

生命ナノシステム科学

物理博士 ミケレット・ルジェロ

知覚情報科学

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(1-2-3-4)

後期2009年

ライフ
サイエンス

医学

バイオ

バイオ技術

ナノ技術

工人生命

ロボット

技術

モーター

電力

物理

工場

電子

情報科学

IT

従来

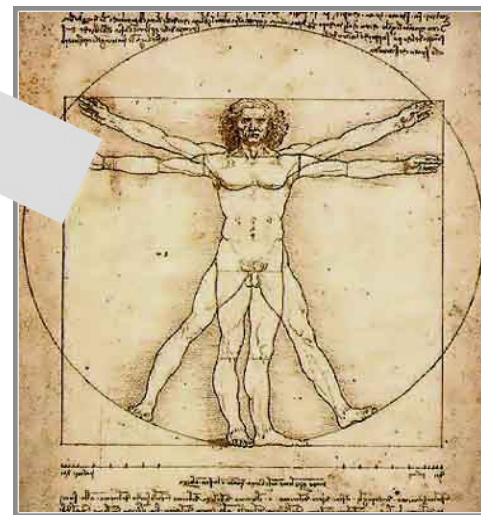
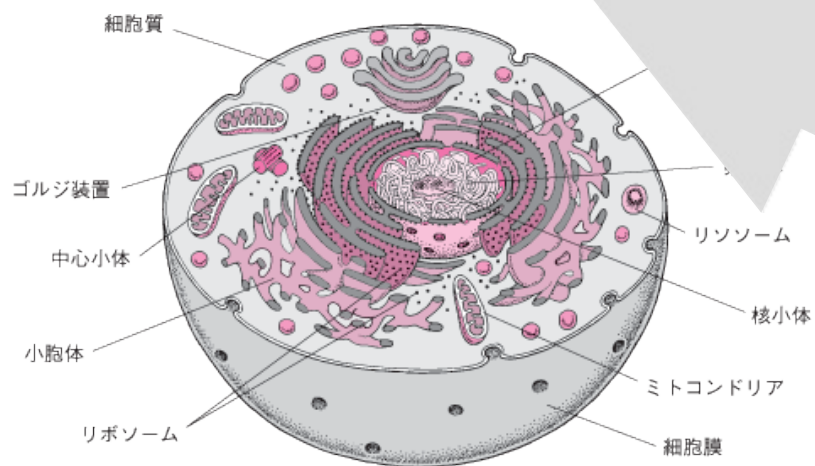
現代

未来



音、光、力、化

知覚



さまざまな細胞の例

上皮細胞



筋細胞



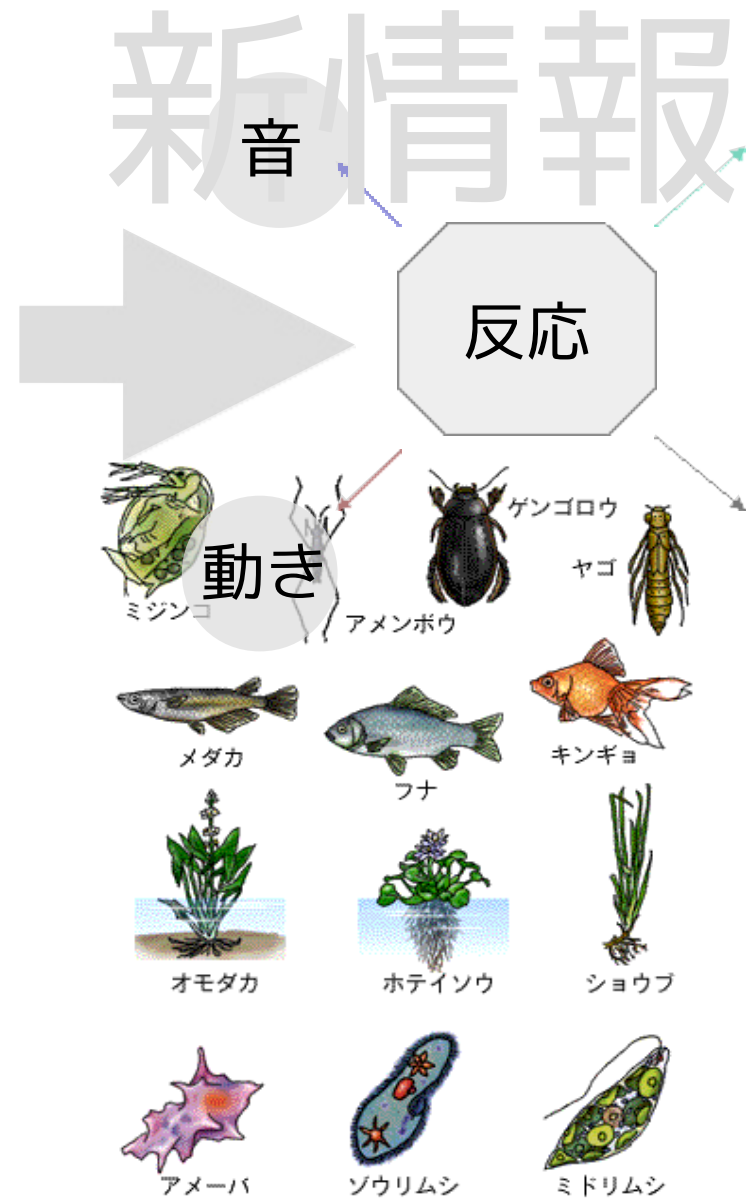
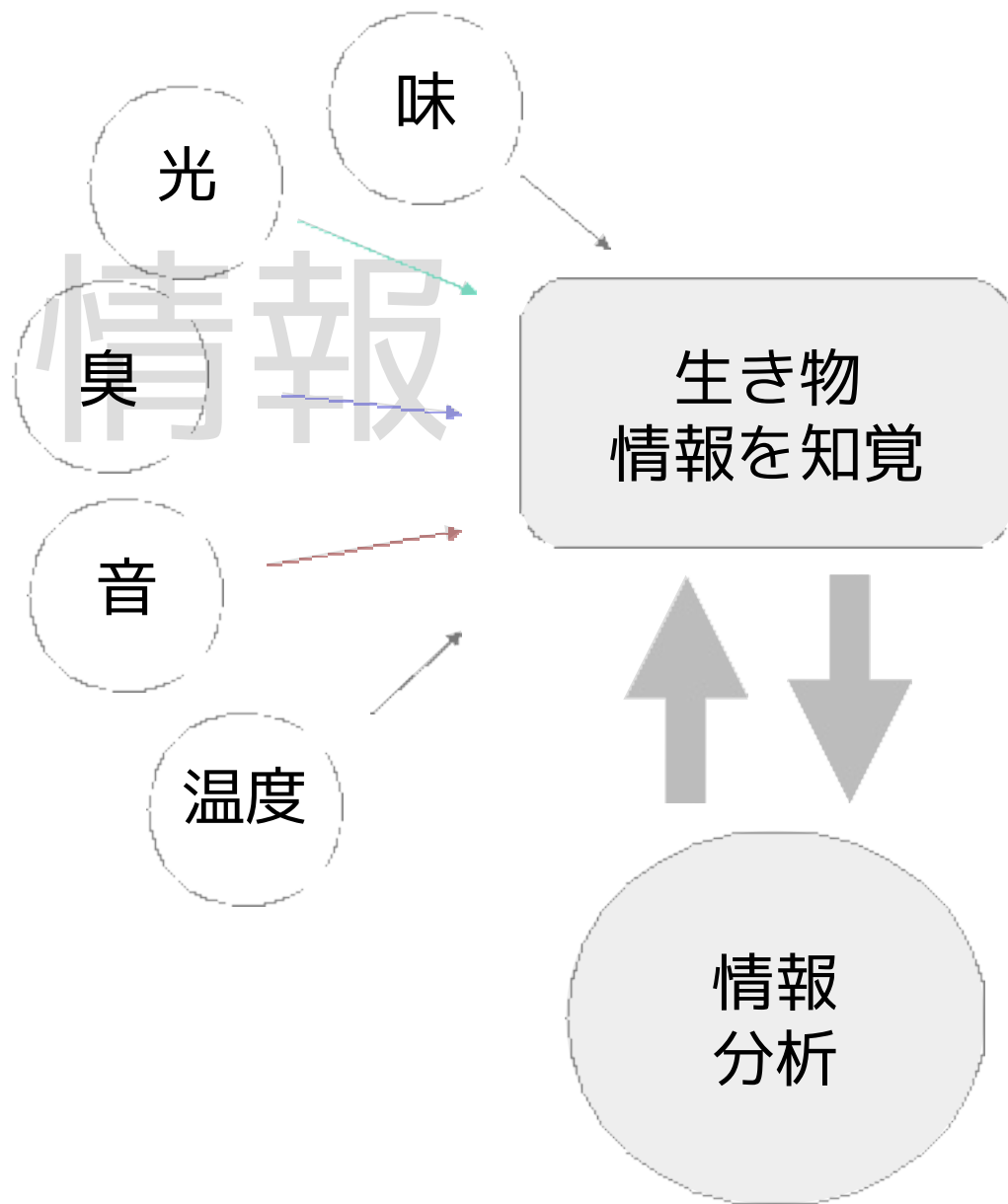
神経細胞



結合組織細胞



生命





知覚情報科学コースのプラン：

トピックスの構造

音、光、視覚、温度 など。 概論

▼
生き物の五感の課程、メカニズム

▼
先端センサー（人工システム）：
CCD, AFM, STM, SNOMの紹介

勉強内容

- *Neural Networks*
- *Noise Reduction*
- *Fourier Analysis*
- *Correlation*
- *Chaos*
- *STM*
- *AFM*
- *SNOM*

知覚情報科学

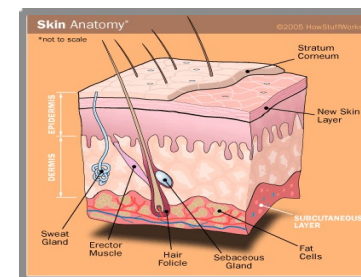
コース内容



味（味覚）：

- 基本、原理
- 人間の舌
- 人工味覚
- 表面プラズモンセンサー
- STM

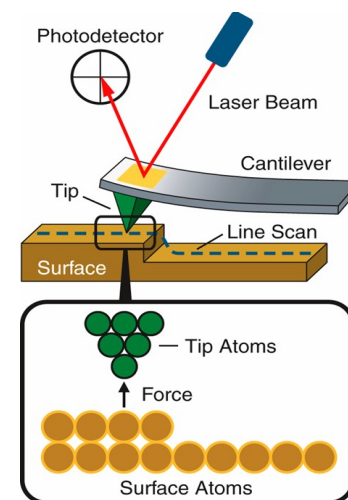
- *noise reduction*
- *pico currents*



触る（触覚）：

- 原理、基本
- 人間のスキン
- ナノ振動センサー
- AFM
- アルゴリズム

- *double tips*
- *correlation*



知覚情報科学

コース内容



聞く（聴覚）：

- 音
- 人間の耳
- マイクロホン



(magnetic, inductive, capacitive, 他)

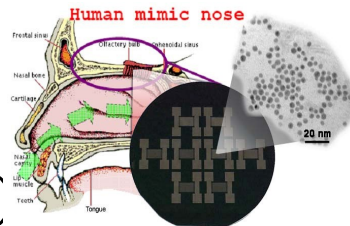
- レーザマイクロホン
- アルゴリズム

- *Waves, time series*

- *Fourier transform*
- *Matlab applications*

嗅ぐ（嗅覚）：

- 嗅ぐ（基本、原理）
- 人間の鼻
- 人工嗅ぐシステム AFM-NOSE



- *Neural networks*

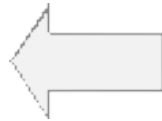
知覚情報科学

コース内容



見る（視覚）：

- 光（基本、原理）
- 人間の目
- 顕微鏡
- CCD カメラ
- 近接場顕微鏡
- アルゴリズム（Image Recognition）



- *Chaos*
- *Correlation*

- *Various algorithms*



知覚情報科学

コース内容

見る（視覚）：

- 光（基本、原理）
- 光学顕微鏡
- ホトでダイオド
- CCD カメラ
- 近接場顕微鏡

聞く（聴覚）：

- 音
- 人間の耳
- マイクロホン

(magnetic, inductive, capacitive, 他)

- レーザマイクロホン

触る（触覚）：

- 原理、基本
- 人間のスキン
- ナノ振動センサー
- AFM

味（味覚）：

- 基本、原理
- 人間の舌
- 工人味覚
- 表面プラズモンセンサー
- STM

嗅ぐ（嗅覚）：

- 嗅ぐ（基本、原理）

人間の鼻

- 工人嗅ぐシステム AFM-NOSE
(ニューラルネットワークの基本説明)

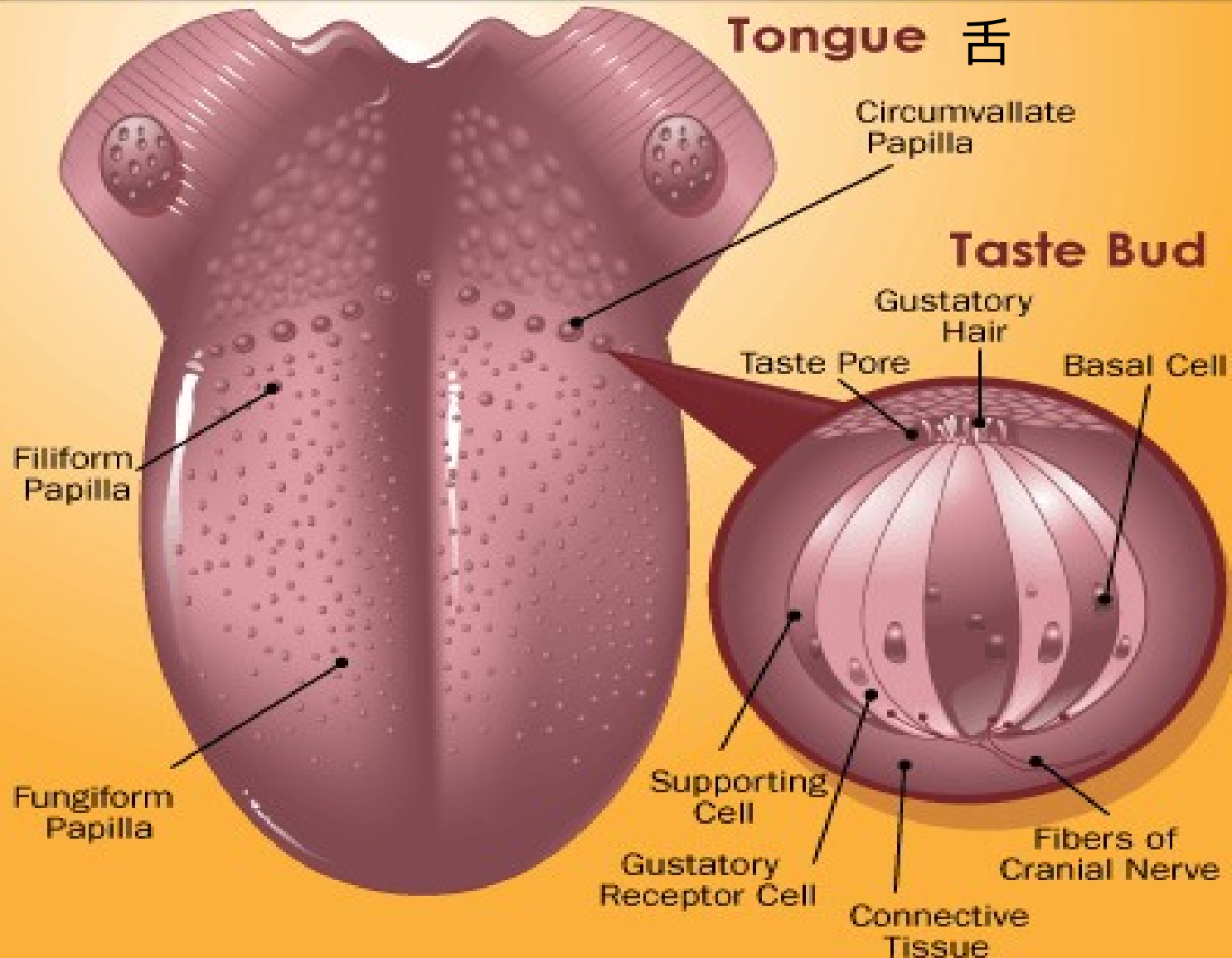
THE TONGUE: the TASTE sense (味覚、みかく)

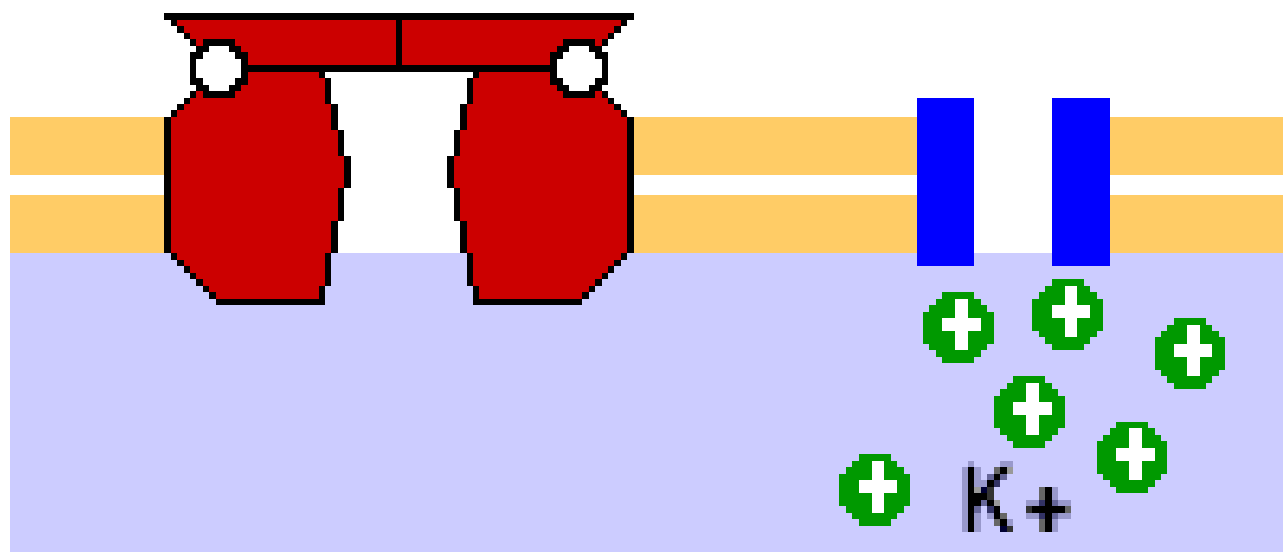
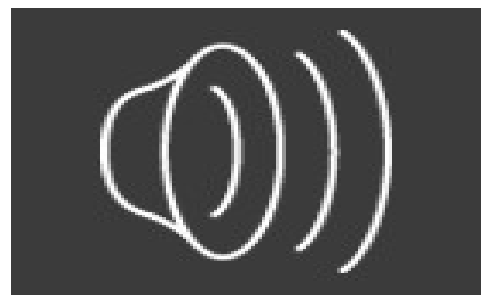


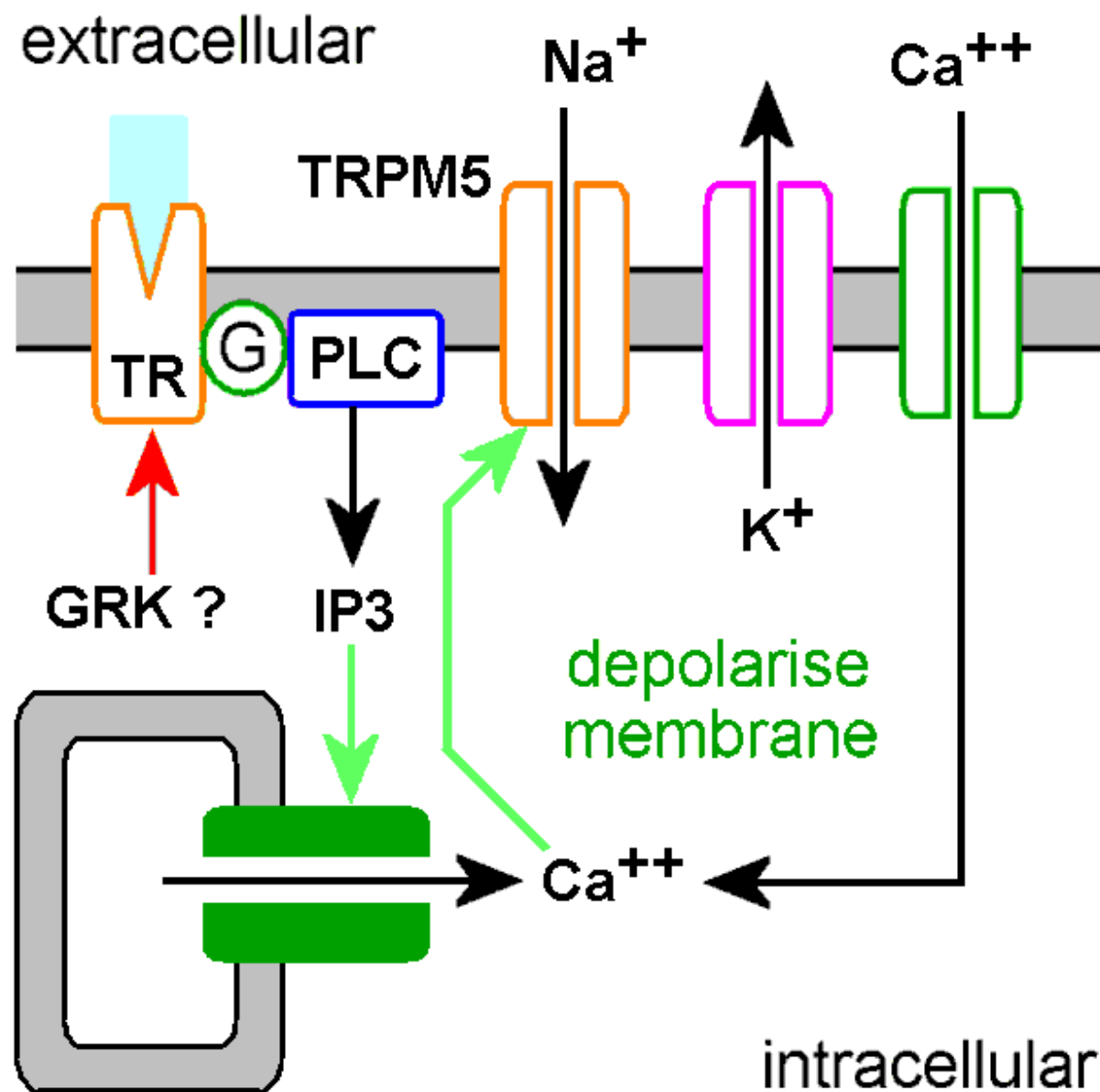
How Taste Works The Tongue

©2007 HowStuffWorks

Tongue 舌







- 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.

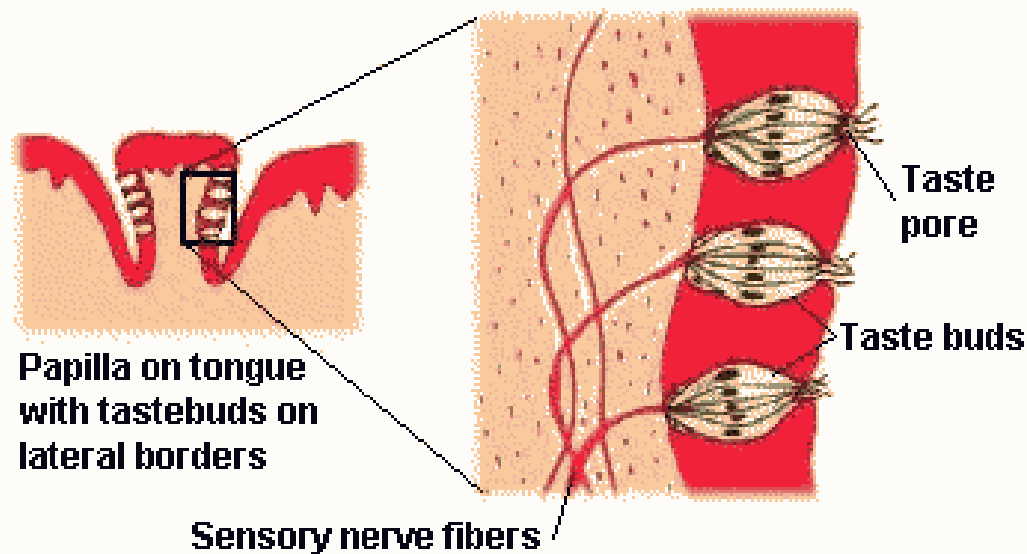
The complex of G proteins has been named **gustducin** because of its similarity in structure and action to the transducin that plays such an essential role in rod vision.

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.

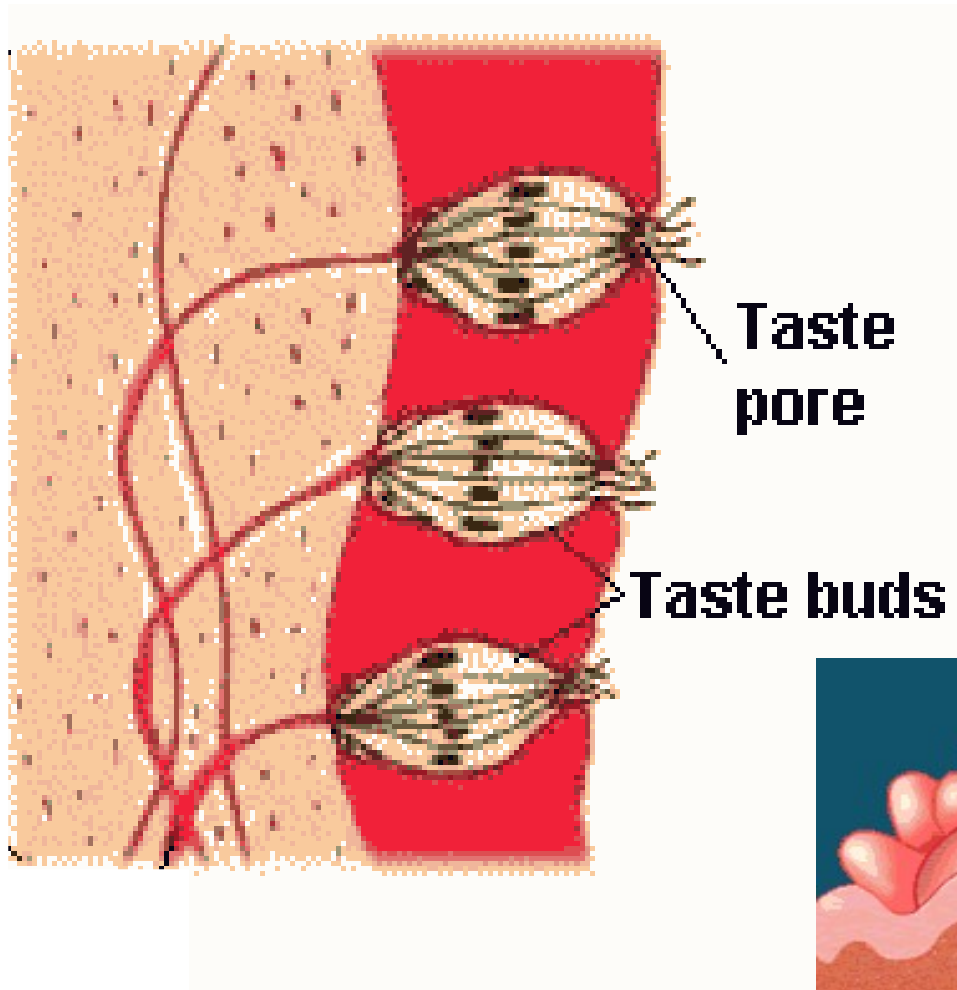
Emission of a electric **discharge signal**

This signal is called **SPIKE**

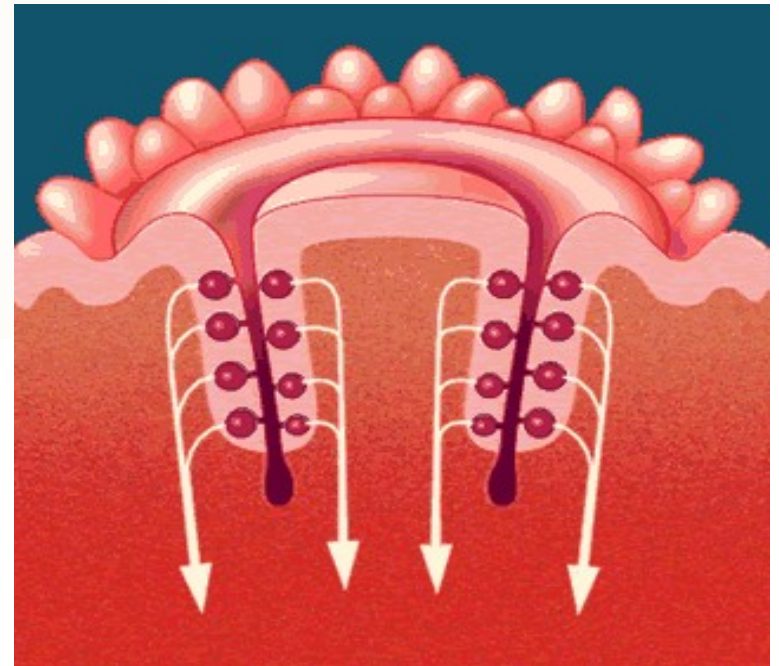


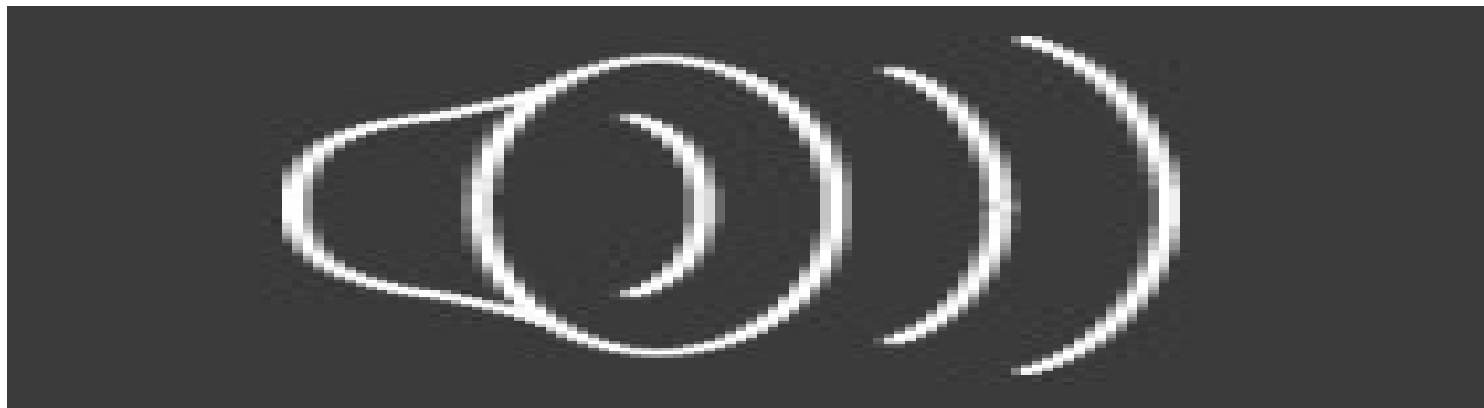
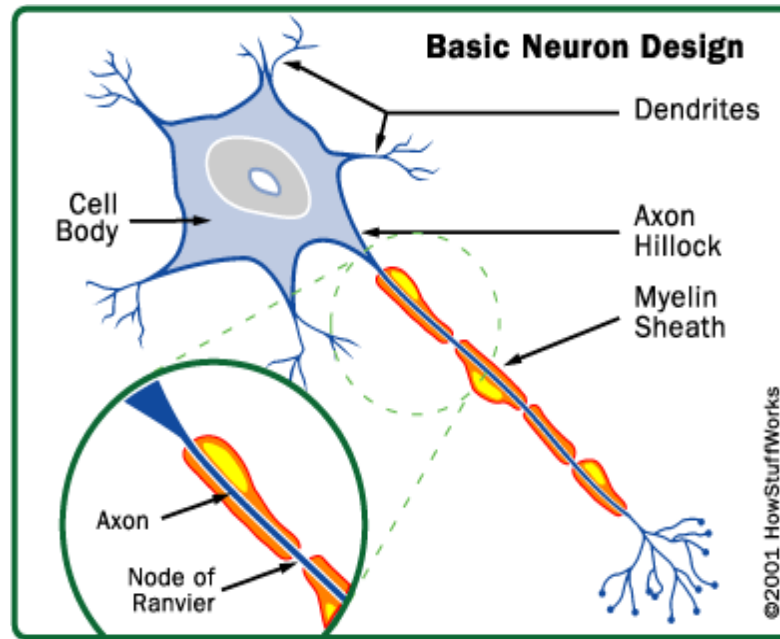
Examples of some human thresholds

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



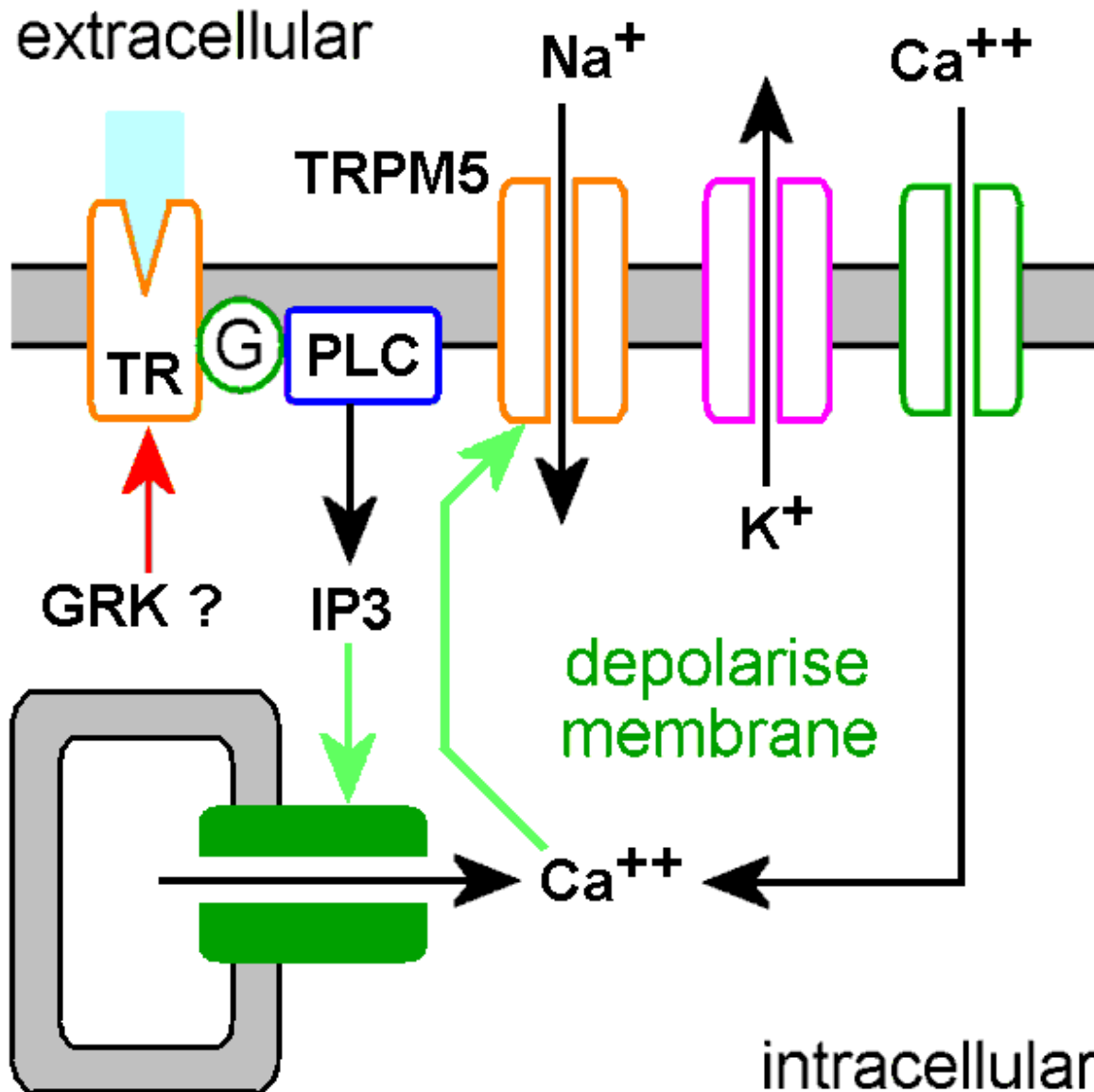




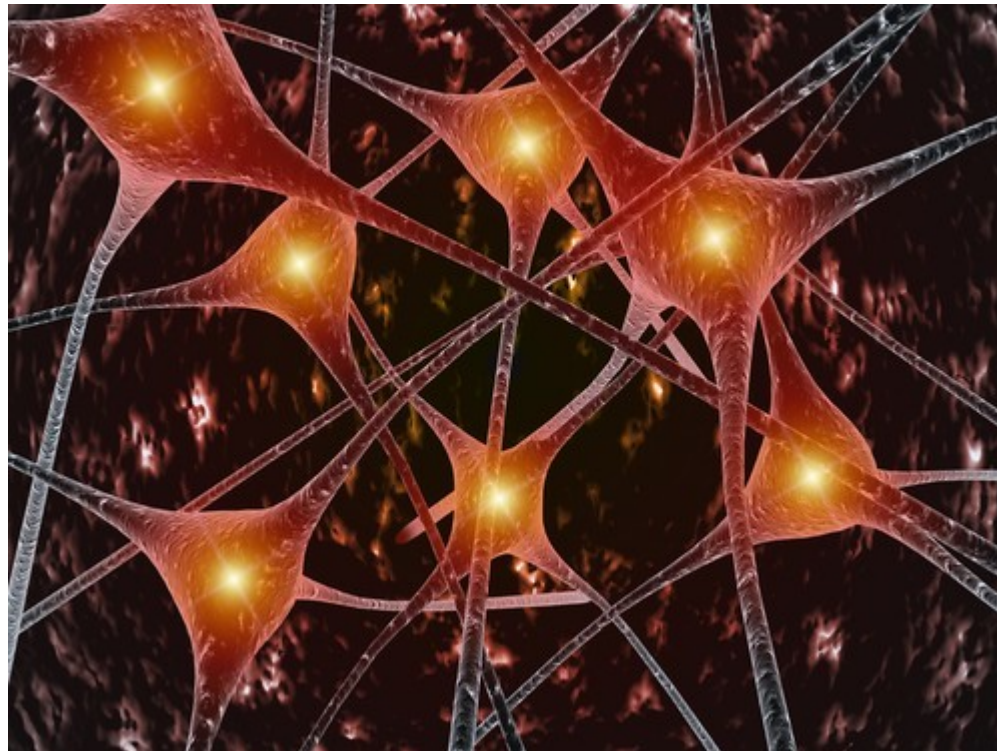
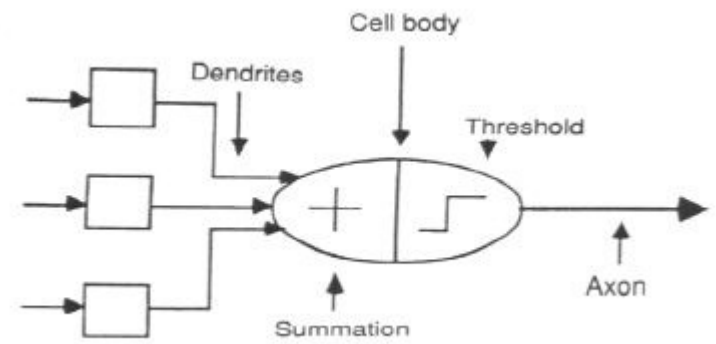
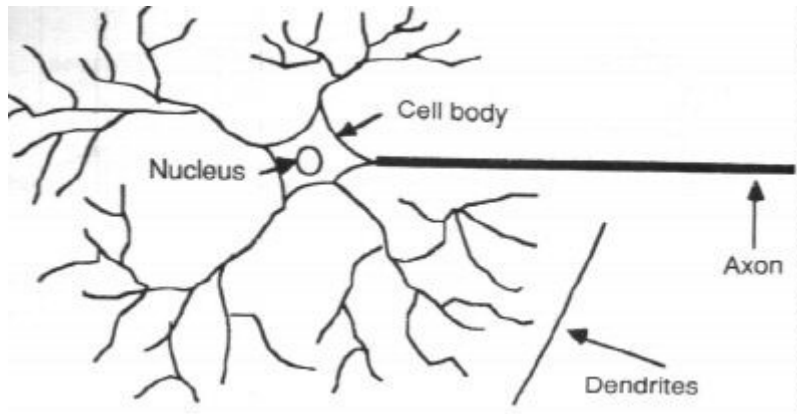
Every RECEPTOR is a SPECIALIZED NEURON

!

Gustatory Receptor Cell



- G - heterotrimeric G-protein
- GRK - G-protein receptor kinase
- IP3 - inositol triphosphate
- PLC - phospholipase
- TR - taste receptor



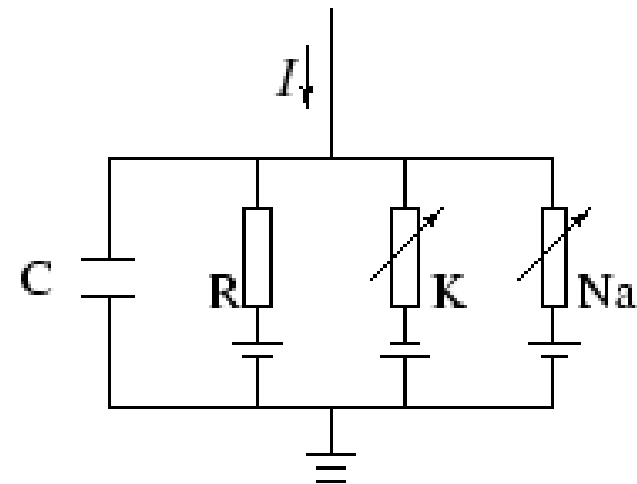
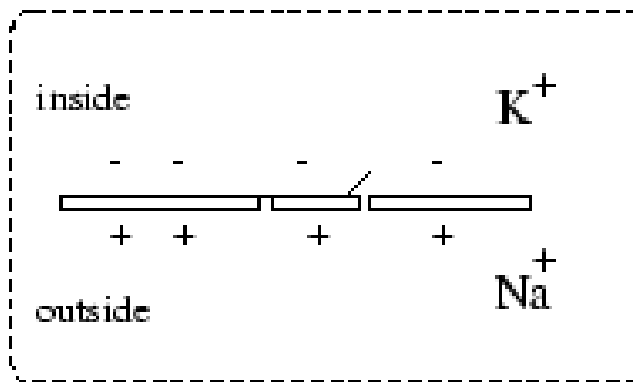
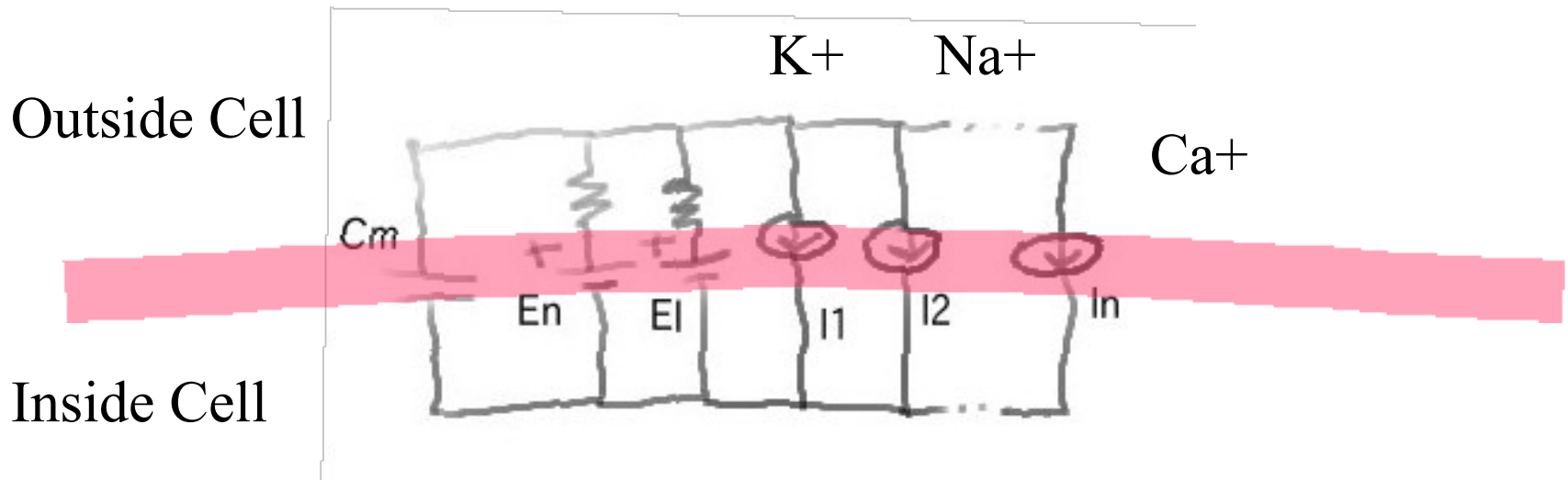
First Neuron Model

1907 by
Lapicque

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

from $Q=CV$

Hodgkin-Huxley Model (1952)



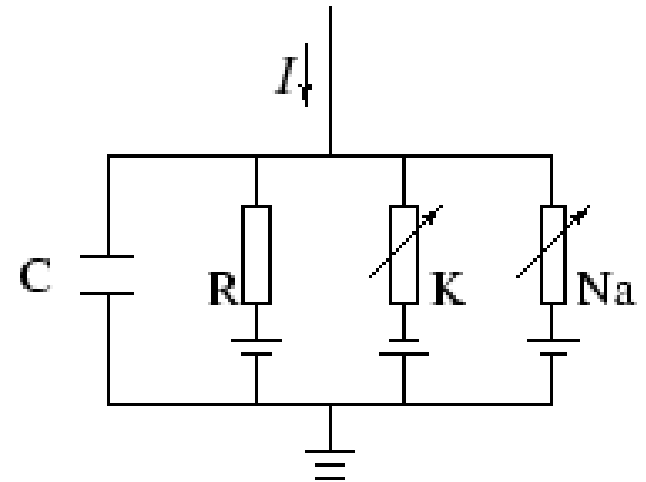
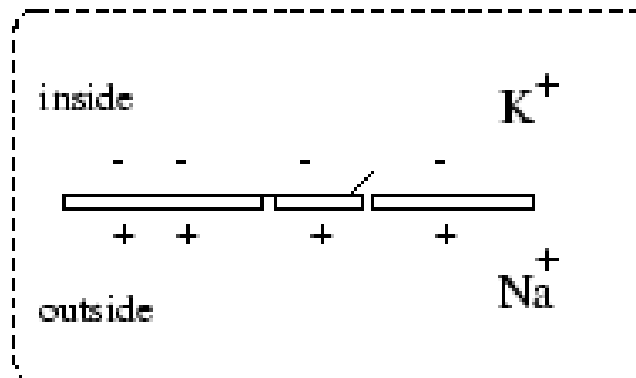


Hodgkin-Huxley Model (1952)

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

Based on Giant Squid experiments

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



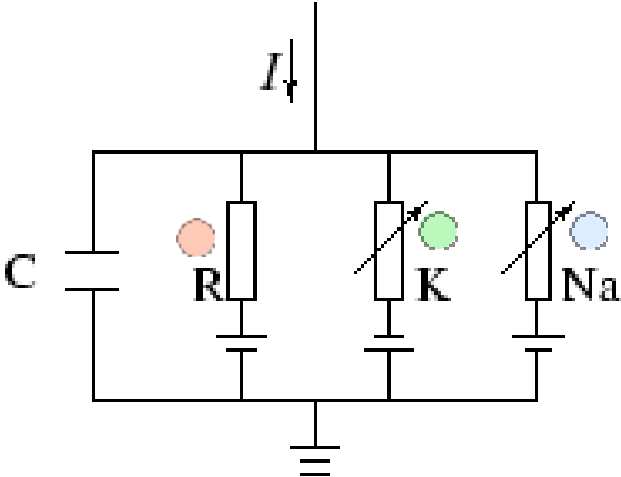
$$C \frac{du}{dt} = - \sum_k I_k(t) + I(t) .$$

$$\sum_k I_k = \overset{\text{Na}}{\bullet} g_{\text{Na}} \overset{3}{m^3} \overset{h}{\bullet} (u - E_{\text{Na}}) + \overset{\text{K}}{\bullet} g_{\text{K}} \overset{4}{n^4} (u - E_{\text{K}}) + \overset{\text{L}}{\bullet} g_{\text{L}} (u - E_{\text{L}}).$$

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

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

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



From Experiments

x	$\alpha_x(u / \text{mV})$	$\beta_x(u / \text{mV})$
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 mS/cm ²
K	-12 mV	36 mS/cm ²
L	10.6mV	0.3mS/cm ²

$$\frac{d m}{d t} = \alpha_m(u)(1 - m) - \beta_m(u) m$$

$$\frac{d n}{d t} = \alpha_n(u)(1 - n) - \beta_n(u) n$$

$$\frac{d h}{d t} = \alpha_h(u)(1 - h) - \beta_h(u) h$$

Sym Matlab

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

```
y =
```

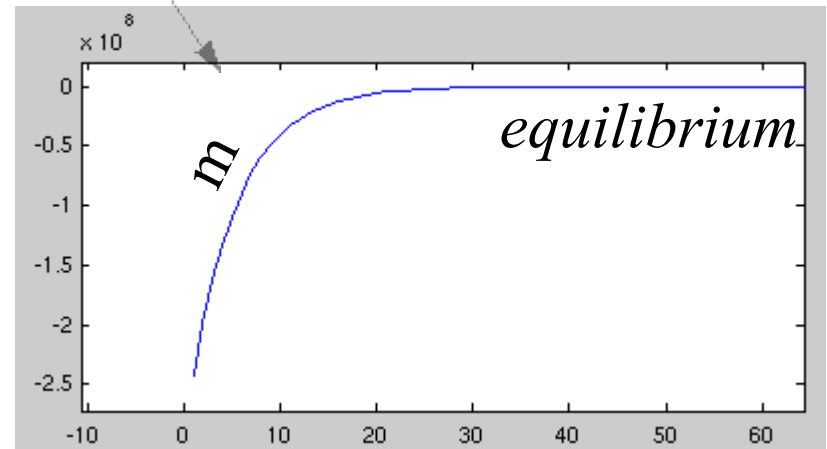
```
(a - C18/exp(t*(a + b)))/(a + b)
```

$a - C18 \exp(-t (a + b))$

α \nearrow $a + b$ \nwarrow β

From Experiments

plot(y)

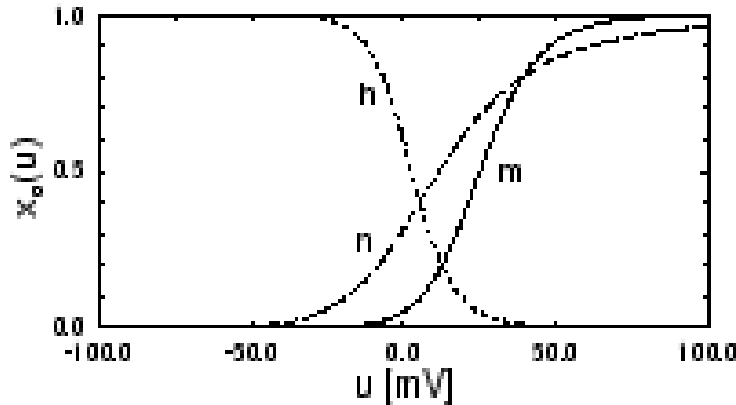


t

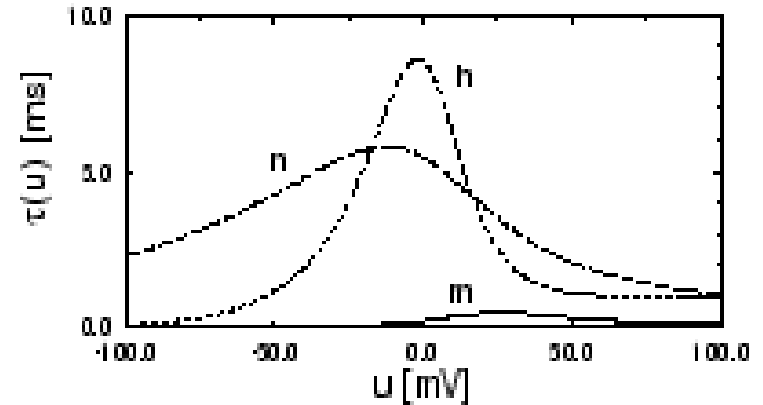
Exponential
fitting

x	$\alpha_x(u / \text{mV})$	$\beta_x(u / \text{mV})$
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	$0.07 \exp(-u / 20)$	$1 / [\exp(3 - 0.1 u) + 1]$

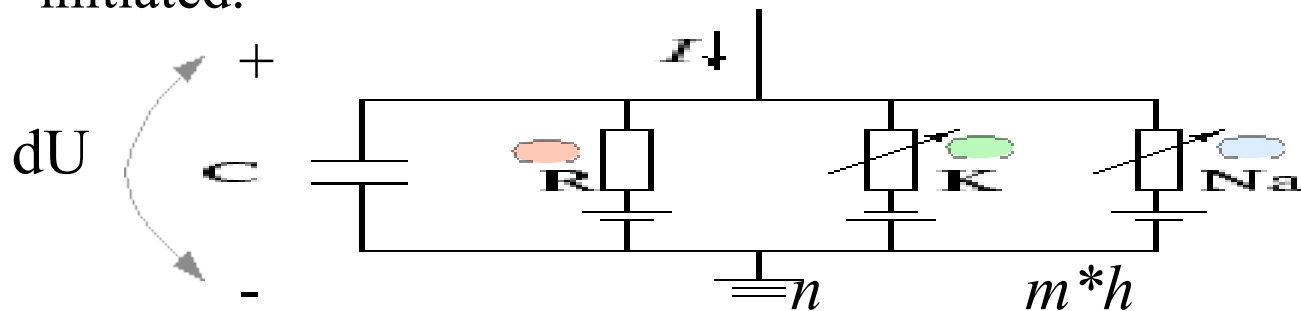
A

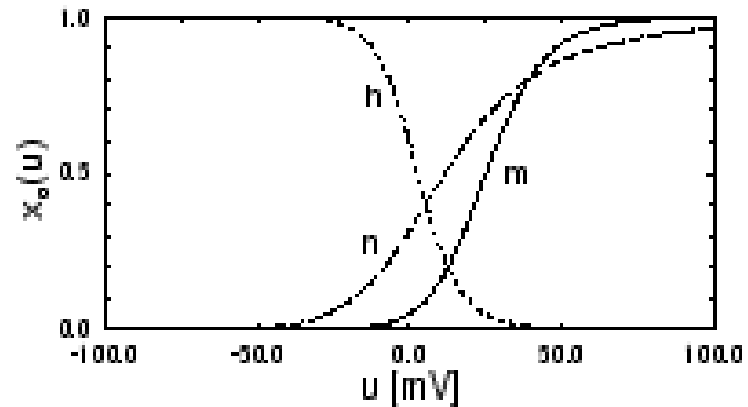
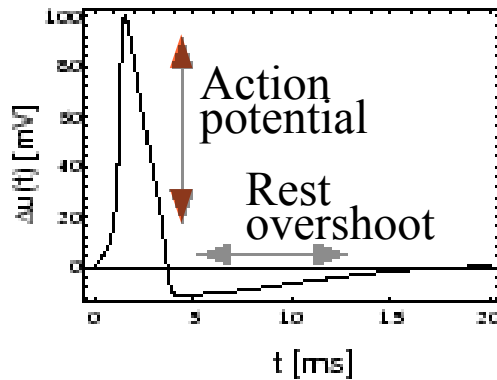


B



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.

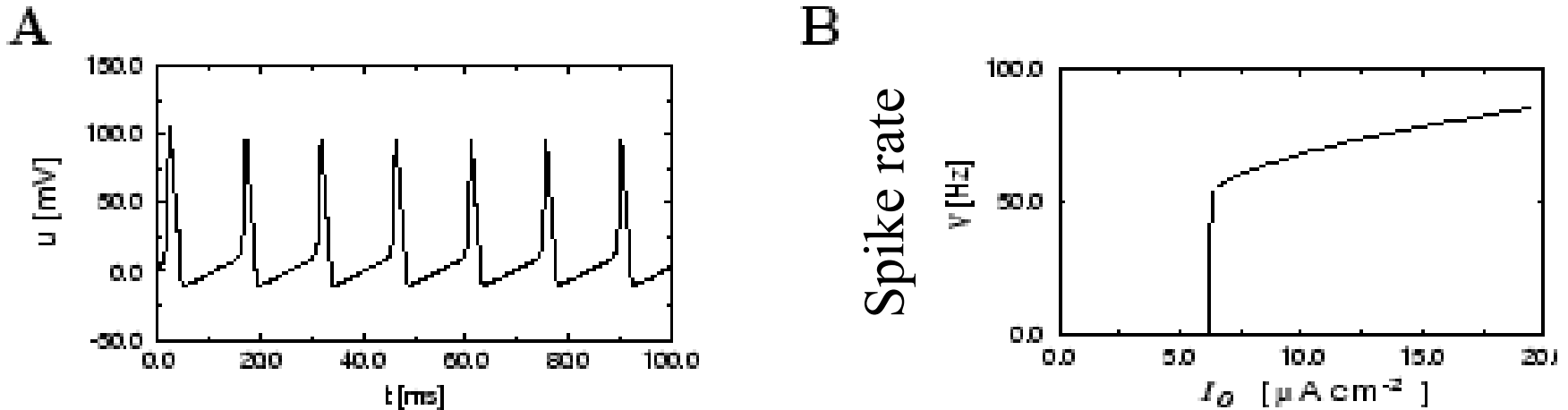




At high values of u the sodium conductance is shut off due to the factor h . As indicated the 'time constant' is always larger than . Thus the variable h which closes the channels reacts more slowly to the voltage increase than the variable m which opens the channel. On a similar slow time scale, the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

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

Auto-oscillation is possible



The Hodgkin-Huxley equations may also be studied for **constant** input $I(t) = I_0$ for $t > 0$. (The input is zero for $t < 0$). If the value I_0 is larger than a **critical value** $I_0 \approx 6 \mu\text{A/cm}^2$, 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 I_0 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

