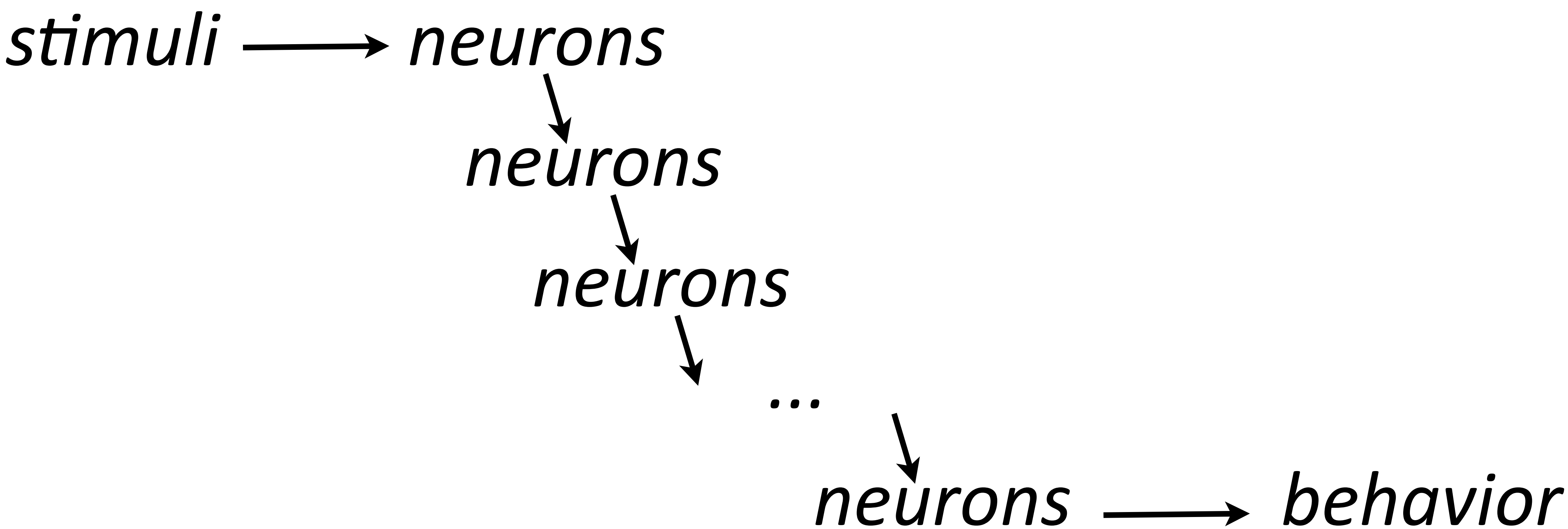
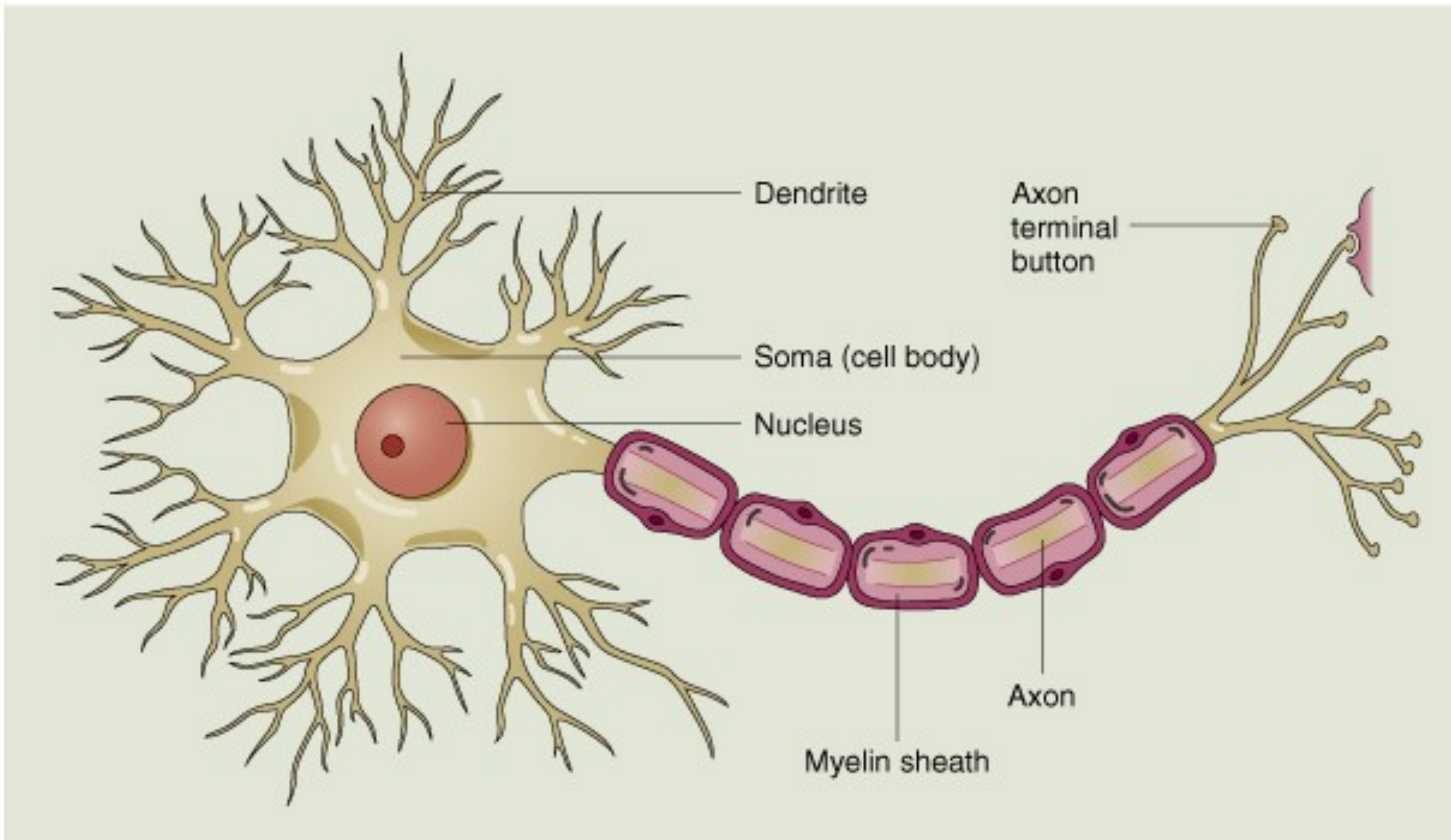
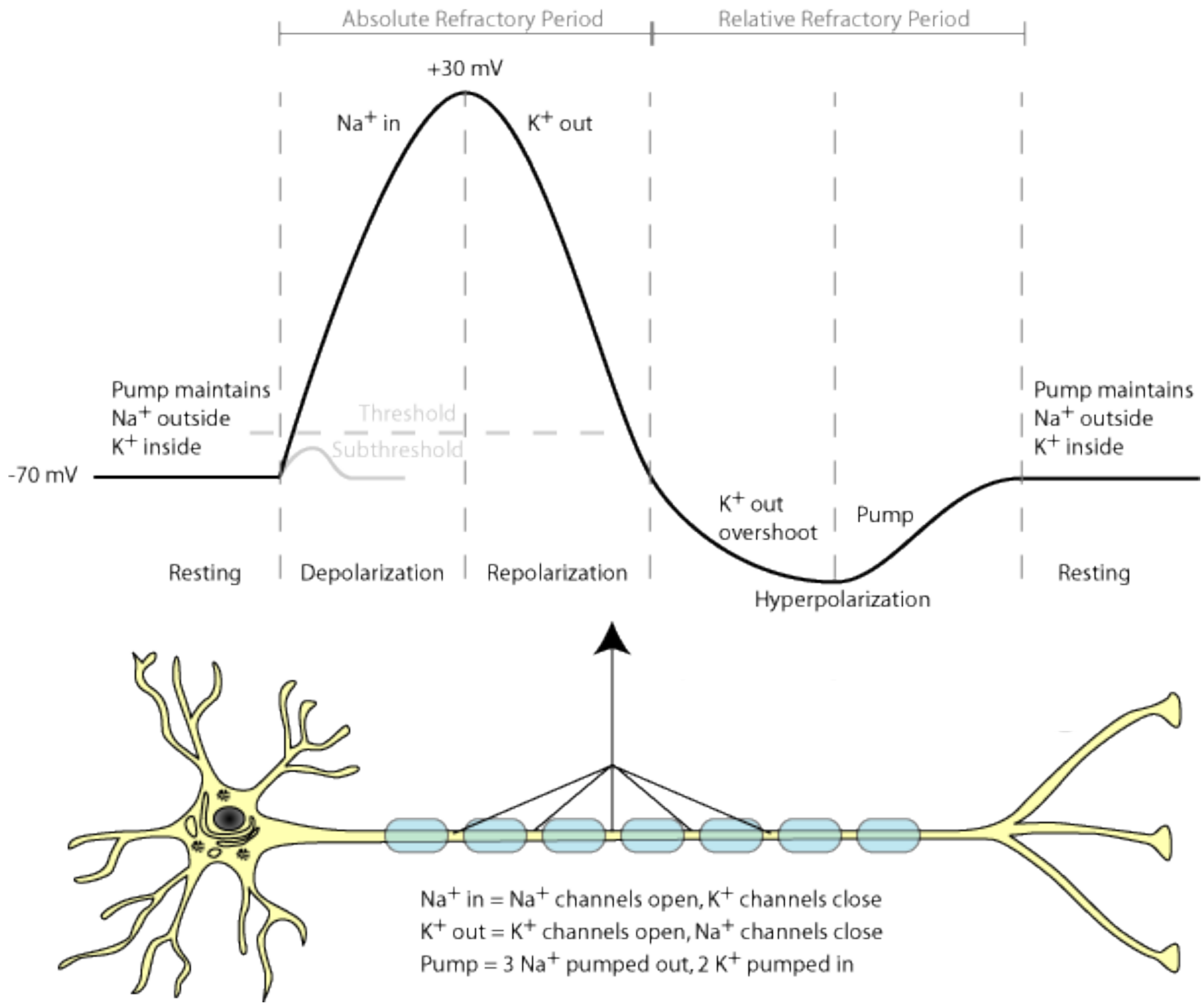

stimuli
neurons
neurons
neurons
...
neurons
behavior

Anatomy of a neuron:

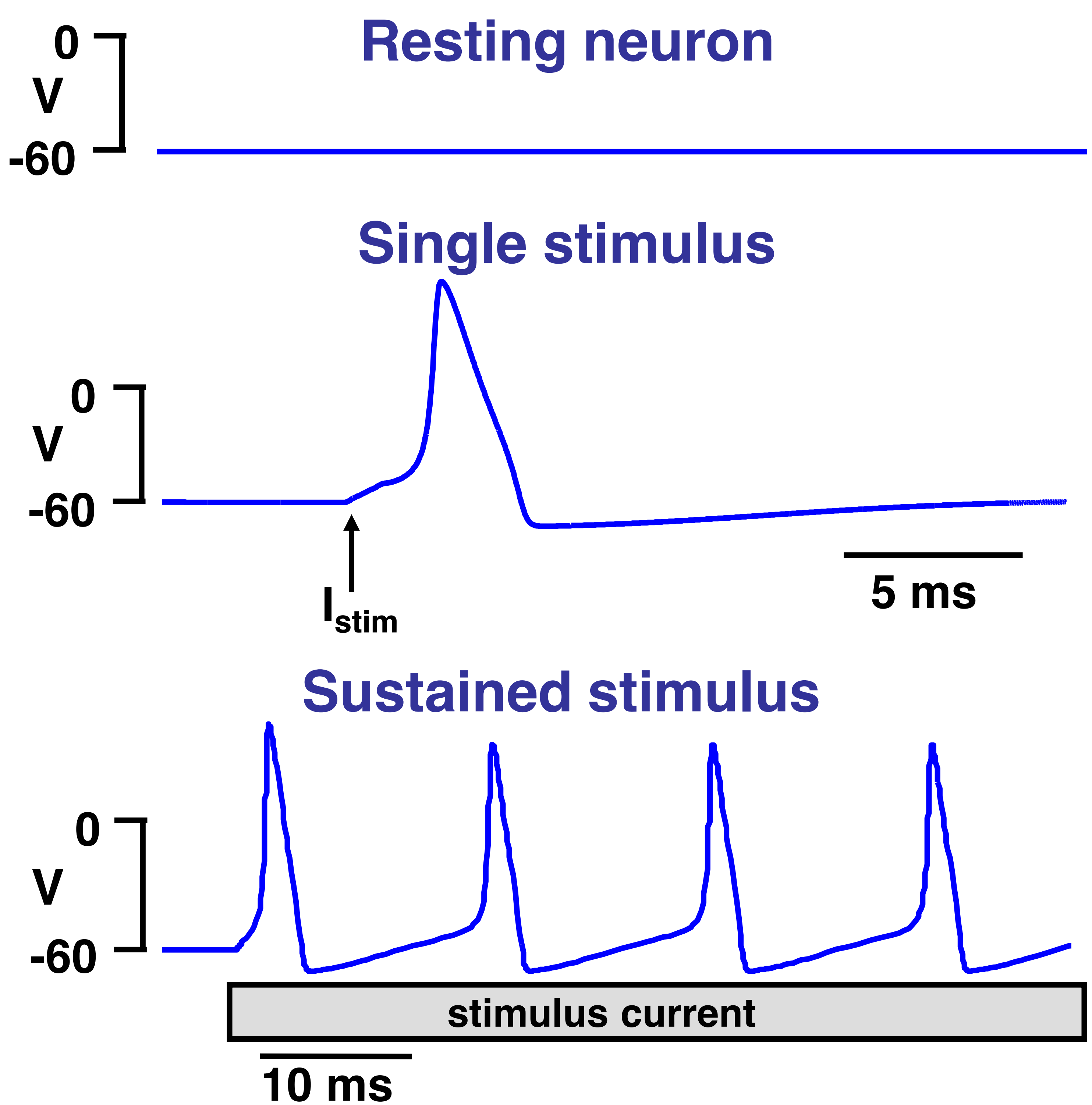


© 2000 John Wiley & Sons, Inc.

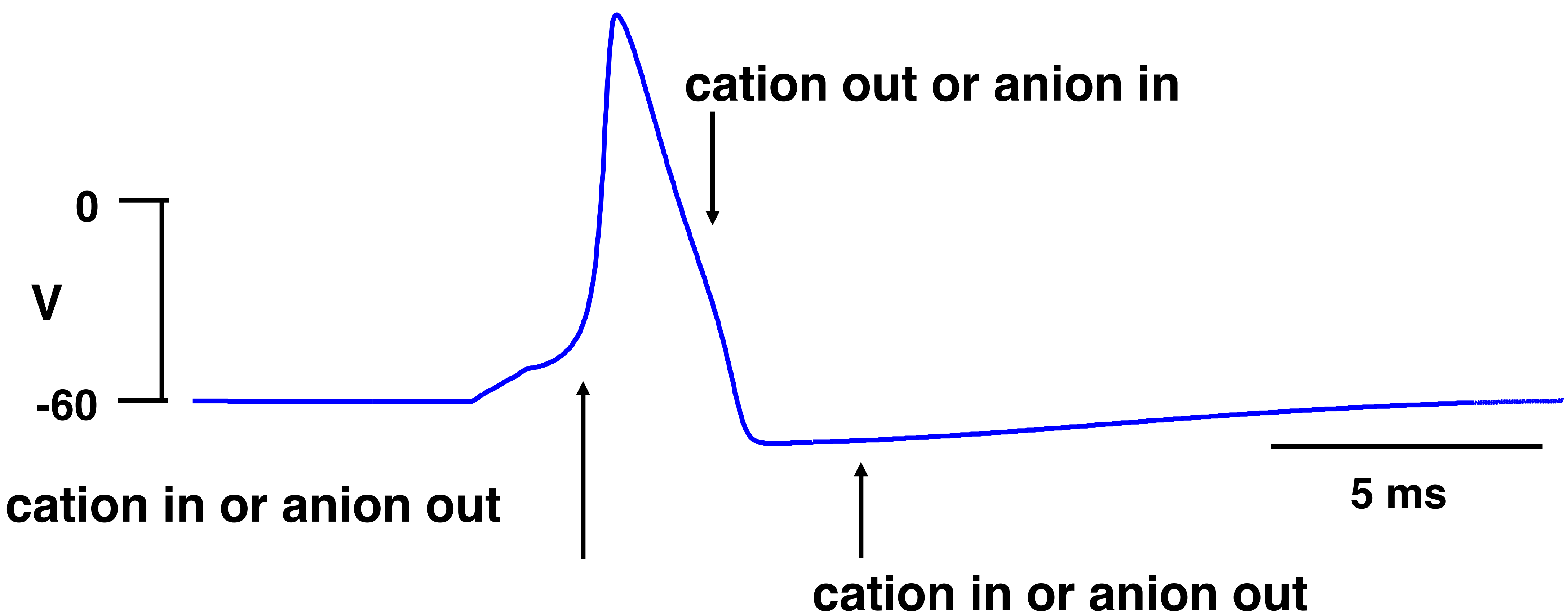
Anatomy of a spike:



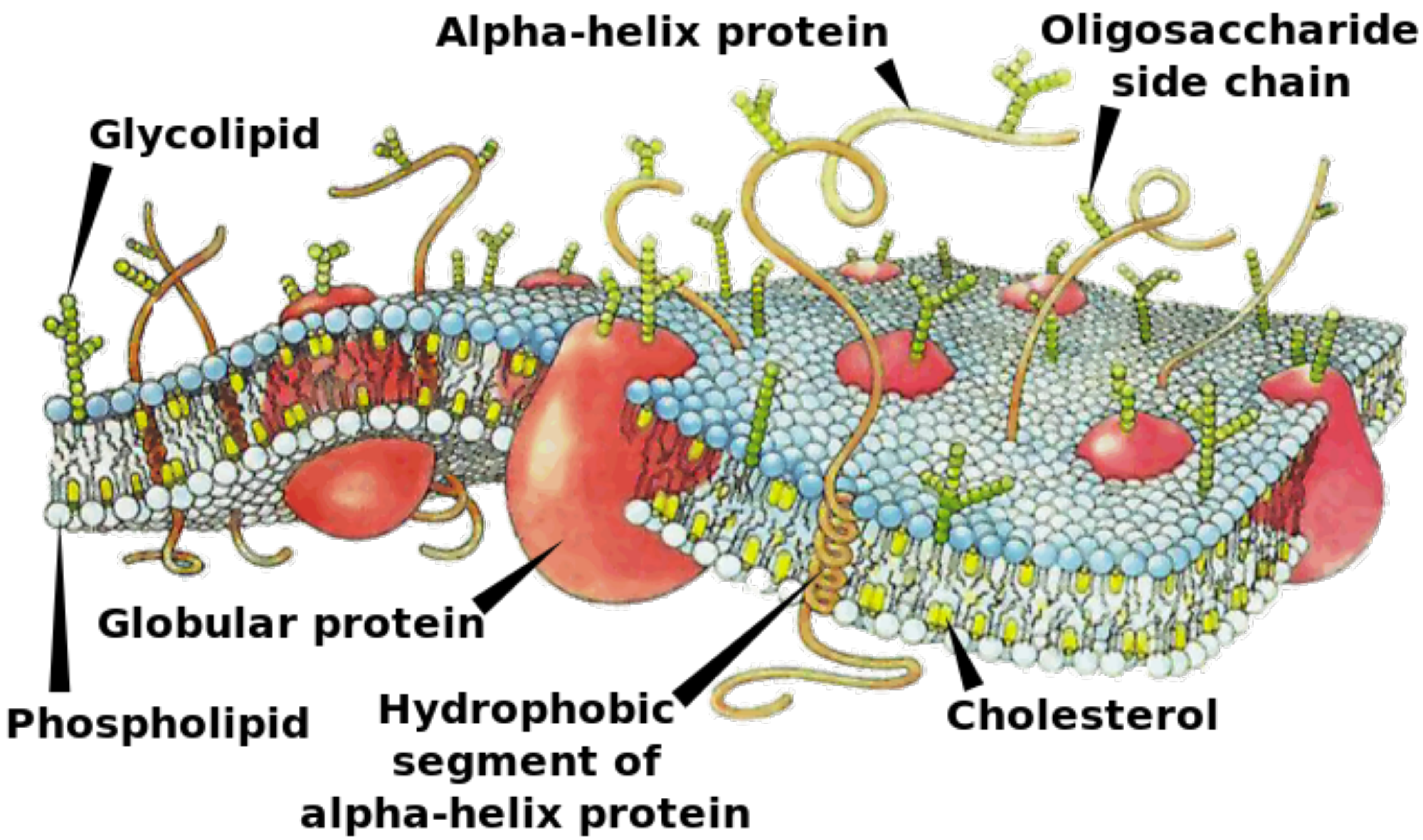
Properties of spiking:



We seek a quantitative description of this behavior:



Some basics:



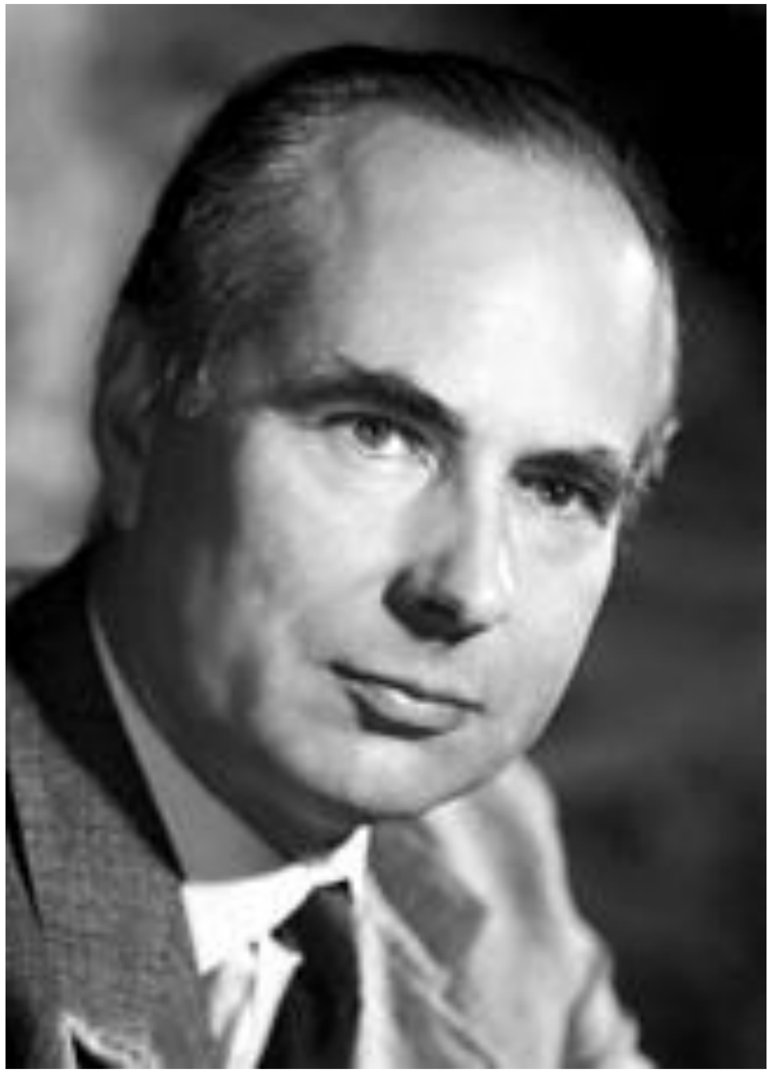
chalkboard interlude

The Hodgkin-Huxley model:

Sir Alan Hodgkin

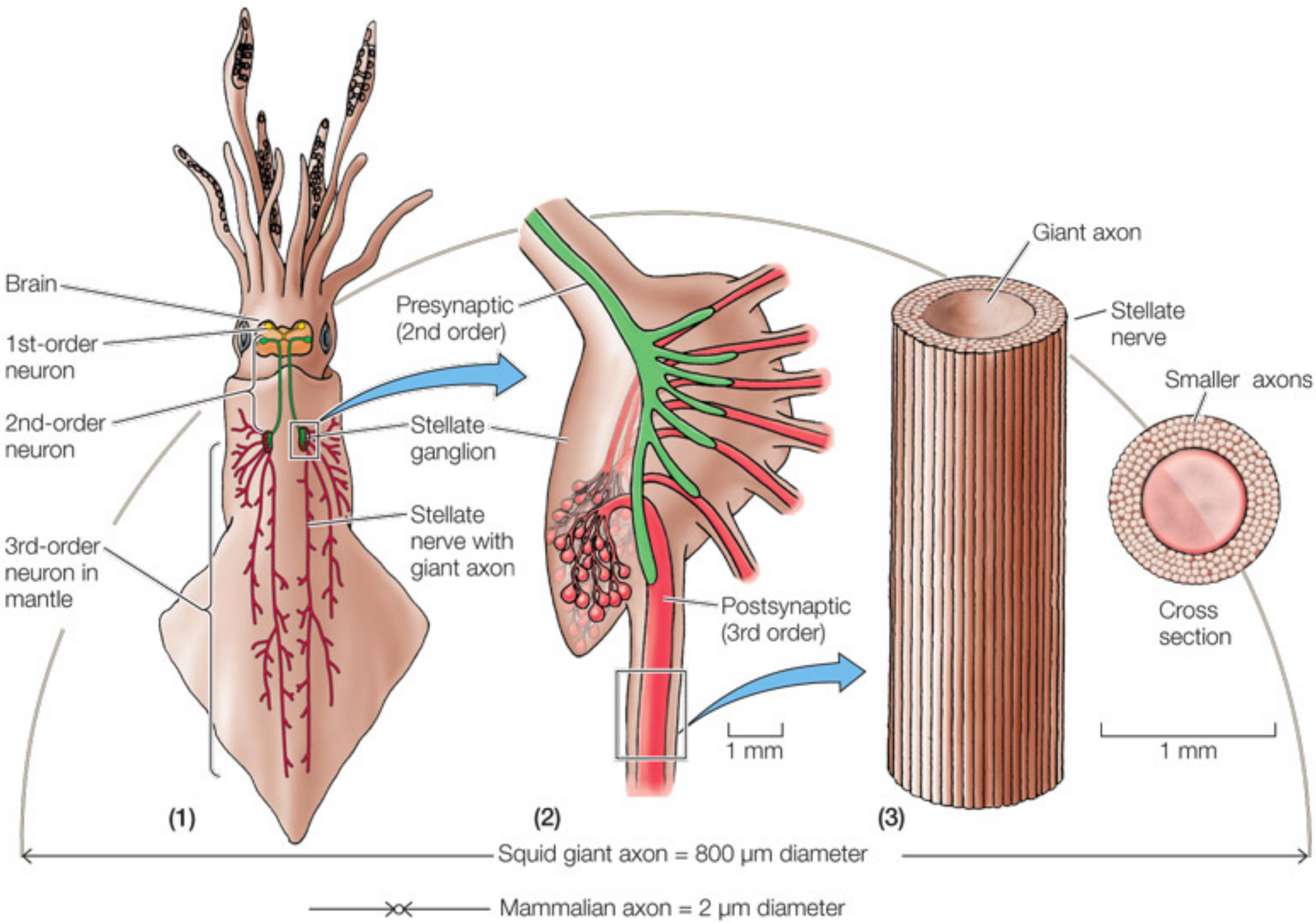
1914-1998
Nobel Prize 1963

Sir Andrew Huxley

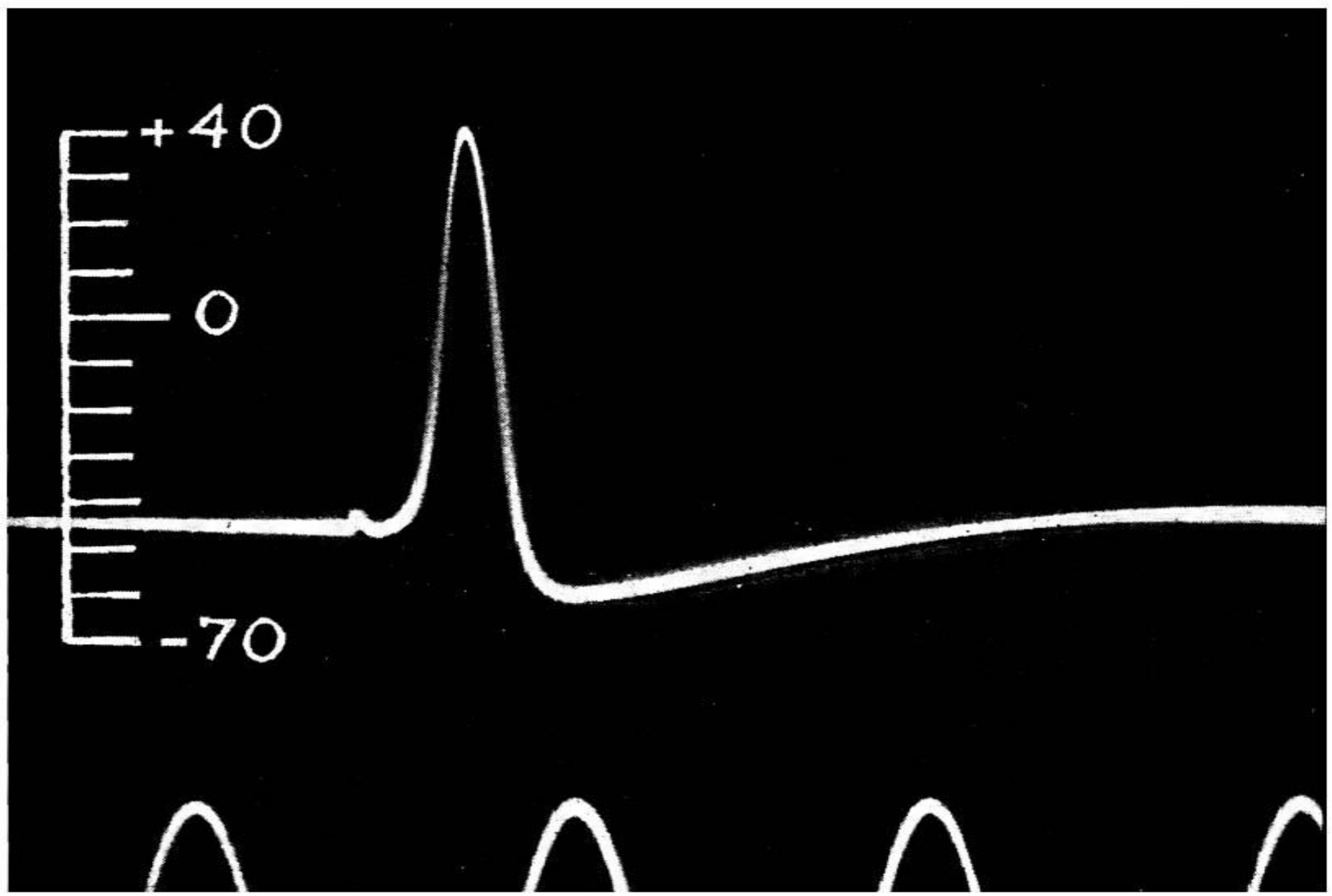


1917-2012
Nobel Prize 1963

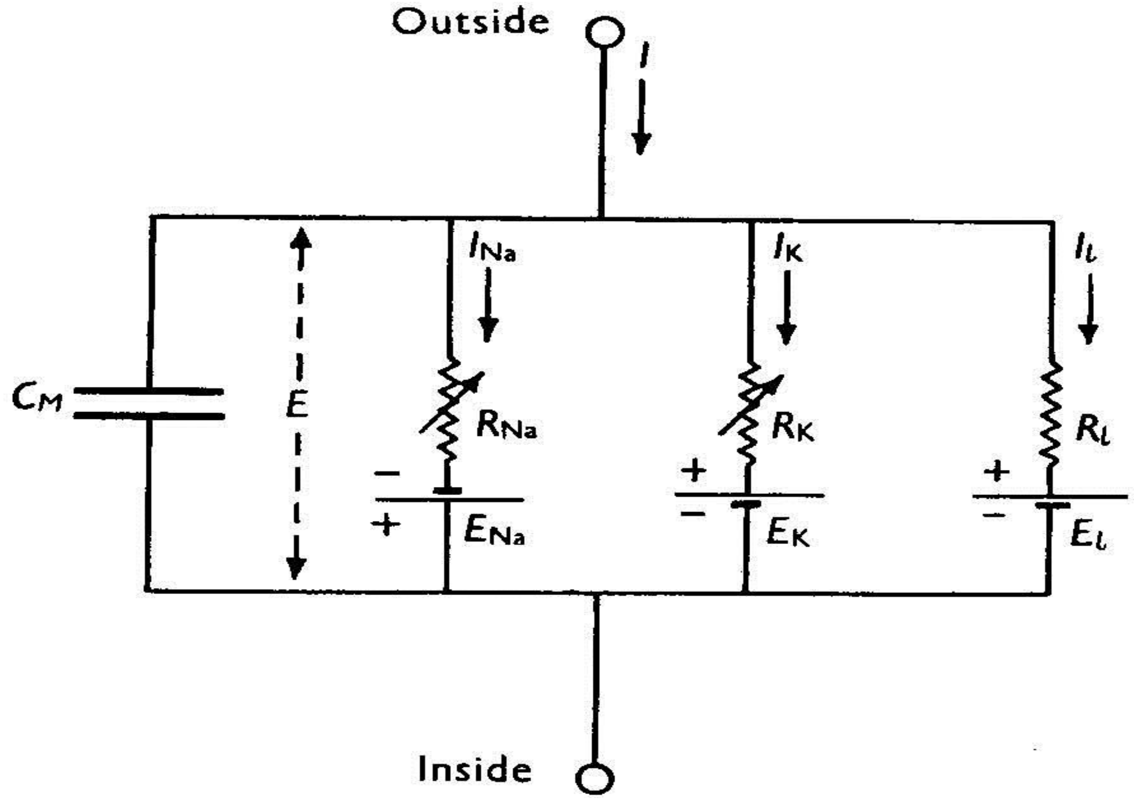
Squid giant axon:



The 1939 letter to Nature:



The final model:



Hodgkin & Huxley (1952), *J. Physiol.* 117:400.

$$C_m \frac{dV}{dt} = -g_L(V - V_L) - \overline{g}_{Na} m^3 h (V - V_{Na}) - \overline{g}_K n^4 (V - V_K)$$

$$\frac{dm}{dt} = \alpha_m(V)(1-m) - \beta_m(V)m$$

$$\frac{dh}{dt} = \alpha_h(V)(1-h) - \beta_h(V)h$$

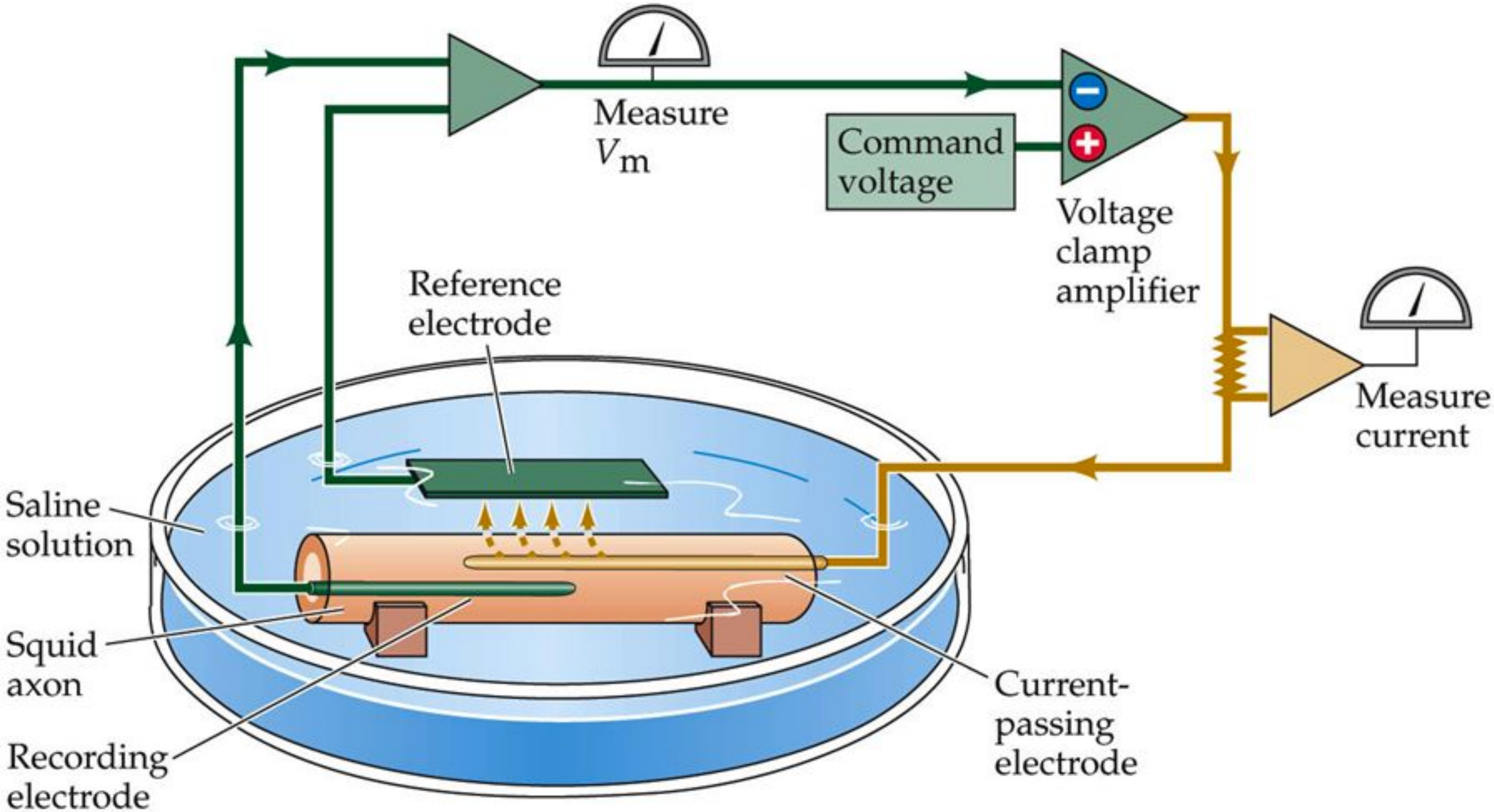
$$\frac{dn}{dt} = \alpha_n(V)(1-n) - \beta_n(V)n$$

$$\alpha_m = 0.1(V_m + 35.0)/(1. - e^{(-(V_m+35.0)/10.0)})$$
$$\beta_m = 4.0\, e^{(-(V_m+60.0)/18.0)}$$

$$\alpha_h = 0.07\, e^{(-(V_m+60.0)/20.0)}$$
$$\beta_h = 1./(1 + e^{(-(V_m+30.0)/10.0)})$$

$$\alpha_n = 0.01(V_m + 50.0)/(1 - e^{(-(V_m+50.0)/10.0)})$$
$$\beta_n = 0.125\, e^{(-(V_m+60.0)/80.0)}$$

Box 3A The Voltage Clamp Technique

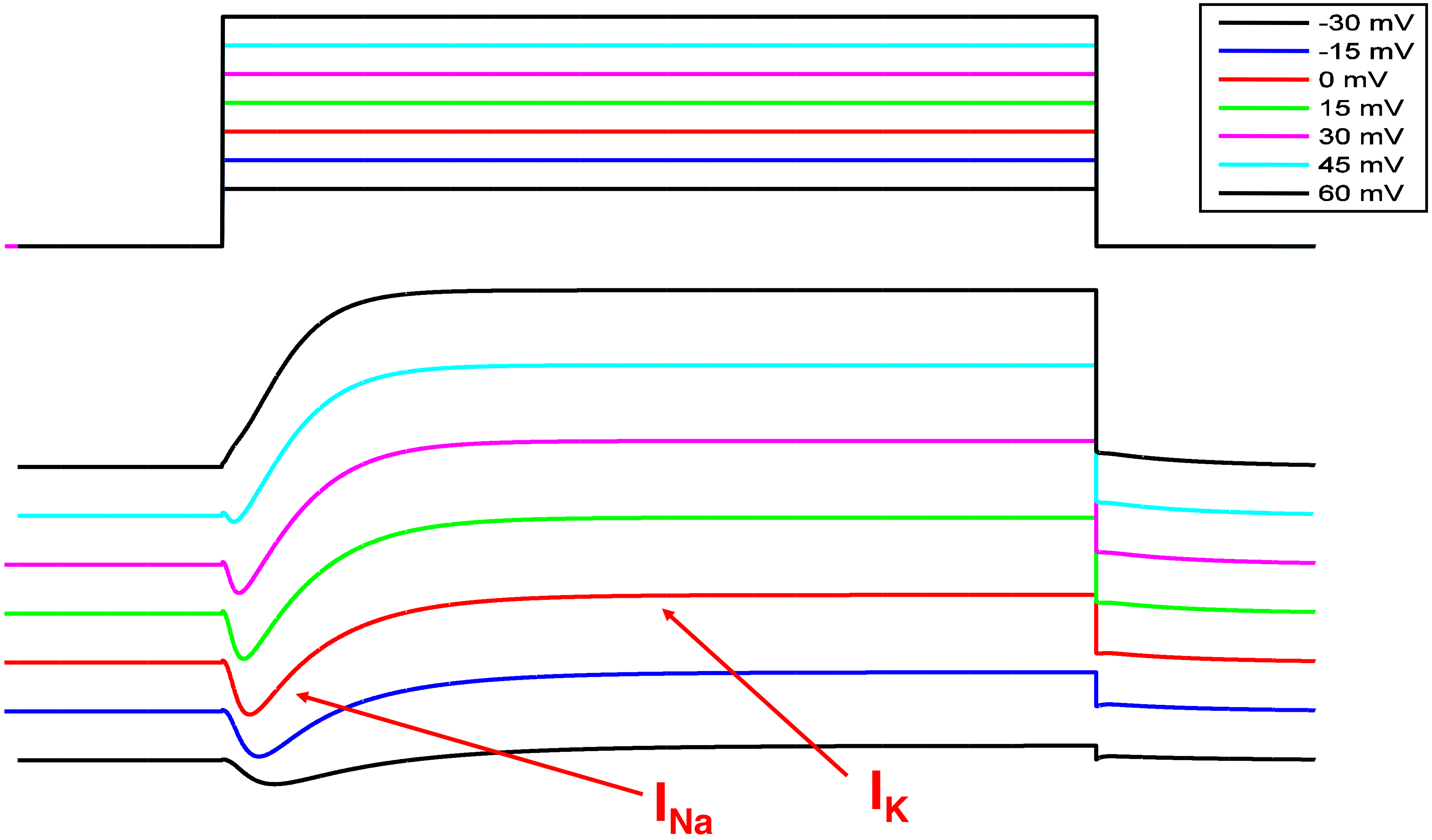


chalkboard interlude

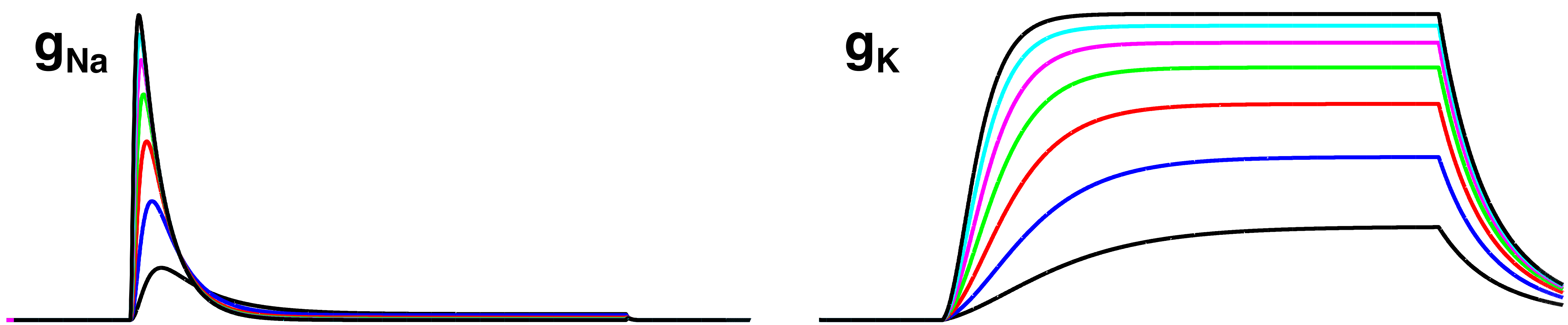
NEUROSCIENCE, Fourth Edition, Box 3A

© 2008 Sinauer Associates, Inc.

Make recordings, separate currents:



...and get conductances:



chalkboard interlude

Structure of the potassium ion channel (tetramer)

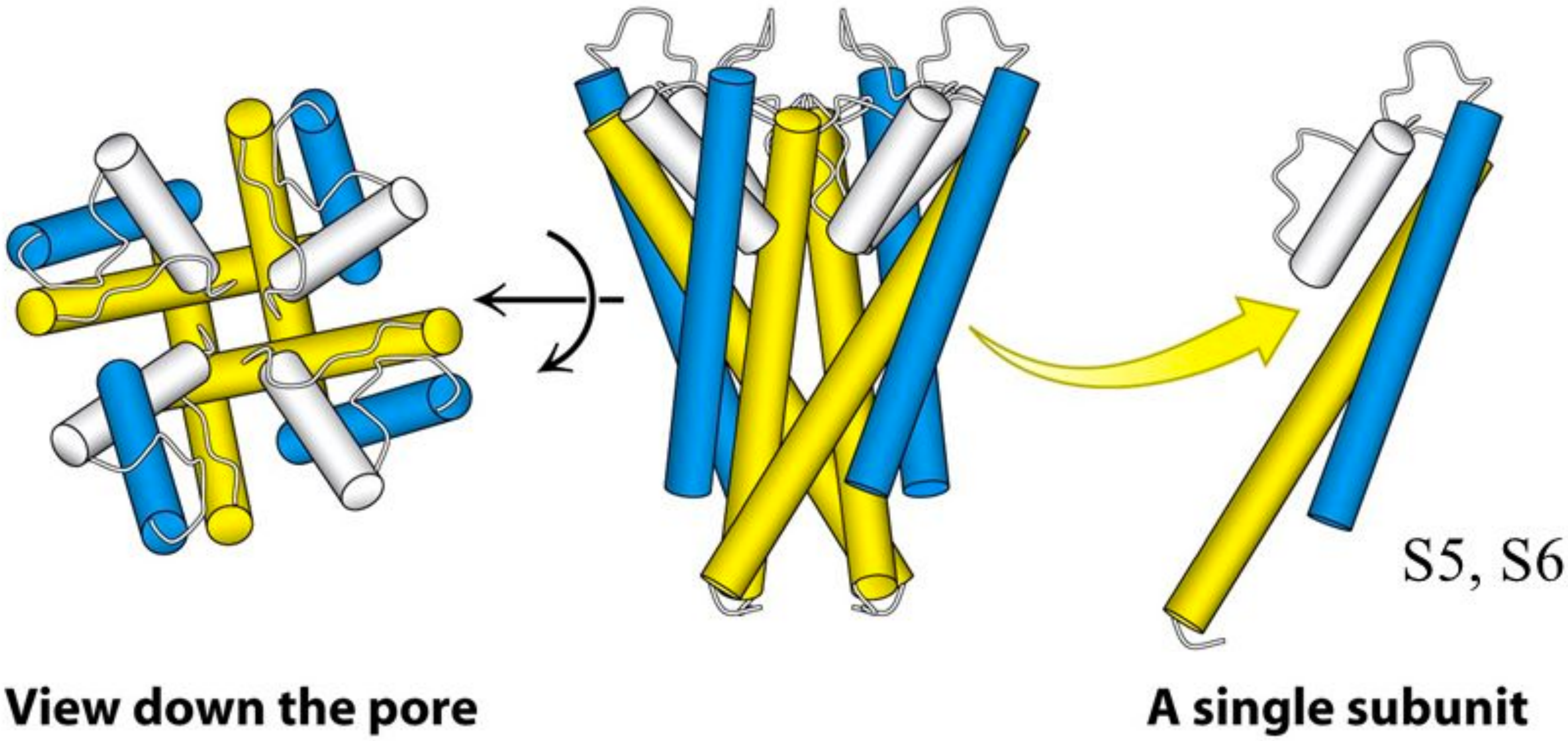
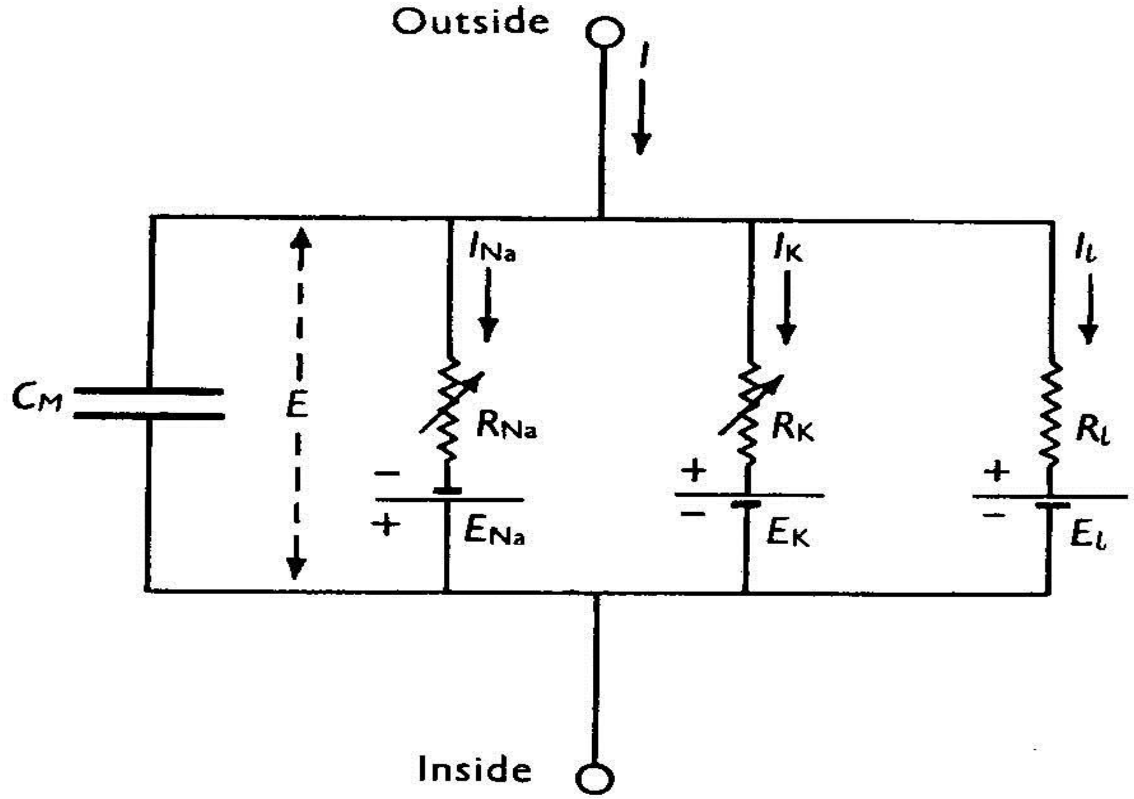


Figure 13-17
Biochemistry, Sixth Edition
© 2007 W. H. Freeman and Company

The final model:



Hodgkin & Huxley (1952), *J. Physiol.* 117:400.

$$C_m \frac{dV}{dt} = -g_L (V - V_L) - \overline{g}_{Na} m^3 h (V - V_{Na}) - \overline{g}_K n^4 (V - V_K)$$

$$\frac{dm}{dt} = \alpha_m(V)(1-m) - \beta_m(V) m$$

$$\frac{dh}{dt} = \alpha_h(V)(1-h) - \beta_h(V) h$$

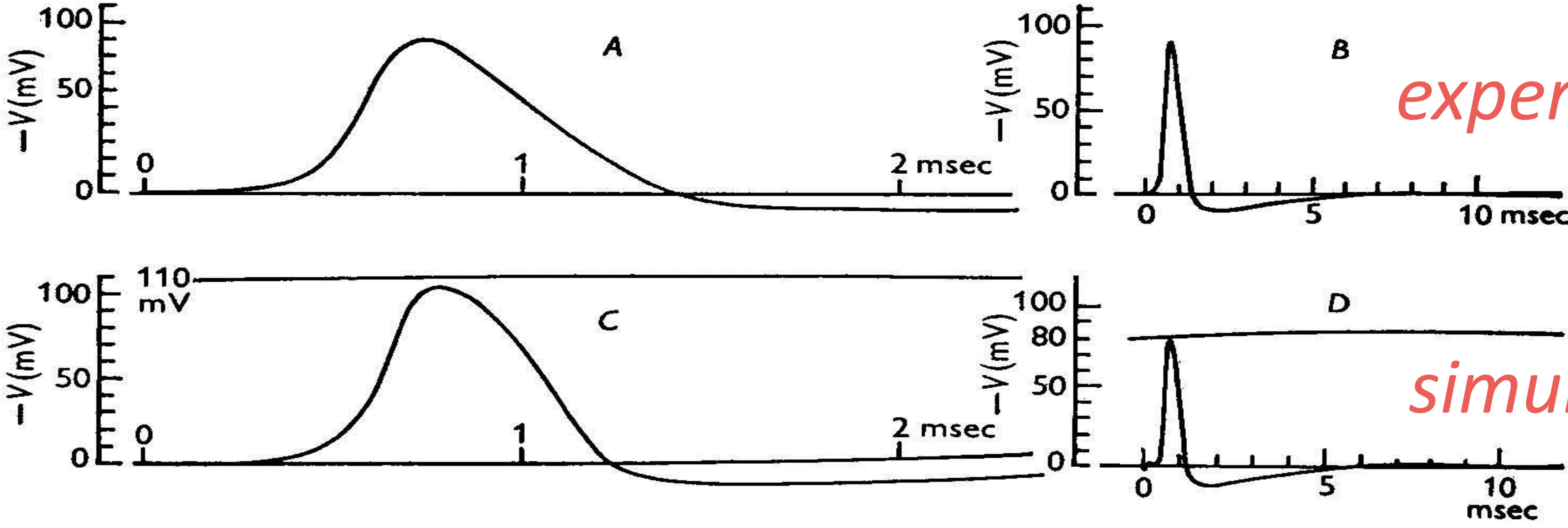
$$\frac{dn}{dt} = \alpha_n(V)(1-n) - \beta_n(V) n$$

$$\alpha_m = 0.1(V_m + 35.0)/(1. - e^{(-(V_m+35.0)/10.0)})$$
$$\beta_m = 4.0\, e^{(-(V_m+60.0)/18.0)}$$

$$\alpha_h = 0.07\, e^{(-(V_m+60.0)/20.0)}$$
$$\beta_h = 1./(1 + e^{(-(V_m+30.0)/10.0)})$$

$$\alpha_n = 0.01(V_m + 50.0)/(1 - e^{(-(V_m+50.0)/10.0)})$$
$$\beta_n = 0.125\, e^{(-(V_m+60.0)/80.0)}$$

…works well:



experiment

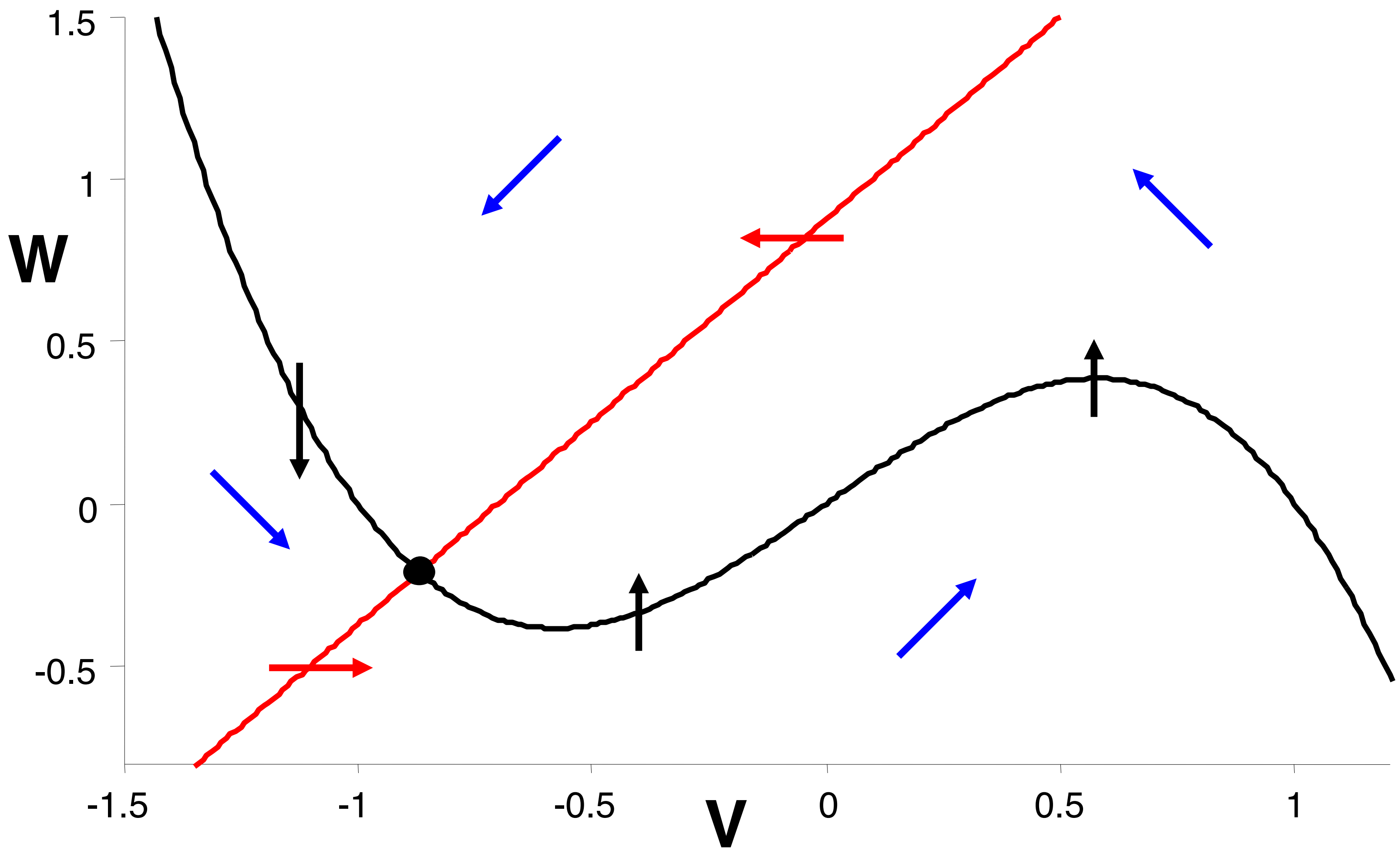
simulation

The Fitzhugh-Nagumo model:

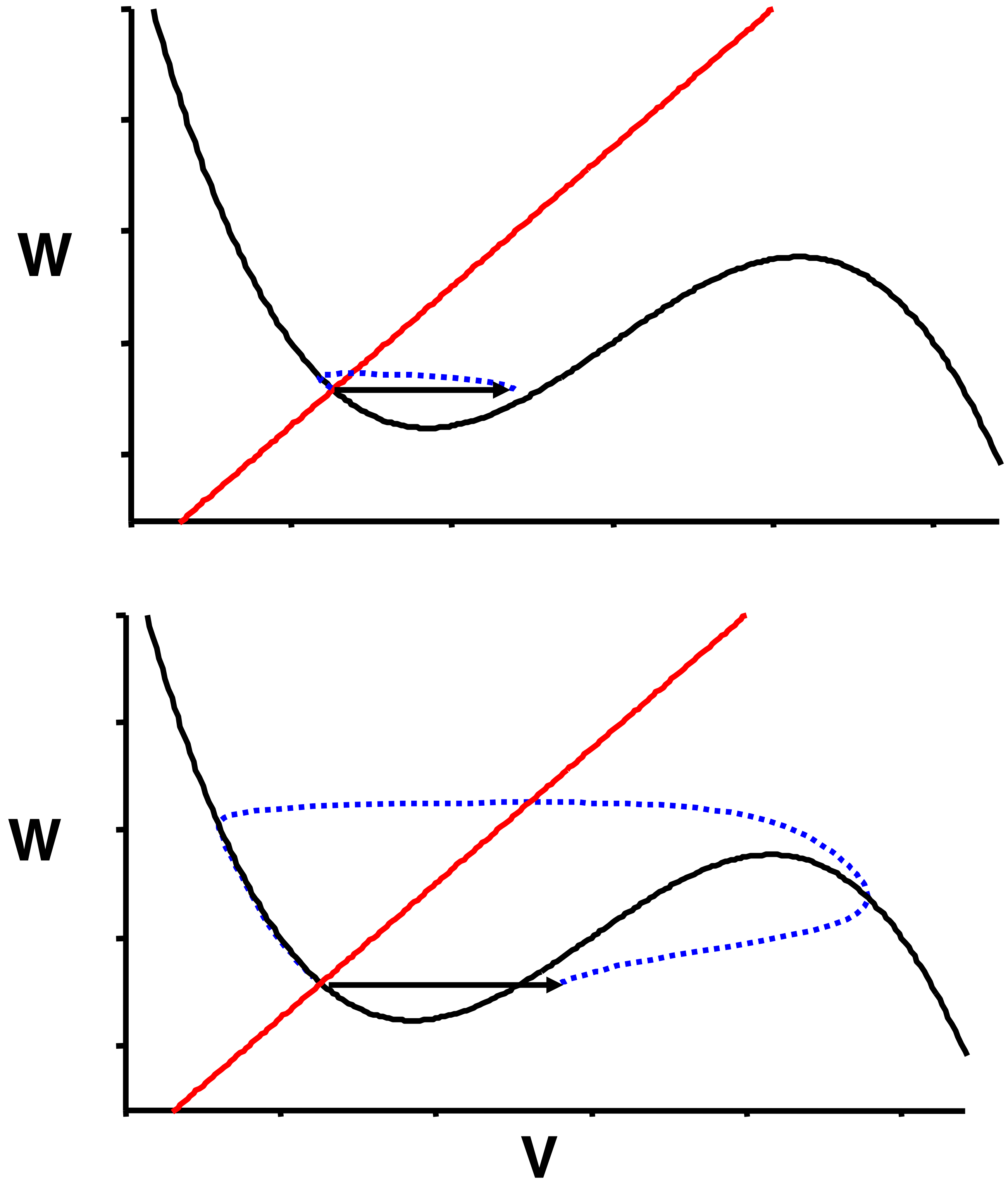
$$dV/dt = V - V^3 - W - I$$

$$dW/dt = 0.08*(V + 0.7-0.8W)$$

The Fitzhugh-Nagumo model is a useful simplification:



The Fitzhugh-Nagumo model is a useful simplification:



return to baseline

spike!

Even explains sustained firing!