BDC223: Pigments and Photosynthesis

… pigments?

New Light on Seaweeds

Recent studies have forced reassessment of the role of light-harvesting pigments in depth zonation of seaweeds

Mary Beth Saffo

Bioscience 37: 654-664 (1987).

PHOTOSYNTHETIC ACTION SPECTRA OF MARINE ALGAE*

BY F. T. HAXO‡ AND L. R. BLINKS

(From the Hopkins Marine Station of Stanford University, Pacific Grove)

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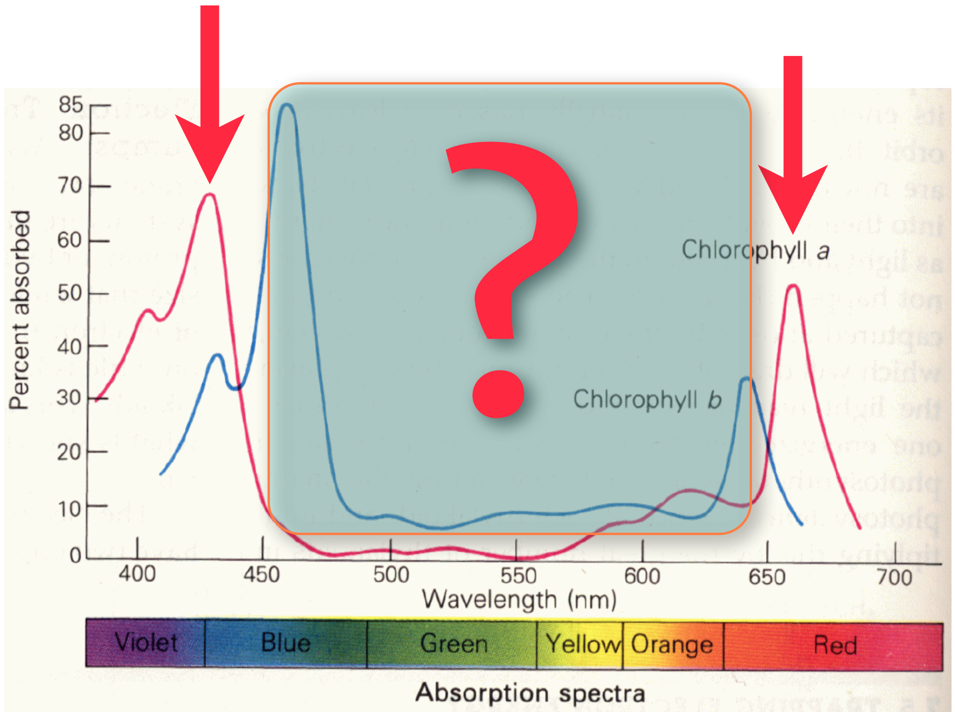
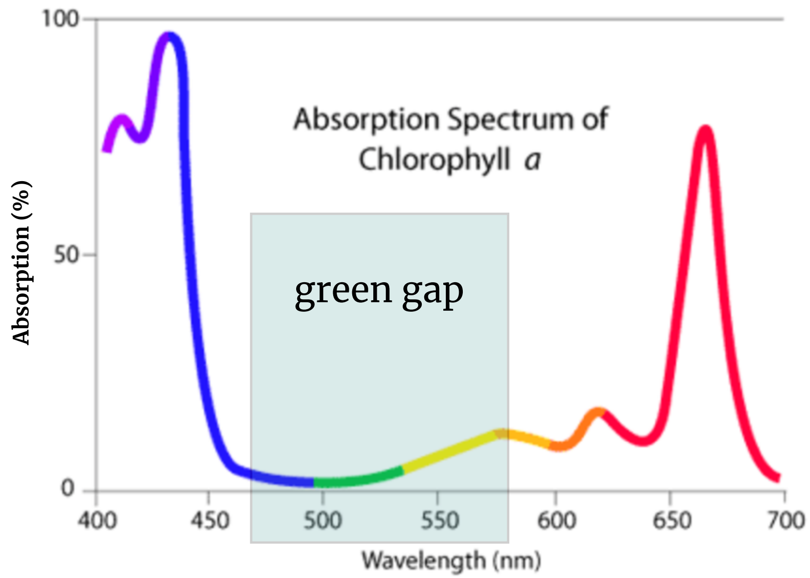
- In order to fully utilise all available light energy, algae and plants have a range of accessory photosynthetic pigments in addition to chlorophyll-*a*.
- All primary producers use chlorophyll-*a* to convert light energy into a chemical form. Chl-*a* is the only pigment that can provide the chemical energy necessary for photosynthesis. It is contained within the light-harvesting complexes, together with other pigments.
- Chl-a have absorption peaks situated mainly at 440 nm (blue light) and 675 nm (red light) allowing primary producers to absorb light in all habitats, terrestrial or marine.
- [see Fig. 4.1, Lobban and Harrison (1994), p. 125 for absorption spectra]

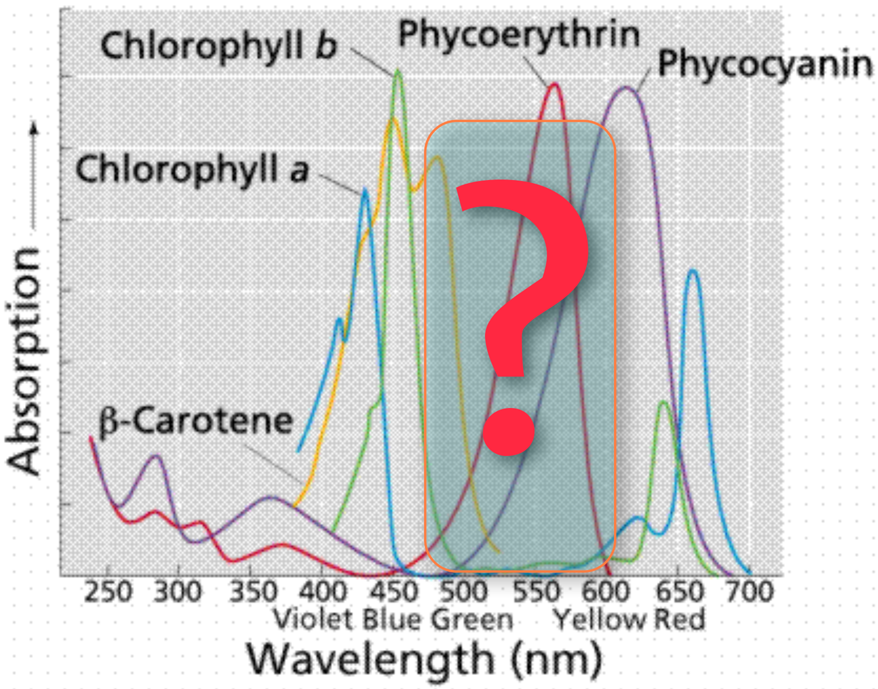


Percent absorbed
85
80
70
60
50
40
30
20
10
0
400
450
500
550
600
650
700
Wavelength (nm)
Chlorophyll a
Chlorophyll b
?
Violet
Blue
Green
Yellow
Orange
Red
Absorption spectra



Absorption Spectrum of
Chlorophyll *a*
green gap
Absorption (%)
100
50
0
400
450
500
550
600
650
700
Wavelength (nm)

Accessory pigments



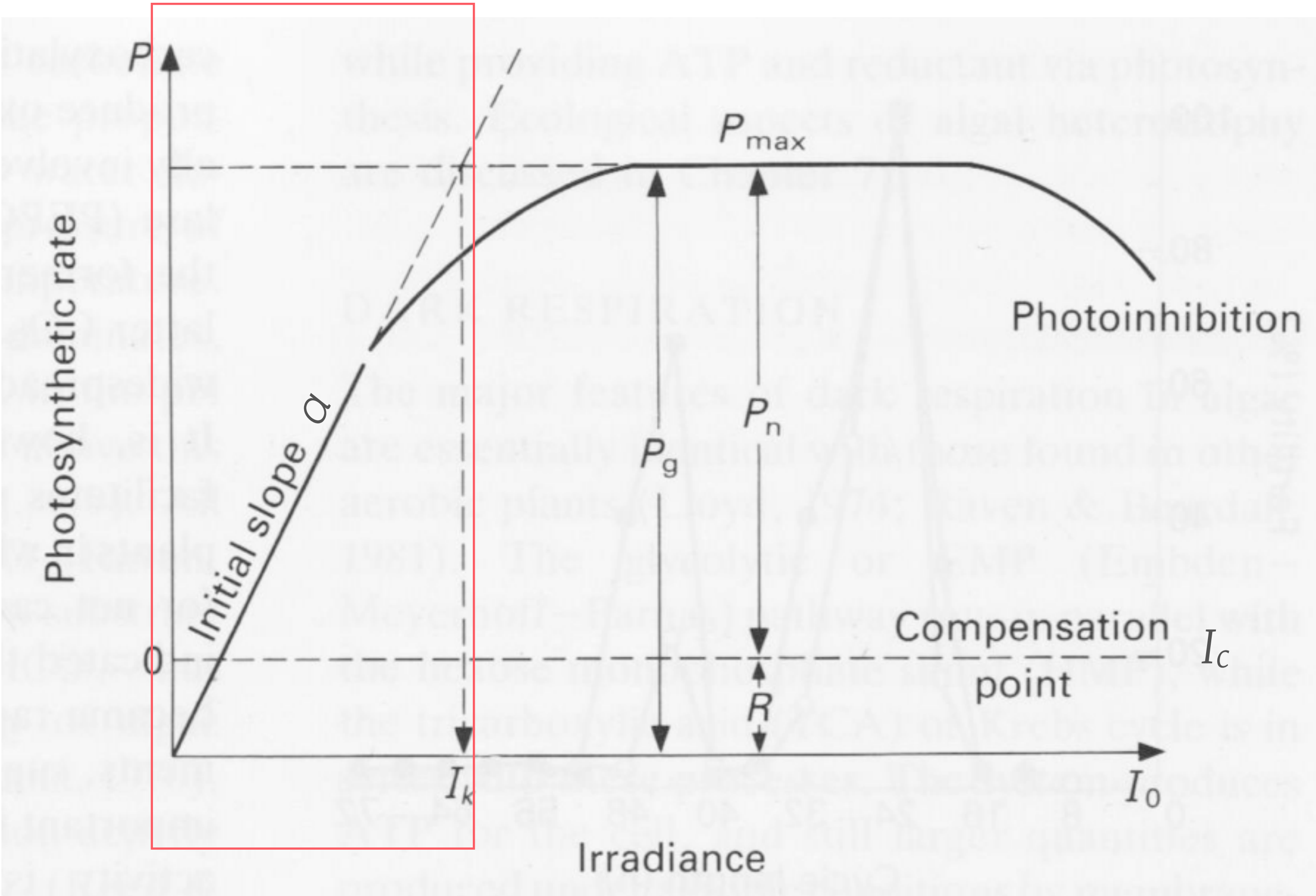
- Plants have a wide range of accessory pigments that pass light on to chl-*a*.
- The diversity of accessory pigments initially seems to complement the diversity of light climates in the oceans and other aquatic systems.
- All pigments fall within the classes **chlorophylls**, **carotenoids** (carotenes and xanthophylls) and **phycobilins** (or phycobiliproteins). There are more than 40 pigments in photoautotrophs.
- Different chlorophylls (especially chl-*a*) bind to proteins in different ways, thus further increasing variation in their absorption spectra, especially around the red peak.

Summarise pigments in Lobban and Harrison (1997)

Algal class	Principal pigments
Bacillariophyceae	Chl *a*; chl *c*; ß-carotene; fucoxanthin; diatoxanthin; diadinoxanthin
Dinophyceae	Chl *a*; chl c_2; ß-carotene; peridinin; neoperidinin
Phaeophyceae	Chl *a*; chl c_1; chl c_2; ß-carotene; fucoxanthin
Raphidophyceae	Chl *a*; chl *c*; diatoxanthin; diadinoxanthin; heteroxanthin; fucoxanthin
Cryptophyceae	Chl *a*; chl c_2; *α*-carotene; diatoxanthin; phycoerythrin; phycocyanin
Euglenophyceae	Chl *a*; chl *b*; ß-carotene; astaxanthin; antheraxanthin; diadinoxanthin; neoxanthin
Chlorophyceae	Chl *a*; chl *b*; *α*, *ß* and *γ*-carotene; lutein, siphonoxanthin; siphonein
Charophyceae	Chl *a*; chl *b*; *α*, *ß* and *γ*-carotene; various xanthophylls
Prasinophyceae	Chl *a*; chl *b*; *ß* carotene; siphonoxanthin; siphonein

(after South and Whittick, 1987)

What is photosynthesis?



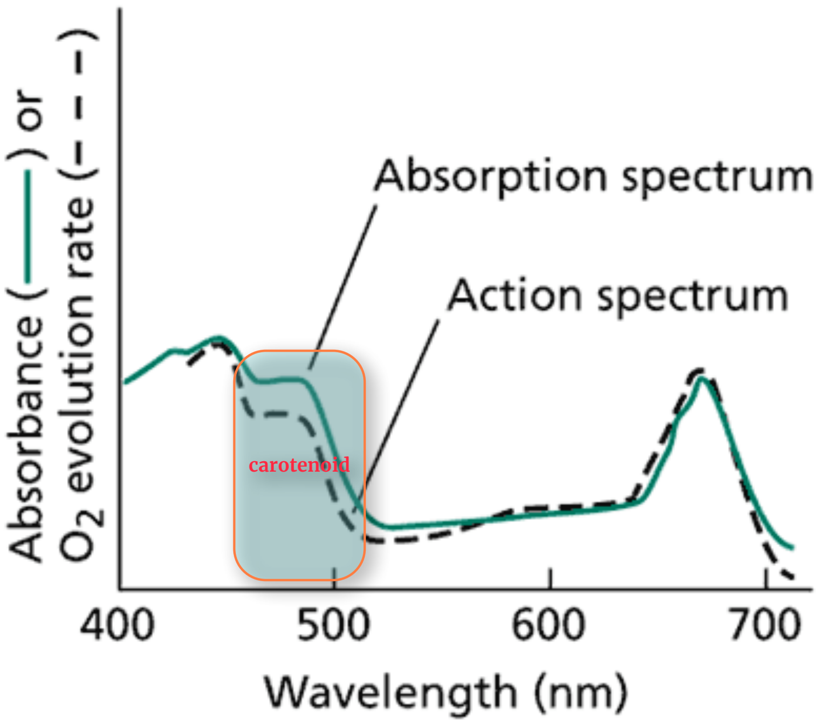
Photosynthesis: PI parameters

- Photosynthetic rate (*P*) depends on the amount of irradiance (*I*) absorbed; this relationship is modeled by a *P*–*I* curve with the following parameters:
  - I_c: the compensation point where *P* = respiration, *R*
  - α: the initial slope of the curve which is an indication of quantum yield (temperature independent)
  - P_{max}: at higher irradiances, where *P* becomes saturated
  - I_k: saturating irradiance; defined as the point at which the extrapolated initial slope intersects P_{ma}
- Neither I_c nor I_k are correlated with functional form

- P_{max} is a function of the carbon-fixation processes of photosynthesis, and is therefore affected by factors such as temperature and nutrient (N, P, C) availability (usually there is a $+^{ve}$ linear relationship).
- Adjustments in pigment concentrations because of changes in PFD usually leads to changes in α and P_{max}. The light compensation point may also be affected.

- *I_c: 2 – 11 µmol $m^{-2}.s^{-1}$ in shallow water, but may be much lower deeper down.*
- *I_k: 400 – 600 µmol $m^{-2}.s^{-1}$ in intertidal habitats; 150 – 250 µmol $m^{-2}.s^{-1}$ for upper to mid-sublittoral species; < 100 µmol $m^{-2}.s^{-1}$ for deeper species. Photosynthesis in diatoms under ice may be saturated at 5 µmol $m^{-2}.s^{-1}$ and may becomes photoinhibited at 25 µmol $m^{-2}.s^{-1}$.*
- *Photoinhibition may occur at high irradiances, especially in vertically mixed phytoplankton, intertidal macroalgae that experience desiccation stress; this involved damage to some components of the photosystems, such as membrane electron transport proteins.*

- **Absorption spectrum:** the measure of the amount of light energy absorbed at each discrete wavelength over a range of wavelength.
- **Action spectra:** critical to the development of our current understanding of photosynthesis.
  - An action spectrum is a graph of the magnitude of the biological effect observed as a function of wavelength.
  - Examples of effects measured by action spectra are oxygen evolution.



“If the pigments used to obtain the absorption spectrum are the same as those that cause the response, the absorption and action spectra will match. In the example shown here, the action spectrum for oxygen evolution matches the absorption spectrum of intact chloroplasts quite well, indicating that light absorption by the chlorophylls mediates oxygen evolution. Discrepancies are found in the region of carotenoid absorption, from 450 to 550 nm, indicating that energy transfer from carotenoids to chlorophylls is not as effective as energy transfer between chlorophylls.” (Plant Physiology online, Chapter 7; http://3e.plantphys.net/)

The next lecture: Chromatic Adaptation

