生命ナノシステム科学

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(3)

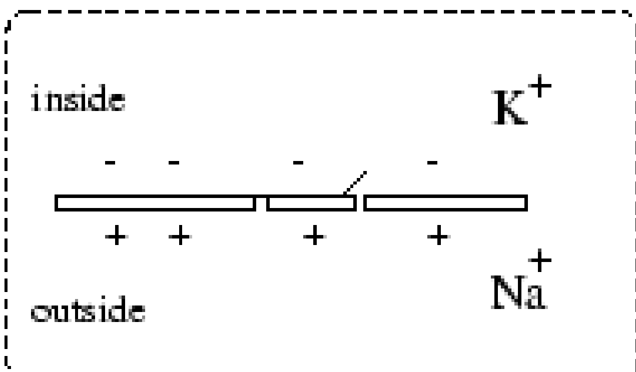
後期２００９年

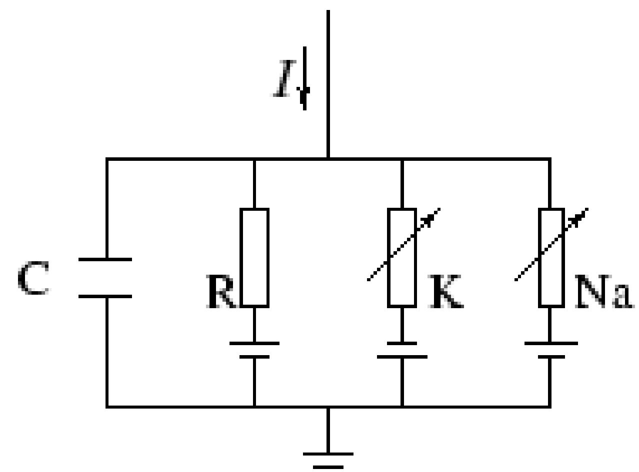
Hodgkin-Huxley Model (1952)

J. Physiol. Vol 117 500-540, 1952 by A.L. Hodgkin and A.F. Huxley.

Based on Giant Squid experiments

$$C\frac{du}{dt} = -\sum_k I_k(t) + I(t)\,.$$





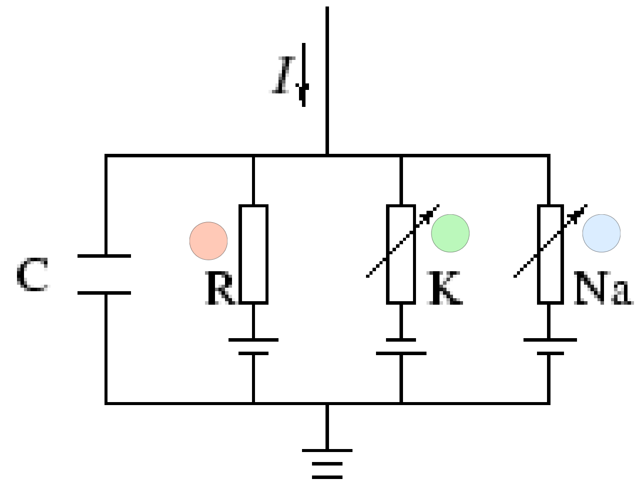
$$C\frac{\mathrm{d}u}{\mathrm{d}t} = -\sum_k I_\mathrm{k}(t) + I(t)\,.$$

$$\sum_k I_\mathrm{k} = g_\mathrm{Na}\, m^3 h\,(u - E_\mathrm{Na}) + g_\mathrm{K}\, n^4\,(u - E_\mathrm{K}) + g_\mathrm{L}\,(u - E_\mathrm{L}).$$

$$\frac{dm}{dt} = \alpha_m^u\,(1 - m) - \beta_m^u\, m$$

$$\frac{dn}{dt} = \alpha_n^u\,(1 - n) - \beta_n^u\, n$$

$$\frac{dh}{dt} = \alpha_h^u\,(1 - h) - \beta_h^u\, h$$



From Experiments

x	$\alpha_x(u\,/\,\mathrm{mV})$	$\beta_x(u\,/\,\mathrm{mV})$
n	$(0.1 - 0.01\,u)\,/\,[\exp(1 - 0.1\,u) - 1]$	$0.125\exp(-u\,/\,80)$
m	$(2.5 - 0.1\,u)\,/\,[\exp(2.5 - 0.1\,u) - 1]$	$4\exp(-u\,/\,18)$
h	$0.07\exp(-u\,/\,20)$	$1\,/\,[\exp(3 - 0.1\,u) + 1]$

x	E_x	g_x
Na	115 mV	120 $\mathrm{mS/cm^2}$
K	-12 mV	36 $\mathrm{mS/cm^2}$
L	10.6mV	0.3$\mathrm{mS/cm^2}$

$$\frac{dm}{dt}=\alpha_m(u)(1-m)-\beta_m(u)m$$
$$\frac{dn}{dt}=\alpha_n(u)(1-n)-\beta_n(u)n$$
$$\frac{dh}{dt}=\alpha_h(u)(1-h)-\beta_h(u)h$$

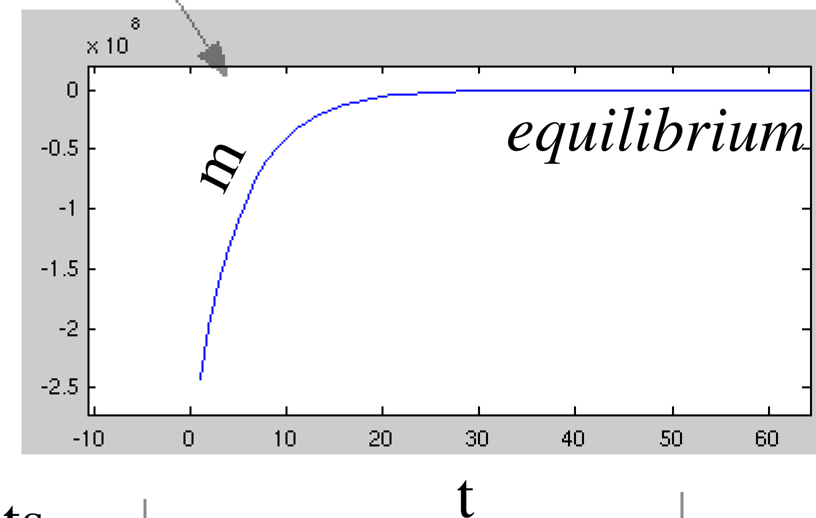
Sym Matlab

```
>> y=dsolve('Dm=a*(1-m)-b*m')

y =

(a - C18/exp(t*(a + b)))/(a + b)
```

```
a - C18 exp(-t (a + b))
-----------------------
         a + b
```

α β

plot(y)



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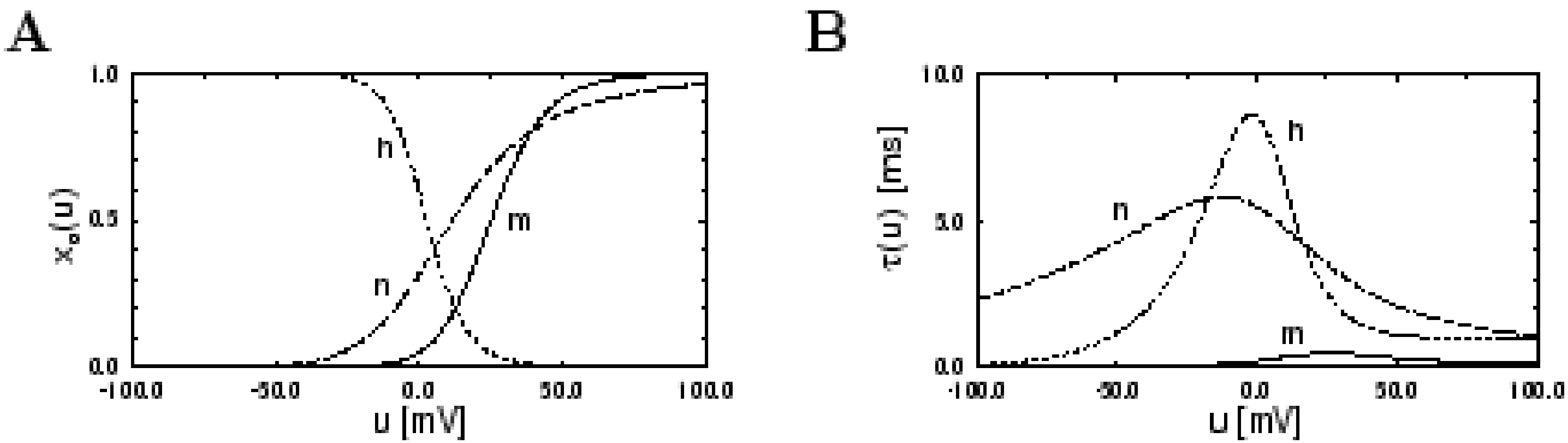
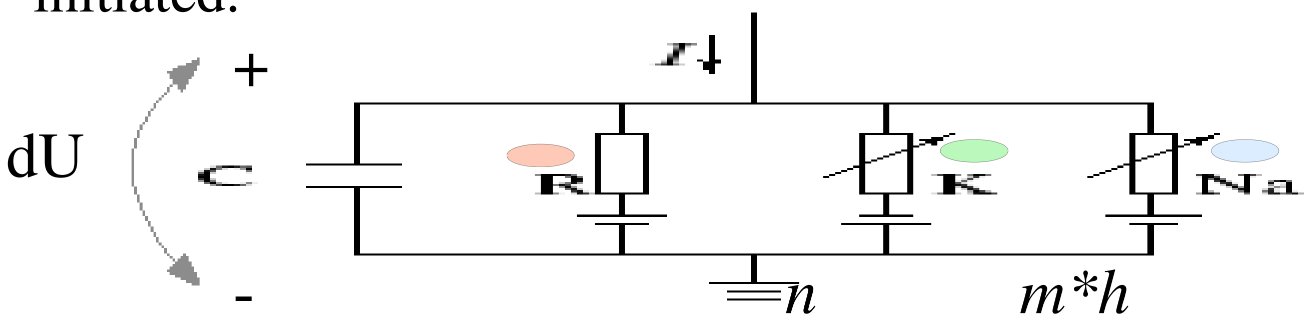
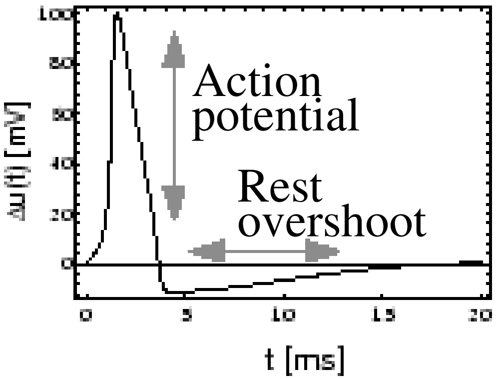
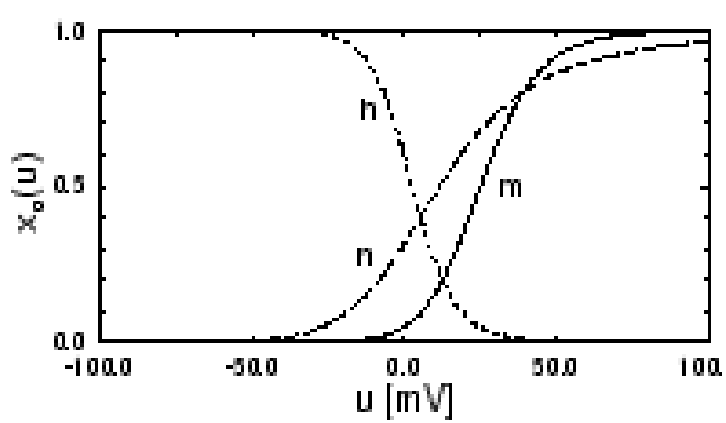
Exponential fitting



We see that the *equilibrium* m and n increase with u whereas h decreases. Thus, if some external input causes the membrane voltage to rise, the conductance of sodium channels increases due to increasing m. As a result, positive sodium ions flow into the cell and raise the membrane potential even further. If this **positive feedback** is large enough, an **action potential** is initiated.



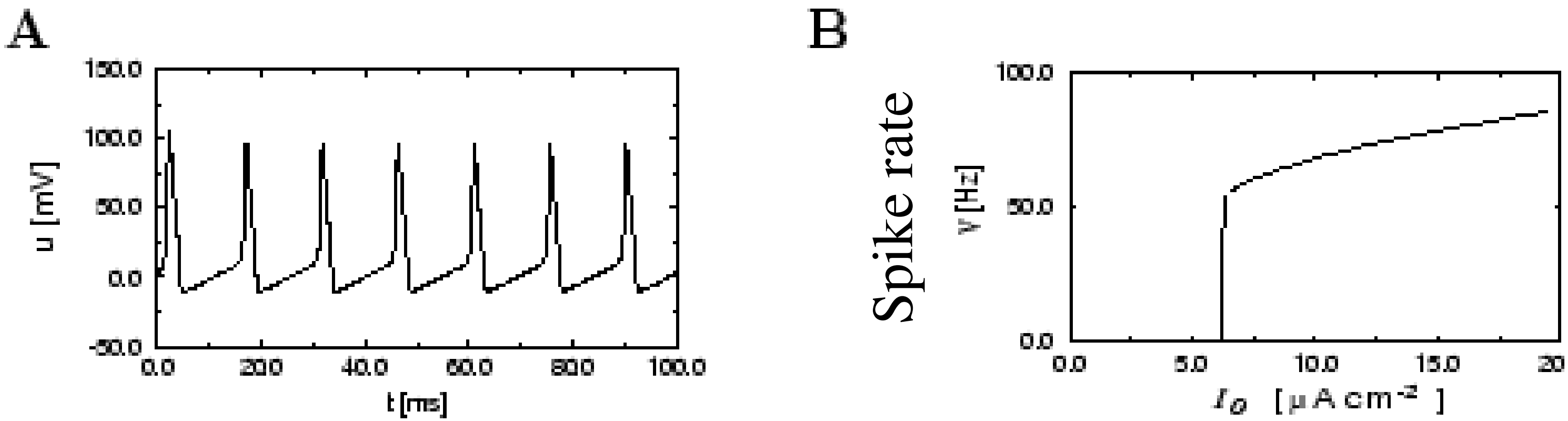




At high values of u the sodium conductance is shut off due to the factor h. As indicated the `time constant' is always larger than . Thus the variable h which closes the channels reacts more slowly to the voltage increase than the variable m which opens the channel. On a similar slow time scale, the potassium (K+) current sets in. Since it is a current in outward direction, it lowers the potential. The overall effect of the sodium and potassium currents is a short **action potential** followed by a **negative overshoot**; The amplitude of the spike is about 100 mV

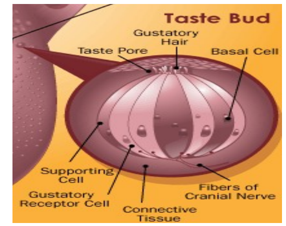
$$\sum_k I_k = g_{Na}\, m^3 h\,(u - E_{Na}) + g_K\, n^4\,(u - E_K) + g_L\,(u - E_L).$$

Auto-oscillation is possible

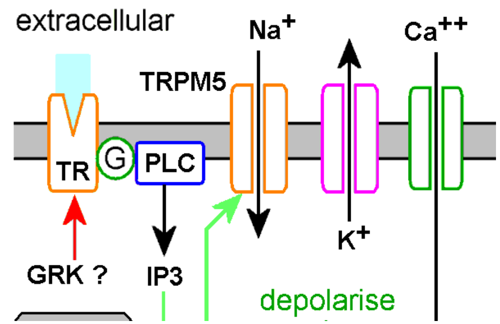


The Hodgkin-Huxley equations may also be studied for **constant** input I(t) = I0 for t > 0. (The input is zero for t 0). If the value I0 is larger than a **critical value** I 6A/cm2, we observe **regular spiking**; We may define a firing rate = 1/T where T is the inter-spike interval. The firing rate as a function of the constant input I0 defines the gain function plotted.

TASTE-TONGUE PROCESS - Conclusions

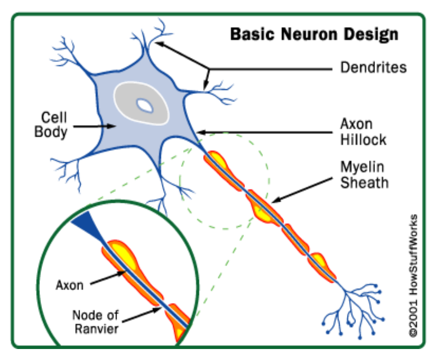


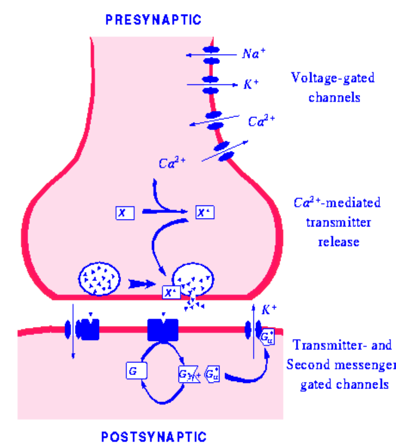
- food is dissolved in mouth
- molecules enter the “Taste Bud”



- contact with cell membrane

- “Taste Receptor” activate (sweet, salty, bitter, sour…)
- ”SPIKE” electrical signal is generated
- transported to brain by neurons





What do we need to make an Artificial Tongue ?

- food is something that must be **TOUCHED**

- sensing **CHEMICAL** properties at **CONTACT**

We need different chemical RECEPTORS
for different TASTES (sweet, salty, bitter, sour...)