GLEN TUTORIALS

GRADE 9 IGCSE BIOLOGY — COMPLETE SOLUTIONS & STUDY NOTES

Chapter 8: Transport in Plants

Comprehensive Workbook Exercise Solutions, Key Concepts & Exam Tips

CHAPTER OVERVIEW & ESSENTIAL CONCEPTS

- **Xylem:** A plant transport tissue made up of dead, empty cells joined end-to-end (lacking end walls), reinforced with **lignin**. Transports **water and mineral ions** unidirectionally from roots to leaves and provides structural support.
- **Phloem:** A plant transport tissue made of living cells (sieve tube elements and companion cells) joined end-to-end. Transports dissolved organic solutes (predominantly **sucrose and amino acids**) bidirectionally from **sources** to **sinks**.
- **Transpiration:** The loss of water vapour from the leaves of a plant by evaporation at the surfaces of mesophyll cells followed by diffusion through the stomata.
- **Translocation:** The movement of sucrose and amino acids in phloem from a source (region of production/release) to a sink (region of storage or utilization).

Exercise 8.1: Xylem and Phloem

Focus & Practice

Question 1 (Focus)

Complete the sentences, using words from the given list:
[amino acids, fatty acids, leaves, mineral ions, organ, roots, sucrose, tissue, water]

Answer:
Xylem is a **tissue** that transports **water** and **mineral ions** from the **roots** of a plant to its **leaves**.

Phloem transports **sucrose** and **amino acids** from the leaves to other parts of the plant.

REMEMBER

Xylem transports **water** + **mineral ions** upward (Roots → Leaves).
Phloem transports **sucrose** + **amino acids** in both directions (Source → Sink).

Question 2 (Practice - Identification of Tissues)

Figure 8.1 shows part of a buttercup root, seen using the high power lens of a light microscope. Use ruled lines to label these tissues: cortex, phloem, xylem.

Answer & Identification Guide:

- **Xylem:** Located at the very center of the vascular bundle forming a star/cross shape ("X" shape) or central cluster with large, thick-walled open vessels (cell **A** is a xylem vessel).
- **Phloem:** Located in small clusters between the arms/lobes of the central xylem star.
- **Cortex:** The outer region surrounding the central vascular cylinder (stele), consisting of large, loosely packed parenchyma cells.

> **EXAM TIP**
>
> In root cross-sections, look for the central "X" or star shape — that is always **xylem**! The regions tucked between the points of the star are **phloem**, and the wide outer packing layer is the **cortex**.

Question 3 (Practice - Magnification Calculation)

The magnification of the image in Figure 8.1 is ×200. Calculate the actual diameter of the cell labelled A. Show your working. Give your answer in millimetres.

Detailed Working & Solution:

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Formula: Actual Size (A) = Image Size (I) / Magnification (M)

1. Measured Image Diameter of Cell A on printed page ≈ 7.0 mm (7000 µm).
2. Magnification (M) = ×200
3. Actual Diameter = Image Size / Magnification
Actual Diameter = 7.0 mm / 200 = 0.035 mm (or 35 µm)
```

Final Answer: 0.035 mm *(Acceptable range depending on ruler measurement: 0.030 mm to 0.040 mm / 6.0 mm to 8.0 mm image size).*

Question 4 (Challenge - Structural Adaptations of Xylem)

Describe how the cells in xylem tissue are adapted for their functions.

Answer:

1. **Dead, hollow cells with no cell contents (cytoplasm/organelles):** Allows an uninterrupted, continuous column for water flow with minimum resistance.
2. **Absence of end walls (joined end-to-end):** Forms long continuous tubes (vessels) extending from roots to leaves.
3. **Lignified walls:** Cell walls are thickened with **lignin**, a tough waterproof polymer that strengthens the vessels, preventing them from collapsing inward under tension (suction pressure) created by transpiration, and providing structural support to the whole plant.
4. **Pits in cell walls:** Unlignified regions (pits) allow lateral movement of water between adjacent vessels.

> **REMEMBER KEY KEYWORDS**
>
> **Lignin** (strength/waterproofing), **No end walls** (continuous tube), **Dead/hollow** (low resistance).

Exercise 8.2: Transport of Water

Investigation & Data Analysis

> **CONTEXT & INVESTIGATION SUMMARY**
>
> Hypothesis: *"Transpiration happens more quickly in windy conditions than in still air."*
> Apparatus: A potometer setup measuring the movement of a water meniscus along a capillary tube containing a leafy shoot placed next to a ruler and fan.

Question 5 (Focus - Results Table)

Draw a suitable results table in the space below, and complete it to show the student's results. ***(Tip: Include units in table headings, not in table cells).***

Time / minutes	Air condition	Position of meniscus / cm	Distance moved in 2-min interval / cm
0	Still air	0.0	—
2	Still air	2.8	2.8
4	Still air	6.1	3.3
6	Still air	10.0	3.9
8	Still air	12.9	2.9
10	Still air	16.2	3.3
12		21.8	5.6

Time / minutes	Air condition	Position of meniscus / cm	Distance moved in 2-min interval / cm
	Moving air (fan on)		
14	Moving air (fan on)	27.9	6.1
16	Moving air (fan on)	31.1	3.2 (Anomalous)
18	Moving air (fan on)	39.5	8.4
20	Moving air (fan on)	44.9	5.4

Question 6 (Practice - Plotting Graph Instructions)

Plot these results on the grid (graph requirements & best-fit lines).

Graph Construction Guidelines for Full Marks:

- **X-axis:** Time / minutes (scaled from 0 to 20 minutes, going up in equal intervals, e.g., 2 min per major block).
- **Y-axis:** Position of meniscus / cm (scaled from 0 to 50 cm, going up in equal intervals).
- **Dividing Line:** Draw a vertical dashed or line at **Time = 10 minutes** to separate "Still air" (0–10 min) and "Moving air" (10–20 min).
- **Plotting:** Plot all data points accurately using neat small crosses (×).
- **Best-Fit Lines:**
  - **Line 1 (0 to 10 min - Still Air):** Straight best-fit line through points at (0,0), (2,2.8), (4,6.1), (6,10.0), (8,12.9), (10,16.2).
  - **Line 2 (10 to 20 min - Moving Air):** Straight best-fit line through moving air points. Note that point at 16 min (31.1 cm) is **anomalous** and should be ignored/circled when drawing the best-fit line.

Peer Assessment Checklist Reference (Page 74)

Checklist Criteria	Standard Requirement
The axes are the right way round.	Independent variable (Time) on X-axis; Dependent variable (Position) on Y-axis.
The axes are fully labelled, with units.	"Time / minutes" and "Position of meniscus / cm".
The scales on both axes are well chosen.	Occupies more than 50% of the grid in both directions, linear scale.

Checklist Criteria	Standard Requirement
The points are very neat with accurately placed crosses.	Crosses (×) plotted within ±0.5 small square precision.
The lines are best-fit lines, and are very clearly drawn.	Two distinct straight best-fit lines drawn; anomalous point excluded.

Question 7 (Challenge - Rate Calculation)

Use your graph to calculate the mean rate of movement, in cm per minute, of the meniscus in:
a. still air; give your answer to three significant figures.
b. moving air; give your answer to three significant figures.

Calculations & Answers:

a. Still air (0 to 10 minutes):

```
Total distance moved = 16.2 cm − 0.0 cm = 16.2 cm
Total time = 10 minutes
Mean rate = 16.2 cm / 10 min = 1.62 cm/min
```

Answer: 1.62 cm/min (3 significant figures)

b. Moving air (10 to 20 minutes):

```
Total distance moved = 44.9 cm − 16.2 cm = 28.7 cm
Total time = 10 minutes
Mean rate = 28.7 cm / 10 min = 2.87 cm/min
(Alternatively, if using line gradient excluding anomalous point: ≈ 2.87 – 2.90 cm/min)
```

Answer: 2.87 cm/min (3 significant figures)

Question 8 (Challenge - Conclusion & Hypothesis Evaluation)

Do the results support the student's hypothesis? Explain your answer.

Answer:
Yes, the results fully support the hypothesis.
Explanation: In still air, the average rate of movement of the meniscus (water uptake) was **1.62 cm/min**, whereas in moving air (windy conditions), the rate increased significantly to **2.87 cm/min**. Moving air removes the humid water vapour boundary layer around the stomata on the leaf surface, maintaining a steep **concentration gradient** for water vapour between the inside of the leaf and the outside air. This increases the rate of diffusion/evaporation (transpiration), causing faster water uptake measured by the movement of the meniscus.

REMEMBER

Windy conditions **increase transpiration** by blowing away water vapour outside the leaf, maintaining a steep concentration gradient.

Question 9 (Challenge - Evaluation of Experimental Method)

Evaluate the student's method. For example, did the student control all the important variables? Did his method really measure what he thought he was measuring?

Answer (Critical Evaluation):

1. **Control Variables Not Controlled / Potential Sources of Error:**
   - **Temperature and Light Intensity:** Over the 20-minute period, light intensity or ambient room temperature in the laboratory might have fluctuated, which affects stomatal opening and evaporation rates.
   - **Humidity:** Laboratory air humidity was not monitored or controlled.
   - **Fan Heating:** Running the electric fan close to the apparatus for 10 minutes could generate heat, raising the temperature around the shoot and confounding wind speed with temperature.
2. **Transpiration vs Water Uptake:**
   - The potometer measures **water uptake** by the cut shoot, not directly water transpiration (loss). A small percentage (≈ 1–2%) of water taken up is used for **photosynthesis** and maintaining cell **turgidity**.
3. **Limitations:** Only a single shoot was tested; repeating the experiment with multiple shoots and calculating a mean would increase reliability.

Exercise 8.3: Translocation of Sucrose and Amino Acids

Focus, Practice & Challenge

KEY DEFINITIONS

- **Source:** Part of a plant that releases sucrose or amino acids to be transported (e.g., photosynthetic leaves or storage organs in spring).
- **Sink:** Part of a plant where sucrose or amino acids are delivered to be used for growth/respiration or converted to starch for storage (e.g., roots, growing buds, flowers, fruits).

Question 10 & 11 (Focus - Multiple Choice Selection)

10. In which form are carbohydrates transported in phloem? *(glucose / starch / sucrose)*
11. In which form are carbohydrates stored in plant cells? *(glucose / starch / sucrose)*

Answers:
10. Transported form in phloem: **sucrose**
11. Stored form in plant cells: **starch**

REMEMBER

Glucose: Produced in photosynthesis.
Sucrose: Transported in phloem (soluble & non-reducing).
Starch: Stored in cells (insoluble, doesn't affect osmosis).

Question 12 (Focus - Seasonal Photosynthesis)

In spring and summer in Switzerland, the leaves of pine trees photosynthesise. Suggest *two* reasons why pine trees photosynthesise in spring and summer in Switzerland, but not in winter.

Answer:

1. **Light intensity / Day length:** In winter, day length is significantly shorter and sunlight intensity is lower compared to spring and summer.
2. **Temperature / Freezing conditions:** Temperatures in winter are below freezing (0°C or lower), causing enzymes controlling photosynthesis to have very low kinetic energy/inactivity, and liquid water may freeze/be unavailable.

Question 13 & 14 (Practice - Sources and Sinks)

13. Would you expect the leaves to be sources or sinks in spring and summer? Explain your answer.
14. Would you expect the leaves to be sources or sinks in winter? Explain your answer.

13. Spring and Summer:
Leaves are **sources**.
Explanation: During spring and summer, leaves active in photosynthesis produce excess glucose, which is converted to **sucrose** and exported (released) into the phloem to supply growing roots, buds, and fruits.

14. Winter:
Leaves are **neither (or weak sinks)**.
Explanation: In winter, leaves are dormant and do not photosynthesise, so they cannot act as sources. Energy is supplied from storage organs (roots/stem) to maintain vital functions, making roots the **sources** and other tissues **sinks**.

Table 8.1 Data Reference

Time of year	Starch in leaves / % of dry mass	Starch in roots / % of dry mass
spring	15.0	2.6
summer	15.6	3.1

Time of year	Starch in leaves / % of dry mass	Starch in roots / % of dry mass
autumn	4.9	4.1

Question 15 (Practice - Starch in Leaves Description)

Describe the changes in the amount of starch in the pine tree *leaves* from spring until autumn. *(Tip: Do not include reasons when asked to 'describe').*

Answer:

- The percentage of starch in leaves remains high and relatively stable from spring (**15.0%**) to summer, slightly increasing to a peak of **15.6%**.
- Between summer and autumn, the percentage of starch drops sharply from **15.6% to 4.9%** (a decrease of 10.7%).

Question 16 (Practice - Starch in Roots Description)

Describe the changes in the amount of starch in the pine tree *roots* from spring until autumn.

Answer:

- The percentage of starch in the roots increases steadily throughout the entire period from spring (**2.6%**) to summer (**3.1%**) and reaches its highest level in autumn (**4.1%**).

Question 17 (Practice - Explanation of Starch Changes)

Suggest reasons for the changes described in your answers to 15 and 16.

Answer:

- **In Leaves (Spring to Summer):** High rates of photosynthesis produce abundant glucose, converted and stored as starch in leaf cells.
- **In Leaves (Summer to Autumn):** Photosynthesis slows down due to reduced day length and temperature. Starch stored in leaves is broken down into **sucrose** and translocated via phloem to roots for storage before winter.
- **In Roots (Spring to Autumn):** Roots act as a **sink**, receiving translocated sucrose from leaves and converting it into **starch** for long-term winter storage.

Question 18 (Challenge - Bud and Leaf Removal Experiment)

In summer, researchers removed buds from some pine trees and leaves from other pine trees. Control trees were untreated. Results shown in Table 8.2:

Treatment	Starch in leaves / % dry mass	Starch in buds / % dry mass
control	4.9	7.1
buds removed	4.9	—
leaves removed	—	6.5

Explain what these results show about sources and sinks in the pine tree during summer.

Answer & Explanation:

- **Leaves act as the primary Source:** When leaves were removed, the starch content in buds dropped from **7.1% to 6.5%**. This demonstrates that buds rely on sucrose translocated from leaves (the source) to build up starch. Without leaves, less carbohydrate is available to transport to the buds.
- **Buds act as Sinks:** Buds accumulate high levels of starch (**7.1%**) when leaves are present. Removing buds did not affect leaf starch levels (remained **4.9%**), indicating that excess sucrose is directed to other sinks such as roots or stem tissues.

> **SUMMARY EXAM TIP**
>
> When analyzing translocation experiments:
> 1. Identify where carbohydrates are produced/stored (**Source**).
> 2. Identify where carbohydrates are used/stored for growth (**Sink**).
> 3. Remember that translocation occurs via **phloem** and can change direction seasonally!