Comments to the presentation "SAR_01" for Botany of Non-vascular Plants

01
- one of the current schemes of eukaryotic phylogenetic structure
- for our purpose, it is important to note that ecologically very important algae with secondary plastids originating from red algae belong to several non-monophyletic deep lineages (Stramenopiles, Haptophyta, Cryptophyta, etc.)

02
- another such scheme, shows the same thing
- while "plants" (Archaeplastida) are monophyletic, secondarily phototrophic algae are not

03
- repetition of this simple and well known scheme, just to be sure that everybody knows what primary and secondary endosymbioses are...

04
- once again this picture; this time it needs to be stressed that secondarily phototrophic algae with secondary rhodoplasts (i.e. originating from Rhodoplantae) belong to dominants of global phytoplankton (haptophytes, diatoms, dinoflagellates)
- they mostly dominate in colder, nutrient-rich parts of the ocean

05
- thus, nowaday, in the ocean secondarily phototrophic groups hugely outnumber the primarily phototrophic groups (archaeplastids) - this is shown at a scheme in the right part of the slide

06
- however, in the Proterozoic (i.e. approximately the first half of the Phanerozoic, at all) the situation was different; "acritarchs", i.e. protists and other microorganisms dominating proterozoic ocean were probably mostly originating from groups like Archaeplastida or sister lineages, possibly with primary plastids

07-09
- interestingly, and importantly, evolutionary diversification of most important lineages with secondary rhodoplasts falls into the time when Paleozoic abruptly ended with the Permian-Triassic extinction event that turned the global ecosystems upside down
- huge changes in oceanic systems led to evolution of the "modern" secondarily phototrophic groups in the Mesozoic (coccolithophorids, diatoms, etc.)

10-12
Permian-Triassic extinction event is mostly ascribed to a catastrophic increase in volcanic activity at about 251 mya
- accompanying environmental changes led to desctruction of the Paleozoic oceanic ecossytems (temperature fluctuations, acidification, loss of oxygenated habitats)

13
- haptophytes are the first of these important groups
- they are all unicellular flagellates, their typical structure is haptonema, which is a microtubular structure between their two flagella, it may rudimentary or prominent and may serve for "catching" bacteria from an environments
- they are often mixotrophic, i.e. besides photosynthesis they also acquire organic compounds and nutrients from the environment

14
- two clases of Haptophyta; coccolithophorids are the most important members of Cocolithophyceae

15
- here they are; they are a lineage of flagellates with invariably cells covered with calcite scales (coccoliths)

- due to this feature and their abundance in oceans, coccolithophorids are one of the most important microorganisms in the global ecosystems; the main reason is that they transport inorganic carbon dissolved in the water from the sea surface to deeper portions (after their death, the cells sink and their calcit shells sink with them, too)
- the haploid and diploid stages have different types of coccoliths (holo-, and hetero-)

16
- hypotheses about the reason why the calcite scales evolved differ but the most accepted one suggests that it is because they serve as a protection against the herbivores
- diploid stage tends to produce huge population numbers (white tides) in the oceanic phytoplankton
- interestingly, their switch into the flagrllated, haploid stage is triggered by a virus that attacks the diploid cells only (they release chemical signal for other diploid cells to do their meiosis quickly to escape the disease)

17
- here, we see once again the global phytoplankton patterns; haptophytes are depicted in blue

18
- white tides formed by extremely large populations of coccolithophorides mostly occur in nutrient-rich shallow and colder seas

19
- the most abundant recent species in E. huxleyi

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- it is, in fact, a species complex formed by a number of closely similar phylogenetic lineages

21
- here, we see three other abundant species
- we see that the oldest recent species date from the beginning of the Tertiary (palaeogene); Mesozoic haptophytes had largely different species composition
- morphological diversity of coccoliths enables their identification both in the living samples and in the fossil record

22
- there are also some interesting calcified taxa in the order Braarudosphaerales that is non-monophyletic with other coccolithophorides
- this order is typical with so called pentaliths; the diploid cells are almost precise dodecahedrons (one of the Platonic solids)

23
- now some (very brief) information to the role of coccolithophorides on global carbon cycle

24
- of course, we know that the Earth climate is largely influenced by CO_2 concentration in the athmosphere
- during the Cenozoic (Tertiary), global temperature has largely been decreasing from the very warm Eocene to relatively cold Pleistocene

25
- coccolithophorides catch HCO_3^- in the oceanic water; however, for each molecule incorporated into the coccoliths ($CaCO_3$), another one is released back into the athmosphere as CO_2
- thus, intense calcification leads to decreased dissolved carbon in the oceanic water and (counterintuitively) to increased CO_2 in the atmosphere
- however, this $CaCO_3$ sinks and goes into the deep parts of the ocean (so called "biological carbonate pump"); the lowered HCO_3^- levels in the surface ocean enable its higher capture from the atmosphere; in the (hypothetical) absence of the biological pump the ability of the ocean to capture the atmospheric CO_2 would be substantially decreased

26

- some non-calcified haptophytes are very important for the global climate, as well
- one example is this colonial genus - Phaeocystis
- these algae (and other haptophyte and marine algae) produce large quantities of dimethylsulfopropionates in their cells that decompose to dimethysulfide and go into the atmosphere
- there, they form SO2 that acts as a nucleation agent for atmospheric H2O, which leads to increased cloud formation with all the key effects for glocal and lobal climate

27
- most non-calcified haptophytes look prety inconspicuously, like Chrychromulina, which, however, is extremely diversified with, possibly, hundreds or thousands of genotypes (species)

28
- cryptohytes are another flagellated group with secondary rhodoplasts
- they are especially interesting due to presence of nucleomorphs (residual nucleus of the red algal endosymbiont)
- they are also mixotrophic (preying on bacteria)

29
- members of this lineage inhabit various planktonic habitats from mesotrophic freshwater lakes or rivers to oceanic shelves

30
- dinoflagellates are a (largely) photrophic group of flagellates belonging to Alveolata
- they are typical by cell covering made by organic plates and cells typically divided into thwo (unequal) halves dividied by the so called equatorial groove
- most of them lives in the oceanic phytoplankton (where they can be one of the dominants, especially in the shelf seas)

31
- interestingly, they have had quite tangled plastid evolution
- in some species, they did not retain their original secondary rhodoplast and acquired tertiary plastids from different groups (such as diatoms or cryptophytes)

32
- Dinophysis is a genus typical for phytoplankton of many European seas, such the Baltic Sea or Mediterranean Sea
- this is the genus with tertiary plastids based on the cryptophyte endosymbiont

33
- Ornithocercus is predominantly a tropical genus that has lost plastids, at all; it also possesses nostocalean endosymbiont; not for photosynthesis but for nitrogen acquisition from the atmosphere

34
- two freshwater genera; Gymnodinium may also have cyanobacterial endosymbionts; it is also typical by very thin cell covering (therefore the name - "gymno-")

35
- Ceratium is a huge genus with species mostly in the marine plankton and (a few also) in the freshwater habitats (like Vltava river in Prague)
- cellular processes are supposed to act as a defense against the herbivores

36
- one of the interesting features of many dinoflagellates is their bioluminiscence; Noctiluca is especially well known for this phenomenon

37
- dinoflagellates in the marine habitats may also form (red) tides that may be toxic for fish and other animals
- Alexandrium is one of the taxa known for their toxicity

38
- finally, a single lineage of dinoflagellates, Symbiodinium, is typical by the endosymbiotic life style
- it lives as an symbiont in foraminiferans, some other protists, and also in scleractinian corals; in this way they make them functionally phototrophic, which has significantly contributed to their evolutionary radiation and wide geographic distribution
- coral bleaching, triggered by temperature extremes, is caused by mass release of Symbiodinium cells from the corals

39-40
- now, we come to stramenopiles; a lineage with most algal classes with secondary rhodoplasts

41
- phylogenetic structure of stramenopiles is quite complex but we will concentrate on the ecologically or biotechnologically important groups

42
- chrysophytes is one such lineage; they mostly live in the freshwater phytoplankton and they can dominate the community, especially in the oligo- and mesotrophic conditiona (large lakes, alluvial pools, clean rivers, peatland pools)
- these algae are usually flagellates and some of the most frequent taxa have cell covering made by silica dioxide scales
- they also form cysts made of silica dioxide (they can survive in the sediment for at least tens of years)

43-46
- Mallomonas (single cells) and Synura (colonial) are the genera typical by production of these scales
- they are hugely morphologically diversified and this has allowed for taxonomic description of more than 150 species of these algae

47
- some chrysophytes do not live as flagellates
- Hydrurus forms elongated mucilaginous colonies in flowing waters (streams, waterfalls)

48
- Dictyochophyceae is another (marine) planktonic, flagellated group producing silica dioxide structures
- in this case, it is a siliceous skeleton
- these algae can be quite abundant in the phytoplankton of cold seas (e.g. northern Atlantic)

49-51
- diatoms are another extremely important microalgal group
- they often dominate in the oceanic and freshwater phytoplankton; in addition, they usually dominate the microphytobenthos communities
- it has been estimated that about 15% of the global primary production is due to diatoms (mostly those living in the marine phytoplankton)
- diatoms invariably possess siliceous cell covering called frustule
- frustules tend to have complex and variable morphologies; this has led to description of literally thousands of diatom species; however the estimated diversity is even higher, possibly close to 100 000 species, most of them still undescribed

52-54
- frustules are composed of tho halves - a bit like a Petri dish; during reproduction the cell always produces the smaller half; this leads to continuous decrease in cell size during asexual reproduction
- therefore, from time to time, sexual process is necessary to establish the original cell size
- there are two basic sexual reproduction types - oogamy, typical for centric diatoms, and isogamy, typical for pennate diatoms

55
- here, we see the basic phylogenetic structure of diatoms
- the blue group, pennate diatoms, are evolutionarily younger and monophyletic

- the orange group (centric diatoms) is paraphyletic, plesiomorphic (evolutionarily more ancestral)

56
- here, the same phylogeny is shown in a different picture with presumed time frame of individual important evolutionary novelties
- we see the Mesozoic origin of most these structures
- how young are the diatoms! (for example, in comparison with red algae, etc.)

57
- here we see the asexual diminution cycle mentioned above

58
- pennate diatoms in left, centric in right

59
- diatoms are species-rich, there are extraordinary numbers of species but most of the are still undescribed
- the reason for that is that they are morphologically "hidden" within traditional taxa
- in some model taxa - like this Sellaphora pupula, which lives in the phytobenthos of lakes and ponds - it has been illustrated that there are possibly more than 100 phylogenetic species hidden within this single traditional species
- in the picture we see six species belonging to "Selaphora pupula" discovered in a single small lake

60
- each of these cells represents different species " S. pupula complex; just look at the morphological similarity of these species

61
- once again, diatoms in the oceanic phytoplankton - mostly the nutrient-rich parts of the global ocean

62
- here we see some typical examples of centric diatoms
- in most cases, they have circular frustules (in the polar view - from the top)

63
- and the pennates; mostly biradial frustules
- in some cases they are colonial - lower three genera
- in some cases, the longitudinal axis may be considerably curved (Cymbella)

64
- some genera live as epiphytes on mucilaginous stalks (Gomphonema)
- some are typical by pronounced transversal asymmetry (Gyrosigma)
- the genus Eunotia is typical by pronounced dorsiventral asymmetry of frustules