物質機能科学**IIb**

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知覚情報科学

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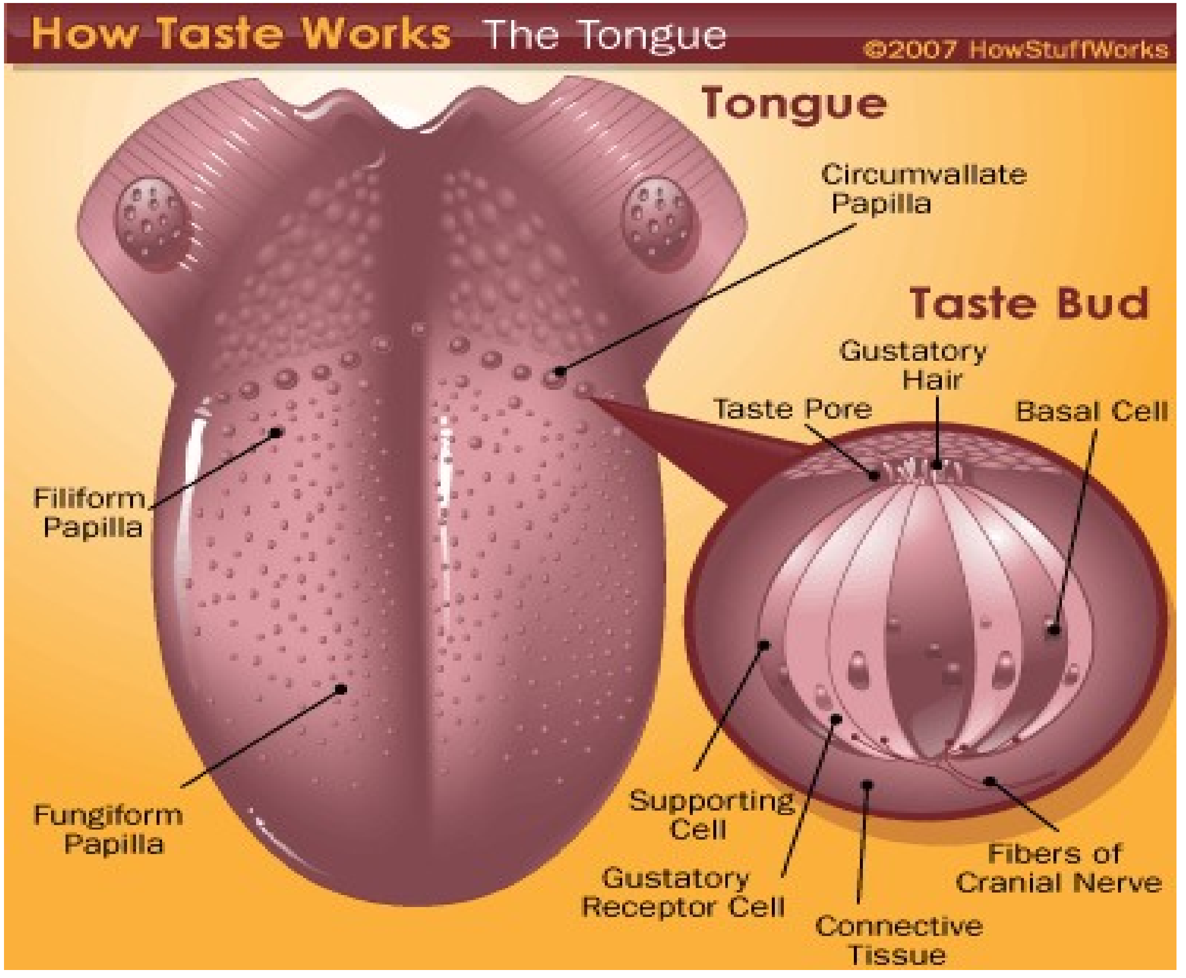
(2)

後期２００９年

The Taste


How Taste Works The Tongue
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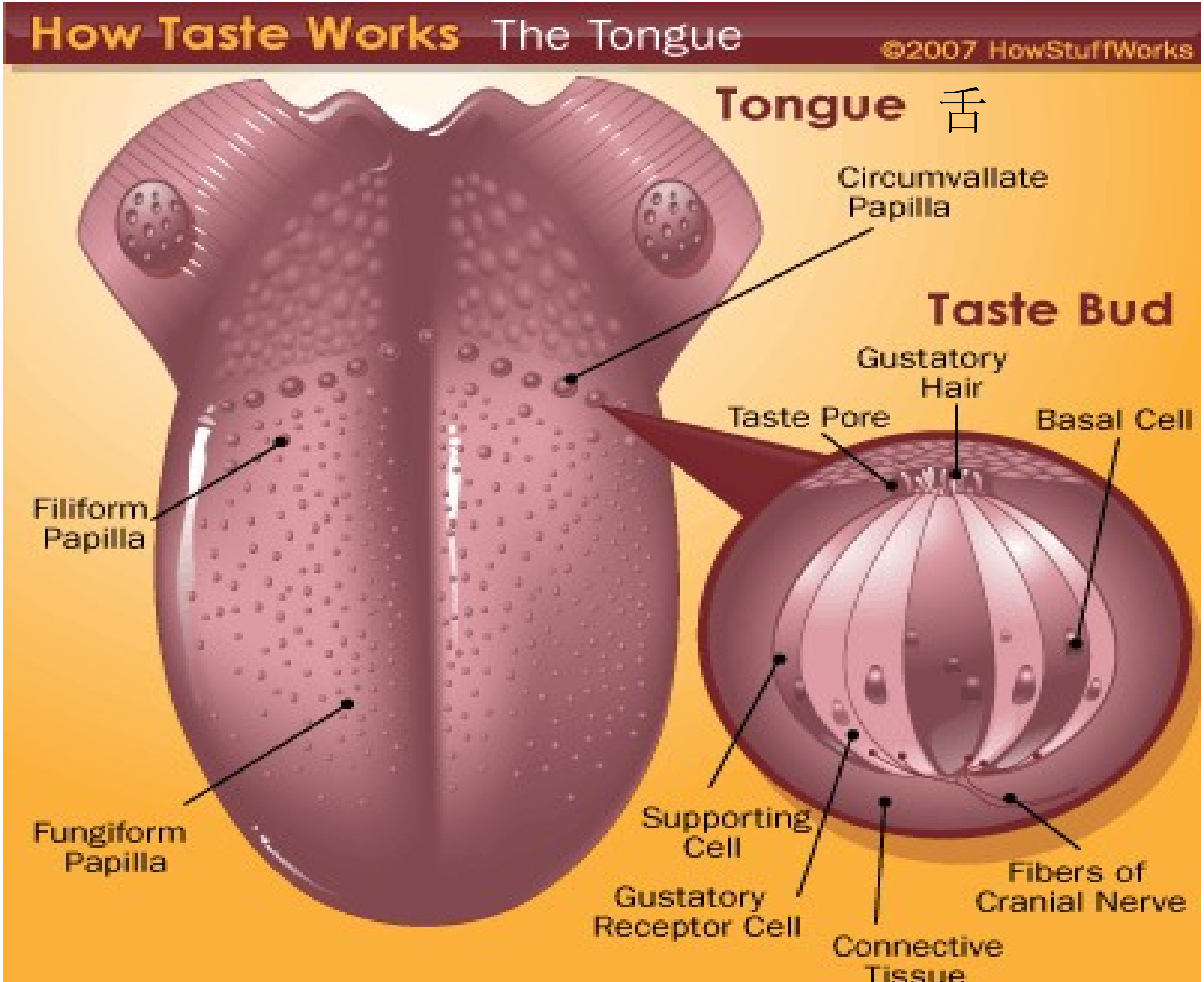
Tongue
Circumvallate Papilla
Filiform Papilla
Fungiform Papilla
Taste Bud
Gustatory Hair
Taste Pore
Basal Cell
Supporting Cell
Gustatory Receptor Cell
Connective Tissue
Fibers of Cranial Nerve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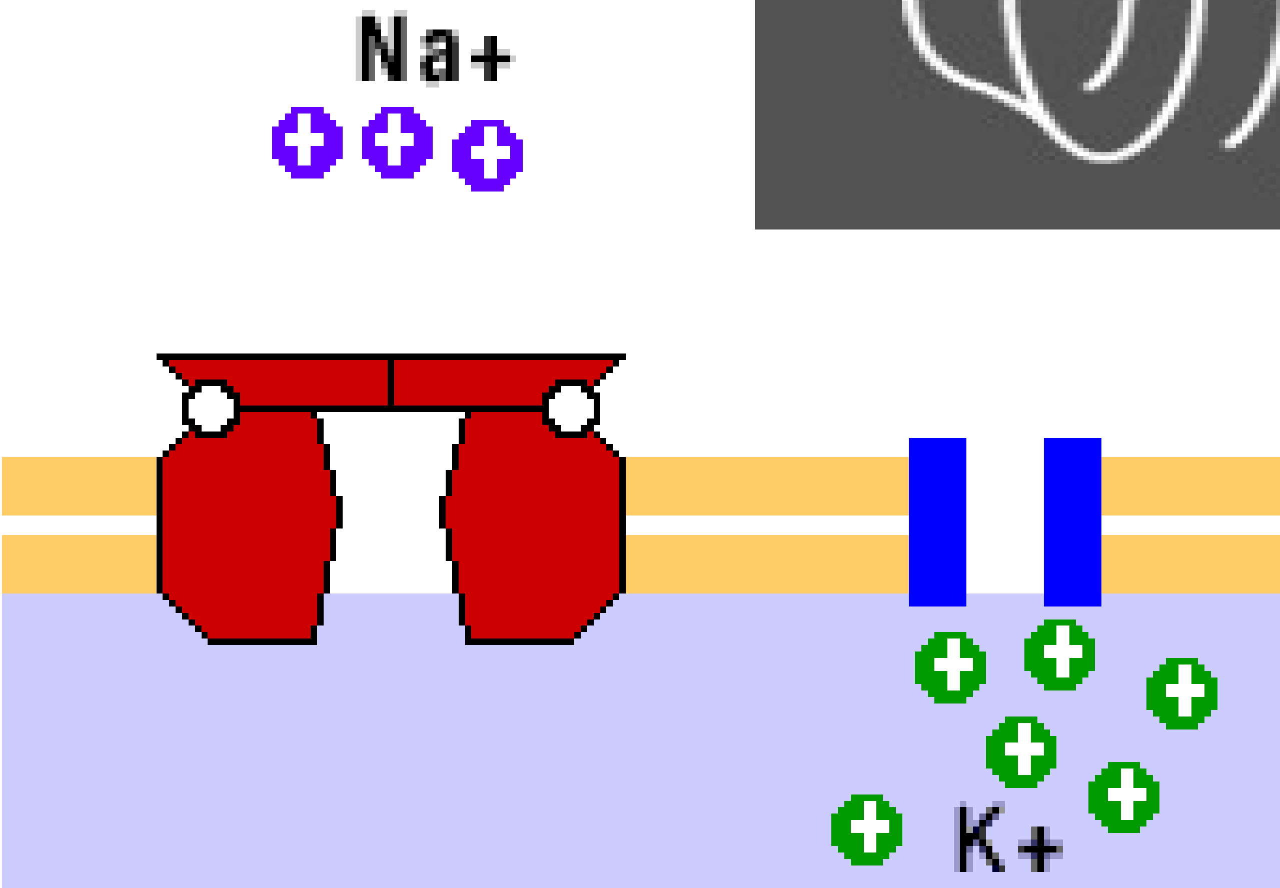
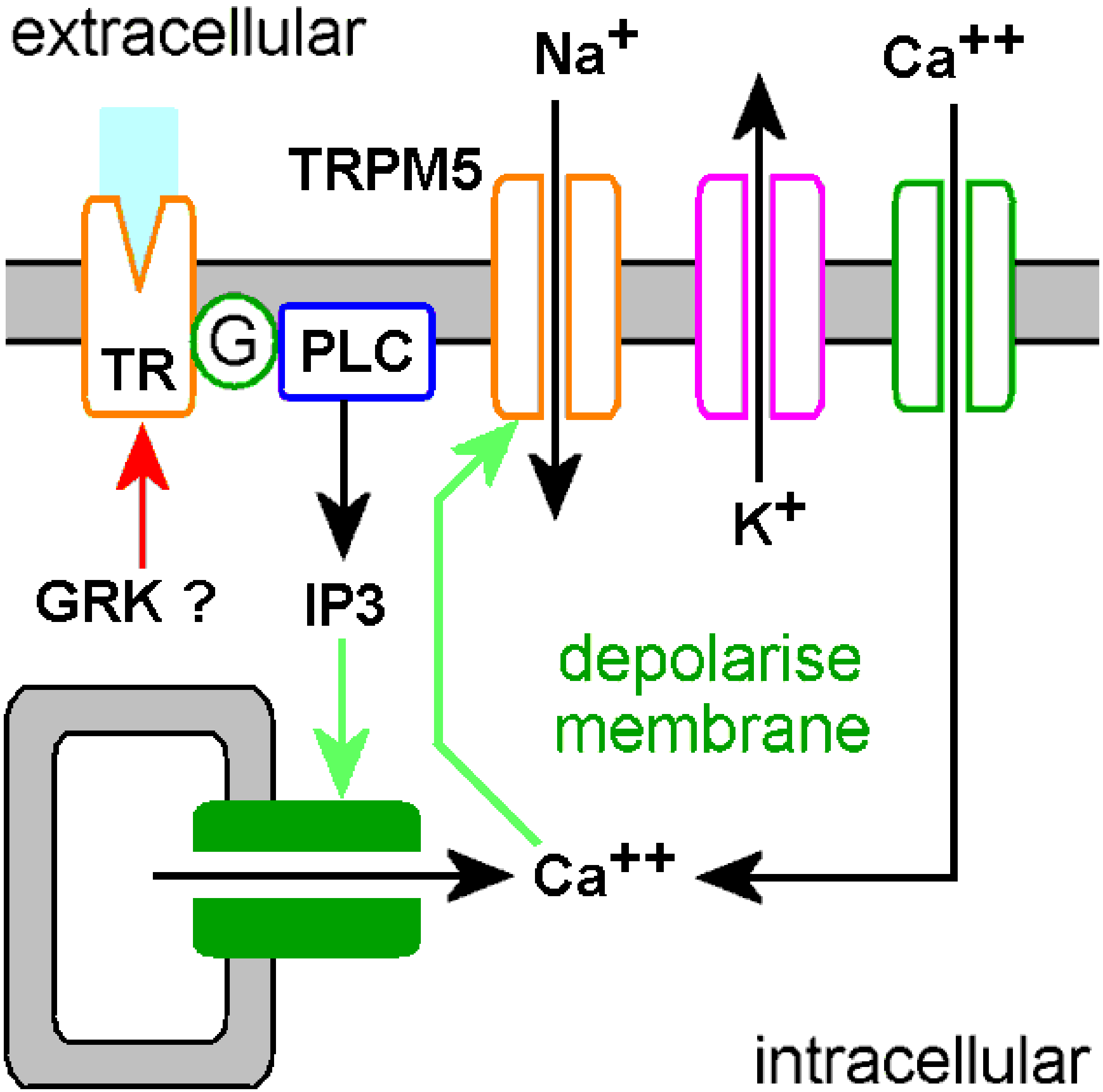

Na+
K+



G - heterotrimeric G-protein

GRK - G-protein receptor kinase

IP3 - inositol triphosphate

PLC - phospholipase

TR - taste receptor

The Sweet Receptor function:

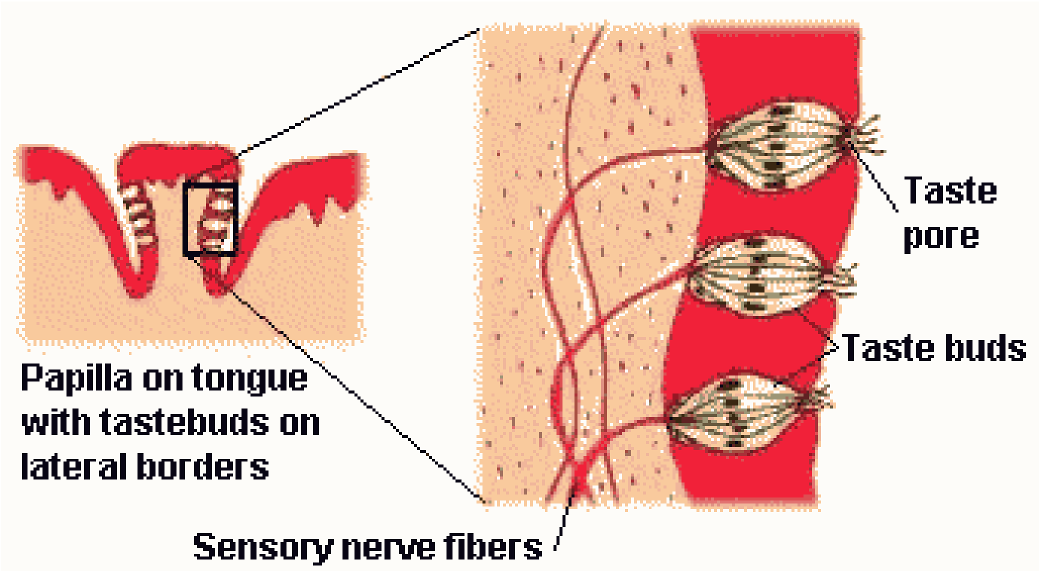
Each receptor contains 2 subunits designated **T1R2** and **T1R3** and is coupled to G proteins.

The complex of G proteins has been named **gustducin** because of its similarity in structure and action to the transducin that plays such an essential role in rod vision.

Activation of **gustducin** triggers a cascade of intracellular reactions:

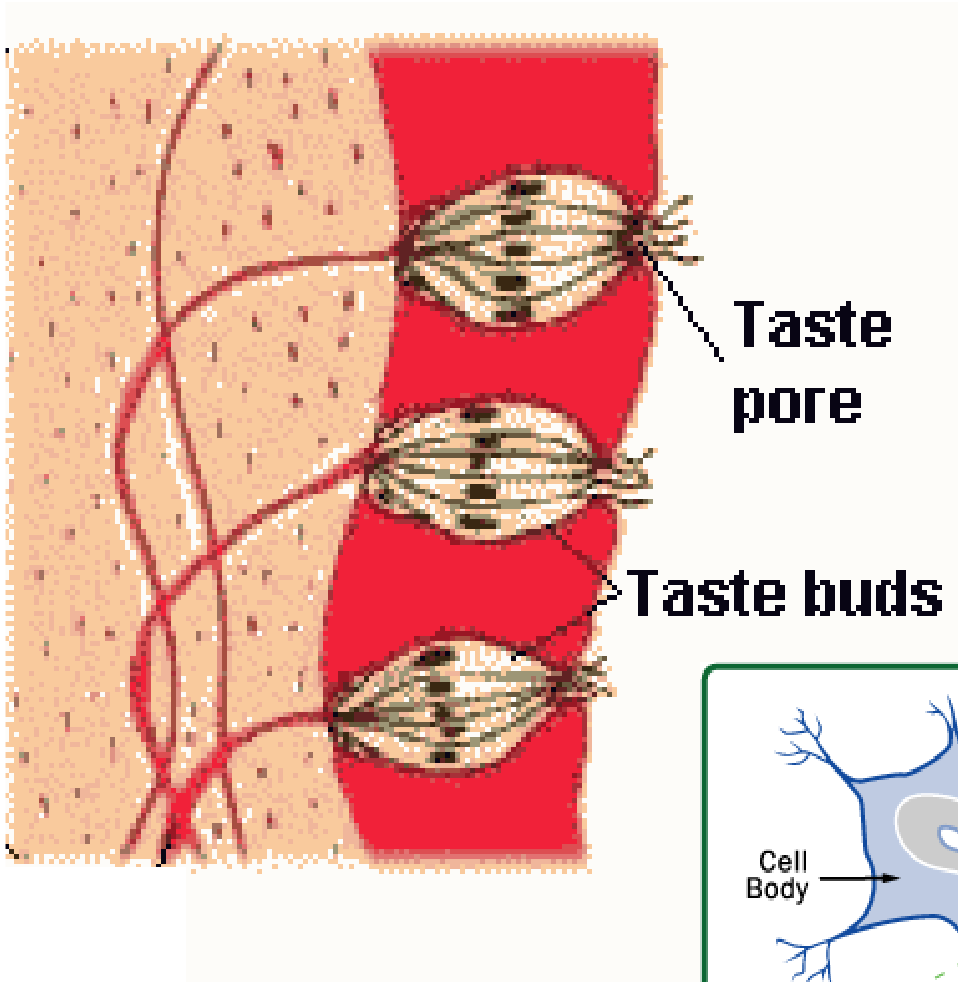
- activation of adenylyl cyclase
- formation of cyclic AMP (cAMP)
- the closing of K+ channels that leads to **depolarization** of the cell.

Emission of a electric discharge signal

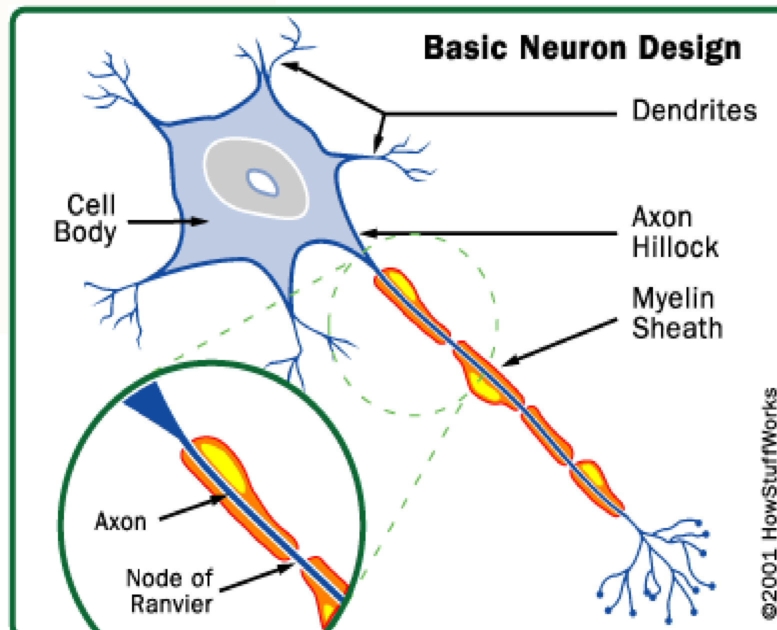


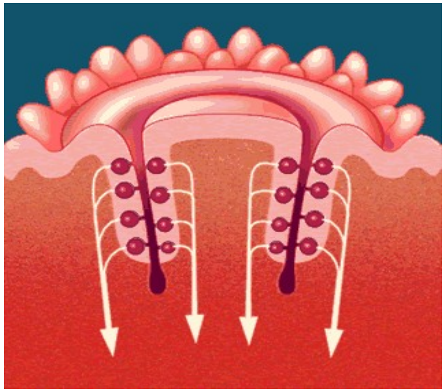
Examples of some human thresholds

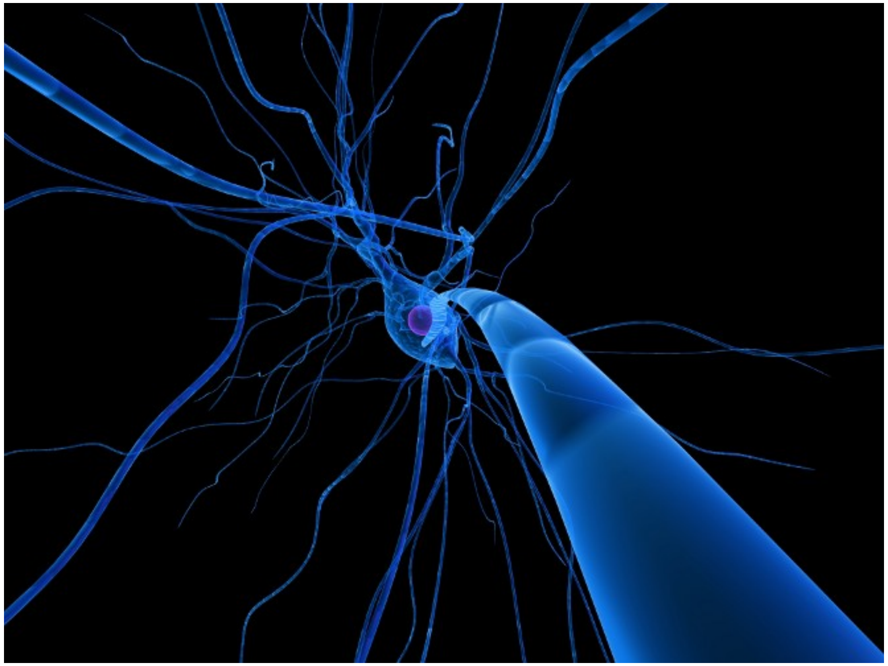
Taste	Substance	Threshold for tasting
Salty	NaCl	0.01 M
Sour	HCl	0.0009 M
Sweet	Sucrose	0.01 M
Bitter	Quinine	0.000008 M
Umami	Glutamate	0.0007 M

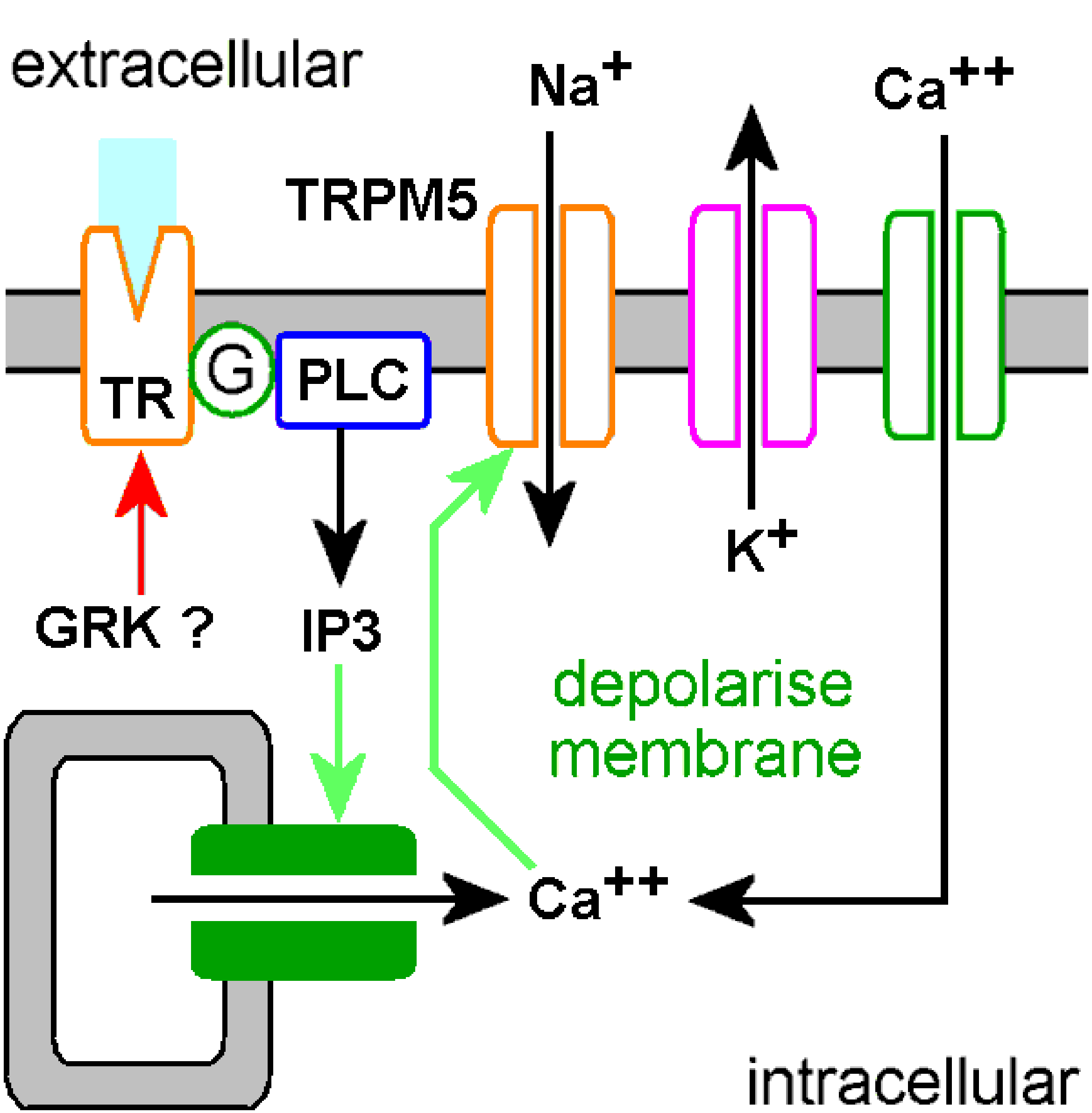


SPIKE signal is transmitted directly to the BRAIN









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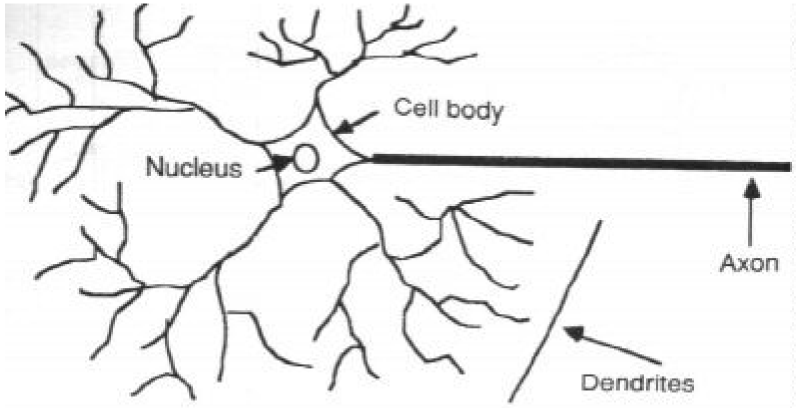
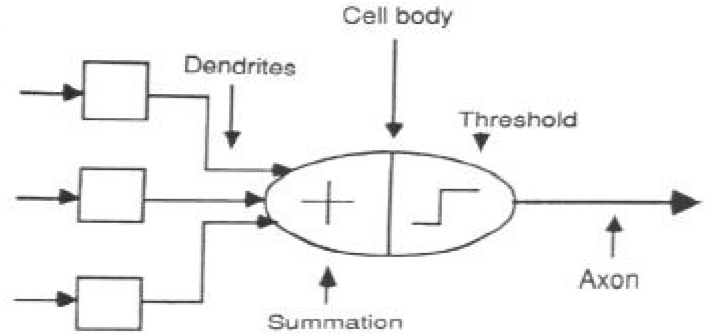
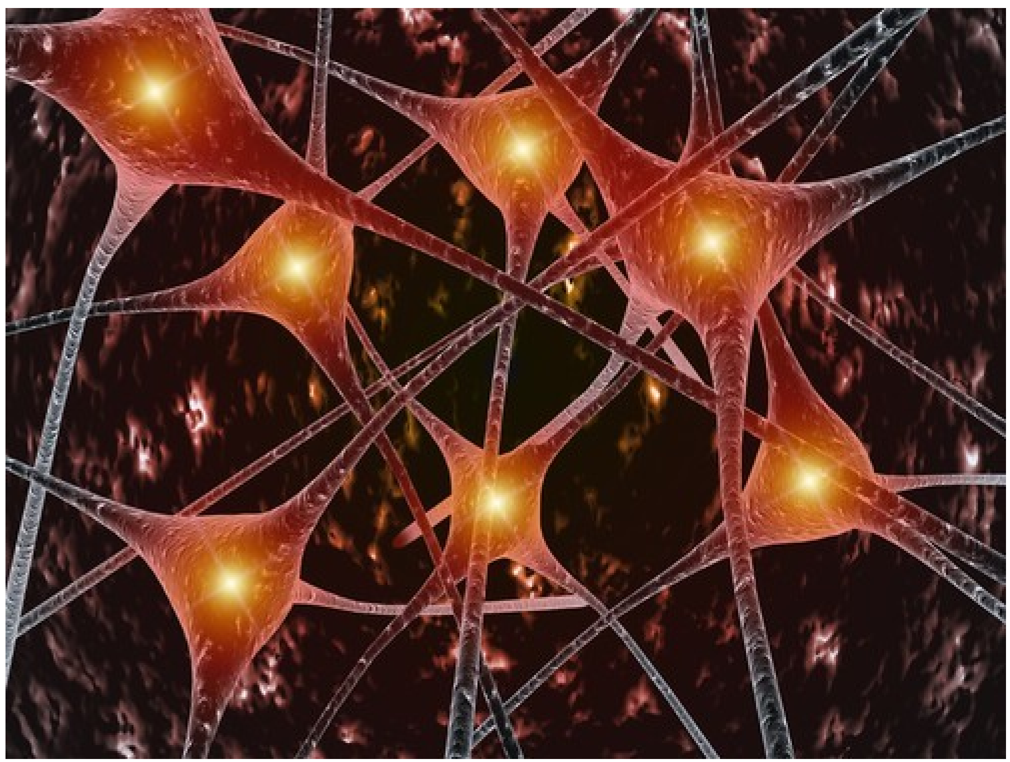

Cell body
Nucleus
Axon
Dendrites


Cell body
Dendrites
Threshold
Axon
Summation



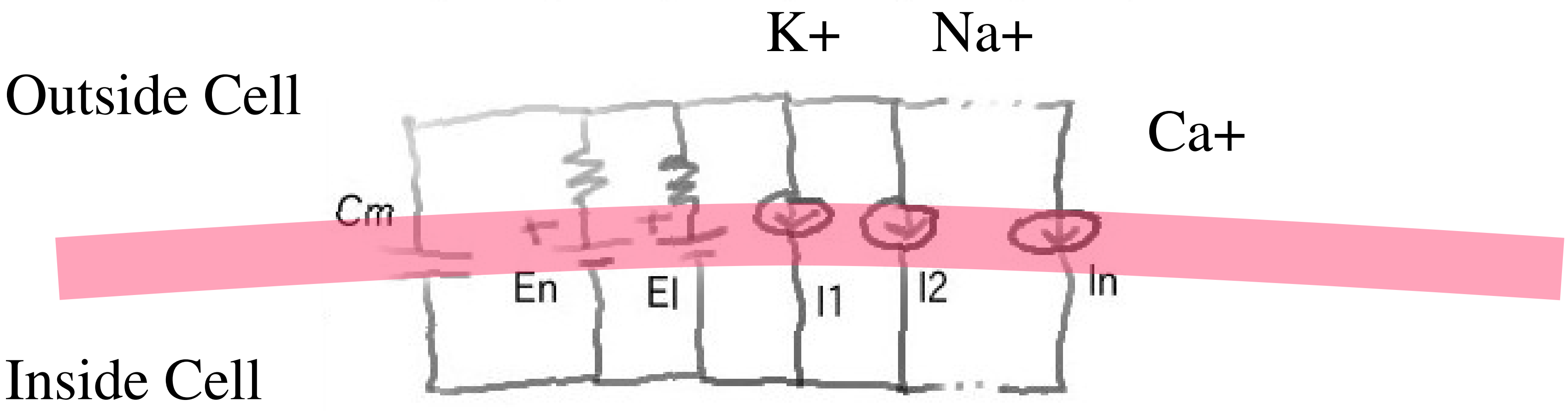
First Neuron Model

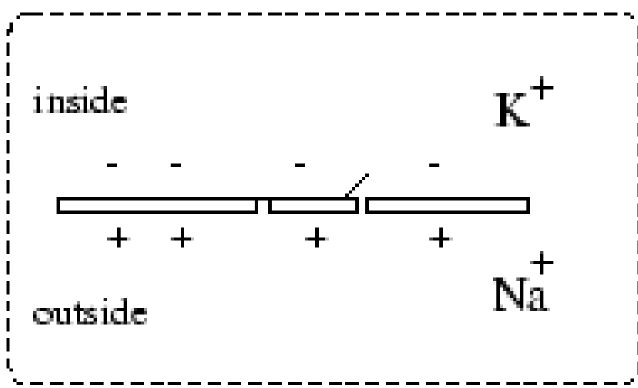
1907 by Lapicque

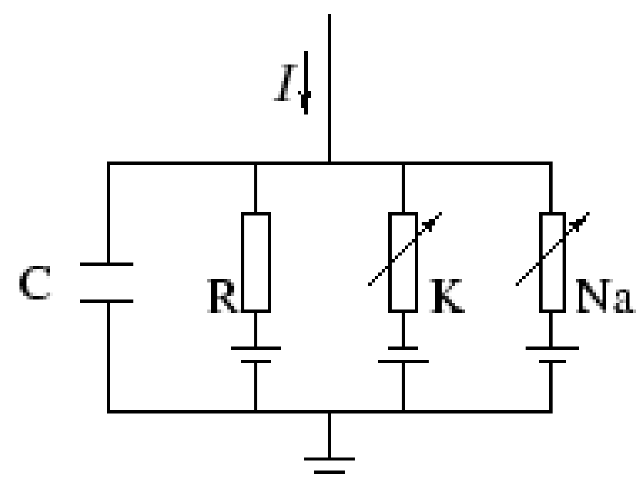
$$I(t) = C_m \frac{dV_m}{dt}$$

from Q=CV

Hodgkin-Huxley Model (1952)





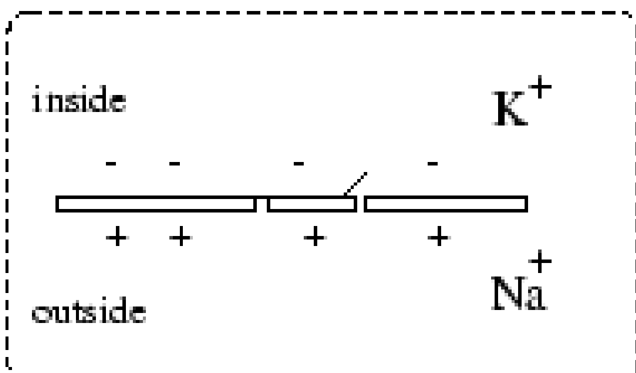


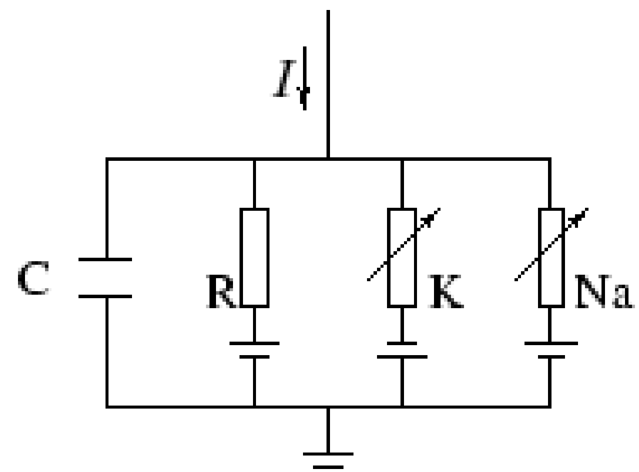
Hodgkin-Huxley Model (1952)

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

Based on Giant Squid experiments

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





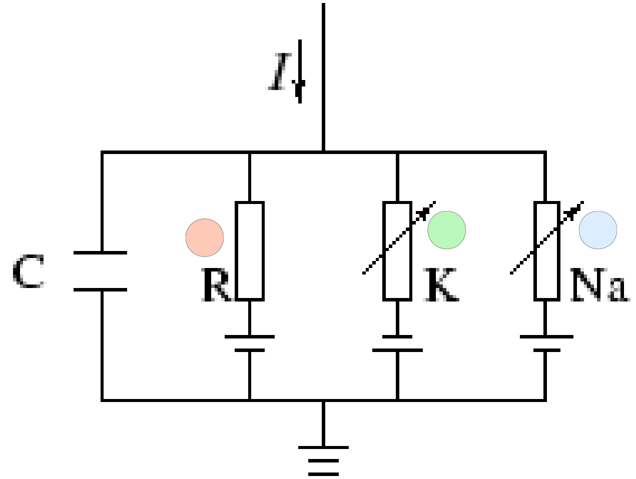
$$C\frac{du}{dt} = -\sum_k I_k(t) + I(t)\,.$$

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

$$\dot{m} = \alpha_m(u)\,(1 - m) - \beta_m(u)\, m$$

$$\dot{n} = \alpha_n(u)\,(1 - n) - \beta_n(u)\, n$$

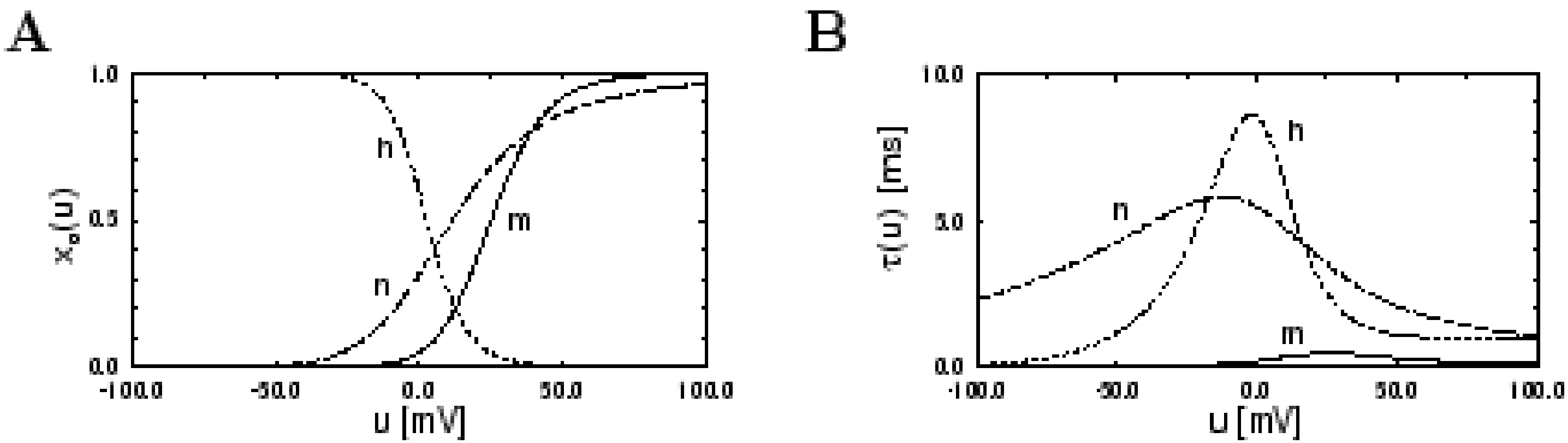
$$\dot{h} = \alpha_h(u)\,(1 - h) - \beta_h(u)\, h$$



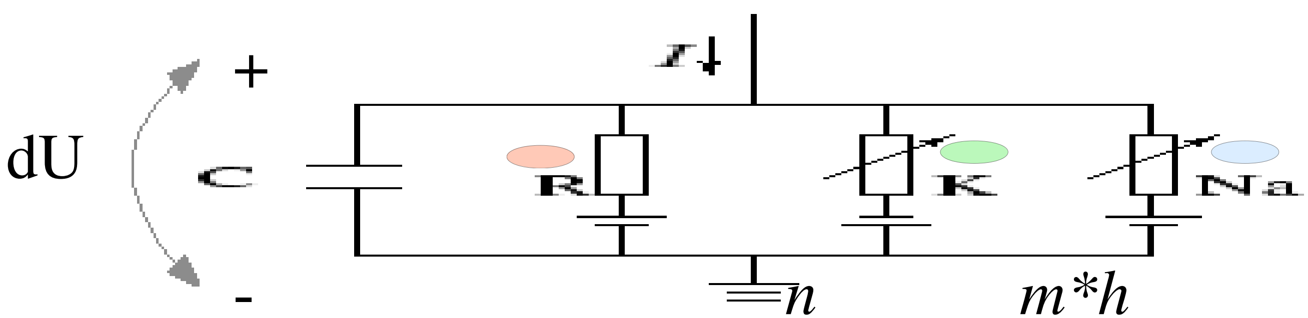
From Experiments

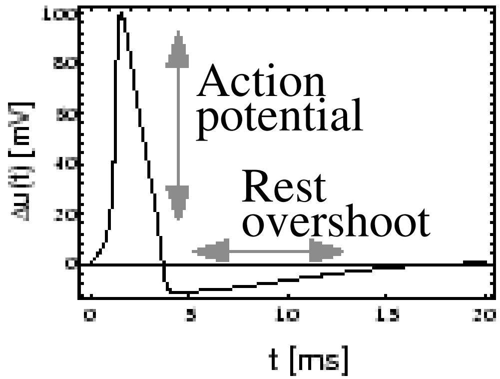
x	$\alpha_x(u\,/\,\mathrm{mV})$	$\beta_x(u\,/\,\mathrm{mV})$
n	$(0.1 - 0.01\,u)\,/\,[\exp(1 - 0.1\,u) - 1]$	$0.125\exp(-u\,/\,80)$
m	$(2.5 - 0.1\,u)\,/\,[\exp(2.5 - 0.1\,u) - 1]$	$4\exp(-u\,/\,18)$
h	$0.07\exp(-u\,/\,20)$	$1\,/\,[\exp(3 - 0.1\,u) + 1]$

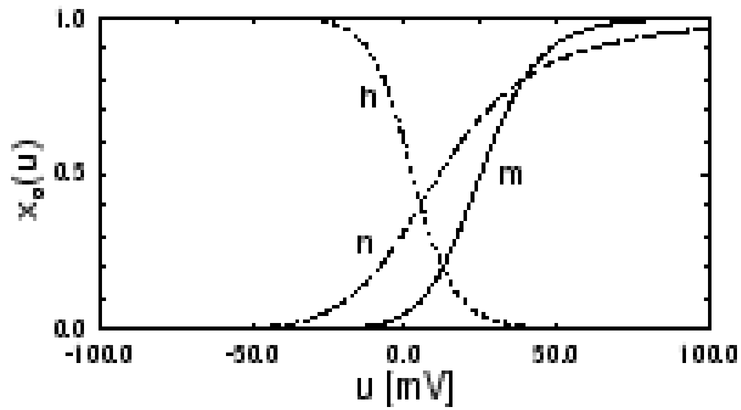
x	E_x	g_x
Na	115 mV	$120\ \mathrm{mS/cm^2}$
K	-12 mV	$36\ \mathrm{mS/cm^2}$
L	10.6mV	$0.3\mathrm{mS/cm^2}$



We see from that 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.



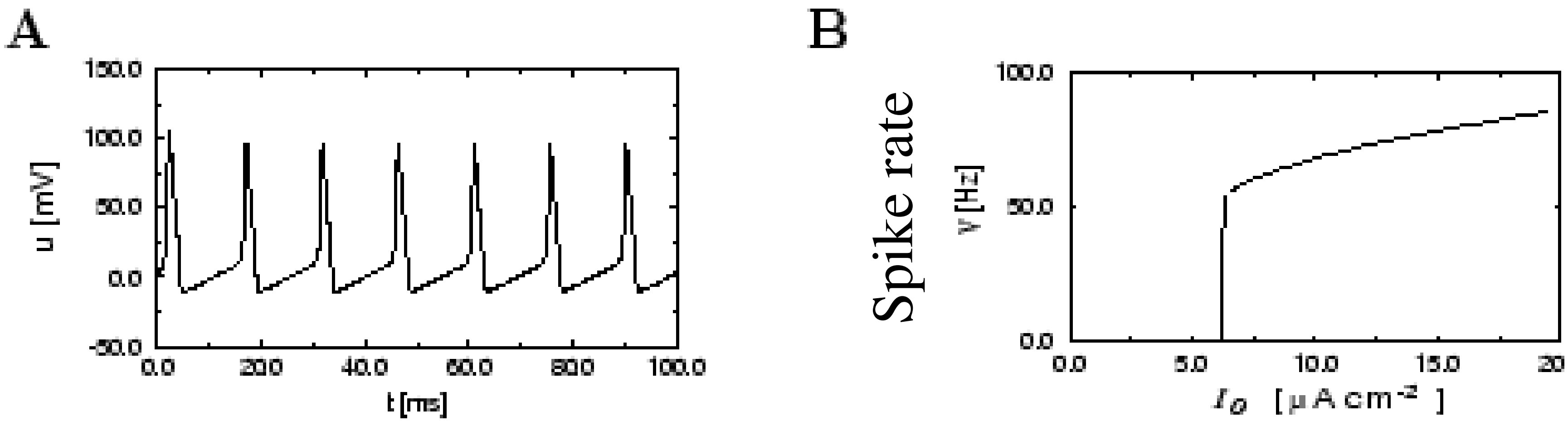




At high values of u the sodium conductance is shut off due to the factor h. As indicated the `time constant' is always larger than . Thus the variable h which closes the channels reacts more slowly to the voltage increase than the variable m which opens the channel. On a similar slow time scale, the 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

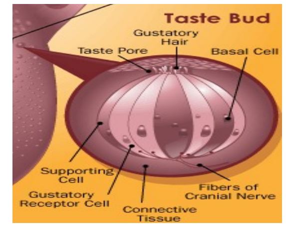
$$\sum_k I_k = g_{Na}\, m^3 h\,(u - E_{Na}) + g_K\, n^4\,(u - E_K) + g_L\,(u - E_L).$$

Auto-oscillation is possible



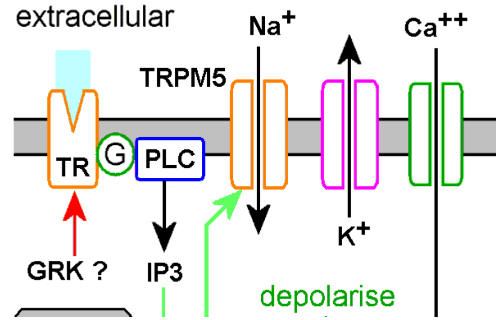
The Hodgkin-Huxley equations may also be studied for **constant** input I(t) = I0 for t > 0. (The input is zero for t 0). If the value I0 is larger than a **critical value** I 6A/cm2, we observe **regular spiking**; We may define a firing rate = 1/T where T is the inter-spike interval. The firing rate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

TASTE-TONGUE PROCESS - Conclusions

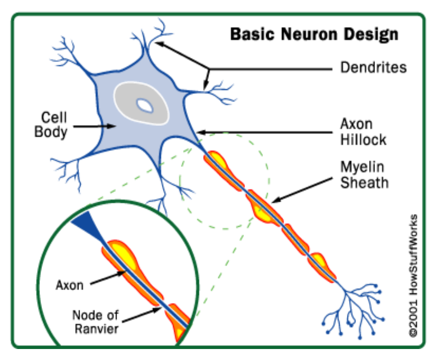


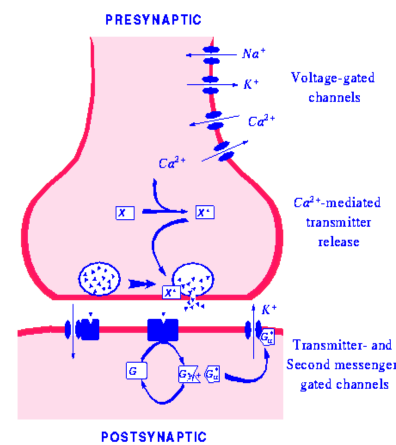
- food is dissolved in mouth
- molecules enter the "Taste Bud"

- contact with cell membrane



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





Synthetic pores with reactive signal amplifiers as artificial tongues

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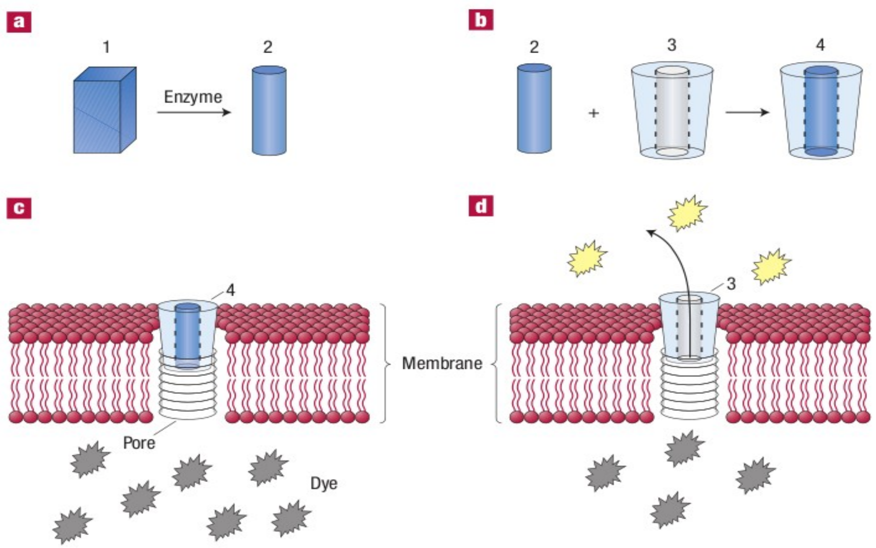

Figure 1 The processes involved in the artificial tongue of Matile and colleagues[9]. **a**, Signal generation. An enzyme converts 1 to 2. **b**, Reactive amplification. The product of the enzyme reaction, 2, reacts with the reactive amplifier 3, to form 4. **c**, Pore blockage. If analyte 1 is present, 4 is formed, which can block the pore and stop release of the dye. **d**, Dye release. If no analyte 1 is present, then 4 is not formed, and only 3 is present. Even though 3 can bind to the pore to some extent, it does not block release of the dye, and 2 cannot block the pore on its own.

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...)