1.9 Osmosis, diffusion and active transport

Name: _____ Class: _____ Date: _____ **Total: 21 marks**

KEY WORDS diffusion • facilitated diffusion • active transport • osmosis • water potential

Objective

Practise statements 2.4–2.5: osmosis in terms of water potential, passive and active transport, bulk transport by vesicles, and Fick's law applied to exchange surfaces.

1 Key knowledge and worked examples

Four transport routes, one table

Route	Direction	Protein	ATP
Diffusion	down gradient	no	no
Facilitated diffusion	down gradient	channel or carrier	no
Active transport	against gradient	carrier (pump)	yes
Osmosis	water, high→low water potential	partially permeable membrane	no

Endocytosis brings bulk material in by vesicle; exocytosis exports it – both need ATP for vesicle movement.

Water potential

Pure water has the highest water potential (0 kPa); any solute lowers it (negative values). Water moves from less negative to more negative water potential through a **partially permeable membrane** . A cell in a more negative solution loses water and shrinks; in a less negative solution it gains water.

■ **Fick's law**

$$\text{rate of diffusion} \propto \frac{\text{surface area} \times \text{concentration difference}}{\text{diffusion distance}}$$

■ **Worked example: applying Fick's law**

Alveolus wall + capillary wall together ≈ 1 µm; a frog's skin ≈ 50 µm. With the same area and gradient, the alveolus diffuses about 50 times faster over distance. This is why lungs fold surface into themselves instead of thickening.

2 Practice

2.1 State what is meant by osmosis, in terms of water potential. [2]

2.2 A channel protein and a carrier protein both do facilitated diffusion. State one way they differ. [2]

2.3 Root hair cells take up nitrate ions against a gradient. Name the transport route and state what it requires. [2]

3 Exam-style questions

3.1 Potato cylinders of identical mass are placed in sucrose solutions of water potential −50, −200, −400, −800 and −1200 kPa for one hour. The cylinder in −50 kPa gains 8 % in mass; the cylinder in −400 kPa loses 6 %. Estimate the water potential of the potato tissue, explain your reasoning, and predict the mass change of the cylinder in −1200 kPa. [5]

3.2 Glucose crosses the gut wall into blood with the help of a sodium gradient: sodium ions are pumped out of the cell by active transport, and glucose enters with sodium through a co-transporter. Explain why this arrangement lets glucose enter the blood even when its concentration in the cell is already high, naming the direct energy user. [5]

3.3 A student models diffusion: drops of dye are placed at one end of three tubes of water 2 cm, 10 cm and 20 cm long. The time for colour to appear at the far end is 40 s, 620 s and 2 100 s. Explain how the results illustrate the relationship between diffusion distance and time, and why multicellular organisms cannot rely on diffusion alone for oxygen supply to deep cells. [5]

Solutions

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

2.1 Movement of water from a region of higher (less negative) water potential to a region of lower (more negative) water potential through a partially permeable membrane.

2.2 Channels are water-filled pores (often gated) through which small ions pass; carriers bind the molecule and change shape to carry it across.

2.3 Active transport; ATP and carrier proteins.

3.1 Tissue water potential lies between −50 and −400 kPa – the two movements are opposite. Zero mass change lies closer to −50 kPa (gain of 8 % smaller in magnitude than loss of 6 %... gains and losses are 8 and 6, similar), so estimate about −220 kPa. At −1200 kPa the gradient is steepest and outward, so the cylinder loses more than 6 %, perhaps 12–15 %.

3.2 The sodium pump keeps intracellular sodium very low; this maintains a sodium gradient into the cell whatever the glucose level. The co-transporter carries sodium down its gradient together with glucose, so glucose can enter even against its own gradient. The direct ATP user is the sodium-potassium pump carrying out active transport.

3.3 Time grows much faster than distance: 2.5× the distance gave ~15× the time, 10× gave ~52× – approximately with the square of distance. Deep cells are centimetres from the surface, so diffusion time would be hours, far too slow for aerobic respiration; hence a transport system delivering oxygen close to every cell.