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Chapter 1 : Measuring metabolites in algae one cell at a time

Algal metabolism concerns the biochemical and transport processes by which algae take up nutrients and convert them into the materials needed for growth, reproduction and defence of the organisms. Many of the metabolic processes that occur in algae are common to those found in other living organisms.

Measuring metabolites in algae one cell at a time June 11, , Nara Institute of Science and Technology The photoporation of a fluorogenic aptamer into single microalgae cells shows exactly where the desired metabolite is located. Yoichiroh Hosokawa In the search for new sources of consumables, scientists have come to realize that life itself could be the solution. Metabolic engineers have altered the metabolism of living organisms to make new drugs, biodegradables and biofuels. One of the best examples in modern times is penicillin. Metabolic engineering bacteria has improved the production rate of this drug more than times. A major challenge in this field is identifying which cells are the most productive. It is relatively easy to study bulk populations, which results in information about the metabolism of the overall cell population. However, it remains extremely difficult to identify which cells in the bulk population stand above the rest in terms of metabolite production and are therefore the best to copy and imitate. This identification requires observing the inner processes of individual cells in real time while the metabolite is made. The system combines fluorogenic aptamers with femtosecond laser photoporation. The study is published in Scientific Reports. First, they are extremely adaptive, as they have the ability to live in a broad range of environments, from the equator to the poles and even in heavily saline or polluted waters," says Professor Yoichiroh Hosokawa, who led the study. Normally, scientists use fluorescence microscopy to look inside a cell. This strategy involves attaching a molecule that fluoresces to the metabolite of interest. However, because of cell wall protection, it has been difficult to introduce fluorescent molecules that detect specific metabolites in microalgae cells from outside. Takanori Maeno, who first-authored the study. It can be refined into biofuels," he added. To get the aptamer inside the cell, the scientists shot the cells with laser pulses only femtoseconds long. These pulses created temporary pores big enough for the aptamers to enter. Once inside, the cells turned green only in places where the aptamers bound to paramylon. While the system was only tested on paramylon, Hosokawa states that other metabolites will be detectable with appropriate aptamers. It will be useful for selecting high-performance cells," he said.

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Chapter 2 : Algal Photosynthesis

Fermentation or anoxic metabolism allows unicellular organisms to colonize environments that become anoxic. Free-living unicellular algae capable of a photoautotrophic lifestyle can also use a range of metabolic circuitry associated with different branches of fermentation metabolism.

References Abstract Algal metabolism concerns the biochemical and transport processes by which algae take up nutrients and convert them into the materials needed for growth, reproduction and defence of the organisms. Many of the metabolic processes that occur in algae are common to those found in other living organisms. This commonality is described, but emphasis is given to those major metabolic processes in algae that are unique to, or differ in detail from, those of other organisms. This includes mechanisms of light harvesting, carbon acquisition and aspects of nitrogen N and sulfur S assimilation as well as formation of unique secondary metabolites. In addition the consequences of growth in extreme environments, such as nutrient limitation and exposure to extremes of visible and UV light, for algal metabolism are considered. The exploitation of algal metabolism and its products in biotechnology is also briefly described. Algal metabolism shares many features in common with that of other living organisms but also differs in unique respects. Algal metabolism gives rise to a range of unique compounds, including secondary metabolites, some of which have toxicity to other organisms. Algal metabolism is modulated to a large extent by environmental factors such as nutrient availability and extremes of temperature and light. Algal metabolism can be exploited to produce compounds of biotechnological importance. These include pigments, nutraceuticals and oils for biodiesel. Outline of the pathways of energy, carbon and oxygen in photosynthesis, photorespiration, dark respiration and growth of an alga. No attempt is made to represent stoichiometries. Australian Journal of Plant Physiology Bhattacharya D and Medlin L Algal phylogeny and the origin of land plants. Journal of Phycology Annual Reviews of Plant Biology Gross W Ecophysiology of algae living in highly acidic environments. Functional Plant Biology Molecular Biology and Evolution Journal of Experimental Botany Annual Review of Genetics Progress in Phycological Research Raven JA a Putting the C in phycology. European Journal of Phycology Raven JA b Multiple origins of plasmodesmata. Raven JA Picophytoplankton. Raven JA Inorganic carbon acquisition by eukaryotic algae: Carboxylases, carbon concentrating mechanisms and carbon oxidation cycles. Reinfelder JR Carbon concentrating mechanisms in eukaryotic marine phytoplankton. Annual Review of Marine Science 3: Plant and Cell Physiology An Introduction to Phycology. Their Environment, Biogeography and Ecophysiology.

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Chapter 3 : Cyanobacteria - Wikipedia

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Red algae These groups have chloroplasts containing chlorophylls a and c, and phycobilins. The shape varies from plant to plant; they may be of discoid, plate-like, reticulate, cup-shaped, spiral, or ribbon shaped. They have one or more pyrenoids to preserve protein and starch. The latter chlorophyll type is not known from any prokaryotes or primary chloroplasts, but genetic similarities with red algae suggest a relationship there. In , Samuel Gottlieb Gmelin â€" published the Historia Fucorum, the first work dedicated to marine algae and the first book on marine biology to use the then new binomial nomenclature of Linnaeus. It included elaborate illustrations of seaweed and marine algae on folded leaves. Harvey â€" and Lamouroux [26] were the first to divide macroscopic algae into four divisions based on their pigmentation. This is the first use of a biochemical criterion in plant systematics. Unlike macroalgae , which were clearly viewed as plants, microalgae were frequently considered animals because they are often motile. Throughout the 20th century, most classifications treated the following groups as divisions or classes of algae: Later, many new groups were discovered e. With the abandonment of plant-animal dichotomous classification, most groups of algae sometimes all were included in Protista , later also abandoned in favour of Eukaryota. However, as a legacy of the older plant life scheme, some groups that were also treated as protozoans in the past still have duplicated classifications see ambiregnal protists. Some parasitic algae e. In other cases, some groups were originally characterized as parasitic algae e. Furthermore, groups like the apicomplexans are also parasites derived from ancestors that possessed plastids, but are not included in any group traditionally seen as algae. Relationship to land plants[edit] The first land plants probably evolved from shallow freshwater charophyte algae much like Chara almost million years ago. These probably had an isomorphic alternation of generations and were probably filamentous. Fossils of isolated land plant spores suggest land plants may have been around as long as million years ago. A three-dimensional, multicellular thallus A range of algal morphologies is exhibited, and convergence of features in unrelated groups is common. The only groups to exhibit three-dimensional multicellular thalli are the reds and browns , and some chlorophytes. Some of the more common organizational levels, more than one of which may occur in the lifecycle of a species, are Colonial: The innovation that defines these nonalgal plants is the presence of female reproductive organs with protective cell layers that protect the zygote and developing embryo. Hence, the land plants are referred to as the Embryophytes. Physiology[edit] Many algae, particularly members of the Characeae , [41] have served as model experimental organisms to understand the mechanisms of the water permeability of membranes, osmoregulation , turgor regulation , salt tolerance , cytoplasmic streaming , and the generation of action potentials. Phytohormones are found not only in higher plants, but in algae, too. In these symbioses, the algae supply photosynthates organic substances to the host organism providing protection to the algal cells. The host organism derives some or all of its energy requirements from the algae. Lichen Rock lichens in Ireland Lichens are defined by the International Association for Lichenology to be "an association of a fungus and a photosynthetic symbiont resulting in a stable vegetative body having a specific structure. In nature they do not occur separate from lichens. It is unknown when they began to associate. A photobiont may be associated with many different mycobionts or may live independently; accordingly, lichens are named and classified as fungal species. The photobiont possibly triggers otherwise latent genes in the mycobiont. Lichen thus share some of the habitat and often similar appearance with specialized species of algae aerophytes growing on exposed surfaces such as tree trunks and rocks and sometimes discoloring them. Coral , Coral reef , and Symbiodinium Floridian coral reef Coral reefs are accumulated from the calcareous exoskeletons of marine invertebrates of the order Scleractinia stony corals. These animals metabolize sugar and oxygen to obtain energy for their cell-building processes, including secretion of the exoskeleton, with water and carbon dioxide as byproducts. Dinoflagellates algal protists are often endosymbionts in the cells of the coral-forming marine invertebrates, where they accelerate host-cell metabolism by generating sugar and oxygen immediately available through photosynthesis using incident light and the carbon dioxide produced by the host. Reef-building stony corals hermatypic corals require endosymbiotic algae from the genus Symbiodinium to be in a healthy condition. Sea sponge Endosymbiontic green algae live close to the surface of some sponges, for example, breadcrumb sponges Halichondria panicea. Asexual reproduction permits efficient population increases, but less variation is possible. Commonly, in sexual reproduction of unicellular and colonial algae, two specialized, sexually compatible, haploid gametes make physical contact and fuse to form a zygote. To ensure a successful mating, the development and release of gametes is highly synchronized and regulated; pheromones may play a key role in these processes. Another checklist reports only about 5, species. Regarding the difference of about 15, species, the text concludes: Most of these are listed in List of seaweeds of South Africa. These exclude phytoplankton and crustose corallines. Most estimates also omit microscopic algae, such as phytoplankton. The most recent estimate suggests 72, algal species worldwide. This dispersal can be accomplished by air, water, or other organisms. Due to this, spores can be found in a variety of environments: The spores of freshwater algae are dispersed mainly by running water and wind, as well as by living carriers. Ocean water presents many vastly different habitats based on temperature and nutrient availability, resulting in phytogeographic zones, regions, and provinces. It is, therefore, possible to identify species occurring by locality, such as "Pacific algae" or "North Sea algae". When they occur out of their localities, hypothesizing a transport mechanism is usually possible, such as the hulls of ships. For example, Ulva reticulata and U. Mapping is possible for select species only: Microscopic forms that live suspended in the water column phytoplankton provide the food base for most marine food chains. In very high densities algal blooms , these algae may discolor the water and outcompete, poison, or asphyxiate other life forms. Algae can be used as indicator organisms to monitor pollution in various aquatic systems. Due to this, the species composition of algal populations may shift in the presence of chemical pollutants.

Chapter 4 : Rhodophyta - microbewiki

Received June 11, Although blue-green algae resemble the photosynthetic bacteria in their cellular structure (Echlin and Morris,) one of them (Anabaena variabilis) has been shown (Levin, Lennarz and Bloch,) to have some similarities to both green algae and the photosynthetic tissue of higher plants.

Posewitz Find articles by Matthew C. Grossman Find articles by Arthur R. Received Mar 1; Accepted May 2. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in other forums, provided the original authors and source are credited and subject to any copyright notices concerning any third-party graphics etc. This article has been cited by other articles in PMC. Abstract Fermentation or anoxic metabolism allows unicellular organisms to colonize environments that become anoxic. Free-living unicellular algae capable of a photoautotrophic lifestyle can also use a range of metabolic circuitry associated with different branches of fermentation metabolism. While algae that perform mixed-acid fermentation are widespread, the use of anaerobic respiration is more typical of eukaryotic heterotrophs. The occurrence of a core set of fermentation pathways among the algae provides insights into the evolutionary origins of these pathways, which were likely derived from a common ancestral eukaryote. Based on genomic, transcriptomic, and biochemical studies, anaerobic energy metabolism has been examined in more detail in Chlamydomonas reinhardtii Chlamydomonas than in any other photosynthetic protist. This green alga is metabolically flexible and can sustain energy generation and maintain cellular redox balance under a variety of different environmental conditions. Fermentation metabolism in Chlamydomonas appears to be highly controlled, and the flexible use of the different branches of fermentation metabolism has been demonstrated in studies of various metabolic mutants. Additionally, when Chlamydomonas ferments polysaccharides, it has the ability to eliminate part of the reductant to sustain glycolysis through the production of H2, a molecule that can be developed as a source of renewable energy. To date, little is known about the specific role s of the different branches of fermentation metabolism, how photosynthetic eukaryotes sense changes in environmental O2 levels, and the mechanisms involved in controlling these responses, at both the transcriptional and post-transcriptional levels. In this review, we focus on fermentation metabolism in Chlamydomonas and other protists, with only a brief discussion of plant fermentation when relevant, since it is thoroughly discussed in other articles in this volume. This alga has several metabolic features in common with those of vascular plants, although it also has structures and activities e. Chlamydomonas represents a robust system for probing biological processes with sophisticated molecular tools. The sequencing of all three Chlamydomonas genomes nuclear, chloroplast, and mitochondrion; Lilly et al. Forward and reverse genetic screens have been developed to generate mutant strains with specific phenotypes, or that are disrupted for specific genes Dent et al. Furthermore, we briefly discuss the evolution of the fermentation processes in prokaryotes and non-photosynthetic eukaryotes, but do not discuss plants since other contributions in this volume detail the responses of plants to hypoxic conditions. To achieve this situation, they must use energy to satisfy their metabolic demands, which includes continuous synthesis of the cellular energy currency mostly ATP along with maintenance of redox and ionic balances. Aerobic metabolism is used by several eukaryotic and prokaryotic organisms to efficiently synthesize ATP through oxidative phosphorylation; O2 serves as the terminal electron acceptor of the respiratory electron transport chain Bailey-Serres and Chang, Nevertheless, life in low O2 hypoxia environments, or even in environments totally devoid of O2 anoxia , is common on our planet. Diminished levels of O2 in various biotopes can result from geochemical or physical conditions, including flooding, excess rainfall, and winter ice encasement, but may also be a consequence of high metabolic activity of bacteria in habitats that are not well aerated. While anoxia is often transient, it can also be protracted, extending from diurnal periods, to months or years, and even to millennia or more Grieshaber et al. Furthermore, even though an organism may live in an oxic habitat, it may still perform anoxic metabolism under certain circumstances. For example, in the presence of sufficient levels of a fermentable substrate, many yeast strains will forego using O2 as a terminal electron acceptor and maintain vigorous fermentation of available substrates van Dijken and

Scheffers, ; Pronk et al. These compounds must be re-oxidized in a process involving the transfer of electrons to suitable terminal acceptor molecules, which are then typically secreted. Among eukaryotes, there are only two processes for maintaining redox balance and conserving energy when organisms experience anoxic conditions:

Chapter 5 : Full text of "The metabolism of algae"

The green algae Chlamydomonas reinhardtii as a model system for studying lipid metabolism and functions in photosynthetic organisms For several decades, algae have been intensively used as model photosynthetic organisms for studies of a number of physiological and metabolic processes, e.g., photosynthesis, respiration, nitrogen assimilation.

Deciphering the role of membrane lipid trafficking and remodeling in protection against abiotic stress. Based on these findings novel strategies for the engineering abiotic stress tolerance will be explored. Depending on the findings novel strategies for the engineering abiotic stress tolerance will be explored. Identifying regulatory mechanisms controlling lipid biosynthesis in microalgae. Knowledge gained here will allow us to overcome the inverse relationship between growth and TAG accumulation hampering algal biofuel feedstock production. We expect to gain new insights into photosynthetic carbon partitioning. New target genes for the engineering of TAG biosynthesis in algae and plants will be identified. A sustained effort to build the molecular tool box for Nannochloropsis will ideally position this organism for further biotechnological applications. Exploring lipid biosynthesis in grasses and enhancing the energy density in green tissues. Efforts will initially focus on the exclusive use of the ER pathway for thylakoid biosynthesis in grasses, differences in the function of TGD proteins and the role of chloroplast phosphatidic acid phosphatase in the production of diacylglycerol in grasses. Project Methods In the following the main approaches used to accomplish the individual objectives will be summarized in order of the subobjectives listed above: We will use two strategies to define the lipid substrate transported by the TGD proteins: In vivo tracking of ER-derived lipids. These lines will be crossed with individual tgd mutants to assess the function of the respective protein in acyl group distribution in the respective lines. In vitro reconstitution of lipid import into chloroplasts. We will reconstitute a lipid transfer system with isolated mutant and wild-type chloroplasts to which mutant or wild-type ER microsomes or synthetic liposomes spiked with labeled lipids are added as lipid donors. We have developed a set of highly specific antibodies against the N-terminal and C-terminal portions of the protein that will allow us to determine the topology of SFR2 relative to the membrane and the composition of the native protein complex. Other possible SFR2 activity-modulating factors will be systematically explored to determine the subcellular signals that tie SFR2 activation with its physiological role. Taking cues from the in vitro studies, we will test SFR2 activity in isolated chloroplasts, leaves, and plants to determine how SFR2 may be activated in response to freezing injury or other stresses. We will begin by comparing Arabidopsis and pea, because pea unlike Arabidopsis uses lipid precursors imported from the ER for galactolipid biosynthesis, it is freezing intolerant, and pea chloroplasts are easily isolated. CHT7 is a component of a multiprotein complex that appears to adjust specific transcriptional subnetworks at quiescence entry and exit. Proteins will be immuno-detected on gels where possible, or identified by mass spectrometry in case of novel components. The pgd1 mutant also exhibited a chlorotic phenotype along with an increase in reactive oxygen species following nutrient deprivation, which was rescued by blocking of photosynthetic electron transport at photosystem II. These observations support the current hypothesis of TAG accumulation in nutrient-stressed algae and make the pgd1 mutant an excellent tool to study the physiological role of TAG accumulation following nutrient deprivation and to gain novel insights into the regulation of the photosynthetic electron transport chain and photosynthetic carbon partitioning. Studies will be undertaken to functionally validate key enzymes in lipid metabolism of Nannochloropsis. We will develop and apply gene inactivation strategies for Nannochloropsis, but initially we will rely on the expression of these genes in heterologous hosts for functional characterization. These studies will involve complementation of null phenotypes in yeast or E. For example, a TAG-deficient S. Similarly, yeast and E. Candidate fatty acid desaturase genes will be tested for their capacity to generate novel unsaturated fatty acids upon expression in yeast or other microbial host, as reported for the characterization of the Chlamydomonas? Because Nannochloropsis lipid metabolism is highly efficient, its genes identified as encoding bona fide enzymes or other proteins for energy dense compound synthesis and storage will be used for metabolic engineering studies in Brachypodium for enhanced production of triacylglycerols or for producing novel fatty acid structures. Basic lipid assembly pathways in grasses differ from those of Arabidopsis, as the latter utilizes both the ER and plastid pathways while grasses primarily assemble lipids through the ER pathway. We have mined the data base to identify orthologs of known or predicted Arabidopsis genes in the Brachypodium genome. A limited but significant number of genes appear to be absent in Brachypodium, which include desaturase and acetyl-CoA carboxylase genes. It has also been proposed that plastid phosphatidic acid phosphatase activity is missing in grasses and can explain the differences in the utilization of the ER and plastid pathways in monocots and dicots. We will test this hypothesis by introducing an Arabidopsis plastid phosphatidic acid phosphatase gene into Brachypodium. We will also introduce the Brachypodium TGD1 gene into the respective Arabidopsis tgd1 mutant to test for its functionality in the heterologous system. Since Brachypodium relies exclusively on the import of lipid precursors into the chloroplast for galactolipid biosynthesis, it seems possible that the TGD proteins from Brachypodium are more efficient than those from Arabidopsis to cope with the increased flux. We believe understanding the role of TGD is important for our understanding of lipid metabolism in grass leaves as we attempt to engineer vegetative oil content. A series of new constructs will be produced for introduction and testing in Brachypodium. The Great Lakes Bioenergy Research Center has set up a Brachypodium transformation facility that we are using for all our needs to generate transgenic Brachypodium lines. Focus will be on the expression of algal DGATs and a monocot DGAT alone and in combination with an algal Nannochloropsis lipid droplet protein known to work in plants as recently demonstrated. The latter presents a new strategy in preventing the turnover of lipid droplets. Recent reports by others suggest that coexpression of DGAT and oleosin from plants will enhance oil accumulation in dicot leaves Winichayakul et al. Lipid droplets may be protected from lipases by the presence of lipid droplet proteins, especially if a heterologous lipid droplet protein is used. Students of plant sciences, scientists in academia with focus on plant sciences, scientists in biotech industries with focus on renewable energy and on industrial compounds. Nothing Reported What opportunities for training and professional development has the project provided? Altogether, 5 postdocs, 6 graduate students, 4 undergraduate students, and 1 technician participated in the described projects. Three graduate students are on track to graduate before the end of this year and two postdocs are currently applying for positions and will likely move on during the coming year to new positions. How have the results been disseminated to communities of interest? Asides from the publications reported Benning gave the following public lectures: From membranes to lipid droplets. GRC on Plant Lipids: Deciphering the role of membrane lipid trafficking and remodeling in protection against abiotic stress: PLIP1 based engineering of seed oil content will be explored in Camelina. The role of PLIP2 and 3 lipases in responses of plants towards abiotic stress will be further explored. The reaction mechanism of FAD4 and the role of cofactors in this reaction will be further investigated. The role of a rhomboid protease located in the chloroplast envelope membranes will be further investigated. Identifying regulatory mechanisms controlling lipid biosynthesis in microalgae: A major effort will continue to be on the identification of direct target genes of the CHT7 complex and the composition of the CHT7 complex in synchronized cultures of Chlamydomonas. The origin of ROS in the Chlamydomonas pgd1 mutant will be explored. Exploring lipid biosynthesis in grasses and enhancing the energy density in green tissues: The analysis of transgenic Brachypodium lines expressing different genes to enhance vegetative oil accumulation will be completed. We will complete the analysis of transcription factors interacting with WRI1. Impacts What was accomplished under these goals? We showed that PLIP1 releases acyl groups from a specific chloroplast phosphatidylglycerol species that contains a PLIP1 is primarily acting in developing embryos. The findings provide a new avenue to engineer seed oil yield. We were able to produce recombinant PLIP2 and assay its activity. We were unable to produced recombinant PLIP3. Individual and double and triple PLIP mutants have been produced and their analysis continues. In addition, we produced over expression line. These are impaired n growth which can be attributed to an over active defense response due to the accumulation of oxylipins. Loss of this lipid in the fad4 mutant reduces seed oil content. We identified a new protein cofactor required for the activity of this protein. Coevolution analysis showed that this loop provides an interaction domain with the TGD2. This study provides a detailed mechanistic insight into the different usage of plastid and ER-pathway of lipid assembly in monocotyledonous and dicotyledonous plant species. The phenotype of the respective mutant suggests that the protein affects lipid trafficking between the ER and the chloroplast. Key findings from this study were that a fraction of phosphatidylglycerol in the chloroplast is derived from imported lipid precursors and that acyl editing on chloroplast lipids is extensive. A paper describing these results is under review. A detailed phenotypic analysis of the cht7 mutant cells has shown that the cht7 mutation causes loss of viability during nutrient deprivation induced quiescence, a phenotype that could not be properly ascertained in the original cell wall compromised mutant background. Furthermore, meiotic viability was compromised in the cht7 mutant following mating. Cell cycle genes are misregulated during nutrient deprivation induced quiescence in the mutant. A manuscript describing these findings has been nearly completed. Using these conditions, we are in the process of generating RNAseq and ChIPseq data sets during different stages of the cell cycle. Furthermore, we have begun to analyze the composition and properties of the CHT7 complex during the cell cycle. The mutant showed increased abiotic stress sensitivity, altered chlorophyll fluorescence and composition of the photosynthetic apparatus. A paper describing these results is under revision. Moreover, we discovered that the algal cells enter the fungal hyphae and are viable and dividing. In essence we were able to observe the initial steps of an endosymbiotic event reproducibly in the test tube. A paper describing this new system is under revision. This work has been completed and published. It was shown that WR1 Affects auxin homeostasis in roots. A paper describing these results was published. The focus is currently on two transcription factors to determine their mode of interaction with WRI1. Nannochloropsis, a rich source of diacylglycerol acyltransferases for engineering of triacylglycerol content in different hosts. A toolkit for Nannochloropsis oceanica CCMP enables gene stacking and genetic engineering of the eicosapentaenoic acid pathway for enhanced fatty acid production Plant Biotech J. A plastid phosphatidylglycerol lipase contributes to the export of acyl groups from plastids for seed oil biosynthesis. The Plant Cell

Chapter 6 : Algal Metabolism

Algal metabolism concerns the biochemical and transport processes by which algae take up nutrients and convert them into the materials needed for growth, reproduction and defence of the organisms.

Published online Nov Find articles by Yngvar Olsen Martin F. Find articles by Martin F. Find articles by Olav Vadstein Atle M. Find articles by Atle M. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution license http: This article has been cited by other articles in PMC. Based on recent transcriptome data a co-expression network of genes involved in lipid metabolism has been created. A future industrialization will depend on optimization of chemical compositions and increased biomass production, which can be achieved by exploitation of the physiological potential, by selective breeding and by genetic engineering. Phaeodactylum tricornutum, long chain polyunsaturated fatty acid synthesis, metabolic engineering, elongases, desaturases, acyl-CoA synthetases, acyltransferases 1. Introduction Long chain polyunsaturated n-3 fatty acids LC-PUFAs are of increasing interest, due to their many positive effects for human health and their use as feed for fish farming. Most fishes cannot produce n-3 LC-PUFAs themselves, but are channelled up the marine food chain, with microalgae as the primary producers [1]. Therefore, it is not surprising that marine microalgae have been targeted as potential candidates for industrial production of n-3 LC-PUFAs such as eicosapentaenoic acid EPA, Many of the n-3 LC-PUFA-producing algae belong to the Chromista kingdom, a diverse group of microorganisms that includes divisions like cryptomonads, haptophytes and heterokonts [6]. The classification is based on the hypothesis that chloroplasts of all Chromista arose from a single secondary endosymbiotic event between a eukaryote and a red alga-like organism [6 , 7]. Interestingly, the heterotrophic thraustochytrid, also belonging to Chromista, have lost their photosynthetic capacity but have retained a vestigial chloroplast and their ability to synthesize and store n-3 LC-PUFAs, as chloroplasts are the site of lipid synthesis in alga. At present, mostly thraustochytrids like Schizochytrium spp. The close relationship between the thraustochytrids and photosynthetic microalgae of the Chromista kingdom suggests a high potential for these microalgae as an alternative n-3 LC-PUFA source in the future. Additionally, algae have advantages such as consuming carbon dioxide, growing in salt water on marginal land and thereof no compete with the agriculture industry or freshwater use [10]. The major genera of commercial microalgae are to date Chromista [11 , 12 , 13]. EPA-producing heterokonts include the photoautotrophic commercial-used Nannochloropsis spp. Whereas DHA-producers include Isochrysis galbana [11 , 18] and the thraustochytrids Aurantochytrium spp. Exposing the algae to environmental stresses such as nitrate starvation [17], increased salinity [20], changes in light intensity [15] or variations in the amount and composition of carbon [14 , 20] can increase both lipid synthesis and accumulation and also the composition of n-3 LC-PUFAs themselves. Several recent reviews have dealt with this topic for different algae [9 , 21 , 22 , 23 , 24 , 25]. For instance, the eustigmatophyceae Nannochloropsis has under mild growth conditions an EPA content of 1. To improve the n-3 LC-PUFAs or the lipid bodies, triacylglycerides TAGs , productivity in algae two main strategies exist; 1 Increase the content of desired lipids per unit of biomass and 2 Increase the biomass density of the given strain to maximize biomass per culture volume or area. These high level skill approaches have advantages and disadvantages, while genetic engineering requires significant resources in establishing a suitable transformation of functional plasmids, selection processes require a sustainable breeding and selecting program [21 , 22]. A combination of approaches like metabolic engineering and selective breeding have been shown to be successful in plants by genetic engineering of n-3 LC-PUFAs and classical mutation strategies to bypass bottlenecks [23 , 24 , 25]. Successful approaches must be based on identification of genetic drivers influencing both qualitative and quantitative aspects of the lipid metabolism in Chromista. Even though genetic drivers are applicable for different approaches, we will in this review focus on the metabolic engineering approach because it has been discussed by Khozin-Goldberget al. Genomic data have been analyzed and a co-expression network has been assembled. Several pathways have been predicted and candidate genes and bottlenecks were identified in order to find strategies for improve the n-3 LC-PUFAs in commercially used Chromista such as Nannochloropis or Isochrysis. In doing so, we have identified and compared parts of the known EPA and DHA pathways of biotechnological important Chromista species which differ from the lipid pathway of P. Humans have the capability to synthesize EPA The membranes of the brain contain high amounts of ARA Positive effects include anti-viral, anti-bacterial and anti-fungal effects [42 , 43]. These benefits appear to be related to the alternations of fluidity in membrane phospholipids composition and function, gene expression and eicosanoid production [44]. In general, it is recommended to increase the dietary n-3 FAs intake for the human population, but the recommendations vary in different countries because of different dietary background and cultural traditions [45 , 46]. EPA-derived eicosanoids have potent anti-angiogenic effects, whereas ARA-derived metabolites have pro-angiogenic effects. A high percentage of n-3 FAs, e.

Chapter 7 : Details - The metabolism of algae. - Biodiversity Heritage Library

The ever-growing body of complete genome information of phototrophic prokaryotes and algae provides an unprecedented data source to explore their metabolic capabilities which have already led to new and surprising metabolic findings.

Algae have a wide range of antenna pigments to harvest light energy for photosynthesis giving different types of algae their characteristic colour. Early work done with algae contributed much to what is presently known about the carbon dioxide fixation pathway and the light harvesting reactions. The processes of photosynthesis in algae and higher plants are very similar. Algae are proposed to play a role in the global carbon cycle by helping remove excess carbon dioxide from the environment. Recently, algae are recognized as a promising biodiesel source due to its efficient absorption and conversion of solar energy into chemical energy. Algal photosynthesis account for almost half of the photosynthetic carbon fixed every year. Scientists have utilized different algal species including algal mutants to study different aspects of photosynthesis. The major antenna pigments in algae include chlorophylls, phycobiliproteins and carotenoids and the variation in the composition and relative abundance of these pigments give algae their distinctive colour. Antenna complexes are proteins with many bound antenna pigments which are important in absorbing light energy. Algal photosynthesis is thought to increase with increase in nutrient, that is, N, P and Fe availability. If the algal photosynthesis would increase more carbon dioxide would be removed from the environment. Algae grow faster and are very efficient in absorbing and converting solar energy into chemical energy which is mainly in the form of triacylglycerols. General scheme of algal photosynthesis showing the separation of the electron transport chain and the Calvin Cycle. General arrangement of antenna complexes in algae. In green algae as well as in higher plants a the antenna complex is in the membrane and associates with the photosystem in the membrane. In red algae and cyanobacteria b the antenna complex is a phycobilisome and is a soluble protein. The phycobilisome attaches to the photosystem where the photosystem extends from the membrane. SeaWiFS satellite image showing chlorophyll content in the ocean. This image was an average of images taken in June The bright green and yellow colours indicate high levels of chlorophyll. Archives of Microbiology Journal of Phycology Gantt E Phycobilisomes. Annual Review of Plant Physiology Raven J Inorganic carbon acquisition in marine autotrophs. Advances in Botanical Research

Chapter 8 : Fermentation metabolism and its evolution in algae

"Algae have a number of attractive qualities for metabolic engineering. First, they are extremely adaptive, as they have the ability to live in a broad range of environments, from the equator to.

Many cyanobacteria form motile filaments of cells, called hormogonia , that travel away from the main biomass to bud and form new colonies elsewhere. To break away from the parent colony, a hormogonium often must tear apart a weaker cell in a filament, called a necridium. Each individual cell each single cyanobacterium typically has a thick, gelatinous cell wall. In water columns, some cyanobacteria float by forming gas vesicles , as in archaea. They are not bounded by lipid membranes , but by a protein sheath. Ecology[edit] Cyanobacterial bloom near Fiji Cyanobacteria can be found in almost every terrestrial and aquatic habitat â€" oceans , fresh water , damp soil, temporarily moistened rocks in deserts , bare rock and soil, and even Antarctic rocks. They can occur as planktonic cells or form phototrophic biofilms. They are found in almost every endolithic ecosystem. Some live in the fur of sloths , providing a form of camouflage. The blooms can have the appearance of blue-green paint or scum. These blooms can be toxic , and frequently lead to the closure of recreational waters when spotted. Marine bacteriophages are significant parasites of unicellular marine cyanobacteria. For this reason blooms of cyanobacteria seldom occur in rivers unless the water is flowing slowly. Growth is also favored at higher temperatures, making increasing water temperature as a result of global warming more problematic. At higher temperatures Microcystis species are able to outcompete diatoms and green algae. This is a concern because of the production of toxins produced by Microcystis. This can lead to serious consequences, particularly the contamination of sources of drinking water. Cyanobacteria can interfere with water treatment in various ways, primarily by plugging filters often large beds of sand and similar media , and by producing cyanotoxins which have the potential to cause serious illness if consumed. Consequences may also lie within fisheries and waste management practices. Anthropogenic eutrophication , rising temperatures, vertical stratification and increased atmospheric carbon dioxide are contributors to cyanobacteria increasing dominance of aquatic ecosystems. It has been widely reported that cyanobacteria soil crusts help to stabilize soil to prevent erosion and retain water. The tiny marine cyanobacterium Prochlorococcus was discovered in and accounts for more than half of the photosynthesis of the open ocean. They are the most genetically diverse; they occupy a broad range of habitats across all latitudes, widespread in freshwater, marine, and terrestrial ecosystems, and they are found in the most extreme niches such as hot springs, salt works, and hypersaline bays. Carbon fixation[edit] Cyanobacteria use the energy of sunlight to drive photosynthesis , a process where the energy of light is used to synthesize organic compounds from carbon dioxide. Because they are aquatic organisms, they typically employ several strategies which are collectively known as a "carbon concentrating mechanism" to aid in the acquisition of inorganic carbon CO_2 or bicarbonate. Among the more specific strategies is the widespread prevalence of the bacterial microcompartments known as carboxysomes. It is believed that these structures tether the CO_2-fixing enzyme, RuBisCO , to the interior of the shell, as well as the enzyme carbonic anhydrase , using metabolic channeling to enhance the local CO_2 concentrations and thus increase the efficiency of the RuBisCO enzyme. While the goal of photosynthesis is to store energy by building carbohydrates from CO_2, respiration is the reverse of this, with carbohydrates turned back into CO_2 accompanying energy release. Cyanobacteria appear to separate these two processes with their plasma membrane containing only components of the respiratory chain, while the thylakoid membrane hosts an interlinked respiratory and photosynthetic electron transport chain. In contrast to green sulfur bacteria which only use one photosystem, the use of water as an electron donor is energetically demanding, requiring two photosystems. In some cyanobacteria, the color of light influences the composition of the phycobilisomes. Thus, the bacteria appear green in red light and red in green light. A few genera lack phycobilisomes and have chlorophyll b instead Prochloron , Prochlorococcus , Prochlorothrix. These were originally grouped together as the prochlorophytes or chloroxybacteria, but appear to have developed in several different lines of cyanobacteria. For this reason, they are now considered as part of the cyanobacterial group. Carbon dioxide is reduced to form carbohydrates via the Calvin cycle. They are known to have evolved from cyanobacteria through endosymbiosis , i. In this case, a photosynthesizing cyanobacteria that was engulfed in some ancient eukaryotic cell. The cyanobacterial origin of plastids is now supported by various pieces of phylogenetic , [65] [57] [60] genomic , [66] biochemical [67] [68] and structural evidence. In other words, all the oxygen that makes the atmosphere breathable for aerobic organisms originally comes from cyanobacteria or their later descendants. Cyanobacteria possess numerous E. For bacterial transformation to take place, the recipient bacteria must be in a state of competence , which may occur in nature as a response to conditions such as starvation, high cell density or exposure to DNA damaging agents. In chromosomal transformation, homologous transforming DNA can be integrated into the recipient genome by homologous recombination , and this process appears to be an adaptation for repairing DNA damage. The first three â€" Chroococcales , Pleurocapsales , and Oscillatoriales â€" are not supported by phylogenetic studies. The latter two â€" Nostocales and Stigonematales â€" are monophyletic, and make up the heterocystous cyanobacteria. The classic taxonomic criterion has been the cell morphology and the plane of cell division. In Pleurocapsales, the cells have the ability to form internal spores baeocytes. The rest of the sections include filamentous species. In Oscillatoriales, the cells are uniseriately arranged and do not form specialized cells akinetes and heterocysts. Stigonematales, unlike Nostocales, include species with truly branched trichomes.

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Summary. Carbohydrates and their immediate derivatives have a number of roles related to photosynthesis in algae (including Cyanobacteria). In the form of phosphorylated sugars, carbohydrates are major intermediates in the photosynthetic carbon reduction cycle and the photorespiratory carbon oxidation cycle.

Taxonomy Genome Description and Significance There are between 2, and 6, species of Rhodophyta; it is a moderately diverse classification. They are an ancient group of organisms; fossil records place them in the mid-proterozoic. It is believed that Rhodophyta were among the first multicellular organisms. In their research on single-celled apicomplexan parasites, Coppin et. Their evidence suggests that the two organisms evolved from cells with similar UDP-glucose-based metabolisms. Genome Structure There are many different species within Rhodophyta, and all have different genome structures. The first plasmid genome from Rhodophyta that was sequenced was the species Gracilaria tenuistipitata var. The sequencing was completed by Hagopian et. They found that this plasmid contained predicted genes, as well as a copy of the ribosomal RNA operon. They noted that this species maintains an ancient gene content. Cell Structure and Metabolism The Wall: Rhodophyta Directory by Michael Gretz Most Rhodophyta are multicellular organisms, although a few are unicellular or colonial. Rhodophyta are pigmented with phycoerythrin, phycocyanin and allophycocyanins. These pigments are found in phycobilisomes. Rhydophyta do not have any flagella or centrioles. Nor do they have chloroplast endoplasmic reticulum. Rhodophyta have unstacked thylakoids in plastids. Some species have pit connections between cells. In their research on cell wall composition on certain species of Rhodophyta, Youngs et. They believe this adaptation is partially facilitated through changes in cell wall chemistry. Rhodophyta are autotrophic, obtaining and storing floridian starch from photosynthesis. Rhodophyta tend to reproduce sexually. Life cycles tend to be diplohaplontic, with alternation between haploid and diploid stages. However, this is not the case with all species. Porphyra nereocystis, for example, has a heteromorphic alternation of generations. Sexual reproduction is oogamous; it involves non-motile spermatia and closed mitosis. Tetraspores are produced in the tetrasporangia during meiosis. If asexual reproduction occurs, it does so through aplanospores. Red Algae by D. Rhodophyta are aquatic organisms that exist in both freshwater and marine habitats, although mostly marine. They are found in tropical, temperate, and cold-water environments. Rhodophyta tend to live at greater depths of water than Charophyta and Chlorophyta. This is because Rhodophyta pigments absorb blue light, which penetrates water to a greater depth than other wavelengths. Rhodophyta are primary producers. They provide habitats for other aquatic organisms. In addition, Rhodophyta play an important part in the establishment and maintenance of coral reefs. Those species found in coral reefs are called coralline algae; they secrete a shell of carbonite around themselves. Rhodophyta are also farmed and harvested for use in food and gels. Sheets of red algae are toasted and used to wrap sushi. Rhodophyta are also used to make nori. Dried nori can be eaten alone, or used in sushi. Rodophyta are rich in protein and vitamins, which makes them especially useful for food. Cultivation of Rhodophyta is a fairly simple process which began in Japan over years ago. One of the ways in which Rhodophyta have to adapt to their aquatic environments is in terms of wave action. Previous research suggested that Rhodophyta are constant in strength when it comes to facing the drag caused by waves. In their examination of Mastocarpus papillatus, Kitzes and Denny showed that these responses are not uniform. Mastocarpus papillatus groups react based on whether or not their sites are exposed or protected. Rhodophyta do not all behave the same way; instead, they adjust their responses based on the immediate conditions of their environment. Rhodophyta have medical purposes. Their objective was to determine whether or not living cells would grow on the granule. The results of their experiment showed that the cells had high viability, meaning that this compound has capabilities for bone engineering. In addition, Rhodophyta are useful for the study of metabolic pathways, cell biological processes, and genetics. One species that is particularly useful for research is Galdieria sulphuraria because of its metabolic versatility. A mix of sushi and nori. Thai-Nichi Industries Company Limited.