# 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**

$V_m = E_K = RT/zF$ .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**

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

**5} The Goldman equation (for resting potential}**

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

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

6) Ohm's law for membranes

$$I_m = g_K (V_m - E_K) + g_{Na} (V_m - E_{Na})$$

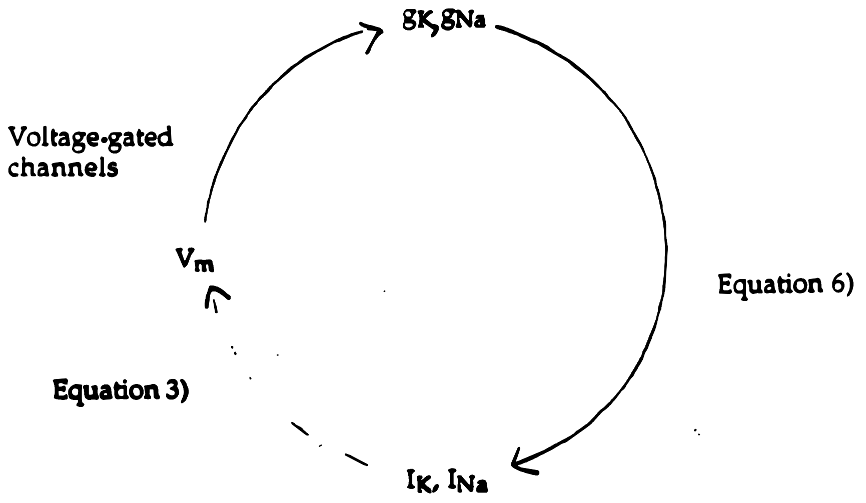
$I_m$ = current through membrane --
inward current is defined as negative by the conventions of the textbook
$g_K$ = membrane conductance to potassium ions
$g_{Na}$ = membrane conductance to sodium ions
$E_{Na}$ = Nernst equilibrium potential for sodium ions

7) The Weighted-average equation

$$V_m = \frac{g_K E_K + g_{Na} E_{Na}}{g_K + g_{Na}}$$

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 much easier to use experimentally. Hodgkin & Huxley use it all of the time.

8) The Hodgkin-Huxley predictive cycle



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

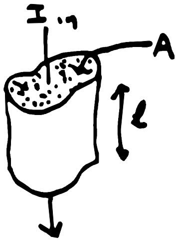
$\lambda$ = space const. = distance for voltage to drop to $1/e$ = 37% of its value at the source

10)

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

$r_m$ = membrane resistance per unit length ($\Omega$ cm) of axon

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



$r = R \cdot \ell / A$

$r$ = resistance

$R$ = specific <u>resistivity</u>, a property of the material

$\ell$ = length of solid

$A$ = cross sectional area of solid

* Note that <u>in Chapter 6 only</u> resistance = r (lower case) and resistivity = R (upper case). In other chapters 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

$\bar{v}_1$ = 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 between 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 quantal size -most easily measured as change in peak voltage for spontaneous mini's.**