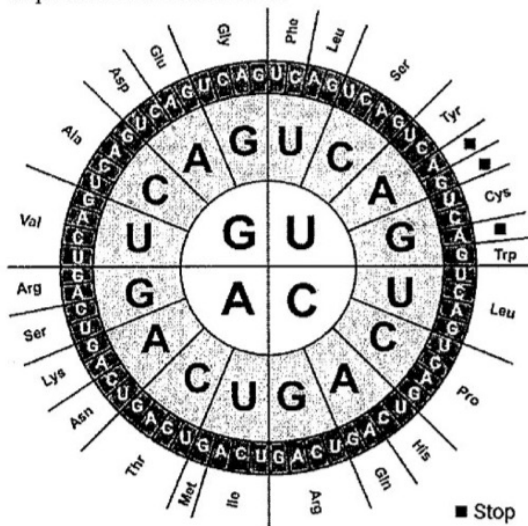


## Part 1: Short Answer

If necessary, use blank sheets provided for calculations or draft answers.

### Equations and Codon Chart



$$V_m = 61 \log \frac{P_{K^+}[K^+]_{out} + P_{Na^+}[Na^+]_{out} + P_{Cl^-}[Cl^-]_{in}}{P_{K^+}[K^+]_{in} + P_{Na^+}[Na^+]_{in} + P_{Cl^-}[Cl^-]_{out}}$$

Where:  $V_m$  is the membrane potential in mV;  $P_{K^+} = 1$ ;  $P_{Na^+} = 0.04$ ;  $P_{Cl^-} = 0.3$ ; and ions in [ ] are the respective concentrations

$$E_x = \frac{61}{Z} \log \frac{[X]_{out}}{[X]_{in}}$$

Where:  $E_x$  is the Nernst potential in mV;  $Z$  = ion valence; and  $[X]$  is concentration

$$\Delta G_{Chem} = RT \ln \frac{[X]_{out}}{[X]_{in}}$$

Where:  $\Delta G_{Chem}$  is the free energy available from the chemical gradient, defined from inside the cell to outside;  $R = 8.314 \text{ J/mol K}$ ;  $T$  is taken to be  $309.65 \text{ K}$ ; and  $[X]$  is the concentration

$$\Delta G_{Elec} = ZFV_m$$

Where:  $\Delta G_{Elec}$  is the free energy available from an electrical potential inside a cell with respect to the outside;  $V_m$  is the membrane potential in V;  $Z$  = ion charge; and  $F = 96485 \text{ C/mol}$

Q1) Below are two complementary strands of DNA that contain a hypothetical gene. Given only the information immediately below, check which DNA sequence represents the template strand. (1)

☐ 5' - ATG | GGG | TTA | AGA | TAT | TGA | TTT | TAG - 3'

☒ 3' - TAC | CCC | AAT | TCT | ATA | ACT | AAA | ATC - 5'

Q2) How do you know which of the DNA strands shown above were used as a template for transcription? List two different characteristics or qualities. (2)

Q3) Using the DNA strands shown above, what is the corresponding transcription of RNA? Include the proper directional notations. (2)

Q4) Using the answer immediately above, assume that there is no more RNA processing (i.e., it represents mRNA), what is the translated protein sequence? (2)

Q5) What molecule brings individual amino acids to the ribosome to create the protein sequence?  
(1) What feature of this molecule allows it to recognize when/where it should attach to mRNA? (1)

Q6) The NASA Astrobiology Rover has discovered a lifeform in the subsurface ocean of Europa that can communicate by generating action potentials in its neurons. Interestingly, the inward current of magnesium exhibits a very steep concentration gradient in these neurons and has been determined to be responsible for the rising phase of these action potentials. Given the intracellular and extracellular ion concentrations of magnesium (see table below), what would the equilibrium potential be? (2)

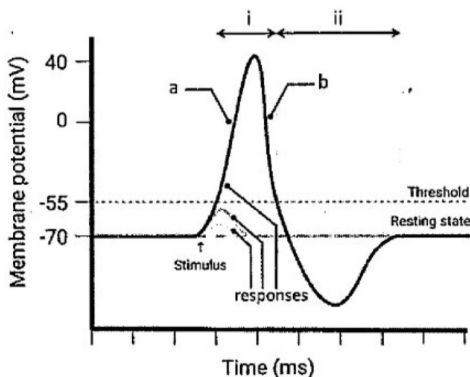
Ion	Mg <sup>2+</sup>
Intracellular (mMol/L)	0.00007
Extracellular (mMol/L)	2.0

Q7) In the Tycho Station orbiting Jupiter, you want to investigate the organism you discovered on Europa. If you experimentally increase the permeability of the cell membrane to magnesium ions, do you expect the equilibrium potential of that ion to increase, decrease, or remain unchanged? (1) In one sentence, explain your answer. (1)

Q8) In your sampling of the organism you find other elements besides magnesium. Based on your knowledge of how a resting membrane potential (RMP) is produced, you expect that the equilibrium potential of magnesium will be different from the RMP. Using a maximum of three sentences, describe, in general, the difference between RMP and equilibrium potential. (3)

This figure is a depiction of a typical response of a neuron at the hillock region. Use the annotations to answer all the questions on this page.

Q9) What term describes what is happening at point "a"? (1) What is the main cause of changes in membrane polarization at this point? (1)



Q10) What term describes what is happening at point "b"? (1) What is the main cause of changes in membrane polarization at this point? (1)

Q11) There are two periods of time labelled "i" and "ii". What are they called? (2)

Q12) Describe (in terms of particular states specifically) what is happening during period "i" and why this period of time is notable. (2)

Q13) There are different potential responses to a stimulus shown in the figure. Beyond the obvious fact that some responses are above and below the threshold, describe the most salient difference between these ~~stimuli~~ (1) responses

Q14) Given the intracellular and extracellular ion concentrations in young neurons (see table below); answer, in three sentences or less, what will happen to the membrane potential of a postsynaptic neuron (that has GABA receptors) if a presynaptic neuron releases GABA upon it? Use the equations given to calculate numbers (in correct units, to one decimal place) to support your qualitative response. (7)

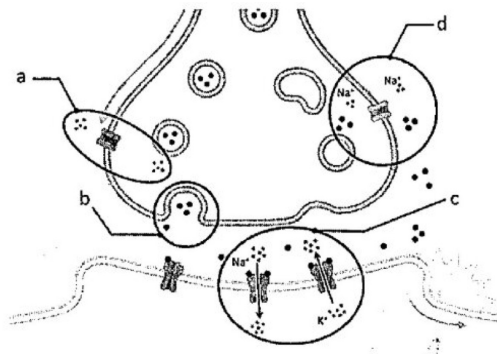
Ion	K <sup>+</sup>	Na <sup>+</sup>	Cl <sup>-</sup>
Intracellular (mMol/L)	150	15	20
Extracellular (mMol/L)	5	150	110

Q15) Calculate the Gibbs free energy, in correct units (to one decimal place) and explain how it helps support your answer above: (4)

This figure displays several specific molecular transport mechanisms that exist at the neuronal synapse and the chain of events that occur during synaptic communication.

Q16) The circled area labelled “a” shows what happens when the action potential reaches the presynaptic terminal knob and has some effect to allow channel-mediated transport of a specific ion that enables the process shown in “b”.

Answer, in more specific terms: a) What type of channel is this is? (2) b) What effect might this ion have? (1)

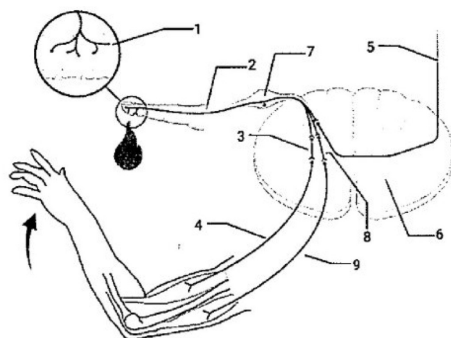


Q17) In the circled area labelled “c” there appears to be movement of ions inward and outward of the cell in response to some ligand. In general terms, this channel could be called a ligand-gated channel. Using more specific terms, answer the following: a) What is another way to describe this channel? (2) b) What type of receptor is this? (1) c) What specific ligand could this be? (1)

Q18) The action of neurotransmitters can be stopped by four different mechanisms. The circled area labelled “d” shows one mechanism. List two additional processes that eliminate neurotransmitters from the synaptic cleft. (2)

A spinal reflex arc is shown in this figure.

Q19) What type of receptor is shown in number 1? (1)



Q20) What kind of neuron is labelled as number 2? (1)

Q21) Where does the postsynaptic neuron, labelled number 5, eventually project to in the brain to have an awareness that the finger is being stimulated? Use keyword terms to be specific (2)

Q22) What does number 3 represent? (1) Is it excited or inhibited? (1)

Q23) What does number 9 represent? (1) Is it excited or inhibited? (1)

Q24) Number 6 points to a region in the spinal cord. Does this area have ascending, descending, or no tracts at all? (1) Explain your answer in one sentence. (1)

## Part 2: Multiple-Choice Questions

Indicate the answer choice that **best** completes the statement or answers the question.

- Which of these statements best describes negative feedback loops that influence homeostasis?
  - Efferent nerves are excited, and the system enhances a particular physical response.
  - ☒ Efferent nerves are excited, and the system diminishes a particular physical response.
  - Efferent nerves are inhibited, and the system diminishes a particular physical response.
- Which of the following analogies best describes how DNA functions?
  - DNA is like a ladder where the hydrogen bonds between matching nucleotides are the steps.
  - DNA is like a zipper because it can be zipped and unzipped during transcription.
  - ☒ DNA is like a series of buttons that can be undone as required to access only the required information, without undoing all buttons.
- The best comparison of how tRNA interacts with the ribosome to create a protein is how:
  - ☒ a wandering catering server is to a plated service meal
  - a concrete delivery truck is to a construction site.
  - a vending machine slot is to the vending machine.
- Which of the following can't cross a lipid bilayer?
  - ☒ Ions because they are charged.
  - H<sub>2</sub>O because it is a polar molecule.
  - Hydrocarbon molecules because they are too large.
- In the game Cytosis, you saw what the initial resource was to produce a steroid hormone. Do steroid molecules need a channel to be transported or diffuse across the cell membrane?
  - ☒ Yes, because they are large molecules and need to be carried.
  - No, because they are hydrophobic and diffuse freely.
  - No, because they all get stuck in the cell membrane.
- Which of the following options best describes the function of the mitochondria in a cell?
  - ☒ The mitochondria are like the engine of a car, providing energy to power functions of a cell.
  - ~~The mitochondria are like the fuel in a car, providing an energy source for functions of a cell.~~
  - The mitochondria are like the hitch hiker you picked up who helped you pay for gas, providing a symbiotic relationship to complete functions of a cell.



7. Where are the enzymes for glycolysis located?
- In the mitochondrial matrix.
  - ☒ In the cytosol.
  - In the inner mitochondrial membrane.
8. Which of these statements does NOT apply to ribosomes?
- They are composed of RNA.
  - They assemble proteins.
  - ☒ They are covered by a membrane.
9. For a given molecule crossing a cell membrane, the chemical driving force:
- Depends only on the concentration gradient if the molecule is uncharged, but also depends on the electrical force if the molecule is an ion.
  - ☒ Depends only on the concentration gradient, regardless of whether or not the molecule is an ion.
  - Is the total driving force on the molecule, whether or not it is an ion.
10. Ouabain (the active ingredient in some poison arrows) blocks the  $\text{Na}^+ \text{K}^+$  ATPase pump. If you get hit by one of these arrows, will you be able to move?
- Yes, for a time, because there is still a concentration gradient of  $\text{Na}^+$  and  $\text{K}^+$  to create action potentials.
  - ☒ No, because after a single action potential there is no more concentration gradient for  $\text{Na}^+$  or  $\text{K}^+$ .
  - Yes, because  $\text{Na}^+$  and  $\text{K}^+$  leak channels will allow a concentration gradient of  $\text{Na}^+$  and  $\text{K}^+$  to be established and action potentials to be created.
11. Which factor would increase the speed of nerve impulses?
- Cold temperatures because ion channels are locked open.
  - Decreasing axon diameter because ion channels can open quicker.
  - ☒ Increasing axon diameter because there is a greater surface area.
12. In comparing a monosynaptic reflex to an email exchange, which of the following is the most accurate?
- A monosynaptic reflex is like when your boss replies immediately to your email.
  - A monosynaptic reflex is like an email that gets buried in the professors' inbox.
  - ☒ A monosynaptic reflex is like an automatic reply email.

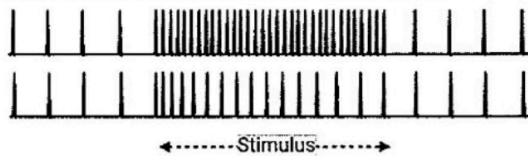
13. Which statement applies to receptor potentials?
- a. They are graded potentials.
  - b. They self-propagate along the efferent fibres.
  - ☒ c. They occur in neuronal cell bodies upon summation of presynaptic input.

14. Which of these structures is at the peripheral end of an afferent neuron?
- a. Cell body
  - ☒ b. Axon terminal
  - c. Sensory receptor

15. Which of these receptors is rapidly adapting?
- ☒ a. Phasic receptor
  - b. Tonic receptor
  - c. Ruffini nerve ending

16. The tracings below represent the frequency of action potential firing in response to some physical stimulus, with some basal level of activation. Given that the dashed line represents the duration of a physical stimulus, which sensory receptor neuron exhibits tonic adaptation?

- a. Top receptor
- b. Neither top nor bottom receptors
- ☒ c. Both top and bottom receptors



17. Which of these statements *best* describes parasympathetic postganglionic fibres?
- a. They arise from the ganglion chain located along either side of the spinal cord.
  - b. They are longer than preganglionic fibres.
  - ☒ c. They are cholinergic fibres.

18. All postganglionic neurons bear \_\_\_\_\_.
- a. alpha-adrenergic receptors
  - b. muscarinic receptors
  - ☒ c. nicotinic receptors

19. Which of the following *best* describes nicotinic receptors?
- a. They bind with acetylcholine released from parasympathetic postganglionic fibres.
  - ☒ b. They respond to acetylcholine released from both sympathetic and parasympathetic preganglionic fibres.
  - ☒ c. They bind with norepinephrine released from sympathetic postganglionic fibres.

20. Which spinal nerves do sympathetic fibres emanate from?
- ☒ a. Thoracic and lumbar levels
  - b. Cranial and sacral levels
  - c. The Vagus nerve

# MC Answers

	A	B	C	D	E
1	CAJ			CDJ	CEJ
2	CAJ	CEJ		CDJ	CEJ
3		CEJ	CDJ	CDJ	CEJ
4		CEJ	CDJ	CDJ	CEJ
5			CDJ	CDJ	CEJ
6		CEJ	CDJ	CDJ	CEJ
7	CAJ		CDJ	CDJ	CEJ
8	CAJ	CEJ		CDJ	CEJ
9	CAJ		CDJ	CDJ	CEJ
10			CDJ	CDJ	CEJ
11	CAJ	CEJ		CDJ	CEJ
12	CAJ	CEJ		CDJ	CEJ
13		CEJ		CDJ	CEJ
14	CAJ			CDJ	CEJ
15		CEJ	CDJ	CDJ	CEJ
16	CAJ	CEJ		CDJ	CEJ
17	CAJ	CEJ		CDJ	CEJ
18	CAJ	CEJ		CDJ	CEJ
19	CAJ		CDJ	CDJ	CEJ
20		CEJ	CDJ	CDJ	CEJ