including their interactions with other organisms and contributions to biogeochemical cycles. Discuss the impact of algae on environmental health, including their roles in pollution control and bioindication. Investigate the economic and industrial significance of algae. Topics include the use of algae in biofuels, pharmaceuticals, and as food sources, as well as the role of fungi in biotechnology, fermentation, and bioremediation

## About the Editors:

**Dr. Meenakshi** is an accomplished Associate Professor of Botany at Career Point University in Kota, Rajasthan, with a total teaching experience of 8 years. She holds a Ph.D., M.Phil., and M.Sc., in Botany and B.Ed. in Education also has specialized in biotechnology. Her research interests include plant tissue culture, biotechnology, and growth hormones. She has published 8 papers in various reputable journals and has authored one book on the effect of growth hormones on potatoes in vitro. Additionally, she holds three patents related to her research work.




**Dr. Anita Singh** is an accomplished academician with a Ph.D. in Botany from the University of Kota, Rajasthan. With a robust background in Plant pathology and taxonomy, she has garnered extensive experience in various laboratory techniques, including colorimetry, spectrophotometry, chromatography, electrophoresis, DNA isolation Bacterial, and Fungal culture. Her research prowess is evident from her 11 published papers, covering diverse topics such as quantification of enzymes in plant diseases, seed-borne mycoflora survey, and biological management of wilt pathogens. Dr. Anita Singh's patent application on lipid quantification in *Fusarium* further underscores her innovative contributions to the field.

**Dr. Teena Agrawal** did her Ph.D. in plant taxonomy, she did her research work through CSIR-NET JRF fellowship, she has also qualified for SLET,GATE competitions with good rank, she has supervised Ph.D. students, working on phytochemistry of the angiosperms trees with the microbiological and pharmacological applications, she has number of research papers in international and national journals with Scopus indexed and UGC care listed. She has also written some books on different plant aspects. She has attended many conferences and workshops on plant sciences to learn and know the various aspects of the plant world.

# ASPECTS OF LOWER CRYPTOGAMES



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# **Aspects of Lower Cryptogames**

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# Preface

Nowadays a very wide range of topics in botany are taught to the students of competition and B.Sc. M.Sc. degree courses. Understanding of algae is very important for the students to acquire a profound knowledge of botany. In view of this aspect, and with an experience of teaching and research for both basic and applied sciences, I felt that a concise book having all the pteridophytes and paleobotany required would be much more comfortable for the students to learn and carry with them. In this edited book, I have tried my best to incorporate all topics of algae.

It gives me great pleasure to present this book as a reference to students of all disciplines of all Major Indian and foreign Universities, Colleges and Schools. This book is written in a simple language with relevant concepts and fundamentals. I assure that this simple presentation of the reactions in this book will certainly enlighten and help all teachers and students to acquire a good command on the subject. I express my wholehearted thanks to the publication team for their sustained interest in the publication of this book. They have done a wonderful job with the neat presentation and quality printing. A lot of thanks are due to all faculty of Basic and Applied Sciences for their support, help and cooperation all through the preparation of this book.

I would also like to thank Pramod Maheshwari Sir, the Managing Director and Chairman of Career Point University, Kota. I profusely thank HOD and Dean for their inspiration, goodwill and unstinted support during the writing of the book. I express my gratitude and love to every member of my family for their constant encouragement and support to all my academic adventures.

I feel a deep sense of gratitude to all the students and the teaching community who have lent me their support and encouragement in bringing out this book. I would welcome any suggestions to improve the quality and preparation of the text of the book.

Dr. Meenakshi Kumari, Dr. Anita Singh & Dr. Teena agrawal



## Book Description

Algae: Foundations, Applications, and Innovations is a comprehensive textbook designed to cater to both undergraduate and postgraduate students pursuing studies in botany, microbiology, environmental science, and related fields. This book delves into the fascinating worlds of algae exploring their biology, ecology, and significance in various ecosystems and human applications. Algae Explore the diversity of algal forms, from microscopic phytoplankton to large seaweeds. Understand their classification, structure, life cycles, and ecological roles. Learn about their critical roles in decomposition, nutrient cycling, and symbiotic relationships. Understand the crucial roles of algae and fungi in ecosystems, including their interactions with other organisms and contributions to biogeochemical cycles. Discuss the impact of algae on environmental health, including their roles in pollution control and bioindication. Investigate the economic and industrial significance of algae. Topics include the use of algae in biofuels, pharmaceuticals, and as food sources, as well as the role of fungi in biotechnology, fermentation, and bioremediation. Explore the medical implications, including the benefits of fungal-derived antibiotics and the challenges posed by fungal pathogens. Discover cutting-edge research and emerging technologies involving algae and fungi, such as genetic engineering, synthetic biology, and their applications in sustainable development. Discuss future trends and potential breakthroughs in algal research, including their roles in addressing global challenges like climate change, food security, and renewable energy. Each chapter is equipped with learning objectives, detailed illustrations, and real-world examples to facilitate understanding and engagement.

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# Editors

## Dr. Pushpendra Yaduvanshi



Dr. Meenakshi is an accomplished Associate Professor of Botany at Career Point University in Kota, Rajasthan, with a total teaching experience of 8 years. She holds a Ph.D., M.Phil., and M.Sc., in Botany and B.Ed. in Education also has specialized in biotechnology. Her research interests include plant tissue culture, biotechnology, and growth hormones. She has published 8 papers in various reputable journals and has authored one book on the effect of growth hormones on potatoes in vitro. Additionally, she holds three patents related to her research work.

With a strong commitment to both teaching and research, she has actively participated in online classes and completed several online courses to enhance her knowledge in various fields, including genomics and herbal medicine. She has also presented her research findings at numerous national and international conferences and seminars, earning recognition and awards for her contributions to the field of botany. Dr. Meenakshi's expertise extends beyond academia, as she has served as a reviewer for several scientific journals and actively engages in faculty development programs to improve her teaching skills. Her dedication to advancing botanical research, coupled with her passion for educating future botanists, makes her a valuable asset to the academic community. She has several research papers, book chapters, and books to his credit in international SCI journals and membership of many scientific and research societies.

## Dr. Anita Singh



Dr. Anita Singh is an accomplished academician with a Ph.D. in Botany from the University of Kota, Rajasthan. With a robust background in Plant pathology and taxonomy, she has garnered extensive experience in various laboratory techniques, including colorimetry, spectrophotometry, chromatography, electrophoresis, DNA isolation Bacterial, and Fungal culture. Her research prowess is evident from her 11 published papers, covering diverse topics such as quantification of enzymes in plant diseases, seed-borne mycoflora survey, and biological management of wilt pathogens. Dr. Anita Singh's patent application on **lipid quantification in Fusarium further underscores her innovative contributions to the field.**

In addition to her academic achievements, Dr. Anita Singh has pursued numerous online courses, enhancing her skills in areas ranging from publishing ethics to plant biology and immunology. She also holds teaching experience spanning over 22 years, including her current position as an Associate Professor at Career Point University, Kota. Dr. Anita Singh's dedication to continuous learning and research, coupled with her extensive expertise in botanical sciences, makes her a valuable asset to any academic or research-oriented institution. Presently, she is serving as an Associate Professor in the Department of Botany at Career Point University, Kota (Rajasthan). Her fields of research are plant pathology. She has several research papers, book chapters, and books to his credit in international SCI journals and membership in many scientific and research societies.

### **Dr. Teena Agrawal**



Dr. Teena Agrawal did her Ph.D. in plant taxonomy, she did her research work through CSIR-NET JRF fellowship, she has also qualified for SLET,GATE competitions with good rank , she has supervised Ph.D. students, working on phytochemistry of the angiosperms trees with the microbiological and pharmacological applications , she has number of research papers in international and national journals with Scopus indexed and UGC care listed . She has also written some books on different plant aspects . She has attended many conferences and workshops on plant sciences to learn and know the various aspects of the plant world.

## Phaeophyceae.- Sargassum

Dr. Anita Singh

### ABSTRACT

Sargassum is a genus within the class Phaeophyceae, comprising brown macroalgae that are widely distributed in temperate and tropical oceans. Known for their distinctive morphology and ecological importance, Sargassum species play a critical role in marine ecosystems and hold significant potential for biotechnological applications. Sargassum is a genus of brown macroalgae within the class Phaeophyceae, known for its complex morphology and significant ecological roles in marine ecosystems. While contributing to marine biodiversity and nutrient cycling, Sargassum also poses challenges when large blooms occur. The genus's diverse biochemical properties and high biomass yield offer promising avenues for biotechnological applications, including alginate production, pharmaceuticals, biofuels, and environmental remediation. Ongoing research into Sargassum's biology, ecological impact, and potential applications will continue to enhance our understanding and management of this important marine resource.

### Occurrence of Sargassum:

The genus Sargassum is represented by about 150 species. The genus is widely distributed; specially in warmer regions mainly in tropical and subtropical seas of the southern hemisphere. The plants form large floating masses in the Atlantic ocean of the African continent between 20° and 35° north latitude. This part of Atlantic ocean is called the Sargasso Sea.

The alga grows abundantly both in east and west coasts of India, Australia and Ceylon. In India Sargassum is represented by about 16 species. Some common Indian species are: *S. carpophyllum*, *S. christifolium*, *S. cinereum*, *S. duplicatum*, *S. ilicifolium*, *S. myriocystum*, *S. plagiophyllum* and *S. wightii*. The alga grows attached to the rocks in little bushes in the intertidal zone or in the shallow puddles of the zone.

### Thallus Structure of Sargassum:

The thallus of Sargassum is diploid and sporophytic. The thallus is differentiated into holdfast and the main axis (Fig. 9). The attaching disc or holdfast is discoid or warty structure, it helps in attachment of thallus to substratum. In some species the hold fast is stolon like and in some free floating forms the holdfast is absent.

The main axis or stipe or 'stem' is erect, elongated, cylindrical or flat up to cm in length. In some species e.g., *S. filipendula* the thallus can be more than a meter in length. The main axis bears large number of primary laterals or branches in spiral phyllotaxy of 2/5 or the primary laterals are arranged on two sides of the main axis. The branching is always monopodial.

Sargassum plants are highly differentiated algae in the organization of the thallus. The main axis and primary laterals bear flat leaf-like branches known as secondary laterals or “leaves” (Fig. 2 A, B). The leaf-like laterals are flat and simple with blade, veins and petiole like structure.

The leaf is a short sterile lateral organ provided with mid rib. The mid rib is absent in some species like *S. enerve*. The margins of the leaves are entire, serrate or dentate. On the surface and margins of the ‘leaves’ are small pores known as ostioles. These pores are openings of small flask shaped sterile cavities called crypto-stomata or sterile conceptacles. These cavities bear hairs and paraphyses inside.

The branch system arises from the base of a ‘leaf’ like lateral. The little branched laterals which arise from the base of ‘leaves’ are variously modified.

The laterals specially those of the lower branchlets modify into air bladders (Fig. 2 A-C). These are globular or spherical, air filled structures. They help in floating of plants by increasing buoyancy. According to some algologists the air bladders also help in respiration. In some species the air bladders terminate into leaf-like structures.

Another modification of these laterals is in the form of highly branched or swollen structures bearing reproductive bodies called receptacles. The receptacles bear reproductive structure in special flask shaped cavities called as conceptacles.

### **Growth of Sargassum:**

The growth in Sargassum is apical. The growth of plant in length is initiated by a single apical cell at the apex of each branch. Increase in diameter of the axis is initiated by the activity of a lateral meristem zone or meristoderm.

### **Internal Structures:**

(A) Main Axis:

The main axis is circular in outline and internally it is differentiated into three regions:

(i) Meristoderm

(ii) Cortex

(iii) Medulla.

The meristoderm is single cell thick outer-most layer (Fig. 3). It is made of compactly arranged columnar cells. The meristoderm functions as protective layer epidermis and as assimilatory layer due to presence of chromatophores in cells. The meristoderm is covered with thin layer of mucilaginous cuticle.

The cortex zone is present between meristoderm and the medulla, this makes the largest part of the main axis. It is made up of narrow, elongated parenchymatous cells. The cells are loosely arranged with intercellular spaces between them. The cortex cells contain reserve food material and form the storage region of the main axis.

The medulla is present in the central part of the main axis.

The medulla is made of thick walled, narrow and elongated cells.

Sometimes the cells may have scalariform thickenings. The function of medulla is transport of water- and metabolites.

#### (B) Leaf:

The internal structure of leaf is like that of main axis. It is differentiated into meristoderm cortex and medulla (Fig. 4A).

The meristoderm is the outermost layer and functions as epidermis. It is made of radially elongated meristematic cells. The cells contain chromatophores and reserve food. The cortex is present between meristoderm and medulla. It is made of thin walled parenchymatous cells. The cortex is thickest in midrib region, it gradually becomes narrow towards the margins. The function of cortex is mostly storage.

The mid rib region or medulla is made of thick walled cells like those in main axis. The function of medulla is conduction. On the margins of leaves and on surface are present many sterile cavities called sterile conceptacles, crypto stomata or crypto blasts.

These are flask shaped structures which open on surface of “leaf” as small pore called ostiole. The wall of crypto stomata is made of sterile thin walled cells. Many un-branched filaments arise from the wall of conceptacles; these filaments are called paraphysis (Fig. 12 B).

#### (C) Air Bladder:

The structure of air bladder is also like main axis and leaf. It is differentiated into meristoderm and cortex but medulla is absent. The meristoderm is made of radially elongated narrow cells. Inner to meristoderm is 4-8 layered parenchymatous cortex. The central part of the bladder is made of large hollow cavity. The air bladder helps in buoyancy and gaseous exchange (Fig. 5).

#### Reproduction in Sargassum:

The reproduction takes place by vegetative and sexual methods. The asexual reproduction is absent.

#### (A) Vegetative Reproduction in Sargassum:

Sargassum multiplies profusely by vegetative fragmentation. The thallus breaks into fragments due to mechanical injury or death and decay of older parts. The species like *S. hystrix* and *S. natans* growing in Sargasso sea are completely sterile as they do not form any reproductive structures. In these species the fragmentation is the only method of multiplication.

#### (B) Sexual Reproduction in Sargassum:

Sexual reproduction in Sargassum is oogamous. The male sex organs are called antheridia and the female oogonia. The sex organs develop in special flask shaped cavity called conceptacle. These conceptacles are present in specially modified laterals called receptacles (Fig. 6 A-C). The male and female sex organs develop in separate conceptacles.

The conceptacles bearing antheridia are called male conceptacles and those bearing oogonia are called female conceptacles.

In homothallic or monoecious species the male conceptacle and female conceptacles are produced on same receptacle, but antheridia and oogonia are not produced in same conceptacles. In dioecious plants

the male and female conceptacles are produced on separate male and female plants. *Sargassum* species are mostly monoecious.

### **Development of Conceptacles:**

The conceptacle develops from a single superficial cell on the receptacular branch. This cell called conceptacle initial is flask shaped and differs from the adjacent cells due to its larger size and prominent nucleus (Fig. 6A). The initial cell divides slower than other cells. As a result it gets lower in position than adjacent cells.

The initial cell divides by transverse division; the two cells formed are separated by a curved septum. The lower cell is called basal cell and the upper is called tongue cell (Fig. 6 B, C).

The tongue cell divides transversely to make small filament which later disintegrates. The basal cell undergoes many vertical divisions to make fertile layer of the conceptacles.

The cells of fertile layer later form antheridia and oogonia (Fig. 6 D-G).

In fertile conceptacles the cells of basal layers do not spread in upper part, this forms narrow opening called ostiole.

### **Development of Antheridium:**

Any cell of the fertile layer can function as antheridial initial. This cell is dense cytoplasmic and develops a papilla like outgrowth. It divides by transverse division to make lower stalk cell and upper antheridial cell (Fig. 7 A-B). The antheridial cell rounds off to make antheridium.

The stalk cell elongates and pushes the antheridium to one side. The growing stalk cell divides again to make basal cell and the antheridial cell. This process repeated many times and results in formation of many antheridia and a sterile paraphysis (Fig. 71).

The antheridia are oval structures with two layered cell walls. The outer wall is called exochite and the inner is called endochite (Fig. 7 G). At young stage the antheridia are inside conceptacles and on maturity the antheridia are detached from stalk and come out of ostiole.

The antheridium has one diploid nucleus which divides first by meiotic division and later by mitotic divisions. This results in formation of 32-64 haploid nuclei. The protoplast of antheridium also divides in equal number of segments. Each protoplast segment with haploid nucleus develops into an antherozoid (Fig. 7 H). The antherozoid is pear shaped structure with two lateral flagella.

The flagella are heterokontic, one being acronematic and the other pantonematic.

The antherozoids are liberated in water after gelatinization of the antheridial wall.

### **Development of Oogonium:**

Any cell of the fertile layer of the female conceptacle can function as oogonial initial (Fig. 8 A). The oogonial initial divides by transverse division to make small, lower stalk cell and the large, upper oogonial cell (Fig. 8 B). The stalk cell further does not divide or elongate, so the oogonial cells are almost sessile.

The oogonial cell enlarges and makes spherical oogonium. The oogonia wall has three layers—the outer exochite, middle mesochite and the inner endochite. On maturity of the oogonium the exochite

ruptures, the mesochite forms the gelatinous stalk and the oogonial nuclei- and protoplast remains surrounded by endochite.

The diploid oogonial nucleus undergoes meiotic and mitotic divisions to form 8 nuclei. The seven of these eight nuclei degenerate and only one remains functional. This nucleus with protoplasm forms single ovum or oosphere (Fig. 8 C-H).

The cells of female conceptacle which do not form oogonia develop into long hair like paraphyses.

**Fertilization:**

The antherozoids are released in water and the oogonia remain attached to the conceptacle base by mucilaginous stalk. The oogonia protrude out of the ostiole (Fig. 8 J). A large number of antherozoids surround the oogonium and attach to oogonial wall with the help of anterior flagellum (Fig. 9 A). Only one antherozoid penetrates the oogonial wall. The male and female nuclei fuse to form a diploid zygote (Fig. 9 B).

**Germination of Zygote:**

The zygote germinates immediately after fertilization when the oogonium still remains attached to the wall of conceptacle by a mucilaginous stalk. After some time the zygote is liberated by gelatinization of the oogonial wall. After liberation the zygote gets attached to any substratum in sea water. The zygote first divides by transverse division to make a lower cell and upper cell (Fig. 9 C-F).

The lower cell forms the rhizoids. The upper cell first divides by transverse division and later by anticlinal and periclinal divisions. It results in the differentiation of three layers—the meristoderm, cortex and medulla. The divisions of upper cell result in formation of a diploid, sporophytic Sargassum plant.

**Life Cycle of Sargassum:**

The life cycle of Sargassum is diplontic type and there is no alternation of generation. The thallus is diploid sporophytic. It forms diploid antheridia and oogonia. The reduction division in antheridia and oogonia forms haploid antherozoid and oogonial nucleus. The gametes only are haploid structure in the life cycle. After fertilization a diploid zygote is formed which divides to make a diploid sporophytic thallus (Fig. 10, 11).