ENGINEERING TRIPOS PART IIA

Wednesday, 9th May 2012 2.30 to 4pm

Module 3G3

INTRODUCTION TO NEUROSCIENCE

*Answer not more than **three** questions.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS
There are no attachments

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

Version: Final

1 (a) The following questions are about hearing.

(i) Describe the mechanisms by which different frequencies of sound can be localised.

(ii) Describe the mechanical and neural mechanisms by which each neuron in the cochlear nerve becomes selective for a particular frequency of sound. [50%]

(b) The following questions are about multisensory integration.

(i) In the presence of a visual and an auditory stimulus, what features of these stimuli determine the degree of enhancement (facilitation) seen in superior colliculus?

(ii) You can see the width of an object and also feel its width using touch. When generating a single estimate of the object's width, describe the computations the brain performs and the rationale behind them. [50%]

2 (a) With regard to synaptic learning:

(i) Describe what is meant by anti-hebbian learning.

(ii) Describe (including a diagram) the circuit and mechanism of learning in the cerebellar-like structure of the weakly electric fish.

(iii) What are the benefits of anti-hebbian learning for sensory processing in the weakly electric fish and what behavioural evidence is there that humans process sensory information in a similar manner? [40%]

(b) A person plans a movement so as to use a knife to cut an apple in half.

(i) What roles might forward (predictive) models play during the movement?

(ii) Why is redundancy of the human arm beneficial for improving the accuracy of such movements?

(iii) How, and why, might stiffness of the arm be different in this task and in cutting a loaf of bread? [40%]

(c) What features of the auditory and motor systems make cochlear implants currently more successful than brain driven neuromotor prostheses? [20%]

3 (a) This question is about GABAergic transmission.

(i) Some GABA receptors (so-called GABA-A receptors) act by directly opening a chloride channel. Explain how the release of GABA by a presynaptic cell influences the membrane potential of the postsynaptic cell through these receptors. [10%]

(ii) The gradient of chloride in certain neurons during development (when the nervous system is not yet mature) is opposite to that in normal, mature neurons. Explain the postsynaptic effect of GABAergic transmission in these neurons during development. [5%]

(iii) There are also metabotropic GABA receptors (so-called GABA-B receptors) that result in the opening of potassium channels via a G-protein-mediated cascade. Describe how the postsynaptic effect of GABA-B receptors are similar to or differ from those of GABA-A receptors. [10%]

(iv) In some cells, the reversal potential of chloride is above the resting membrane potential, but only by a few millivolts. However, the activation of GABA-A receptors is said to inhibit the cell in the following sense: when these receptors are activated at the same time as the glutamate receptors (by a different set of presynaptic cells), the firing rate of the postsynaptic neuron is lower than if only the glutamate receptors were activated. Explain how this is possible. [40%]

(b) The following questions are about the gill-withdrawal reflex in the Aplysia.

(i) Describe the experimental procedure for sensitising the gill-withdrawal reflex in the Aplysia.

(ii) A sensitisation experiment is performed. State how each of the following quantities change in response to stimulating the siphon before and after sensitisation (i.e. do they increase, decrease or stay the same after sensitisation):

A. number of action potentials emitted by sensory neurons that respond to siphon touch

B. magnitude of potassium current in the synaptic terminal of these sensory neurons

C. amount of calcium influx into synaptic terminal of the sensory

neurons

D. amount of transmitter released by the sensory neurons

E. amount of transmitter released by the motor neurons responsible for gill withdrawal [35%]

4 (a) An in vivo experiment found that the size of (field) EPSPs in CA1, in response to Schäffer collateral stimulation, was larger after a session of active exploration of the environment than before it. The conclusion drawn from this study was that exploration induces LTP. Give an alternative explanation of the findings, and describe control experiments in which one could show that exploration itself is neither necessary nor sufficient for increasing the size of EPSPs. [40%]

(b) Describe the main differences between the Rescorla-Wagner and temporal-difference theories of classical conditioning. In your answer address the following points:

(i) In these theories, how do the different key quantities (CS, US, predictions, prediction weights and errors) depend on time?

(ii) What are the quantities that animals are trying to predict according to these theories?

(iii) Which theory involves an element of bootstrapping, what kind of bootstrapping is it, and why is it necessary in the theory?

(iv) What are the predictions these theories make about what happens in secondary conditioning? [60%]

END OF PAPER