Instructor’s Response(s) to Discussion Question(s) - Module 2

Consider an electrically excitable cell in which the time at which the voltage-activated potassium channel conductance begins to increase above its baseline value (i.e., when the voltage-activated potassium channels begin to open) is the same as in a "normal" electrically excitable cell (see, e.g., Module 2, Video 1, Slide 5) BUT the time course of the rise to a maximum value and the subsequent return to baseline of potassium conductance is abbreviated (time to reach peak conductance from baseline is reduced; time to return to baseline from peak conductance is reduced) in comparison to that of a "normal" electrically excitable cell (again, see, e.g., Module 2, Video 1, Slide 5). In addition, assume that (1) the time course and amplitude course of the voltage-activated sodium channel conductance is as it is in a "normal" cell and (2) the amplitude range of the potassium channel conductance is the same as in a "normal" cell. How would the described change in potassium channel conductance affect the cell's action potential (amplitude and time course)? Briefly explain your reasoning; use sketches and text as necessary. Please **post your response to the Discussion Board by 6 PM on day 4 of the module**.

Based on the replacement slide 5 (see also slide 4 and the additional slide immediately following slide 4) of video 1, it appears that the increase in g_K begins while g_{Na} is early[1] in its rising phase and V_m is further along[2] in its rising phase; this this will not change in the altered cell. In the normal cell g_{Na} continues to increase as time goes forward, as does V_m. G_{Na} and V_m reach their maximal values at about the same time[3]; the increase in g_K at the time g_{Na} reaches its maximal value is small[4]. In the altered cell g_K increases more rapidly than in the normal cell, so that the outflow of K^+ will have more of an influence on the late phase of the increase in V_m and on the early phase of the decline in V_m. So, one would expect that Vm reaches a less positive peak value and reaches that peak value a bit sooner than in the normal cell.

The falling phase of the AP initially depends on the timing of the decrease in g_{Na} (same for both cells) and the time course of the rise in g_K; the latter being abbreviated[5]. So – the initial portion of the falling phase of the AP is likely to be faster in the altered cell, since g_K rises faster (time course is shortened, amplitude is unchanged) in the altered cell.

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[1] g_{Na} is at less than 50% of its peak value and increasing.

[2] V_m is closer to its peak value than to its baseline value.

[3] g_{Na} perhaps peaks marginally sooner than does V_m; see slide 4 and the additional slide 4, but that does not affect the following discussion.

[4] At the time that g_{Na} reaches its maximal value g_K is at ≈30% of its maximal value.

[5] Assume that the rising and falling phases of the potassium conductance are equally abbreviated – that is, if the total time of the transient in potassium channel conductance is N% (N < 100) of that in the ‘normal’ cell, the time of each of the phases of the potassium channel conductance in the ‘altered’ cell is N% of the time of the corresponding phase in the ‘normal’ cell.

Rev 0, 8/17/17 - adapted from Rev 2 of Spring 2017
Rev 1, 9/8/17 - revise response, esp. late rise and peak of AP
Rev 2, 7/13/18 - from Fall 2017, up-dated to 601; no content change
Rev 3, 9/13/18 - add explanatory footnotes; no other content change
Rev 4, 2/10/19 - revise in accordance with revised slide 5 of video 1

As time moves forward g_K in the altered cell falls more rapidly than in the 'normal' cell. This might slow the rate of decrease in the falling "foot" of the AP; as well, depending on the timing (of the return of g_K to baseline), the hyperpolarized portion of the AP recovery might be diminished (less hyperpolarized) or possibly eliminated. Depending on the amplitude and duration of the hyperpolarization (if any) the return of V_m to baseline might occur a bit earlier in the altered cell.

NOTE that if the abbreviation of the time course of the transient in potassium channel conductance is such that the transient is over at or a bit after the transient in sodium channel conductance ends then the recovery of the AP will be stretched out in time, since K^+ efflux will be ended quite early and the restoration of resting membrane potential will depend on the Na^+-K^+-ATPase pump. In such a case there will likely be no hyperpolarization seen.

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