UNIVERSITY MEDICINE • EXERCISE SHEET

1.1 Cell organisation and organelles

Name: _____ Class: _____ Date: _____ **Total: 22 marks**

KEY WORDS lysosome

Objective

Reason about organelle scale, surface-to-volume limits, and compartment failure as disease mechanism.

1 Key knowledge and worked examples

■ **The size ladder**

Ribosome 25 nm, membrane 8 nm, mitochondrion 2 µm, nucleus 6 µm, cell 20 µm; 2.2 m of DNA packs into the 6 µm nucleus (~10^5 linear).

■ **Worked example: the surface argument**

$SA/V = 3/r$: a 20 µm cell has 0.3 μm^{-1}, a 200 µm oocyte 0.03 – ten times worse ✓. Big cells are rare and membrane-folded.

2 Practice

2.1 Compute SA/V for a 5 µm bacterium. [3]

2.2 How many 25 nm ribosomes span one 20 µm cell diameter? [3]

2.3 Why does the ER fold so much membrane into the cytoplasm? [3]

3 Exam-style questions

3.1 A hepatocyte (20 µm) and a reticulocyte (5 µm).

Compute SA/V for both and state which has more membrane service per unit cytoplasm. The hepatocyte packs ~1000 mitochondria: give the surface argument for why energy demand scales with volume but ATP synthesis scales with inner membrane. State one design consequence for large secretory cells. [7]

3.2 A (fictional) patient lacks one lysosomal hydrolase.

Explain the mechanism from missing enzyme to cell death. State why the disease is called a storage disease. Name the compartment's working pH and why it differs from the cytosol. [6]

Solutions

2.1

- $3/2.5 = 1.2\ \mu m^{-1}$ – four times the hepatocyte's service ✓.

2.2

- $20/0.025 = 800$ ✓.

2.3

- $SA/V = 3/r$ falls as cells grow; folding membrane raises effective surface without raising volume.

3.1

- Hepatocyte $3/10 = 0.3$; reticulocyte $3/2.5 = 1.2$ – the small cell has $4\times$ the membrane service ✓.
- Demand (protein synthesis, pumping) scales with volume; the electron-transport chain lives on inner membrane, so mitochondria multiply to supply area.
- Consequence: secretory cells fold membrane (ER) and/or stay small or flat.

3.2

- Substrate cannot be dismantled at pH 4.8 → accumulates → lysosome swells → cell dies of failed recycling.
- Storage disease: the undigested substrate is stored in swollen lysosomes.
- pH ≈ 4.8; proton pumps keep it acidic so hydrolases are active only inside, protecting the cytosol (pH ~7.2).