BSc Degree Examinations 2018-9

Department: BIOLOGY

Title of Exam: Cell and Development Biology

Time Allowed: 1.5 hours

Marking Scheme:
Total marks available for this paper: 50
The marks available for each question are indicated on the paper

Instructions: Answer all questions in the spaces provided on the examination paper

DO NOT WRITE ON THIS BOOKLET BEFORE THE EXAM BEGINS
DO NOT TURN OVER THIS PAGE UNTIL INSTRUCTED TO DO SO BY AN INVIGILATOR
1. “Mature erythrocytes are not eukaryotic cells”. Justify this statement and construct an argument against it. (2 marks)
   Justification: A defining feature of eukaryotes is the presence of a nucleus, but mature erythrocytes don’t have nuclei (1 mark)
   Argument against: Enucleation occurs post-differentiation and therefore mature erythrocytes could not exist without having had a nucleus (1 mark).
   Relation to module learning outcomes: Describe the organisation and key features of eukaryotic cells.

2. a) How are macromolecules moved between intracellular compartments within eukaryotic cells? (1 mark)
   By means of vesicular traffic with transport vesicles carrying cargo from donor to acceptor compartments (1 mark)

   b) How are eukaryotic cells thought to ensure specificity to the movement of macromolecules between intracellular compartments? (2 marks)
   This can be explained by the SNARE hypothesis (1 mark) which states that each transport vesicle carries a specific v-SNARE that will only recognise its cognate t_SNARE localised on the appropriate target organelle (1 mark).

   c) Outline an experiment that demonstrates the molecular mechanisms that regulate movement of macromolecules between intracellular compartments in eukaryotic cells are conserved through evolution. (3 marks)
   Human NSF and yeast SEC18 have high sequence homology (1 mark)
   Expression of human NSF in yeast cells lacking SEC18 (1 mark) restores membrane trafficking defects of the mutant yeast (1 mark)
   Relation to module learning outcomes: Describe the organisation and key features of eukaryotic cells AND Discuss experimental evidence that supports the key concepts presented in the module.

3. What are the evolutionary advantages of multicellularity? (3 marks)
   Answer: Multicellular organisms are bigger and better protected from predation (1 mark). Larger organisms are buffered more effectively from the external environment (homeostasis) (1 mark). Multicellularity allows the development of cell-types with specialised functions within organisms (1 mark).
   Relation to module learning outcomes: Explain how the properties of eukaryotic cells have allowed the evolution and development of multi-cellular organism
4. a) Briefly describe the process of cloning an animal. (3 marks)

**Answer:** Destroy frog egg nucleus with UV light (1 mark). Remove nucleus from differentiated cell (gut epithelial cell or cultured skin cells)(1 mark). Implant nucleus into enucleated egg and allow development to proceed (1 mark). (similar description for Dolly the sheep would also attract full marks).

**Relation to module learning outcomes:** Discuss experimental evidence that supports the key concepts presented in the module.

b) What does the ability to clone animals tell us about the nature of development and gene expression? (2 marks)

**Answer:** Genetic information is not lost during the process of development (1 mark). The process of development is dependent upon differential gene expression (1 mark).

**Relation to module learning outcomes:** Describe and illustrate with specific examples the mechanisms regulating cell growth, cell death and cell-type specification in multicellular organisms. Discuss experimental evidence that supports the key concepts presented in the module.

5. a) How do morphogens give positional information to cells? (2 marks)

**Answer:** Morphogen diffuses away from a source and establishes a concentration gradient (1 mark). Cell is able sense concentration of morphogen in its environment and therefore is able to sense its position relative to the source (1 mark)

**Relation to module learning outcomes:** Explain and illustrate with specific examples the general principles that underpin cell signalling in multicellular organisms.

b) Provide a piece of experimental evidence that the vegetal hemisphere of the frog embryo is the source of mesoderm inducing signals. (1 mark)

**Answer:** In animal and vegetal explant combination experiments, the resulting mesoderm is derived from the animal tissue and not the vegetal tissue. (Therefore, the vegetal tissue is the source of the mesoderm inducing signal and the animal tissue is the responding tissue.)

**Relation to module learning outcomes:** Discuss experimental evidence that supports the key concepts presented in the module.

c) How does nodal binding to its receptor lead to changes in gene transcription? (4 marks)

**Answer:** Binding of nodal to its receptor leads to dimerization and activation of intracellular serine/threonine kinase activity (1 mark). Smad2/3 are phosphorylated and activated by receptor complex (1 mark). Smad2/3 form complexes with
co-smad (smad4) and translocate to the nucleus, binding to cis-regulatory elements of target genes to activate or inhibit gene transcription (2 marks).

**Relation to module learning outcomes:** Describe the mechanisms regulating eukaryotic gene expression. Explain and illustrate with specific examples the general principles that underpin cell signalling in multicellular organisms.

### 6. a) Explain why peptide hormone receptors and steroid hormone receptors are located in different regions of the cell. (2 marks)

**Answer:** Peptide hormones are typically hydrophilic, therefore, are unable to diffuse across the hydrophobic cell membrane and receptors are typically present at the cell's surface (1 mark). Steroid hormones are hydrophobic and are able to diffuse across the cell membrane, therefore, receptors are typically located in the cell (1 mark).

**Relation to module learning outcomes:** Explain and illustrate with specific examples the general principles that underpin cell signalling in multicellular organisms.

### b) FGF proteins typically contain an N-terminal domain of 25 amino acids with a core of hydrophobic residues. What is the function of this domain? (1 mark)

**Answer:** It targets them to the secretory pathway.

**Relation to module learning outcomes:** Explain and illustrate with specific examples the general principles that underpin cell signalling in multicellular organisms. Interpret evidence.

### c) How does the MAP kinase cascade act as an amplification step during FGF signalling? (3 marks)

**Answer:** The three components of the cascade, raf, mek and erk, are enzymes (1 mark). Therefore, one molecule of raf (MAPK3) is able to phosphorylate and activate many mek molecules (MAPK2). Each activated mek molecule is able to phosphorylate and activate many erk molecules (MAPK) (2 marks).

**NB.** Needs to demonstrate appropriate knowledge of the order of components in the pathway.

**Relation to module learning outcomes:** Explain and illustrate with specific examples the general principles that underpin cell signalling in multicellular organisms.

### 7. a) What effects do transcription factor proteins bound to enhancers and silencers have on gene expression? (1 mark)

**Answer:** Factors bound at enhancers have a positive effect on gene transcription and factors bound at silencers have a negative effect on gene
transcription (1 mark)

**Relation to module learning outcomes:** Describe the mechanisms regulating eukaryotic gene expression

b) How do transcription factors bound at distant enhancers and silencers influence the activity of RNA polymerase II?  
**Answer:** Transcription factors bound to these cis-regulatory elements cause DNA to loop and allows them to contact and influence the activity of the transcription initiation complex at the promoter (2 marks).  
**Relation to module learning outcomes:** Describe the mechanisms regulating eukaryotic gene expression

c) What are E-boxes and why are they important in muscle differentiation?  
**Answer:** They are the binding sites for heterodimers of myogenic regulatory factors (myod, myf5 etc) and E-proteins and are present in the cis-regulatory of proteins required for muscle differentiation (2 marks). Binding of MRFs to the E-boxes activates transcription of genes such as actin and myosin (1 mark)  
**Relation to module learning outcomes:** Describe the mechanisms regulating eukaryotic gene expression

8. The diagram below depicts a stage in early human embryo development. Annotate the diagram to label the key structures and indicate cell potency.  
**(5 marks)**
9 a) Describe the tissue location and function of epidermal stem cells. (2 marks)

Epidermal stem cells are located in the basal layer of the epidermis in skin (1). Their function is to divide and differentiate into new epidermal cells (keratinocytes) to maintain skin health (1).

b) Describe an experiment, using epidermal stem cells that would allow you to determine how their expression of Cyclins changes during the cell cycle. (4 marks)

Example marking: Answers will need to recognise that the approach will be a modification of the Tim Hunt sea urchin experiments, but reference to these will attract marks (1). Epidermal stem cells can be isolated from skin epidermis (1). Some thought of how to synchronise the cells in the cell cycle is required. This could be through contact inhibition or reduced serum to synchronise the cells in G0, or at least some evidence/attempts to time the start of cycling activity (1). Cycling activity initiated (e.g. replated, addition of growth factors/mitogens) and protein samples taken at different times using a sensible time frame (e.g. 0-24h) (1) and separated by SDS-PAGE to show variation in expression levels (of Cyclins) with cell cycle. Also accept appropriate alternatives such as Western blotting for Cyclin expression during cell cycle sampling (1).

Relation to module learning outcomes: Explain and illustrate with specific examples the general principles that underpin cell signalling in multicellular organisms AND Discuss experimental evidence that supports the key concepts.
presented in the module.

10. Describe how different types of cells contribute to the structure, organisation and function of a long bone. Include reference to a specific stem cell. (4 marks)

Example marks: Osteoblasts act to produce bone by synthesising type I collagen, other bone matrix proteins and initiating mineralisation (1). Osteoblasts originate from mesenchymal stem cells (1). Osteocytes differentiate from osteoblasts and are located within the bone matrix where they can act as mechanosensory cells (1). Osteoclasts differentiate from haematopoietic stem cells (HSCs) as monocytes fuse to form multinucleated resorptive osteoclasts (1). Additional marks available for more details on location/function of all these cells (e.g. bone surface, lacunae, canaliculi, resorptive enzymes). HSCs are located in bone marrow and differentiate into all blood cell lineages (1) and therefore contribute to all levels of haematopoietic function (1).

**Relation to module learning outcomes**: Describe the organisation and key features of eukaryotic cells.