AP Bio FRQ Fridays

2013 #2

Photosynthesis, Spectrometry

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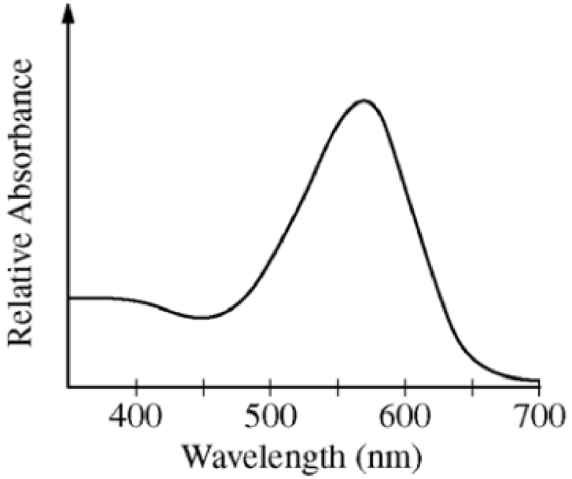
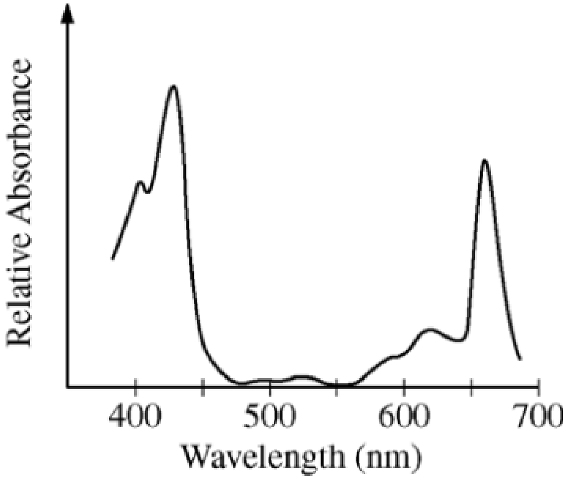


Graph I



Graph II

Color	Wavelength (nm)
Violet	380–450
Blue	450–475
Cyan	475–495
Green	495–570
Yellow	570–590
Orange	590–620
Red	620–750

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An absorption spectrum indicates the relative amount of light absorbed across a range of wavelengths. The graphs above represent the absorption spectra of individual pigments isolated from two different organisms. One of the pigments is chlorophyll *a*, commonly found in green plants. The other pigment is bacteriorhodopsin, commonly found in purple photosynthetic bacteria. The table above shows the approximate ranges of wavelengths of different colors in the visible light spectrum.

(a) **Identify** the pigment (chlorophyll *a* or bacteriorhodopsin) used to generate the absorption spectrum in each of the graphs above. **Explain** and **justify** your answer.

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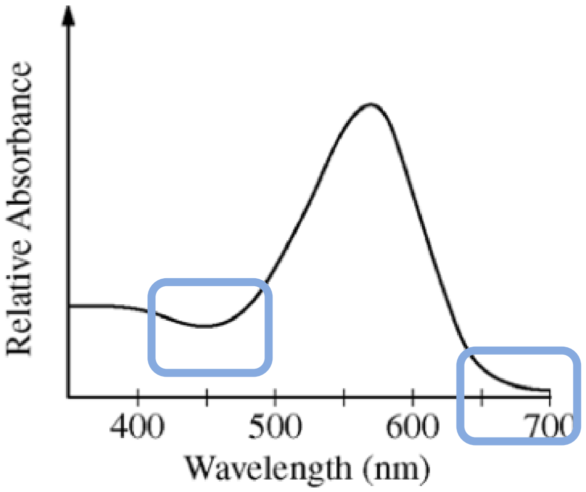
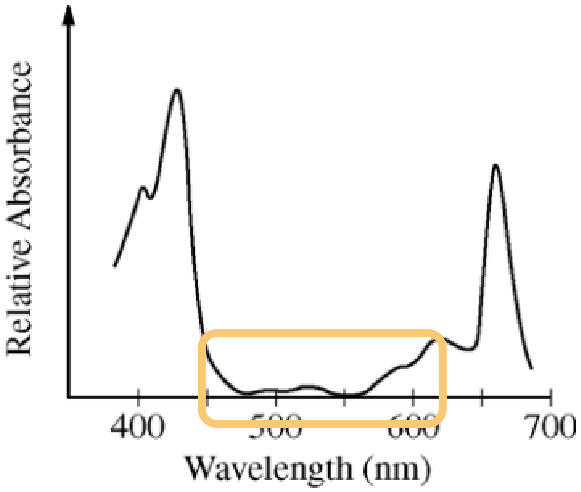


Graph I



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(a) **Identify** the pigment (chlorophyll *a* or bacteriorhodopsin) used to generate the absorption spectrum in each of the graphs above. **Explain** and **justify** your answer.

1 point per box
Identify BOTH pigments: Graph 1 = bacteriorhodopsin AND graph 2 = chlorophyll *a*
Explain that an organism containing bacteriorhodopsin appears purple because the pigment absorbs light in the green range of the light spectrum and/or reflects violet or red and blue light. The reflected red and blue light appears purple.
Explain that an organism containing chlorophyll *a* appears green because the pigment absorbs light in the red and blue ranges of the light spectrum and/or reflects green light.

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(a) In graph I bacteriorhodopsin is used to generate the absorbtion spectrum. This is known because Graph I shows a relatively low absorbtion rate for the color violet which is wavelength 380-450. Bacteriorhodopsin is usually found in purple photosynthetic bacteria and since the organism is purple, then it reflects rather than absorbs purple light. Graph II shows the absorbtion spectrum for chlorophyll a because it shows a low level of absorbtion of wavelengths 490-650 which correlates with the wavelength of green light (495-570). Chlorophyll a is found in green plants which means that green light would not be absorbed it would be reflected. Therefore, Graph II would represent chlorophyll a due to its low absorbtion of green light.

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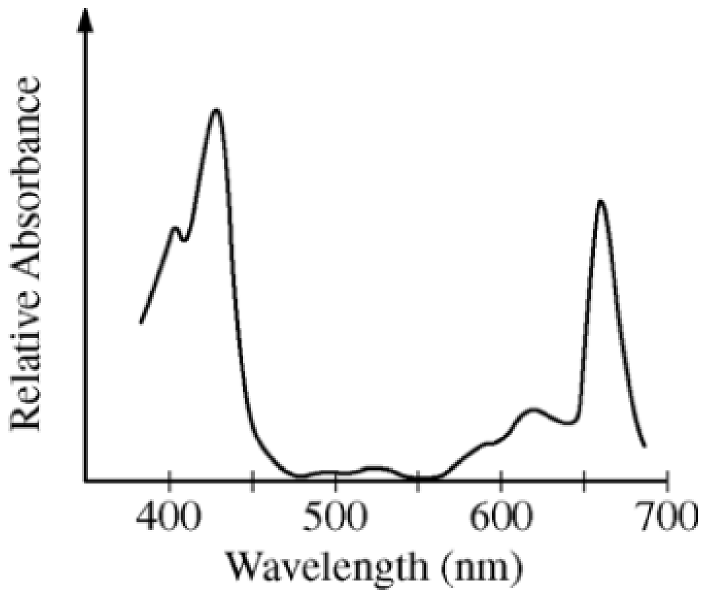
(b) In an experiment, identical organisms containing the pigment from Graph II as the predominant light-capturing pigment are separated into three groups. The organisms in each group are illuminated with light of a single wavelength (650 nm for the first group, 550 nm for the second group, and 430 nm for the third group). The three light sources are of equal intensity, and all organisms are illuminated for equal lengths of time. **Predict** the relative rate of photosynthesis in each of the three groups. **Justify** your predictions.



Graph II

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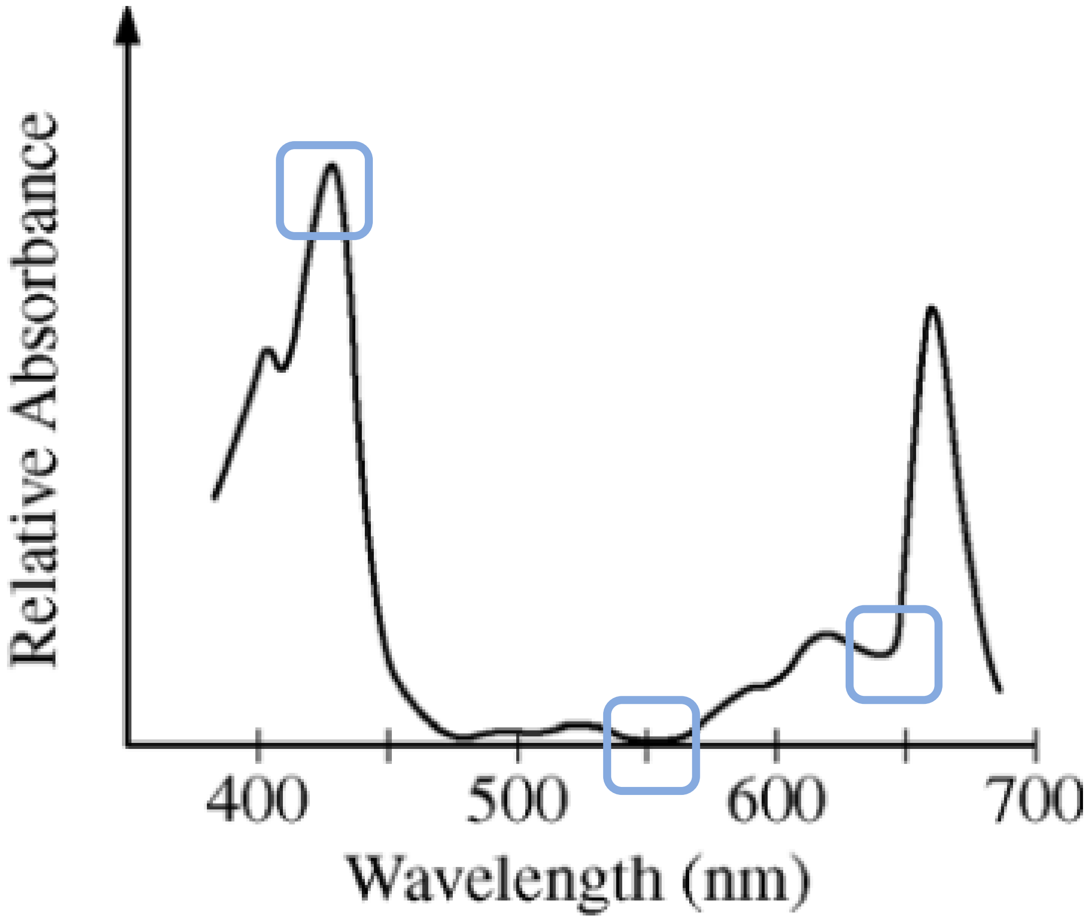

Graph II

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(b) In an experiment, identical organisms containing the pigment from Graph II as the predominant light-capturing pigment are separated into three groups. The organisms in each group are illuminated with light of a single wavelength (650 nm for the first group, 550 nm for the second group, and 430 nm for the third group). The three light sources are of equal intensity, and all organisms are illuminated for equal lengths of time. **Predict** the relative rate of photosynthesis in each of the three groups. **Justify** your predictions.

Wavelength (Group)	Prediction (**1 point each box**)	Justification (**1 point each box**)
650 nm (1st Group)	Intermediate rate	An intermediate level of absorption occurs at 650 nm (compared to 430 nm and 550 nm); *therefore*, an intermediate amount of energy is available to drive photosynthesis.
550 nm (2nd Group)	Lowest rate	The lowest level of absorption occurs at 550 nm; *therefore*, the least amount of energy is available to drive photosynthesis.
430 nm (3rd Group)	Highest rate	The highest level of absorption occurs at 430 nm; *therefore*, the greatest amount of energy is available to drive photosynthesis.

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(b) In an experiment, identical organisms containing the pigment from Graph II as the predominant light-capturing pigment are separated into three groups. The organisms in each group are illuminated with light of a single wavelength (650 nm for the first group, 550 nm for the second group, and 430 nm for the third group). The three light sources are of equal intensity, and all organisms are illuminated for equal lengths of time. **Predict** the relative rate of photosynthesis in each of the three groups. **Justify** your predictions.

(b) The second group of organisms illuminated by 550nm light will have the lowest level of photosynthesis. This is because the main light-capturing pigment has a low absorbance of light in 550nm. Photosynthesis will be slow because the photosystems will not be able to capture enough light to excite the electrons and produce ATP and NADPH, the products of the light dependent reaction. The first group of organisms illuminated by 650nm will have a higher rate of photosynthesis than the second group

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but lower than the third group. The absortion spectrum of the predominant light-capturing pigment absorbs more light at 650 nm than at 550 nm. The organisms will be able to absorb more light than the second group and be able to send more NADPH and ATP from the light-dependant reactions to the light-independant reactions, also known as the Calvin Cycle. The third group that is illuminated by 430 nm will have the highest rate of photosynthesis because 430 nm light is absorbed relatively easier than the other two wavelengths of light. The organisms in the third group will be able to absorb more light and there fore create more NADPH and ATP which will then cause more products of the Calvin cycle to form. The third group of organisms will also produce the most amount of oxygen.

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(c) Bacteriorhodopsin has been found in aquatic organisms whose ancestors existed before the ancestors of plants evolved in the same environment. **Propose** a possible evolutionary history of plants that could have resulted in a predominant photosynthetic system that uses only some of the colors of the visible light spectrum.

Proposal that includes an environmental selective pressure:

- Green light was being absorbed by aquatic organisms using bacteriorhodopsin.
- Unabsorbed wavelengths of light were available resources that organisms could exploit.
- Absorbing visible light at all wavelengths may provide too much energy to the organism.
- Absorbing light from ultraviolet wavelengths (shorter wavelengths = higher energy) could cause damage to the organism.
- Absorbing light with longer wavelengths may not provide sufficient energy for the organism.

Appropriate reasoning to support the proposal:

- Natural selection favored organisms that rely on pigments that absorb available wavelengths of light.
- Endosymbiosis: chloroplasts evolved from cyanobacteria with pigments that used only certain wavelengths.
- Genetic drift eliminated pigments that absorbed certain wavelengths of light.
- Mutation(s) altered the pigment(s) used by organism.

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(c) In an aquatic environment a plant would have access to mostly blue and cyan colors of light of around 450-495 nm wavelength. If the plant contained many pigments that absorbed red light, that ~~is barely~~ a plant could rarely gain access to,

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the plant would not be able to absorb enough light to undergo photosynthesis. The plant would most likely not be able to reproduce before it died. But if a plant had many photo pigments that could absorb blue light (which is plentiful in its environment) then the plant would thrive. It could pass on its genes and its offspring would have a higher fitness than plants that could only absorb red light. The remaining plants would only use the blue colors of the visible light spectrum because it wouldn't be efficient to have ~~photo~~ pigments that could absorb red lights.

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