9.09J/7.29J - Cellular Neurobiology, Spring 2005
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List of Equations (plus helpful facts)

Equations you need to know for the midterm:

1) Ohms law

$V = IR$

$I = gV$ g = conductance = l/R; 1 Siemen (5)=1 ohm-l

2) Definition of capacitance

$Q = CV$ C = capacitance -a defined constant

Q = charge

3) Differentiated definition of capacitance

$I = dQ/dt = CdV/dt$

4} The Nernst equation:

Shown here for potassium

$V_m = E_K = RT/zF \,.\text{in}\, [K+]_0/[I<+]_i$

V_m = voltage across membrane

E_K = Nernst equilibriwn potential for potassium ions

R = gas law constant

T = temp in °K

z = charge number

z = I for K^+; z = 2 for Ca^{++}

F = Faraday constant = charge (coulombs) on 1 mole of protons

For z ~ 1; T -25°C

$V_m = 58\text{ mV} .\log_{IO} [K+]_0/[K+]_i$

5} The Goldman equation (for resting potential}

$$V_m = 58\text{ mV} .\log_{IO} \frac{[K+]_0 + P_{Na}/P_K([Na+]_o + P_{C1}/P_K[C1-]_i}{[K+]_i + P_{Na}/P_K [Na+]_i + PC1/P_K [C1-]_o}$$

P_{Na}/P_K = Permeability of the cell membrane to sodium ions relative to its permeability to potassium Ions

6) Ohm's law for membranes

$$I_m = gk\ (V_m - E_K) + gNa\ (V_m - E_{Na})$$

$I_m =$ current through membrane inward current is defined as negative by the conventions of the textbook.
gk = membrane conductance to potassium ions
gNa = membrane conductance to sodium ions
E_{Na} = Nernst equilibrium potential for sodium ions

7) The Weighted-average equation

$$V_m = \frac{gk\,E_K + gNa\,E_{Na}}{gk + gNa}$$

This equation is derived from equation 6) above for the equilibrium condition $I_m = 0$. It describes the same situation as the Goldman Equation; it is less accuracy but easier to use experimentally. Hodgkin & Huxley use it all of the time.

8) The Hodgkin-Huxley predictive cycle

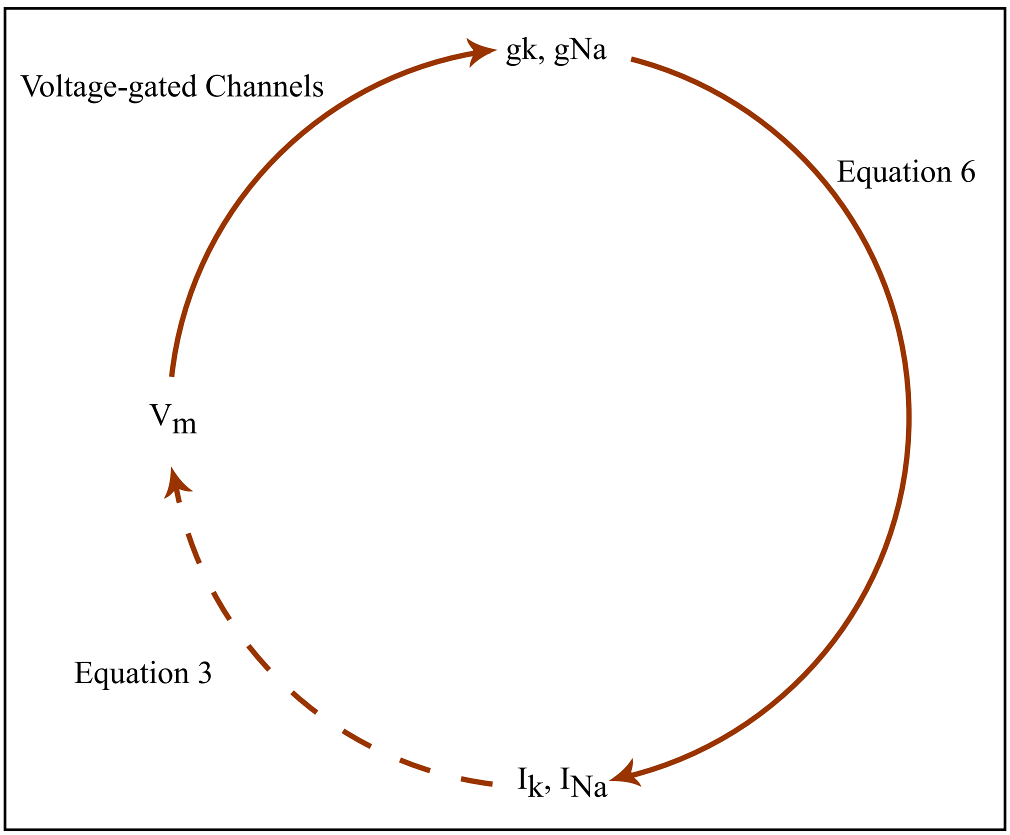

Figure by MIT OCW.

9) Passive spread of current in leaky cable – decrease in voltage excursion with distance

$$V(x) = V(o)e^{-x/\lambda}$$

x = distance from current source

λ = space const. = distance for voltage to drop to i/e = 37% of its value at the source

10)

$$\lambda = \sqrt{\frac{r_m}{r_i + r_o}}$$

r_m = membrane resistance per unit length (Eg cm) of axon

11) For a cylindrical (with arbitrary shaped cross-section) solid, the resistance to Current flow through the cylinder

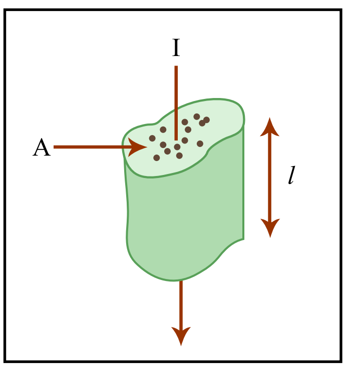

Figure by MIT OCW.

= R.*l*/A

= resistance
= specific <u>resistivity</u> a property of the material
l = length of solid
= cross sectional area of the solid

* Note that in chapter 6 only resistance = r (lower case) and resistivity = R (upper case). In other chapter R = resistance. Also, charge Q and current I become q and i in chapter 6 only. I don't understand this change in notation, but students get confused if my lectures depart from it.

12) Definitions for Quantal analysis

$\overline{v_1}$ = mean quantal size (recorded postsynaptically, measured in millivolts)

m = mean quantal content (average number of quanta per synaptic stimulation – Measured in quanta)

n = number of quanta (vesicles?) available for release at a synapse

p = probability of a given individual quantum being released at a given stimulation

When n = small – the binomial distribution applies:

13) $P(x) = n!/x!(n-x)!\ p^{x} (l-p)^{n-x}$

so when n = **small the probability of failures** $P(o) = (l-p)^{x}$

When n = large, we use the Poisson distribution which you need not memorize. From this, the probability of failures (n = large)

14) $P(o) = e^{-m}$

<u>Some facts.</u> quantal analysis distinguishes bet\4/een presynaptic and postsynaptic effects.

A. **Presynaptic change -> change in m. Most easily measured by measuring change in Po, the rate of failures in stimulated evoked synaptic transmission.**

B. **Postsynaptic change --> change in V_1 = change in quanta! size -most easily measured as change in peak voltage for spontaneous mini's.**

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Spring 2012