Study question answers 2014 – Topic 1 Introduction to cell biology

Multiple choice questions (1 mark per answer). Note that questions are based both on the lecture material and on the recommended/required readings.

1. Which one of the following statements concerning prokaryotic cells is true?
   a. They have no nucleus and hence no DNA.
   b. They have no Golgi apparatus
   c. They include bacteria, yeast, and protists.
   d. They are all able to live on inorganic energy sources.
   e. Both (a) and (b) are true of prokaryotic cells.

2. Which one of the following model organisms is favoured by plant molecular biologists for its small genome?
   a. *Arabidopsis thaliana*
   b. *Caenorhabditis elegans*
   c. *Escherichia coli*
   d. *Danio rerio*
   e. *Drosophila melanogaster*

3. Which one of the following statements regarding the cytoskeleton is false?
   a. It is made up of microfilaments, microtubules and intermediate filaments.
   b. It is involved in cell movement and thus is absent from plant cells.
   c. It provides support to the plasma membrane.
   d. It is dynamic and is constantly being rearranged.
   e. It is not present in prokaryotic cells.

4. The cell sketched at right is most likely:
   a. A prokaryotic cell
   b. A protist
   c. A plant cell
   d. An animal cell
   e. Either a protist or an animal cell; it is impossible to distinguish between these possibilities on the basis of the schematic pictured at right.

5. Which one of the following statements about the evolution of present-day organisms is true?
   a. Eukaryotes preceded prokaryotes.
   b. Eukaryotes acquired chloroplasts before they acquired mitochondria.
   c. The common ancestral cell was likely an archaean.
   d. All of a, b, and c are true of the evolution of present-day organisms.
   e. None of a, b or c is true of the evolution of present-day organisms.

6. Order the following in size from smallest to largest:
   a. Protein molecule
   b. Ribosome
   c. Carbon atom
   d. Endoplasmic reticulum
   e. Yeast cell

__c__ < __a__ < __b__ < __d__ < __e__

7. The endosymbiont theory…
   a. Is supported by the fossil record, which indicates that eukaryotic cells evolved before prokaryotic cells.
   b. Suggests that mitochondria may have originated as photosynthetic bacteria and chloroplasts as aerobic bacteria that established stable, symbiotic relationships with a prokaryotic host cell.
   c. Is supported by similarities between mitochondria/chloroplasts and protists, including the use of binary fission for reproduction, and the presence of genetic material in the form of a single, circular chromosome of DNA that lacks protein.
   d. Is supported by the observation that some animals, such as the sea slug *Elysia chlorotica*, are able to acquire chloroplasts that are incorporated into and function within the animal's cells, a phenomenon termed kleptoplasty.

8. The third tenet of the cell theory, that cells can arise only by division from a pre-existing cell, is attributed to:
   a. Schleidan & Schwann
   b. Gorter & Grendel
   c. Singer & Nicolson
   d. Virchow
   e. Crick & Watson

9. Which one of the following statements about limitations on cell size is **not** correct?
   a. Compartmentalization of the intracellular environment is a strategy used by eukaryotic cells to achieve larger cell sizes because it restricts the need for adequate concentrations of substrates to a specific region of the cell rather than the entire cell volume.
   b. As cell size increases, the surface area available for exchange of nutrients and waste products does not keep up with the requirements of the cell, which are determined by its volume.
   c. An internal transport system based on motor protein movement along the cytoskeleton can overcome limitations on cell size imposed by the slow rate of diffusion.
   d. Elaboration of the internal membrane systems of the cell (e.g. endoplasmic reticulum, Golgi complex) can provide a means of overcoming limitations on the surface area for exchange as cell dimensions, and hence volume, increase.
   e. A tripling of the linear dimension of a cell results in a 27-fold increase in the number of molecules needed to maintain adequate concentrations; the synthetic machinery of the cell may not be able to keep up with this demand.

10. A typical prokaryotic cell is...
    a. 0.03 mm long
    b. 3×10^{-6} m long
    c. 30 nm long
    d. 3×10^{6} µm long
    e. None of the above

Written answer questions (use the marks specified to gauge the content needed for your answer; in all cases, the answer must not exceed the space indicated)

1. In a eukaryotic cell specialized for secretion (e.g. a peptide hormone-producing cell in an endocrine gland of an animal), which internal organelles would you expect to be particularly abundant? Explain your answer. (2 marks)

Rough endoplasmic reticulum, Golgi complex and possibly vesicles would be expected to be particularly abundant in a eukaryotic cell specialized for secretion, because these organelles are involved in the synthesis (rough ER) and packaging (Golgi complex) of proteins that are exported from the cell.

2. True OR false (**circle one**): A virus is a cell.
   Justify your answer. (2 marks)

A virus lacks essential elements of a cell, such as the cell membrane, and is therefore not a cell.

3. Distinguish between a vacuole and a vesicle. (2 marks)

A vesicle typically contains proteins and is used to shuttle proteins between organelles or to the plasma membrane for export, whereas a vacuole is a storage organelle that often contains water or metabolites.

4. Identify a model organism by both scientific and common names, and comment on its usefulness or value (i.e. by virtue of what characteristics has it come to be popular as a model organism?). (3 marks)

The common house mouse, *Mus musculus*, is used as a model for humans in studies related to the physiology and disease states of humans. As mammals, mice share many characteristics in common with humans. They are also small and relatively easy to maintain in a lab setting.

5. Discuss the strategies employed by eukaryotic cells to overcome the limitations that constrain prokaryotic cells to sizes that are typically an order of magnitude smaller. (4 marks)

The cytoskeleton of eukaryotic cells provides a transport system within the cell that does not rely upon diffusion. As cell size increases, the distances over which solutes must diffuse become longer and the slow rate of diffusion over these longer distances places limitations upon cell size. Eukaryotic cells can overcome this limitation via the internal transport system provided by the cytoskeleton.

Organelles in the cytoplasm of eukaryotic cells function as intracellular compartments that reduce the need for the cell to synthesize substrates. To maintain adequate concentrations of substrates for biochemical reactions, the number of molecules required increases as a function of the volume of the cell. Synthesizing the necessary number of molecules can tax the synthetic machinery of the cell, limiting cell size. Compartmentalization overcomes this problem by reducing the volume within which the adequate concentration of a given substrate must be achieved.

6. The endosymbiont theory hypothesizes that mitochondria evolved from the incorporation of an aerobic prokaryote into an ancestral, probably anaerobic prokaryote. What evidence can be used to support this hypothesis? (6 marks)

The main line of evidence that supports the endosymbiont theory comes from the similarities between mitochondria and prokaryotic cells. For example, mitochondria are similar in size to prokaryotic cells (~2 µm long). They are surrounded by a double membrane, and the inner mitochondrial membrane lacks sterols, as do prokaryotic membranes. The presence of a double membrane is consistent with the endosymbiont theory – the inner membrane would be derived from the plasma membrane of the prokaryotic cell that was engulfed, and the out membrane would be derived from the host cell membrane that surrounded the engulfed cell. Mitochondria possess mitochondrial DNA (mDNA) in the form of a single circular chromosome without protein. Mitochondria possess ribosomes that are similar in size and structure to prokaryotic ribosomes (and smaller and simpler than eukaryotic cell ribosomes). Mitochondria reproduce by binary fission, as do prokaryotic cells. All of these similarities are consistent with the evolution of mitochondria from the incorporation of an aerobic prokaryote into an ancestral host cell. In addition, the fossil record supports the earlier evolution of prokaryotic than eukaryotic cells, which is also consistent with the endosymbiont theory. Finally, recent examples of endosymbiotic processes, such as the kleptoplasty exhibited by the sea slug *Elysia chlorotica*, provide confidence in the ability of endosymbiosis to explain the evolution of mitochondria.