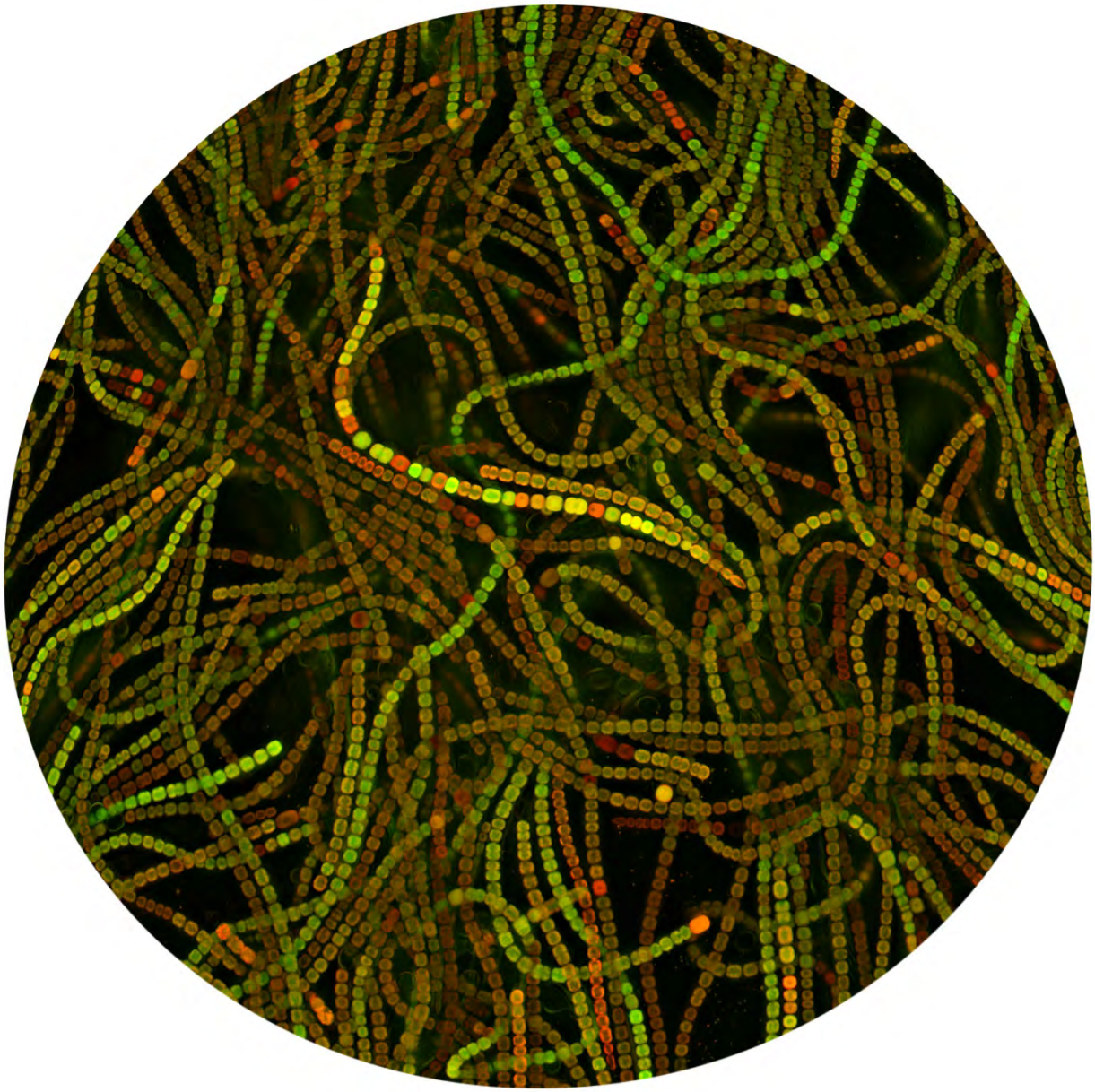
# BOOK OF ABSTRACTS



# PHOTOSYNTHETIC MICROORGANISMS FOR SUSTAINABLE DEVELOPMENT

**6 - 7 December 2022**

**Rome, Italy**

edizioni
Consiglio Nazionale delle Ricerche

# CONFERENCE PROGRAM AND ABSTRACTS

## GREEN CHRISTMAS SESSION

## PHOTOSYNTHETIC MICROORGANISMS FOR SUSTAINABLE DEVELOPMENT

## INTERNATIONAL ONLINE CONFERENCE

**TOPICS:**

Green factories

Environment and Sustainability

for details visit the conference webpage

free registration is available here

contact us at gcs.org@cnr.it

6-7 December 2022, Rome, Italy

Consiglio Nazionale delle Ricerche
Istituto per i Sistemi Biologici/Dipartimento di Scienze Bio Agroalimentari
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Confocal laser scanning microscopy imaging of *Trichormus variabilis* VRUC168 cells. This filamentous, nitrogen-fixing cyanobacterium was successfully exploited as an oxygen-producing cellular scaffold for a microbial consortium serving as a biofilter for removing nutrients from dishwasher wastewater (*Congestri et al, Water Sci Technol, 2020, 82: 1142*).

The **Green Christmas Session** has been thought of as a series of interactive online meetings to be organized annually. The discussions will focus on different fundamental and applied aspects of photosynthesis research and its potential to propose sustainable solutions in resolving emerging questions and problems of modern society.

The **Green Christmas Session 2022** is under the patronage of the International Society of Photosynthesis Research (*ISPR*), European Society of Photobiology (*ESP*), Marie Curie Alumni Association (*MCAA*), Italian Society of Photobiology (*SIFB*) and Italian Association for the Study and Applications of Microalgae (*AISAM*).

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Maya Dimova Lambreva (*ISB, CNR, Italy*)

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The Conference is hosted by the Institute for Biological Systems, National Research Council, Research Area Roma 1

## WELCOME

Dear participants,

On behalf of the Scientific Committee, I am delighted to welcome you to the second edition of the online **Green Christmas Session *"Photosynthetic microorganisms for sustainable development"***. The GCS 2022 will showcase the potential of photosynthetic microorganisms and photosynthetic components to promote the development of technology enabling the sustainable growth of modern society.

The employment of photosynthetic microorganisms as living *cellular devices* and *cellular factories* with self-propagating and self-repairing capacity continues to gain momentum in developing solar-powered biotechnology for fuel, chemicals and energy production. Both oxygenic and anoxygenic photosynthetic microorganisms are highly efficient in light-energy conversion and possess an astonishing capacity to adapt to different growth environments and unique metabolic diversity and flexibility. Knowing better the mechanisms of their photochemistry and environmental adaptation might promote the carbon-neutral production of a vast number of desirable compounds and the generation of green energy and might strengthen the notion of the circular economy.

The purpose of the GCS 2022 is to provide a platform for discussing the latest trends and advancements in the development of bio-based applications employing photosynthetic microorganisms or their photosynthetically active pigment-protein assembles.

It will bring together scholars, early-stage researchers, and students from all around the world. The format of the conference envisages the participation of preselected *Invited Speakers* and free attendance for the audience and foresees time for Q&A after the individual presentations.

Again, welcome and experience a fruitful exchange of knowledge!

Maya Dimova Lambreva,
Institute for Biological Systems, CNR
(*Chair of the conference*)

# CONFERENCE PROGRAM

***The conference schedule is set to Central European Time***

## 6th December 2022

08:50 Online Platform Opening

09:00 Welcome addressed by **Zeineb Aturki** *(Director of the Institute for Biological Systems)*

Opening: **Massimo Trotta** *(President Elected of the European Society of Photobiology)*

### *SESSION: Green factories*

***CHAIRS: Maya D. Lambreva, Alexandra Dubini, Giorgio Perin***

09:15 **Keynotes by Yagut Allahverdiyeva-Rinne** *(University of Turku, Finland)* Page 1

*Photosynthetic microorganisms as biocatalysts for the production of targeted chemicals*

10:00 **Alexandra Dubini** *(University of Cordoba, Spain)* Page 2

*Algae-bacteria consortium a new avenue for biological hydrogen production*

10:25 **Szilvia Toth** *(Biological Research Centre Szeged, Hungary)* Page 3

*Thin cell layer cultures of the pgr5 mutant of Chlamydomonas reinhardtii perform enhanced $H_2$ production at the intensity of sunlight*

10:50 **Giuseppe Torzillo** *(Institute of Bioeconomy, CNR, Italy)* Page 4

*Progress in the biotechnology of hydrogen production with microalgae*

11:15 **Kyle J. Lauersen** *(King Abdullah University of Science and Technol., Saudi Arabia)* Page 5

*Synthetic biology and metabolic engineering applications in microalgae – sustainable biotechnology beside the Red Sea at KAUST*

11:40 **Break**

## 7th December 2022

08:50 Online Platform Opening

***SESSION: Sustainability and environment***

***CHAIRS: Francesco Milano, Joanna Kargul, Maya D. Lambreva***

| | | |
|---|---|---|
| | *Semiconductor-free photovoltaics* | |
| 11:00 | **Parveen Akhtar** *(Biological Research Centre Szeged, Hungary)*<br>*Extending the absorption cross-section of Photosystem I toward higher energy conversion efficiency* | Page 14 |
| 11:25 | **Break** | |
| 11:35 | **Paolo Bombelli** *(University of Cambridge, UK)*<br>*Bio Photo Voltaic (BPV): from fundamental principles to practical applications* | Page 15 |
| 12:00 | **Roberto Abdala-Díaz and Luciana Regaldo** *(CONICET, Argentina)*<br>*Potentiality of microalgae: advances and challenges in the recovery of nutrients from wastewaters and production of valuable biomass, useful for biotechnological applications* | Page 16 |
| 12:25 | **Roberta Congestri** *(Tor Vergata University of Rome, Italy)*<br>*Microbial consortia in water treatment and upcycling* | Page 17 |
| 12:50 | **Fabrizio Di Caprio** *(Sapienza University of Rome, Italy)*<br>*Microalgae biomass production integrated with cheese whey wastewater treatment* | Page 18 |
| 13:15 | **Round table & Closing remarks** | |

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# Photosynthetic microorganisms as biocatalysts for the production of targeted chemicals

**Keywords:** photosynthesis, whole-cell biotransformation, immobilisation, solid-state production

Photosynthetic cell factories based on living algae or cyanobacteria have vast potential for carbon-neutral production of desired compounds, and can thus become integral components of sustainable bioeconomies. To improve bioproduction efficiency we are tackling regulation of photosynthesis and engineering the electron transport pathways to redirect photosynthetically produced reducing power toward targeted chemicals in algae and cyanobacteria. In 'direct solar fuels' production scenario, the production of photo-hydrogen in *Chlamydomonas* was enhanced by designing a pulse-illumination protocol that prevents the activation of competitive electron sinks and accumulation of $O_2$. Removal of the Mehler-like reaction catalysed by flavodiiron proteins further enhanced the channelling of photosynthetic electrons toward hydrogenase in *Chlamydomonas*. In 'photobio-transformation' scenario, heterologous oxidoreductases integrated into cyanobacteria or green algae, use the photosynthetic reductants (NADPH) for conversion of externally added substrates to the high-value compounds. Wiring recombinant enzymes as a strong electron sink to the electron transfer chain allows full exploitation of photosynthetic light reactions, while outcompeting alternative electron transport routes. In a 'solid-state production platform', photosynthetic cell factories are 3D-printed in a leaf-inspired hierarchical architecture of bio-based polymers that allows control over the energy loss to biomass, transport of products and gases as well as the nutrient fluxes.

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## Algae-bacteria consortia, a new avenue for hydrogen production

**Keywords:** algae, consortia, hydrogen, remediation

Microalgae are microorganisms capable of surviving and adapting to many environmental conditions. Their complex metabolism allows them to activate or inhibit specific metabolic routes and produce metabolites in order to respond adequately to different stimuli. Thus, microalgae are powerful factories able to secrete many high-value end-products, one being hydrogen. On the other hand, microalgae are also capable to grow in many types of waters which compounds can be used as nutrients, making microalgae useful tools to uptake organic matters. Interestingly bacteria have similar abilities for metabolite production and bioremediation capacity. Therefore, combining algae and bacteria is a powerful avenue to benefit from and improve hydrogen production while using different growth media. Here we report our investigation on consortia resulting from the co-cultivation of the freshwater green alga *Chlamydomonas reinhardtii* and different bacteria strains. Consortia of Chlamydomonas either with *Methylobacterium sp, Escherichia coli or Rhizobium etli* were able to improve and sustain hydrogen production depending on the light condition and the carbon sources used. Whereas other Chlamydomonas-bacteria consortium demonstrated increased nitrogen uptake capabilities. A specific consortium was able to remove nitrate ($NO_3^-$), nitrite ($NO_2^-$) and ammonium ($NH_4^+$) from synthetic medium while generating a much larger amount of biomass compared with the control corresponding monocultures. Taken together our research indicates that the quest for finding suitable partners for algae can be a promising biotechnological approach to produce more hydrogen and more biomass while removing nitrogen from the media.

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**Nagy V.[1], Podmaniczki A.[1,2], Vidal-Meireles A.[1], Kuntam S.[1], Herman É.[1], Tóth D.[1,2], Kovács L.[1], Scoma A.[3], Tóth S.Z.[1]**

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## Thin cell layer cultures of the *pgr5* mutant of *Chlamydomonas reinhardtii* perform enhanced $H_2$ production at the intensity of sunlight

**Keywords:** biohydrogen, hydrogenase, photosynthesis, thin cell layer cultures

Photobiological $H_2$ production is a promising renewable energy source. HydA hydrogenases of green algae are efficient but $O_2$-sensitive and compete for electrons with $CO_2$-fixation. We developed a $H_2$ production protocol for the green alga *Chlamydomonas reinhardtii*, based on a short anaerobic incubation in the dark, followed by continuous illumination during which the Calvin-Benson cycle is kept inactive by substrate limitation. Hydrogenase is protected by employing a simple $O_2$ absorbent. Under these conditions, the electrons feeding the hydrogenases mostly originate from water and the cultures remain photosynthetically active for several days. Our goal is to make significant progress towards a marketable $H_2$ producing technology by optimizing cultivation conditions and selecting suitable photosynthetic mutants. We achieved an additional, three-fold increase in the $H_2$ production yield by using thin-layer alga cultures. Productivity was maintained when increasing the light intensity to the range of sunlight intensity, i.e. 1000 µmol photons $m^{-2}s^{-1}$. The L159I-N230Y photosystem II mutant and the *pgrl1* photosystem I cyclic electron transport mutant produced 50% more $H_2$ than CC-124, while the *pgr5* mutant generated 250% more (1.2 ml $H_2$/ml culture in six days). The photosynthetic apparatus of the *pgr5* mutant and its in vitro HydA activity were preserved under continuous illumination of 1000 µmol photons $m^{-2}s^{-1}$ (Bioresource Technology, 2021, 333: 125217), and in fluctuating light as well.

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## Progress in the biotechnology of hydrogen production with microalgae

**Keywords:** biohydrogen; microalgae; *C. reinhardtii*; *Chlorella* sp; photobioreactors

There is an increasing concern and a mounting opposition by public opinion to continue with the use of fossil energy. Western countries are presently involved in the so-called energy transition with the objective to abandon of the fossil energy for the renewable sources. In this connection hydrogen can play a central role. One of the sustainable ways to produce hydrogen is the use of microalgae which possess two important natural catalysts: the photosystem II and the hydrogenase, used to split the water and to combine proton and electron to generate gaseous hydrogen, respectively. For about 22 years of study on photobiological hydrogen production, our scientific hopes were based on the application of sulfur protocol, which indisputably represented a very important advancement in the field of the biotechnology of hydrogen production. However, there are increasing evidence that this strategy is not economically viable. Therefore, a change of paradigm is mandatory in the photobiological hydrogen production based on microalgae. This review points out that an increasing number of microalgal strains other than *Chlamydomonas reinhardtii*, are being tested and can produce sustainable amount of hydrogen without nutrient starvation and to fulfil this goal. Recently a novel photobioreactor for hydrogen production with microalgal has been designed and constructed.

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**Lauersen K.J.**

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## Synthetic biology and metabolic engineering applications in microalgae - Sustainable Biotechnology on the shores of the Red Sea

**Keywords:** synthetic biology, metabolic engineering, algal biotechnology

The development of standardized molecular tools for genetic engineering can unlock the potential of emerging organisms for fundamental and applied goals in biotechnology. Since 2014, I have worked with small, dedicated, team to develop two different standardized molecular toolkits for the model green microalga *Chlamydomonas reinhardtii*. We complemented these efforts with a discovery that spreading of introns throughout synthetic transgenes could overcome previously observed limitations in their expression. Together, the optimized tools and transgene designs allowed reliable expression of heterologous targets and the first examples of metabolic engineering in a eukaryotic green alga. C. reinhardtii has been a powerful workhorse for testing eukaryotic algal metabolic engineering over the past 8 years, especially for isoprenoid targets. In this presentation, I will describe our strategies to optimize *C. reinhardtii* molecular toolkits, highlight new developments in cell-line engineering, bio-process designs, and discuss the value of practical engineering targets to expanding our fundamental understanding of metabolism. Finally, I will introduce our engineering efforts in extremophile red algae as the next generation of host organisms for photosynthetic biotechnology.

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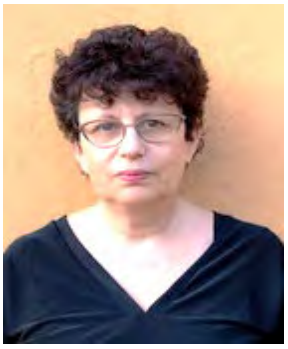

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## Bioactive lipids from microalgae

**Keywords:** LC-PUFA, glycerolipids, lipidomics, inflammation,pathogens

Algae (macroalgae and microalgae) and cyanobacteria are a rich natural trove of bioactive lipids, including a wide range of fatty acids, their derivatives, oxygenated products, and complex lipids with beneficial properties for human health and medicinal uses. Further evaluation and exploration of algal lipidomes is critical for discovering novel bioactive molecules and advancing their pharmaceutical potential. Photosynthetic microalgae are a renewable, clean, and sustainable source of health-beneficial PUFA and LC-PUFA. ω-3 LC-PUFA and ω-6 LC-PUFA, their oxygenated derivatives and glycerolipids esterified with them, are the most studied bioactive lipids with pharmaceutical potential for the treatment and alleviation of inflammation, the common component of human diseases. The therapeutic potential of algal lipids in inflammatory diseases such as inflammatory bowel disease (IBD) has increased the in-depth investigation of lipidomes of microalgae and macroalgae. The components of plastidial membranes, glycoglycerolipids, show anti-inflammatory, antiviral, antibacterial, and anticancer properties. Microalgae and macroalgae may also produce the oxygenated products of PUFA and LC-PUFA enzymatically (oxylipins) and nonenzymatically (isoprostanoids) with a high potential to modulate inflammatory responses. Furthermore, certain fatty acids from microalgae exhibit activities against human and fish bacterial pathogens and parasites. I will present the results of the research performed in our laboratory, which explores the anti-inflammatory, immunomodulatory and antiparasitic potential of some LC-PUFA-producing microalgae.

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## Metabolite regulation of the bacterial Calvin cycle revealed by interaction proteomics

**Keywords:** metabolites, Lip-SMap, bacterial Calvin cycle

Metabolite-level regulation of enzyme activity allows microbes to quickly regulate metabolic pathways during environmental shifts. This same regulation can complicate metabolic engineering strategies, as pathway flux becomes restricted. However, our knowledge of such regulations is limited for most microbial strains. Here I will describe our work using recently developed proteomics. methods, such as limited proteolysis small molecule mapping (LiP-SMap) to identify metabolite-protein interactions in the proteomes of cyanobacteria and lithoautotrophic bacteria that fix $CO_2$ using the Calvin cycle. Clustering analysis of the hundreds of detected interactions showed that some metabolites interacted in a species-specific manner, such as interactions of glucose-6-phosphate in *Cupriavidus necator* and of glyoxylate *in Synechocystis* sp PCC6803. Metabolite interactions were tested for their effects on enzyme activity with Calvin cycle enzymes fructose-1,6/sedoheptulose-1,7-bisphosphatase (F/SBPase). The Calvin cycle intermediate GAP activated both *Synechocystis* and *Cupriavidus* F/SBPase, indicating a feed-forward activation of the Calvin cycle in both photoautotrophs and chemolithoautotrophs. I will discuss implications of these findings for metabolic engineering in these strains.

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## Engineering cyanobacteria for direct solar chemical and fuel production from $CO_2$, example butanol

**Keywords:** $CO_2$, cyanobacteria, genetic engineering, photosynthetic butanol, solar chemicals

Cyanobacteria, photosynthetic microorganisms with the same type of photosynthesis as plants and algae, can be engineered to produce solar chemicals and solar fuels in direct processes from carbon dioxide. I will outline our strategies to engineer cyanobacteria to produce the alcohol butanol. Butanol is a four-carbon alcohol ($C_4H_9OH$) occurring in several structural isoforms. It is an important bulk chemical, as solvent or intermediate in chemical synthesis, and an excellent blend-in fuel. Presently butanol is produced from fossil resources. Additionally, there are biological routes for fermentative butanol production, mainly to produce 1-butanol. Cyanobacteria do not produce butanol naturally, they lack the butanol biosynthetic pathways and corresponding relevant genes. Introduction of a single gene encoding KivD resulted in isobutanol producing strains of the unicellular cyanobacterium *Synechocystis* PCC 6803. Knowledge based modelling of the identified bottleneck KivD resulted in strains with significantly increased isobutanol production. Using our best isobutanol strain in long-term experiments a cumulative titer of 911 mg per L was observed with a maximal rate of 43.6 mg per L and day. A similar approach to systematically engineer *Synechocystis* to produce 1-butanol resulted in cells with a cumulative titer of 4.8 g per L and a maximal rate of 302 mg per L and day, recently doubled to 600 mg 1-butanol per L and day and a carbon partitioning of 60%. Present progress towards a practical system will be presented and discussed.

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## Towards Industrial microalgae production: challenges and opportunities

**Keywords:** microalgae, single cell protein, omega-3 fatty acids

Microalgae have demonstrated the potential to meet the population's need for a more sustainable supply of food, feed and chemicals. Due to decades of research and a few demonstration projects in the last years, the cultivation of microalgae has been scaled-up over the last years towards a doubling in commercial production worldwide. Despite this last increase, it remains relatively small in comparison to other feedstocks such as palm oil, soy, or fish oil, for which microalgae represent a sustainable alternative. Microalgae express high protein levels and can be produced in contained cultivation systems with low water requirements and complete fertilizer use. The production potential is 22-44 tons of protein per hectare per year although the current production scale is small. Techno-economic analyses have shown good potential for scale-up and cost reduction. Large-scale production of microalgae in the post-fossil era will rely on the capture of carbon dioxide from the air or sugars from crops. Several developments have been realized including the production and commercialization of a few microalgae strains as a source of functional ingredients, and meat replacers, among others. Major challenges are to reduce production costs and energy requirements and increase production scale. Although microalgae are not yet produced at large-scale for bulk applications, recent advances – particularly in systems biology, genetic engineering, process control, and biorefinery – present opportunities to develop this process in a sustainable way. Our recent progress to improve microalgae strains and processes for robust industrial production of microalgae will be presented.

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## Expanded solar energy conversion by engineered biohybrid photosystems employing components from anoxygenic and oxygenic photosynthesis

**Keywords:** reaction centre, light harvesting complex, chlorophyll, bacteriochlorophyll

Reaction centre (RC) and RC-light harvesting 1 complexes from anoxygenic photosynthetic prokaryotes such as *Rhodobacter* (*Rba*.) *sphaeroides* have been incorporated into a variety of devices for *in vitro* solar energy conversion. Recent years have seen impressive increases in the photocurrents and photovoltages achievable by these proteins, and the development of device architectures for stable operation. However, a drawback of these photoproteins is their limited harvesting of visible sunlight, their bacteriochlorophyll pigmentation absorbing primarily blue/near-ultraviolet and near-infrared light. To address this, we have explored mechanisms for expanding the range of solar energy harvested by *Rba. sphaeroides* RCs by conjugation to synthetic and/or natural materials with complementary absorbance. Non-covalent conjugation of RCs to synthetic quantum dot (QD) nanocrystals enhances the harvesting of visible light by RCs through high-efficiency Förster resonance energy transfer (FRET) with a lifetime of a few tens of nanoseconds. Conjugation to QDs of a mixture of *Rba. sphaeroides* RCs and chlorophyll-containing LHCII antenna complexes from oxygenic phototrophs further enhances light harvesting through both direct LHCII→RC and indirect LHCII→QD→RC FRET. Both LHCII and dimeric LHCI complexes can also be covalently conjugated to RCs through a genetically-encodable, all-protein linking system to produce self-assembling polychromatic complexes capable of enhanced solar energy conversion in solution and on surfaces. Key findings on these biohybrid photosystems will be described.

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## Photosynthesis: how to convert physics to (bio)chemistry

**Keywords:** excess light, photoprotection, chloroplast, biomass, singlet oxygen

Mass cultures of microalgae in photobioreactors (PBRs) are a promising source of biomass for biofuel production on a large scale, due to the high productivity, far exceeding the best crops. Microalgae biotechnology, however, still suffers from biological constraints such as low efficiency of light use, which can be ascribed to a number of factors, including (i) light saturation effect, (ii) inhomogeneous light distribution within a mass culture and (iii) photoinhibition. At high irradiance, the photosynthetic rate increases non-linearly with respect to light intensity, reaching light saturation, while at even higher fluency net assimilation decreases due to oxidative photoinhibition. Additional energy loss derives from the inhomogeneous light distribution in the algal culture: a large antenna, favoured in the natural environment, do not enhance overall productivity in a PBR because the high optical density readily leads to saturation of photosynthesis in the surface layers, while the inner space becomes light limited. Thus, domesticating microalgae for enhanced growth rate in PBRs requires introduction of traits alleviating these physiological constraints in order to (i) optimise the light-use efficiency and (ii) increase the resistance to photo-oxidation.

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## Rational design of bio-organic interface in photosystem I-based solar conversion systems

**Keywords:** artificial photosynthesis; photosystem I; biomolecular systems

To efficiently capture the practically inexhaustible solar energy and convert it into green electricity and high energy density solar fuels provides an attractive 'green' alternative to the present-day fossil fuel-based energy systems. Of many different systems for solar energy conversion, the artificial photosynthesis (AP) approach takes inspiration from nature, where solar energy, water and carbon dioxide are directly transformed into chemical energy in the form of carbon-based compounds. The concept of the biomolecular AP is attractive as it includes evolutionary optimised non-toxic and self-renewable natural solar converters (photosynthetic reaction centres) which can produce not just green electricity but also solar chemicals, when interfaced with abiotic catalysts or enzymes. What is urgently needed for advancing the technological readiness of biomolecular AP systems is to boost their efficiency and stability by a robust bottom-up rational design of the bio-organic conductive interface. This is to ensure the generation of unidirectional electron flow and minimisation of wasteful charge recombination. Here I will overview our recent work showing that incorporating transitional metal redox centres together with plasmonic nanoparticles in the bio-organic interface significantly improves not only the light-harvesting functionality of the robust photosystem I (PSI) biophotocatalyst but also increases the photostability and overall photoconversion output of various types of PSI-based biomolecular AP devices.

**Acknowledgements:** This work has been supported by the Polish National Science Centre (OPUS 14 and 17 grants no. 2017/27/B/ST5/00472 and 2019/33/B/NZ3/01870) and the European Horizon Europe Research and Innovation Programme (SUNER-C CSA, GA no. 101058481).

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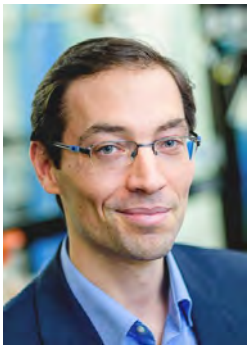

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## Semiconductor-free biohybrid photovoltaic cells

**Keywords:** reaction center, kinetic barrier, charge recombination

Despite the outstanding properties of photosynthetic proteins for light-induced charge separation, their integration in semiconductor-free photovoltaic cells remained unproductive due to undesired recombination pathways of the charge carriers at the electrode surface. Herein, we combine a mobile inner-sphere charge carrier and a polymer-bound outer-sphere electron mediator to kinetically suppress charge recombination by regulating their respective electron transfer rates at the electrode. Chemical modification of the surface of the electrode with a self-assembled monolayer led to an efficient kinetic barrier that substantially decreases the rate of recombination of the inner-sphere charge carrier by two orders of magnitude. Simultaneously, the low activation energy for charge transfer with the outer-sphere electron mediator maintains the favored predominant kinetic pathway for reduction of the photo-oxidized photoprotein and thus generates a substantially increased net power output under illumination. These findings open a unique and general approach to prevent charge recombination in biophotovoltaic cells that are free of semiconductor materials.

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## Extending the absorption cross-section of Photosystem I toward higher energy conversion efficiency

**Keywords:** Photosystem I, energy conversion, antenna complexes

Photosystem I (PSI) is nature's most efficient solar energy converting device that uses captured photon energy to drive vectorial electron transport with a quantum yield near unity. Owing to its efficient photochemistry as well as structural robustness and natural abundance, it is considered as a potential component in biohybrid photovoltaic, photocatalytic or biosensor applications. The high quantum yield of photochemistry suggests that the light-harvesting antenna, or the effective absorption cross section of the PSI core complex can be extended. Indeed, most oxygenic photosynthetic organisms – from cyanobacteria to algae and plants – exploit this by having various specialised peripheral light-harvesting antenna complexes attached to PSI. Here we present experimental data on evaluating the efficiency and dynamics of excitation energy transfer from peripherally antenna complexes to PSI *in vitro* and *in vivo* by means of time-resolved fluorescence spectroscopy. We show that PSI is promiscuous with regards to the types of light-harvesting complexes it can accept as excitation donors, including light-harvesting complex II, photosystem II and cyanobacterial phycobilisomes, and that its absorption cross section can be significantly enhanced with a marginal loss of quantum efficiency. We find that PSI trimers favour energy transfer from phycobilisomes as compared to monomers, which appears to bring a physiological advantage of the PSI oligomerization in cyanobacteria.

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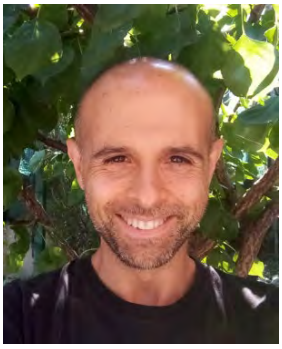

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## Bio Photo Voltaics (BPV): from principles to practical applications

**Keywords:** algae, cyanobacteria, energy, electrochemistry

**Abstract.** Algae (photosynthetic microorganisms) are able to generate electrons that can be harvested by a suitable electrochemical setup and be used as a source of electrical current. This concept forms the basis of Bio Photo Voltaic (BPV) devices [1,2].A number of aspects have been considered for enhancing the electrical output and making the BPV systems suitable for real-world applications. These include the availability of electrons from the organisms involved, the transfer of electrons outside the organisms to the electrode, and the nature of the materials used to build the electrochemical setup. To focus on possible areas of application we will present ongoing projects where BPV systems constitute a useful source of electricity. We will discuss, for example the use of BPV systems to power an Arm Cortex M0+, a microprocessor widely used in Internet of Things applications. The BPV generated enough power to run the Arm Cortex M0+ for over six months in a domestic environment under natural light [3]. In addition, we will also discuss the possibilities for scaling up of devices to provide electrical output in the range of milliwatts-to-watts. This would open up applications such as running mobile phone chargers or low level lighting. These might be particularly attractive in rural areas of low- or middle-income countries (LMICs) or in disaster relief, where small amounts of power, and the ability to charge a phone, could be particularly useful.

[1] Energy Environ. Sci., 2015, 8: 1092-1109; [2] Joule, 2020, 4 (10), 2065-2069.; [3] Energy Environ. Sci., 2022; 15:2529-2536.

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## Potentiality of microalgae: advances and challenges in the recovery of nutrients from wastewaters and production of valuable biomass, useful for biotechnological applications

**Keywords:** phycoremediation, biorefinery, urban wastewater, circular economy

Urban effluents are commonly referred to as "urban wastewater" (UW) and include domestic wastewater or its mixture with industrial wastewater and/or stormwater runoff. In recent years, the need to contribute to the development of efficient and economically convenient methods for UW treatment has motivated the study of new technologies. In this sense, microalgal applications have increased in the last decade, due to their importance in phycoremediation of urban and livestock effluents and renewable energy industries. Based on this background, the present work focuses on (1) the evaluation of the potential of *Chlorella fusca* to grow and synthesize metabolites of biotechnological interest, after being exposed for fourteen days to urban wastewater (UW) from Malaga city (UW concentrations: 25%, 50%, 75%, and 100%); (2) the study of the capacity of *C. fusca* to bioremediate UW in photobioreactors at laboratory scale; and (3) the evaluation of the effect of UW on the physiological status of *C. fusca*, as photosynthetic capacity by using in vivo Chl a fluorescence related to photosystem II and the production of photosynthetic pigments. In the framework of circular economy, we seek to deepen the study to use the biomass of microalgae to obtain metabolites of interest for biofuel production and other biotechnological areas.

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## Microbial consortia in wastewater treatment and upcycling

**Keywords:** dishwasher wastewater, microbial consortia, biofilter, Zero-Mile System

The consumption of water by household appliances, e.g. dishwashers, is an underestimated problem and wastewaters from appliances are rarely taken into account as a recoverable resource. Although dishwasher wastewaters (DWWs) are nutrient-rich (due to leftovers) and have low levels of pathogens, heavy metals, and pharmaceuticals, they are not reused due to the small amount produced by point sources. The Jetsons' Kitchen Project has been designed to face this issue, i.e. to reuse dishwasher wastewater. The system has been recently patented by Tor Vergata and Polytechnic University of Milan (2019) it consists of a prototype of dishwasher integrated with an indoor vertical garden which, in combination, allow the reuse and up-cycling of the DWW in the cultivation of edible and ornamental plants. Since the system produces healthy and safe, zero-mile food it has been nicknamed 'Zero-Mile system'. A biofilter is the core of the Zero-Mile system: it contains an *ad hoc* engineered microbial consortium, including the filamentous photosynthetic and nitrogen-fixing cyanobacterium, *Trichormus variabilis* (from the VRUC, Tor Vergata Rome Collection), and three heterotrophic bacteria isolated from DWW. The degradative capability of the biofilter challenged with different DWWs will be reported to describe its degradative capacity versus a variety of nutrient loads and amounts; the biofilter effectiveness, in terms of survival and growth, will be discussed also in the light of consortium composition changes by Next Generation Sequencing. Preliminary results on the reuse of DWW in the fertilization of the vertical garden for *Lactuca sativa* production at home will be also presented.

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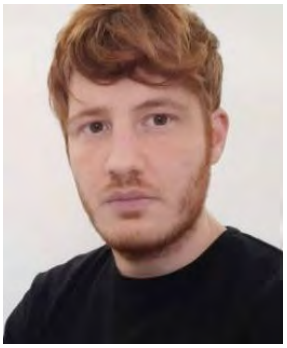

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## Microalgae biomass production integrated with cheese whey wastewater treatment

**Keywords:** circular economy; heterotrophy; contamination control; dairy by-products

Cheese industry produces about 9 L of whey per 1 kg of cheese. This whey is usually processed by ultrafiltration to obtain high-value whey proteins and whey permeate as wastewater, that is currently scarcely valorised. Since it is rich of sugars, P and N, it could be used as nutrient source for microalgae to obtain high value proteins and other products. At the same time, whey sugars can feed the heterotrophic metabolism of microalgae, increasing the economic sustainability of the process, allowing to reduce the dependence from reactor S/V ratio. However, conventional sterilization is hardly applicable to such kind of processes. As result, contamination by heterotrophic bacteria remains a main obstacle for the scale up. Here, an innovative approach is proposed to integrate an efficient removal of pollutants from whey with a strategy to control bacteria contamination, achieving microalgae biomass production rates higher than the sole phototrophic condition. The strategy includes a first phase replete with the organic substrate (feast) followed by a second phase without organic substrate (famine). By determining the specific growth rate ($\mu_{max}$) of microalgae and bacteria, the feast phase could be designed to avoid excessive contamination, while by studying the different decay behaviour, the famine phase could be designed to avoid excessive reduction in biomass production rate. The applicability of this strategy to two-stage photo-heterotrophic and photo-mixotrophic (under day-night cycles) processes is described to show how the integration with wastewater treatment can be used to boost microalgae biomass productivity while maintaining contamination below threshold values.

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MARIE CURIE ALUMNI

https://www.mariecuriealumni.eu/

## Congress call MCAA 2023

The 2023 conference is scheduled for **24-25 February**
and will be held in **Cordoba**, Spain

The 10th edition of the MCAA Annual Conference will be held in Cordoba, Spain on the 24th and 25th of February 2023, as a hybrid event. It will host plenary speakers, several parallel sessions, poster sessions, and satellite events. The general theme of the 2023 edition is Challenges in Science Diplomacy and Sustainable Development, which will be deepened through a rich programme of plenary and parallel sessions, posters, workshops and satellite events. The MCAA Annual Conference is also a highly effective venue for visibility and developing connections, while meeting some of the best researchers. It offers a unique opportunity at the European level and beyond to network.

# Green Christmas Session

PHOTOSYNTHETIC MICROORGANISMS FOR SUSTAINABLE DEVELOPMENT

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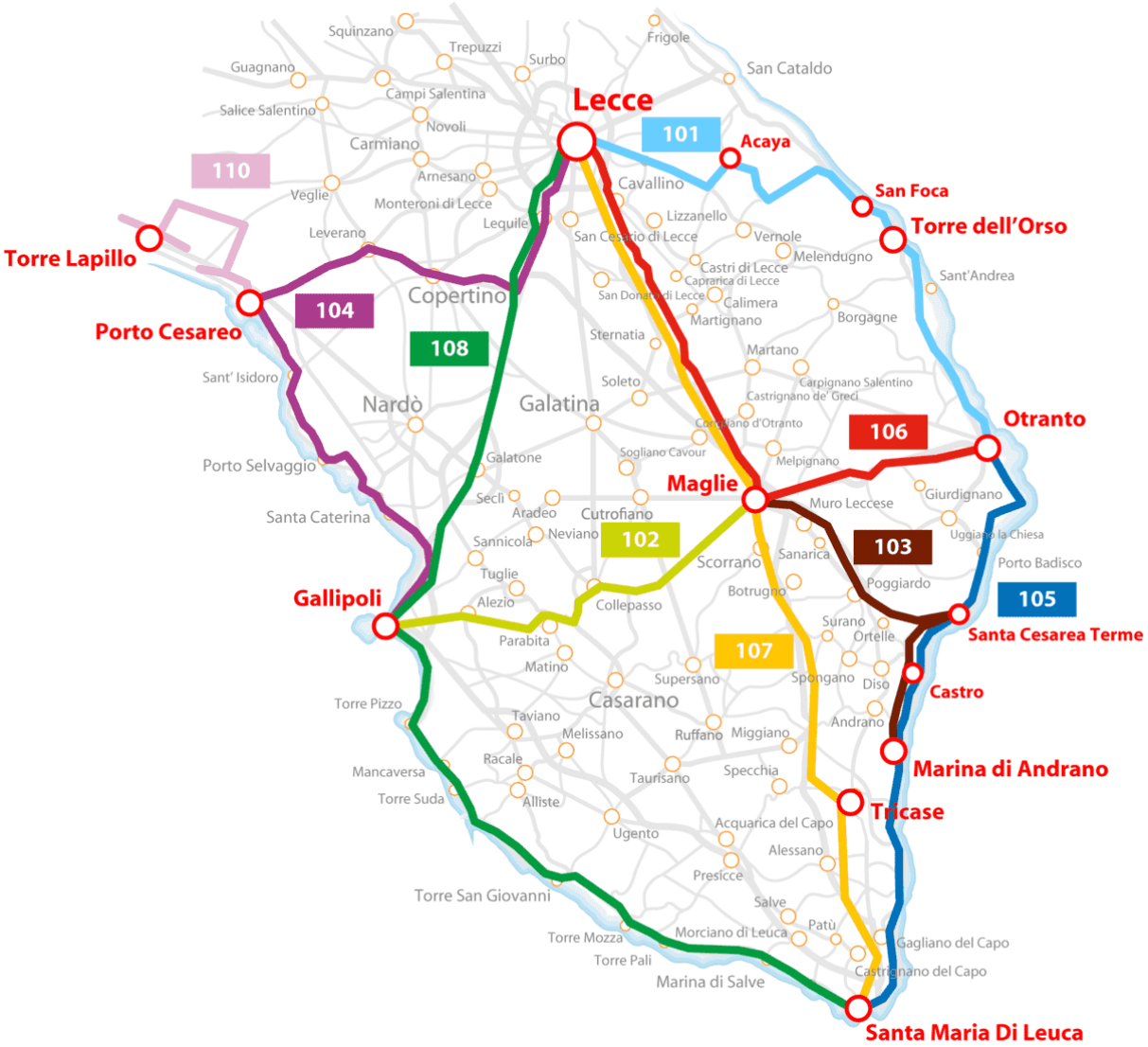
SIFB

http://www.sifb.it/

## Congress call ISFB 2023

The 2023 conference is scheduled for **28-30 June**
and will be held in **Lecce**, Italy.



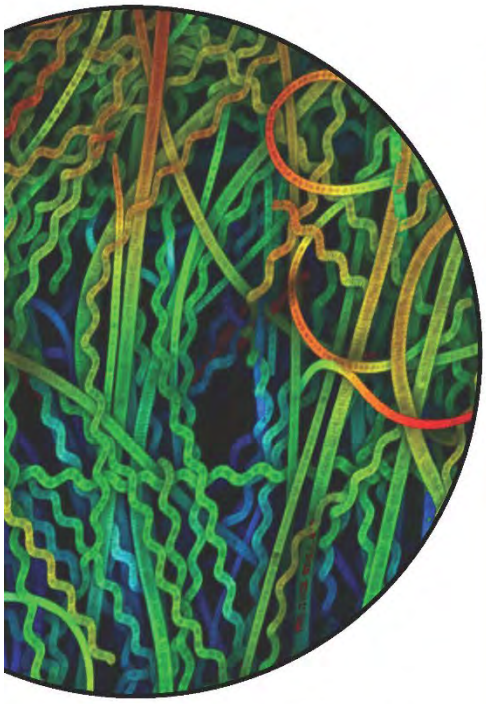
# Green Christmas Session

**PHOTOSYNTHETIC MICROORGANISMS FOR SUSTAINABLE DEVELOPMENT**

2022

AISAM
ASSOCIAZIONE ITALIANA PER LO STUDIO E LE APPLICAZIONI DELLE MICROALGHE

**https://www.aisam-microalghe.it/**



AISAM is a non-profit association that operates in the microalgal field with the aim to promote studies and scientific research, training of young people and to support companies. AISAM fosters interchange and cooperation between academia and enterprises in the production and processing of microalgal biomass to meet the current demand for bio-based technologies and transition to a greener and circular economy.

*https://www.aisam-microalghe.it*