1. For parts a,b,c, assume: (i) a hypothetical channel only conducts a hypothetical negative ion, (ii) the Nernst potential for this ion is -40 mV, (iii) a cell has this channel in its membrane, (iv) the cell is currently at rest (defined as -70 mV), and, (v) this channel starts out closed.

(a) Is there more of this kind of ion inside or outside of the cell?

(b) Which direction will the ions flow (in/out of cell) if the channel is briefly opened (with cell at rest: -70mV)?

(c) Would you expect the direction of flow of the ions though this channel to change (compared to (b)) if you first voltage clamp the cell to -10 mV and then briefly open the channel?

(d) Channels responsible for the resting potential (not the channel discussed in part a,b,c!) are permanently open. What stops net current from continuously flowing through them when the cell is at rest (a few words)?

2. The opening and closing of voltage-gated sodium and potassium channels supports the action potential.

(a) Draw one graph with 2 lines showing amount of inward current flow through axonal fast sodium channels (use a solid line) and amount of outward current flow through potassium channels (use a dashed line) versus time, immediately after a squid axon is suddenly voltage-clamped to -10 mV (starting from rest) and kept there. Label units on both x- and y-axes, and use arrow to mark onset of voltage clamp.

(b) When voltage-gated sodium channels open on the rising edge of a spike, the resulting inward sodium current can (and does) flow in both directions along the axon. Why does the spike keep going in one direction?

(c) The same mammalian neuron can generate a burst of spikes or evenly spaced spikes in response to a stimulus. A slow calcium current, $I_{T}$, is thought to contribute to bursting. Under what initial condition will this current be disabled? (so that a stimulus will not cause a burst of spikes)
3. Hebbian-like changes in synaptic strength (e.g., long-term potentiation, LTP) are thought to be mediated by NMDA channels that are found in the post-synaptic membrane.

(a) Since NMDA channels are not required for the 'expression' of LTP, which channels are responsible for 'expressing' the larger/strengthened excitatory post-synaptic potential?

(b) What two conditions are required in order for NMDA channels to open?

(c) Recent experiments on spike-timing-dependent plasticity have modified our original understanding of LTP. Would you expect an increase or decrease in the strength of an NDMA synapse if the pre-synaptic cell released glutamate shortly (50 msec) before the post-synaptic cell was strongly depolarized?

(d) The strength of a simple abstract "Hebbian synapse" increases if input is correlated with output, so a simple Hebb rule is: change in weight is proportional to input times output. Give a short rationale (use simple equations or a few words) for why we can rewrite that simple Hebb rule using just inputs and weights.

4. A simple electrical model of a dendrite is shown below.

(a) Label single examples of the four electrical parts below that correspond to: membrane resistance ($R_M$), longitudinal resistance ($R_L$), membrane capacitance ($C_M$), extracellular fluid.

(b) Assume a constant current is suddenly injected at point A. Out of all parts shown, circle the part(s) that will have the smallest amount of current flowing through it/them during earliest stages of the current injection.

(c) After a long period of current injection (e.g., a second), draw a BOX/BOXES around the part/parts shown that will have the smallest amount of current flowing through it/them.

(d) Increasing the diameter of a dendrite changes the values of all the parts in the circuit above. Which part experiences the largest change in value, and why does that part change the most?
5. Primate area V1 and V2 each have a visual hemifield map. Below **left**, a visual stimulus (textured shading) in shown in the **left and right** hemifield using **thick-dashes/small-circles/star/plus-minus** to indicate **horizontal/vertical/center-of-gaze/upper-lower** in the visual field. At **right**, draw what activity this stimulus would elicit in the maps in V1 and V2 in **just** the **right hemisphere** using same **dashes/small-circles/star/plus-minus** convention.

Entire Visual Field

Right Hemisphere of Brain

6. Diagram the neural tube in the box below and **label** its 6 main caudal-to-rostral segments. Include the **cerebellum**, the **two ventricle openings**, and use **dotted lines** to show where the ventricle is **not** open.

(a)

(b) Which segment of the neural tube does the **cerebellum** belong to and what segment does the **red nucleus** belong to?

(c) State a general rule to predict whether the connection between two **brain structures** will likely be **crossed** or **uncrossed**.
7. The dorsal lateral geniculate nucleus (dLGN) receives a projection from both the left and the right retina and projects to primary visual cortex, area V1.

(a) Using **solid** line, indicate how an X-like, OFF-center, non-lagged cell in the cat dLGN would respond. Then with a **dashed** line, indicate how an Y-like, ON-center, lagged cell would respond (same axes!).

(b) Which **stimulus feature strongly modulates** the firing of a V1 cell in a **cytochrome oxidase 'interblob'**? Which **stimulus feature is mostly ignored** by these cells?

(c) We discussed a model for direction selectivity called a **'Reichardt detector'** (originally developed for housefly vision!) Describe how it works in a sentence or with a simple diagram.

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8. Diagram at right shows a simple recurrent network with 2 units (**A** and **B**, current state inside each unit) and 4 weights (smaller numbers). The **update rule** for this network is the one given in class: if sum of [input × weight] across all inputs is greater than 0, unit activation is 1, else if less than zero, unit activation is -1. **Energy** is defined as the negative of the sum across all weights of [input × weight × output].

(a) What is the **current** value for the **energy** of the network? (show calculation)

(b) Is the **current state** of the network **stable**? Briefly explain **Why** or **why not**?

(c) Give a brief example what the **approach to a stable state** is supposed to be a **model of**