

## Part A – Short answers

1. Name at least four features that clearly distinguish neuronal signaling from endocrine signaling.

(1) The distance over which the signaling molecule acts; Neuronal signaling (NS): short distance; Endocrine signaling (ES): long distance

(2) The medium through which the signaling molecule is distributed; NS: axon + extracellular medium; ES: the bloodstream

(3) The speed with which the signal molecule is delivered; NS: 100 m/s; ES: much slower

(4) NS: electrical impulses involve; ES: electrical impulses don't involve

2. The feature that clearly distinguishes paracrine signaling from autocrine signaling is:

Paracrine signaling: signaling cells synthesize and release signaling molecules that then act on target cells having receptors for these signaling molecules. Autocrine signaling: signaling cells synthesize and release signaling molecules that then act on the same signaling cells because they have receptors for these signaling molecules

3. Name three classes of cell-surface receptors that are involved in the primary signal transduction step.

(1) G-protein-linked receptors

(2) ion-channel-linked receptors

(3) enzyme-linked receptors

4. The function of GTP in the adrenaline-induced cAMP signaling pathway is:

When GTP binds to the  $\alpha$  subunit of the heterotrimeric Gs protein, the activated GTP-bound  $\alpha$  subunit dissociates from the  $\beta$  and  $\gamma$  subunits of the heterotrimeric Gs protein and then binds to and activates the adenylate cyclase enzyme

5. Name the isoform of the enzyme that catalyzes the synthesis of DAG (diacylglycerol) and IP<sub>3</sub> (inositol 1,4,5-triphosphate) from PIP<sub>2</sub> (phosphatidylinositol 4,5-bisphosphate) and is activated by growth factor-dependent receptor tyrosine kinases.

Phospholipase C- $\gamma$  (PLC-  $\gamma$ )

6. Why does the rise in the cytosolic Ca<sup>2+</sup> increase the level of cAMP in the cytosol?

Ca<sup>2+</sup> binds to and activates calmodulin (CaM). The Ca<sup>2+</sup>-bound, active CaM then binds to and activates the CaM-dependent protein kinase for cAMP phosphodiesterase. This CaM-dependent protein kinase then phosphorylates and inactivates cAMP phosphodiesterase, thereby increasing the level of cAMP in the cytosol

7. How does the binding of the epidermal growth factor (EGF) to its receptor activate the Ras protein?

(1) EGF binding to the receptor tyrosine kinase causes its dimerization

(2) The receptor tyrosine kinase undergoes autophosphorylation

(3) The phosphorylated form of the receptor tyrosine kinase binds to the adapter protein Grb2

(4) Grb2 binds to the protein Sos, which then interacts with the inactive GDP-bound form of Ras

(5) Sos acts as a guanine nucleotide-exchange factor (GEF), which helps to convert the inactive GDP-bound form of Ras to its active GTP-bound form

8. You have purchased cytochrome c from a biotechnological company. Briefly describe how you would use this commercially available protein in order to determine the subcellular location of cytochrome c with the help of electron microscopy.

- (1) Use the purchased cytochrome c as an antigen molecule to create antibodies that interact only with cytochrome c
- (2) Attach these antibodies to electron-dense colloidal gold particles
- (3) Treat thin sections of glutaraldehyde-fixed cells with the gold-labeled anti-cytochrome c antibodies
- (4) Use electron microscopy to determine the subcellular location of cytochrome c within these cells

9. Name three glycerol and non-glycerol phospholipids that have polar heads with the net charge 0 (zero) at pH 7.

Glycerol phospholipids:

Phosphatidylcholine (a glycerol phospholipid), phosphatidylethanolamine (a glycerol phospholipid), sphingomyelin (a non-glycerol phospholipid)

10. When placed in a hypertonic solution, the cells and organelles shrink. Why?

Because water flows out of cells until the ion concentration inside and outside of the cell is the same

11. What are the two functions of a receptor for an extracellular signaling molecule in signal transduction and what are the two functions of the secondary signal transduction steps?

Two functions of a receptor for an extracellular signaling molecule in signal transduction: (1) binds to the extracellular signaling molecule; (2) transduces (converts) extracellular signals into intracellular signals

Two functions of the secondary signal transduction steps: They amplify and distribute the intracellular signals within the target cell

12. In light microscopy, placing oil between the specimen and the objective lens increases resolution. Why?

Because it increases the value of refractive index (n), thereby decreasing the value of D (the minimum distance between two distinguishable objects)

13. Name five functionally distinct compartments of the Golgi apparatus and briefly describe the function of the Golgi compartment that points towards the plasma membrane.

The cis-Golgi network, cis-Golgi cisterna, medial cisterna, cis-Golgi cisterna and trans-Golgi network. Trans-Golgi network points towards the plasma membrane; it is actively involved in sorting proteins into vesicles that then deliver these proteins to the lysosome, plasma membrane or extracellular medium

14. Name three features of transport vesicles that allow each organelle of the endomembrane system to maintain its own distinctive protein composition.

High selectivity of the processes of transport vesicle packaging, budding and fusion.

15. Briefly describe two functions of the Hsp70 protein in the ER lumen.

(1) Binds to the extending polypeptide chain in the ER lumen and uses the energy of ATP hydrolysis to pull the polypeptide chain into the lumen

(2) Act as a chaperone by using the energy of ATP hydrolysis to assist in the final folding of the translocated protein into its mature, functionally active confirmation

16. Name three proteins that assist in the final folding of polypeptides translocated across the membrane of the endoplasmic reticulum (ER) and in the assembly of these folded polypeptides into multimeric complexes within the ER lumen.

Hsp70, calnexin, calreticulin

## Part B – Multiple choice questions

1. In paracrine signaling, the extracellular signaling molecules released by a signaling cell act on:  
B. target cells in the close proximity to the signaling cell
2. Which of the following is not considered a second messenger:  
E. GTP
3. Adrenaline-induced activation of adenylate cyclase depends on:  
F. none of the above
4. The  $\beta$  isoform of phospholipase C (PLC- $\beta$ ) is activated by:  
E. heterotrimeric Go protein
5. The  $Ca^{2+}$ - and DAG-activated form of protein kinase C phosphorylates and inactivates:  
F. none of the above
6. Large heterotrimeric G proteins and small monomeric G proteins are involved in a variety of signal transduction pathways. Regardless of differences in structure, all G proteins are activated by:  
F. none of the above
7. Glycogen phosphorylase catalyzes the breakdown of glycogen to glucose. This enzyme is activated by:  
C. phosphorylation
8. Detergents and phospholipids have similar property in that they both:  
E. are amphipathic
9. The excitation wavelength of fluorescein is 470 nm. The emission wavelength of fluorescein is 540 nm. If fluorescein is used as a reporter molecule for fluorescence microscopy, the second barrier filter in a fluorescence microscope:  
A. lets through only the light with a wavelength between 520 nm and 560 nm
10. COPII-coated secretory vesicles are involved in protein transport:  
C. from the endoplasmic reticulum to the Golgi apparatus
11. Resolution in light microscopy can be improved by:  
F. increasing the angular aperture
12. The asymmetric distribution of sphingomyelin between the extracellular and cytosolic leaflets of the plasma membrane is due to:  
B. lack of flippases that can translocate this lipid between the leaflets of the plasma membrane
13. Immunogold electron microscopy:  
E. is used to determine the subcellular localization of proteins
14. Protein import into the mitochondrial matrix requires:  
E. all of the above

15. The nucleus communicates with the cytosol via:

C. nuclear pore complexes

16. The  $\text{Ca}^{2+}$ -bound form of calmodulin (CaM) activates kinases that phosphorylate:

D. all of the above

17. The nucleolus is:

E. the assembly centre for ribosomes

18. Free ribosomes in the cytosol synthesize proteins for:

D. the nucleus

19. If pure phospholipids are applied to a small hole in a partition that separates two compartments, each filled with a non-polar solvent, which of the following structures are they likely to form in the hole:

A. bilayered sheets (flat bilayers) with the hydrophobic groups facing the outside surfaces of the bilayer

20. Inositol 1,4,5-triphosphate (IP3) causes  $\text{Ca}^{2+}$  to be released into the cytosol from:

F. none of the above