

ENGINEERING TRIPOS PART IIA

Monday 26 April 2010 9.00 to 10.30

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

SPECIAL REQUIREMENTS

Single-sided script paper

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

- 1 (a) The following questions are about hearing.
- (i) Describe the features of the external ear (also known as the pinna or auricle) that are relevant for sound localisation and the mechanism by which they work.
 - (ii) What role does the middle ear play in hearing and why is it necessary?
 - (iii) Describe the evidence that the inner ear performs active amplification and the mechanism by which it amplifies incoming sound. [40%]
- (b) The following questions are about vision.
- (i) Describe the spatial frequency (channel) theory of vision. Provide two pieces of experimental evidence that support the theory.
 - (ii) In three-dimensional (3D) movies a separate image is provided to each eye to create the perception of depth. What cues to depth are such 3D movies unable to reproduce?
 - (iii) Explain what colour constancy is and why it is beneficial. Give an example of a mechanism by which colour constancy might arise. [40%]
- (c) The following questions are about sensory replacement technology.
- (i) Describe the structure and mechanism of action of a cochlear implant.
 - (ii) Why is sensory replacement for the loss of an eye a more difficult problem than sensory replacement for loss of hair cells in the inner ear. Your answer should include a brief comparison of implants in the eye and in the visual cortex. [20%]

2 (a) Write notes on:

(i) Why the probability of perceiving a sensory stimulus tends to be an increasing sigmoidal (S-shaped) function of stimulus intensity and what the slope of the sigmoidal function can tell you about sensory processing.

(ii) The mechanisms for novelty detection in sensory processing.

(iii) The neural basis of the stretch reflex and its use.

[50%]

(b) The following questions are about the action potential.

(i) What mechanisms are responsible for the repolarising phase of the action potential? In particular describe the states of the gates within any channels you describe.

(ii) Describe, with the aid of a sketch, the results of a voltage clamp experiment conducted using a typical axon (without application of any drugs). Discuss the significance of each of the important features of the sketch. What are the advantages of using a voltage clamp to study the axon?

(iii) What is the role of the myelin sheath in action potential propagation. Explain how it works.

[50%]

3 (a) Describe the experimental procedure for habituating the gill-withdrawal reflex in the *Aplysia*. In response to stimulating the siphon over the course of habituation, specify for each of the following quantities whether they increase, decrease or do not change

- (i) activity of the sensory neuron;
- (ii) amount of transmitter released by the sensory neuron;
- (iii) activity of interneurons;
- (iv) amount of transmitter released by interneurons;
- (v) activity of the motor neuron;
- (vi) amount of transmitter released by the motor neuron. [20%]

(b) Describe the experimental procedure for inducing and demonstrating homosynaptic and heterosynaptic long-term depression. [20%]

(c) In a classical conditioning experiment, two different CSs, CS₁ (a light), and CS₂ (a tone) are used to signal the same US (delivery of food). Before training, none of the CSs evoke a response. During training, three kinds of trials are intermixed:

- CS₁, US
- CS₂, US
- (CS₁+CS₂), no US

where X, Y stands for sequential presentation of stimuli X followed by Y, and (X+Y) means simultaneous presentation of stimuli within a trial. After training, the following are observed in response to the CSs (where the response is salivation):

- CS₁ → response
- CS₂ → response
- (CS₁+CS₂) → no response

(i) Explain with reasons whether the Rescorla-Wagner rule can account for these results.

(ii) Someone proposes a new theory to describe animal learning in this experiment. The new theory starts from assuming that an animal's response to a combination of CSs reflects how much it predicts the occurrence of a US.

In the case of two CSs this prediction, r , is given by the following equation:

$$r = w_1 s_1 + w_2 s_2 + w_3 s_1 s_2$$

where s_1 and s_2 indicate the presence (1) or absence (0) of CS₁ and CS₂, respectively, and w_1 , w_2 , and w_3 are prediction strength parameters. Just like the Rescorla-Wagner theory, the new theory also assumes that during learning the prediction strength parameters are gradually changed over trials such that the average squared prediction error $E = (u - r)^2$ is minimised, where u indicates the presence (1) or absence (0) of the US in a trial.

- A. Write down the equations describing how each of the prediction strength parameters will change in a trial, based on u , s_1 , s_2 , and r , according to this new theory.
- B. Explain with reasons if this new theory can account for the experimental results described above. [60%]

4 (a) Sketch the postsynaptic current as a function of the postsynaptic membrane potential for an AMPA, and an NMDA receptor under the following four conditions:

(i) when glutamate is available in the synaptic cleft;

(ii) when glutamate and AP5 are available in the synaptic cleft;

(iii) when AP5 is available in the synaptic cleft;

(iv) when NMDA is available in the synaptic cleft.

[40%]

(b) Describe how the Morris water maze and its variants are used in learning experiments. Include the following in your answer:

- What are the physical properties of the apparatus?
- What is the animal's task?
- What aspects of behavioural performance are measured to quantify learning?
- What variants of the Morris water maze can be used to show that a treatment specifically impairs spatial learning as opposed to other factors required for the task?

[40%]

(c) Explain the difference between retrograde and anterograde amnesia. Which kind of amnesia did H.M. suffer from?

[20%]

END OF PAPER