
PHYCOLOGICAL NEWSLETTER

MESSAGE FROM THE PRESIDENT



PSA President Deborah Robertson

Dear PSA Members,

It is with optimism that I begin 2022 and hope the same for you. There are many exciting events in our near future, new initiatives for the society, and exciting changes in the Journal of Phycology Editorial Office.

This year, PSA will be participating in the **Joint Aquatic Sciences Meeting (JASM 2022) in Grand Rapids, MI May 14-21**. The meeting is organized by the **Consortium of Aquatic Sciences Societies (CASS)** and includes the following groups: American Fisheries Societies, Association for the Sciences of Limnology and Oceanography, Coastal and Estuarine Research Foundation, Freshwater

Mollusk Conservation Society, International Association for Great Lakes Research, North American Lake Management Society, Phycological Society of America, Society for Freshwater Science, and the Society of Wetland Scientists. **Dr. Schonna Manning**, PSA's indefatigable Program Director, has been hard at work to ensure we have an exciting program and that phycological voices are heard. The meeting will include in-person and virtual sessions. PSA highlights include the Bold Award Symposium and of course, the ever-popular PSA Auction. I am pleased to announce that **Dr. Virginia Weiss** (University Distinguished Professor, Oregon State University) will deliver the keynote address for the PSA Presidential Symposium. As of January 15, approximately 2500 abstracts had been submitted.

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This past year, the PSA membership approved the establishment of the **Inclusivity, Diversity, Equity, and Access Committee** and I am pleased to announce that **Dr. Robin Kodner** (Western Washington University) has agreed to serve as the inaugural chair of the committee. Dr. Kodner brings considerable experience and expertise and is a welcome addition to the PSA Executive Committee as we begin this work in earnest.

The IDEA committee has already been hard at work. Dr. Kodner is one of the leaders of the NSF-supported LEAPS CASS IDEA Audit Tool Workshop. This invited workshop will help participating scientific societies identify policies and practices that perpetuate the status quo and specific barriers that limit participation of members of marginalized populations. An important aspect of the NSF LEAPS program (LEAding cultural change through Professional Societies of Biology) is that it encourages scientific societies to work collaboratively to generate and share evidence-based best practices that help reduce barriers and create more welcoming communities. This workshop will provide an important foundation for ongoing PSA efforts to build a more inclusive and welcoming scientific society.

The COVID pandemic changed the landscape of how scientific societies conduct annual meetings and build community. It has been remarkable to see how quickly societies were able to pivot to online formats and create spaces for conversations and networking. It also provides an opportunity to pause and reflect on the benefits that professional societies provide their members. The PSA has a strong history of providing financial support to students and more recently has expanded support for early-career, post-graduate scientists. Now is the time to explore how we can continue to use online technologies to build a stronger, larger, and more inclusive society; to consider ways in which we connect more frequently and outside our annual meeting times; and to develop avenues to make algal research more open and accessible. We have lessons to learn from our

extraordinary student member, **Sabrina Heiser**. Sabrina hosted several on-line social events for our student members during the pandemic, events that offered much needed connection and laughter during the pandemic.

January 2022 marks the inauguration of our new **Journal of Phycology Managing Editor Kirsten Müller** and team of Co-Editors (**Andrew Allen, Melinda Coleman, Sonya Dyhrman, Christopher Lane, and Thomas Mock**). While I am excited to see the new initiatives this team brings to the journal, I want to thank and acknowledge the work of **Michael Graham** as the managing editor for the past ten years and the co-editor team of **Debashish Bhattacharya, Arthur Grossman, and Jonathan Zehr**.

This year marks the end of the terms of several Executive Committee Members: **Dale Casamatta** (Past President), **Joe Zuccarello** (International Vice President) and **Sabrina Heiser** (Student Member). **Patrick Martone** is changing hats, having finished as Secretary, Patrick will now take the helm as President-Elect. We welcome **Heather Spaulding** (Secretary), **Soren Huber** (Student member) and **Robin Kodner** (Chair, IDEA Committee). A special thanks to everyone who also agreed to be nominated for positions on the Executive Committee – your willingness to participate is appreciated.

Our society is fiscally sound and aspiration rich. I thank the membership for providing me with this opportunity to serve as President and look forward to conversations as to how the PSA might best benefit its members. I encourage each member to connect with the PSA in whatever way you feel comfortable, whether encouraging someone to join or joining one of our many committees. Please reach out to me or any member of the Executive Committee if you have questions. Committee information can be found as psaaglae.org and self-nomination/volunteering is encouraged and appreciated.

**Wishing you all a healthy, productive, and joyful
New Year,**

Deborah Robertson





Mark your calendars for the Joint Aquatic Sciences Meeting in Grand Rapids, Michigan, May 14-20, 2022.

The Joint Aquatic Sciences Meeting (JASM) will be the world's largest gathering of aquatic scientists, students, practitioners, resource agency staff, and industry representatives in history. JASM's parent organization, The Consortium of Aquatic Science Societies (CASS), is comprised of 9 groups representing various interests within the aquatic science realm. The JASM 2022 meeting is designed to bring together deep, multidisciplinary subject-matter expertise to collaboratively educate one another and solve the complex environmental problems facing our society and our planet today.

The meeting will be held at the DeVos Place convention center and it is organized by the Consortium of Aquatic Science Societies (CASS), which includes:

- American Fisheries Society
- Association for the Sciences of Limnology and Oceanography
- Coastal and Estuarine Research Federation
- Freshwater Mollusk Conservation Society
- International Association for Great Lakes Research
- North American Lake Management Society
- Phycological Society of America
- Society for Freshwater Science
- Society of Wetland Scientists

For more information, see the following links:

- ✦ **For registration:** <https://jasm2022.aquaticsocieties.org/registration/>
- ✦ **For travel and hotel information:** <https://jasm2022.aquaticsocieties.org/hotels/>
- ✦ **For frequently asked questions:** <https://jasm2022.aquaticsocieties.org/faq/>

We hope to see you in Grand Rapids!

An Interview with 2021 Norma J. Lang Fellow Jozef Nissimov



2021 Lang Fellow Dr. Jozef Nissimov

Earlier this year, I got a chance to ask 2021 Norma J. Lang fellow Jozef Nissimov a few questions about his research, his life, and how he became a successful phycologist.

JM: Hi Jozef, it's good to get to talk with you and congratulations on receiving the Lang Fellowship. Can you tell us a little about your background? What are the big questions that have motivated you as you've come up through the ranks?

JN: I have had an interesting and unexpected journey that spans different continents and oceans that led me to what I do now, which can be broadly defined as Aquatic Microbiology. I was always fascinated by the ocean and what lies beneath it because when I was younger, I was a very keen SCUBA-diver, which obviously exposes a person to

the incredible diversity of marine life that is often hidden from most people.

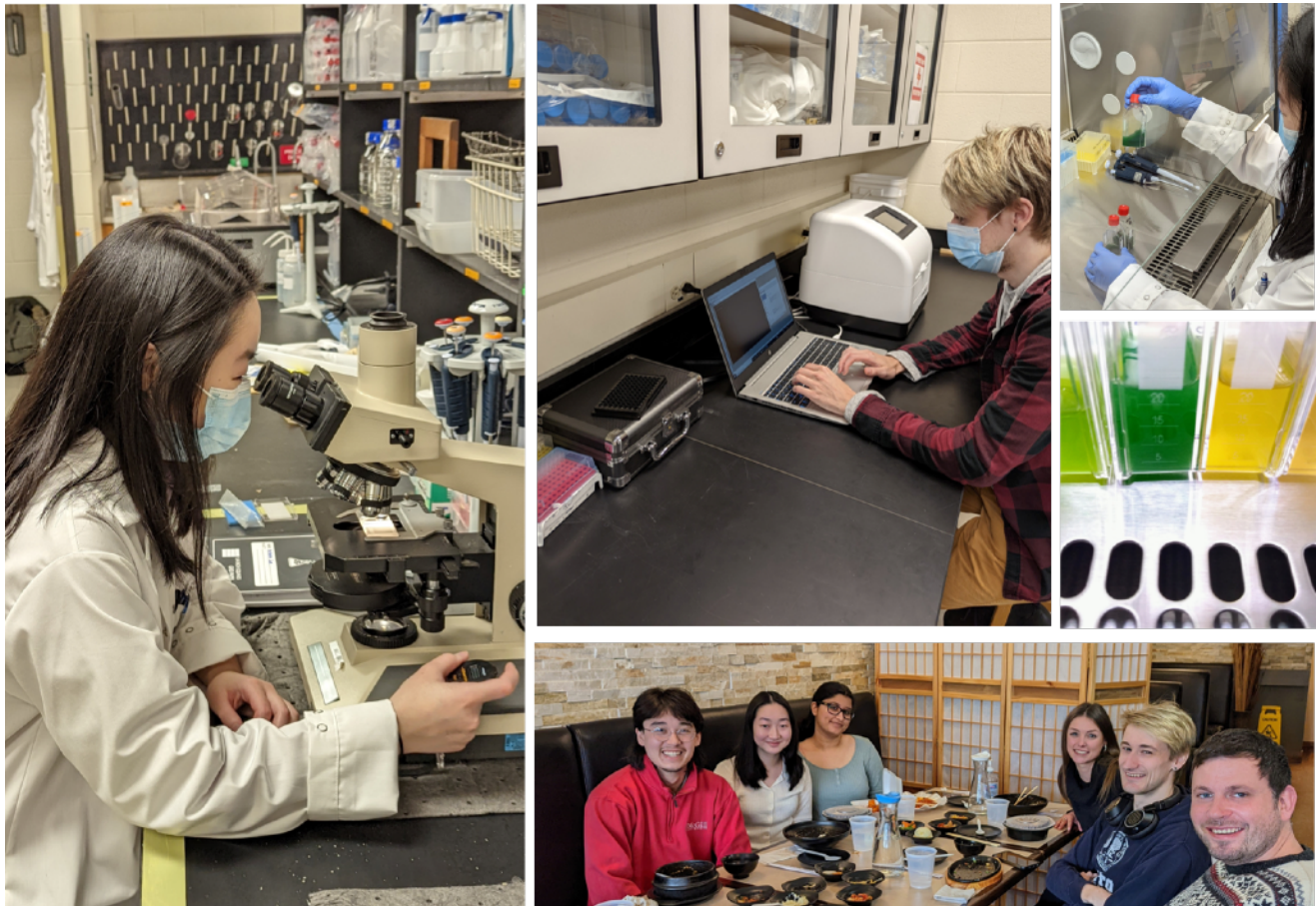
I therefore decided that I wanted to pursue a career in Marine Biology, and one of the best places to do that was Plymouth, in the southwest of England. So, I enrolled in a BSc degree in Marine Biology at the University of Plymouth. And although I found most of the subjects captivating, one subject that stood out to me was Marine Microbiology, which was delivered through an elective course led by an incredibly enthusiastic and inspiring lecturer. Until that point, I was mainly interested in fish, sharks and dolphins. However, this course exposed me to the fact that it is really the microbes in the ocean that sustain the majority of life, because they are not only at the bottom of most food webs, but also because microbes such as phytoplankton are responsible for the production of almost half of the oxygen we breathe. Another thing that stood out to me during one of the lectures in that course was an image of a phytoplankton bloom seen from space, and the realisation that blooms are actively being infected by viruses, which also turn out to be the most abundant biological entities in the ocean. This was enough to inspire me to continue my education into graduate school and eventually obtain a PhD degree from the University of Nottingham in England in partnership with the Plymouth Marine Laboratory, and to continue after my PhD to a postdoctoral position at Rutgers University.

When it was time to think of the next steps in my career, I was considering two choices. The first one was a potential career in industry. This option was less appealing to me because I wanted to also teach university level students. The second option was to become a PI and lead my own group at a University or a Research Institute, which would have also allowed me to teach courses. Now, one of the things that they don't tell you in graduate school is that academic positions are in a very short supply. And indeed, despite my cross-continent research experience, the collaborations that I have developed during the years, and the decent publications that I authored, it took me more than 20 faculty job applications, 5 in-person interviews, and a one-year long Lectureship position at the Scottish Association for Marine Science, before I finally settled on a tenure-track faculty position, which now allows me to grow as an independent scientist, develop my own research direction, and teach large classes of students. In that regard, my current position as an Assistant Professor at the University of Waterloo (Canada) is perfect, because it enables me to apply for grants, have

undergraduate and graduate students, and diversify my research interests by branching out towards freshwater microbiology. In parallel, this position also allows me to teach large courses on subjects that I am passionate about, such as ‘applied microbiology’ and ‘virology’. Being at Waterloo also allows me to learn from others in the field of biology, because our department has diverse expertise in plant ecology, bat biology, cellular biology, immunology, neurosciences, and microbiome research.

JM: *What do you plan to accomplish in your first year as a Lang Fellow? Give us your “elevator speech” explaining the work you’ve proposed.*

JN: In my lab, the Environmental Virology and Ecology Research Group (ENVERG), we focus on different aspects of host-virus infection dynamics, with a current emphasis on freshwater harmful algal bloom (HAB) forming species and their viruses. One of our projects is a seasonal study of the cyanobacterial and viral community in Turkey Lake, which is in North Western Ontario. In this collaborative project with members of the forWater Research Network (<https://www.forwater.ca/>) we are aiming to elucidate the types of viruses that are associated with dominant algal and cyanobacterial species in that lake across the different seasons and also discover if there are any seasonal patterns related to the type of virus ‘auxiliary metabolic genes’ present. These genes are commonly found in algal viruses and those that infect cyanobacteria and are thought to have been “stolen” from the host cell in order to augment and/or supplement different aspects of host metabolism during infection. Another project related to HABs is looking at the extent to which virus infection in the laboratory alters toxin production and release from different strains of *Microcystis aeruginosa*. Recent



Research and researchers in the Nissimov Lab

in situ studies have suggested that virus infection during HABs may make things worse because of a potential increase in toxins in the dissolved phase during infection.

For my first year as a Lang Fellow, we have a project that uses different computational tools, databases, and 3D protein structure predictions, to reveal the functional role of genes within viruses infecting *E. huxleyi*. So far, nearly 80% of genes in these virus genomes have no known function, so it is essential to get a sense of what the proteins that these genes code for do, if we want to fully understand how these viruses take over the host machinery for replication. While we have a fairly good understanding of the role of viruses in controlling algal blooms in oceans and seas, and their different roles in various biogeochemical processes, we lack the same understanding in freshwater habitats. For example, we don't see large-scale HAB collapse due to virus infection and we don't know why that is. One possible explanation is that eutrophication may be driving viruses that otherwise would be lytic and would quickly terminate the host population, to enter cells and remain there until the hosts are physiologically stressed. To test this, some of the things that we will be doing in the first year of the Lang Fellowship are controlled experiments in the laboratory, where we will be assessing the type of infection mode of *M. aeruginosa* viruses under different nutrient regimes. These initial experiments aim at revealing whether host-specific viruses of freshwater HAB-formers can act as their viral counterparts in marine systems, or if they make things worse, by either making HAB-formers resistant to other lytic viruses, or by contributing to an increased pool of dissolved toxins during HAB formation.

JM: *Would you mind sharing a little insider information about Jozef the person? What do you enjoy doing in your off-time? As a successful early-career scientist, what's your philosophy on balancing your professional responsibilities and your personal time?*

JN: One of my main passions is travel. I am always proud of the fact that by the age of 30, I managed to set foot on all seven continents. This of course may not have been possible if I had a different career, because many places that I have visited were related to work. Nevertheless, I always try to add a fun component to these trips and explore a place, either before or after a conference and/or a field trip. While traveling, my second passion is to try the food that a place and its people has to offer. For me, food is an essential part of the diversity of different cultures and a great way to learn more about a place. Another thing that I enjoy a lot, but unfortunately haven't had the chance to do much of recently is live music. When I was younger, I often went to music festivals for several days with a tent. It was a great way to see some of your favourite bands in the flesh and spend time with friends and make new ones in the process. Recreationally speaking, I still enjoy scuba-diving, and skiing. At home I also like to have some time off with a book. Although I am not a very fast reader, I try to get through 20-30 books each year. I often read several books at the same time, because I like to have a diverse reading list I can choose from depending on my mood. Some of my favourite genres and types of books I read are science fiction, science reference books, history books about WWII, books written by astronauts, and biographies of football (i.e., soccer) players.

I think that it is important to balance your professional responsibilities and your personal time, no matter what career stage you are at. I have seen people in academia working 14-16 hours straight, six days a week, and I have seen people that stick to an 8-10 hour work day, break up that time into smaller chunks with appropriate breaks, and avoid doing much work on the weekend. In my own experience, productivity is a personal thing, and what works for some doesn't for others, but my general impression is that appropriate time off work makes people more productive in the longer run. And of course, it is difficult to find that balance, specially as an early career researcher, because it takes time to get into a rhythm that allows you to balance research, teaching, and service responsibilities. The work of academics in the university is often work that at other jobs would be done by five people, so I guess my general philosophy is that we should reward ourselves for the hard work that we do. Its ok to sometimes 'play hard' because most of the time we also 'work hard'. A while ago, my PhD supervisor was juggling between establishing himself as an independent scientist and maintain a good balance at home; he had a young family at the time. His advice was that there is

always going to be more work, but no one will give you back that precious time and those moments that you could have spent with our family, friends and other loved ones. I am sure that this is something that I will experience soon as a father to be; I will try to implement my PhD supervisor's advice.

JM: Do you have any advice you'd like to give young phycologists?

JN: If you enjoy your research, you should keep going, even if there are often times when you don't see immediate progress or success. The hard work will eventually pay off. At the same time, if you don't enjoy your work, it is never too late to change direction, because I truly believe that you can only be good at something if you enjoy doing it. In many ways, graduate studies can be a bit narrowing because we usually focus on a few very specific questions in lets say one biological system. However, it is important to keep in mind that we gain many more valuable skills during our studies that go beyond the research objectives of the thesis. These skills are very valuable and may open the door to new careers that are not necessarily in academia, so it is worth exploring these alternative options if you are not sure exactly on where you would like to go with your career. My second advice would be to always ask questions, even if it seems like your supervisor is very busy. This is because the supervisor will always be busy, but if your questions remain unanswered then your whole project may be compromised (not to mention that this by itself will make your supervisor even more busy). And finally, never be afraid to ask for help because we can't do everything by ourselves. We can't be experts on everything, so being open to collaborations and being inclusive to the ideas of others is a key to doing well.

THE NORMA J. LANG EARLY CAREER FELLOWSHIP

Norma J. Lang Early Career Fellowship

In 2022, PSA will select its 6th Lang Fellow. Named in honor of the late Norma J. Lang, this fellowship will grant a one-time payment of \$10,000 USD to one early career researcher, who will be a Norma J. Lang Fellow for three years. Applications will be accepted from Postdoctoral Fellows, Pre-Tenure Faculty, and others (those not in traditional academic positions) who are members of the society and are within 10 years of completing their Ph.D. Applications from international members are welcome, but all application materials must be in English. Individuals must be employed by a university or other non-commercial entity and be doing research on algae. The purpose of this award is to provide "seed" money for projects, with the ultimate goal of increasing the likelihood of federal or other grant funding for the recipient. It is expected that the Fellow's home institution will cover any indirect costs as an institutional match.

For more information please go to <https://www.psaalgae.org/norma-j-lang-fellowships>

Deadline: April 15, 2022

The Lang Fellowship and PSA's many other student and postdoc awards are sustained by charitable contributions to the Phycological Society of America Endowment. Contributions can be made via Paypal:

<http://www.psaalgae.org/endowment-donations>



The banner features the U.S. Department of Energy logo at the top center, which includes a stylized green leaf and a circular emblem with four dots. To the right of the logo, the text reads "U.S. DEPARTMENT OF ENERGY" in small letters, followed by "AlgaePrize" in a large, bold, green font, and "NextGen Algal Innovators" in a smaller font below it. Below the logo and text is a green horizontal bar with the text "HIGH SCHOOL THROUGH GRADUATE-LEVEL STUDENTS GET READY TO GET INNOVATIVE WITH" in white. The main part of the banner is a large, stylized word "ALGAE" where each letter is filled with a different image related to algae: 'A' is a green leaf, 'L' is a green field, 'G' is a blue and orange landscape, 'A' is a blue and green landscape, and 'E' is a green field. Below the "ALGAE" text is a row of four small images showing students in a laboratory setting, working with equipment and handling samples. At the bottom of the banner is a green horizontal bar with the text "REGISTRATION IS NOW OPEN AT ENERGY.GOV/ALGAEPRIZE" in white.

[Office of Energy Efficiency & Renewable Energy](#)

The U.S. Department of Energy's (DOE) Bioenergy Technologies Office (BETO), in collaboration with the Algae Foundation and the National Renewable Energy Laboratory, have announced a **new AlgaePrize competition for high school through graduate students** studying at a U.S.-based high school, college, community college, university, and/or graduate school.

Fast-growing and able to store energy from sunlight, algae can be transformed into a variety of products, such as fuel, food, fertilizer, industrial compounds, and animal feed. In the emerging bioeconomy, algae, a renewable, abundant, and flexible source of energy could replace fossil fuels. During the competition, teams will participate in a nearly 18-month process of pursuing innovative ideas for the development, design, and invention of technologies within the

commercial algae value chain, exploring novel solutions to algae production, processing, and new product development.

“President Biden’s energy strategy aims to create a safer and more sustainable planet, while ensuring American students and workers have the skills they need for the challenging jobs of today and tomorrow,” said Dr. Valerie Sarisky-Reed, Director for BETO. “The AlgaePrize competition supports this commitment by providing a channel for developing the nation's science, technology, engineering, and mathematics research and by helping to engage the next generation of green energy workforce.”

Teams will focus their project on the topics of algae production, downstream processing, and/or identification of novel products or tools.

“These students bring new perspectives, new ideas, and new insights to the field of bioenergy,” said President of the Algae Foundation, Ira (Ike) Levine. “By engaging with students, harnessing their ideas, and providing an avenue for discovery, we ultimately pave the way for faster, more efficient algae commercialization, ultimately leading to quicker gigaton-scale CO₂ reduction.”

STUDENTS ACROSS THE UNITED STATES WILL COMPETE TO DEVELOP, DESIGN, AND INVENT ALGAL TECHNOLOGIES TO HELP REDUCE CO₂ EMISSIONS THROUGH ALGAE COMMERCIALIZATION

The competition opens Thursday, January 13, 2022, and teams of two or more students currently enrolled in a U.S.-based education program must register by **March 2, 2022**. The grand champion competition winner will receive a total of \$20,000 cash prize.

For more information, including media resources, please visit [DOE’s AlgaePrize](#). Prospective students can find competition rules and details [here](#).

Any questions, please contact:

algaeprize@ee.doe.gov, or Ira Levine (ilevine@maine.edu), AlgaePrize Director

HISTORICAL CORNER:

On the 1958 historical lecture of Robert (Bob) Emerson: Discovery of auxiliary pigments working in synchrony with chlorophyll *a* in algae

Govindjee Govindjee

**Department of Plant Biology, University of Illinois at Urbana- Champaign,
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Prelude

In August 1958, the late Robert (Bob) Emerson (1903-1959; see Rabinowitch, 1959) delivered a very important (i.e., of high significance) historical lecture where he presented his speculations concerning the synergistic role of light absorbed by accessory pigments (e.g., chlorophyll *b*, phycobilins, and fucoxanthol) and chlorophyll *a* in diverse groups of algae; it was published in the November, 1958 News Bulletin of the Phycological Society of America, and is reproduced below (see Emerson and Chalmers, 1958; note that his coauthor Ruth Chalmers was his highly talented technical assistant). Emerson had three brief abstracts on this topic, all presented at the annual meetings of the US National Academy of Sciences (Emerson, Chalmers, Cederstrand, and Brody, 1956; Emerson, 1957; Emerson, 1958; see footnote #1), and his key (highly recognized) paper on the synergistic effect of light absorbed in chlorophyll *b* on photosynthesis by light absorbed in chlorophyll *a* in the green alga *Chlorella* was published in the *Proceedings of the National Academy of Sciences* (Emerson, Chalmers and Cederstrand, 1957).

Robert Emerson was already the ‘*Grand Master of Photosynthesis and Related Processes*’ in this World when I knew him during 1956-1958, as my mentor and advisor (see Govindjee and Govindjee, 2021). In his PhD thesis, in Berlin, Germany, Emerson (1927) explored in depth, in several algae, the intriguing absence of inhibition of respiration by hydrogen cyanide (HCN) and carbon monoxide (CO); this phenomenon baffled him, as well as his advisor Otto Warburg; full molecular understanding of this phenomenon still needs attention. [See Lichtenthaler and Bjorn (2020) for the English translation of this 32-page thesis, as well as comments by Govindjee (2020) on Emerson.] Further, Emerson’s famous 1948 Stephan Hales lecture is now available (see: Govindjee, 2018).

In 1932, Emerson, together with his undergraduate student William Arnold (see Govindjee and Srivastava, 2014), discovered the concept that hundreds of chlorophyll *a* molecules ‘cooperate’ in doing photosynthesis (Emerson and Arnold, 1932a,b), which has led to the concept of ‘Photosynthetic Unit’ (i.e., ‘antenna and the reaction center’). In 1943, Emerson, together with Charlton M. Lewis, not only confirmed that the minimum quantum requirement for the evolution of one oxygen molecule was 8-12, not 3-4, as the Nobel Laureate Otto Warburg had insisted, but there was a “Red Drop” in the

long-wavelength region, beyond 685 nm (Emerson and Lewis, 1943)—both were early “teasers” to the current concepts of photosynthesis (see Govindjee, 2001, for Emerson’s contributions; Nickelsen and Govindjee, 2011, for the controversy on the minimum quantum requirement for oxygen evolution; and Govindjee et al., 2017, for the evolution of the current Z-scheme of photosynthesis). It is very unfortunate that Emerson passed away, in a tragic plane crash, long before we showed that different spectral forms of chlorophyll *a* are present in both the photosystems I and II (Govindjee and Rabinowitch, 1960a,b); Emerson’s two light effect is in photosynthesis, not in respiration (see R. Govindjee et al. 1960), and the minimum quanta requirement, even under conditions dictated and insisted by Otto Warburg, are 8-12, not 3-4 (see R. Govindjee et al., 1968) confirming Emerson. Lastly, the two-light effect of Emerson in photosynthesis was confirmed through observations of a two-light effect on chlorophyll *a* fluorescence, also in 1960 (G. Govindjee et al., 1960).

I provide below a brief personal commentary on Emerson’s 1958 lecture, along with full references cited in his lecture (the latter are marked with a *). (For readers unfamiliar with the background and details of photosynthesis, we refer to Rabinowitch and Govindjee (1969), to Shevela et al. (2019), and most importantly to Blankenship (2021) for the thorough and complete current understanding of the mechanism of photosynthesis.

In addition to the 1958 lecture of Emerson (discussed here), his famous 1948 Stephan Hales lecture on the present, past and future of photosynthesis., was also unavailable earlier, now published in Govindjee, (2018). For a history of all aspects of photosynthesis research, see different chapters in the book edited by Govindjee et al. (2005).

Commentary on Emerson and Chalmers (1958)

The major discovery, presented here for the first time, is the very first action spectra, in different algae, of what we now call the ‘Emerson Enhancement Effect’ (i.e., enhancement in the yield of oxygen in far-red light), by adding supplementary light absorbed by various accessory pigments. This included: chlorophyll *b* (peaks at 480 nm and 655 nm) in *Chlorella* (a green alga), phycoerythrin (peak at 546 nm) in *Porphyridium* (a red alga), phycocyanin (peak at 600 nm) in *Anacystis* (a cyanobacterium), and a carotenoid fucoxanthin (fucoxanthol; peak at 540 nm) and chlorophyll *c* (peak at 645 nm) in the diatom *Navicula*. Although shown in the lecture, the 1958 paper has no figures, and Emerson died on February 4, 1959. They were published only 2 years later by Eugene Rabinowitch (Emerson and Rabinowitch, 1960). We must point out that Emerson missed the action band of a short-wavelength absorbing form of chlorophyll *a* along with that of accessory pigments because he had used Hg-Cd lines for his supplementary light and not a monochromator, providing all wavelengths of light. I have always regretted that I could not have his name on my paper when we observed (Govindjee and Rabinowitch, 1960a,b) that chlorophyll *a* 670 was in the same system as chlorophyll *b* (in *Chlorella*) and fucoxanthol (in *Navicula*).

Emerson began his lecture by talking about the function and phylogenetic significance of so-called accessory (or auxiliary) pigments in algae (1) by pointing out that the older ideas in the book by Josephine Elizabeth Tilden (Tilden, 1935) needed to be reexamined, and (2) by stating that there was a real need to understand the physiological significance of different combinations of pigments present

in algae. He then talked about the “Red drop” in the yield of photosynthesis (Emerson & Lewis, 1943) and the Enhancement by Supplementary light he had just observed (Emerson et al., 1957, not 1956 as in the paper); he also mentioned his earlier presentation at a conference (e.g., Emerson, 1957). Then, he talked about his unusual data with yellow-green algae: *Polyhedriella helvetica* and *Tribonema aequale*. We mention this so that someone may reexamine the available literature and even engage in doing new experiments to find the reasons why Emerson had failed to find the ‘Enhancement effect’ in these organisms. I regret that I did not pursue it then (or even later) because this is what Emerson wanted me to do for my PhD and I did not – yes, I grew these two algae during 1958 but was frustrated with their slow growth! Emerson also mentioned in his lecture that he had not yet tested *Ochromonas* (see Myers & Graham, 1956). Tanabe et al. (2011) have now published as to how some *Ochromonas* species use the xanthophyll cycle to their advantage. However, further research is needed on the “two photosystems” of this alga.

Emerson ended his lecture by relating his observations to the evolution of the combination of pigments. He cited Oparin (1957). He speculated that the earliest organisms contained not only chlorophyll *a*, but carotenoids, but may have had limited photosynthesis as in *Ochromonas*. The rest of Emerson’s talk dealt with how the accessory pigments helped in the evolution of efficient photosynthesis – not only for capturing light not absorbed by chlorophyll *a* but in a different way, as we know now -- through their use in capturing light for the two distinct photosystems I and II. Lastly, Emerson noted that he had not done any experiment on anoxygenic photosynthetic bacteria (see Chapter 6 in Blankenship, 2021, for further information on the mechanism of photosynthesis in such bacteria).

Footnote #1: Experiments on the two-light effect were done by Emerson only after he had failed to understand the “red drop” in the action spectrum of the quantum yield of photosynthesis, as in Emerson and Lewis (1943). Emerson et al. (1956) was his first attempt in *Chlorella* and *Porphyridium*; together with his assistant Ruth Chalmers (who grew algae and did manometry), Carl Cederstrand (who managed the instruments), and Marcia Brody (a graduate student), he explored the “red drop” at 5° C and 20-26° C, and at different light intensities. We recognize that it was here that the first experiments on the use of supplementary light and enhancement of photosynthesis is mentioned. Further, it was here that he suggested that the conclusion of Haxo and Blinks (1950) about inactive chlorophyll (Chl) *a*, in the red region, may have been due to temperature effects and that Chl *a* was fully active and normal at shorter wavelengths! Emerson’s (1957) presentation is a preliminary summary of the (Emerson) Enhancement Effect in *Chlorella* that was published soon thereafter by Emerson et al. (1957) – and led later to provide background for the two-light reaction-two-pigment system concept of photosynthesis. The last presentation (Emerson, 1958) was mainly to show that the “two-light effect” he had discovered had nothing to do with the catalytic blue-light effect Warburg et al. (1957) had reported on—it was a totally different phenomenon.

References

- Blankenship RE. 2021. Molecular Mechanisms of Photosynthesis. 3rd edition, John Wiley & Sons, USA and UK, 328pp.
Emerson, R. 1927. #Uber die Wirkung von Blausure Schwefelwasserstoff und Kohlenoxyd auf die Atmungverschiedener Algen. Friedrich Wilhelms-Universitat zu Berlin, 32 pages

- Emerson, R. 1957. Dependence of yield of photosynthesis in long-wave red on wavelength and intensity of supplementary light. In: National Academy of Sciences "Abstracts of Papers to be Presented at the Annual Meeting, 22-24 April 1957, Washington, D.C." *Science* 125 (3251): p. 746.
- Emerson, R. 1958. Yield of photosynthesis from simultaneous illumination with pairs of wavelengths. In: National Academy of Sciences "Abstracts of Papers Presented at the Annual Meeting, 28-30 April 1958, Washington, D.C." *Science* 127 (3305), pp. 1059-1060.
- Emerson, R. & Arnold, W.A. 1932a. A separation of the reactions in photosynthesis by means of intermittent light. *Journal of General Physiology* 15: 391-420.
- Emerson, R. & Arnold, W.A. 1932b. The photochemical reaction in photosynthesis. *Journal of General Physiology* 16: 191-205.
- Emerson, R. & Chalmers, R. V. 1958. Speculations concerning the function and phylogenetic significance of the accessory pigments of algae. *The Phycological Society of America News Bulletin* XI (35): 51-56.
- *Emerson, R. & Lewis, C.M. 1943. The dependence of the quantum yield of *Chlorella* photosynthesis on wavelength of light. *Amer. Jour. Bot.* 30: 165-178.
- Emerson, R. & Rabinowitch, E. 1960. Red drop and role of auxiliary pigments in photosynthesis. *Plant Physiol.* 35 (4):477-485. (See Fig.6,7, 8 and 9 on page 480 for Anacystis; *Chlorella*; *Navicula* and *Porphyridium*.)
- Emerson, R., Chalmers, R.V., Cederstrand, C.N., & Brody, M. 1956. Effect of temperature on the long-wave limit of photosynthesis. In : National Academy of Sciences "Abstracts of Papers to be Presented at the Annual Meeting, 23-25 April 1956, Washington, D.C." *Science* 123 (3199): 673.
- *Emerson, R., Chalmers, R.V. & Cederstrand, C.N. 1957. Some factors influencing the longwave limit of photosynthesis, *Proc. Nat. Acad. Sci. USA* 43: 133- 143.
- Govindjee, G. 2001. Lighting the path: a tribute to Robert Emerson (1903-1959). PS2001 Proceedings, 12th International congress on Photosynthesis, Brisbane, CSIRO Publishing; S 43-001, 6 pages
- Govindjee, G. 2018. Robert Emerson's 1949 Stephen Hales Prize Lecture: "Photosynthesis and the World". *Journal of Plant Science Research* 34 (2):119-125.
- Govindjee, G. 2020. Robert Emerson, a major contributor to Photosynthesis, had pioneered research in Respiration in the 1920s, under Otto Warburg. *Journal of Plant Science Research* 36 (1-2):1-4.
- Govindjee, G. & Govindjee, R. 2021. Personal reminiscences of Robert Emerson and Eugene Rabinowitch. *Journal of Plant Science Research* 37 (1):101-106.
- Govindjee, G. & Rabinowitch, E. 1960a. Two forms of chlorophyll a *in vivo* with distinct photochemical function. *Science* 132: 355-356.
- Govindjee, G. & Rabinowitch, E. 1960b. Action spectrum of the second Emerson effect. *Biophysic. J.* 1: 73-89.
- Govindjee, G. & Srivastava, N. 2014. William A. Arnold (1904—2001): A Biographical Memoir. National Academy of Sciences, USA, Washington, DC, 18 pages; available at: www.nasonline.org/memoirs
- Govindjee G., Ichimura, S., Cederstrand, C. & Rabinowitch E. 1960. Effect of combining far-red light with shorter wave light on the excitation of fluorescence in *Chlorella*. *Arch. Biochem. Biophys.* 89: 322-323.
- Govindjee, G., Beatty, J.T., Gest, H., Allen J.F. (Eds). 2005. Discoveries in Photosynthesis. Springer, Dordrecht.
- Govindjee, G. Shevela, D. & Bjorn, L-O. 2017. Evolution of the Z-scheme of photosynthesis: A perspective. *Photosynth. Res.* 133: 5-15
- Govindjee, R., Thomas, J.B., & Rabinowitch, E. 1960. Second Emerson effect in the Hill reaction of *Chlorella* cells with quinone as oxidant. *Science* 132 (3424): 421. Doi: 10.1126/science.132.3424.421.
- Govindjee, R., Rabinowitch, E. & Govindjee, G. 1968. Maximum quantum yield and action spectra of photosynthesis and fluorescence in *Chlorella*. *Biochimica et Biophysica Acta* 162: 530-544.
- Haxo, F.T. & Blinks, L.R. 1950. Photosynthetic action spectra of marine algae. *Journal of General Physiology* 33: 389-422. PMID 15406376
- Lichtenthaler, H.K. & Bjorn, L.O. 2020. English translation of the 1927 doctoral thesis # of Robert Emerson, a pioneer in Photosynthesis: [On the Effect of Hydrogen Cyanide, Hydrogen Sulfide and Carbon Monoxide on the Respiration of various Algae] *Journal of Plant Science Research* 36 (1-2): 5-24.
- *Myers, J. & Graham, J. 1956. The role of photosynthesis in the physiology of *Ochromonas*. *J. Cell Comp. Physiol.* 47: 397—414.
- Nickelsen, K. & Govindjee, G. 2011. The Maximum Quantum Yield Controversy: Otto Warburg and the MidWest Gang. *Bern Studies in the History and Philosophy of Science*, Bern, 138pp; ISBN: 978-3-9523421-9-0
- *Oparin, A.I. 1957. The Origin of Life on the Earth; 3rd edition, pp, xviii + 495 pp, Edinburgh
- Rabinowitch, E. 1959. Robert Emerson 1903-1959. *Plant Physiol.* 34(3): 179-184.
- Rabinowitch, E., & Govindjee, G. 1969. Photosynthesis. Wiley & Sons, NY, xiv, 274 pp; also see: <https://www.life.illinois.edu/govindjee/photosynBook.html>
- Shevela, D., Bjorn, L., and Govindjee G. 2019. Photosynthesis: Solar Energy for Life. World Scientific, Singapore.
- *Strain, H. 1951. Chapter 13: The Pigments of Algae. In: Smith, G.M. (ed.) *Manual of Phycology*, Waltham, Massachusetts, pp. 243-262.
- Tanabe, Y., Shitara, T., Kashino, Y., Hara, Y., & Kudoh, S. 2011. Utilizing the effective xanthophyll cycle blooming of *Ochromonas smithi* and *O. itoi* (Chrysophyceae) on the snow surface. *PLoS One* 6(2): e14690; doi: 10.1371/journal.pone.0014690
- *Tilden, Josephine E. 1935, *The Algae and their Life Relations*. University of Minnesota Press, Minneapolis [reprinted by Hafner; 1969], 550 pages; ISBN-10 : 0028535502 and ISBN-13: 978-0028535500
- Warburg, O., Schröder, W., Krippahl, G. & Klotzsch, H. 1957. Photosynthese. *Angewandte Chemie* 69(20): 627-634.

Speculations Concerning the Function and Phylogenetic Significance of the Accessory Pigments of Algae

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Special interest attaches to the accessory pigments of algae for two reasons. First, the natural occurrence of the pigments in certain combinations, each peculiar to a phylum or group of phyla, is accepted as evidence that the pigments are taxonomically and phylogenetically significant, but there seems to have been no serious attempt to provide a plausible and comprehensive explanation for the development and survival of the existing combinations of pigments since Tilden (J. E. Tilden, *The Algae and Their Life Relations*, Univ. of Minnesota Press, Minneapolis, 1935). The scheme she devised was in accord with information then available, but there have been important advances in our knowledge of the algal pigments which call for a fresh look at the problem. Second, it is now well established that light absorbed by the accessory pigments can be contributed to photosynthesis with high efficiency, and something is known of the manner in which this contribution is made, but the physiological significance of the different pigment combinations is not clearly understood.

Chlorophyll *a* is common to all autotrophic algae and higher plants. It is always accompanied by other plastid pigments, some of which have been shown to contribute the light energy they absorb to photosynthesis. These include chlorophylls *b* and *c*, the carotenoid fucoxanthol, and the phycobilins phycoerythrin and phycocyanin. We refer to these as accessory pigments. Various carotenoids other than fucoxanthol always accompany chlorophyll, β carotene apparently being as universally distributed among photosynthetic plants as chlorophyll *a* itself. The extent to which light energy absorbed by carotenoids other than fucoxanthol can be contributed to photosynthesis is uncertain, so for the present we are not including them among the accessory pigments.

The primary role as sensitizer of photosynthesis is now usually assigned to chlorophyll *a*, both because of its universal distribution in photosynthetic plants above the bacteria and because of the evidence (from observations on fluorescence) that excitation energy acquired by the accessory pigments through absorption of light can be transferred to the chlorophyll *a*, thus leading to the same excited state of the chlorophyll *a* as that which results from direct absorption of light by the chlorophyll *a* itself. The accessory pigments are believed to act only indirectly in photosynthesis, by absorbing light in various parts of the spectrum and transferring the excitation energy thus acquired to the chlorophyll *a*.

Our measurements of the quantum yield of photosynthesis in longer wave lengths of red light have suggested that the accessory pigments may play a more direct part. Emerson and Lewis showed in 1943 (*Amer. J.*

Bot. 30: 165) that longer wave lengths of red light are utilized for photosynthesis with a relatively low quantum yield. This was surprising, because these wave lengths, being within the red absorption band of chlorophyll *a*, must be expected to bring about the same excited state of chlorophyll *a* as would result from the absorption of shorter wave lengths. The yield of photosynthesis should not depend upon the wave of light which produced the excited state, if the excited state is the same in all cases.

We found (Emerson *et al.*, Proc. Nat. Acad. Sc. 43: 133, 1956) that the range of wave lengths where the yield of photosynthesis is low was different for the red alga *Porphyridium cruentum* and the green alga *Chlorella pyrenoidosa*. *Porphyridium* showed a diminished yield beginning at about 650 m μ . For *Chlorella*, the yield did not begin to decline until about 685 m μ . We thought it possible that the difference might be correlated with the accessory pigments characteristic of these algae.

In *Chlorella*, chlorophyll *a* is accompanied by chlorophyll *b*. Light absorption by chlorophyll *b* probably does not extend as far toward long wave lengths as absorption by the *a* component. Direct observation of the limit of the red absorption band of chlorophyll *b* in live cells is not possible, but estimates based on comparison of the absorption spectra of chlorophylls *a* and *b* in solvents suggest that the wave lengths where the yield of photosynthesis is low are probably beyond the absorption band of the *b* component, and in a region where the *a* component accounts for all the light absorption.

In *Porphyridium*, chlorophyll *a* is accompanied by phycobilins, and there is no chlorophyll *b*. The zone where absorption is attributable to chlorophyll *a* alone must begin where absorption by the phycobilins terminates. The most prominent phycobilin of *Porphyridium* is phycoerythrin. Its absorption probably does not extend beyond 600 m μ . Some phycocyanins are present, but since their concentration is low, they probably do not contribute much to absorption beyond 650 m μ . At wave lengths longer than this, absorption of light must be attributable almost entirely to chlorophyll *a*. This is also the beginning of the region where *Porphyridium* shows a declining yield of photosynthesis.

We speculated that the yield of photosynthesis might be low in long wave lengths because these wave lengths were exciting chlorophyll *a* alone, and that maximum yield of photosynthesis might require excitation not only of the chlorophyll *a*, but also of some accessory pigment having an absorption band on the short-wave side of the red band of chlorophyll *a*. In the case of *Chlorella*, this requirement could be met by chlorophyll *b*, and in *Porphyridium*, by either phycocyanin or phycoerythrin.

We tested this hypothesis by measuring the yield of photosynthesis in two beams of light, to which the cells could be exposed either separately or simultaneously (Emerson, Science 127: 1059, 1958). We found that as long as the wave lengths of both light beams were within the range of absorption by accessory pigments, the yield of photosynthesis for the two wave lengths together was equal to the sum of the yields for the two wave lengths taken separately. But if one of the beams was limited to long wave lengths

of red light which could only be absorbed by chlorophyll *a*, and the other beam provided shorter wave lengths which could be absorbed at least partly by accessory pigments, then the photosynthesis for the two beams given simultaneously exceeded the sum of the yields of the two beams given separately.

We interpreted this to mean that the shorter wave lengths increase the yield from the beam of longer wave lengths. The alternative possibility, that the long wave lengths increase the yield from the shorter wave lengths, seems to us unlikely because in general the yields for the shorter wave lengths alone appear to be maximal, while the yield from the long wave lengths alone is lower than the maximum. By treating the increase due to combination of long and short wave lengths as an increase in the yield from the long wave lengths only, it can be shown that the yield from the long wave lengths approaches the maximum attainable with shorter wave lengths, while interpreting the increase in the opposite way, as an effect of long wave lengths upon the yield from short wave lengths, would lead to yields above the maximum, making this the less probable alternative.

We then compared the effects of different wave lengths upon the yield from a beam of long-wave red of fixed wave length and intensity. To do this, we adjusted the intensity of the beam of shorter wave lengths so that at each wave length setting, this beam by itself gave the same rate of photosynthesis. We found that the effectiveness of the shorter wave lengths in improving the yield from the beam of long-wave red corresponded approximately with the absorption spectrum of the accessory pigment or pigments of the alga being tested. More precisely, the effectiveness varied with the fraction of the absorption of the short-wave beam which could be attributed to the accessory pigment or pigments.

This fraction can be only roughly estimated for live cells, but the regions where it is obviously large are clearly identifiable with maxima in the effectiveness of supplementary light. With *Chlorella*, we found maximum effectiveness of supplementary light at about 480 m μ , a region where absorption by chlorophyll *b* is at its maximum and absorption by chlorophyll *a* is very small. The fraction absorbed by chlorophyll *b* attains its largest value here. There is a lower peak of effectiveness of supplementary light at about 655 m μ , coinciding approximately with the red maximum of chlorophyll *b*. Here absorption by chlorophyll *a* is also considerable, so that the fraction absorbed by the *b* component is much less than at 480 m μ . For *Navicula*, the maximum effectiveness of supplementary light is at about 540 m μ , where fucoxanthol contributes most to absorption, and there is a second smaller maximum in the neighborhood of 645 m μ , probably attributable to the contribution of chlorophyll *c* to the absorption of light. *Anacystis* and *Porphyridium* each show single peaks in effectiveness of supplementary light, near where phycoerythrin and phycocyanin contribute most to light absorption (at about 600 and 546 m μ , respectively).

The evidence seems clear that at least at long wave lengths of light, full efficiency of photosynthesis is not sustained by excitation of chlorophyll *a* alone, and that simultaneous excitation of some second pigment, with an ab-

sorption band or bands at shorter wave lengths, serves to restore to normal the efficiency of the long wave lengths absorbed only by chlorophyll *a*.

Inevitably, this raises a question in regard to the Chrysophyceae and Xanthophyceae. These algae contain chlorophyll *a*, but lack the common accessory pigments clearly identifiable as photochemical contributors to photosynthesis. Strain (*In* Smith, G. M., ed., *Manual of Phycology*, Waltham, Mass., 1951, chapter 13) lists *Tribonema bombycinum* as containing a new chlorophyll which he designates chlorophyll *e*, but it remains to be seen whether this component will prove to be generally characteristic of the Xanthophyceae and whether it occurs in amounts sufficient to account for an appreciable fraction of the light absorbed. Some of the Chrysophyceae are reported to contain small amounts of fucoxanthol, and it may be present in all members of the group, but it is not yet known whether this pigment can contribute to photosynthesis when it is not accompanied by chlorophyll *c*.

We have tested two Xanthophyceae supplied to us through the kindness of Professor Starr of the University of Indiana (*Polyedriella helvetica* and *Tribonema aequale*) and have failed to find any evidence of effects of supplementary light upon the yield of photosynthesis from longer wave lengths of red. Provisionally, we attribute this to absence of accessory pigments. In the case of *Tribonema*, the quantum yield of photosynthesis seems to be low throughout the spectrum, as if the chlorophyll *a* without accessory pigments were incapable of sustaining a high yield of photosynthesis, either in long wave red or at shorter wave lengths. Many more comparisons must be made with a wider range of algal types before we can have confidence that such a generalization is valid.

We have not yet tested any Chrysophyceae for their response to supplementary light, but we consider it significant that at least one representative of this group (*Ochromonas malhamensis*) seems to show only a limited capacity for photosynthesis (Myers and Graham, *J. Cell. Comp. Physiol.* 47: 397. 1956).

On the basis of the effects of supplementary light which we have described here, we are tempted to sketch a possible sequence of evolution of the combinations of pigments to be found in algae. In agreement with Oparin's premises concerning the origin of life (A. I. Oparin, *The Origin of Life*, Edinburgh, 1957), we suppose that when organisms containing chlorophyll first appeared, organic substances were available in abundance, and evolution of heterotrophic forms of life must have been well advanced. Because of the universal presence of chlorophyll *a* in all photosynthetic plants except bacteria, it is likely that all are derived from a common ancestor containing the *a* component. Since none of the accessory pigments is to be found in all the phyla of photosynthetic algae and higher plants, we may suppose that chlorophyll *a* appeared first without accessory pigments. Throughout the phyla of plants, chlorophyll *a* is always accompanied by β carotene and also by other carotenoids, so that in all probability the earliest organisms containing chlorophyll *a* also contained carotenoids, perhaps exclusive of fucoxanthol. These organisms may have been capable of limited photosynthetic activity such as we can see in the chrys-

ophycean *Ochromonas*. Organic nutrition may have made up for the low photosynthetic efficiency which we suppose to be characteristic of chlorophyll *a* when it is unaccompanied by other active pigments.

We may suppose that organisms containing various pigments in addition to chlorophyll *a* appeared in the course of geologic time and that some of these were capable of supplementing the activity of chlorophyll *a* in such a way that efficient photosynthesis, with production of organic material and oxygen from carbon dioxide and water, could sustain a fully autotrophic mode of life. The various combinations of pigments may have initiated parallel lines of evolution, the end results of which we see today in the different classes of algae.

Our suggestion, that the accessory pigments may endow the photosynthetic system with an effectiveness which it could not have if chlorophyll *a* were the only photosynthetic pigment, seems to offer a plausible explanation for the success of the combination of chlorophylls *a* and *b*. We see that light absorbed by the accessory pigments can extend efficient photosynthesis to longer wave lengths. Possibly, all the light absorbed by chlorophyll *a*—at long and also at short wave lengths—must be supplemented by light absorbed by some accessory pigment in order to sustain maximum yield of photosynthesis. If this is the function served by the accessory pigments, then the farther the absorption of light by the accessory pigment extends towards the red absorption band of chlorophyll *a*, the greater will be the range of wave lengths which can sustain maximum efficiency for the light absorbed by chlorophyll *a*. From this standpoint, chlorophyll *b* should be superior to the other accessory pigments, because the red absorption band of the *b* component is about as close as it can be on the short-wave side of the corresponding band of the *a* component. (We assume that any pigment, such as chlorophyll *d*, with its absorption band on the long-wave side of the *a* component, would be ineffective, because its excited state would be lower than that of chlorophyll *a*). Phycoerythrin, on the other hand, with its absorption extending only to about 600 $m\mu$, makes available the smallest range of wave lengths for sustaining efficient use of red light absorbed by chlorophyll *a*, and phycocyanin is in an intermediate position. Of all the algal groups, the Rhodophyceae are abundant over the smallest part of the earth, while the widespread occurrence of the Myxophyceae, particularly in highly specialized environments, is probably due to broad physiological tolerances not related to pigmentation. The fucoxanthol might offer no greater spectral range than the phycoerythrin were it not for the fact that chlorophyll *c* usually accompanies fucoxanthol, making a combination with chlorophyll *a* which may be as good as, or perhaps better than, the combination of chlorophylls *a* and *b*. Certainly these are the two combinations which are most outstandingly successful—fucoxanthol-chlorophyll *c*-chlorophyll *a* in the oceans, and chlorophyll *a*-chlorophyll *b* on land and in fresh water.

If the carotenoid peridinin of dinoflagellates serves the same function as the fucoxanthol of brown algae and diatoms, then the combination of chlorophylls *a* and *c* with peridinin may be as effective as the combination of fucoxanthol with these two chlorophylls and may contribute to the competitive success of the dinoflagellates.

In contrast, the classical outlook that the value of accessory pigments lies in their capacity to increase absorption of light in parts of the spectrum poorly covered by the absorption bands of chlorophyll *a* does not seem to account for the outstanding success of the combination of chlorophylls *a* and *b*. The *b* component, with its absorption bands closely overlapping those of chlorophyll *a*, hardly increases the range of absorption at all. The combination of chlorophyll *a* with the phycobilins looks most promising from the standpoint of maximum coverage of the visible spectrum with pigment absorption bands, but the more specialized distribution of the organisms for which this pigment combination is characteristic leaves room for doubt whether coverage of the spectrum has been the primary factor in determining the survival value of the accessory pigments.

We have omitted the photosynthetic bacteria from our discussion because the biochemical changes brought about by their photosynthesis seem to be fundamentally different from the biochemistry of photosynthesis as we encounter it in the algae and high plants. The bacteria produce no free oxygen and require hydrogen donors from which hydrogen can be separated at much smaller energy cost than from water—the hydrogen donor for algae and higher plants. The evolutionary position of the photosynthetic bacteria seems to have no direct bearing on the problem of the evolution and function of the accessory pigments of algae and higher plants.

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Are non-cosmopolitan species of the coastal, Dinoflagellate genus *Triplos* better monitors of global warming than cosmopolitan species?

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The aim of this study was to examine the proposal [1,2] that the sensitivity of the *Triplos* genus to sea surface temperature (SST) makes it a relevant genus for monitoring the effects of global warming and its potential devastating effect on algal blooms, biodiversity, and water masses. There is an established biogeographical distribution associating different *Triplos* species with different oceanic SSTs [3,4,5,6,7,8,9], despite there being extensive intra-species morphological variability. One key temperature-dependent biogeographic analysis [4] divided the North Atlantic and adjacent seas into six biogeographical zones (from Arctic to Warm/Tropical, a 2 °C to 30 °C range) and concluded that mean SST was the most important factor in species zonal distribution. Also five “cosmopolitan” species were identified [4], three of which - *T. furca*, *T. fusus* and *T. muellerii* - are known to cause serious ecosystem stress by forming harmful (discolouration and hypoxic) algal blooms.

As global warming causes SST to rise, “non-cosmopolitan” warm/tropical *Triplos* species could be expected to expand their biogeographical range into higher latitude, colder waters. To test this hypothesis a diversity analysis was carried out within and between *Triplos* species at different latitudes from 2010 to 2019 inclusive, over a SST range of ca.15 °C and at 49 different coastal locations in four countries: the high latitude, cold/temperate waters of Chile and Scotland’s west coast; and the low latitude, warm/tropical coastal waters of Belize and Thailand. A sub-surface, 53 µm mesh, plankton net, (filtering c.5 cu. m. of water at each site) was towed in optimal growth seasons and at similar times of day. SST was measured using a thermometer and a bucket and it was well correlated with the average SSTs that have been recorded at the sites over several years [10]. Mature cells were identified from unstained photomicrographs, classified into one of their temperature-dependant, six biogeographical groups [4,8], and cell width, length and antapical horn span (but only in cells where the antapical horns curved towards the apical horn) were carefully measured. Cell width is the most reliable of all these measurements as broken horns, undulating focal planes and cell debris compromise span and length measurements.

As found for oceanic waters species, diversity increases with increased coastal SST, however, non-cosmopolitan species from the cold/temperate coastal waters of Chile (21 sites, 10 species) and the west coast of Scotland (16 sites, 7 species) were not readily classified into discrete, biogeographical groups - classification ranged from Groups 1-6 - Arctic to Tropical. Similarly in the coastal, tropical waters of Belize (9 sites, 27 species) and Thailand (3 sites, 16 species) biogeographical group classification ranged from Groups 3-6 - Intermediate to Tropical/Warm. The temperature range of each of the six groups is large (2 to 20 °C) compared to the small changes of SST (1.2 to 3.2 °C) due to global warming that are predicted to occur by 2100 [11]. Thus the temperature-dependent biogeographical distribution of coastal, non-cosmopolitan species of the *Triplos* genus, is probably not sufficiently stenothermic to be an effective biological monitor of global warming, unlike, as proposed here, the more eurythermal, cosmopolitan species *T. furca*, *T. fusus*, and *T. muellerii*. In cold, high latitude waters these cells are large and more robust compared to those in lower latitude, warmer waters (Fig. 1) and, as shown in the following Tables 1a-c, their cell width, the most reliable of cell measurements, is inversely correlated with an increase in SST. Tables 1a-c give a summary of mean of cell body width, length and, where appropriate, span, along with standard deviations (±SD) and observation numbers (n) for the four countries and the latitude and longitude of their respective sampling sites.

Table 1a: *T. furca* var *eugrammus*

Sites: Lat. Long.	Body width (µm)	Cell length (µm)	SST
<i>T. furca</i>			
Temperate/Cold			
Chile (actual sites)			
30 13.2S 71 30.6W	44.80±3.96 (n=5) *	229.55±16.27 (n=20)	18.4 °C
39 14.0S 73 46.4W	49.45±4.06 (n=11)	234.36±14.42 (n=11)	15.4 °C
41 50.7S 73 20.7W	49.50±3.73 (n=15) *	232.50±16.06 (n=6)	14.4 °C
Scotland			
55.52.04N 05 23.25W	42.23±4.82 (n=40) **	224.93±34.17 (n=40)	13.5 °C
Tropical			
Belize/Gulf Honduras			
17 29.32N 88 10.04W	27.53±5.33 (n=21) **	166.14±45.11 (n=21)	28 °C
Thailand			
07 50.51N 98 28.30E	32.14±2.60 (n=14) **	203.79±12.79 (n=14)	29 °C

*Statistically significant difference ($P < 0.05$; two-tailed, unpaired t-test) between mean cell body width in between sites at 18.4 °C and 14.4 °C. Assuming a linear relationship there is a 2.3% fall in mean cell body width per 1°C increase in SST. **The average of the tropical cell body widths compared to the Scottish mean cell body width gives, for a 15°C SST range, a 1.96% fall per 1 °C increase in SST - a similar result for a 4°C SST range within Chilean waters. There also appears to be an inverse relationship between cell length and SST. A similar inverse relationship between cell width and SST probably exists in cosmopolitan species, but non-cosmopolitan cells are easier to measure as they are less variable, more abundant and robust, and less liable to sampling damage than the more flamboyant cosmopolitan species.

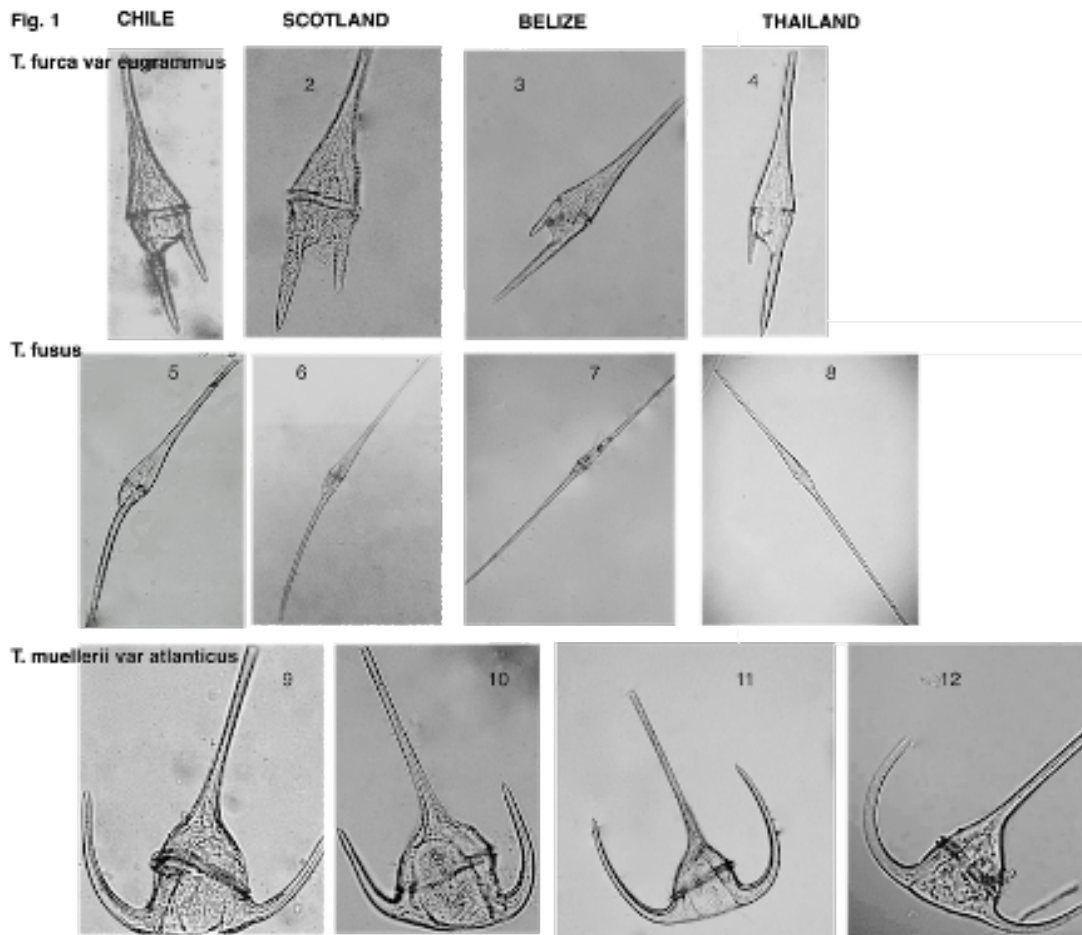
Table 1b: *T. fusus*

Sites: Lat. Long.	Body width (µm)	Cell length (µm)	SST
<i>T. fusus</i>			
Temperate/Cold			
Chile (actual sites)			
41 50.7S 73 20.7W	26.57±2-30 (n=7)	312.14±13.89 (n=7)	14.4 °C
42 36.1S 73 23.1W	25.83±2.72 (n=8)	285.38±22.61 (n=8)	14.4 °C
42 43.4S 73 29.3W	28.33±3.98 (n=6)	307.00±39.97 (n=6)	14.4 °C
42.37.5S 73 13.5W	24.75±1.71 (n=4)	323.00±25.31 (n=4)	14.4 °C
Scotland			
55.52.04N 05 23.25W	25.85±4.14 (n=62)	399.53±42.07 (n=62)	13.5 °C
Tropical			
Belize/Gulf Honduras			
17 29.32N 88 10.04 1W	20.63±2.75 (n=6)	532.91±104.20 (n=6)	28 °C
Thailand			
07 50.51N 98 28.30E	18.59±2.24 (n=27)	376.52±47.77 (n=27)	29 °C

At a SST of ca. 14°C the average of all Chilean body widths is 26.37 µm, similar to the Scottish widths of 25.85 µm. Averaging Belizean and Thai width means gives 19.61 µm and when compared to a mean Scottish cell body width of 25.85 µm gives an average fall of 1.61% mean cell body width per 1 °C increase in SST. Cell lengths are more difficult to compare as cells are long, spindly and easily broken.

Table 1c: *T. muellerii* var *atlanticum*

Sites: Lat. Long.	Body width	Cell length	Cell span (µm)	SST
<i>T. muellerii</i>				
Temperate/Cold				
Chile (actual sites)				
30 13.2S 71 30.6W	73.33±6.04	229.55±16.27	163.00±11.34	18.4 °C
39 14.0S 73 46.4W	76.47±4.46	227.26±24.89	154.00±44.75	15.4 °C
41 50.7S 73 20.7W	76.33±7.13	220.73±11.15	146.60±12.97	14.4 °C
41 39.1S 73 01.6W	75.30±4.90	196.90±13.25	172.00±10.49	13.7 °C
Scotland				
55.52.04N 05 23.25W	74.87±5.18	217.52±22.07	153.78±15.43	13.5 °C
Tropical				
Belize/Gulf Honduras				
17 29.32N 88 10.04W	67.00±6.86	222.30±25.39	172.21±11.60	28 °C
Thailand				
07 50.51N 98 28.30E	55.00 (n=1)	271.00 (n=1)	173.00 (n=1)	29 °C



DV=Dorsal View. VV= Ventral View. Measurement = width x length

***T. furca* var *eugrammus*.** (Right apical horn less than cell body diameter. Coastal variety)

1. Chile: 53 x 250 µm. DV. 2. Scotland: 3.5 x 240 µm. DV. 3. Belize: 36 x 240 µm. VV. 4. Thailand 28 x 201µm. VV.

***T. fusus*.**

5. Chile: 32 x 335 µm. VV. 6. Scotland: 28 x 412 µm. VV. 7. Belize: 20 x 620 µm. VV. 8. Thailand 19 x 507 µm

***T. muellerii* var *atlanticus*.** (Variable species. Triangular epitheca, equal length antapical horns)

9. Chile: 75 x 194 µm, span 175 µm. DV. 10. Scotland: 75 x 220 µm, span 130 µm. VV.

11. Belize: 82 x 240 µm. VV. 12. Thailand 55 x 271 µm, span 173 µm. DV.

Chilean cell body width appears to be falling over a over ca. 4°C SST rise 4°C. Scottish and Chilean cell widths were similar at ca. 4°C SST. Scottish mean cell body width compared to Belizean over a 15 °C increase in SST range, gives a 0.7% drop a percentage fall, but less than that obtained for *T. furca* and *T. fusa*. Note: *T. muellerii* is a large cell with very variable morphology, also length and span measurements are subject to error as its apical horns are long, delicate, and easily broken.

In conclusion Tables 1a-c show that, paradoxically, the coastal, *non-cosmopolitan* species are probably best for monitoring global warming as they are more abundant, robust, easily identifiable, least variant, exhibit visual changes in temperature-dependent cell morphology and show a quantifiable, inverse correlation between SST and cell body width. The relationship is most marked and quantifiable in *T. furca* var *eugrammus* and *T. fusa* and similar to results for cell volumes (2.5% °C⁻¹) found in protists [12]. The relationship is irrespective of a climate induced increase in SST having either a direct or indirect effect on cell body width, but does not rule out that an increase in SST will not trigger measurable phenotypic plasticity and/or adaptive evolutionary changes.

References

1. Tunin-Ley, A., & Lemee, R. (2013). The Genus *Neoceratium* (Planktonic Dinoflagellates) as a Potential Indicator of Ocean Warming. *Microorganisms*, 1, 58-70.
2. Hays, G., Richardson, A., & Robinson, C. (2005). Climate change and marine plankton. *Trends in Ecology and Evolution*, 20 (8), 337-344.
3. Sournia, A. (1968). Le genre *Ceratium* (péridinien planctonique) dans le canal de Mozambique. Contribution a une revision mondiale. *Vie et Milieu*, 18, 375-499.
4. Dodge, J., & Marshall, H. (1994). Biogeographic analysis of the armoured planktonic dinoflagellate *Ceratium* in the North Atlantic and adjacent seas. *J. Phycol.*, 30, 905-922.
5. Gómez, F. (2005). A list of free-living dinoflagellate species in the world's oceans. *Acta. Bot. Croat.*, 64, 129-212
6. Semina, H., & Levashova, S. (1993). The biogeography of tropical phytoplankton species in the Pacific Ocean. *Int. Rev. ges. Hydrobiol. Hydrogr.*, 78, 243-262.
7. Marshall, M. W. (2016). A first study of the diversity of the *Tripes* genus in the marine waters of Belize and the Gulf of Honduras. *Harmful Algal News*, 53, 12-13.
8. Hallegraef, G., Davies, C. & Eriksen, R. (2020) *Tripes* dinoflagellates as indicators of Australian marine bioregions. State and Trends of Australia's Ocean Report. Internet: www.imosoceanreport.org.au.
9. McDermott, G., & Raine, R. (2006). The Dinoflagellate genus *Ceratium* in Irish Shelf Seas. Martin Ryan Institute, Galway. viii + 1-86.
10. Internet site: (<https://www.seatemperature.org>).
11. Genner, M. J., Freer, J. F. & Rutterford, L. A. (2017). Biological Response to Global Warming.
12. Atkinson, D., Ciotti B.J. & Montagnes, D.J.S. (2003). Protists decrease in size linearly with temperature ca. 2.5% °C⁻¹. *Proc. R. Soc. Lond. B.* (270) 2605-2611.



PSA Membership

Happy New Year, Bonne Année, ¡Feliz Año Nuevo!, Frohes Neues Jahr, Buon anno, あけましておめでとう, Szczęśliwego Nowego, Feliz Ano Novo, 새해 복 많이 받으세요, 新年快乐, Gott nytt år, Gelukkig Nieuwjaar, Mutlu yıllar, С НОВЫМ ГОДОМ, Ευτυχισμέdoes νο το νέο έτος, הבוט הנש, Maligayang bagong Taon from the Phycological Society of America!

The above greeting represents a few of the many languages spoken amongst our members and reflects the international reach and global diversity of PSA with members from 46 countries.

Last year PSA welcomed **115 new members** and of this writing has **644 active members**. That number will certainly swell as renewals continue to roll in via the Wiley Online platform. You should now have received two renewal notifications from Wiley Membership Services. Two more notices will be sent out as reminders to **renew now!** Until you renew Wiley will hold your print journal and inactivate your online journal access.

If you have not received a renewal notice no worries. Simply head to the PSA website to maintain your active status (<https://www.psaalgae.org/membership-info>). I can supply your account reference number if you do not have record of it. It is never too late to renew but **do so soon** so as not to miss receiving the latest issue of *Journal of Phycology*. If you have any trouble renewing online do not hesitate to contact your kindly Membership Director (mamsler@uab.edu).

In the near future you will be able to track your own membership details using PSA's independent member database, **Wild Apricot**. Other features of this member-accessible database include the oft-requested member directory, streamlined meeting registrations, and voting. Expect an email soon regarding how to access Wild Apricot.

Want to contribute PSA's health beyond your own membership? Be a PSA ambassador and invite algal-minded colleagues to join or, and more generously, gift a membership to a fellow phycophile. Remember too that secondary school teachers and/or pupils qualify for the same amazing rate as students. And in case you need some talking points when **promoting PSA** and the benefits of membership:

- All PSA members enjoy the privilege of receiving the *Journal of Phycology*, six times a year. Members can access the *Journal of Phycology* using the Wiley Online Library. Log in information is sent after joining the Society or renewing a membership. If you experience any problems accessing your online journal contact cs-membership@wiley.com for assistance.

- PSA members can search and obtain full-text electronic papers from **all issues** of the Journal of Phycology (back to Volume 1, 1965).
- PSA members are **NOT charged** page fees when they publish in the Journal of Phycology as communicating authors.
- Members can access the Journal of Phycology through an **iPad and iPhone** app. Instructions detailing access are available at the PSA website.
- Members receive a pdf copy of the **Phycological Newsletter** or they can download it from our website. The Newsletter includes upcoming Society activities, colleague highlights, book reviews, information on summer field courses and graduate programs, algal history retrospectives, general articles of interest, and much more.
- Members receive a **discount** of annual meeting registration fees.
- Postdoctoral and student members of PSA are eligible for **grants-in-aid of research**.
- Postdoctoral and early career members are eligible to apply to the Norma J. Lang **Early Career Fellowship**.
- Student members are eligible for grants in support of research, travel to the Annual Meeting, and **tuition for field courses**.

Finally, and most importantly, the greatest benefit of being associated with the Phycological Society of America is membership in a **vibrant, diverse, algal-embracing community**. Please continue to demonstrate your algal zeal by keeping your PSA membership up to date!

Thank you, Muchas gracias, Merci mille fois, Grazie mille, Danke sehr, Dankuwel, Obrigada, Çok teşekkürler, Большое спасибо, 感谢, 정말 고마워, Cảm ơn bạn rất nhiều, Stokrotne dzięki, Mange tak, Děkuji vám, Σας ευχαριστώ! , どうもありがとう, for your support of and membership in the Phycological Society of America!

Wishing you healthy, algal-rich 2022,

Maggie Amsler

PSA Membership Director

IN MEMORIAM

David J. Chapman (December 12, 1939 - August 19, 2021)



David was born in Kingston, Jamaica, to Phylis Claire and Valentine Jackson Chapman (1910-1980, an eminent phycologist). The family emigrated to England in 1940, and in 1946 they moved to Auckland, New Zealand where, after WWII, Valentine Chapman was head of the Botany Department of the University of Auckland. David received an early introduction to the classics and developed a love of languages. He studied Latin for nine years and Greek for three. He also developed a love of calligraphy, and produced many wonderful works until recent years.

At the University of New Zealand (now University of Auckland) he received his BSc degree in Botany in 1960. And then at Scripps Institution of Oceanography, David obtained his PhD in 1965. His postdoctoral work as a research associate marine biologist was in Brookhaven National Laboratory until 1967, and he subsequently taught at the University of Chicago until 1973, then moved to the University of California, Los Angeles until 1994. He took the position of Dean of Mathematical, Life and Physical Sciences at the University of California, Santa Barbara in 1994 and continued until 2000, after which he continued his full time work in research and guiding his graduate students at UCSB.

In all the memorials received since his death, it is clear that he took to heart a saying generally attributed to Stephen Grellet (French Quaker and missionary, 1773-1855): "I expect to pass through this world but once: any good thing that I can do, or any kindness that I can show to any fellow-creature, let me do it now; let me not defer or neglect it, for I shall not pass this way again." In his work, he put his students and faculty responsibilities first. He is sorely missed by his family, former graduate students, and colleagues.

A list of his publications may be found in Algaebase, several of which were authored with his father, notably *Seaweeds and their Uses* (London & New York, Chapman & Hall, 1980).

May he rest in peace.

Michael D. Guiry and Russel L. Chapman.

(Modified from an Obituary in the *Santa Barbara Newspress*)

Meetings and Workshops



Updated information about the 2024 International Botanical Congress in Madrid

Earlier this year it was announced that due to the pandemic the next International Botanical Congress will be delayed one year and held in Madrid, Spain, in July 2024. The dates for the rescheduled Botanical Congress are as follows:

- Nomenclature Section, July 15-19, 2024
- Congress, July 21-27, 2024

The officers of the IBC Organizing Committee are Gonzalo Nieto Feliner (President), Juan Carlos Moreno (Vice-President) and Marcial Escudero (General Secretary). The organizing team has been working hard to form the necessary planning committees, hire the conference venue and conference management team, and prepare a website to provide details on the upcoming Congress. The Congress website is now live and additional details about the Congress will be added as they become available (<https://ibcmadrid2024.com/>)





Registration and Abstract Submission for the 14th Workshop on Cyanobacteria at Michigan State University are NOW OPEN.

The Workshop on Cyanobacteria is an international scientific conference held every three years in North America, bringing together research teams specializing in cyanobacteria and other photosynthetic prokaryotes. The conference has been an important component of the cyanobacterial community since the inaugural meeting, bringing together academic and industrial researchers to discuss trends in fundamental and applied research and to promote early-career scientists in the field.

Session topics will include: Biotechnology; Molecular Physiology; Interactions and Environment; Nitrogen fixation; Photosynthesis and Carbon Capture; Metabolic Engineering & Synthetic Biology.

- ◆ Access updated general information through the main conference website: <https://www.cyanocon14.com/>
- ◆ Register through our EventBrite page: <https://www.eventbrite.com/preview?eid=264322715357/>
- ◆ "Early Bird" Rates are available through April 1st.
- ◆ Submit an Abstract through our Google Form: <https://forms.gle/vb2gvGBDCuBz1km27>
- ◆ Submit your Abstract by April 15th if you wish to be considered for an oral presentation slot.
- ◆ Have questions? Try our FAQ: <https://www.cyanocon14.com/faq>
- ◆ Still have questions? Email me (ducatdan@msu.edu) and I will do my best to answer ASAP.

I am very much looking forward to seeing you this summer and hope that 2022 is off to a good start for you all!

**Cheers,
Danny & the Conference Organization Team**

BOOK TITLES

New:

Cohn, S.A., Manoylov, K.M. and Gordon, R. (eds.) (2021) *Diatom Gliding Motility* [DIGM, Volume in the series: *Diatoms: Biology & Applications*, series editors: Richard Gordon & Joseph Seckbach]. Wiley-Scrivener, Beverly, MA, USA. <https://www.wiley.com/en-ca/Diatom+Gliding+Motility-p-9781119526353>

Annenkov, V., Seckbach, J. and Gordon, R. (eds.) (2021) *Diatom Morphogenesis* [DIMO: Volume in the series: *Diatoms: Biology & Applications*, series editors: Richard Gordon & Joseph Seckbach]. Wiley-Scrivener, Beverly, MA, USA. <https://onlinelibrary.wiley.com/doi/book/10.1002/9781119488170>

Previously:

Seckbach, J. and Gordon, R. (eds.) (2019) *Diatoms: Fundamentals & Applications* [DIFA, Volume 1 in the series: *Diatoms: Biology & Applications*, series editors: Richard Gordon & Joseph Seckbach]. Wiley-Scrivener, Beverly, MA, USA.

<https://www.wiley.com/en-us/Diatoms%3A+Fundamentals+and+Applications-p-9781119370215>

Forthcoming:

Mazumder, N. and Gordon, R. (eds.) (2022) *Diatom Microscopy* [DIMI, Volume in the series: *Diatoms: Biology & Applications*, series editors: Richard Gordon & Joseph Seckbach, in press]. Wiley-Scrivener, Beverly, MA, USA. <https://www.amazon.com/Diatom-Microscopy-Diatoms-Biology-Applications/dp/1119711533>

Pappas, J.L. and Gordon, R. (eds.) (2023) *The Mathematical Biology of Diatoms* [DMTH, Volume in the series: *Diatoms: Biology & Applications*, series editors: Richard Gordon & Joseph Seckbach, In preparation]. Wiley-Scrivener, Beverly, MA, USA.

https://www.amazon.com/gp/product/1119749859/ref=dbs_a_def_rwt_bibl_vppi_i14

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An accelerating interest in all things seaweed and kelp has kept me busy with art commissions, project proposals, and new thinking about historical kelp maps as well as the words we use for naming seaweeds and kelp and the places it is found. I also start a new semester teaching my astounding design students at SF State. I have done webinars, talks, and interviews, all of which are archived on my [EVENTS](#) page.

[EarthShot/Revive Our Oceans: Finally, the short film segment is here!](#) The clip was filmed last spring, in my studio here in SF and snorkeling in the bull kelp of Mendocino. The kelp forests of Northern California serve as ambassadors to kelp forest issues across the globe. I hope you will watch the entire *Revive Our Oceans* episode.

[The Curious World of Seaweed continues at the Beaty Biodiversity Museum at UBC until April 24th.](#) A super fun panel discussion and presentation is being planned for the museum's monthly [Nocturnal event](#) on **March 17th at 5:30 pm**. I will be there with the incomparable Patrick Martone, phycologist, and Linda Jennings, curator at the Beaty. My [events page](#) will have the details as they arise.



November 18, 2021 – April 24, 2022

The Curious World of Seaweed

Josie Iselin

 **BEATY** BIODIVERSITY
MUSEUM
beatymuseum.ubc.ca



**Submit your contributions to the next
Phycological Newsletter by August 15, 2022**

**We also welcome your announcements
regarding field courses, workshops, meetings,
job opportunities, graduate student positions
and other algal information throughout the
year to add to the PSA webpage:**

Please forward this information to

Jeffrey Morris

communications@psaalgae.org