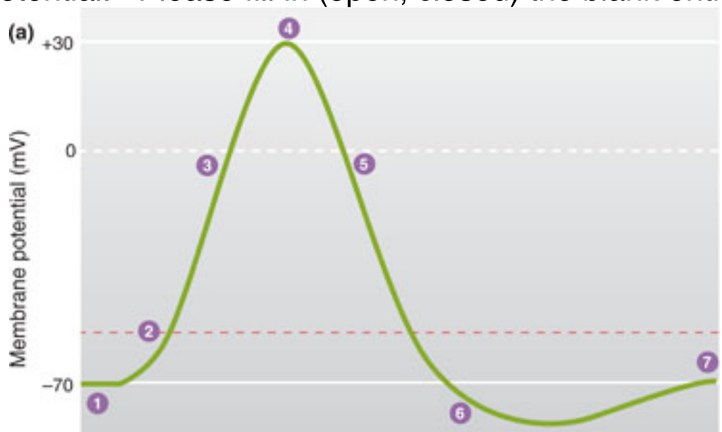
Solutions – Homework Assignment – Module 2

1. [20 points[1]] The Figure (below) shows the membrane potential *vs.* time for an action potential fired on the membrane of an excitable cell; the Table (below) indicates the state (open or closed) of the sodium channel gates and of the potassium channel at some of the various labeled time points (1, 2, … 6, 7) during the action potential. Please fill in (open, closed) the blank entries



Time

Time Point	Na^+ channel		K^+ channel
	Activation gate	Inactivation gate	
1	closed	open	closed
2	open	open	closed
3	**open**	**open**	**closed**
4	open	closed	open
5	**open**	**open**[2]	**open**
6	**closed**	**open**	**open**
7	closed	open	closed

2. [20 points] With reference to a post-synaptic membrane, explain the mechanism(s) of, and differentiate between, *spatial summation* and *temporal summation*.

Spatial Summation

If a post-synaptic membrane is slightly depolarized (to a voltage more negative than the threshold for firing an AP) that depolarization spreads in space; the depolarization decays (to baseline) as the distance from the initial depolarization increases (video 3, slides 4 and 5). As well, the depolarization decays in time (see, e.g., B&L[6+], Figures 5-1, 6-3; B&L[7], Figures 5.1, 6.3). The same idea applies

[1] 2 points for each correct response plus 2 points to add up to 20 points.
[2] The Na^+ channel inactivation gate is open based on revised slide 5 of video 2 (P_{Na^+} is above baseline). The Na^+ inactivation gate is closed based on the original slide 5 of video 1 (P_{Na^+} has returned to baseline).

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for a slight hyperpolarization as well. So, if two spatially distinct post-synaptic sites are stimulated such that the hypo/hyperpolarization fields of each overlap in time and space the fields will either reinforce (if both sites are either hyper- or hypopolarized) or will cancel (at least partially, if one is hyperpolarized and the other is hypopolarized) each other.

Temporal Summation

If a post-synaptic membrane is slightly (sub-threshold, if hypo polarized) or hyperpolarized the disturbance in membrane potential will decay in time at the site of the disturbance, as well as in space in the region surrounding the disturbance (see explanation of Spatial Summation, above). If the same (post-synaptic) site is again stimulated (i.e., by the same pre-synaptic neuron) with a hypo- or hyperpolarizing (sub-threshold) stimulus, before the response to the first stimulus has decayed (in time) to baseline, the disturbance in response to the second stimulus will build on the response to the first stimulus. See also video 4, slide 5.

3. [5 points] With reference to the conduction of action potentials and/or sub-threshold changes in membrane potential along the axons or dendrites of neurons, indicate the most correct statement among those given below:
   A. The propagation velocity of action potentials in unmyelinated axons is inversely proportional to axon diameter.
   B. The conduction velocity of action potentials in an unmyelinated axon of diameter 10 μm will be higher than in a myelinated axon of diameter 1 μm.
   C. Saltatory conduction (of an action potential) does not occur in unmyelinated axons.
   D. In a myelinated axon the cells that wrap around the axon are wrapped most thickly at the Nodes of Ranvier.

4. [20 points] How would the action potential on the cell membrane of an electrically excitable cell change (amplitude and time course) if the ratio of maximal to minimal g_{Na} was 80% of that in a "normal" electrically excitable cell? Assume that the value of the minimum g_{Na} is the same as in a "normal" cell. **NOTE: The statement of the problem is intentionally a bit vague – you will have to make some assumptions. Make sure to explicitly state any assumptions that you make in order to answer this question.**

The problem offers no information as to the time course of the changes in g_{Na} and g_K of the modified cell during the action potential (AP). So, I will assume that the time courses of g_{Na} and g_K in the "altered" cell are the same as in the "normal" cell (i.e., that the gating characteristics of the "altered" sodium channel are the same as those of the "normal" sodium channel and that the gating characteristics of the potassium channels in both cells are the same). So, this means that the curve of

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g_K (P_K) *vs*. time in the "altered" cell is identical to the curve of g_K (P_K) *vs*. time in the "normal" cell (see video 1, slides 4 and 5). As for g_{Na} (P_{Na}) in the "altered" cell, I assume that that curve lies within the envelope of the curve for the "normal" cell – the rise starts at the same time in both cells and the curves return to baseline value at the same time in both cells; as well, the peak value for both curves occurs at the same time in both cells. This implies that the rate of rise and the rate of fall of g_{Na} (P_{Na}) are smaller in the "altered" cell than in the normal cell.

Given these assumptions, in the "altered" cell (*vs*. the "normal" cell) I would expect to see a somewhat slower initial rate of rise in V_m, with V_m reaching a less positive peak value. The falling phase of V_m will be quicker, the hyperpolarization minimum will be more negative, and the eventual return to baseline (resting membrane) value will take a bit longer.

Note that there are other variants to "the" answer (there is no "the" answer), depending on the specific assumptions made. Grading accounted for variants if the assumptions made were internally consistent and if the predictions made regarding the V_m amplitude and time course were consistent with the assumptions made.

5. [5 points] Consider a synapse in which the binding of a neurotransmitter to a receptor on the postsynaptic membrane causes a transient increase in K^+ channel conductance in the region immediately surrounding the receptor. Indicate the most correct statement among those given below.
   A. This will result in an IPSP if the resting membrane potential of the postsynaptic cell was less negative than the potassium Nernst potential for the postsynaptic cell.
   B. This will result in an EPSP if the resting membrane potential of the postsynaptic cell was less negative than the potassium Nernst potential for the postsynaptic cell.
   C. The potassium channel inactivation gates would transiently close in response to the binding of the neurotransmitter to its receptor on the postsynaptic cell.
   D. Such a change in the local potassium channel conductance of the postsynaptic cell membrane will always trigger an action potential.

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