9.09J/7.29J - Cellular Neurobiology, Spring 2005
Massachusetts Institute of Technology
Department of Brain and Cognitive Sciences
Department of Biology
Instructors: Professors William Quinn and Troy Littleton

7.29 / **j9.09 Cellular Neurobiology**

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

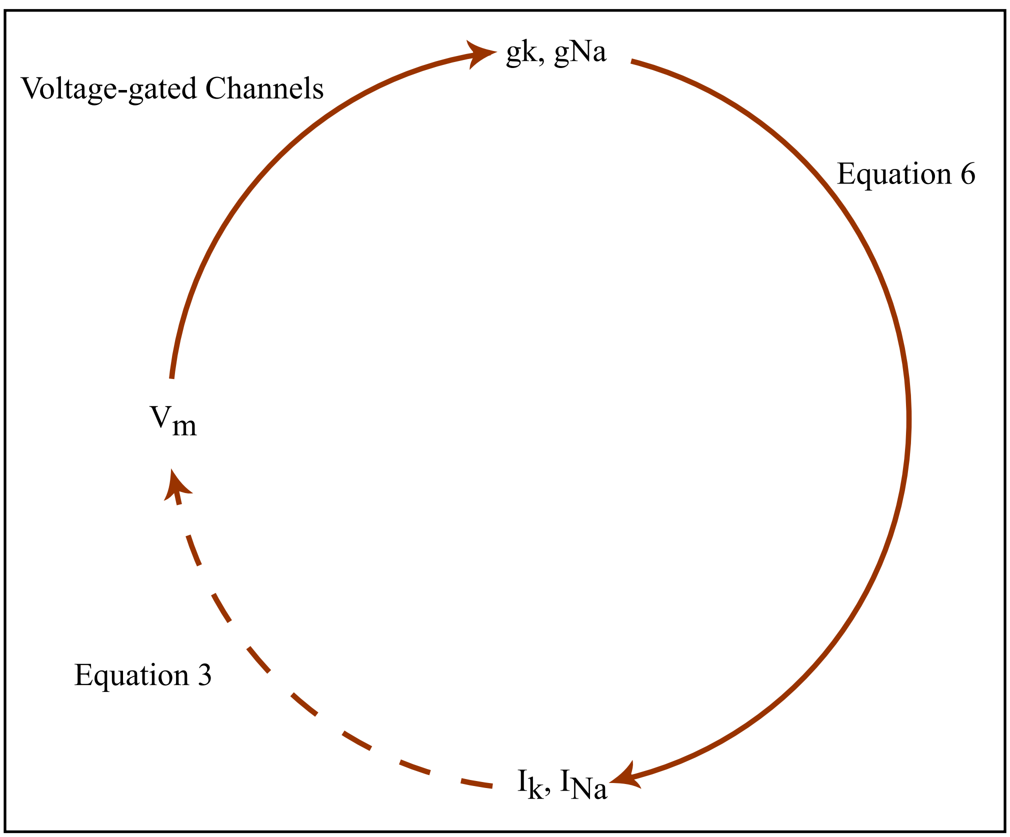


Figure by MIT OCW.

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

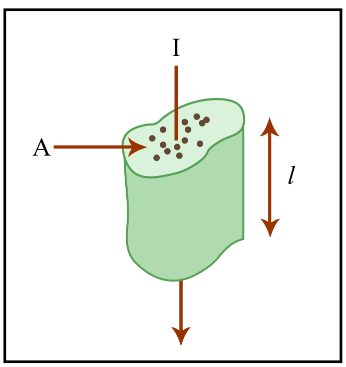
λ = space const. = distance for voltage to drop to i/e = 37% of its value at the source

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



r = R.*l*/A

r = resistance

R= specific resistivity a property of the material

l = length of solid

A = cross sectional area of the solid

Figure by MIT OCW.

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

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) **$P(o) = e^{-'''}$**

<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.**