AP® BIOLOGY
2010 SCORING GUIDELINES (Form B)

Question 1

Biological molecules can be separated by using chromatographic techniques. The diagram shows the separation of several spinach leaf pigments by paper chromatography. Using the diagram,

(a) **Explain** how paper chromatography can be used to separate pigments based on their chemical and physical properties. **(4 points maximum)**

Separation property 2 points maximum	**Relationship to movement 2 points maximum**
Solubility in solvent used.	Greater solubility → further movement.
Molecular size/weight.	Smaller size → further movement.
Polarity/hydrophobicity/H-bonding.	Chemical similarity between solvent/pigment (solvent: pigment) → further movement.
Adhesion (affinity for paper).	Less adhesion → further movement.

- Description of chromatography protocol.

(b) **Discuss** the role of pigments both in capturing light energy and in converting it to the chemical energy of ATP and NADPH. **(3 points maximum for capturing; 3 points maximum for converting; 5 points maximum)**

Capturing

- Electromagnetic spectrum is described.
- Specific pigments absorb specific wavelength.
- Absorption/reflection (e.g., chlorophyll absorbs red/blue; reflects or transmits green).
- Pigments are embedded in thylakoid membranes.
- Antennae and/or accessory pigments.
- Electron energy level is boosted by absorption of photons (light).

Converting

- Photosynthesis is the process.
- Brief description of pathway through photosystems II and I.
- Electron transport or chemiosmosis, or both, transform light energy to chemical energy (produce NADPH/H^+/ATP).
- Brief description of electron transport or chemiosmosis, or both.
- Cyclic pathway.
- Splitting of water/photolysis.
    - H^+, e^-, O_2

(c) Use the ruler shown above to **determine** the R_f value of xanthophyll. **Show** your calculations. **(2 points maximum**)

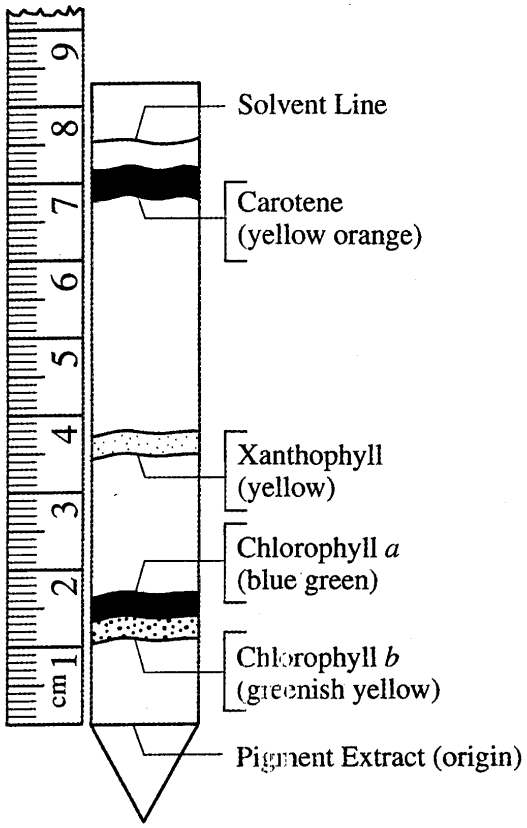
- Formula or description $d_{pigment}/d_{solvent}$
- Calculation 3.5/7.5 ≈ 0.5

BIOLOGY
SECTION II
Time—1 hour and 30 minutes

/A1

Directions: Answer all questions.

Answers must be in essay form. Outline form is not acceptable. Labeled diagrams may be used to supplement discussion, but in no case will a diagram alone suffice. It is important that you read each question completely before you begin to write. Write all your answers on the pages following the questions in this booklet.



1. Biological molecules can be separated by using chromatographic techniques. The diagram above shows the separation of several spinach leaf pigments by paper chromatography. Using the diagram above

   (a) **Explain** how paper chromatography can be used to separate pigments based on their chemical and physical properties.

   (b) **Discuss** the role of pigments both in capturing light energy and in converting it to the chemical energy of ATP and NADPH.

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a) The distance that a certain pigment will travel up the paper is dependent on several factors By knowing about the properties of the different pigments it is possible

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to ~~determi~~ identify them using paper chromatography. ~~A pigme~~ The distance the pigment travels can be affected by how well it forms bonds with the paper. A pigment that has strong interactions with paper will not travel as far as a pigment that doesn't form ~~strong~~ bonds with paper. Distance travelled ~~is~~ can also depend on how well the pigment interacts with the solvent. ~~Pigments that form~~ Pigments that dissolve more readily in the solvent and form stronger bonds with it will travel ~~fast~~ up the paper faster than ones that do not. Size is another factor. Smaller molecules will travel faster than large ones. ~~Knowing about these properties can help you determine which pigment will travel~~ These properties mean that each pigment travels up the paper at a different speed so it is possible to separate them using paper chromatography.

b) Pigments are used to capture light energy during photosynthesis and transfer it to an electron transport chain which generates ATP ~~during~~ by chemiosmosis. They also use energy to take electrons at the end of the chain and use them to reduce $NADP^+$ to NADPH. ~~There~~ The light-dependent reactions start when

light energy is absorbed by pigments in the grana of chloroplasts. The energy is used to excite electrons, which are then passed to different pigment molecules until they hit photosystem II (p680). Different pigments absorb different wavelengths of light. Photosystem II best absorbs light with a wavelength of 680nm, which is why it is also called p680. P680 uses this energy to put an electron from the splitting of water into the electron transport chain, which generates ATP by chemiosmosis. At the end of this chain the electron goes to photosystem I (p700), which has chlorophyll a as its central molecule. P700 uses light energy to transfer this electron to $NADP^+$, creating NADPH.

1A4

c) $R_f = \frac{\text{distance moved by pigment}}{\text{distance moved by solvent}}$

$= \frac{3.5}{7.0}$

$= \frac{7}{2} \times \frac{2}{15} = \frac{7}{15}$

The R_f value for xanthophyll is $\boxed{7/15}$

BIOLOGY
SECTION II
Time—1 hour and 30 minutes

1B1

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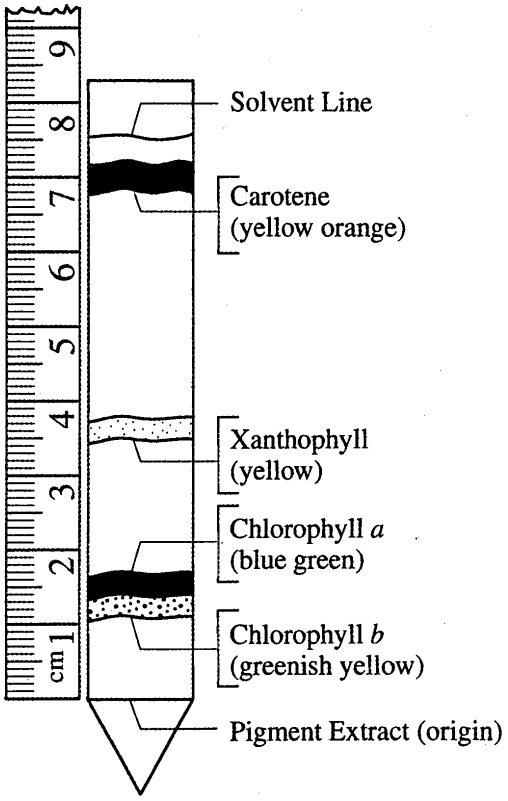

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1.a. Paper chromatography is used to seperate pigments. By placing the bp of the paper in water, you can observe ~~and observing~~ the different pigments rising. The pigments are seperated

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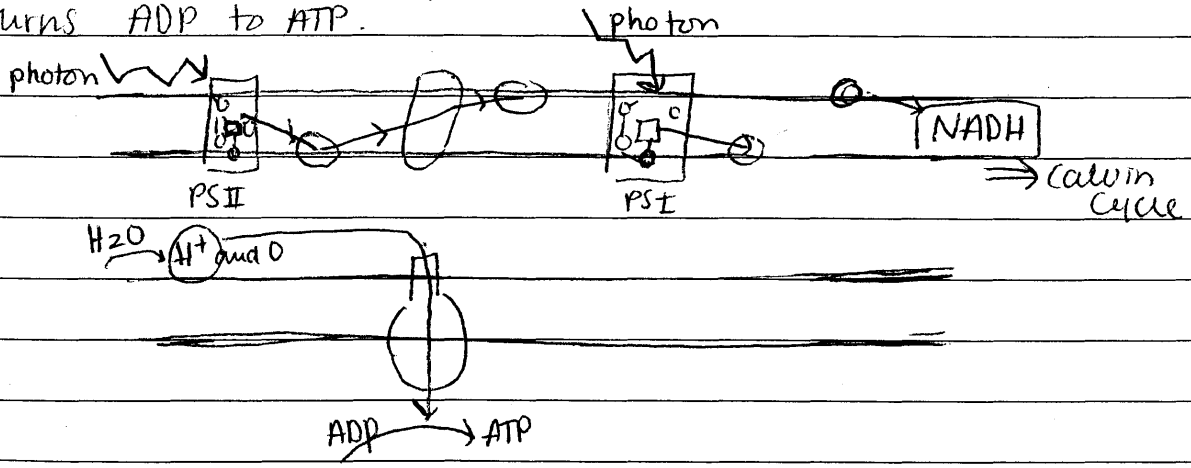
1B2

according to the pigment's sizes (the heavier, the less distance the pigment will travel up the paper) & density. (& how soluable they are in H2O.) As water moves up the paper, it carries the pigment extract with it, leaving a trail of the different pigments. (As pigments rise up, the colors are lighter in color.)

b. Pigments play a major role in photosynthesis. When photosystems 2 captures light, an electron is excited & passed down a series of proteins. Then when a photon hits Photosystems 1, the electron is again excited and moves down through proteins which activate NADH to enter the calvin cycle. During this process, a water molecule is broken down to H^+ and $\frac{1}{2} O_2$. The H^+ moves down the membrane passing through ATP synthase, which in turn turns ADP to ATP.

2a.



1c. Xanthophyll, 4.8 cm

BIOLOGY
SECTION II
Time—1 hour and 30 minutes

1C,

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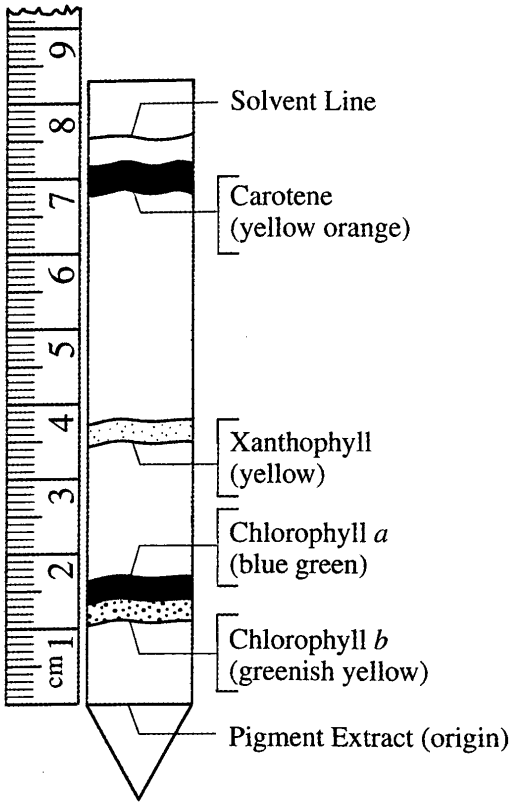

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a. In the process of paper chromatography, the solvent used acts by moving up the paper, carrying the different pigments with it. This separation occurs as

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the pigments of differing masses get carried further or shorter by the solvent. This causes pigments such as chlorophyll a and chlorophyll b to move the shortest distance up the paper, while carotenes, which is lighter than the other pigments, moves up the furthest. These pigments will show up as different colors, representing the wavelength of light that they can't absorb (which is why plants are green).

b. pigments are heavily involved in the light reactions, in the chloroplasts of plant cells which capture light energy and convert it to ATP and NADPH to pass on to the dark reactions (Calvin cycle). This involves pigments, such as chlorophyll a and b in photosystems I and II. These photosystems absorb light, which excites electrons produced through photolysis (breaking of H_2O to H^+ and O) and sends them down an electron transport chain, which produces ATP via chemiosmosis (a proton gradient) with ATP synthase, the last protein in the ETC finally synthesizing ATP. This process is characteristic of noncyclic photophosphorylation, which differs from cyclic photophosphorylation in that it produces ATP and NADPH (cyclic only produces ATP).

1C3

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

c. The frequency of ~~xanthophyll~~ is about 3.5 cm as shown on the ruler which translates to 380 nm, again showing the wavelength of light that the xanthophyll can't absorb.

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AP® BIOLOGY
2010 SCORING COMMENTARY (Form B)

Question 1

Sample: 1A
Score: 10

A total of 4 points were earned in part (a) for explaining two factors that affect pigment migration during paper chromatography. The first 2 points were earned for the explanation that strong interactions between the paper and the pigment will retard the pigment's movement. The second 2 points were earned for indicating that pigments that dissolve better in the solvent will diffuse further than those that do not dissolve as readily. The molecular size points were not awarded since the maximum 4 points had already been earned.

In part (b) the maximum 5 points were earned. One point was earned for indicating that photosynthesis is the process for capturing light energy through pigments. Another point was earned for discussion of the electron transport chain and the production of ATP by chemiosmosis. A point was earned for indicating that pigments absorb at different wavelengths, using an example of photosystem II absorbing at 680 nm. A fourth point was earned for the indication that water is split, providing an electron. A point could have been awarded for describing the electron flow through the photosystems, but the maximum 3 points had been earned for the conversion of light energy part of the question. The electron flow point was earned for describing electron movement through the photosystems to $NADP^+$.

One point was earned in part (c) for the correct R_f formula. The second point for the correct values was not awarded since the response had already received the maximum 10 points.

Sample: 1B
Score: 7

Two points were earned in part (a) for explaining that size and solubility in a solvent affect pigment separation. One point was earned for stating that heavier pigments migrate less.

In part (b) 4 points were earned. The point for capturing light energy was earned for stating that "[w]hen photosystems 2 captures light, an electron is excited." One point was earned for indicating that photosynthesis is the process. Two points were earned for describing electron movement through proteins (electron transport) and for describing ATP synthesis by chemiosmosis. Although the response states that "a water molecule is broken down," it does not mention the electron and therefore did not earn a point for that discussion.

No points were earned in part (c).

Sample: 1C
Score: 6

In part (a) 2 points were earned for explaining that pigments separate due to their masses and that a lighter pigment (carotene) moves the farthest.

Four points were earned in part (b). One point was earned for the statement in part (a) that pigment color is because of "the wavelength of light that [it] can't absorb." One point was earned for explaining that "photosystems absorb light, which excites electrons." Another point was earned for the indication that photolysis produces H^+, O_2 and electrons. The fourth point was earned for describing the role of electron transport in ATP production by chemiosmosis.

No points were earned in part (c).