1999 Paper 7 Question 7

Neural Computing

Explain the mechanisms and computational significance of nerve impulse generation and transmission. Discuss each of the following aspects:

(a) The equivalent electrical circuit for a nerve cell membrane.

(b) How different ion species flow across the membrane, in terms of currents, capacitance, conductances, and voltage-dependence. (Your answer can be qualitative.)

(c) The role of positive feedback and voltage-dependent conductances.

(d) The respect in which a nerve impulse is a mathematical catastrophe.

(e) The approximate time-scale of events, and the speed of nerve impulse propagation.

(f) What happens when a propagating nerve impulse reaches an axonal branch.

(g) What would happen if two impulses approached each other from opposite directions along a single nerve fibre and collided.

(h) How linear operations like integration in space and time can be combined in dendritic trees with logical or boolean operations such as AND, OR, NOT, and veto.

(i) Whether "processing" can be distinguished from "communications", as it is for artificial computing devices.

(j) The respects in which stochasticity in nerve impulse time-series may offer computational opportunities that are absent in synchronous deterministic logic.

[2 marks each]