

## 4.1 Photosynthesis and chloroplast pigments

Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_

Total: 21 marks

**KEY WORDS** photophosphorylation • RuBP  
• absorption spectrum • action spectrum • limiting factor

### Objective

Practise Topic 5 statements 5.1-5.8 with Core Practical 10: the two stages of photosynthesis, chloroplast structure, absorption and action spectra, chromatography with R<sub>f</sub> values, and limiting factors.

### 1 Key knowledge and worked examples

#### ■ Stage and place

Light-dependent (thylakoid membranes): photolysis of water  $\rightarrow \text{O}_2 + \text{H}^+$ ; **photophosphorylation** of ADP; reduction of NADP. Light-independent (stroma): CO<sub>2</sub> fixed onto **RuBP** by **rubisco**, products reduced by ATP and reduced NADP to **GALP**, most regenerated to RuBP.

#### ■ Two spectra, one argument

The **absorption spectrum** (what pigments take up) matches the **action spectrum** (what drives photosynthesis) – evidence that the pigments do the work. Chromatography:  $R_f = \text{pigment distance} / \text{solvent front distance}$ .

#### ■ Limiting factors

Light intensity, CO<sub>2</sub> concentration, temperature – whichever is lowest sets the rate; greenhouses lift the weakest one.

#### ■ Worked example: R<sub>f</sub> and identification

A chromatogram run 8.0 cm: pigment X moved 6.4 cm ( $R_f = 0.80$ ), pigment Y moved 3.2 cm ( $R_f = 0.40$ ). Comparing with standards run in the same solvent,  $R_f$  0.80 identifies  $\beta$ -carotene and 0.40 chlorophyll a – identification is only as good as the standards and solvent match.

## 2 Practice

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**2.1** Name the two products of the light-dependent reactions used in the light-independent stage. [2]

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**2.2** State where in the chloroplast the Calvin cycle occurs. [1]

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**2.3** Explain why increasing light intensity beyond a certain point does not increase the rate of photosynthesis. [2]

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## 3 Exam-style questions

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**3.1** A student runs chromatography of leaf pigments with a solvent front at 9.6 cm. Bands move: 7.7 cm, 5.8 cm, 4.3 cm and 2.9 cm. Standard  $R_f$  values in this solvent: carotene 0.80, chlorophyll a 0.60, chlorophyll b 0.45, xanthophyll 0.30. Identify each band showing your  $R_f$  calculations, and explain why the identification could be wrong if the solvent were different. [6]

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**3.2** Describe how the structure of a chloroplast is adapted to both stages of photosynthesis, naming three structural features and the stage each serves. [5]

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**3.3** A glasshouse grower measures photosynthesis of a tomato crop against CO<sub>2</sub> concentration at two light intensities. Rate plateaus at low light with CO<sub>2</sub> above 0.10 %, but keeps rising to 0.15 % CO<sub>2</sub> at high light. Explain these results using limiting factors, and state the most profitable combination for the grower to provide. [5]

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## Solutions

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Original-task marking: M1 method, A1 accuracy, B1 reasoning.

**2.1** ATP and reduced NADP.

**2.2** The stroma.

**2.3** Another factor ( $\text{CO}_2$  or temperature) has become the limiting one, so raising light no longer raises the rate.

**3.1** Rf values:  $7.7/9.6 = 0.80 \rightarrow$  carotene;  $5.8/9.6 = 0.60 \rightarrow$  chlorophyll a;  $4.3/9.6 = 0.45 \rightarrow$  chlorophyll b;  $2.9/9.6 = 0.30 \rightarrow$  xanthophyll. Rf depends on each pigment's relative solubility in the specific solvent; a different solvent changes those solubilities, so the same pigment yields a different Rf and the standard table no longer applies.

**3.2** Thylakoid membranes stacked into gran a give a large surface for the light-dependent reactions' pigments and electron carriers; the stroma surrounds them, holding the Calvin-cycle enzymes adjacent to their ATP/NADP supply; the double membrane controls transport of  $\text{CO}_2$  and products; (accept starch grains storing the product).

**3.3** At low light,  $\text{CO}_2$  above 0.10 % adds nothing because light is limiting; at high light,  $\text{CO}_2$  becomes the limiter and extra  $\text{CO}_2$  raises the rate until 0.15 %. The profitable combination: high light with  $\text{CO}_2$  at 0.15 % – the cheapest next increment of whichever factor currently limits decides profit.