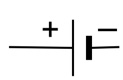
Electricity Basics

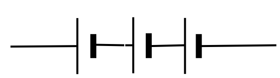
- Current(I)=the rate that charge Q passes a point in a conductor I=dQ/dt
- Resistance(R)=extent to which current is impeded in a conductor. It is measured in Ohms(Ω).
- Potential Difference: energy required to move an electron or any charge between two points in a conductor. Measured in volts (V)
- Battery is a device which employs a chemical reaction to create a potential difference across the terminals of the battery.The potential difference across the terminals of a battery is referred to as its electromotive force EMF and is measured in volts.

Electricity Basics

Resistor

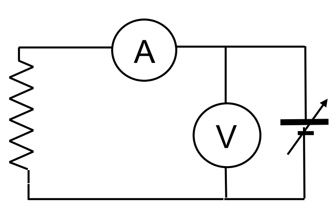
Battery



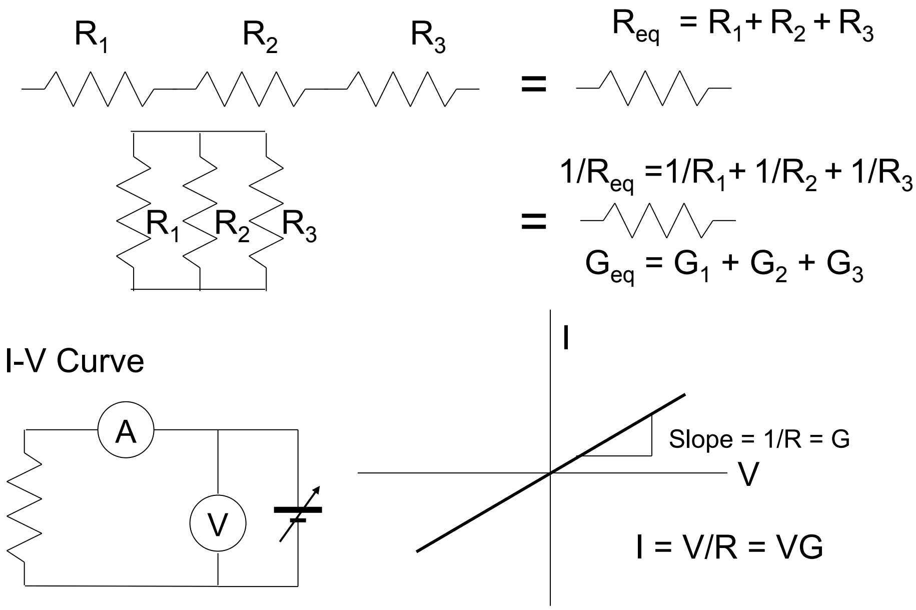


Ohms Law

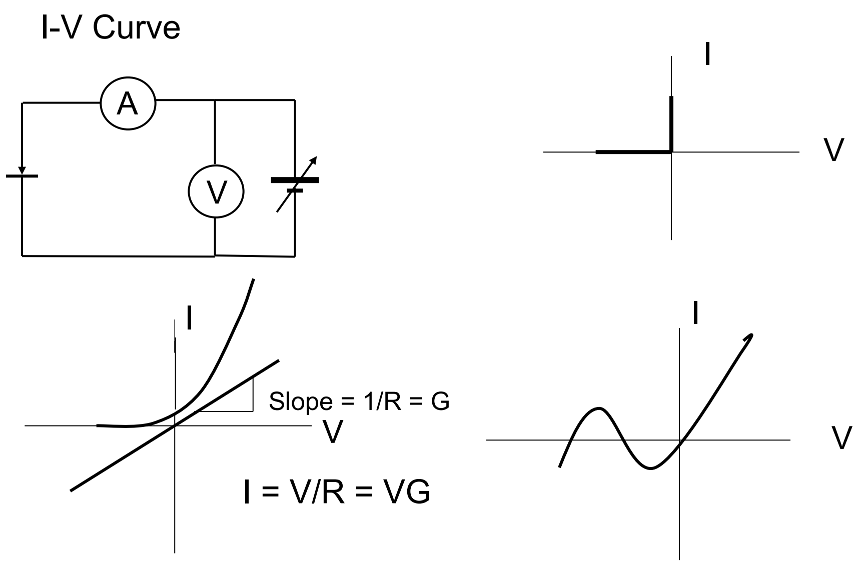
V=IR



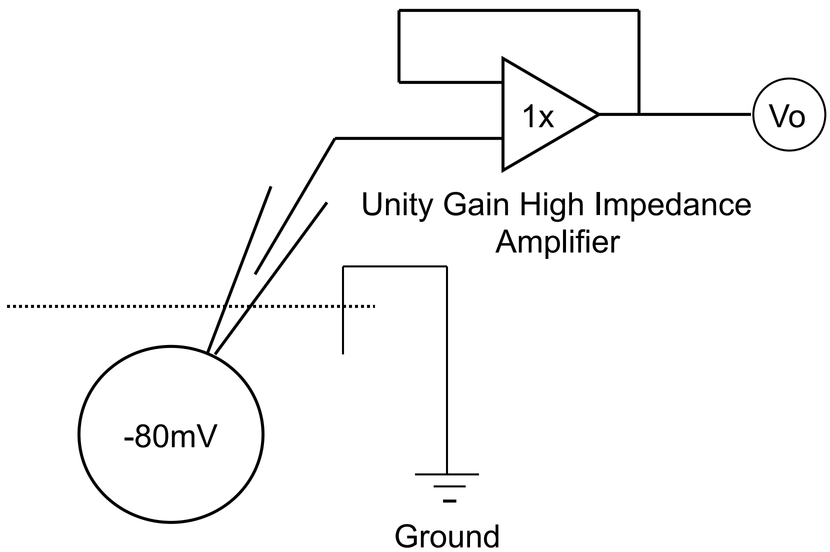
Electricity Basics:Resistance



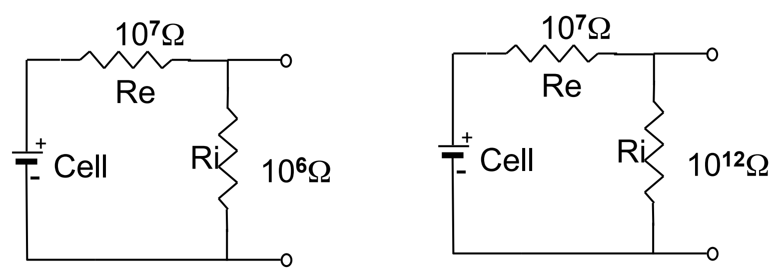
Electricity Basics:Rectification.



Measuring Membrane Potential



Amplifier Circuit

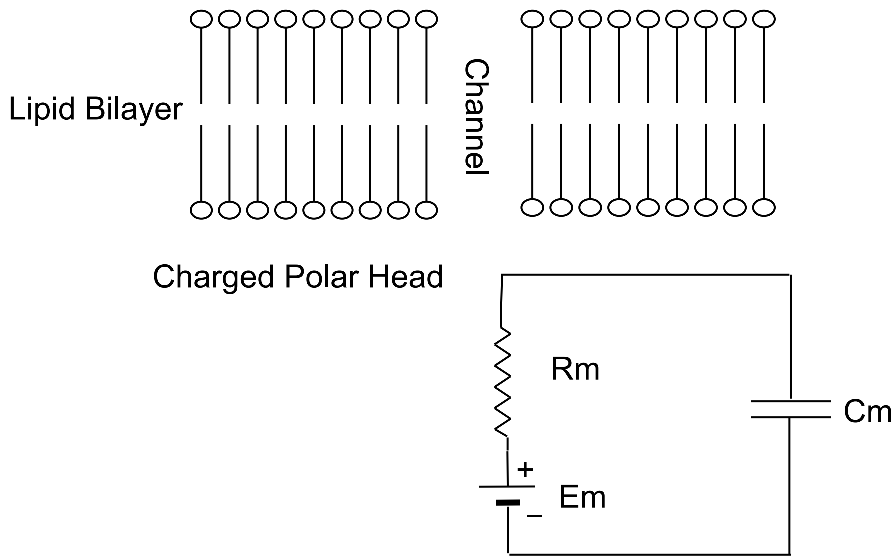


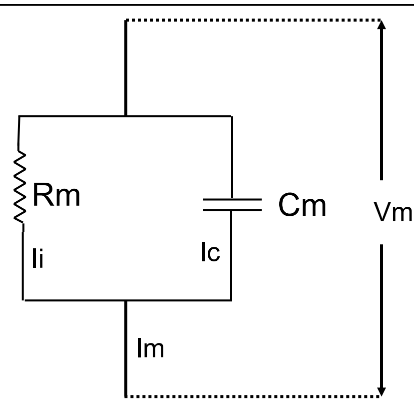
$V_{measured}=I(10^6)$

$V_{cell}=IR=I(10^7+10^6)$

$V_{measured}=1/11V_{Cell}$

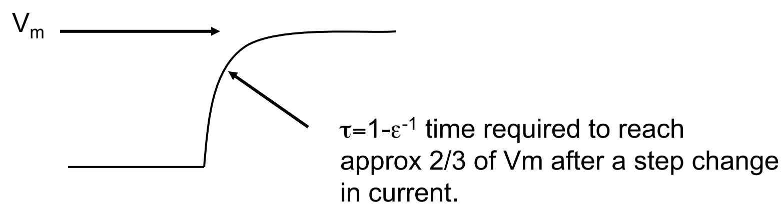
Membrane Equivalent Circuit





$Im=Ic+Ii$
By Ohms Law $Im=V/Rm$
and $Im=Cm.dV/dt + Im$

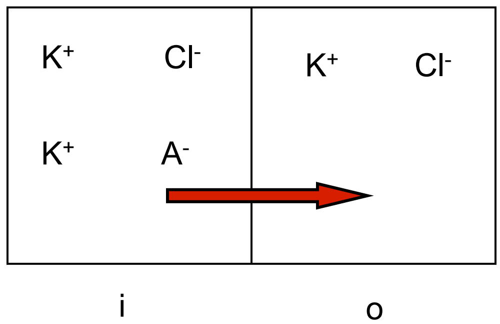
The solution to this equation is $V=ImRm(1-e^{t/\tau})$
t/τ is the membrane time constant=$RmCm$



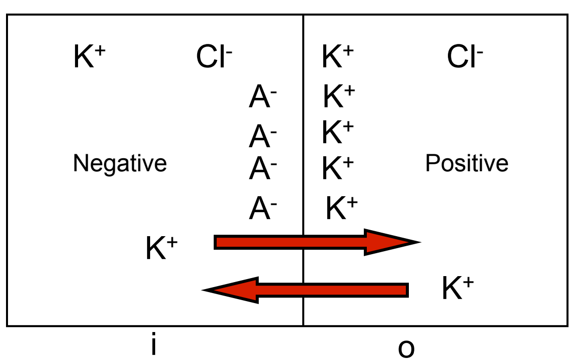
Ionic concentration (mM)

	Ion	External	Internal	Nernst Potential (mV)
Frog muscle	K	2.25	124	-101
	Na	109	10.4	+59
	Cl	77.5	1.5	-99
Squid axon	K	20	400	-75
	Na	440	50	+55
	Cl	560	108	-41

How Does the Membrane Potential Arise Donnan's Theory.



Donnan Equilibrium



Nernst Equation

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$zF\psi_1$ $zF\psi_2$

$$\mu_1 = \mu_o + RTLn\alpha_1 \qquad \mu_2 = \mu_o + RTLn\alpha_2$$

1 2

$$C = \gamma\alpha$$

$$\mu_1 = \mu_o + RTLn\alpha_1 + zF\psi_1$$

$$\mu_2 = \mu_o + RTLn\alpha_2 + zF\psi_2$$

At equilibrium $\mu_1 = \mu_2$

We can define the electrochemical potential as:

$$\mu_1 = \mu_o + RTLn\alpha_1 + zF\psi_1$$

$$\mu_2 = \mu_o + RTLn\alpha_2 + zF\psi_2$$

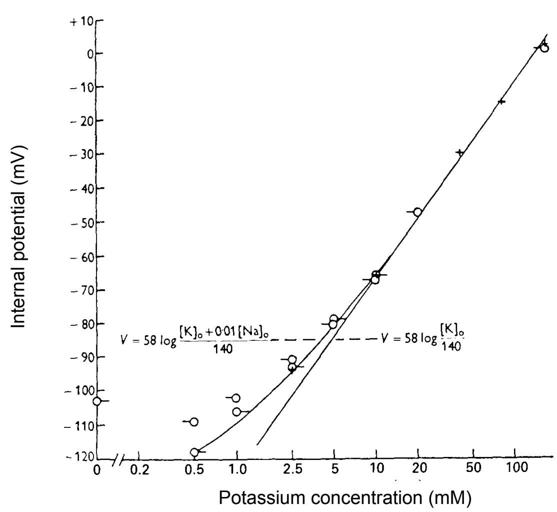
At equilibrium $\mu_1 = \mu_2$

$$\therefore RTLn\alpha_1 + zF\psi_1 = RTLn\alpha_2 + zF\psi_2$$

$$\psi_1 - \psi_2 = E = \frac{RT}{zF} Ln\frac{\alpha_1}{\alpha_2} = \frac{RT}{zF} Ln\frac{C_1}{C_2}$$

$$E = \frac{RT}{zF} Ln\frac{C_1}{C_2}$$ *Nernst equation*

The effect of the external potassium ion concentration on the membrane potential of isolated frog muscle fibres. The external solutions were chloride-free, the principle anion being sulphate. (From Hodgkin and Horowicz, 1959.)



Hodgkin Goldman Katz Equation (Modified).

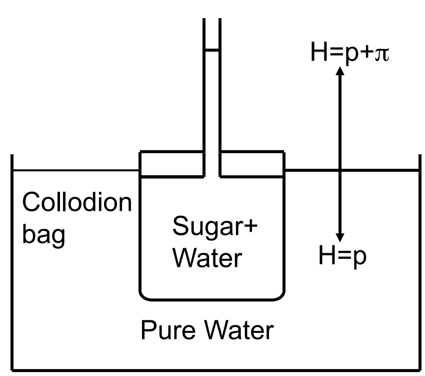
It is possible to derive an equation that predicts the Effect on Em of permeabilities to other ions e.g Na.

For the contribution of Na to membrane potential We may write the following equation:

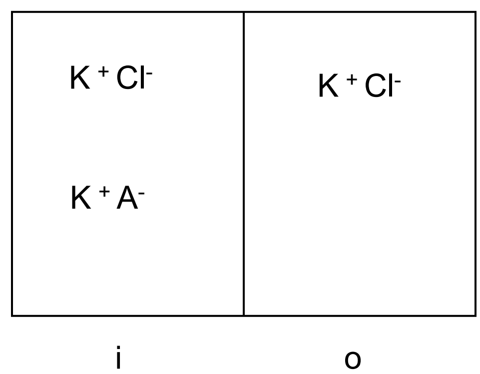
$$E = \frac{RT}{F} \ln \frac{[K]_o + \alpha [Na]_o}{[K]_i + \alpha [Na]_i}$$

$\alpha = P_{Na}/P_K$ Assume $\alpha = 0.01$

Osmosis



The Donnan equilibrium system



Add a small quantity of KA to i. The membrane is impermeant to A
K is at higher concentration in i and diffuses to o. Cl follows the K.
eventually an equilibrium arises in which $[K]_I$ is not equal to $[K]_o$ and
$[Cl]_I$ is not equal to $[Cl]_o$. This creates a concentration cell and the condition
$E_k = E_{cl}$ must hold.

The Donnan Product

For K^+ $$E_k = \frac{RT}{zF} \ln \frac{[K+]_o}{[K+]_i}$$

For Cl^- $$E_{Cl} = \frac{RT}{-zF} \ln \frac{[Cl-]_o}{[Cl-]_i}$$

$$\therefore E_K = E_{Cl}$$

$$\therefore \frac{[K]_o}{[K]_i} = \frac{[Cl]_o}{[Cl]_i} = [K]_i \times [Cl]_i = [K]_o \times [Cl]_o \quad \text{(Donnan Product)}$$

The Osmotic Argument

We cannot apply this simple Donnan system to an animal cell because it will swell.

For approximate electrical neutrality $[K_o]=[Cl_i]$ and $[K_o]>[Cl_i]$.

now $[K]_i x[Cl]_i = [K]_o x[Cl]_o$,

therefore

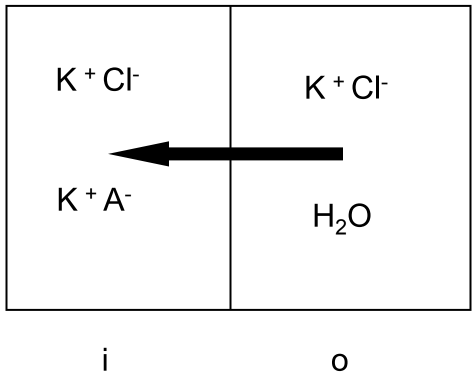
$K]_I+[Cl]_i >[K]_o+[Cl]_o$

therefore

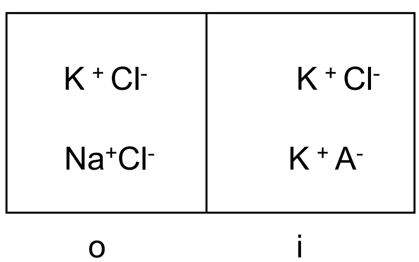
$K]_I+[Cl]_I+[A] >[K]_o+[Cl]_o$

therefore the osmotic concentration is greater in i than in o. Thus if the constant volume constraint is moved water moves from i to o.

The Donnan equilibrium system



Impermeant Anion in Outer Compartment prevents Water Loss



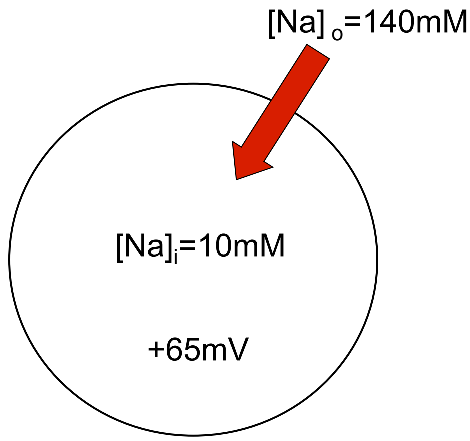
With an impermeant anion present water will move until the Donnan equilibrium is established i.e. $[K]_i x[Cl]_i = [K]_o x[Cl]_o$,

Driving Forces

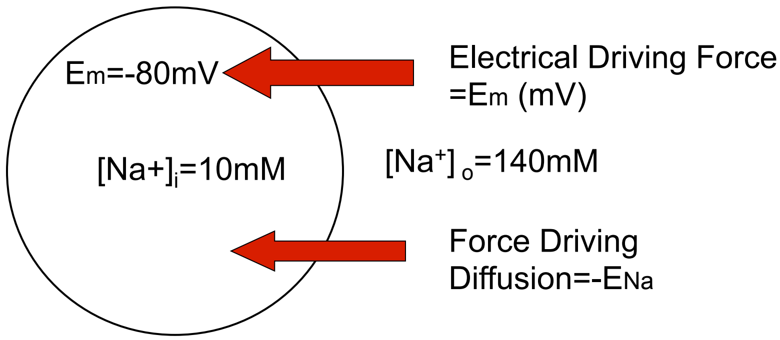
Ohms Law I=gV

$$E_{Na} = \frac{RT}{zF} \ln \frac{[Na+]_o}{[Na+]_i}$$

E_{Na}=+65mV



65mV required to oppose Na diffusion. -65mV=effective force exerted by the Na gradient.Thus the chemical driving force is -E_{Na}



Net Driving Force(mV)=E_m+(-E_{Na})
Or E_m-E_{Na} (mV)

Ohms Law and Electrophysiolgy

Net Driving Force(mV)=E_m-E_{Na} (mV)

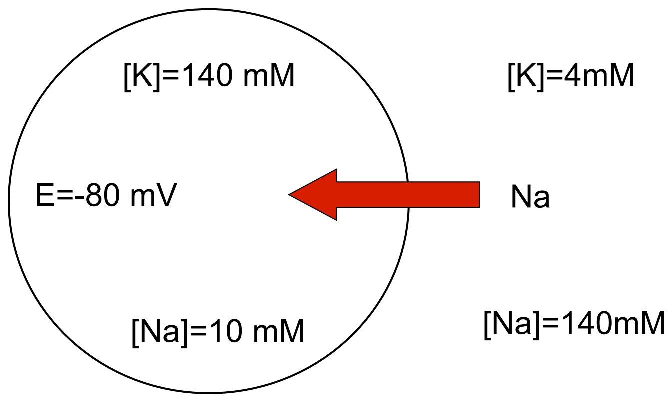
From Ohms Law Na current ,I_{Na} (ion flux) will be given by:

$$I_{Na}=g_{Na}(E_m-E_{Na})$$

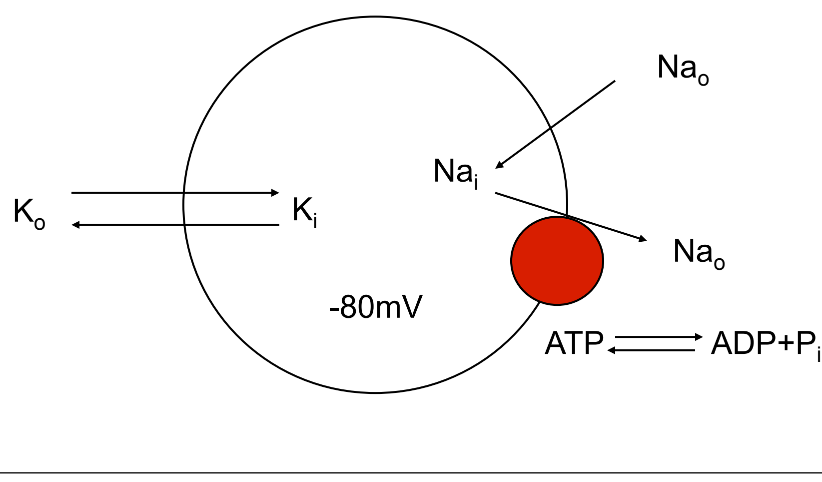
When $E_m=E_{Na}$ $I_{Na}=0$

By changing E_m until $I_{Na}=0$ we can find E_{Na}.

Calculations with the Nernst equation indicate that $[Na_i]$ should = 3,434 mM if it is at electrochemical equilibrium.



Na Pump Maintains the Inward Na Gradient



Summary of Pumps and Leaks for Resting Membrane