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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(全)

後期2011年

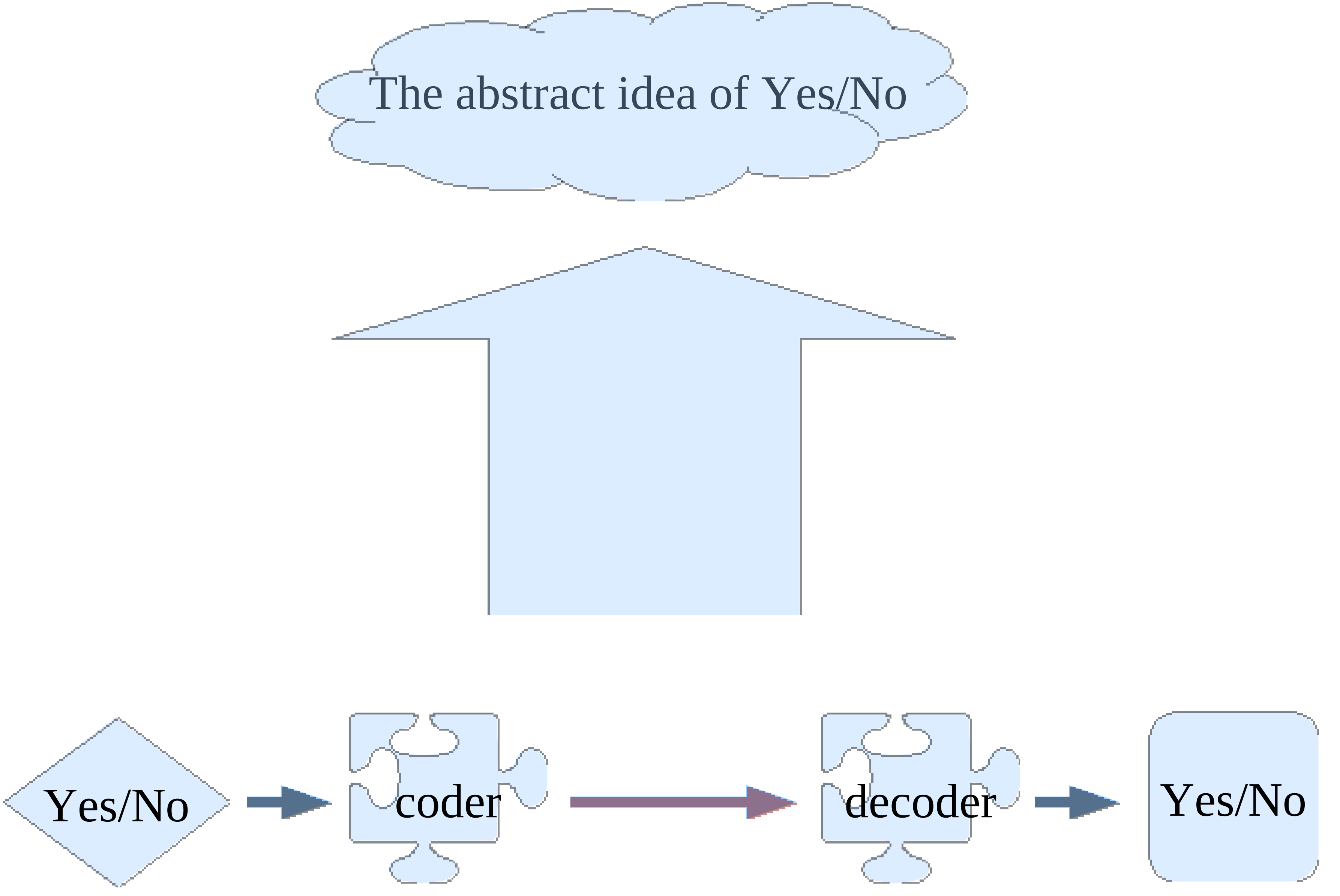
THE INFORMATION, what is it?

I like cakes!

ケーキは好き！

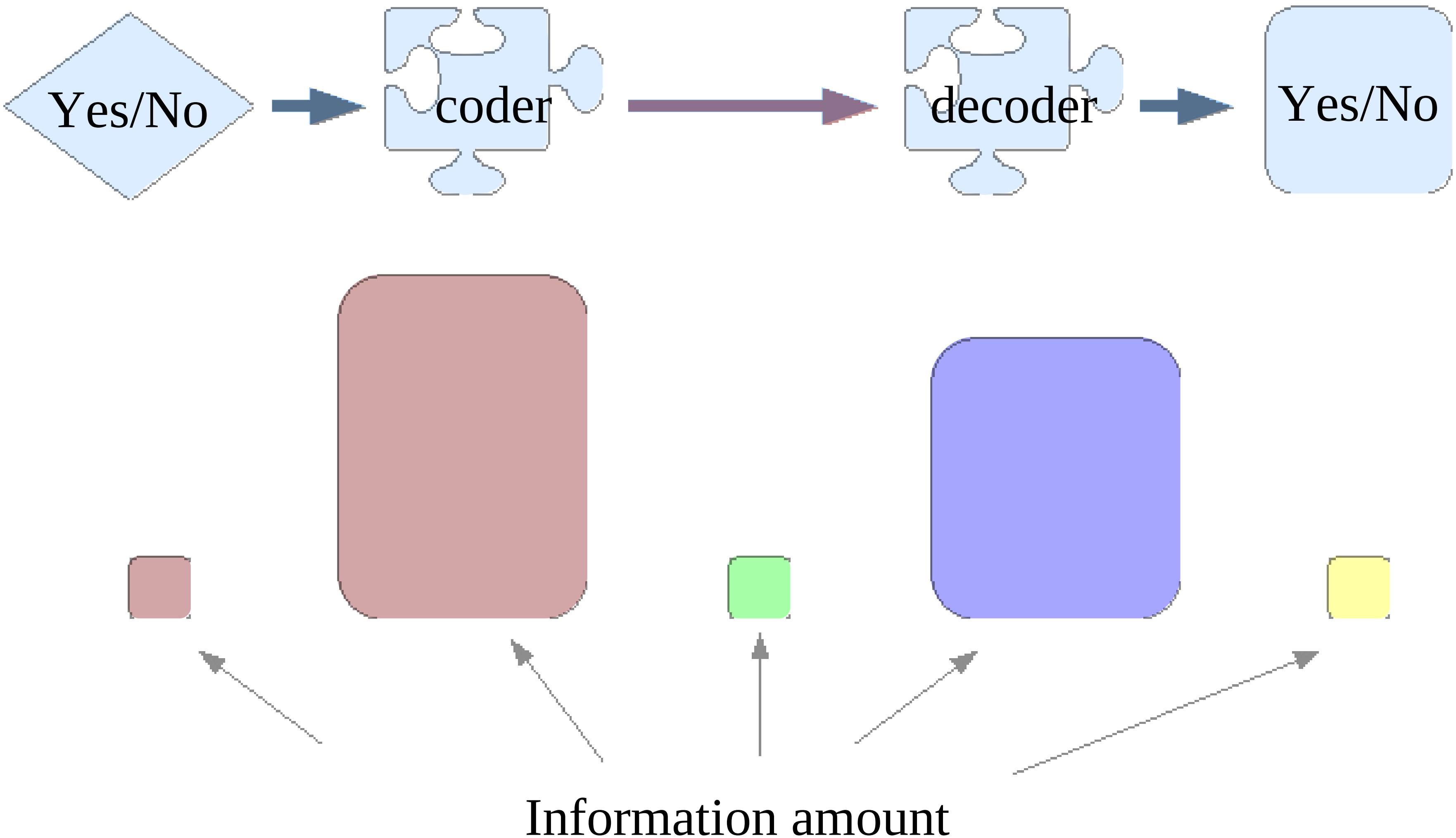
Mi piacciono i dolci !

Same INFORMATION contents, different representation



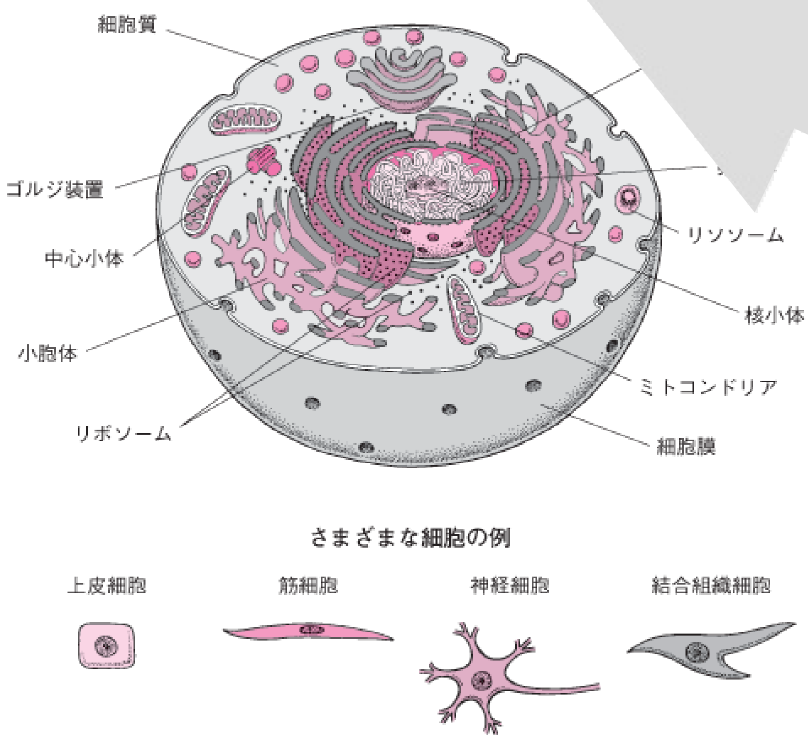
The abstract idea of Yes/No
Yes/No
coder
decoder
Yes/No

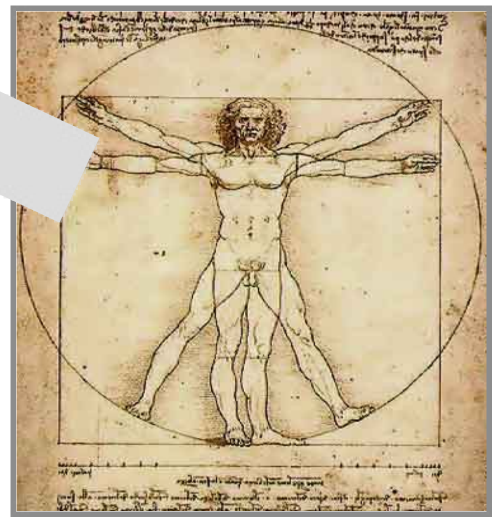
Can we measure amount of information ?



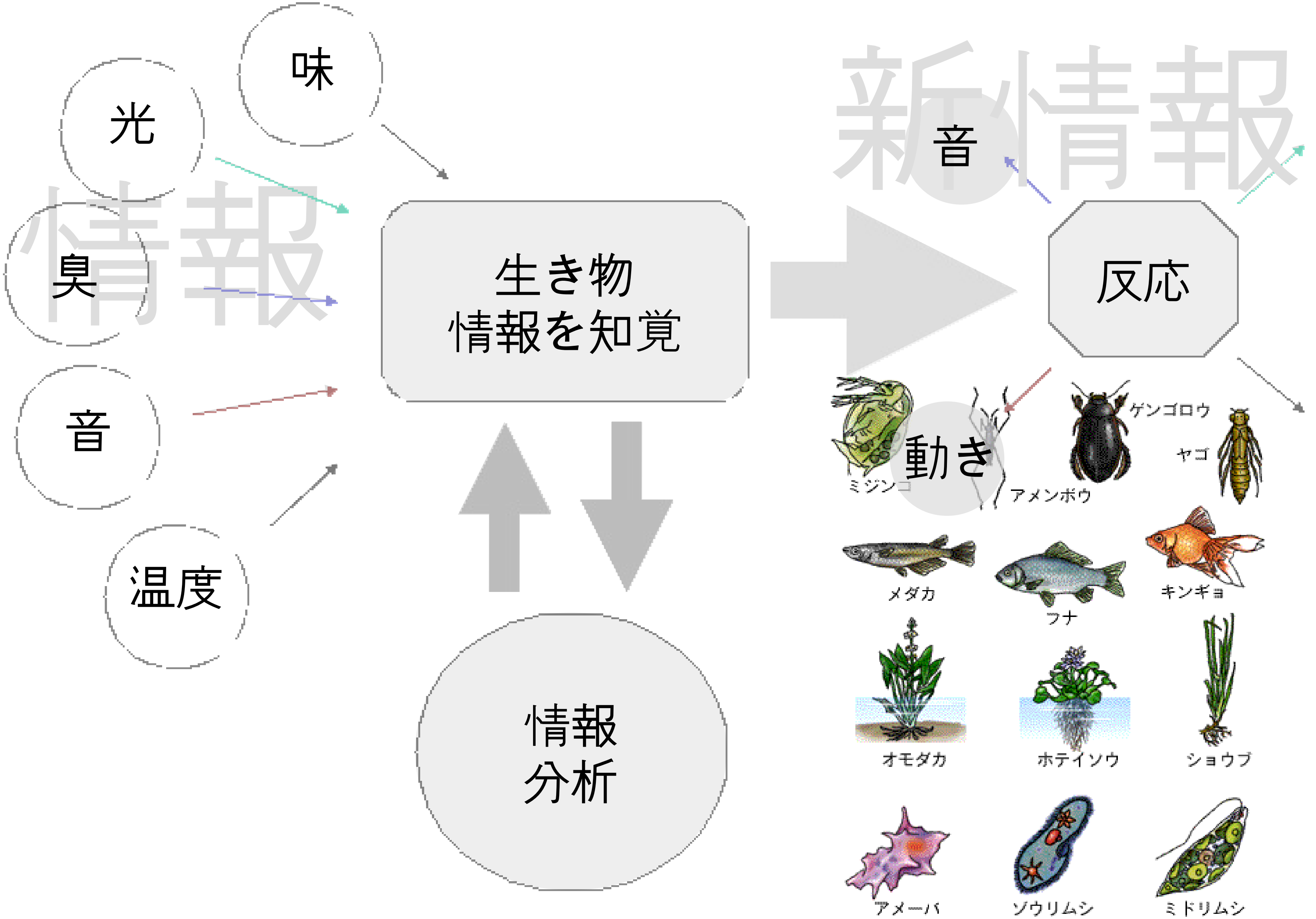
音、光、力、化

知覚


細胞質
ゴルジ装置
中心小体
小胞体
リボソーム
リソソーム
核小体
ミトコンドリア
細胞膜
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


情報
味
光
臭
音
温度
生き物
情報を知覚
情報
分析
新情報
音
反応
動き
ミジンコ
アメンボウ
ゲンゴロウ
ヤゴ
メダカ
フナ
キンギョ
オモダカ
ホテイソウ
ショウブ
アメーバ
ゾウリムシ
ミドリムシ

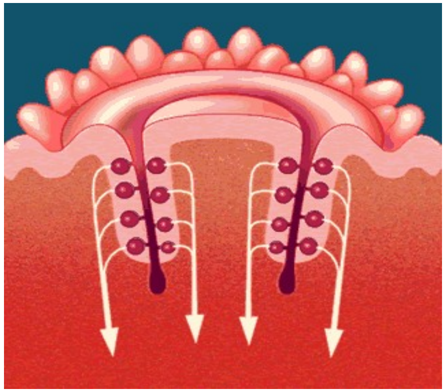
Neuron and other Cells basic characteristics

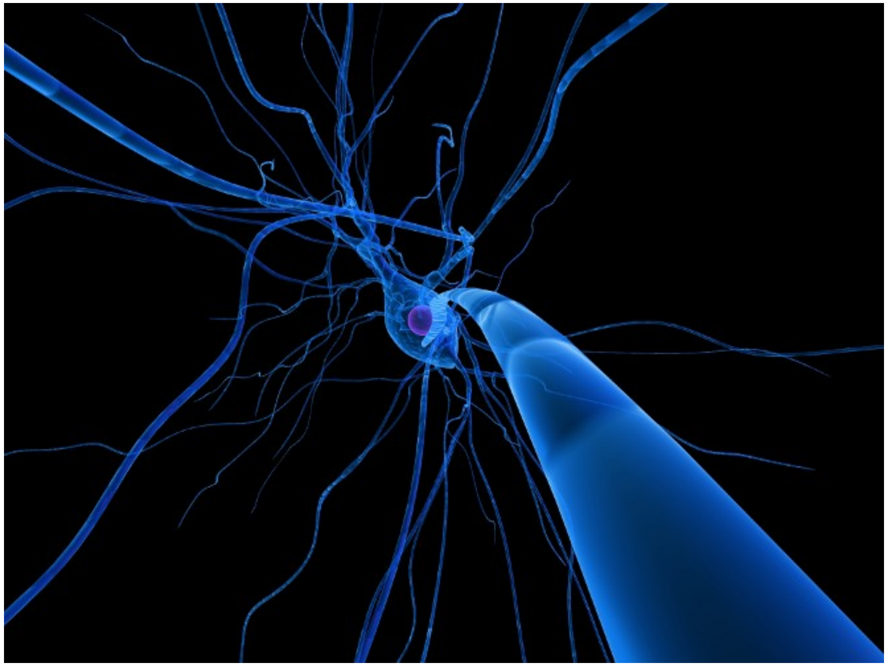
1. There is a membrane. Internal/External **ion density is different**

2. On the membrane there are channels. If a channel opens (for any reason), the **density difference** provoke migration of ions, migration provoke **difference of potential**.

3. The Opening and closing of channels depends on Potential Difference between inside/outside of cell. When potential rise too much, a channel can close, and some other may open. A steep **Spike** of potential is generated (action potential).

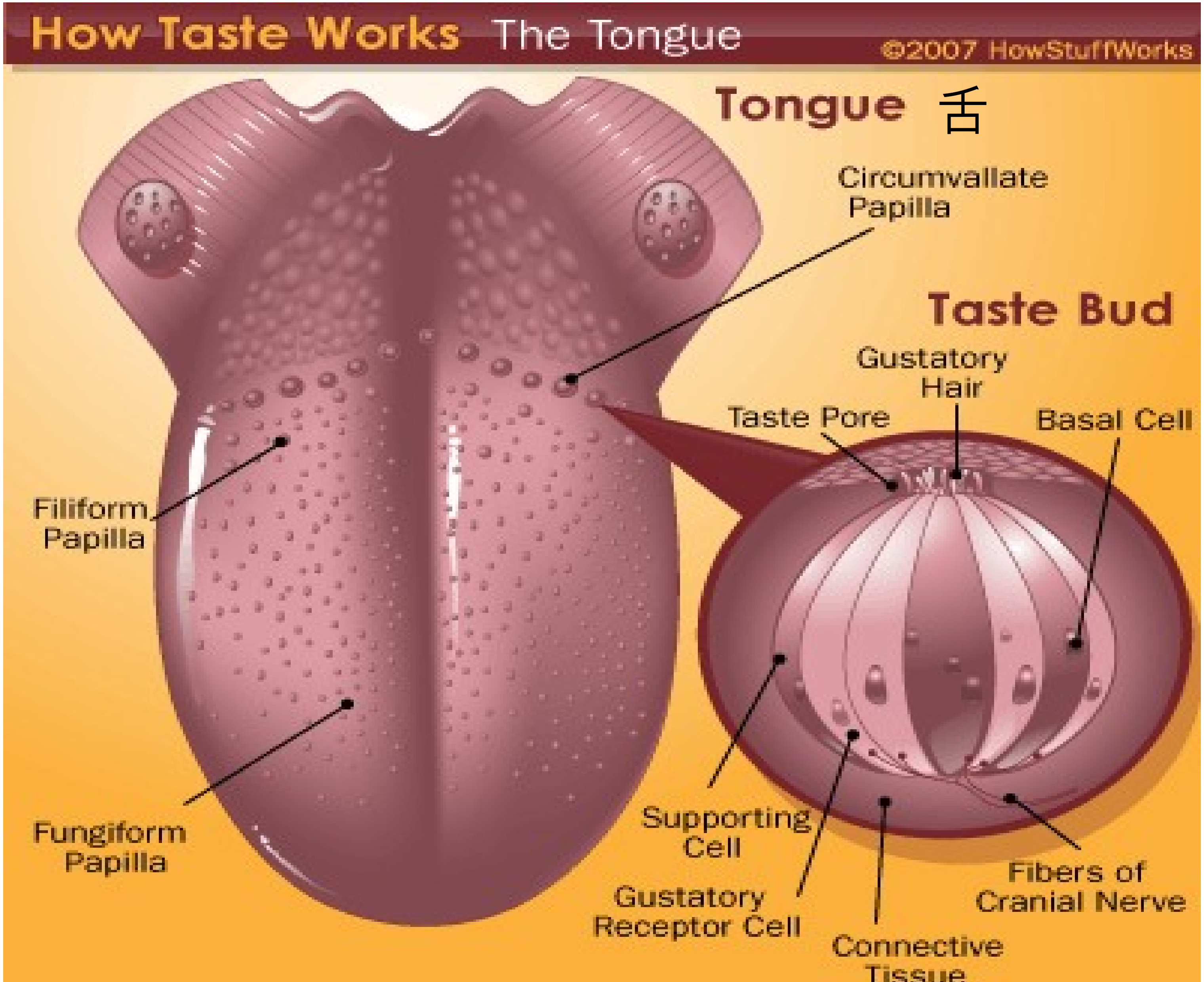
4. There is a **rest time** (refractory period), after a Spike the cell cannot do anything else, but rest.

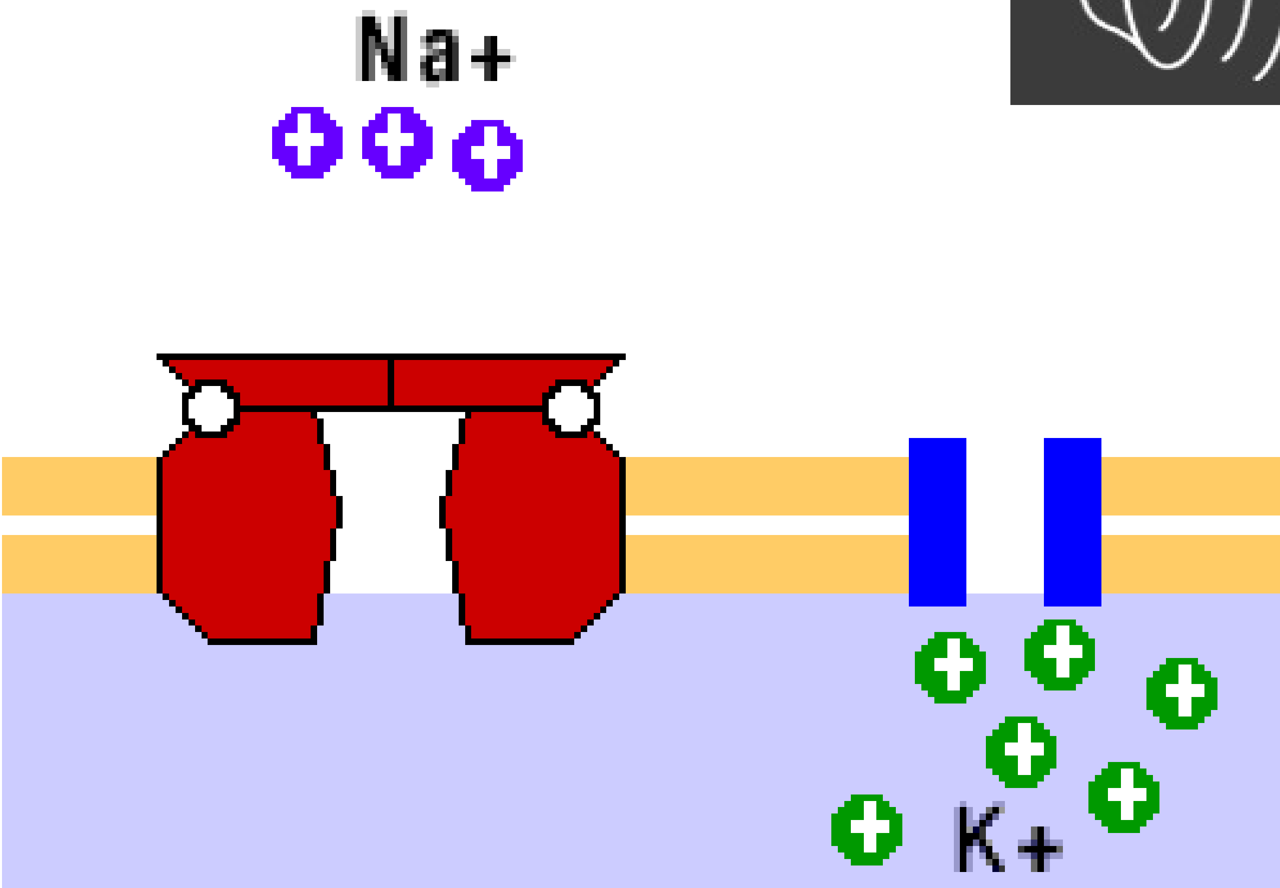




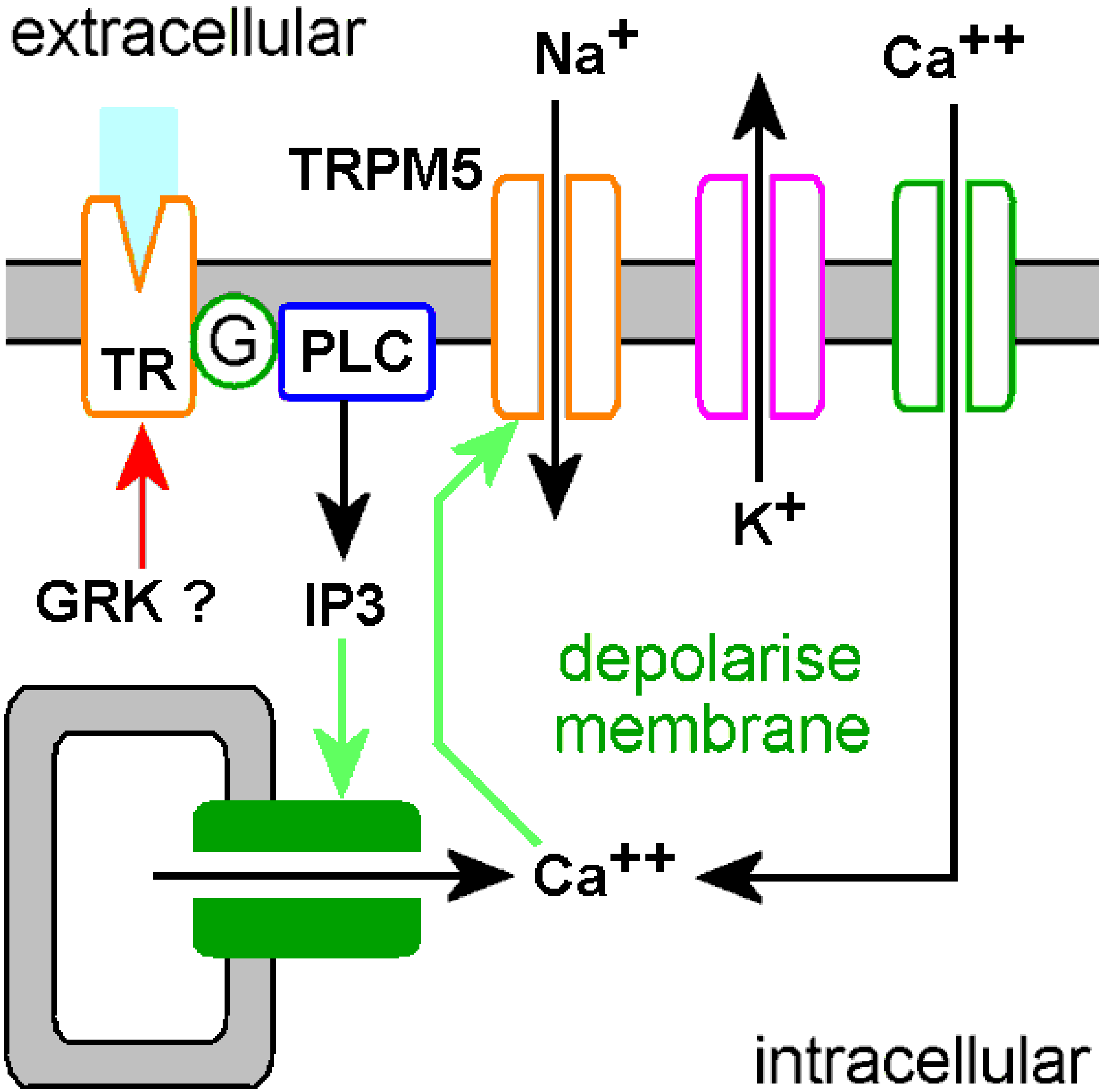
THE TONGUE: the TASTE sense　（味覚、みかく）

CITY UNIVERSITY YOKOHAMA


How Taste Works The Tongue
©2007 HowStuffWorks
Tongue 舌
Circumvallate Papilla
Taste Bud
Gustatory Hair
Taste Pore
Basal Cell
Filiform Papilla
Fungiform Papilla
Supporting Cell
Gustatory Receptor Cell
Connective Tissue
Fibers of Cranial Nerve



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:

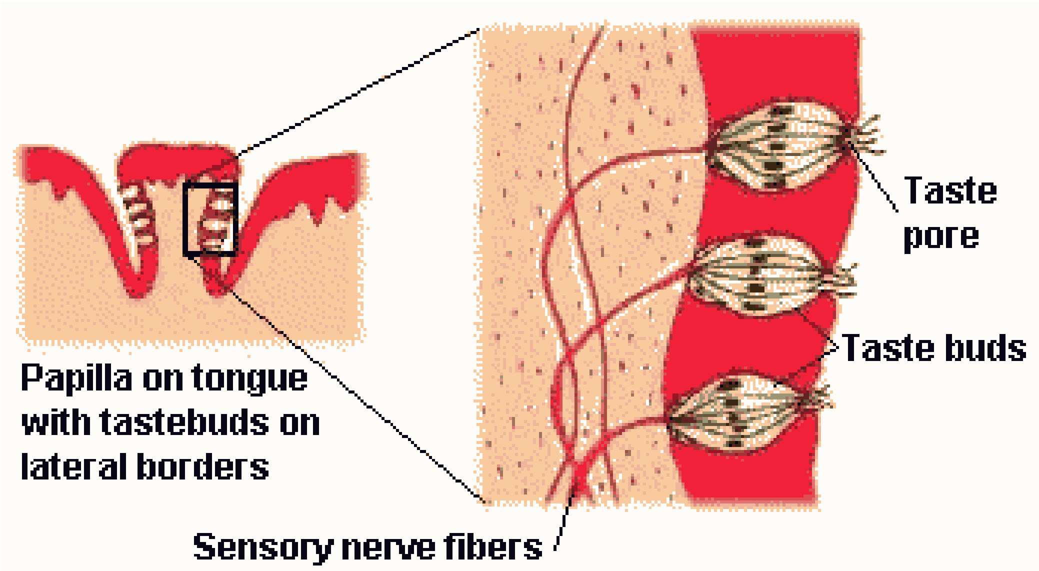
- activation of adenylyl cyclase

- formation of cyclic AMP (cAMP)

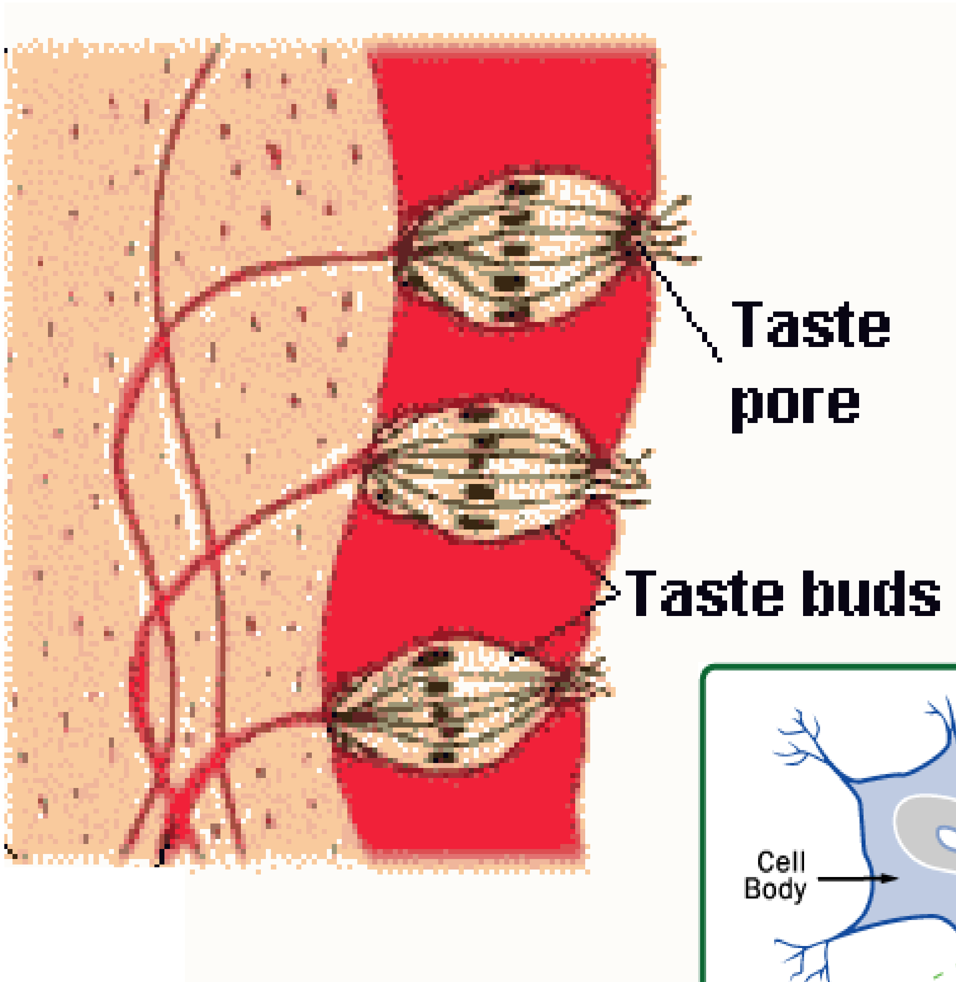
- the closing of K+ channels that leads to **depolarization** of the cell.

Emission of a electric discharge signal

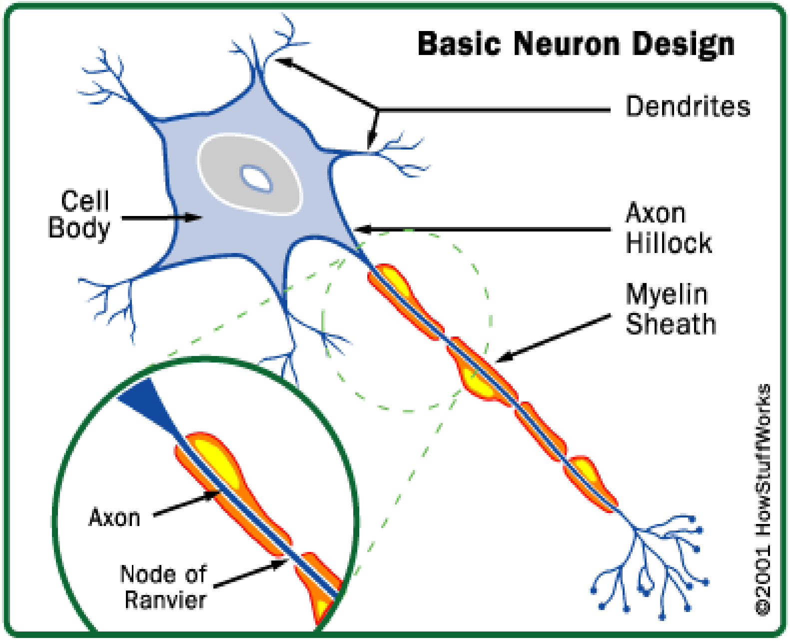
This signal is called **SPIKE**

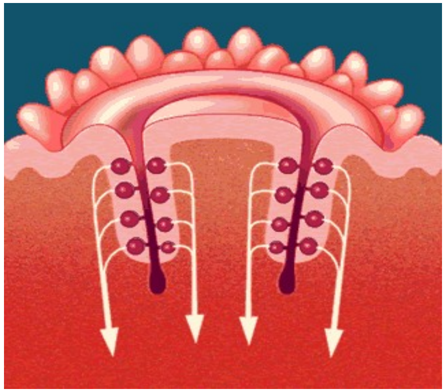


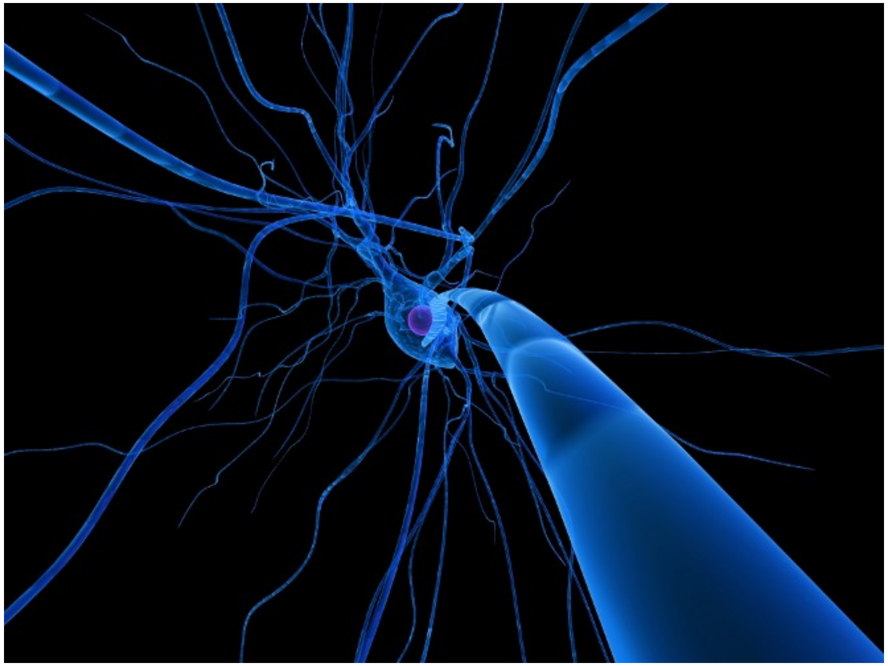
Examples of some human thresholds		
Taste	Substance	Threshold for tasting
Salty	NaCl	0.01 M
Sour	HCl	0.0009 M
Sweet	Sucrose	0.01 M
Bitter	Quinine	0.000008 M
Umami	Glutamate	0.0007 M

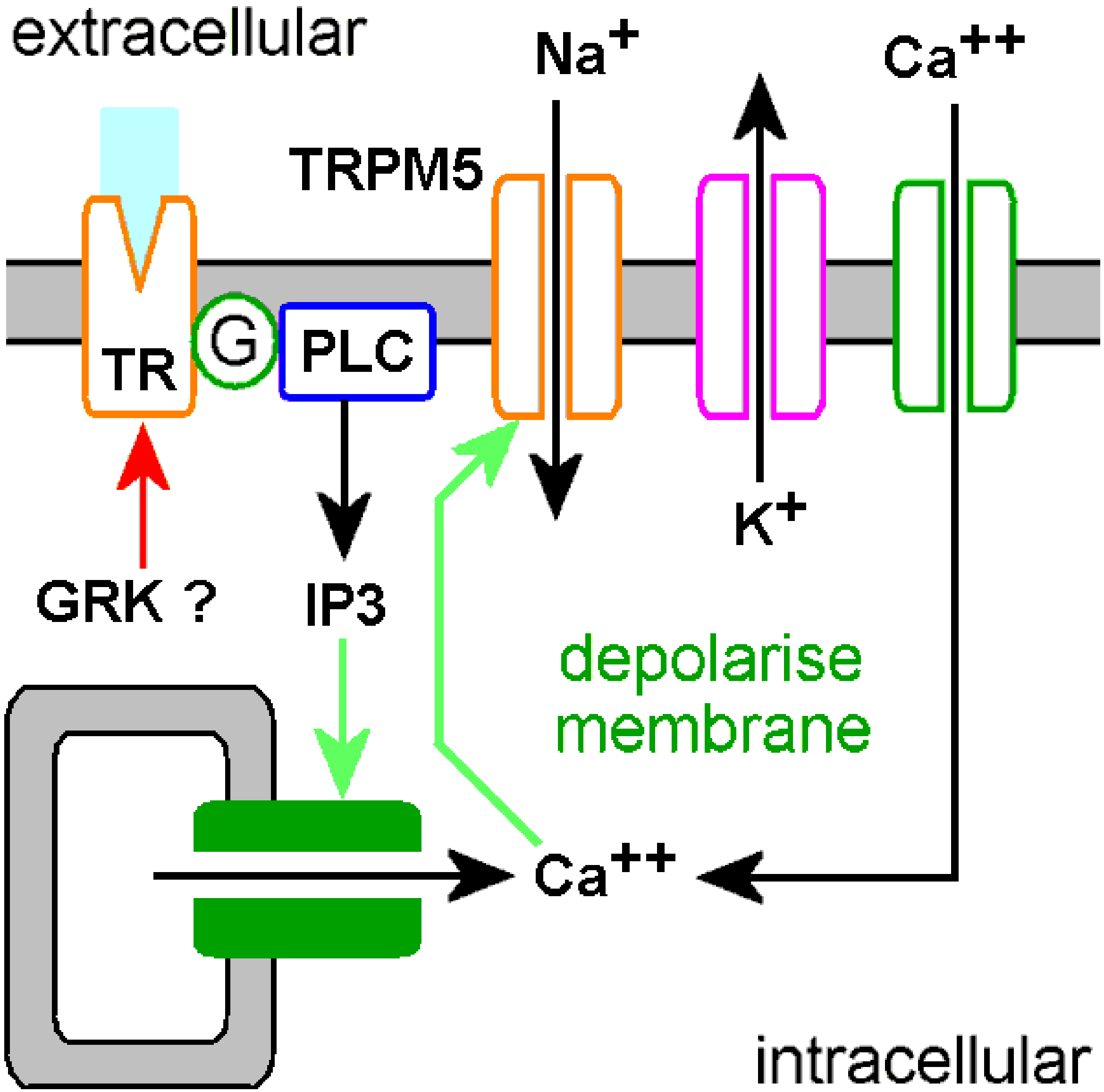


SPIKE signal is transmitted directly to the BRAIN









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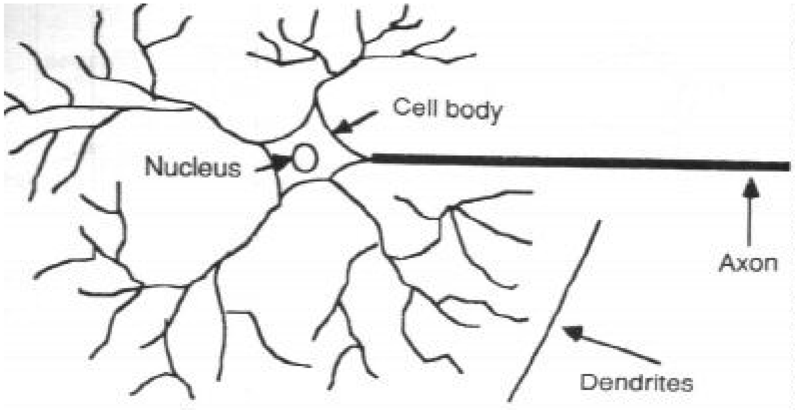
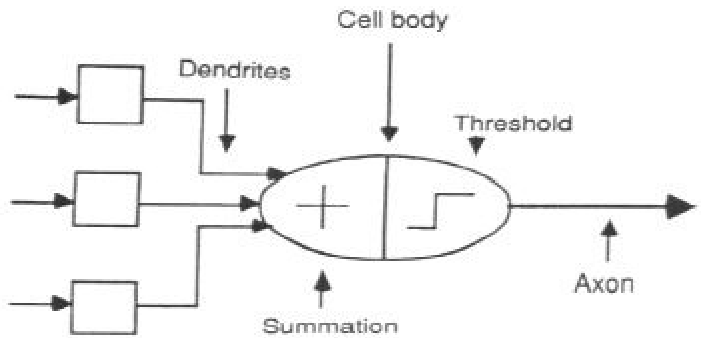
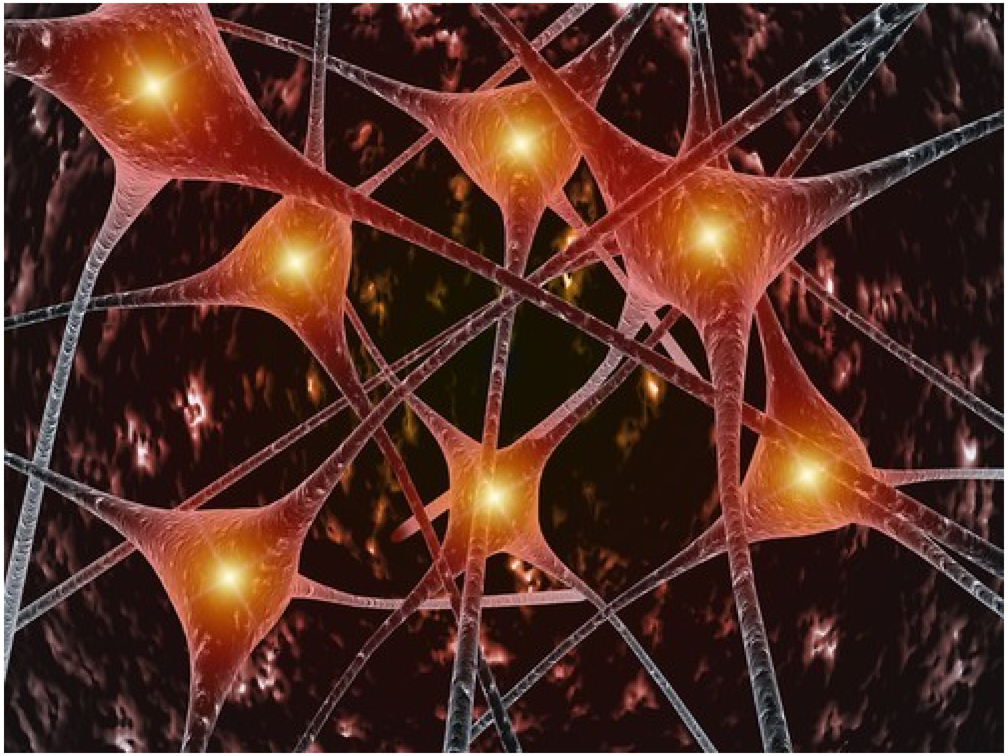

Cell body
Nucleus
Axon
Dendrites


Cell body
Dendrites
Threshold
Axon
Summation



First Neuron Model

1907 by Lapicque

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

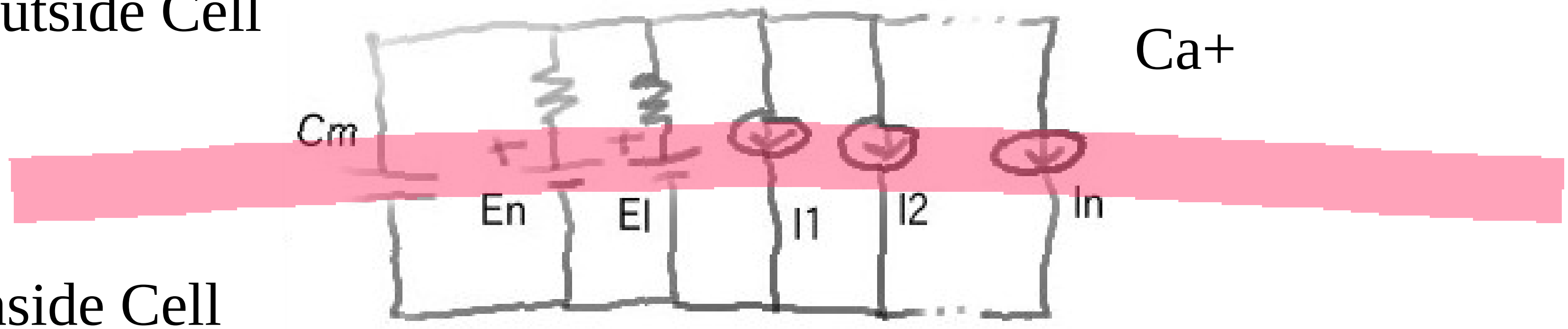
from Q=CV

Hodgkin-Huxley Model (1952)

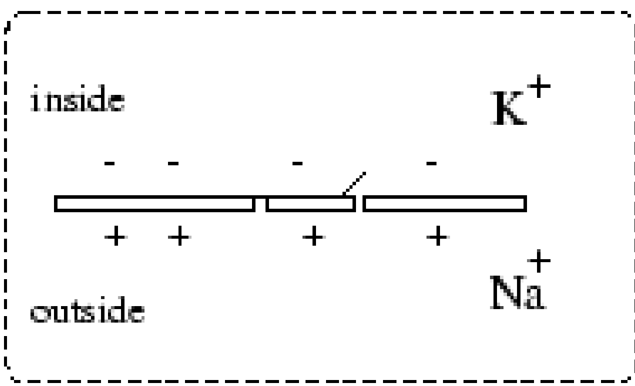
K+ Na+

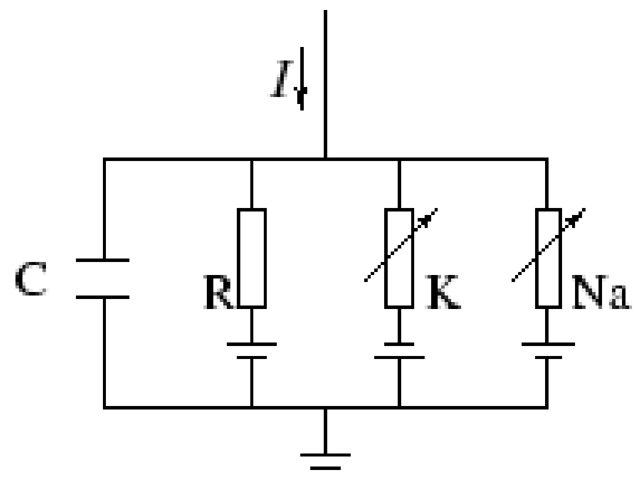
Outside Cell

Ca+



Inside Cell



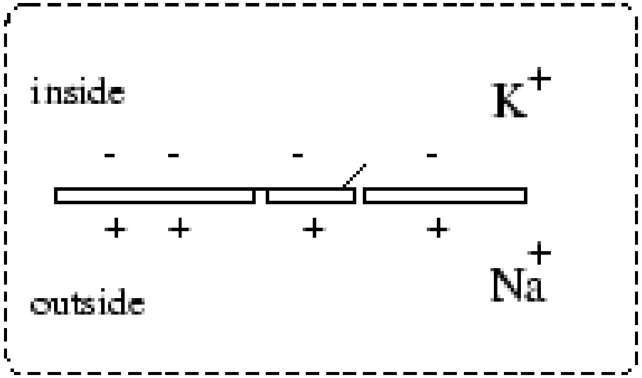


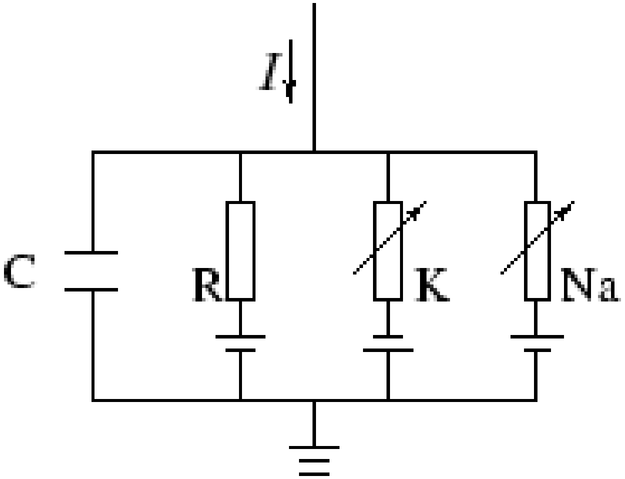
Hodgkin-Huxley Model (1952)

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

Based on Giant Squid experiments

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





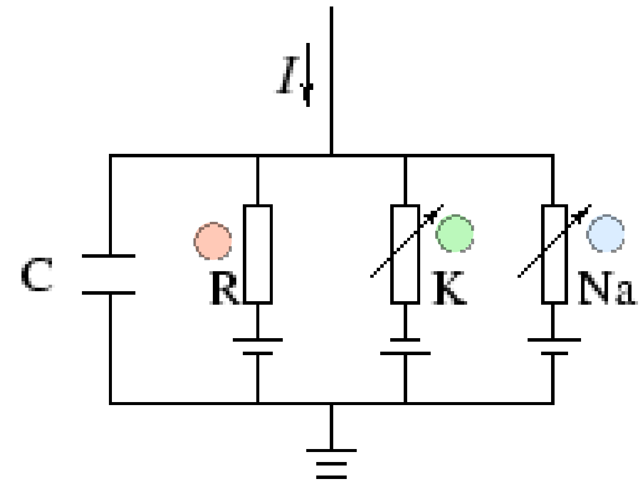
$$C\frac{\mathrm{d}u}{\mathrm{d}t} = -\sum_k I_k(t) + I(t)\,.$$

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

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

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

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



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	$0.3\mathrm{mS/cm^2}$

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

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

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

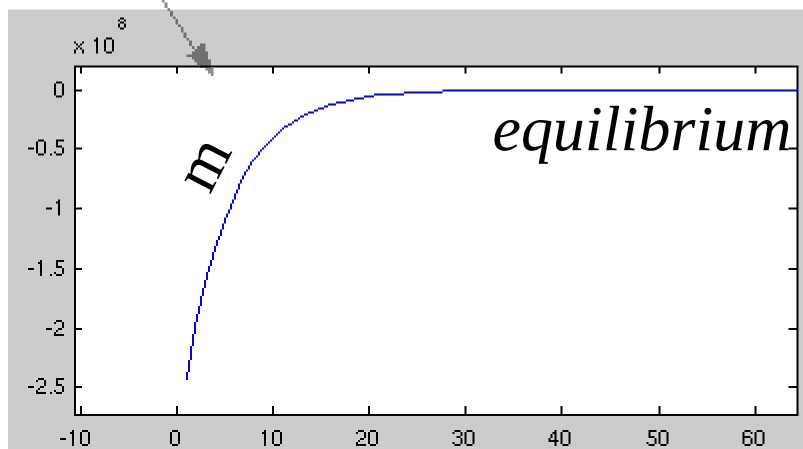
Sym Matlab

```
>> 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 → a, β → b

plot(y)

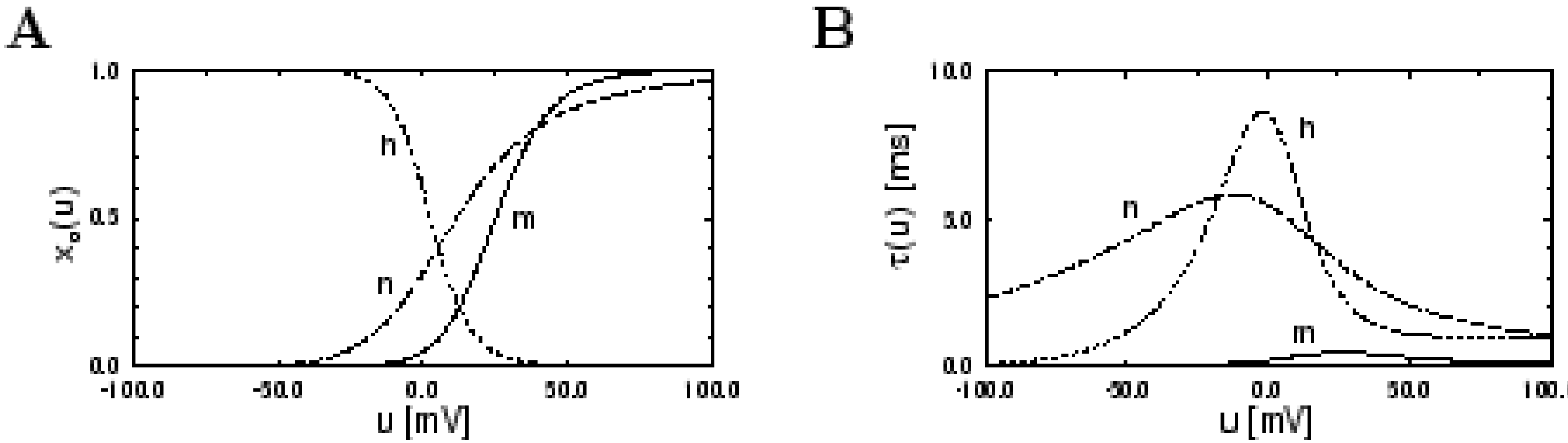


t

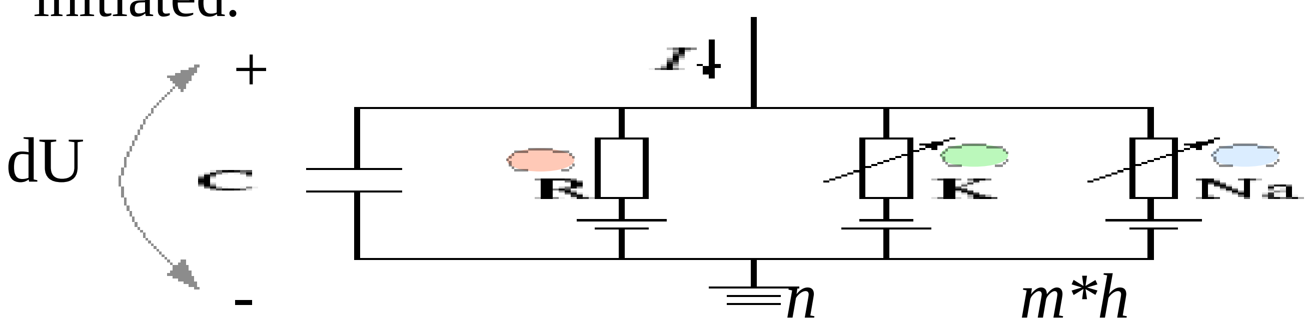
From Experiments

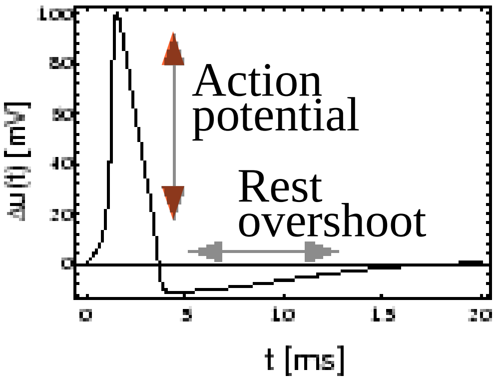
x	$\alpha_x(u\,/\,\mathrm{mV})$	$\beta_x(u\,/\,\mathrm{mV})$
n	$(0.1 - 0.01\,u)\,/\,[\exp(1 - 0.1\,u) - 1]$	$0.125\exp(-u\,/\,80)$
m	$(2.5 - 0.1\,u)\,/\,[\exp(2.5 - 0.1\,u) - 1]$	$4\exp(-u\,/\,18)$
h	$0.07\exp(-u\,/\,20)$	$1\,/\,[\exp(3 - 0.1\,u) + 1]$

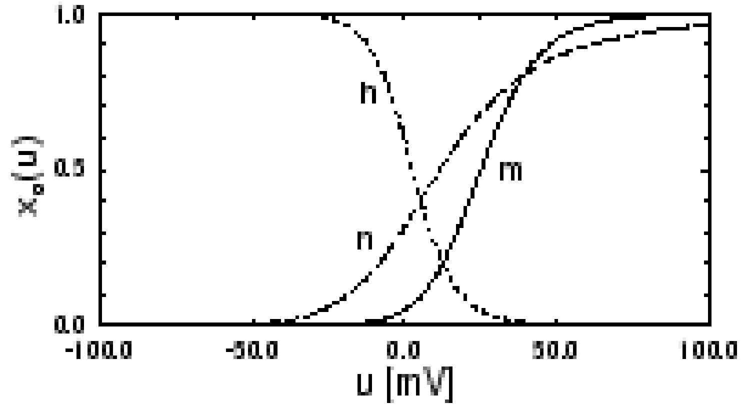
Exponential fitting



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.



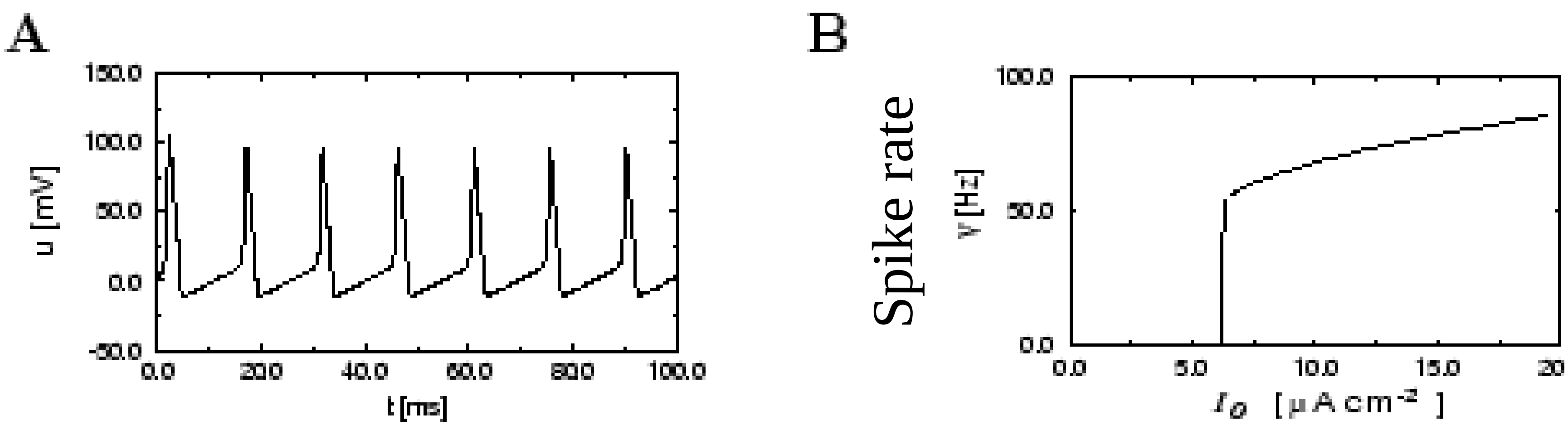




At high values of u the sodium conductance is shut off due to the factor h. As indicated the `time constant' is always larger than . Thus the variable h which closes the channels reacts more slowly to the voltage increase than the variable m which opens the channel. On a similar slow time scale, the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

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

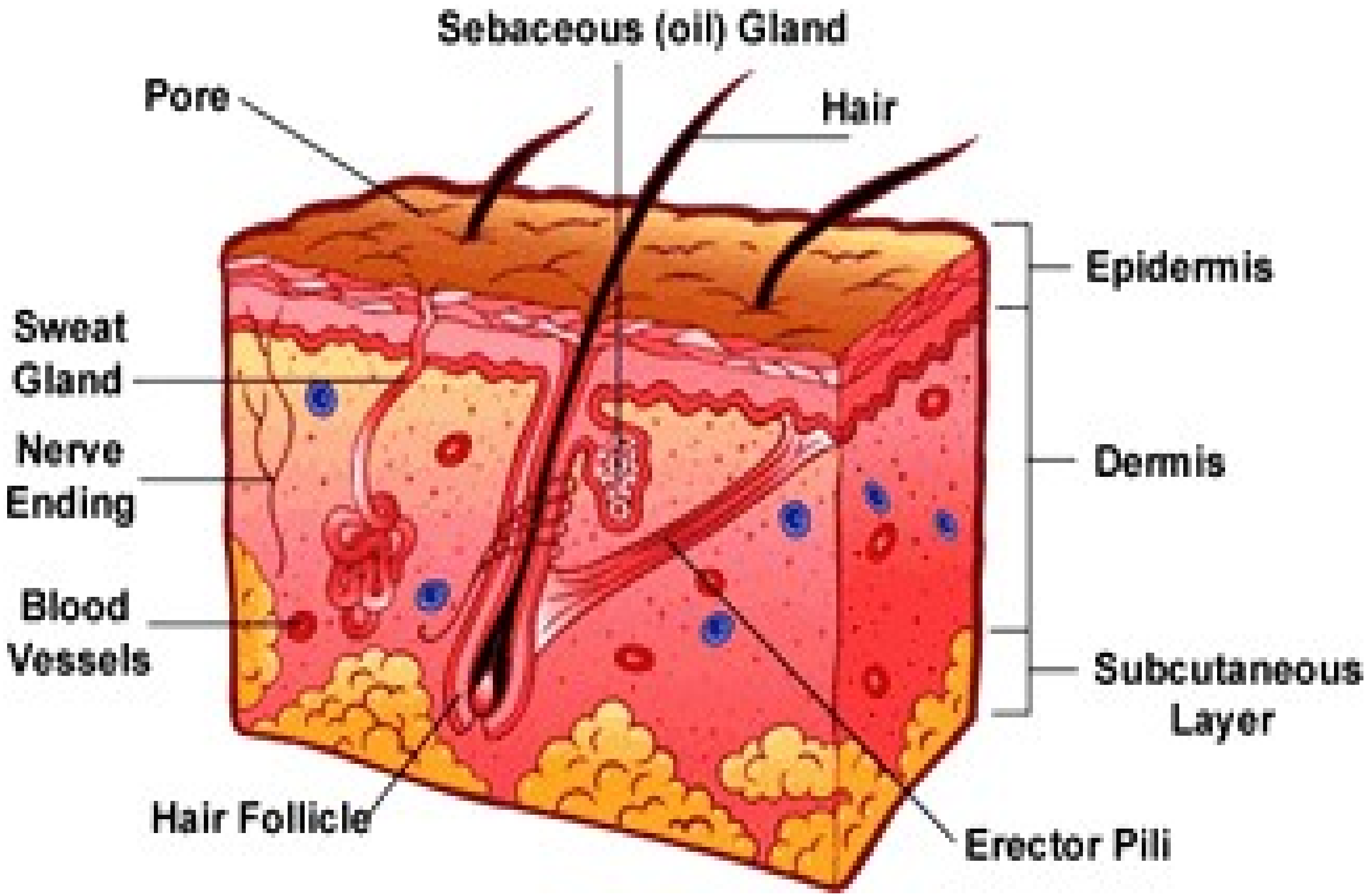
Auto-oscillation is possible

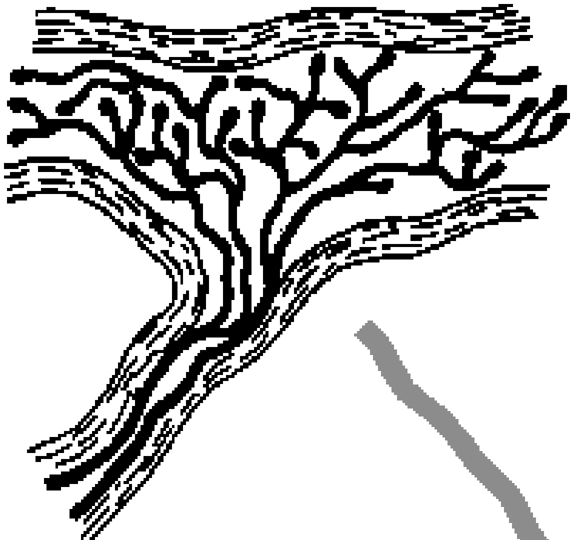


The Hodgkin-Huxley equations may also be studied for **constant** input I(t) = I0 for t > 0. (The input is zero for t 0). If the value I0 is larger than a **critical value** I 6A/cm2, we observe **regular spiking**; We may define a firing rate = 1/T where T is the inter-spike interval. The firing rate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

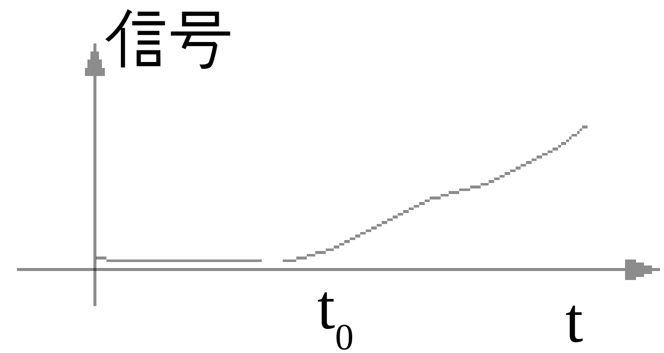
THE SKIN: the TOUCH sense （触覚）

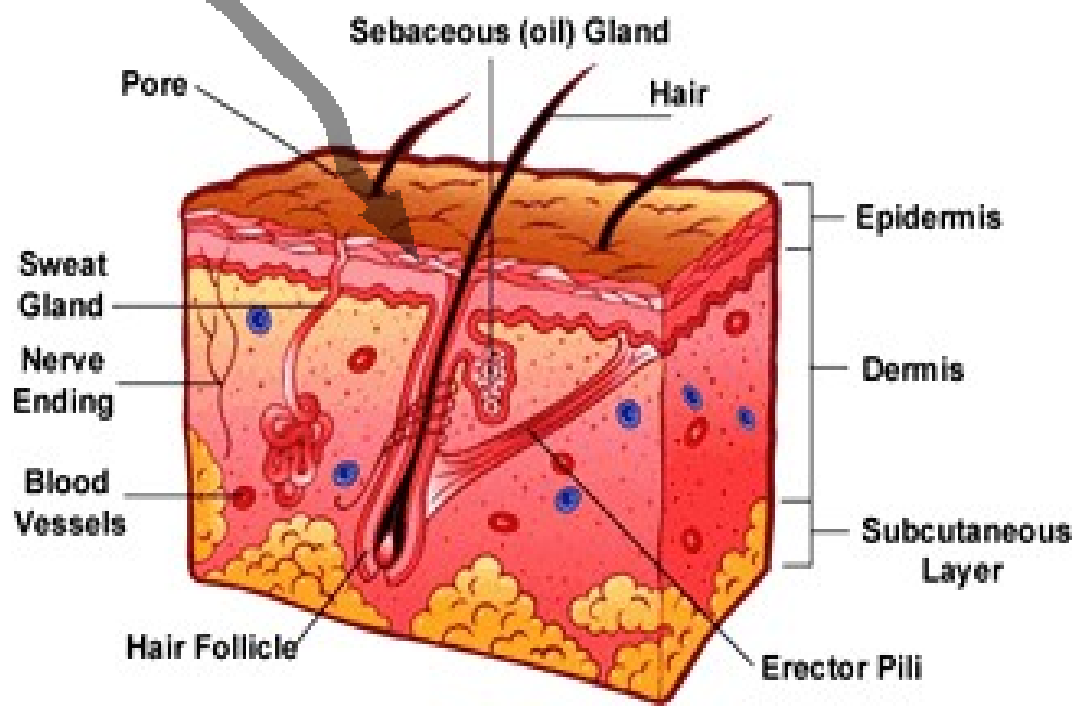
THE SKIN: the TOUCH sense （触覚）



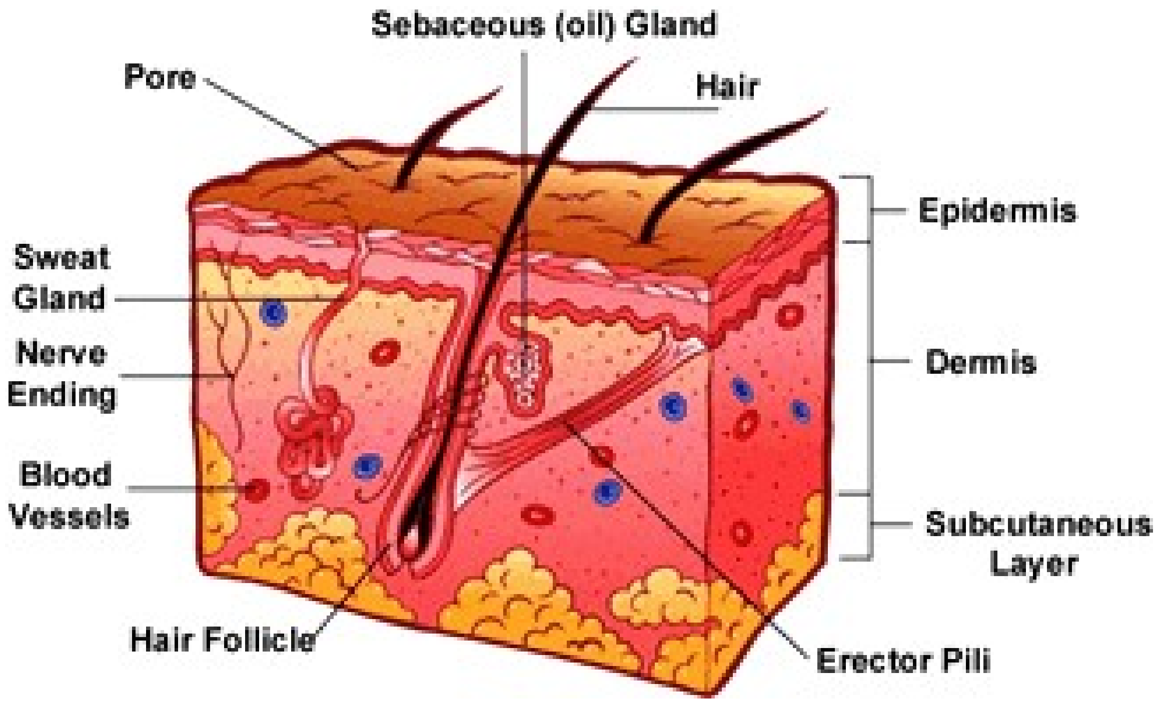


Ruffini Endings



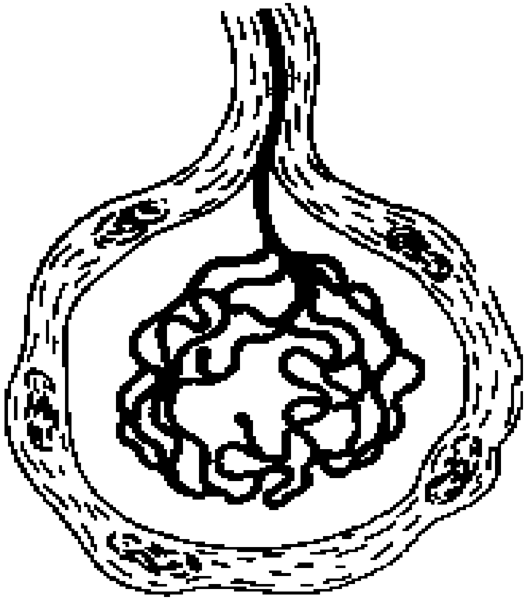


スロー
圧力センサー

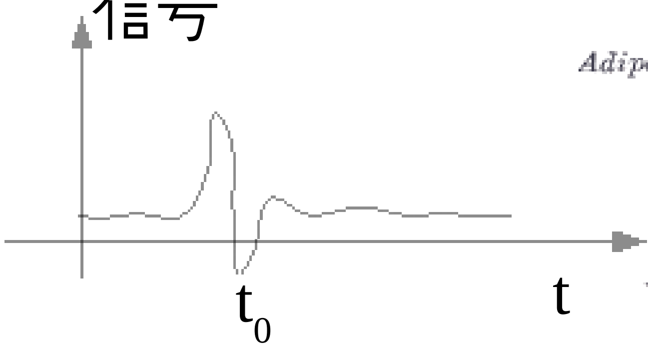


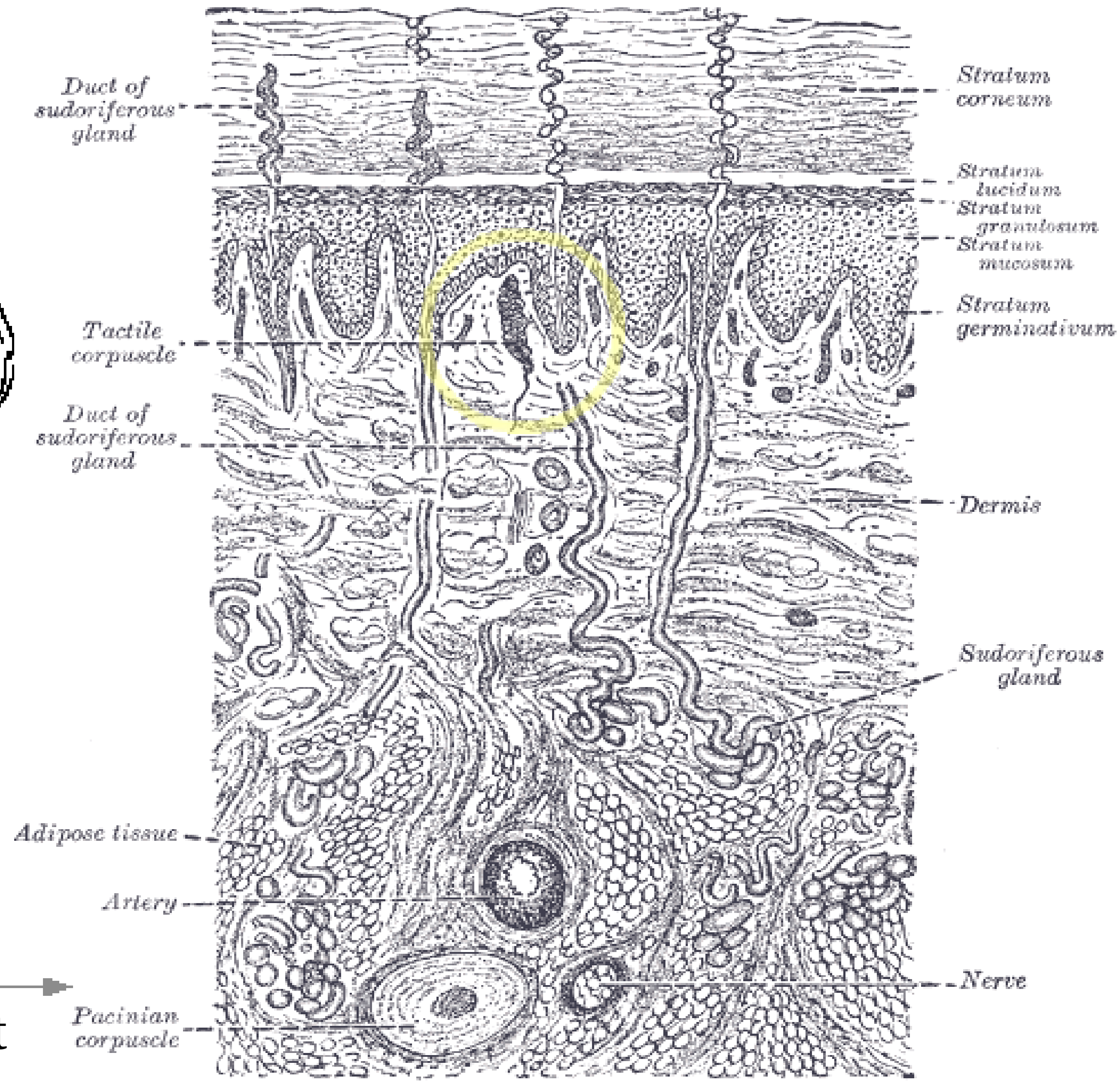
A mechanical *deformation* of the sensory dendrite causes a *depolarization* to occur within the dendrite. This dendrite is at the tip of a unipolar neuron; The sensory dendrite is embedded within the sensor corpuscle. Any depolarization that is large enough in the dendrite itself will cause an *action potential* to be generated at the trigger zone. This action potential will *run* all the way down the *axon* and reach the brain.

圧力センサー



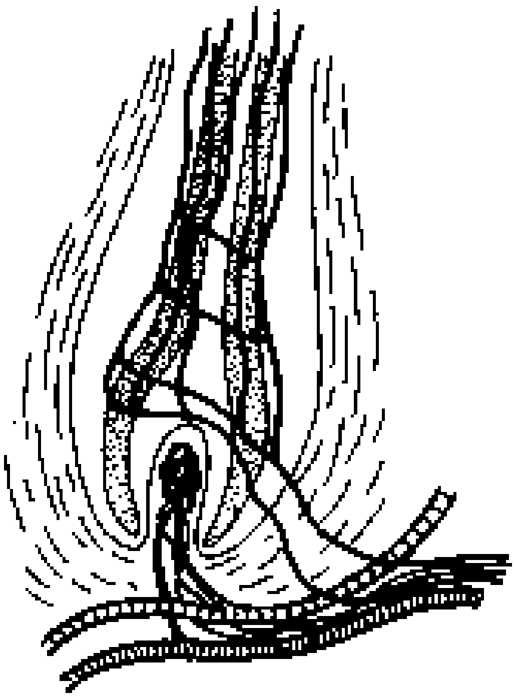
Krause corpuscole



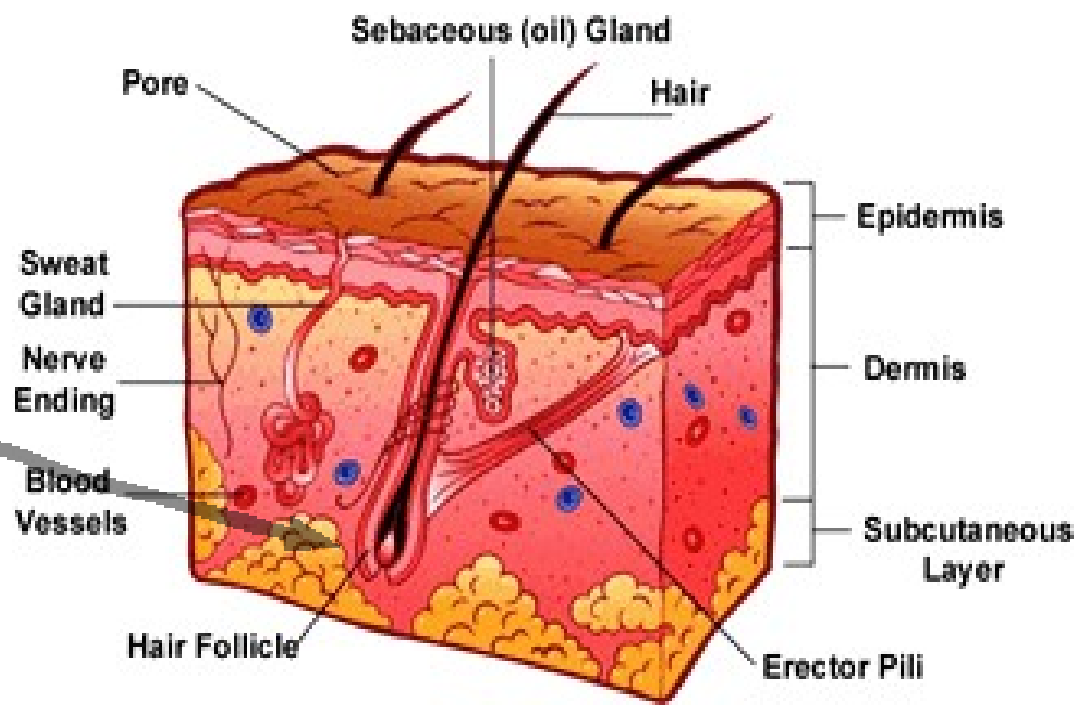


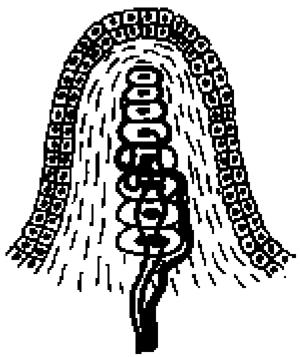
Responds to hair displacement.

Wraps around hair follicle in, of course, hairy skin.



Hair Follicle Ending





最大感度：20-40 Hz

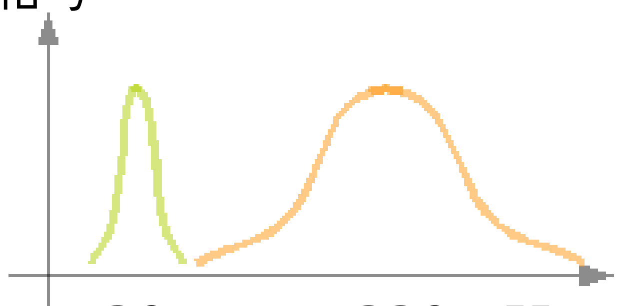
Meissner corpuscole

最大感度：150-300 Hz

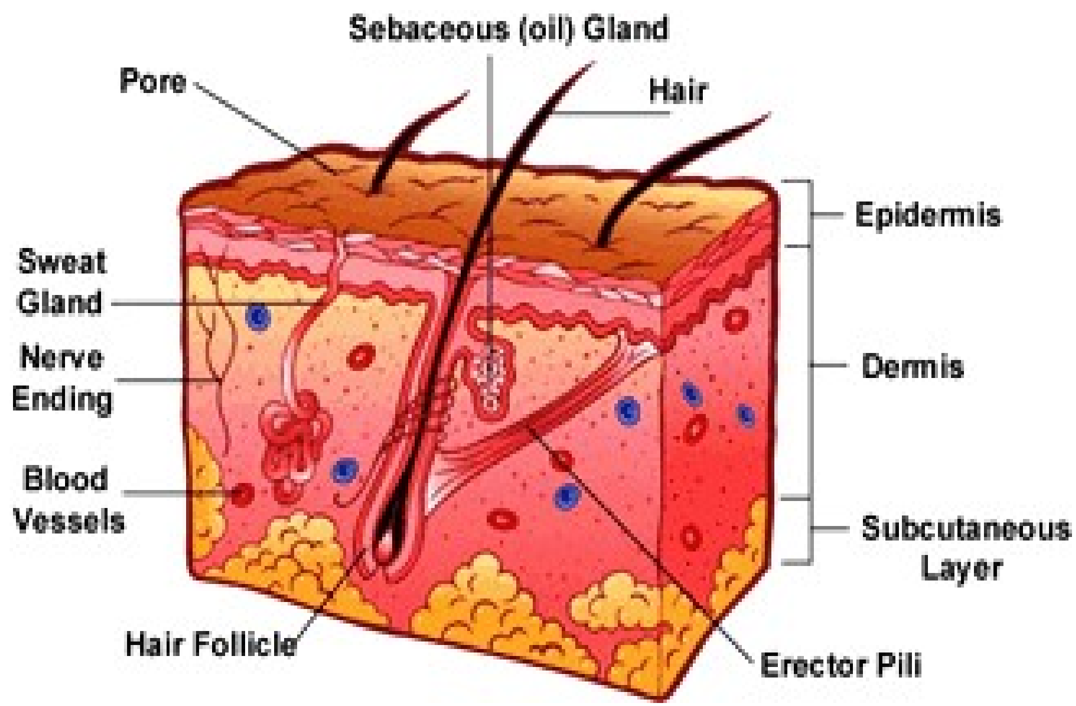
Pacinian corpuscole

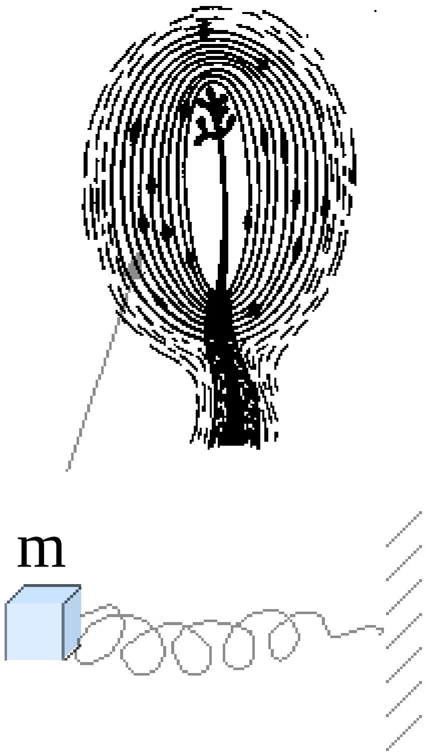
振動センサー

信号



30 220 Hz





$$F = -kx$$

$$m\,a = -k\,x$$

$$m\,\frac{d^2x}{dt^2} = -k\,x$$

Wave equation

$$\frac{d^2x}{dt^2} + \frac{k}{m}\,x = 0$$

Wave function

$$x = -\sin(\omega\,t)$$

pulsation

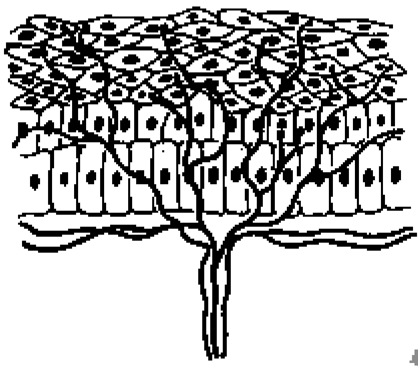
$$\omega = \sqrt{\frac{k}{m}} = (2\pi\,f)$$

Frequency depends on material “m” and “k”

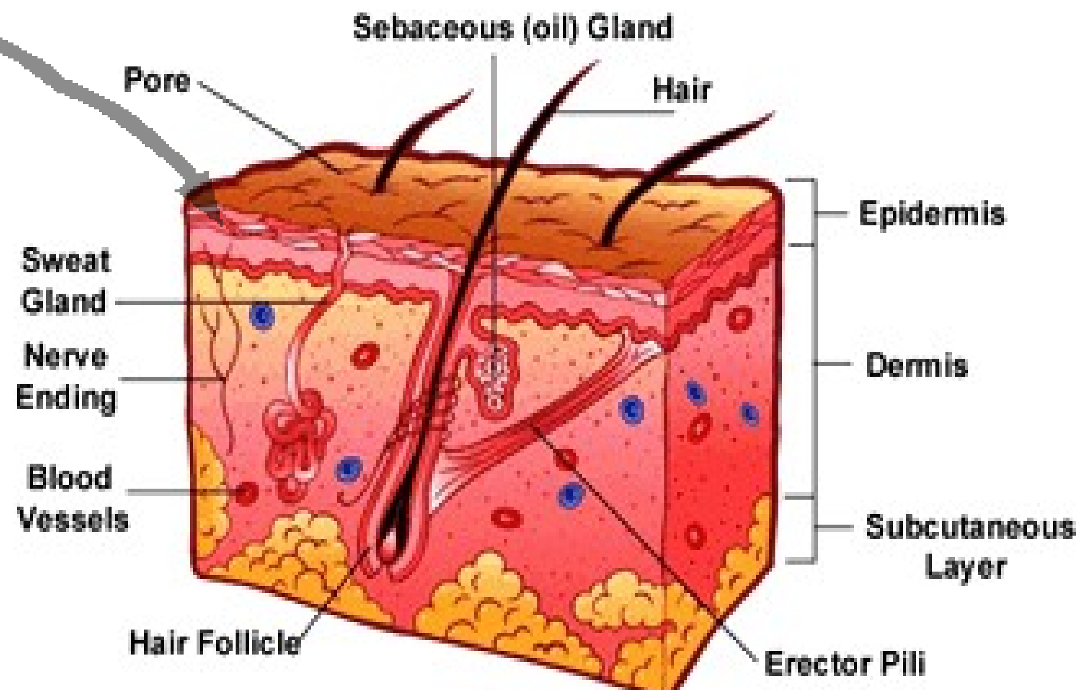
温度センサー

圧力センサー

化学センサー



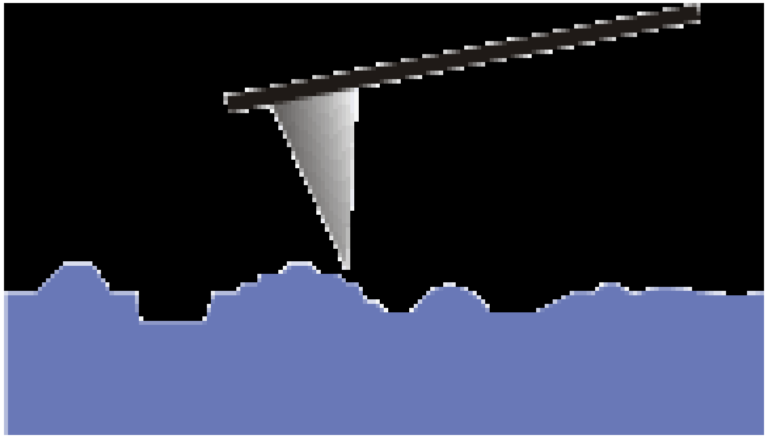
Free nerve endings

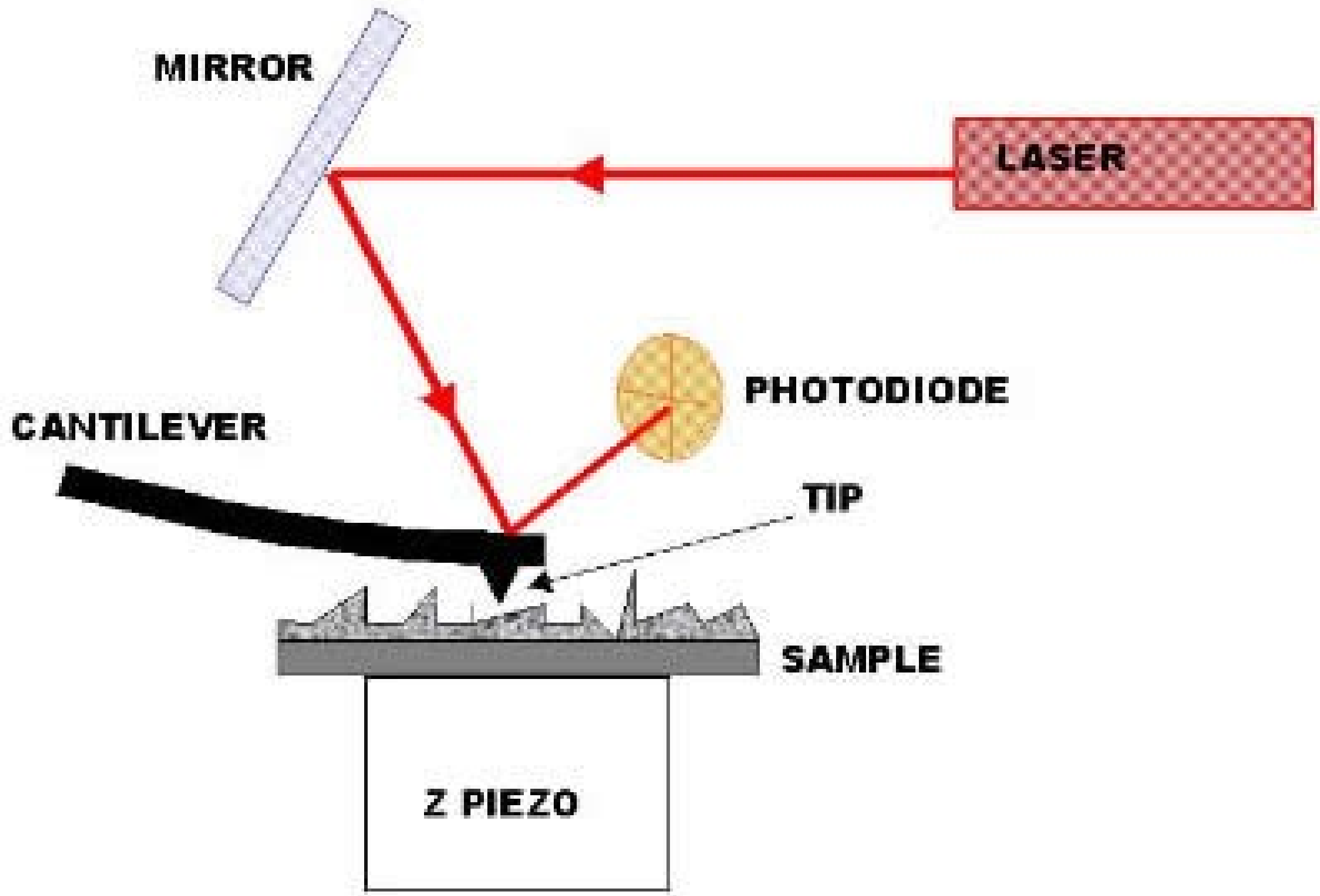


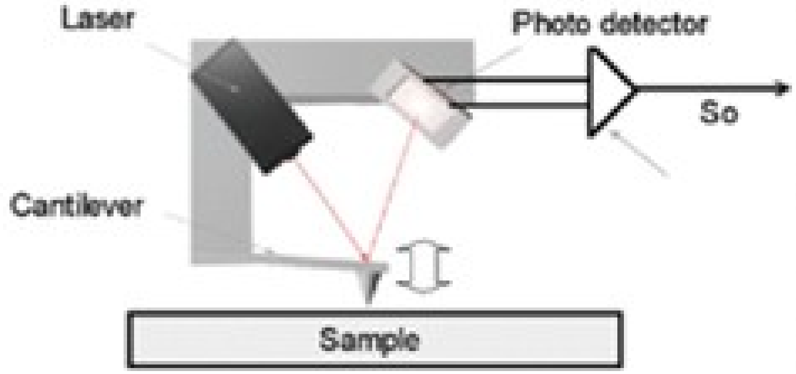
Different types of free nerve endings that respond to mechanical, thermal or noxious stimulation.

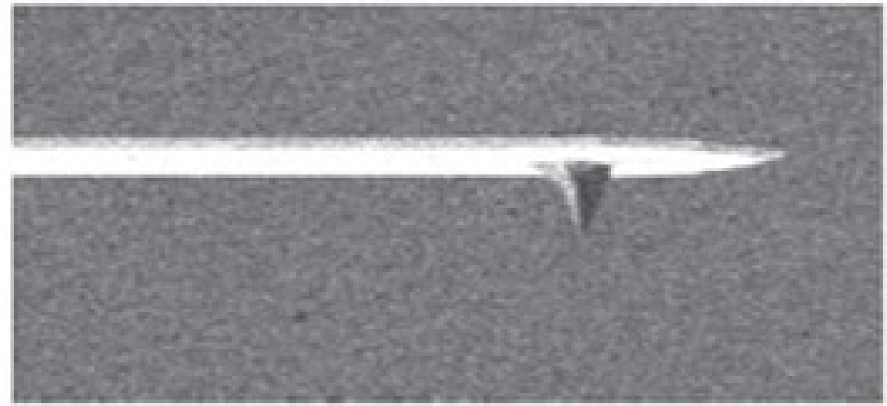
先端人工触覚センサー：原子間力顕微鏡

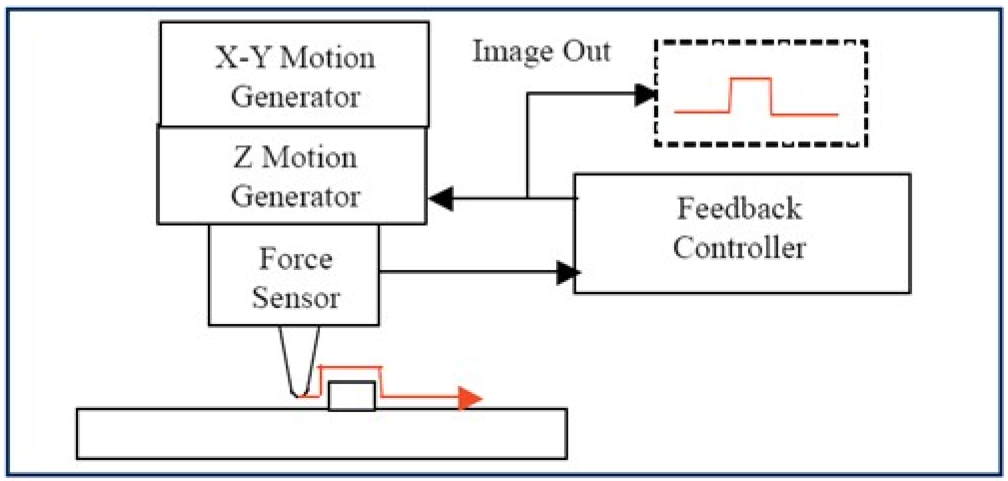
(AFM: Atomic Force Microscope)

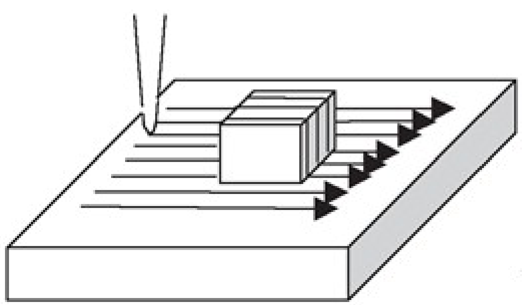


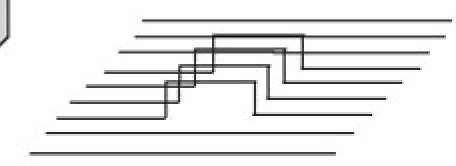

MIRROR
LASER
PHOTODIODE
CANTILEVER
TIP
SAMPLE
Z PIEZO

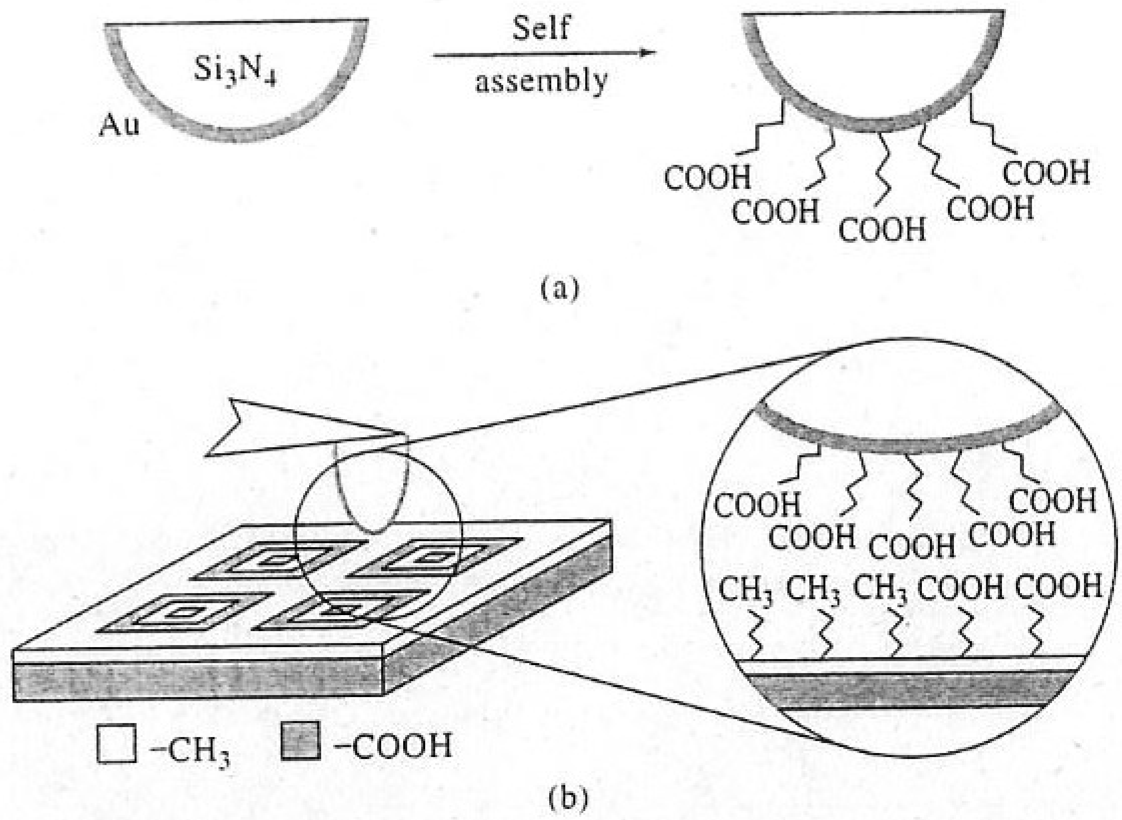

Laser
Photo detector
So
Cantilever
Sample




X-Y Motion Generator
Image Out
Z Motion Generator
Feedback Controller
Force Sensor







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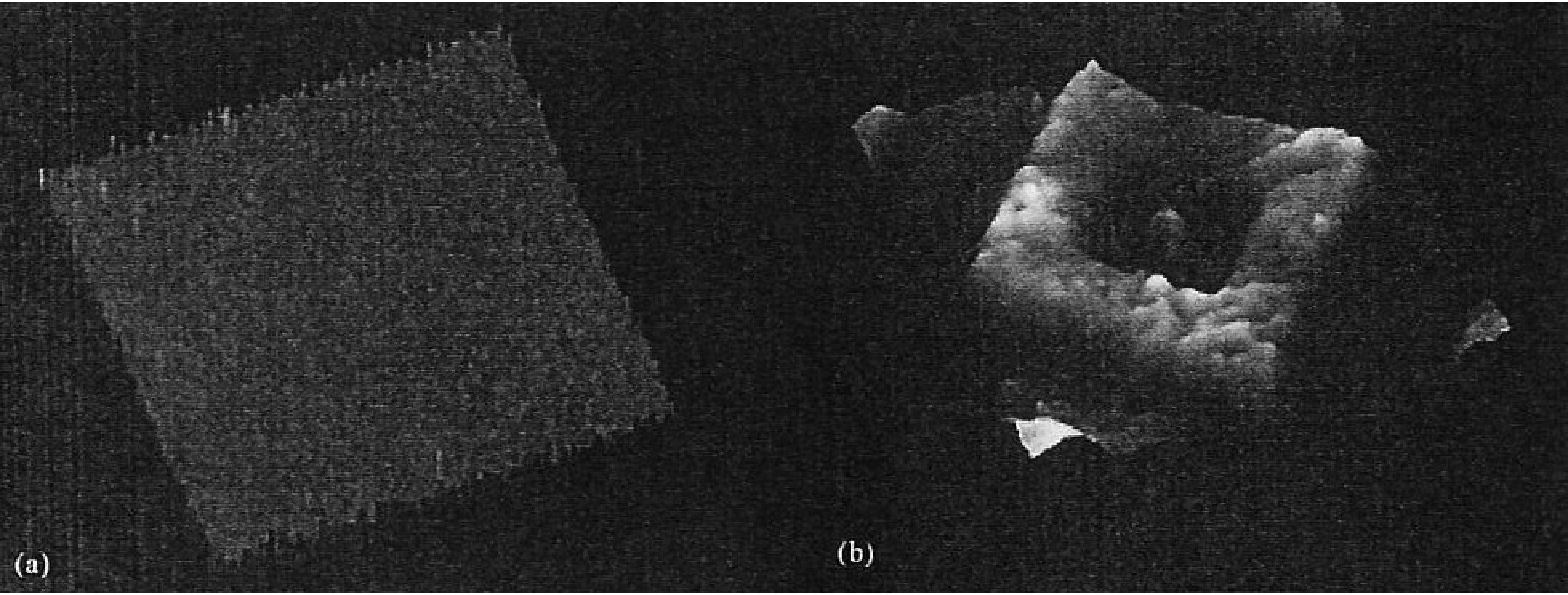
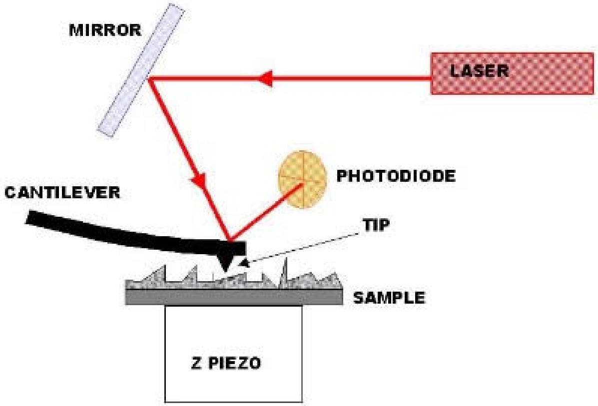
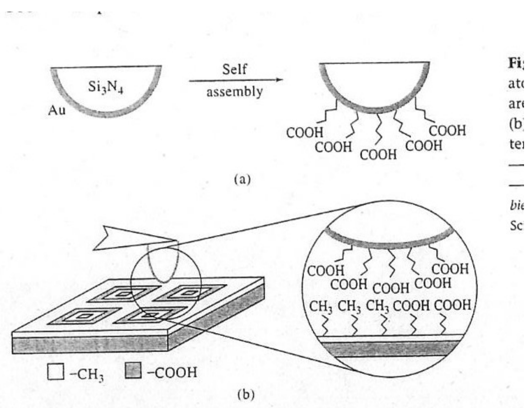
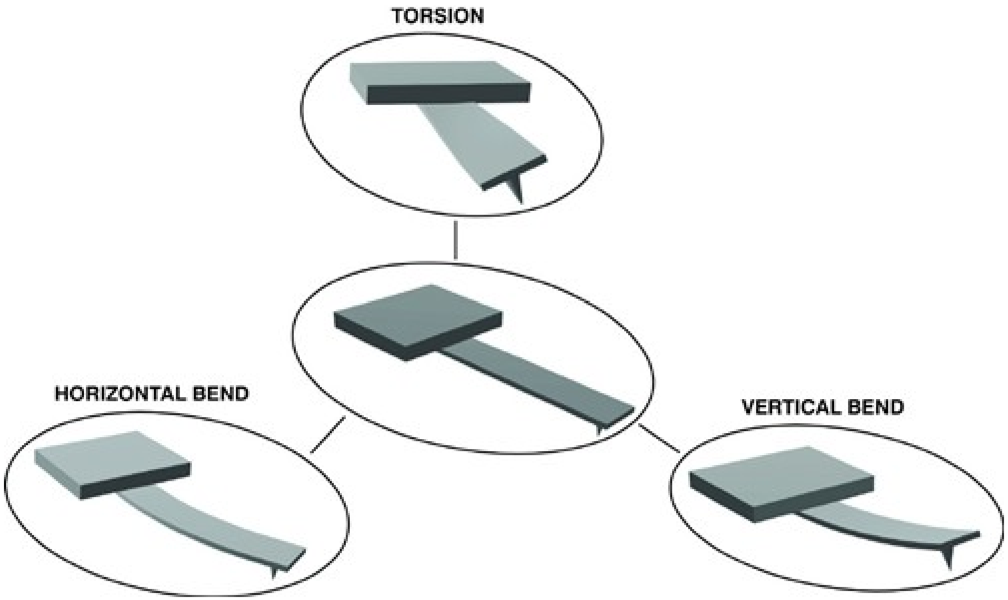
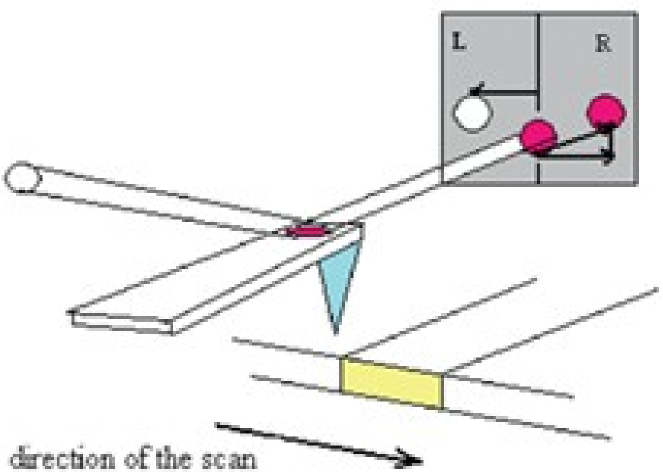
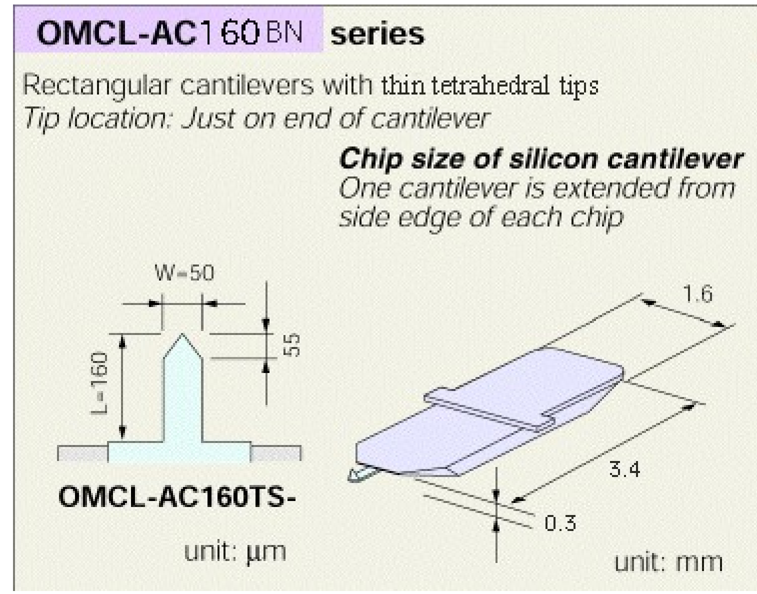

(a)
(b)


MIRROR
LASER
PHOTODIODE
CANTILEVER
TIP
SAMPLE
Z PIEZO

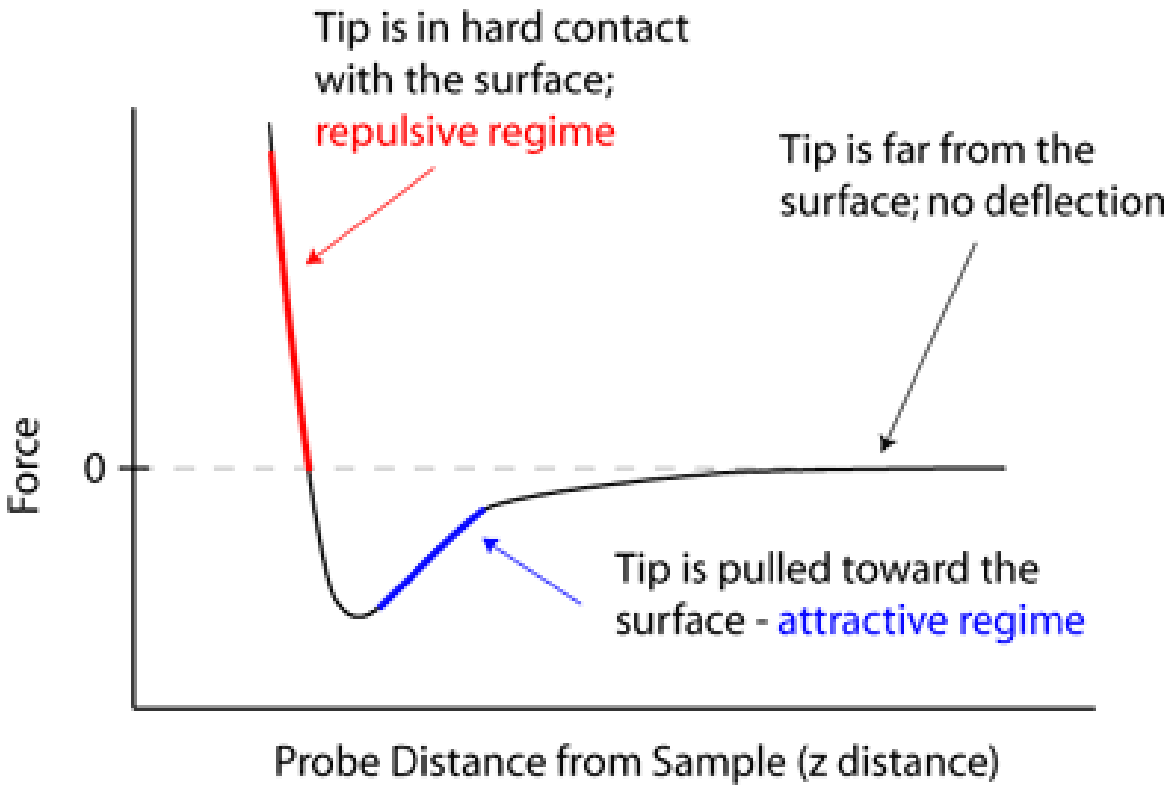

Au
Si_3N_4
Self
assembly
COOH COOH COOH COOH COOH
(a)
COOH COOH COOH COOH COOH
CH_3 CH_3 CH_3 COOH COOH
$-CH_3$
$-COOH$
(b)

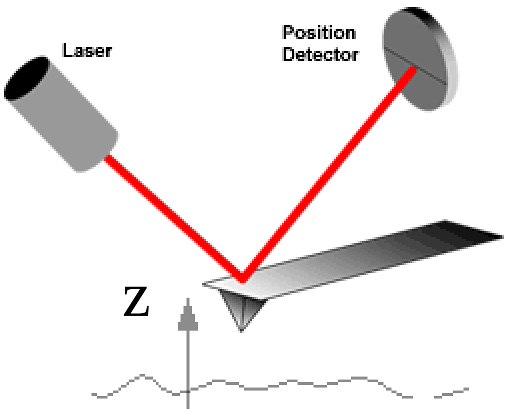

TORSION
HORIZONTAL BEND
VERTICAL BEND

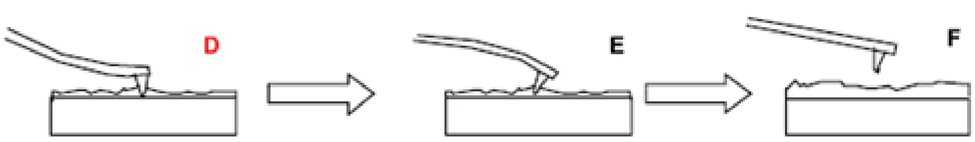

L
R
direction of the scan


OMCL-AC160BN series
Rectangular cantilevers with thin tetrahedral tips
Tip location: Just on end of cantilever
Chip size of silicon cantilever
One cantilever is extended from side edge of each chip
W=50
55
L=160
OMCL-AC160TS-
unit: µm
1.6
3.4
0.3
unit: mm

Operational Modes: CONTACT-MODE

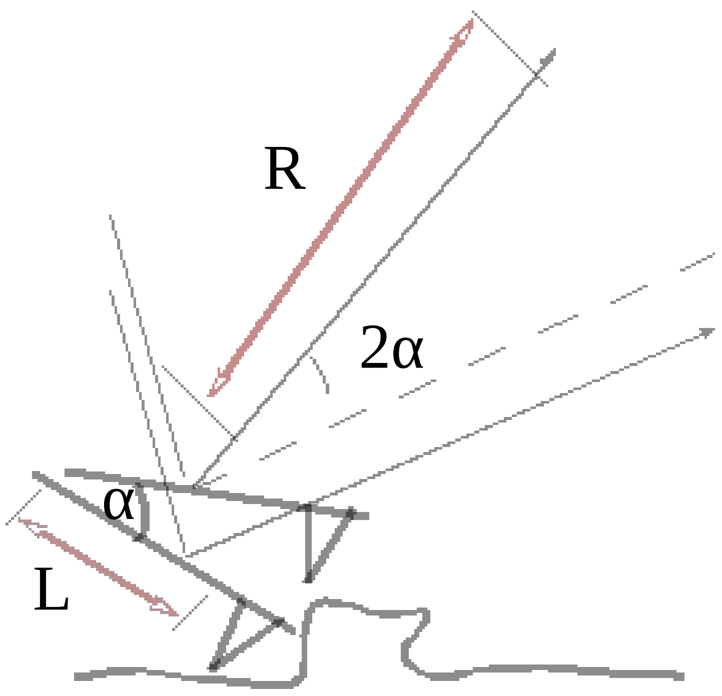






F= - k*D

F= force
k= force constant
D= Deflection distance

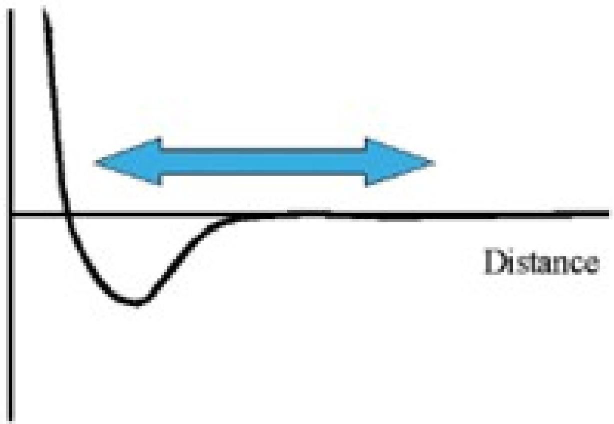


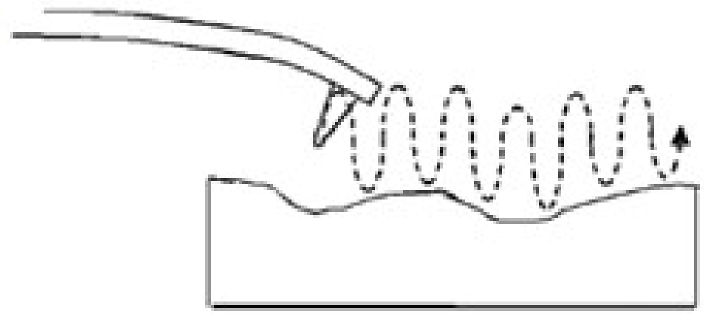
$$L = 1\ mm$$
$$\Delta z = 1\ \text{nm}$$

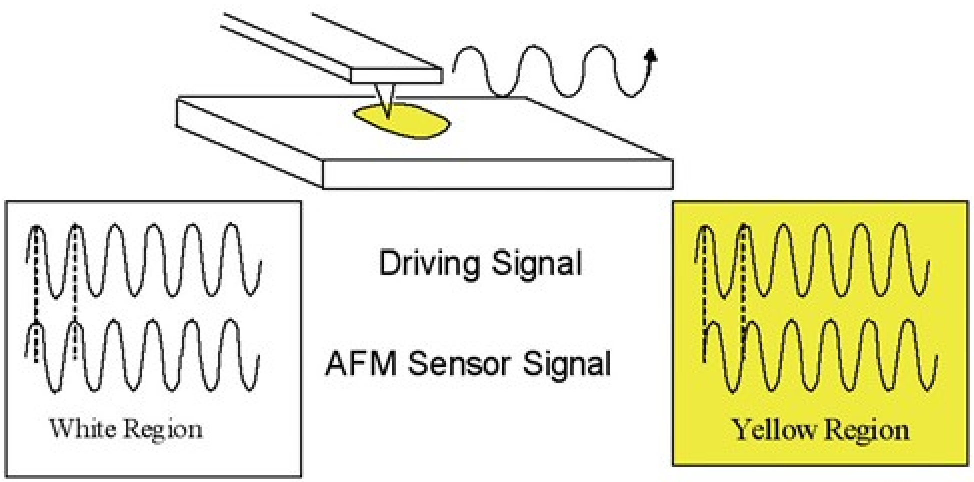
$$\alpha = \arctan\left(\Delta \frac{z}{L}\right)$$

$$L \sin(alfa) = \Delta z$$
$$R \sin(2\ alfa) = \Delta x$$
$$\frac{\Delta x}{\Delta z} = 2\ \frac{R}{L}$$

Operational Modes: VIBRATING-MODES







- Phase Changes
- Amplitude Changes

Equation 4-3: $\omega_o - \omega_o' \approx \omega_o \, {f'}/{2k}$

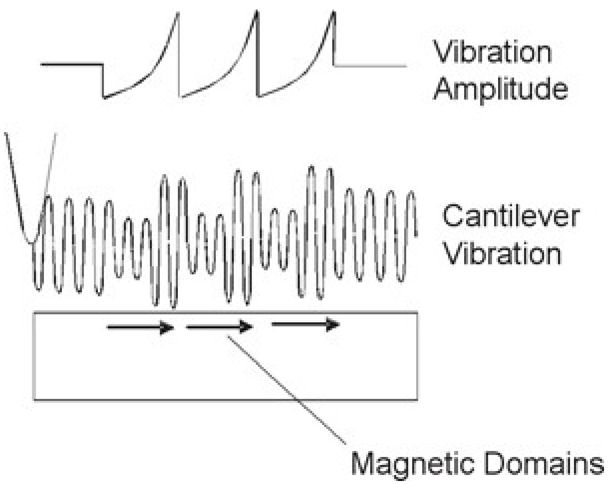
Equation 4-4: $$f' = \frac{dF}{dz}$$

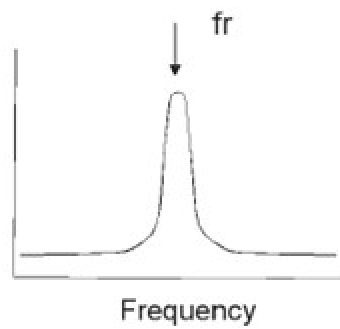
k Force constant

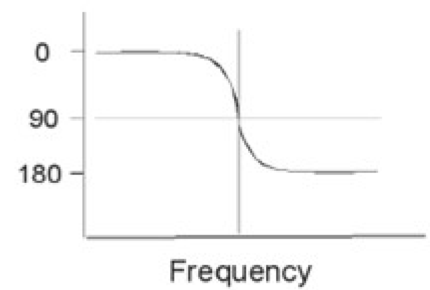
ω_o Resonance frequency

ω_o' New resonance frequency

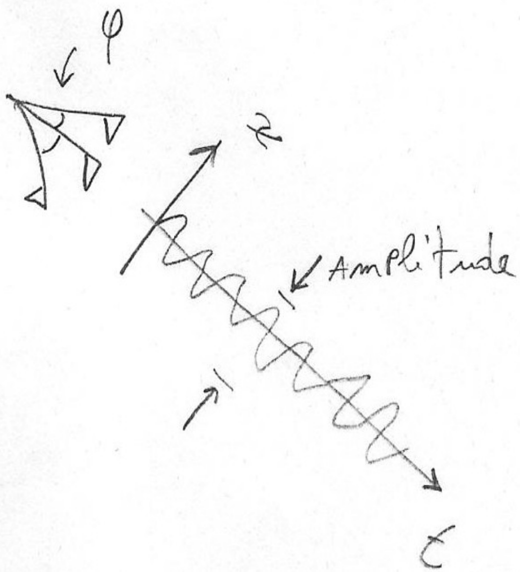
F Force on probe

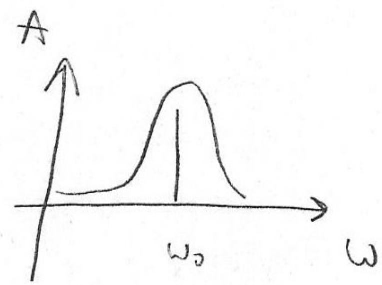






The cantilever vibration Physics:





$$\vec{F} = -k^{*}\,\Delta\varphi$$

$$m\,\frac{d^{2}z}{dt^{2}} = -k^{*}\,d\varphi$$

$$m\int\frac{d^{2}z}{dt^{2}} = -k\int d\varphi$$

$$\boxed{dz = \ell \, d\varphi}$$

$$m \ell \frac{d^2\varphi}{dt^2} = -k \, d\varphi$$

$$m \ell \ddot{\varphi} = -k\varphi$$

$$\boxed{m \ell \ddot{\varphi} + k\varphi = 0}$$

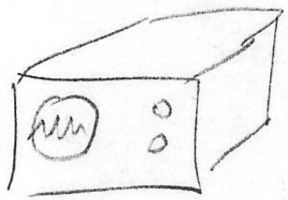
WAVE EQUATION → SOLUTION

$$\boxed{\ddot{\varphi} + \frac{k}{m\ell}\varphi = 0}$$

$$\begin{cases} \varphi(t) = A \sin(\omega_0 t) \\ \omega_0^2 = \dfrac{k}{m\ell} \end{cases}$$

How to measure the cantilever Force:

(1) OBSERVE ω_0 on oscilloscope

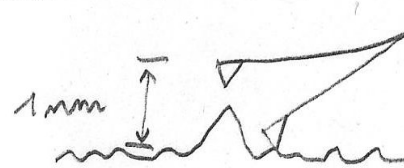


$\Rightarrow \omega_0 \Rightarrow f_0 = \frac{\omega_0}{2\pi}$

$$k^* = m\, l\, \omega_0^2 = m\, l\, 2\pi f_0$$

Suppose $\Delta z = 1\,nm = 1 \cdot 10^{-9}$ [m]

$$\vec{F}_{(\text{over } 1nm)} = -k^*\, tg^{-1} \frac{10^{-9}}{l[m]}$$

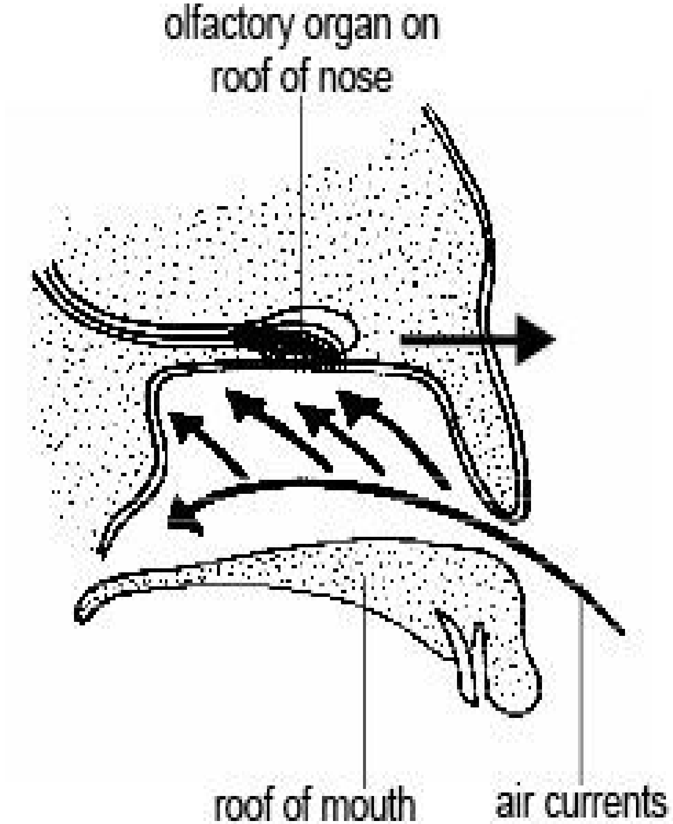


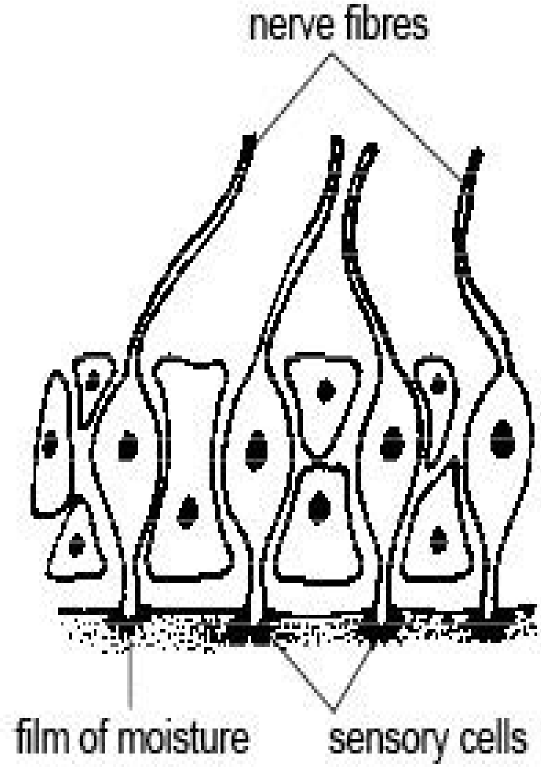
$m = 0.01$ [g] $\quad l = 0.001$ [m]

$f = 50$ kHz

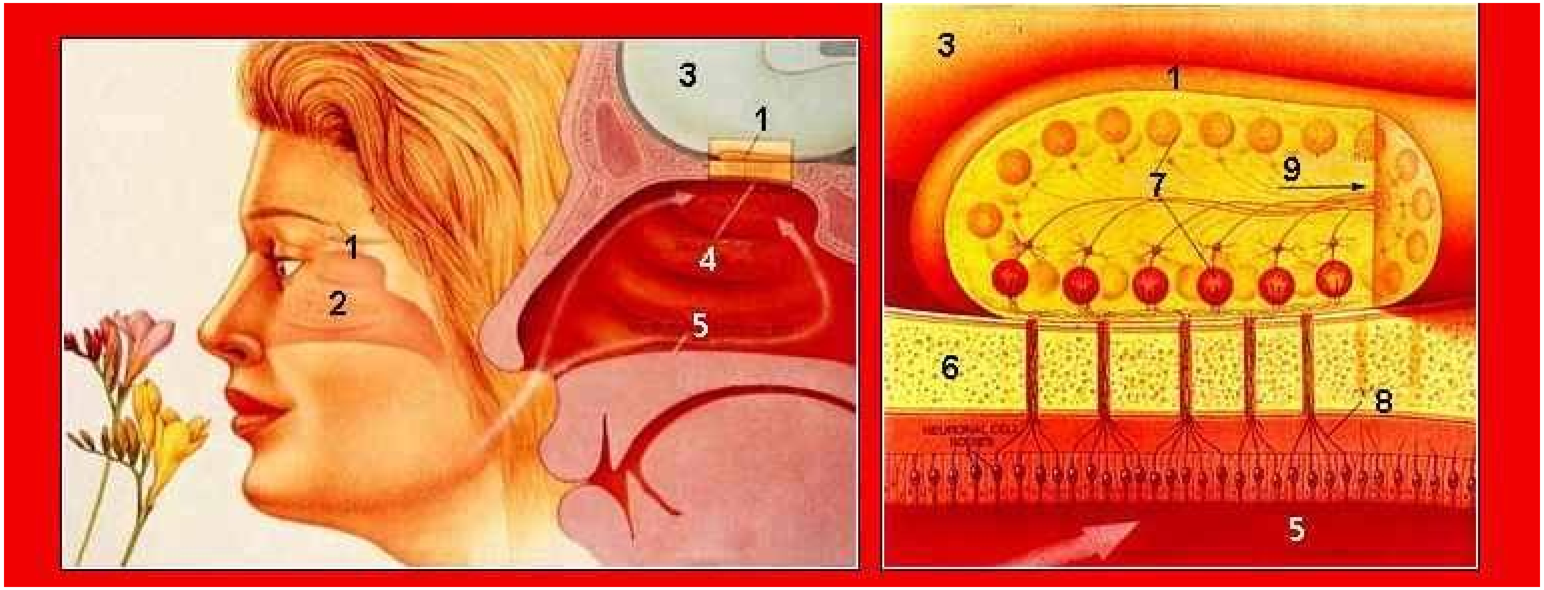
$k^* = ?$ $\quad F\big|^{1nm} = ?$

THE NOSE: the OLFACTORY sense （嗅覚、きゅうかく）

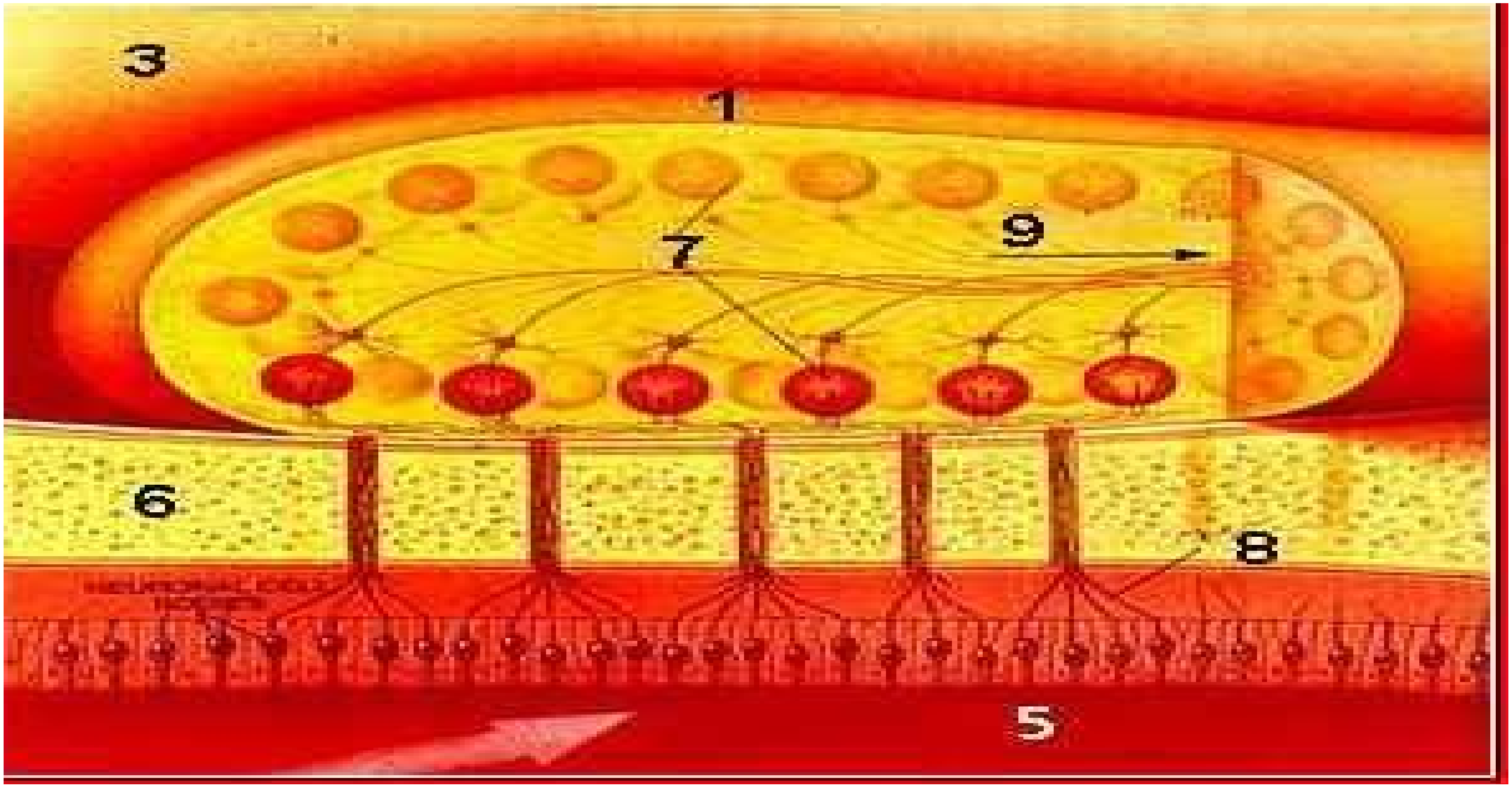




magnification of part of
olfactory organ



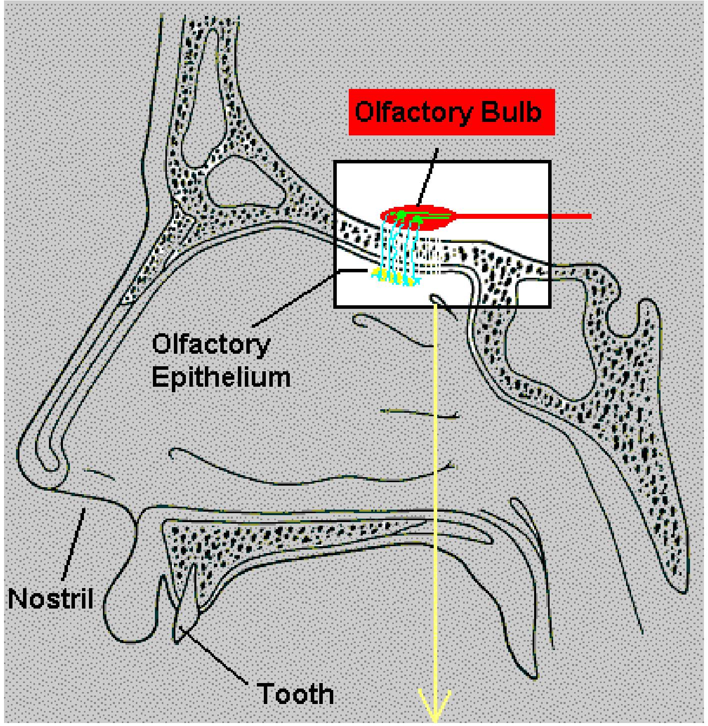
The olfactory sensors are located in yellow pigmented areas on each side of the inner nose. These areas are about 2.5 cm^2 in area each, and contain chemoreceptors, which are nerve cells responding to certain chemicals that are carried to the sensors as gases. The detailed functioning of these cells does not appear to be known.

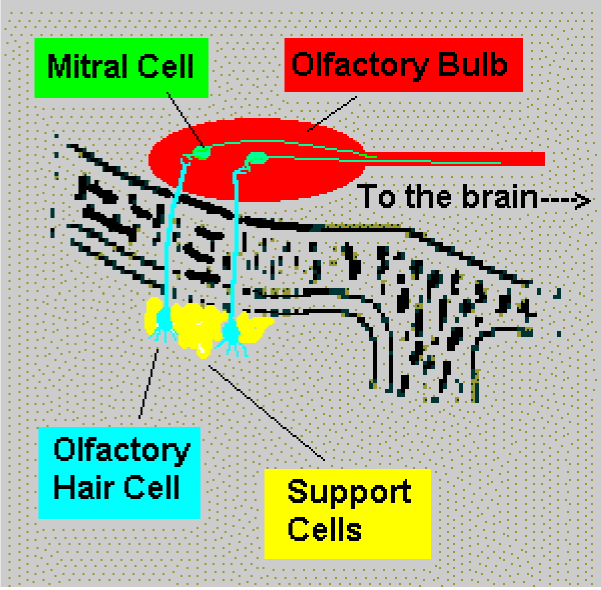


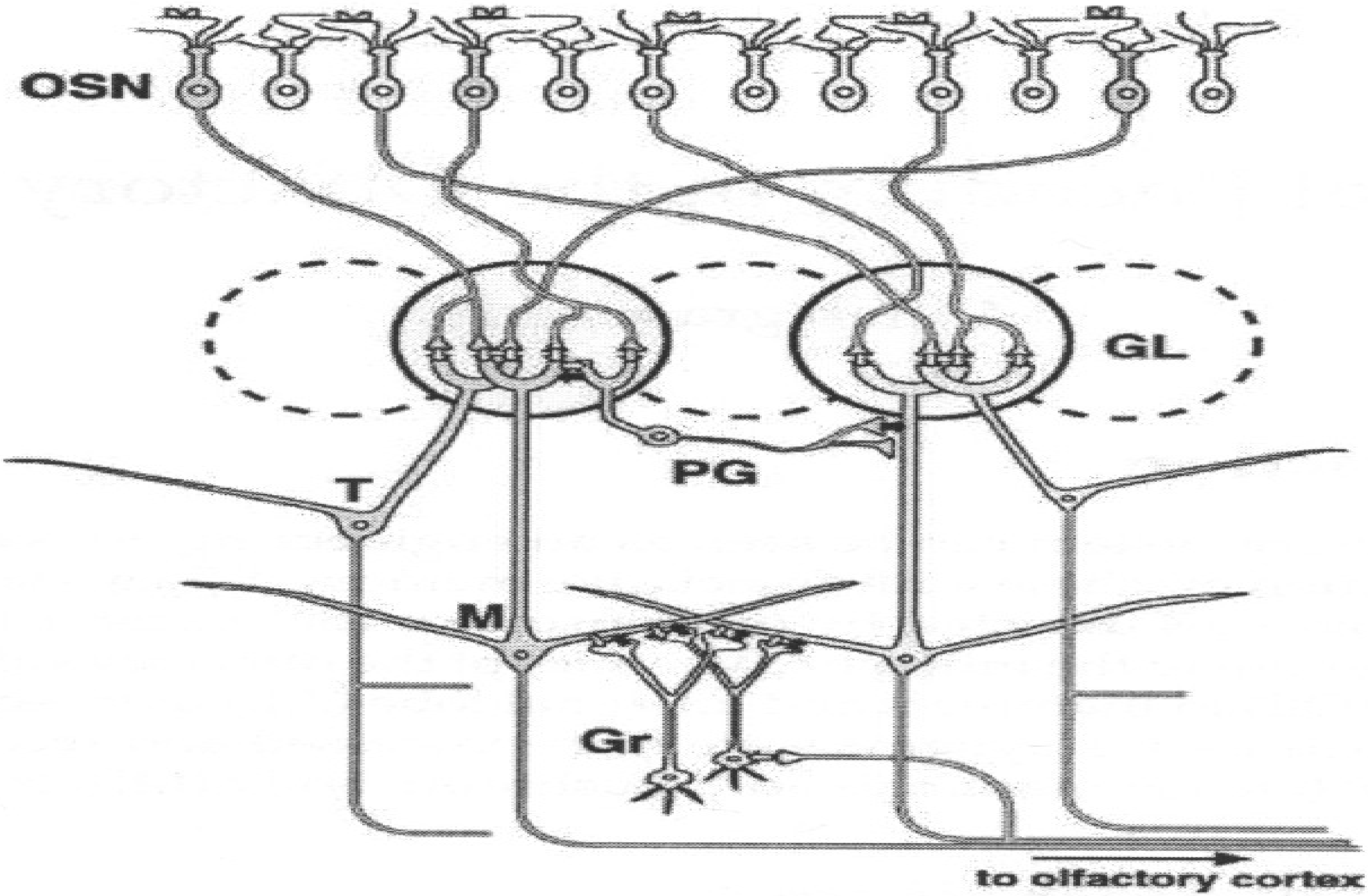
The glomeruli, each receiving signals from some 26 000 receptors. The olfactory bulbs on either side are cross-connected. Finally nerve fibres reach the olfactory areas in the anterior lobes of the brain.

- The olfactory sense is some 10000 times as sensitive as taste, and is primarily responsible for the flavours of food.

- The types of olfactory sensations are 6: fruity, flowery, resinous, spicy, foul (rotten), and burned.






OSN
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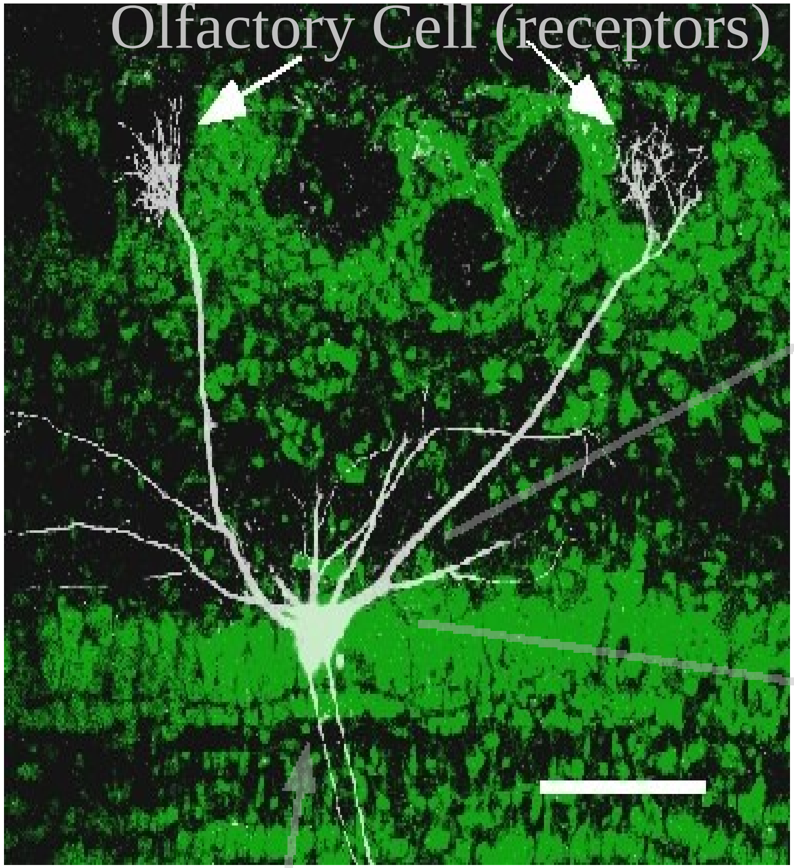
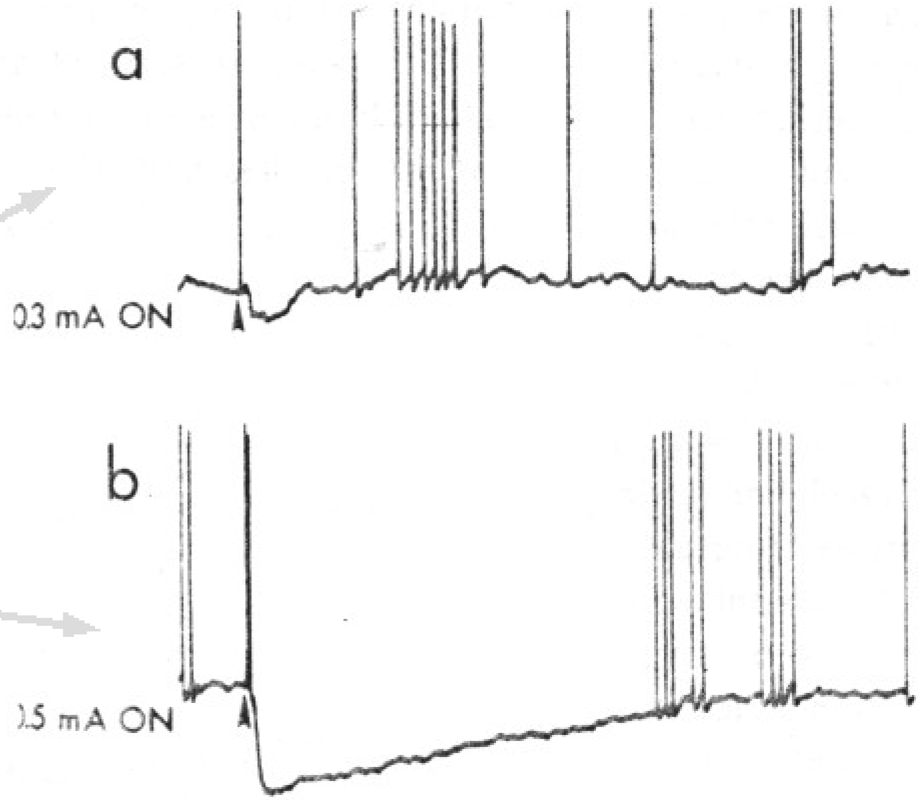
Gr
to olfactory cortex

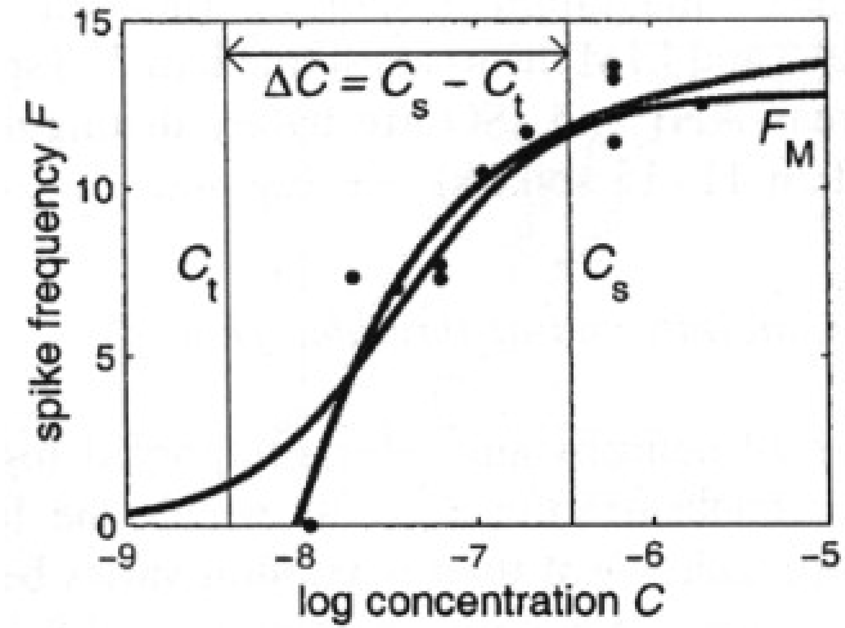
Signal from Mitral Cells





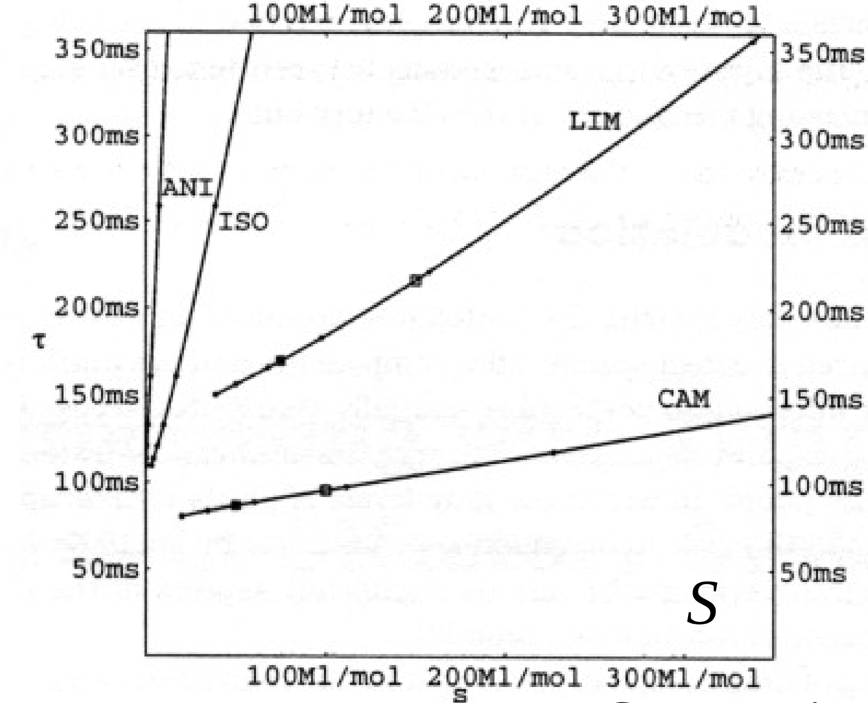
Mitral Cell

スパイク周波数



香料密度

スパイクの時間間隔



香料密度

S=sparsity

$$\tau = \tau_0 + Gs$$

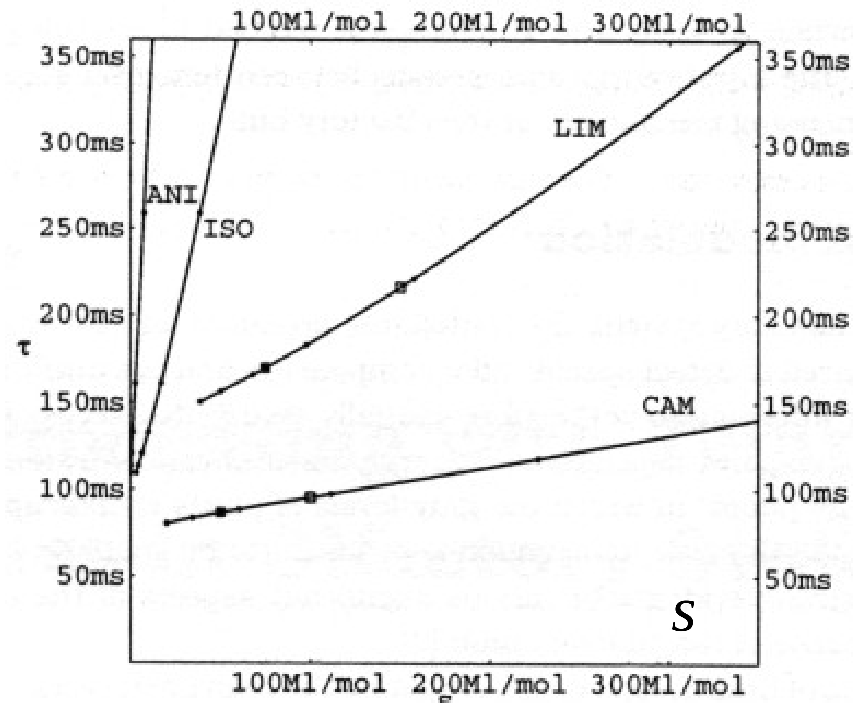
$$\tau = \tau_0 + Gs$$

Gはガインといます。

香料によってGは違います。

例：$G_{camphor}$=1.0
G_{lemon}=2.5
$G_{anisole}$=20

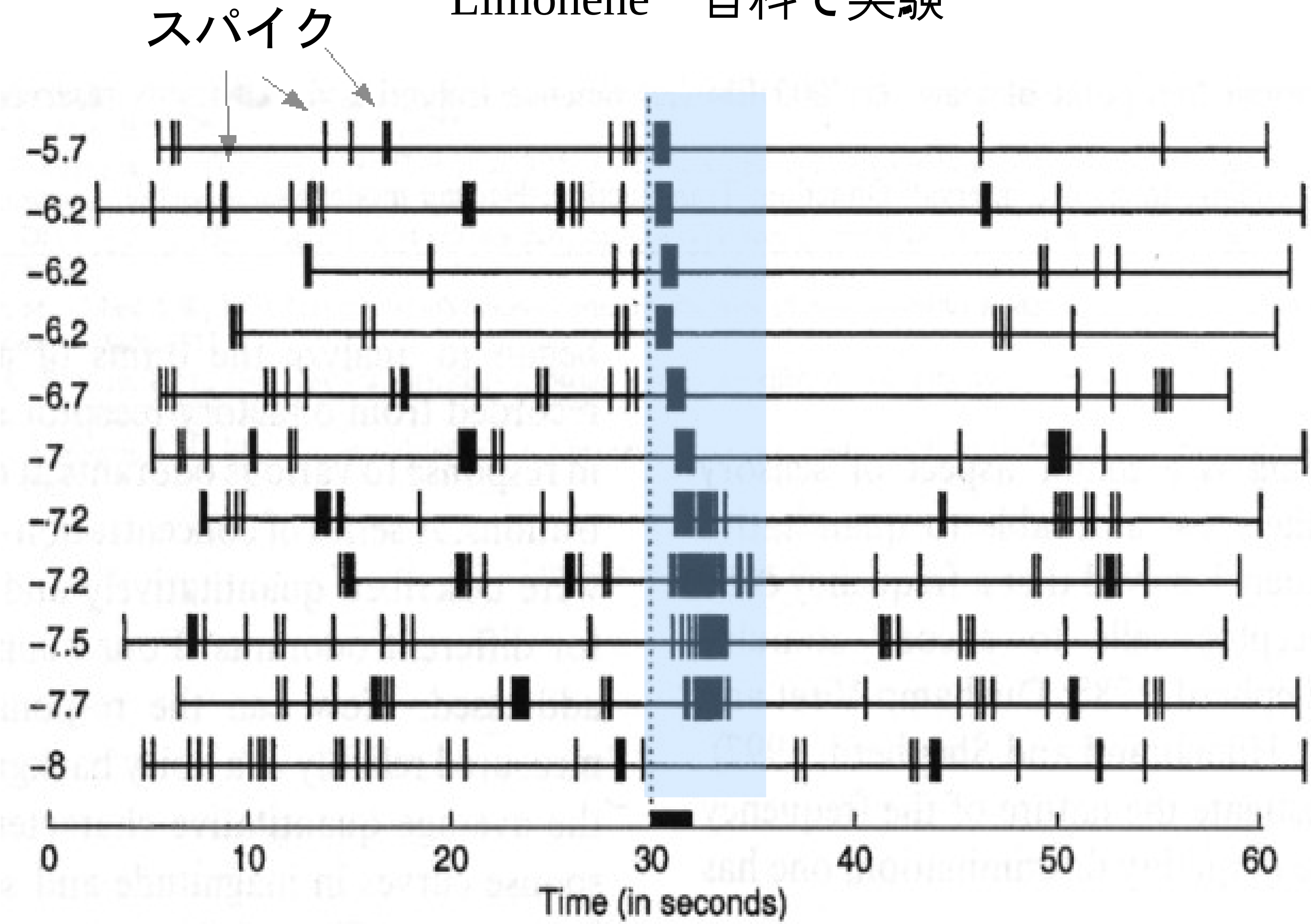
スパイクの時間間隔



香料密度

s=sparsity

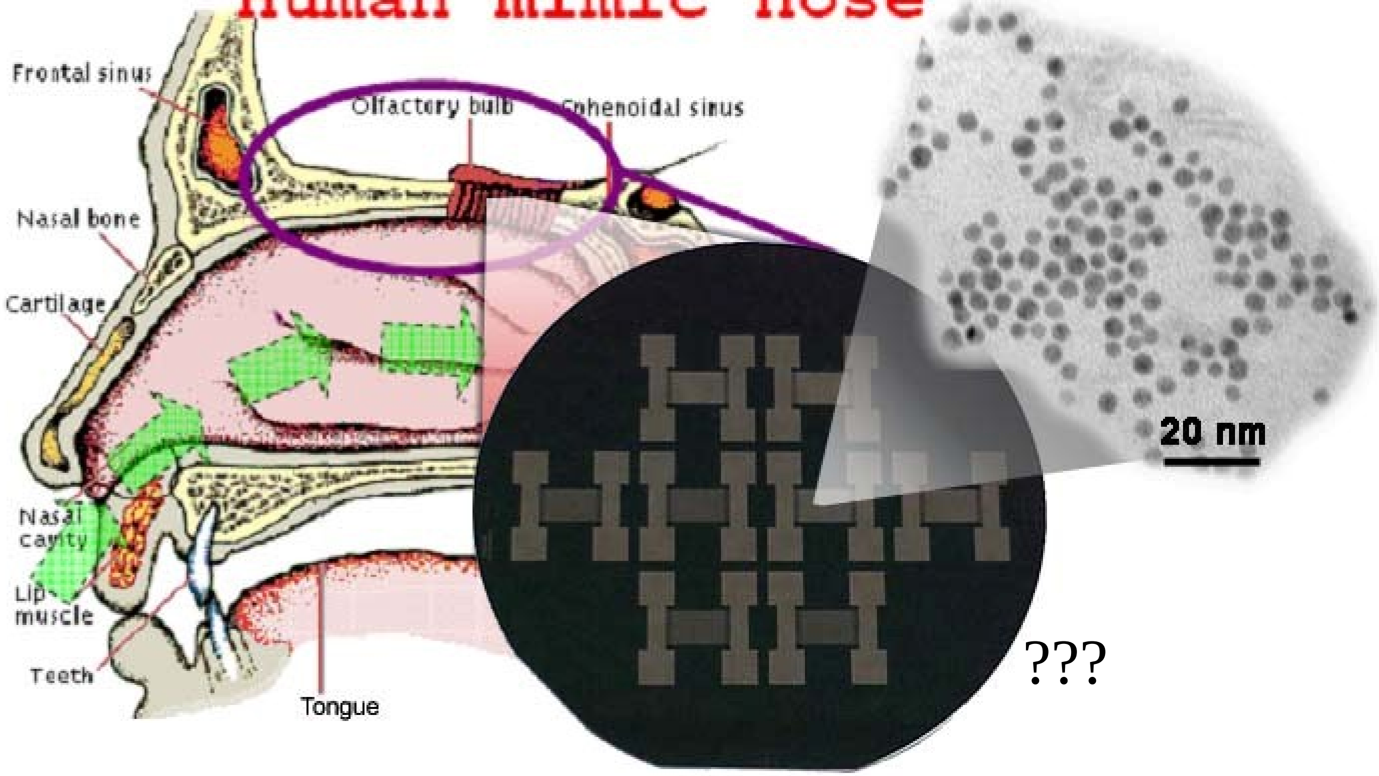
Limonene　香料で実験



人工嗅覚

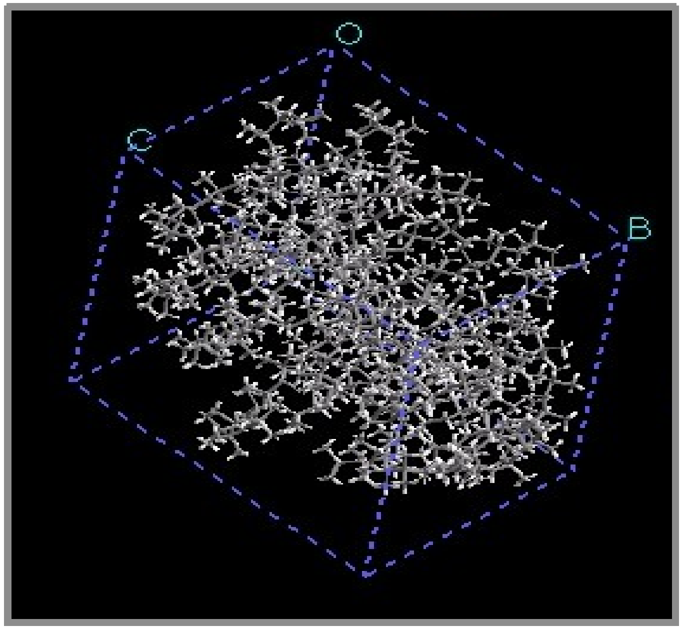
JPL 人工嗅覚デバイス

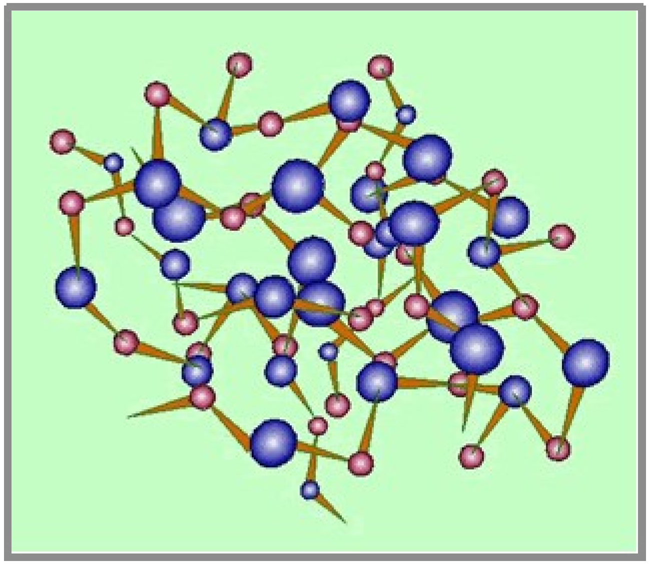
Human mimic nose

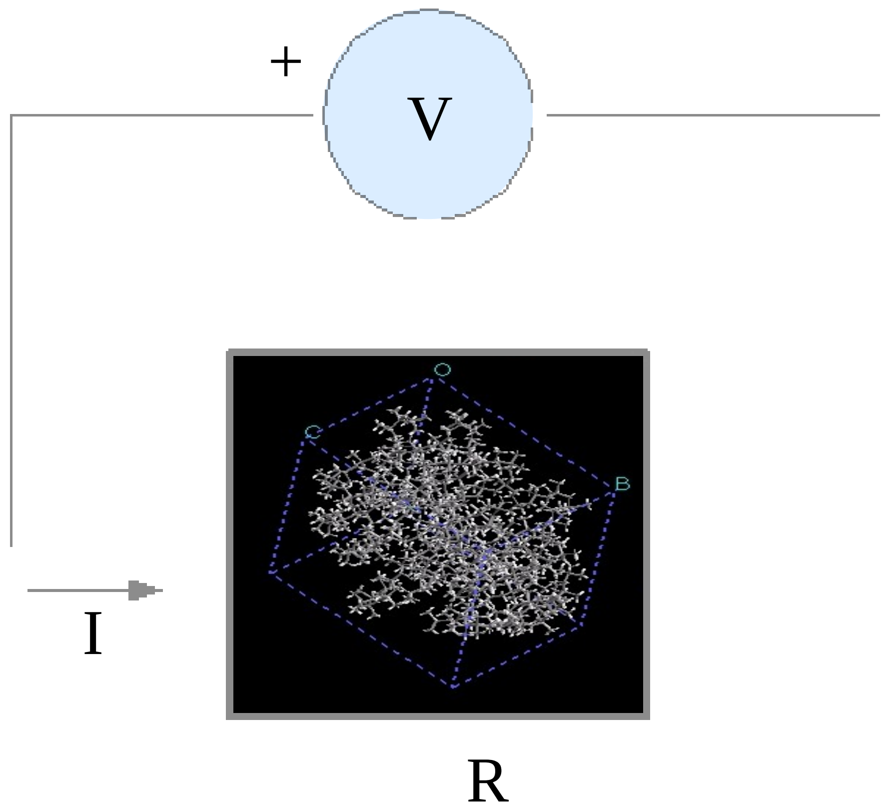


???

Polymers complex structure



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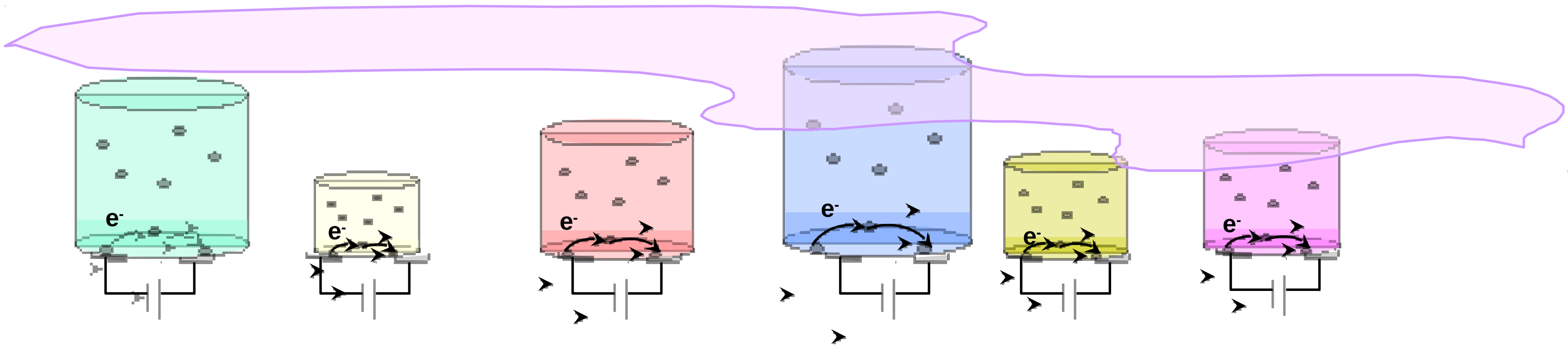
C
B

THE ELECTRONIC NOSE SMELLS SOMETHING

Each polymer changes its size, and therefore its resistance, by a different amount, making a pattern of the change



If a different compound had caused the air to change, the pattern of the polymer films' change would have been different:

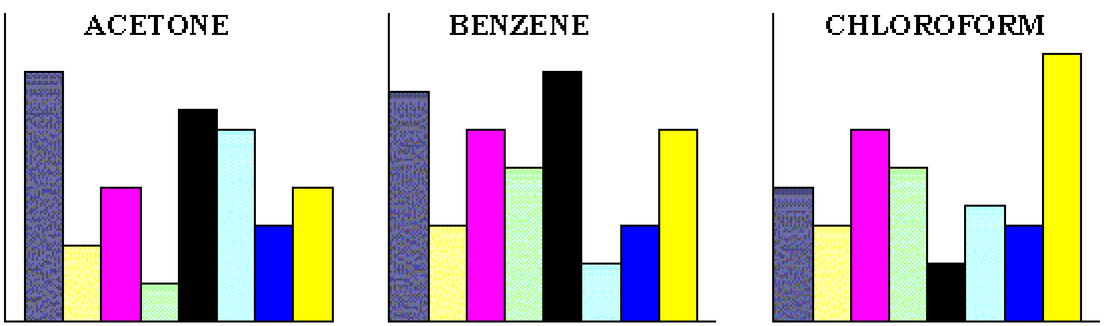
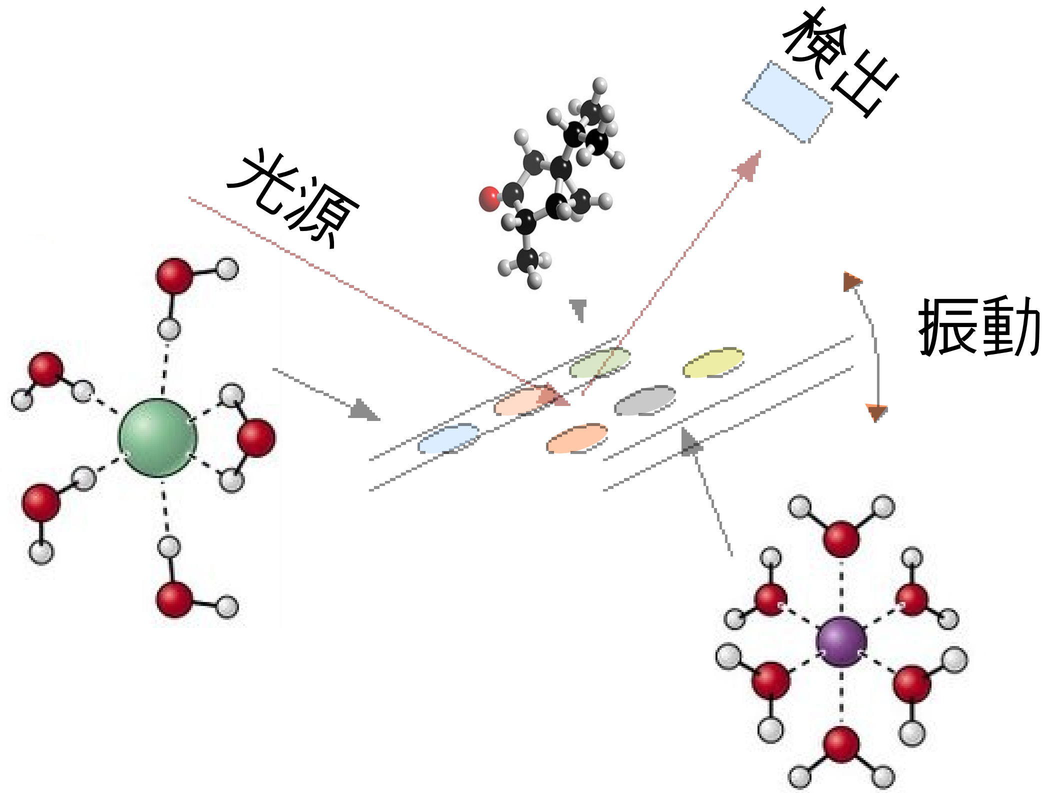


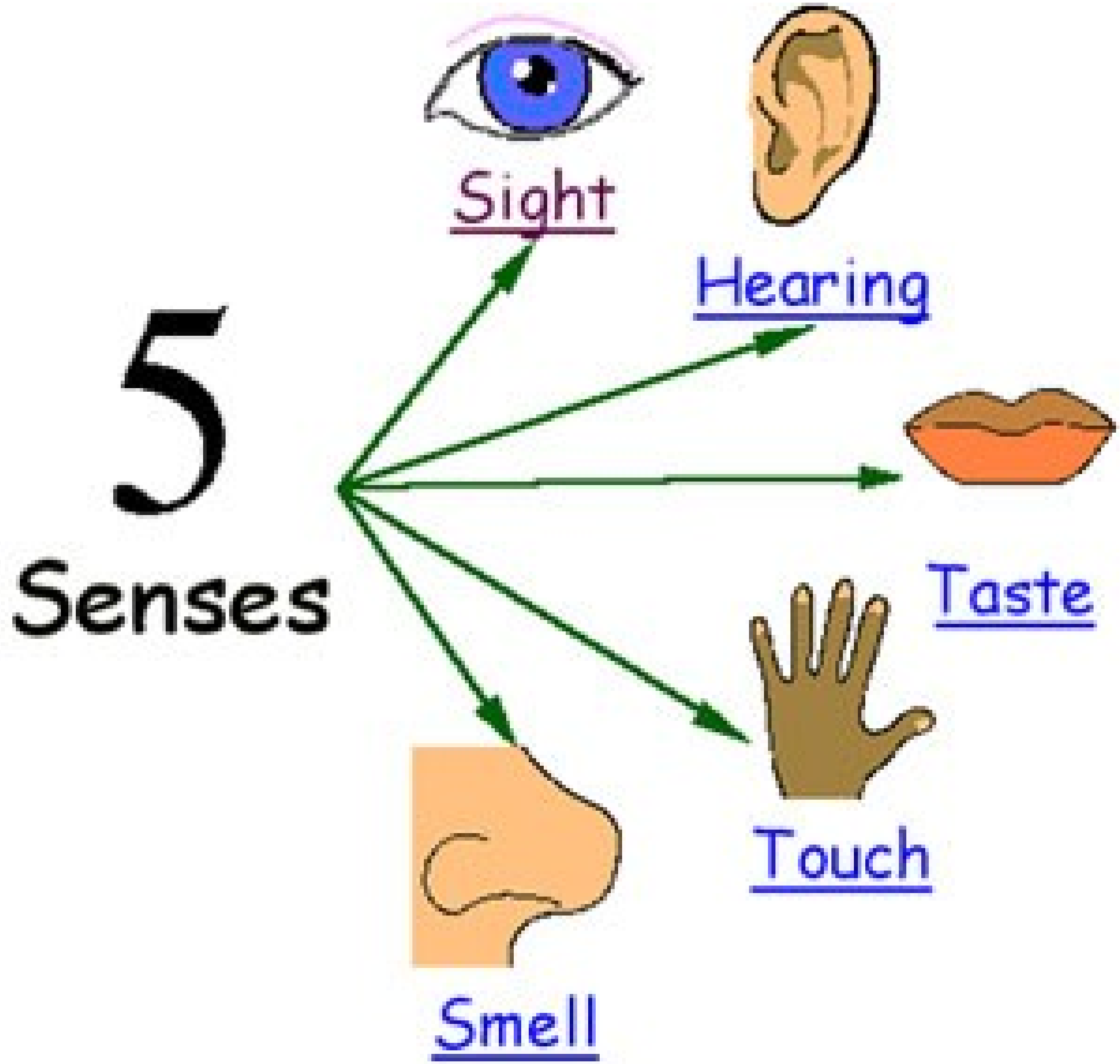
Figure 1.

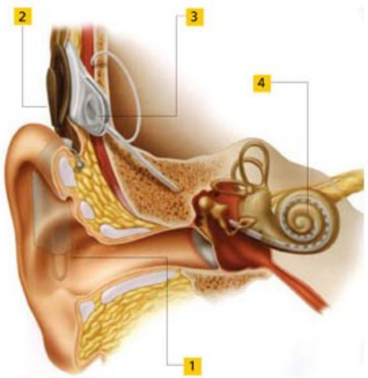
AFM NOSE



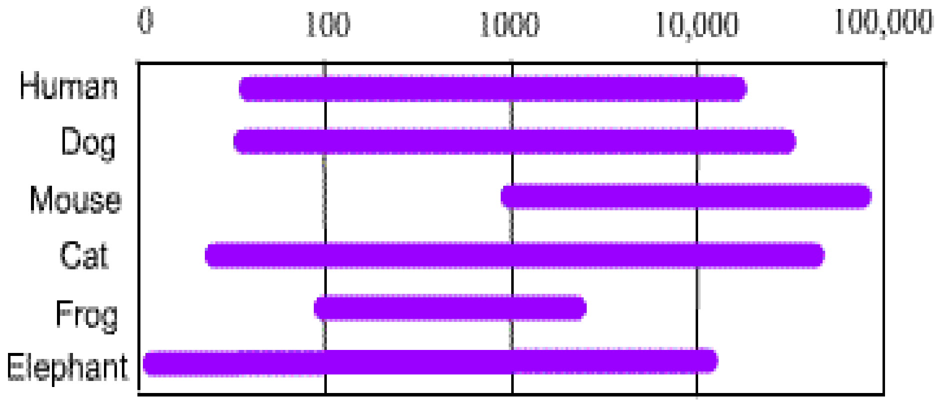
結合する分子によって振動のパターンが異なる。

THE EAR: the HEARING sense （聴覚、ちょうかく）


5
Senses
Sight
Hearing
Taste
Touch
Smell



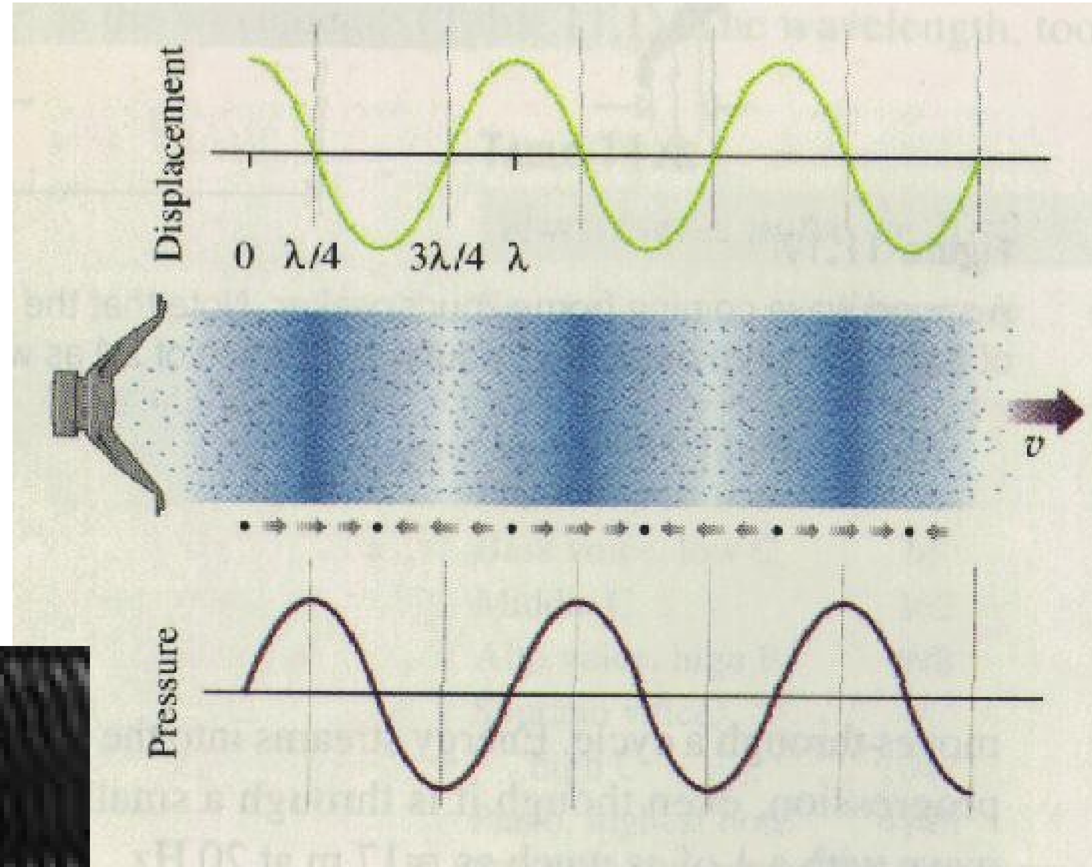
Frequency

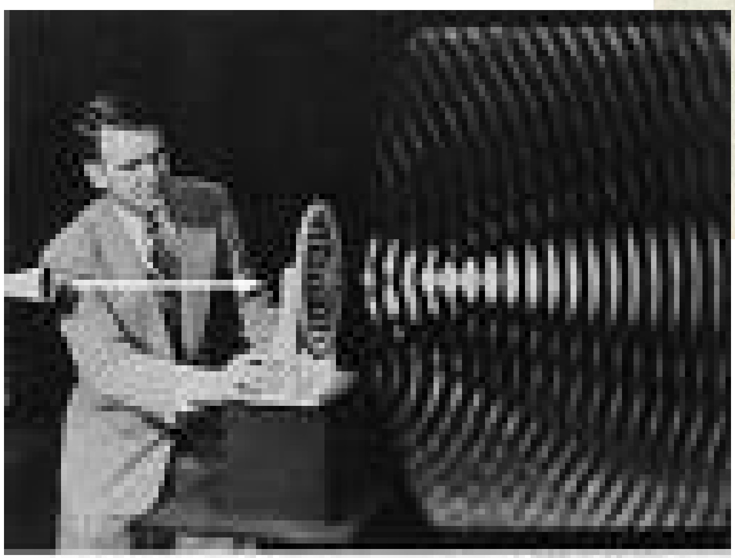


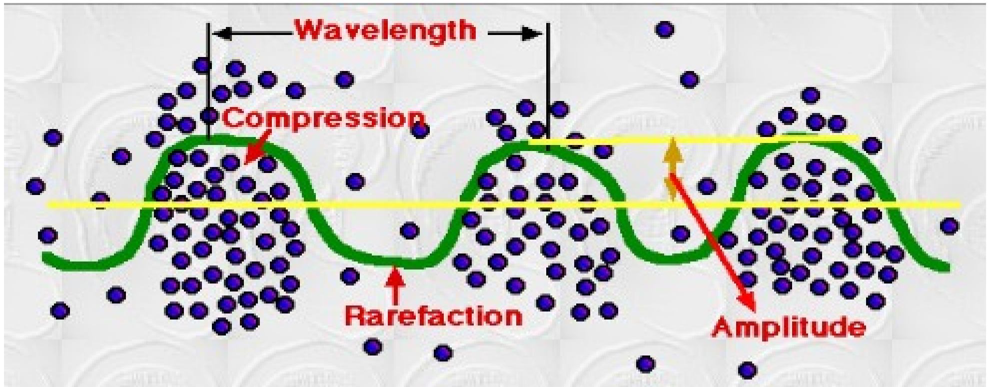
Noise	Decibels
Whisper	20
Normal Talking	50-60
Car Traffic	70
Alarm Clock	80
Lawn Mower	95
Rock Concert	100
Jackhammer	115
Jet Engine	130
Gun Shot	140

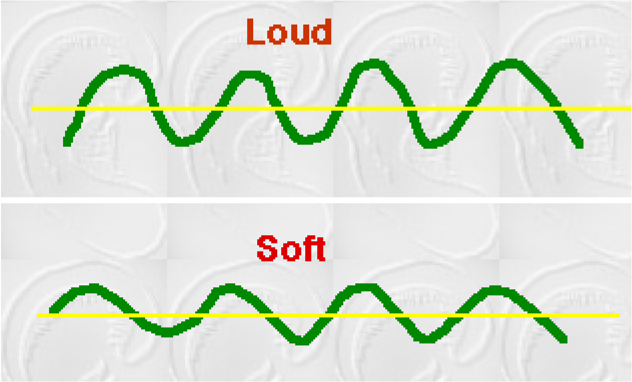
Amplitude

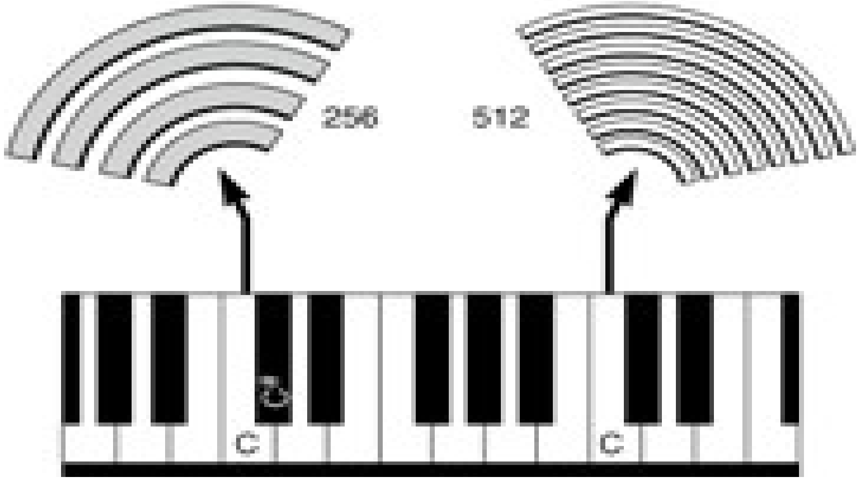
The sound it is a PRESSURE WAVE

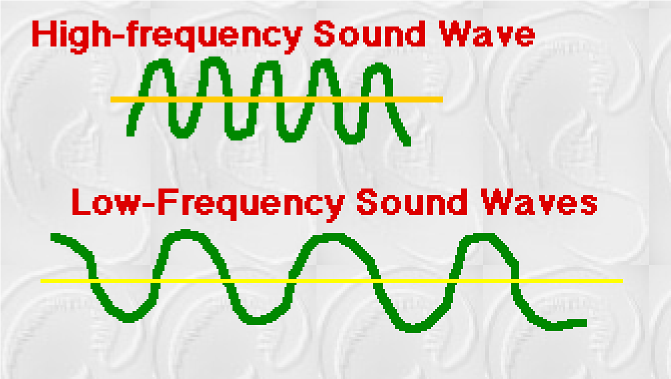





Wavelength
Compression
Rarefaction
Amplitude


Loud
Soft


256
512
C
C


High-frequency Sound Wave
Low-Frequency Sound Waves

The sound it is a PRESSURE WAVE

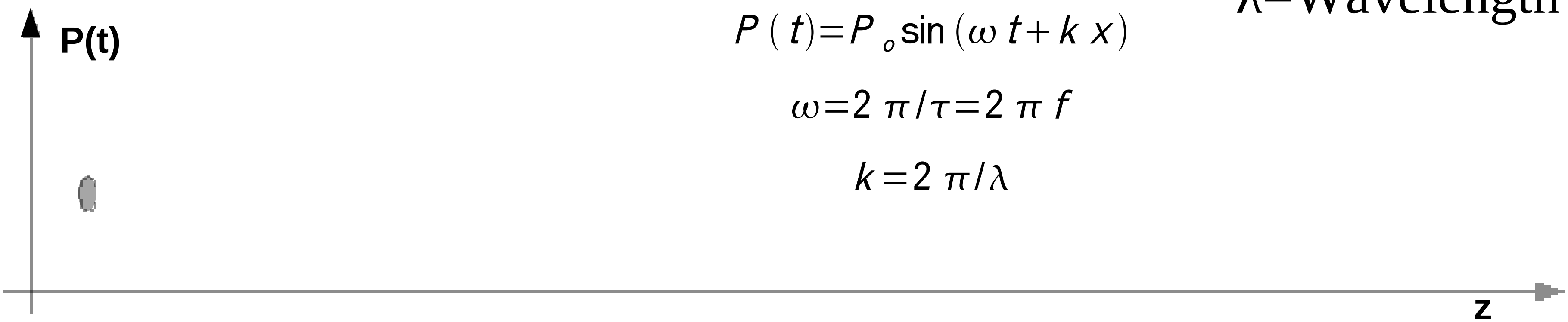
空気の圧力

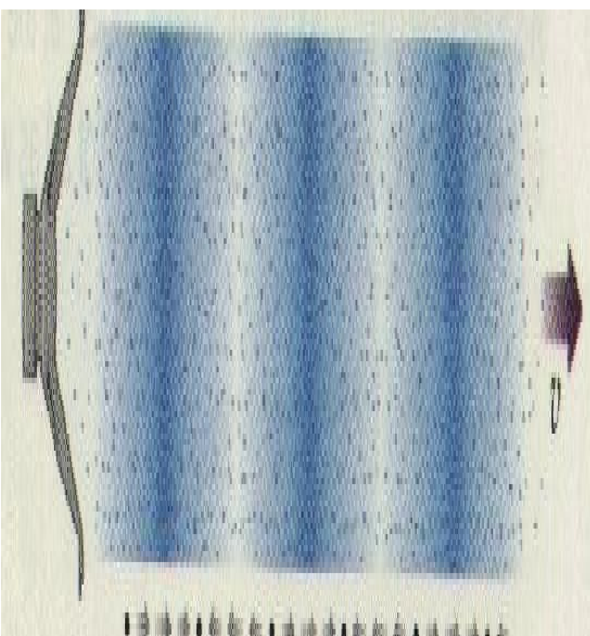
f=Frequency
λ=Wavelength

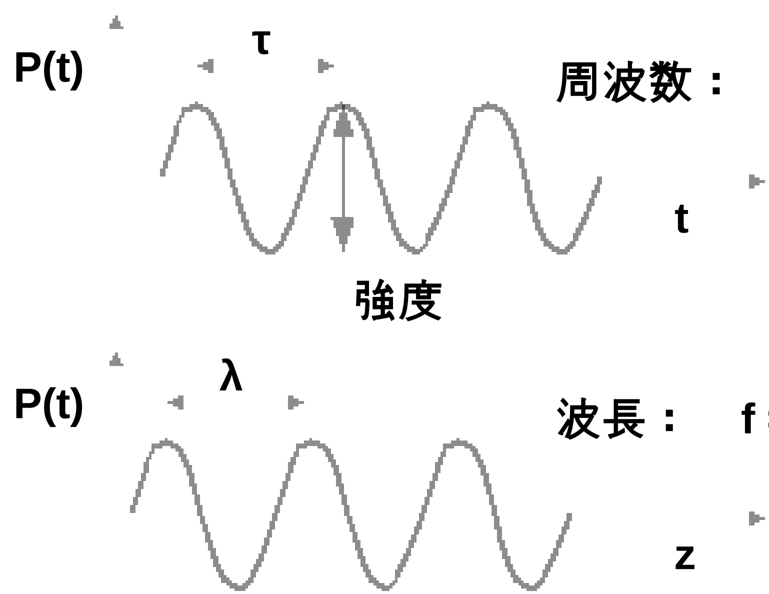
$$P(t) = P_o \sin(\omega t + k x)$$

$$\omega = 2\pi/\tau = 2\pi f$$

$$k = 2\pi/\lambda$$



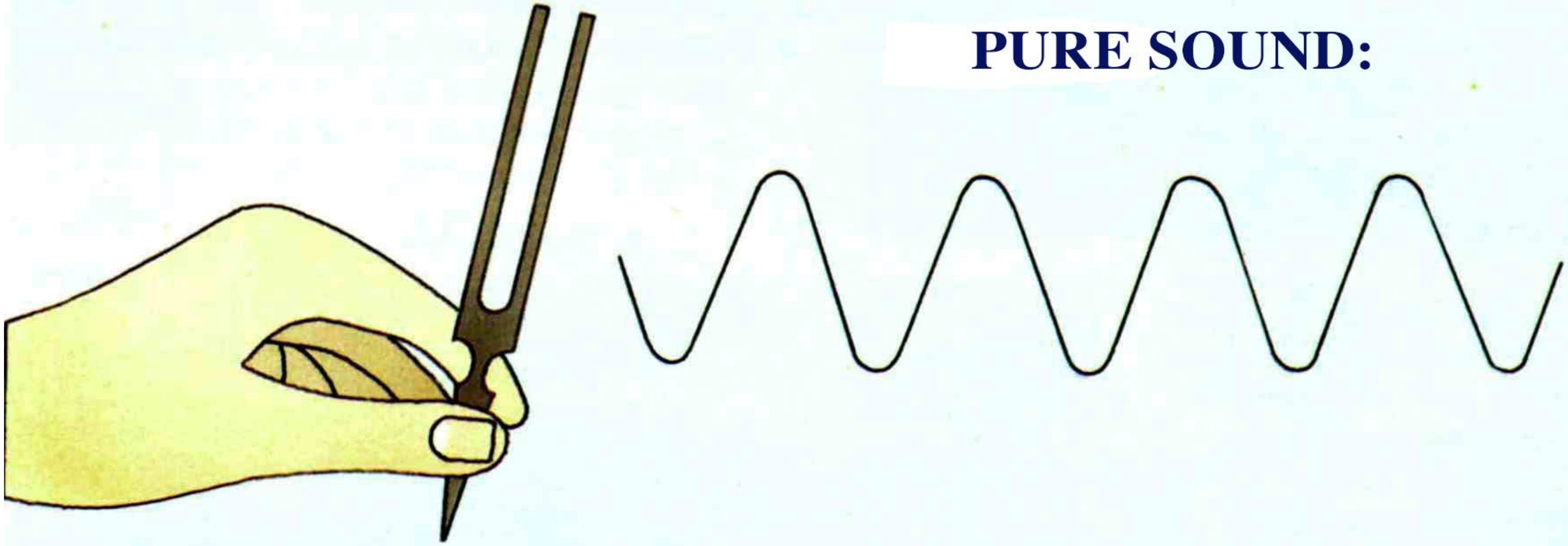




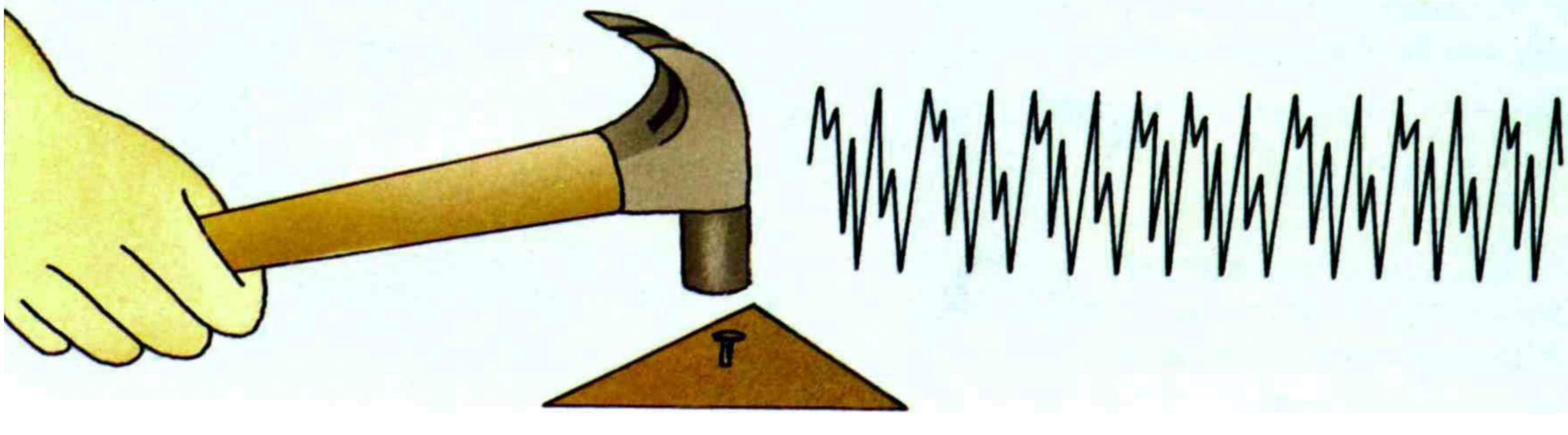
周波数： $f = 1/\tau$

波長： $f = \lambda$

PURE SOUND:

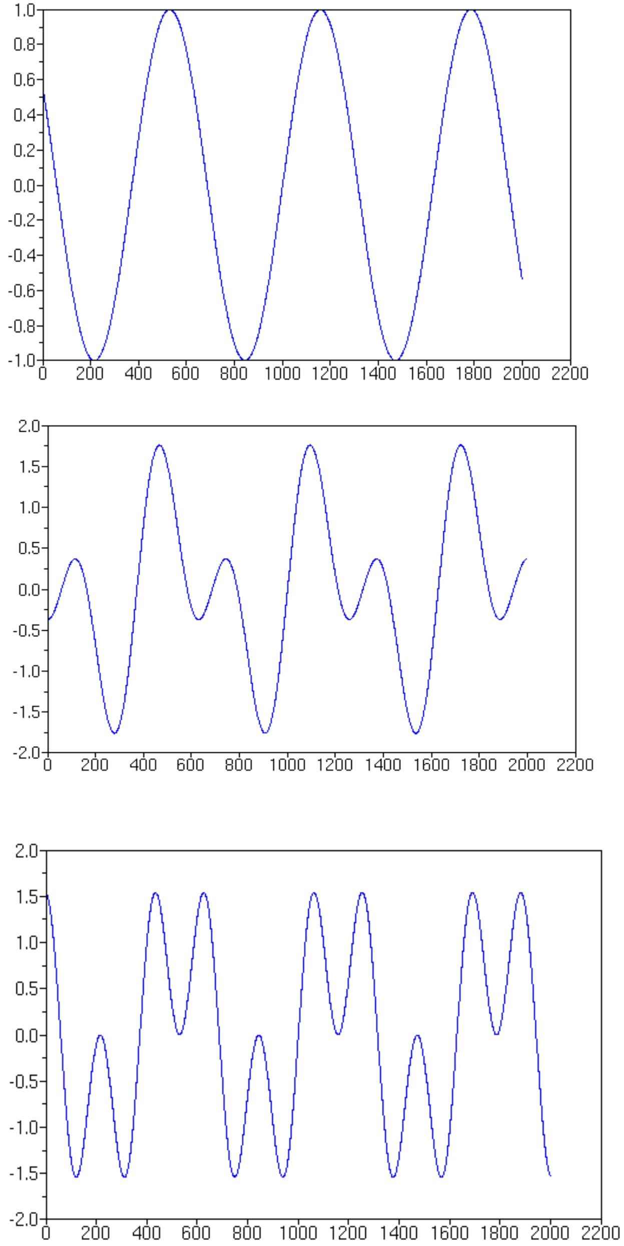


NOISE:

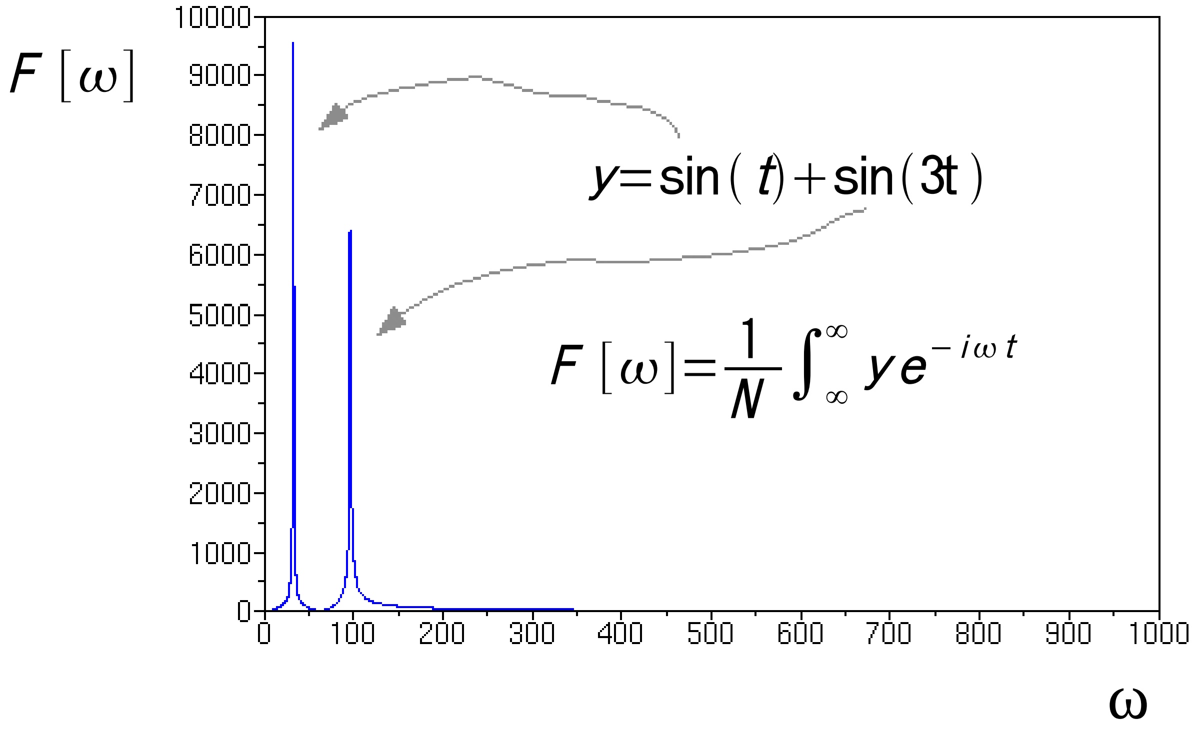


The sound SPECTRUM

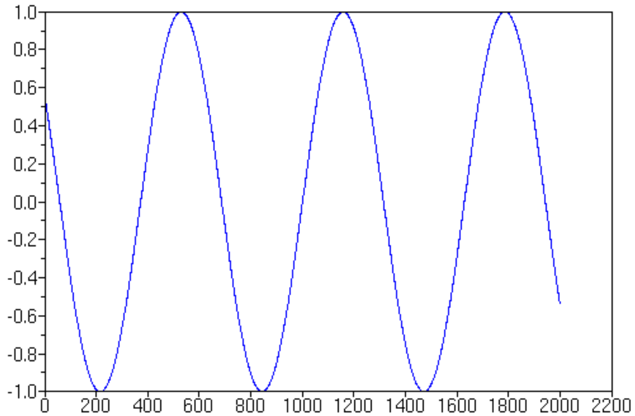
$$y = \sin(t)$$
$$y = \sin(t) + \sin(2t)$$
$$y = \sin(t) + \sin(3t)$$



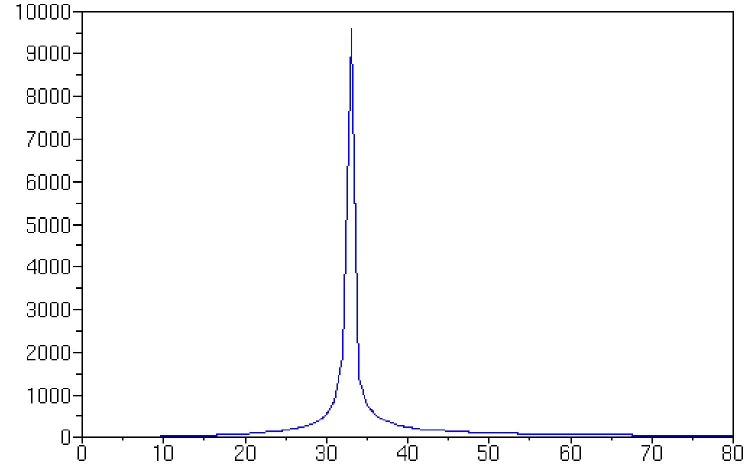
The FOURIER trasformation



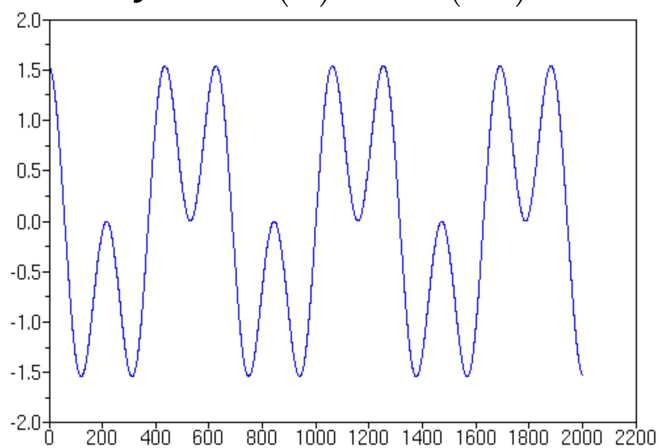
$$y = \sin(t)$$



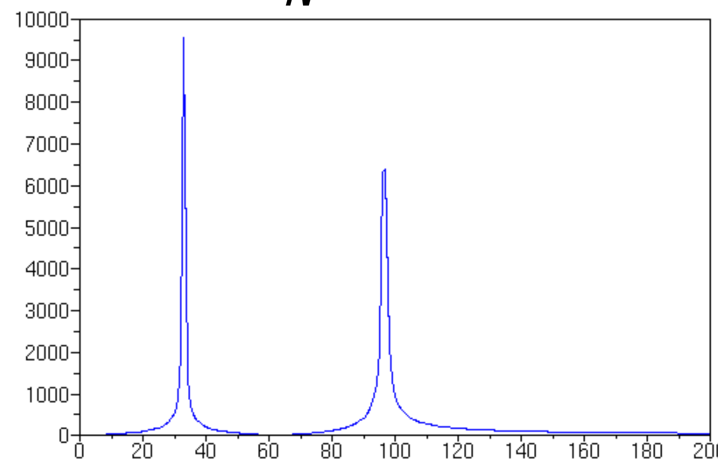
$$F[\omega] = \frac{1}{N}\int_{\infty}^{\infty} y e^{-i\omega t}$$



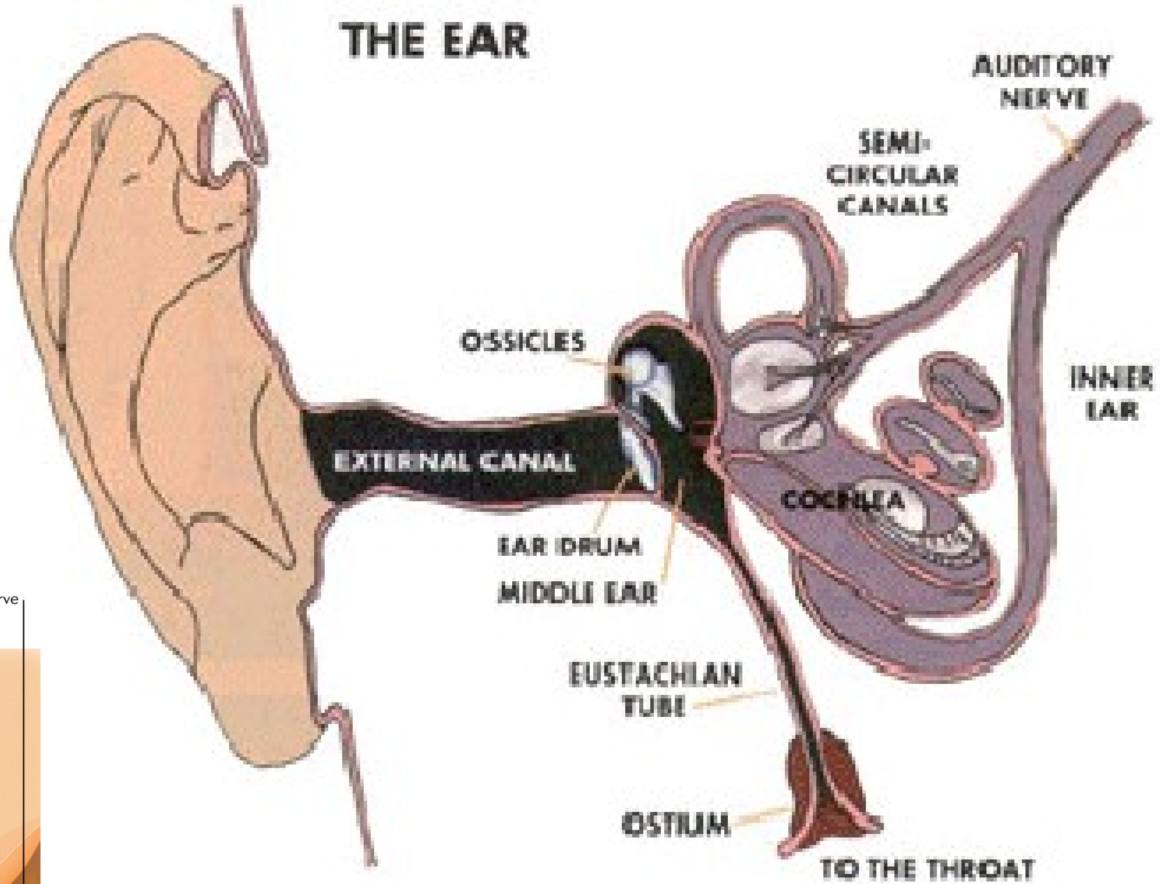
$$y = \sin(t) + \sin(3t)$$

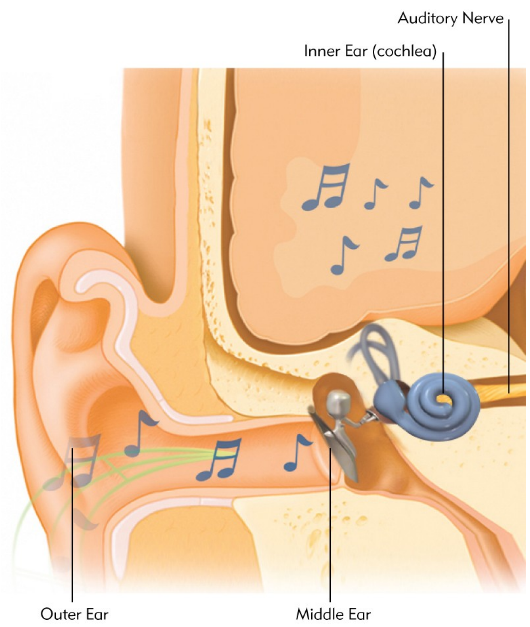


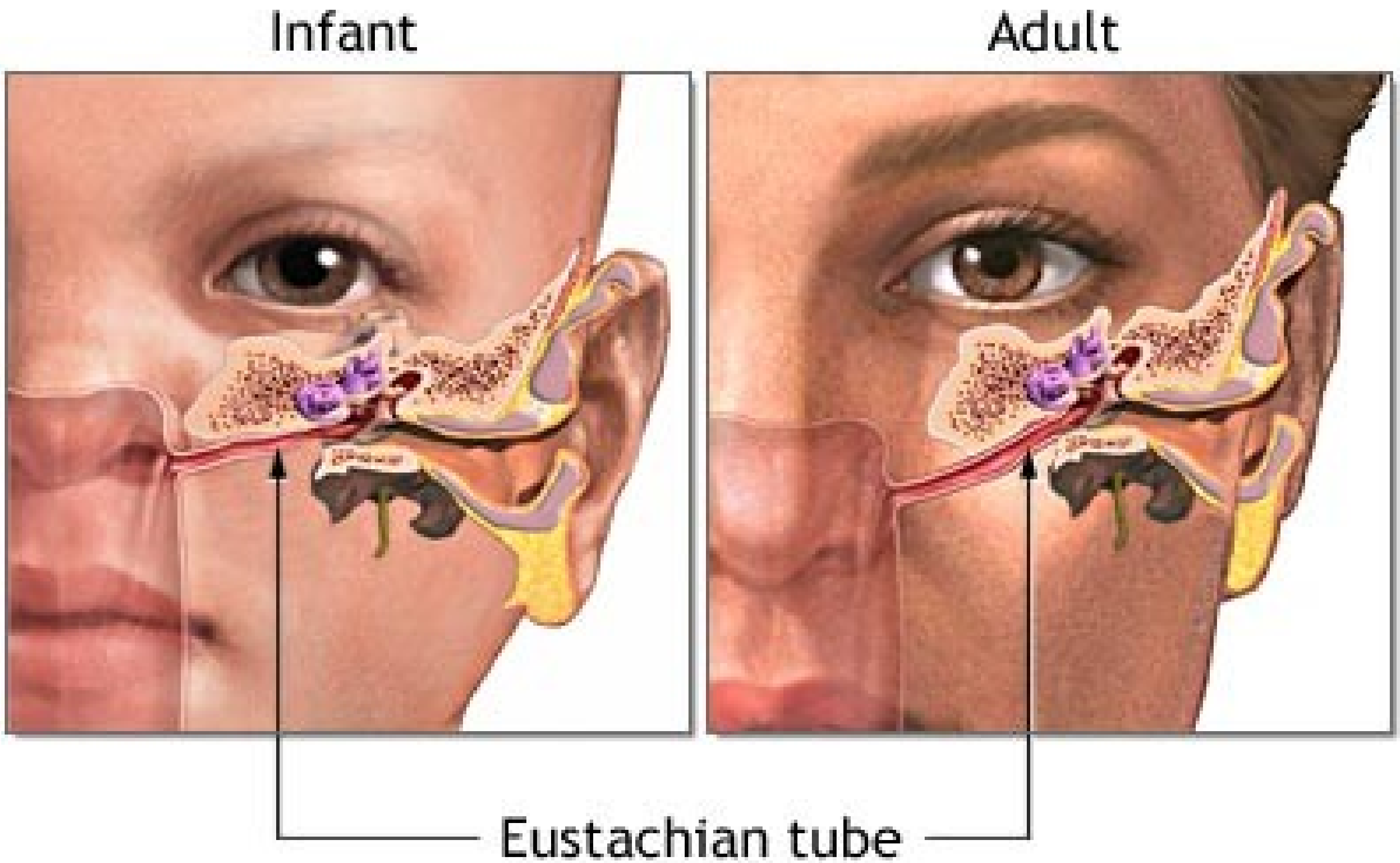
$$F[\omega] = \frac{1}{N}\int_{\infty}^{\infty} y e^{-i\omega t}$$

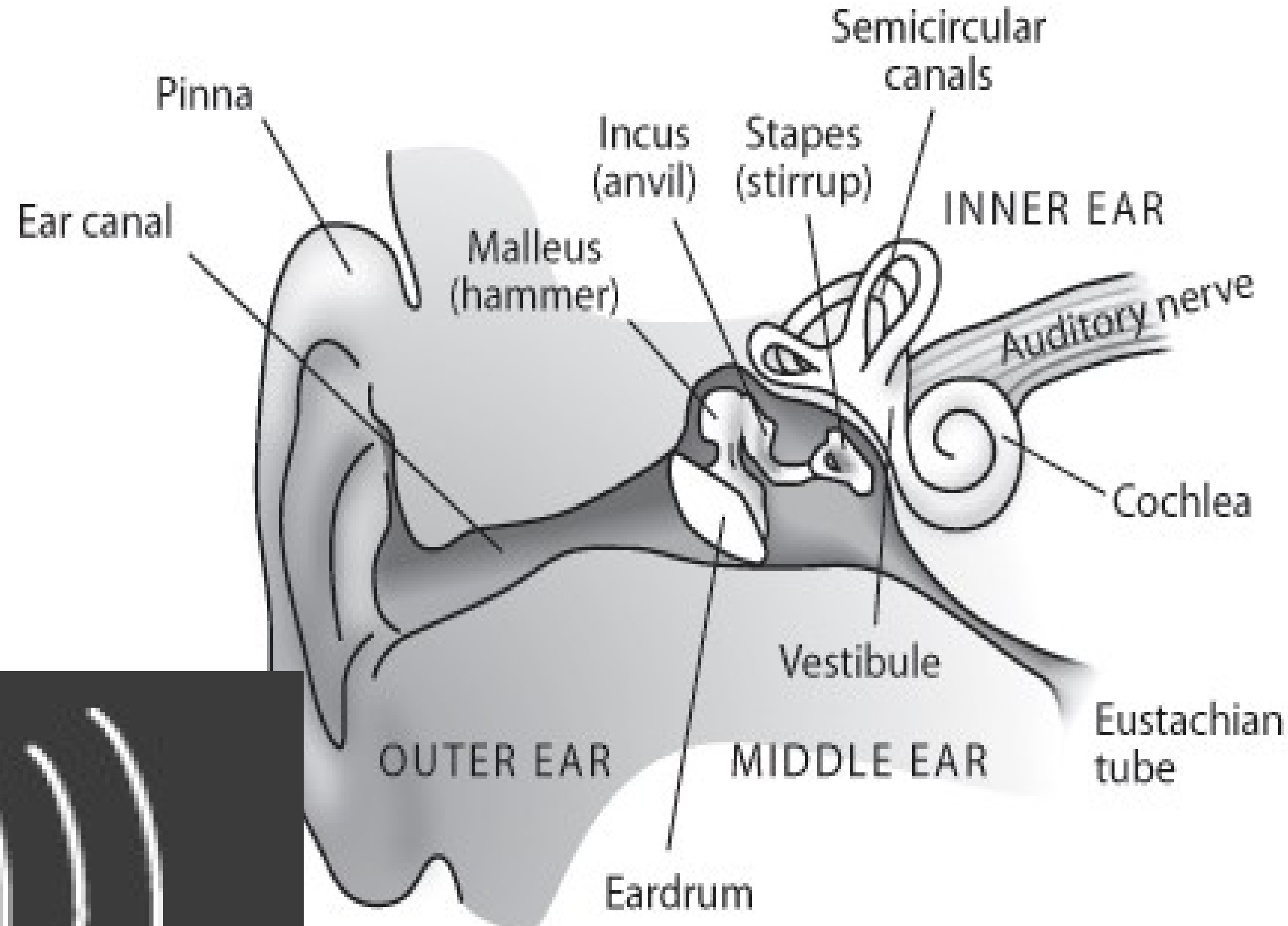


Inner Ear
Middle Ear
Outer Ear



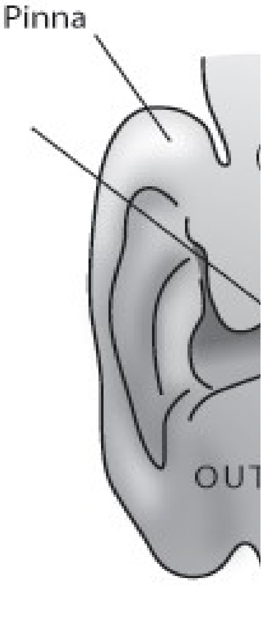



Infant
Adult
Eustachian tube

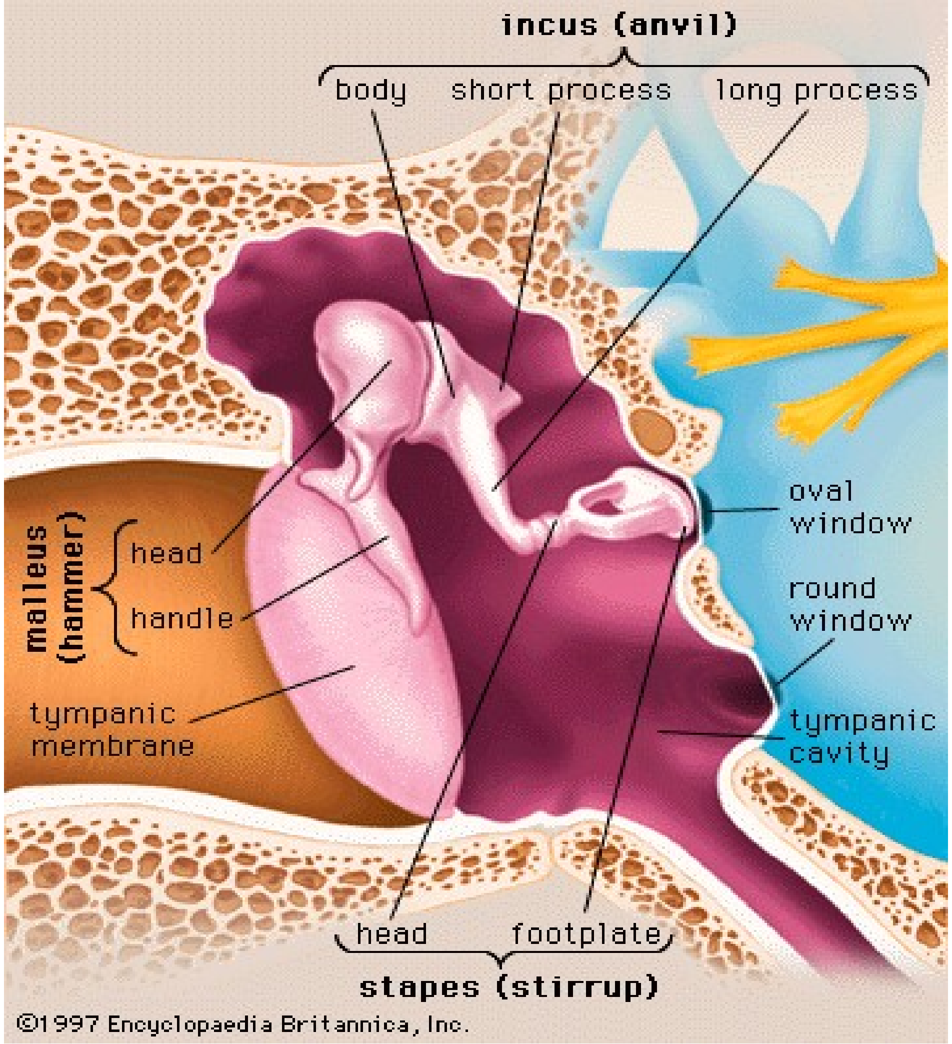

Pinna
Ear canal
Malleus (hammer)
Incus (anvil)
Stapes (stirrup)
Semicircular canals
INNER EAR
Auditory nerve
Cochlea
Vestibule
Eustachian tube
OUTER EAR
MIDDLE EAR
Eardrum

Outer Ear

- the “Pinna” is not frequency flat. Different frequencies are detected at different intensities.

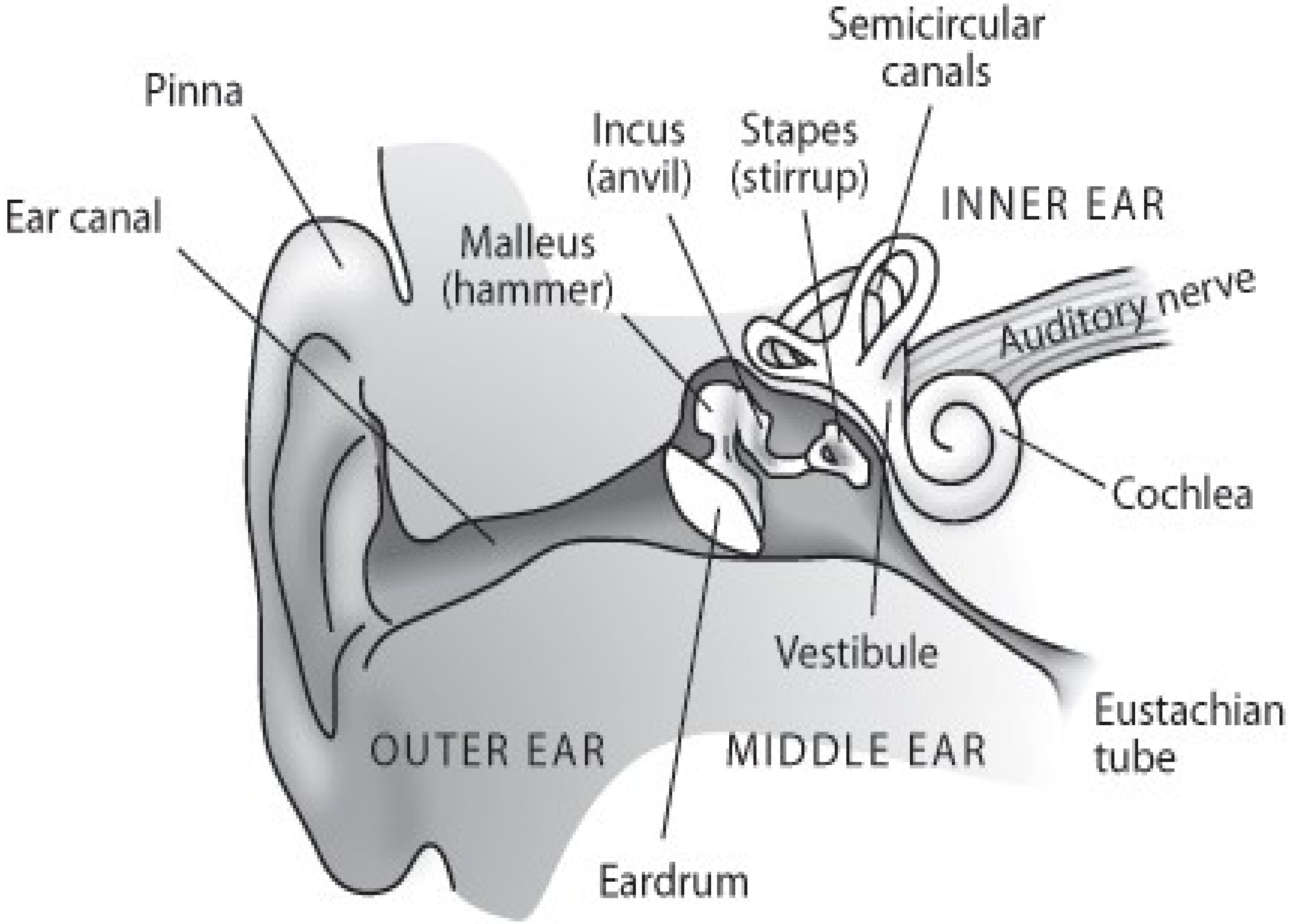


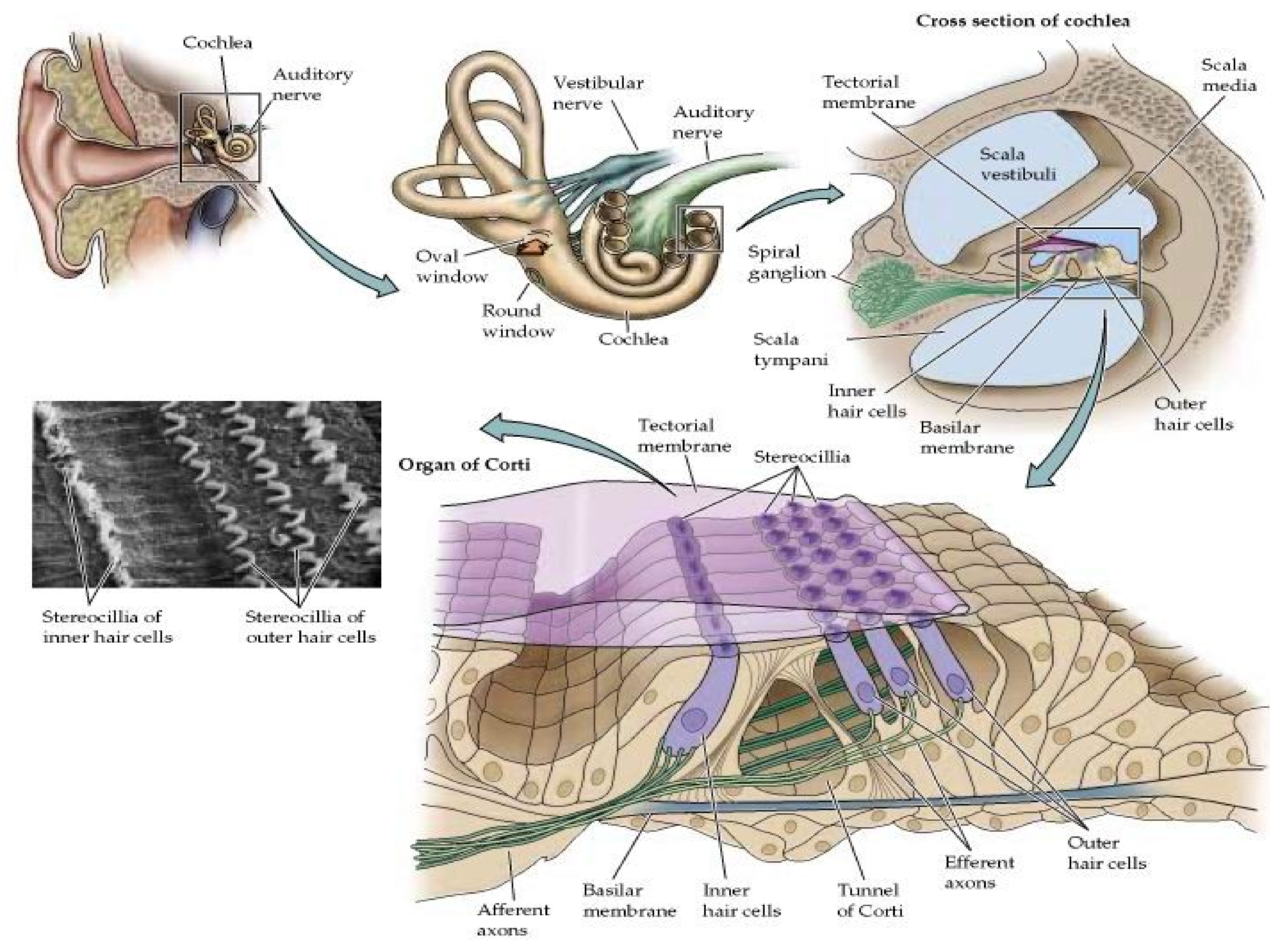
Middle Ear



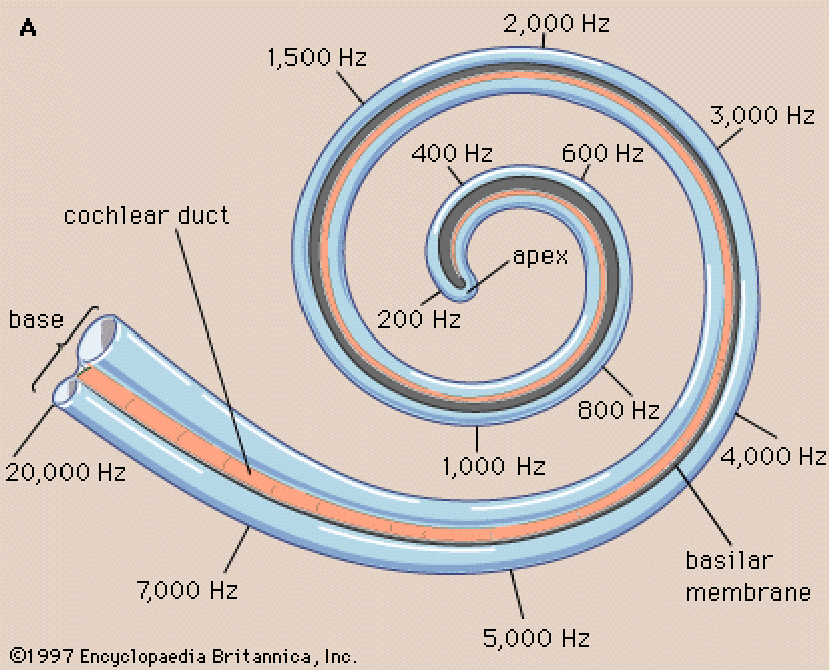
incus (anvil)
body
short process
long process
malleus (hammer)
head
handle
tympanic membrane
oval window
round window
tympanic cavity
head
footplate
stapes (stirrup)
©1997 Encyclopaedia Britannica, Inc.

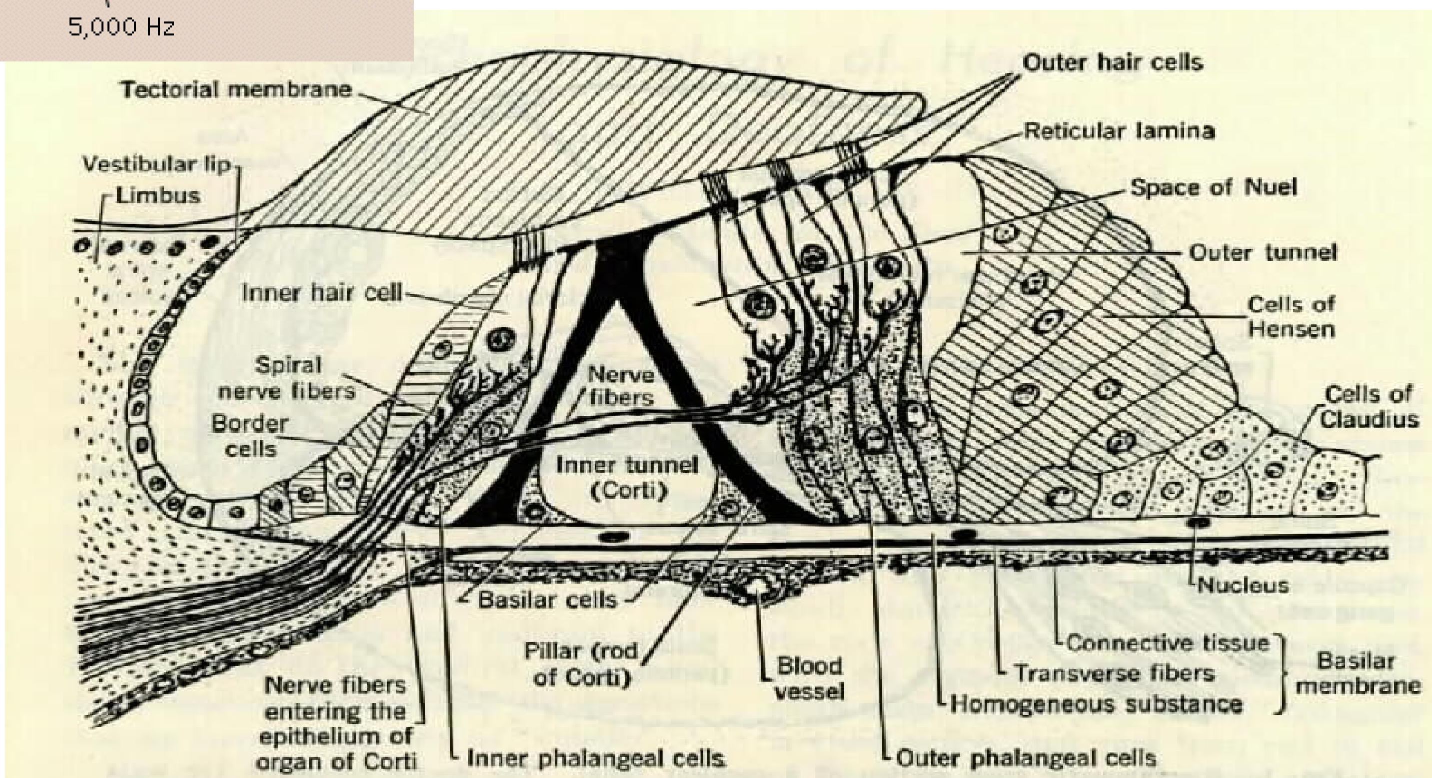
Inner Ear


Semicircular canals
Pinna
Incus (anvil)
Stapes (stirrup)
INNER EAR
Ear canal
Malleus (hammer)
Auditory nerve
Cochlea
Vestibule
Eustachian tube
OUTER EAR
MIDDLE EAR
Eardrum

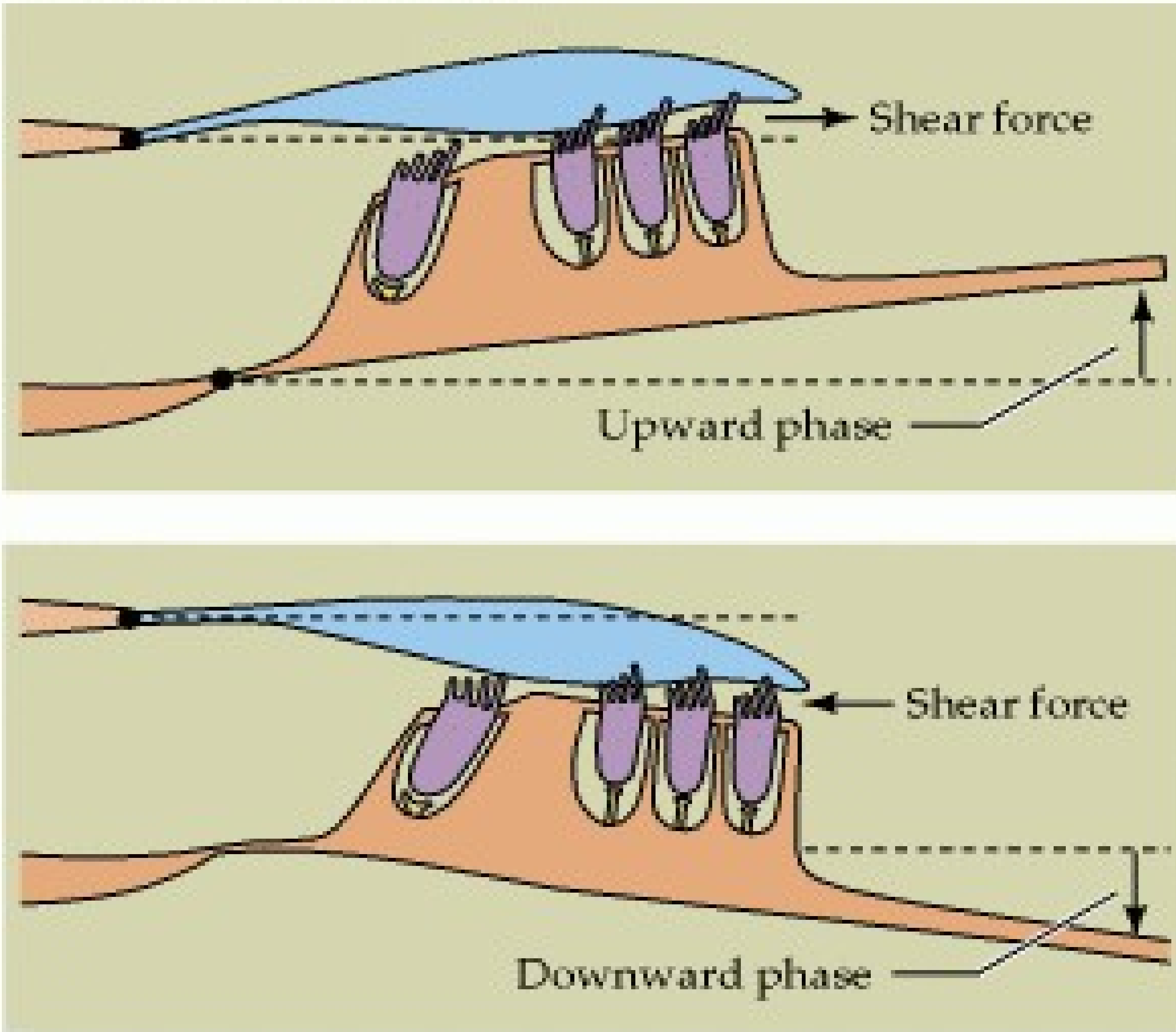


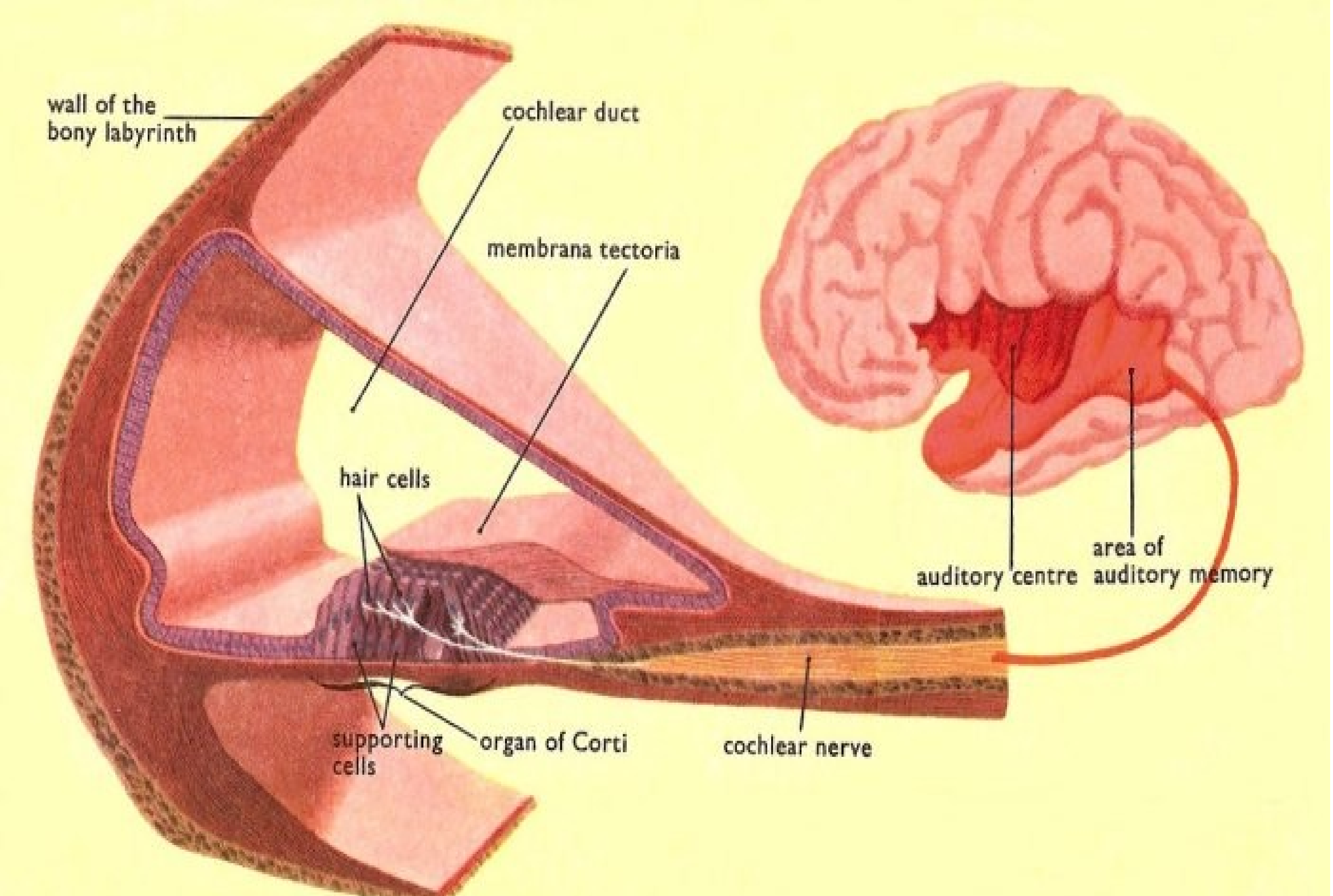
Cochlea
Auditory nerve
Vestibular nerve
Auditory nerve
Oval window
Round window
Cochlea
Cross section of cochlea
Tectorial membrane
Scala media
Scala vestibuli
Spiral ganglion
Scala tympani
Inner hair cells
Basilar membrane
Outer hair cells
Stereocillia of inner hair cells
Stereocillia of outer hair cells
Organ of Corti
Tectorial membrane
Stereocillia
Afferent axons
Basilar membrane
Inner hair cells
Tunnel of Corti
Efferent axons
Outer hair cells

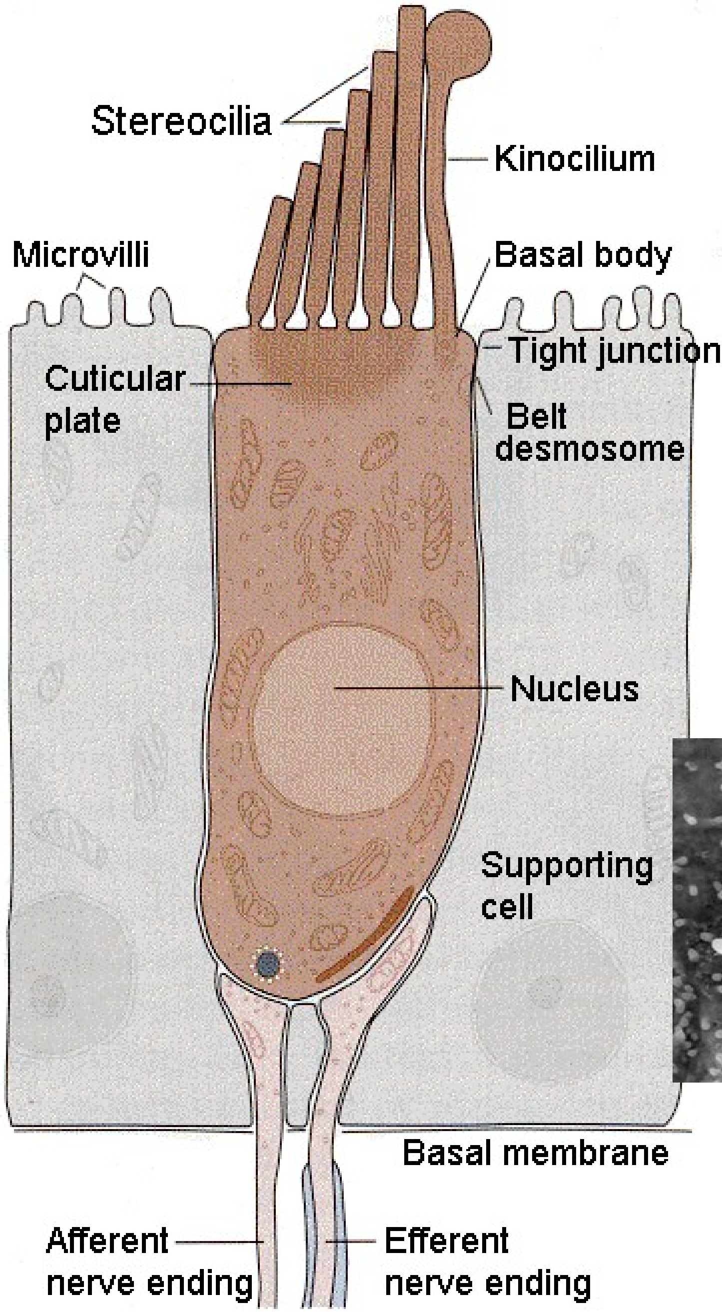

A
2,000 Hz
1,500 Hz
3,000 Hz
400 Hz
600 Hz
cochlear duct
apex
200 Hz
base
800 Hz
20,000 Hz
1,000 Hz
4,000 Hz
basilar membrane
7,000 Hz
5,000 Hz
©1997 Encyclopaedia Britannica, Inc.

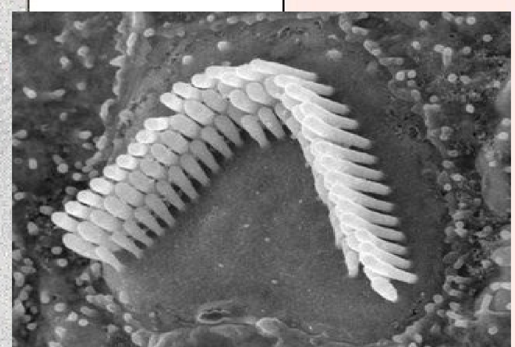

Outer hair cells
Tectorial membrane
Reticular lamina
Vestibular lip
Limbus
Space of Nuel
Outer tunnel
Inner hair cell
Cells of Hensen
Spiral nerve fibers
Nerve fibers
Border cells
Cells of Claudius
Inner tunnel (Corti)
Nucleus
Basilar cells
Pillar (rod of Corti)
Blood vessel
Connective tissue
Transverse fibers
Homogeneous substance
Basilar membrane
Nerve fibers entering the epithelium of organ of Corti
Inner phalangeal cells
Outer phalangeal cells

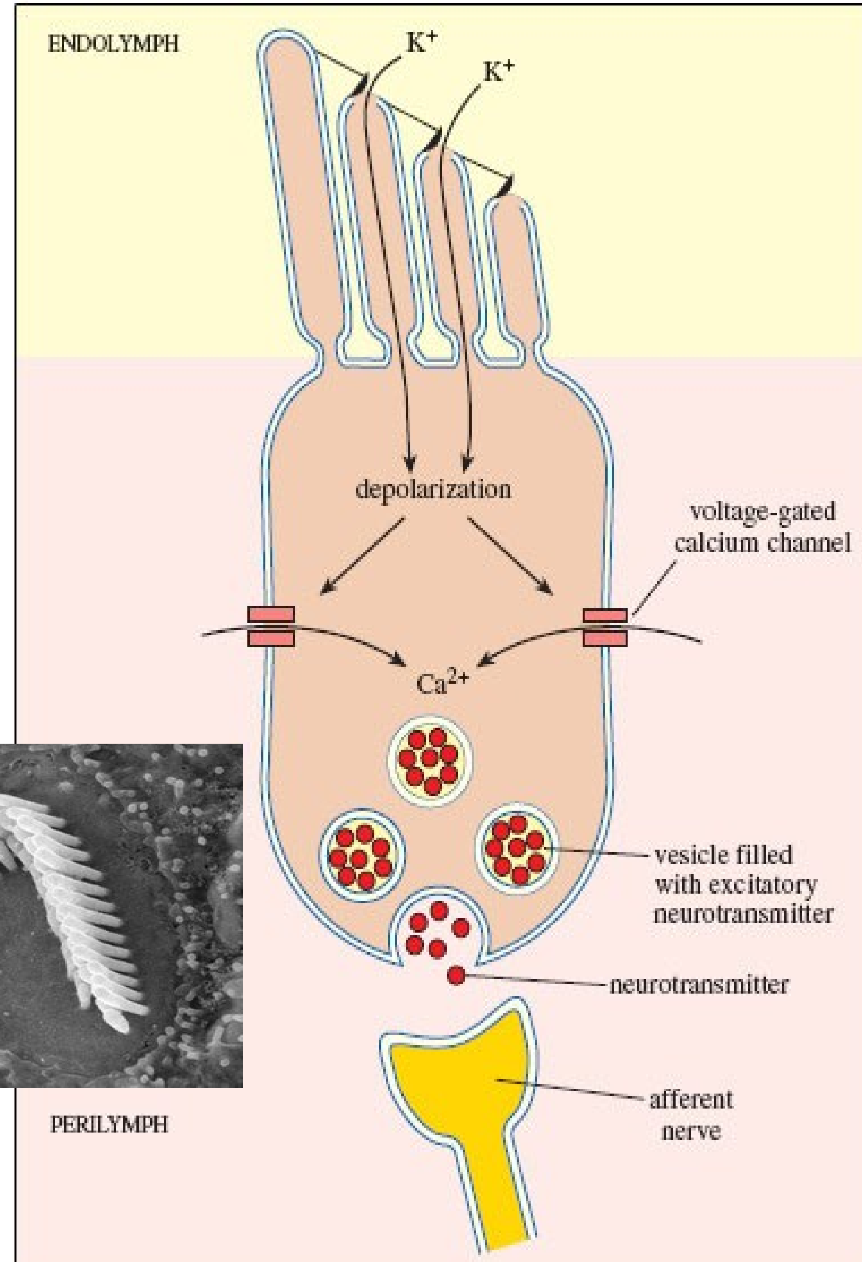
Sound-induced vibration

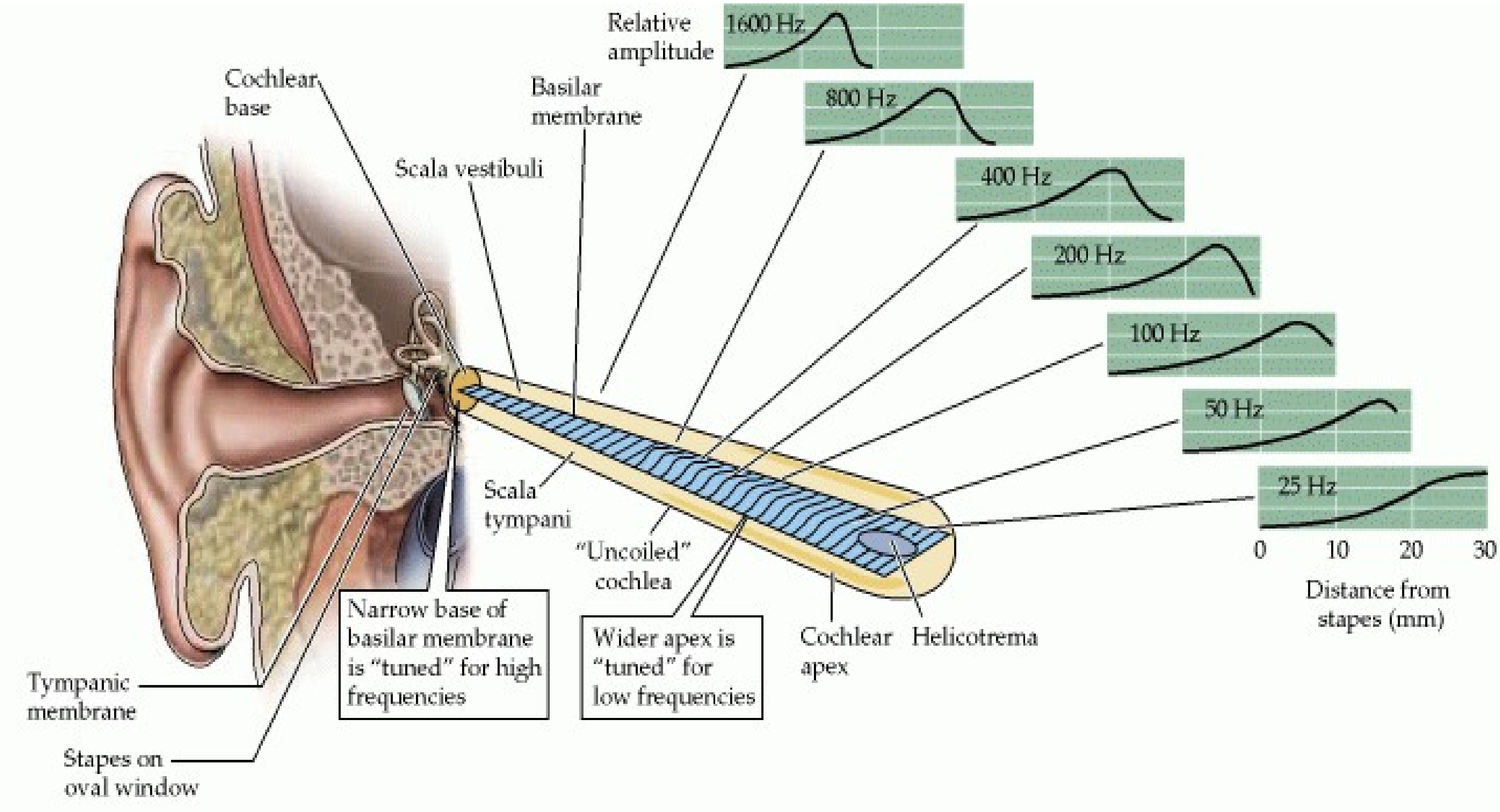



wall of the
bony labyrinth
cochlear duct
membrana tectoria
hair cells
auditory centre
area of
auditory memory
supporting
cells
organ of Corti
cochlear nerve

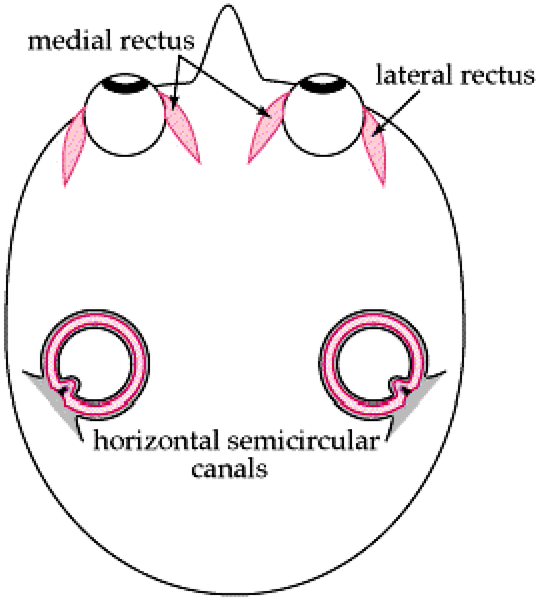

Stereocilia
Kinocilium
Microvilli
Basal body
Tight junction
Cuticular plate
Belt desmosome
Nucleus
Supporting cell
Basal membrane
Afferent nerve ending
Efferent nerve ending

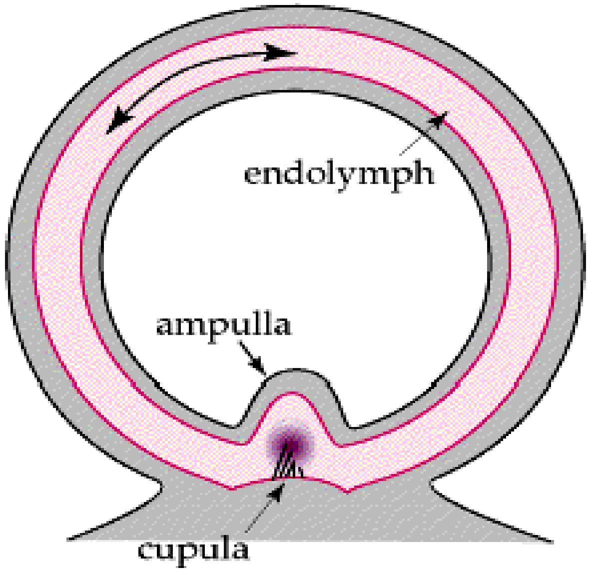



ENDOLYMPH
K+
K+
depolarization
voltage-gated calcium channel
Ca2+
vesicle filled with excitatory neurotransmitter
neurotransmitter
afferent nerve
PERILYMPH


Relative amplitude
1600 Hz
800 Hz
400 Hz
200 Hz
100 Hz
50 Hz
25 Hz
0
10
20
30
Distance from stapes (mm)
Cochlear base
Basilar membrane
Scala vestibuli
Scala tympani
"Uncoiled" cochlea
Narrow base of basilar membrane is "tuned" for high frequencies
Wider apex is "tuned" for low frequencies
Cochlear apex
Helicotrema
Tympanic membrane
Stapes on oval window

The semicircular canals detect angular acceleration. There are 3 canals, corresponding to the three dimensions in which you move, so that each canal detects motion in a single plane. Each canal is set up as shown below, as a continuous endolymph-filled hoop. The actual hair cells sit in a small swelling at the base called the ampula.



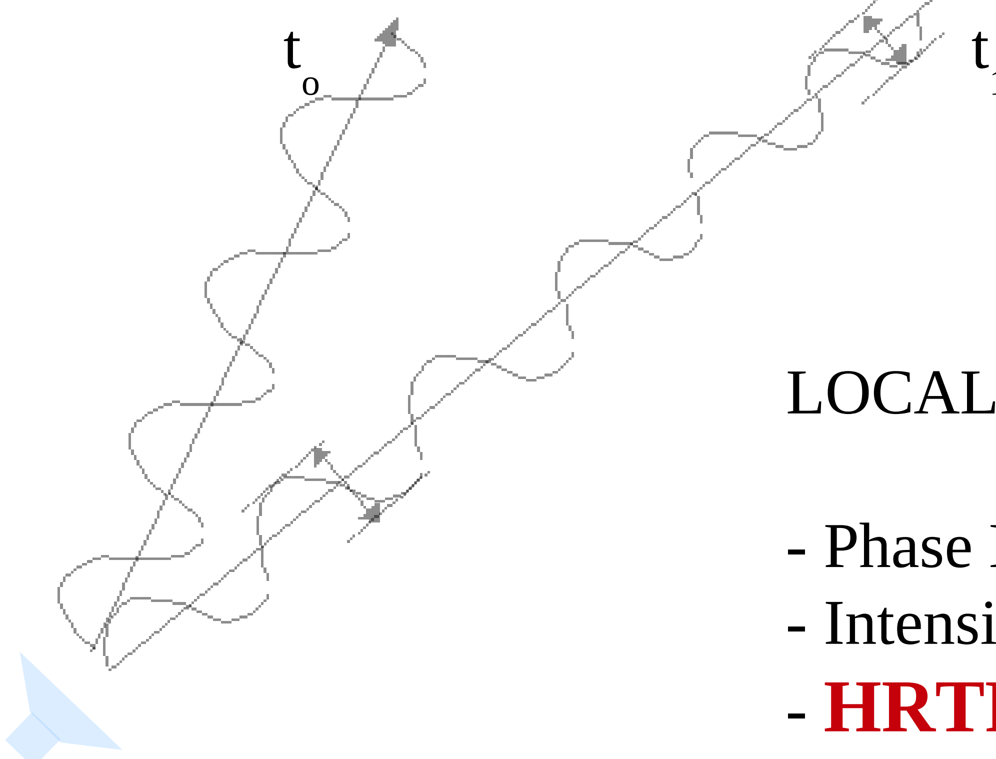


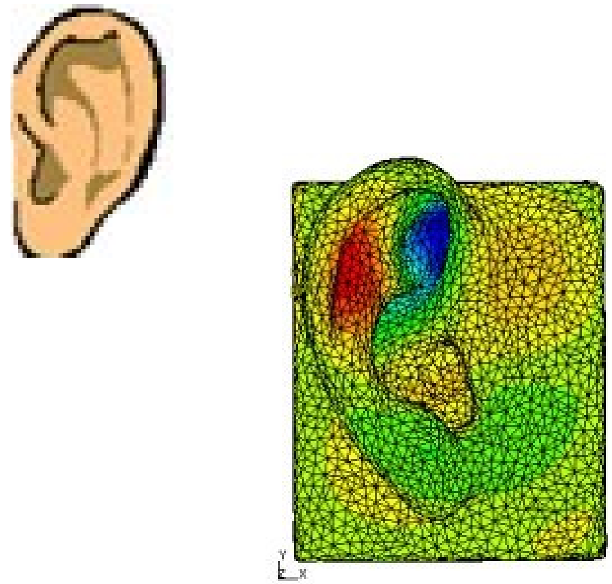
Localization of sound

The ability to estimate just where a sound is coming from, sound localization, is dependent on hearing ability of each of the two ears, and the exact quality of the sound. Since each ear lies on an opposite side of the head, a sound will reach the closest ear first, and its amplitude will be larger in that ear.

The shape of the pinna (outer ear) and of the head itself result in frequency-dependent variation in the amount of attenuation that a sound receives as it travels from the sound source to the ear. Furthermore, this variation depends not only on the **azimuthal angle** of the source, but also on its elevation. This variation is described as the head-related transfer function, or HRTF. As a result, humans can locate sound both in azimuth and altitude. Most of the brain's ability to localize sound depends on interaural (between ears) **intensity** differences and interaural **temporal**, or phase, differences. In addition, humans can also estimate the distance that a sound comes from, based primarily on how **reflections** in the environment modify the sound, for example, as in room reverberation.

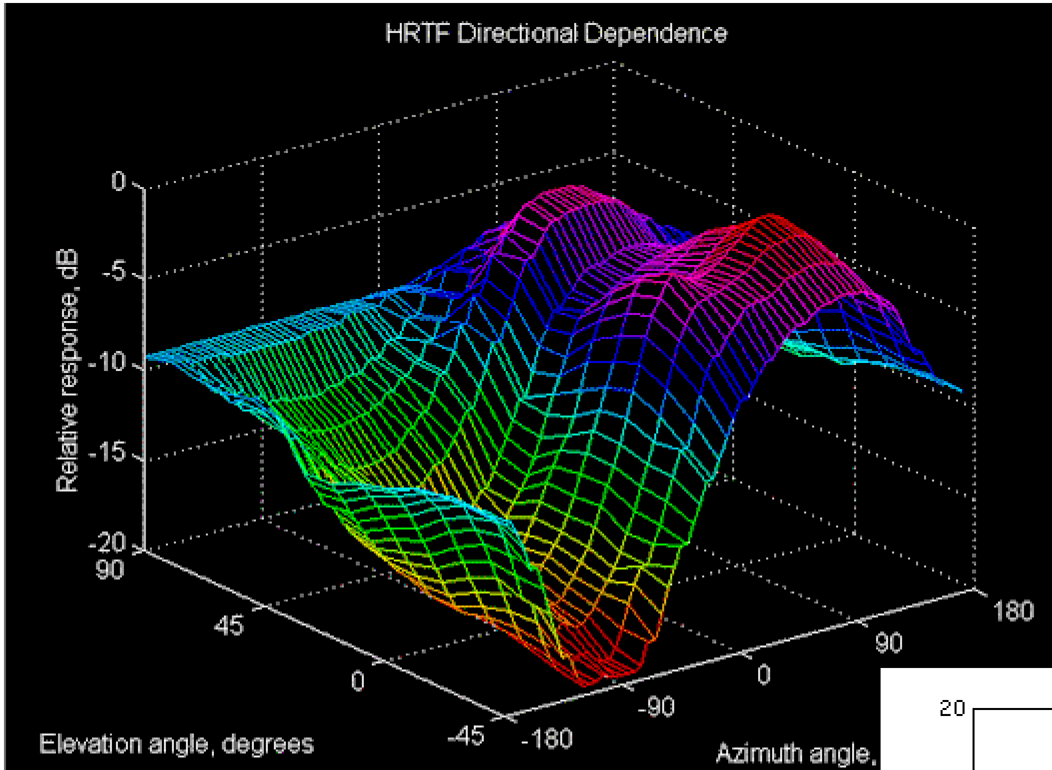
Human echolocation is a technique used by some blind humans to navigate within their environment by listening for echoes of clicking or tapping sounds that they emit.

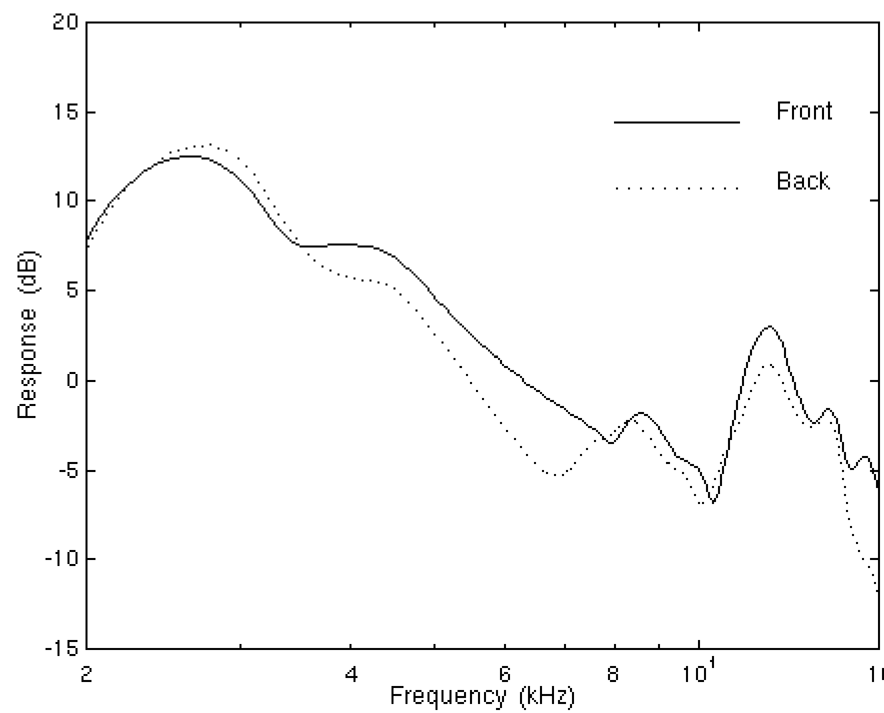




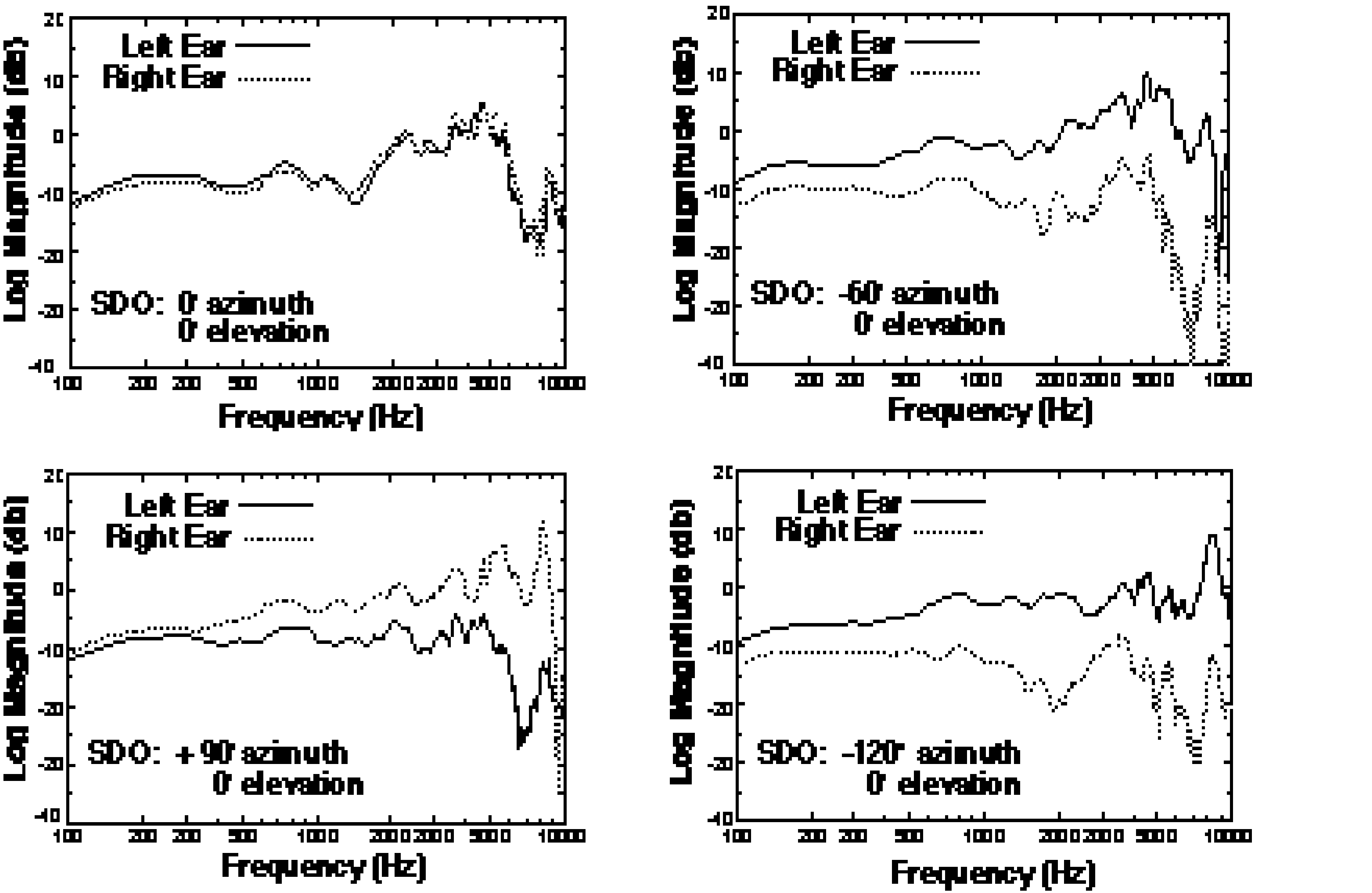
LOCALIZATION

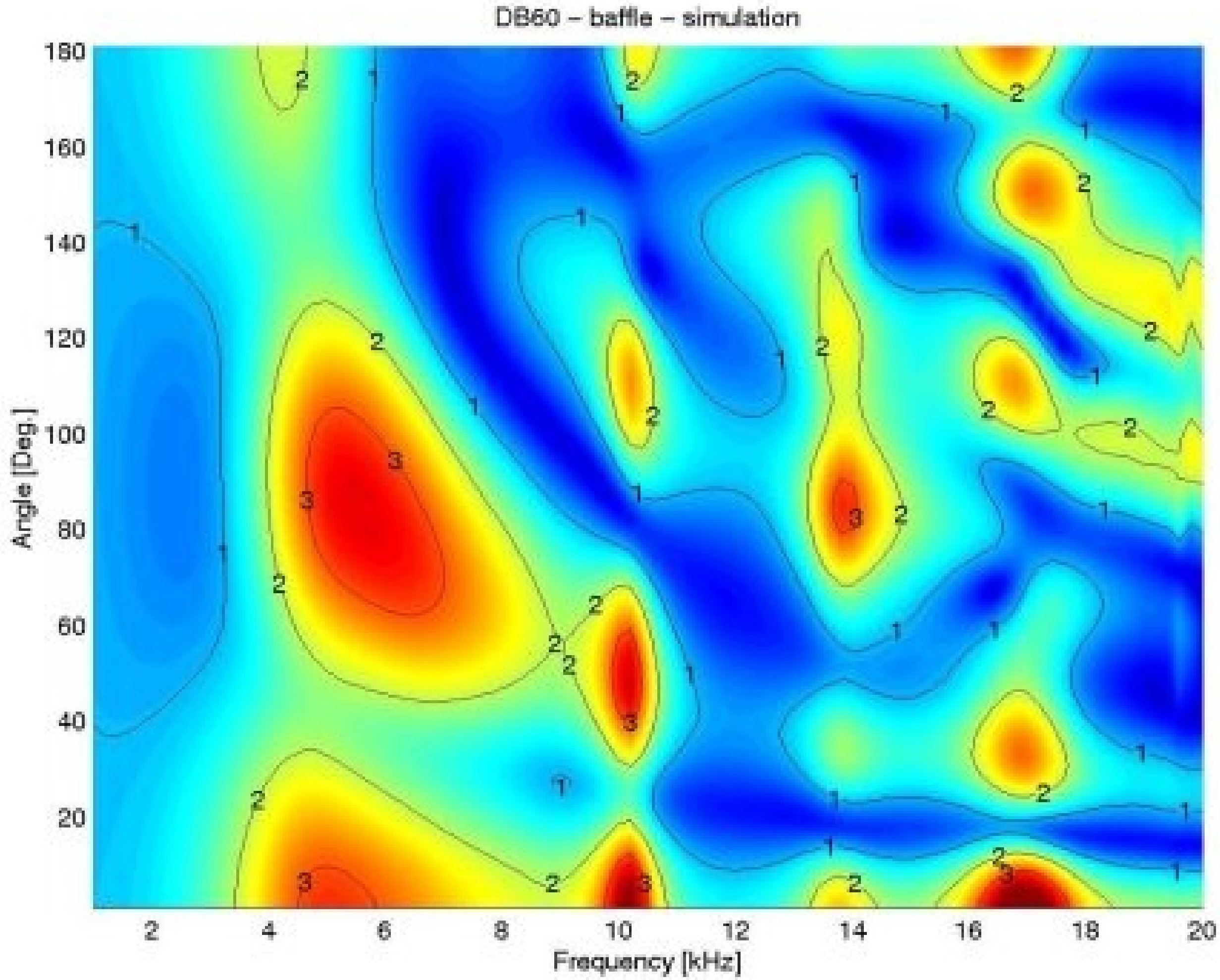
- Phase Difference 位相
- Intensity Difference 強度
- **HRTF**


HRTF Directional Dependence
Relative response, dB
0
-5
-10
-15
-20
90
45
0
-45
Elevation angle, degrees
-180
-90
0
90
180
Azimuth angle,


20
15
10
5
0
-5
-10
-15
Response (dB)
Front
Back
2
4
6
8
10
16
Frequency (kHz)

Head-Related Transfer Functions (HRTFs)
Frequency Domain: Magnitude Spectra

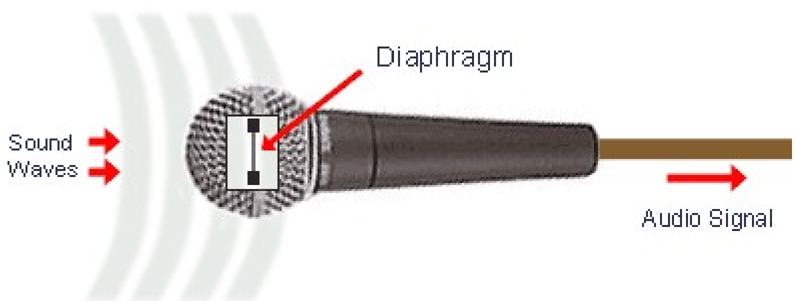


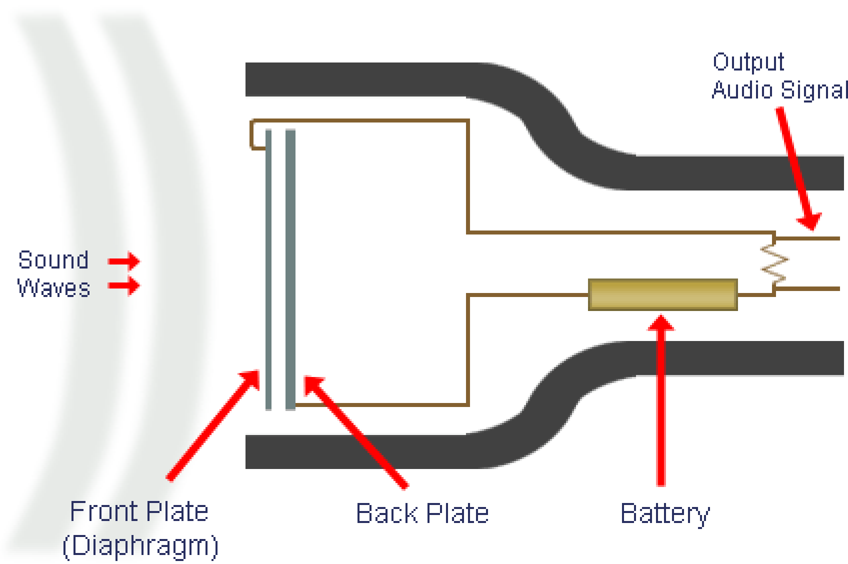

DB60 – baffle – simulation
Angle [Deg.]
Frequency [kHz]
180
160
140
120
100
80
60
40
20
2
4
6
8
10
12
14
16
18
20

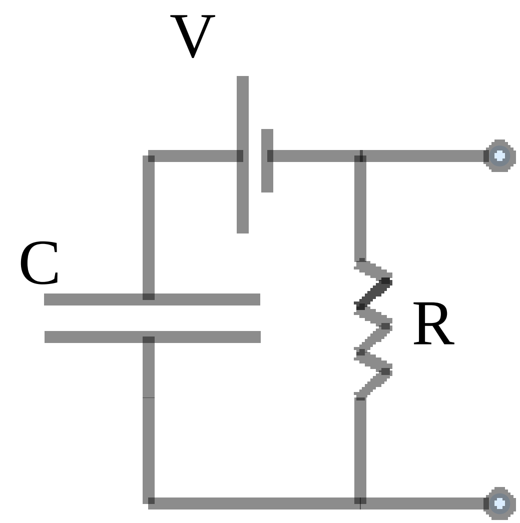
THE ARTIFICIAL EARS: (マイクロホン)

Frequency response
Dynamic Response

Condenser microphones



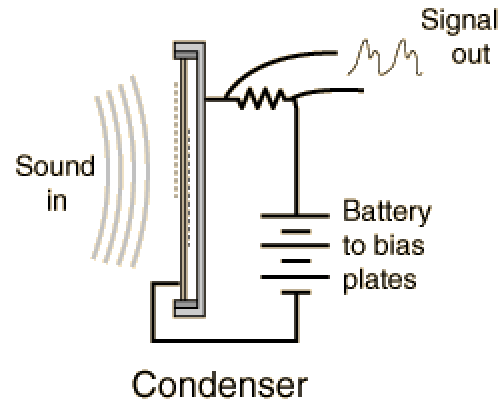




$$C = \epsilon \frac{S}{d}$$

$$V_C = \frac{Q}{C}$$

Condenser microphones have a flatter frequency response than dynamics



$$Q = CV = \frac{\alpha(\text{Area of plate})(\text{voltage})}{(\text{plate spacing})}$$

Advantages:

Best overall frequency response makes this the microphone of choice for many recording applications.

Disadvantages:

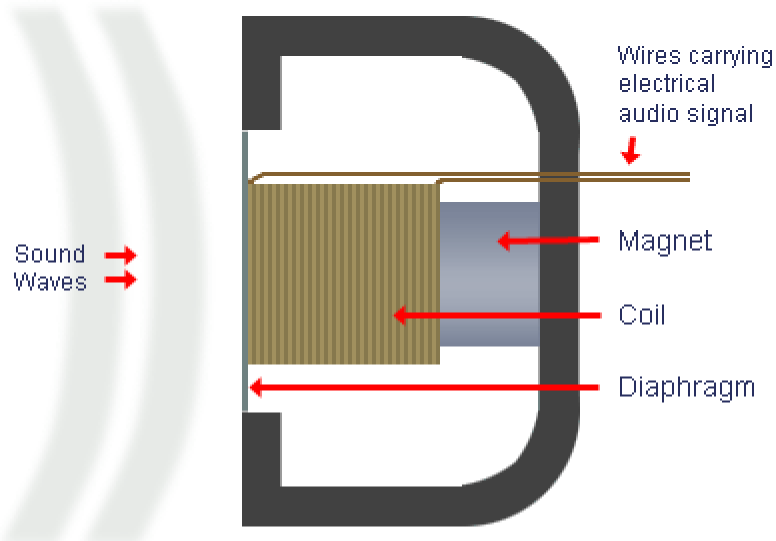
Expensive

May pop and crack when close miked

Requires a battery or external power supply to bias the plates.

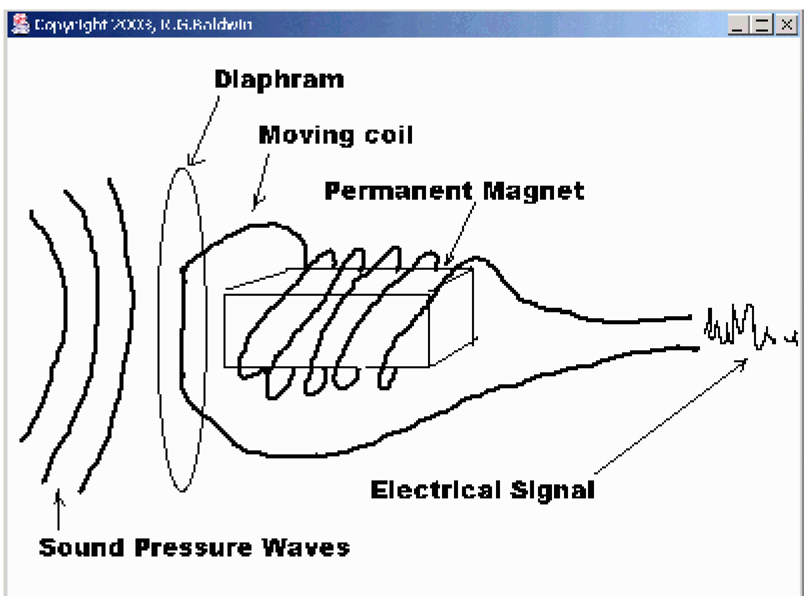
Dynamic microphones (Electromagnetic Microphones)

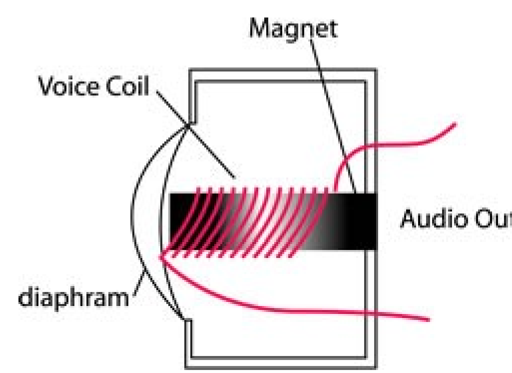
Cross-Section of Dynamic Microphone



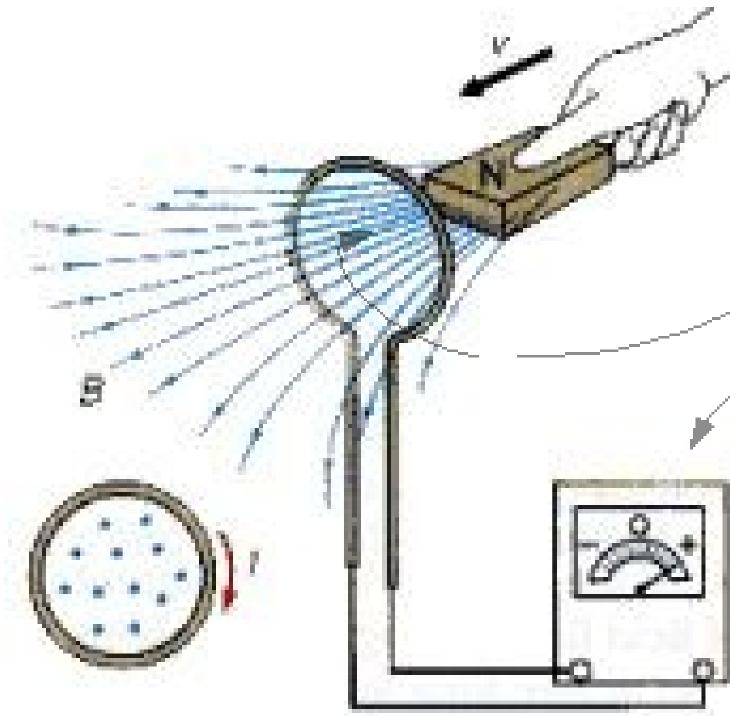
Dynamics do not usually have the same flat frequency response as condensers. Instead they tend to have tailored frequency responses for particular applications.

However they have a good Dynamic response.



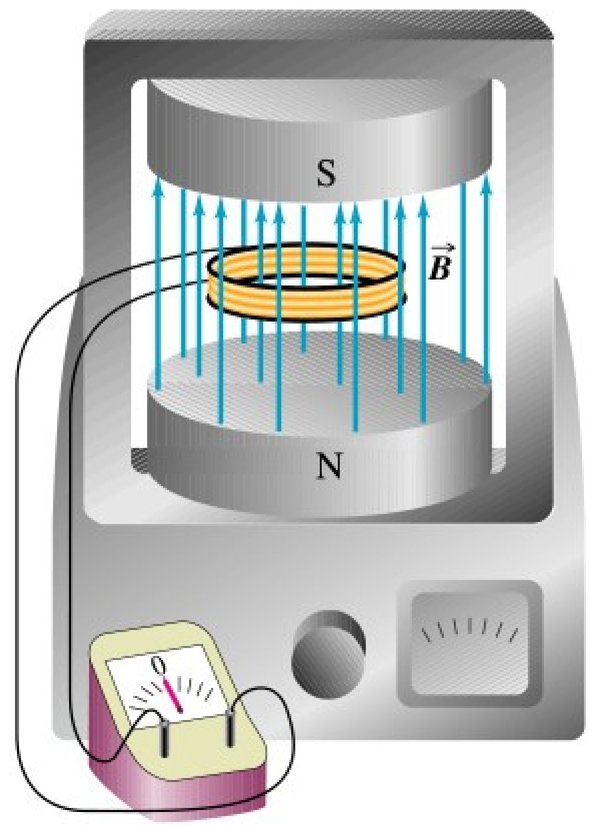


Dynamic Microphone

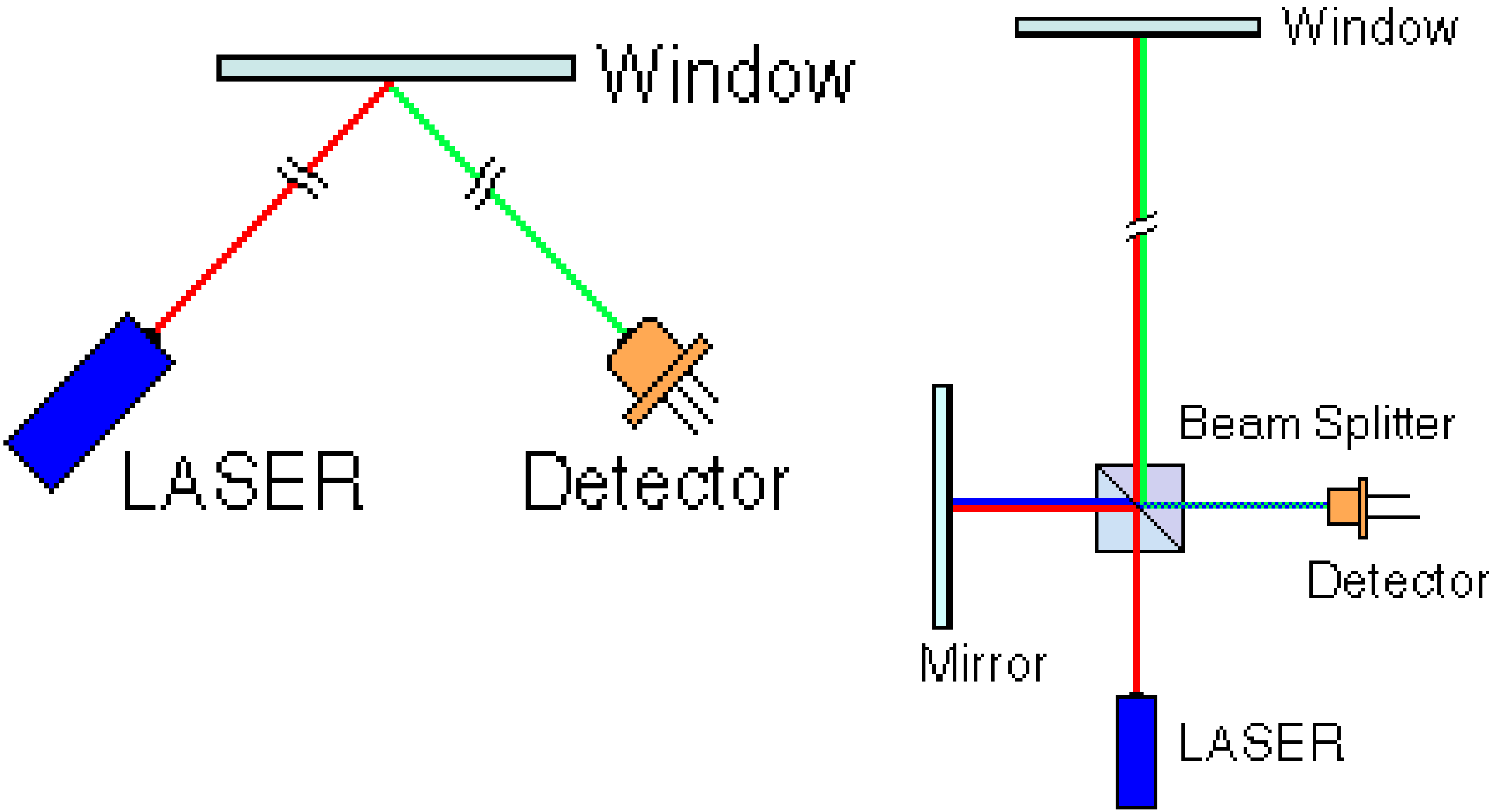


$$\phi = \oint B.\,dA$$

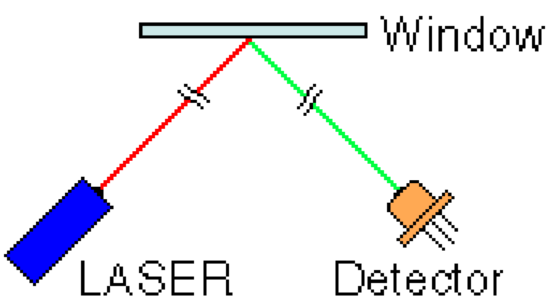
$$e = \frac{-d\,\phi}{dt}$$

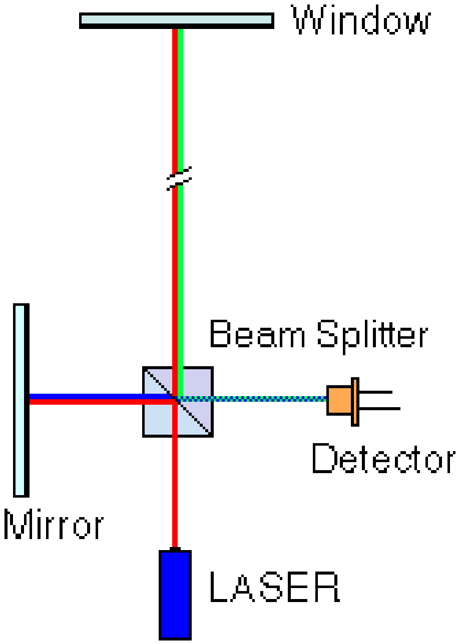


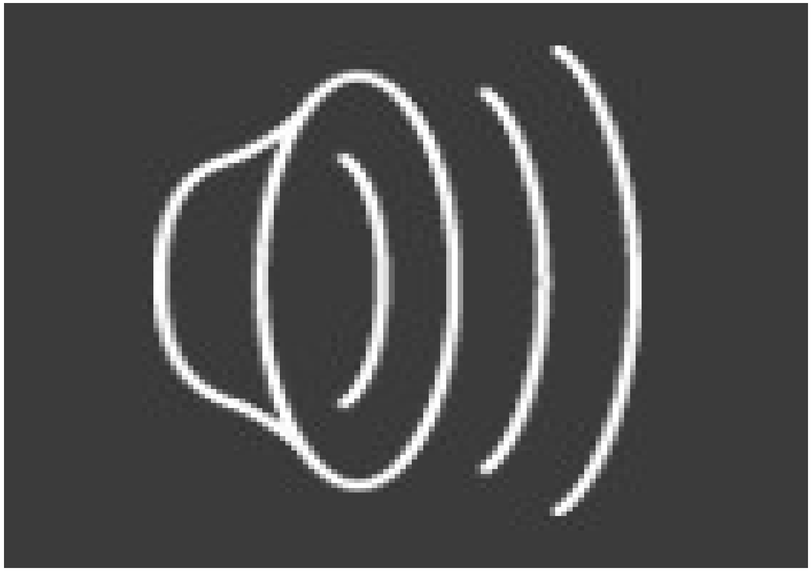
LASER microphone (Spy Microphone)

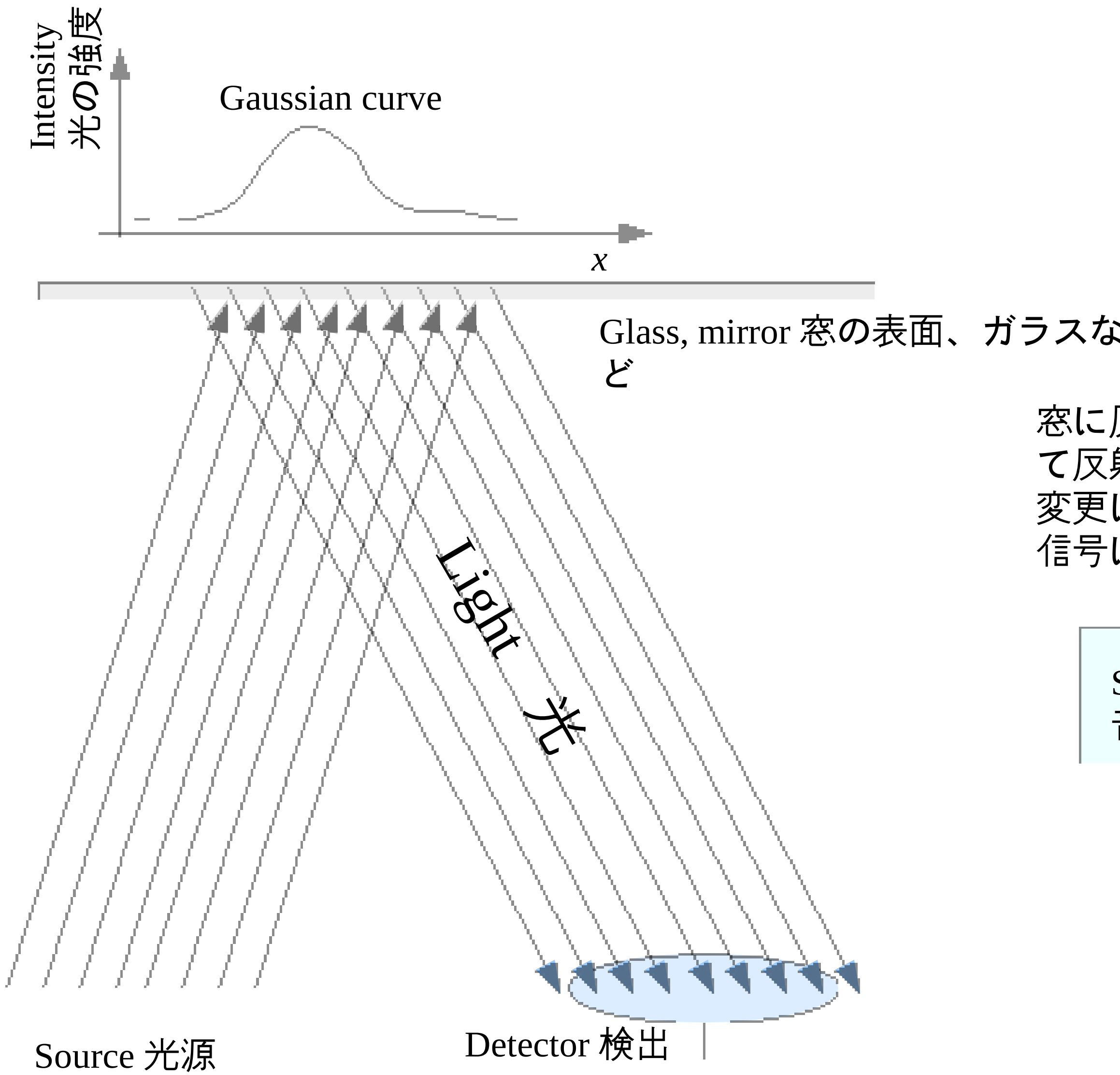


LASER microphone (Spy Microphone)

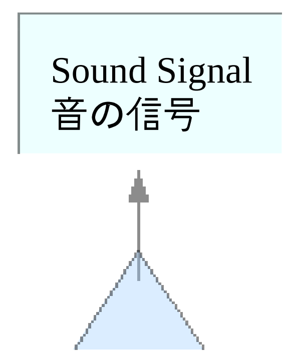




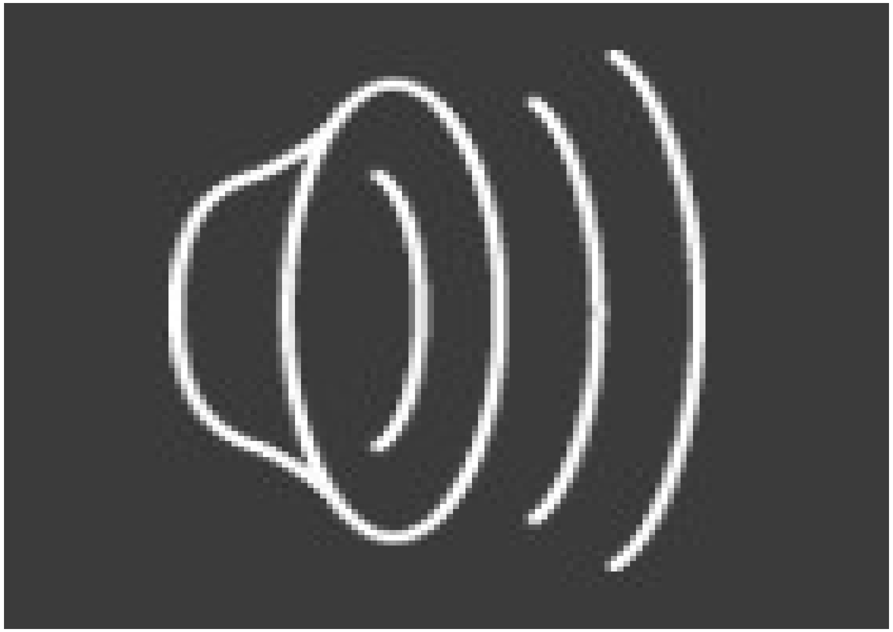




窓に反射するときに音の強度によって反射角度は少し変更します。角度変更によって、検出に得られた光の信号は同じように変更します。



The sound system, a summary: documentary



THE VISION, What is light ?

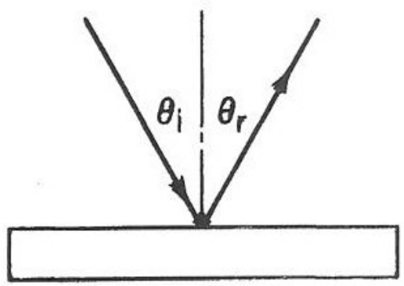


Fig. 26–1. The angle of incidence is equal to the angle of reflection.

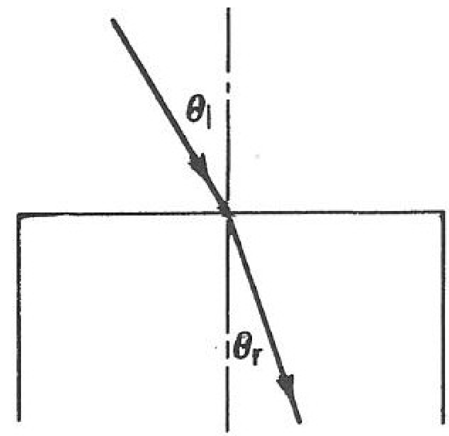


Fig. 26–2. A light ray is refracted when it passes from one medium into another.

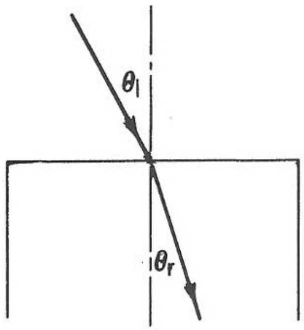


Table 26–1

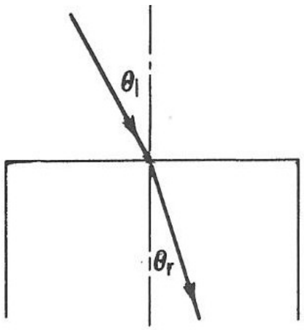
Angle in air	Angle in water
10°	8°
20°	15-1/2°
30°	22-1/2°
40°	29°
50°	35°
60°	40-1/2°
70°	45-1/2°
80°	50°

140 A.D., Claudius Ptolemy

Table 26–2

Angle in air	Angle in water
10°	7-1/2°
20°	15°
30°	22°
40°	29°
50°	35°
60°	40-1/2°
70°	45°
80°	48°

$$\sin\theta_i = n\sin\theta_r.$$



Snell law (1621)

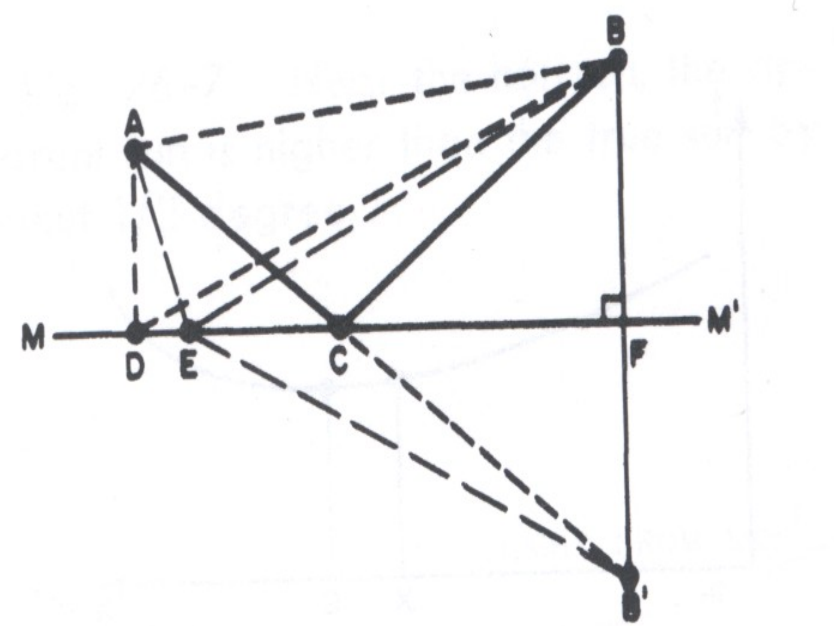
Principle of Fermat (1650, Snell+29 years!)

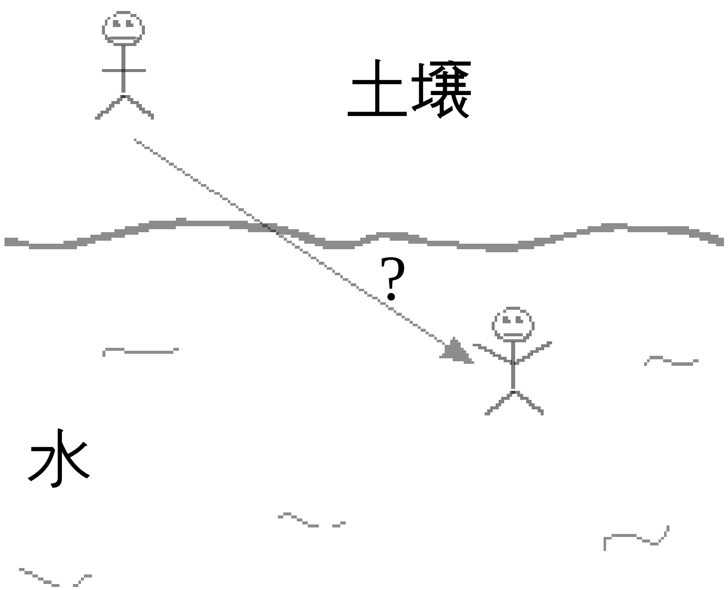
フェルマット原則

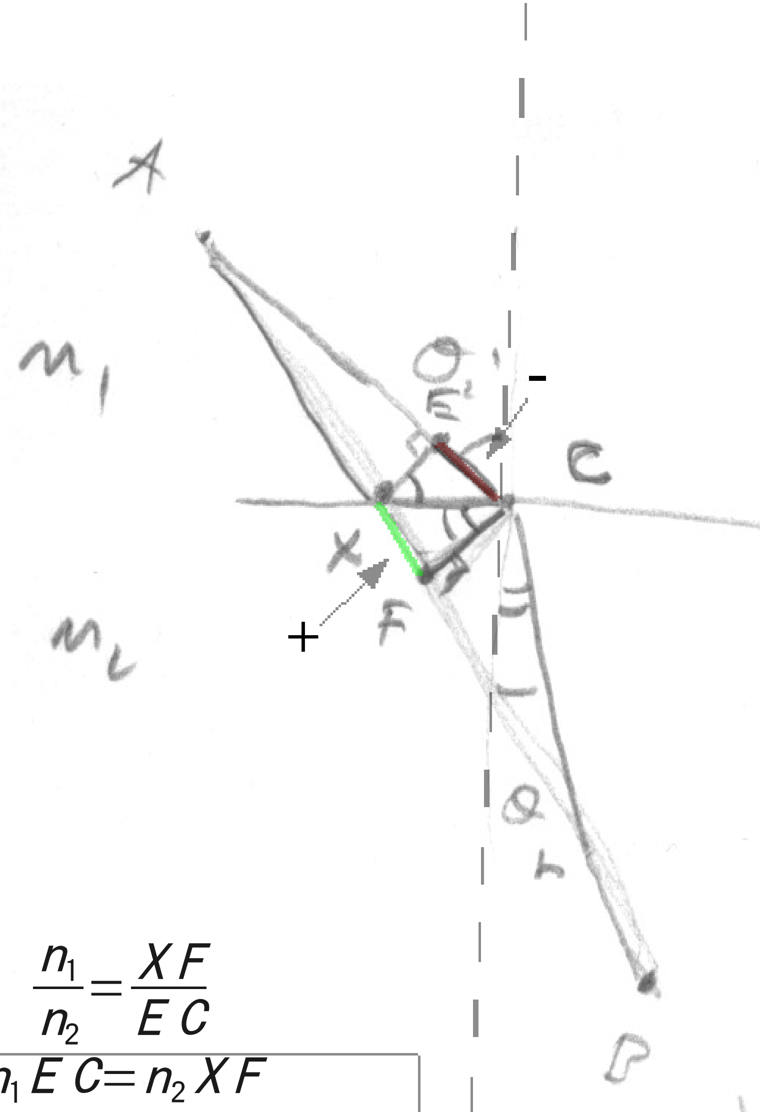
Out of all possible paths, light takes the path which requires the *less time*

$$n = \frac{c}{V_{\text{光のスピード}}}$$

$$c = 300.000\text{Km}/sec$$







$$\frac{n_1}{n_2}=\frac{XF}{EC}$$

Snell Law
(1650)

$$n_1 EC = n_2 XF$$
$$n_1 XC sin(\theta_i) = n_2 XC sin(\theta_r)$$

$$n_1 \sin(\theta_i) = n_2 \sin(\theta_r)$$

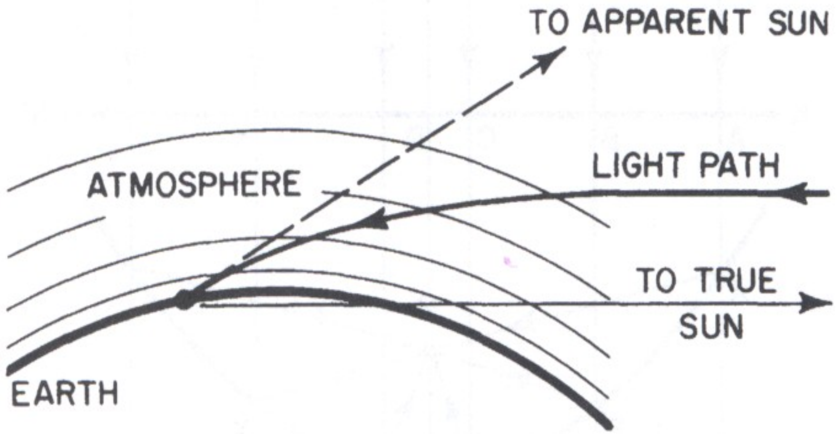


Fig. 26–7. Near the horizon, the apparent sun is higher than the true sun by about 1/2 degree.

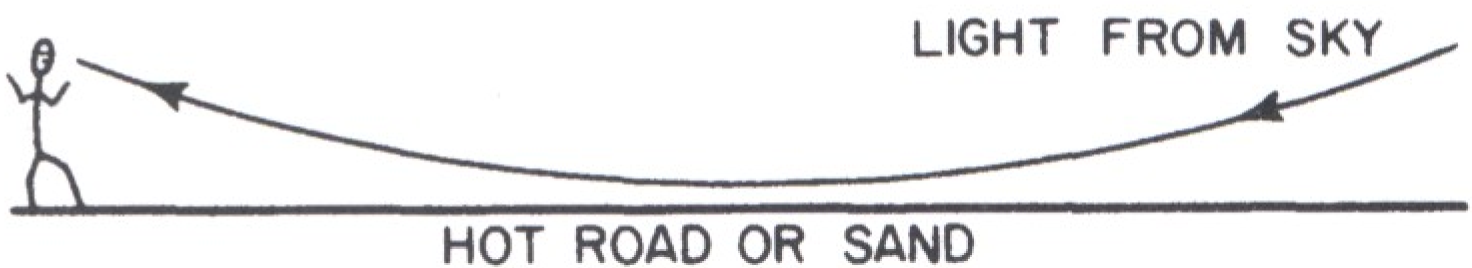
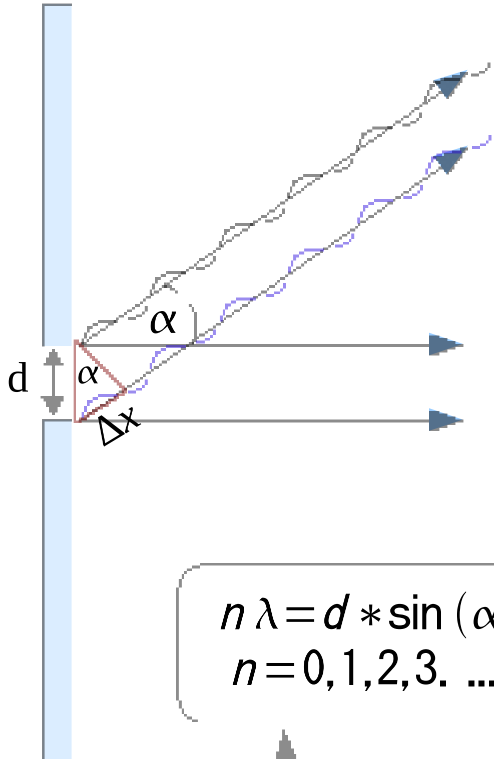


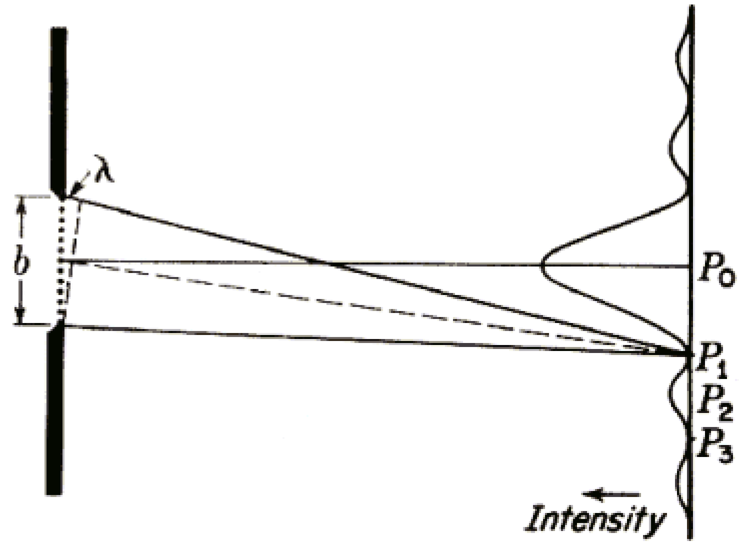
Fig. 26–8. A mirage.

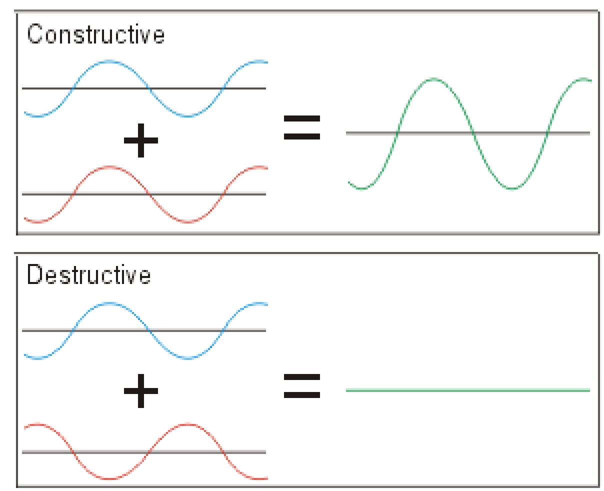
干涉

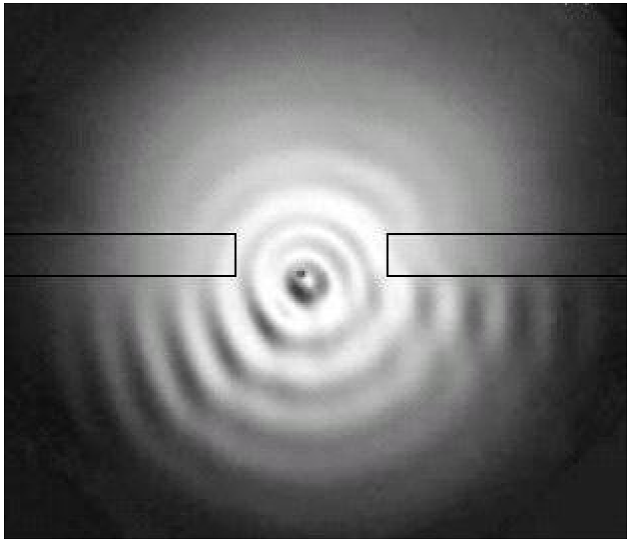


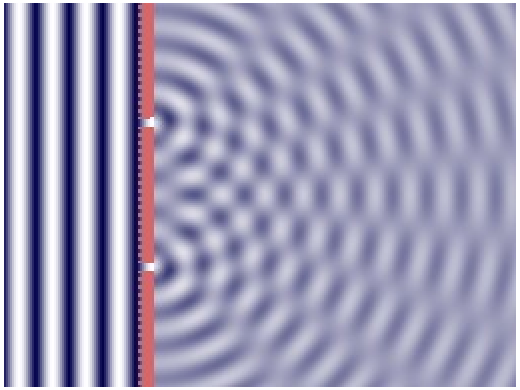
$$n\lambda = d * \sin(\alpha)$$
$$n = 0, 1, 2, 3. \dots$$

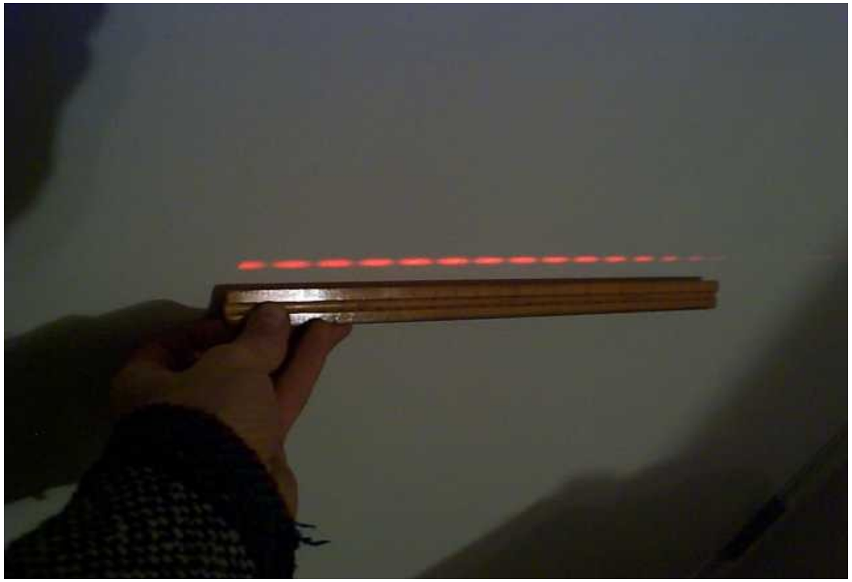
Interference: **Max** condition



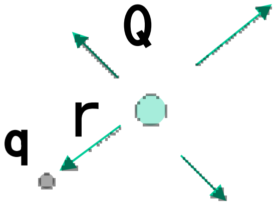








チャージを存在



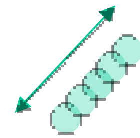
静電場

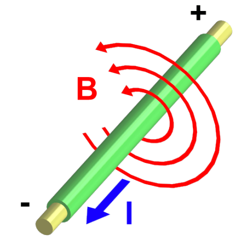
Coulomb法:

$$\mathbf{E} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\hat{\mathbf{r}}$$

$$\mathbf{F} = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}\hat{\mathbf{r}} = q\mathbf{E}$$

チャージを動くと



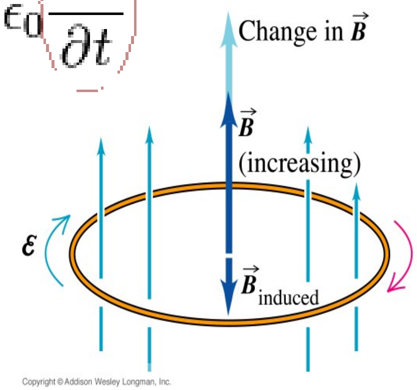


Ampere法

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

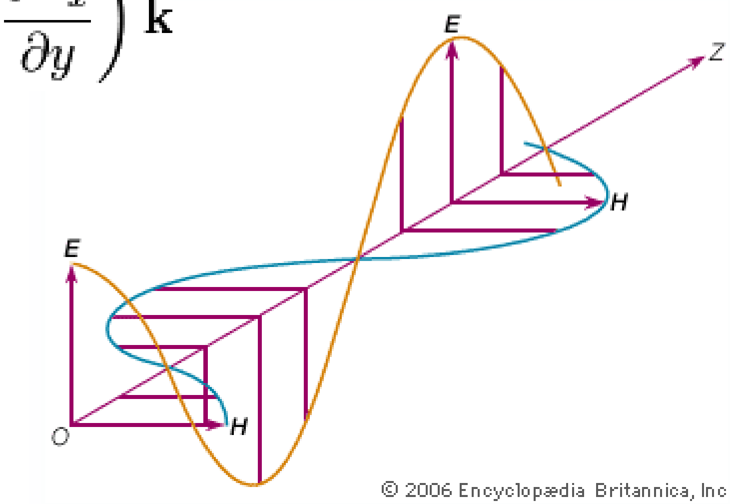
$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

Faraday法



$$\nabla \times \mathbf{F}$$

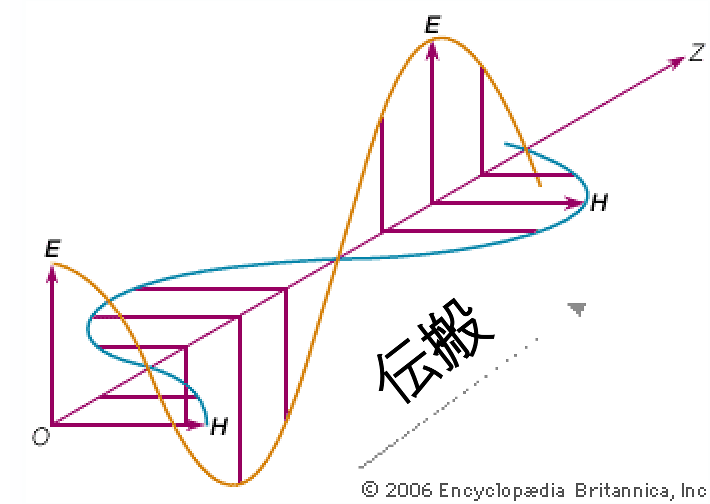
$$\left(\frac{\partial F_z}{\partial y} - \frac{\partial F_y}{\partial z}\right)\mathbf{i} + \left(\frac{\partial F_x}{\partial z} - \frac{\partial F_z}{\partial x}\right)\mathbf{j} + \left(\frac{\partial F_y}{\partial x} - \frac{\partial F_x}{\partial y}\right)\mathbf{k}$$

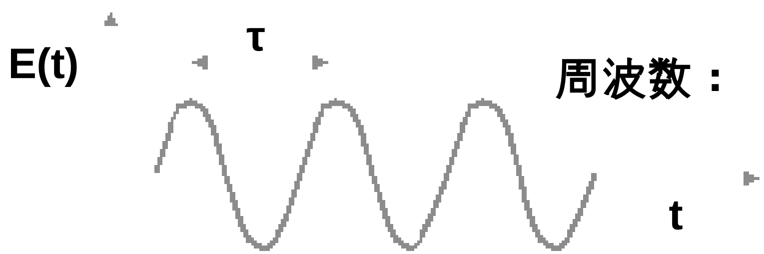


チャージを存在 ▸ 静電場
（Coulomb法）

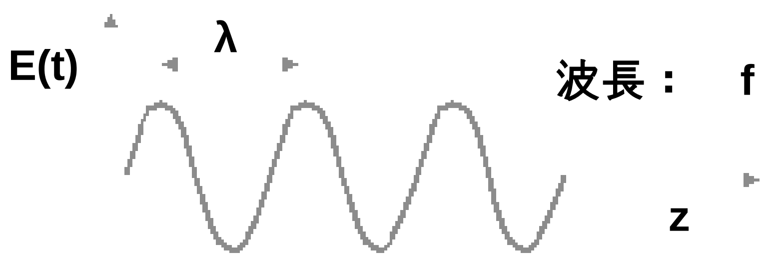
チャージを動く ▸ 変動磁場 ▸ 変動電場
(Ampere法) (Faraday法)

$$
\begin{cases}
\mathbf{E}(\mathbf{r},t) = \mathbf{E}_0 \cos(\omega t - \mathbf{k}\cdot\mathbf{r} + \phi_0) \\
\mathbf{B}(\mathbf{r},t) = \mathbf{B}_0 \cos(\omega t - \mathbf{k}\cdot\mathbf{r} + \phi_0)
\end{cases}
$$

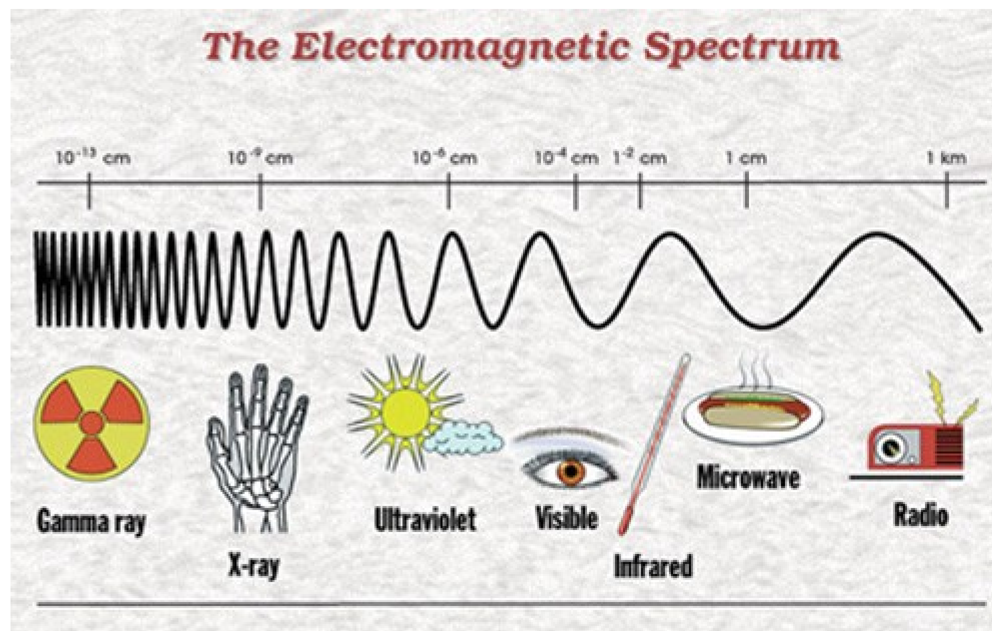


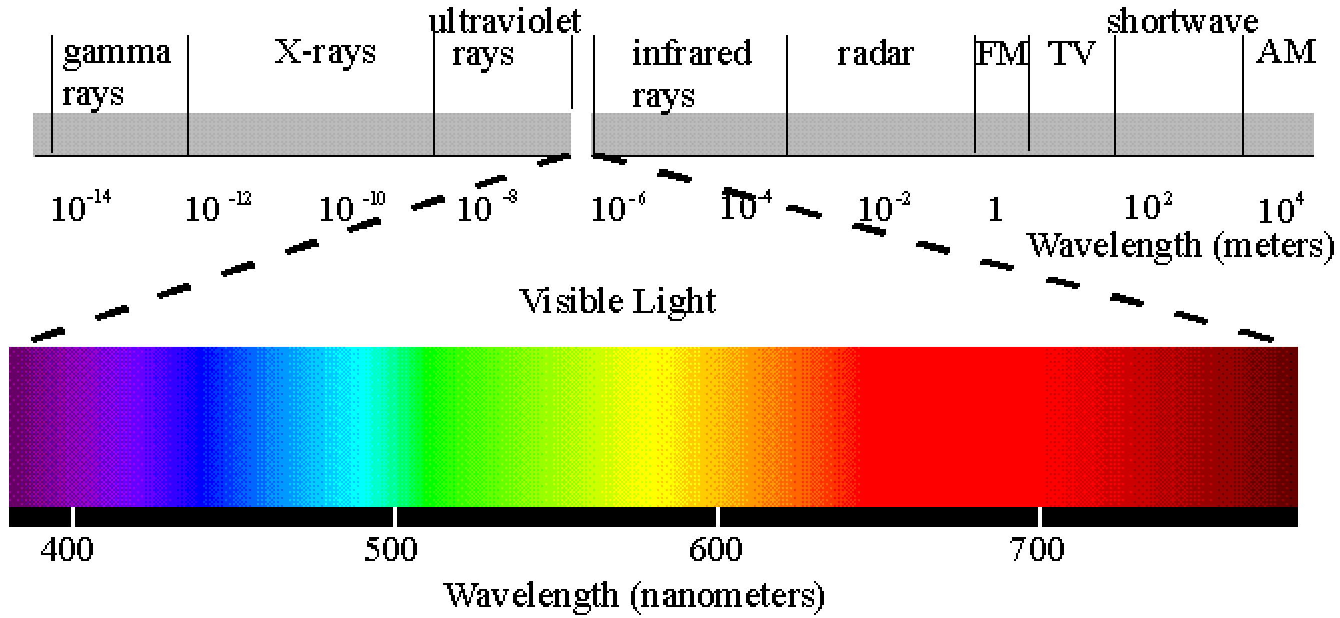


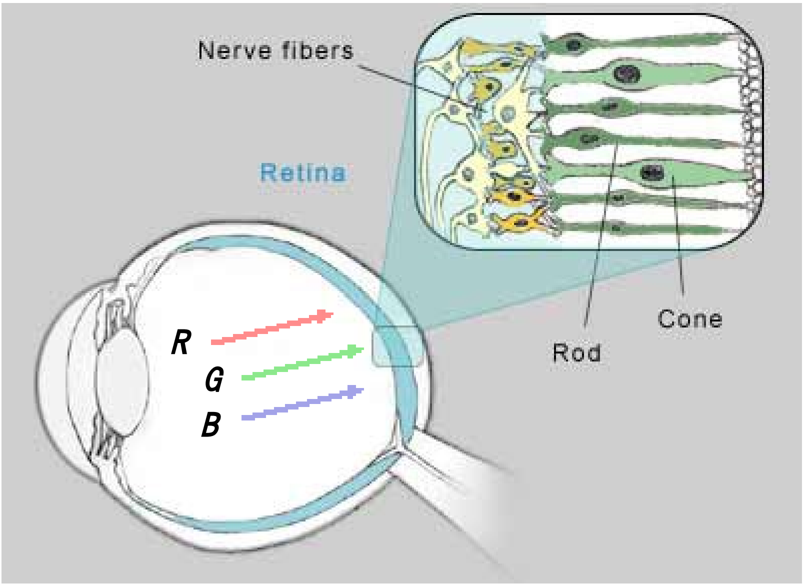
周波数：　f = 1/τ

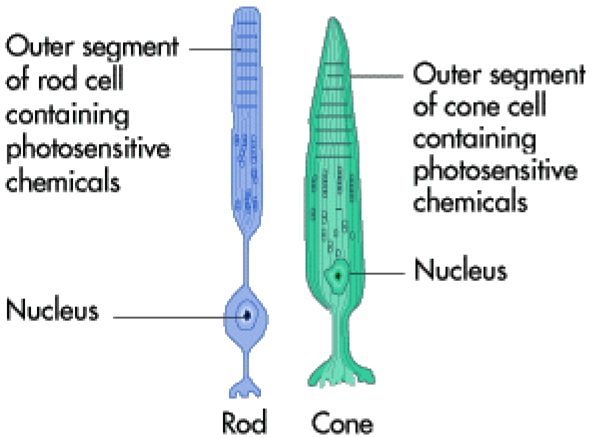


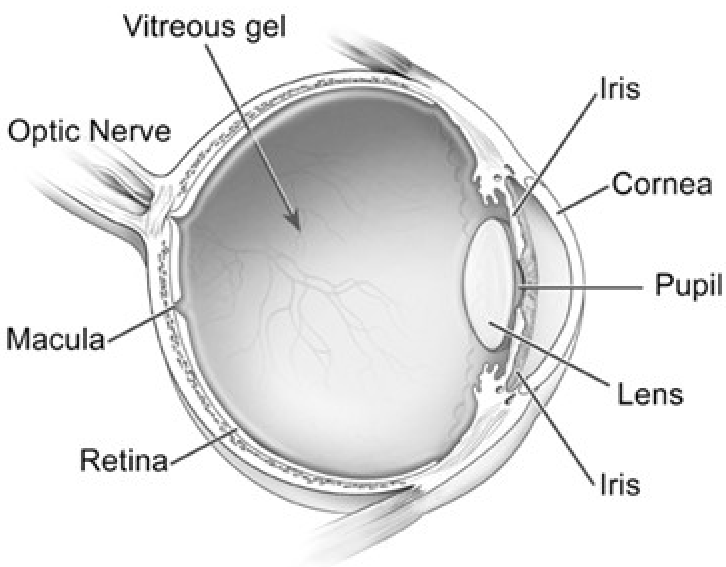
波長：　f = λ

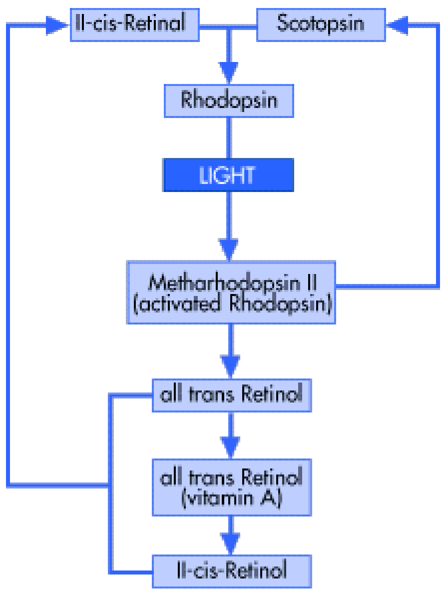


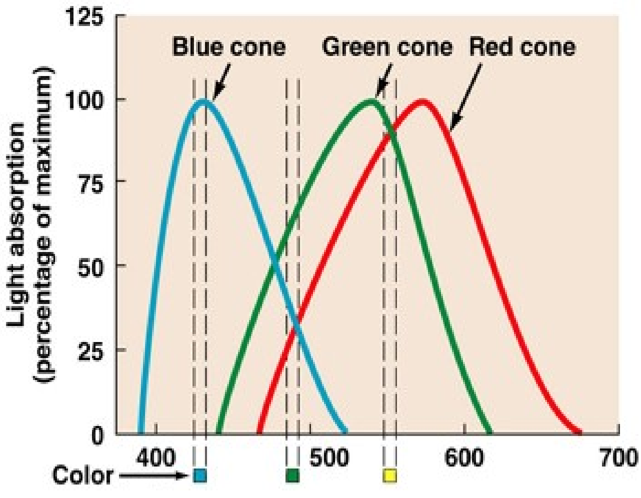

gamma rays
X-rays
ultraviolet rays
infrared rays
radar
FM
TV
shortwave
AM
10^{-14} 10^{-12} 10^{-10} 10^{-8} 10^{-6} 10^{-4} 10^{-2} 1 10^{2} 10^{4}
Wavelength (meters)
Visible Light
400
500
600
700
Wavelength (nanometers)


Nerve fibers
Retina
R
G
B
Cone
Rod


Outer segment of rod cell containing photosensitive chemicals
Outer segment of cone cell containing photosensitive chemicals
Nucleus
Nucleus
Rod
Cone





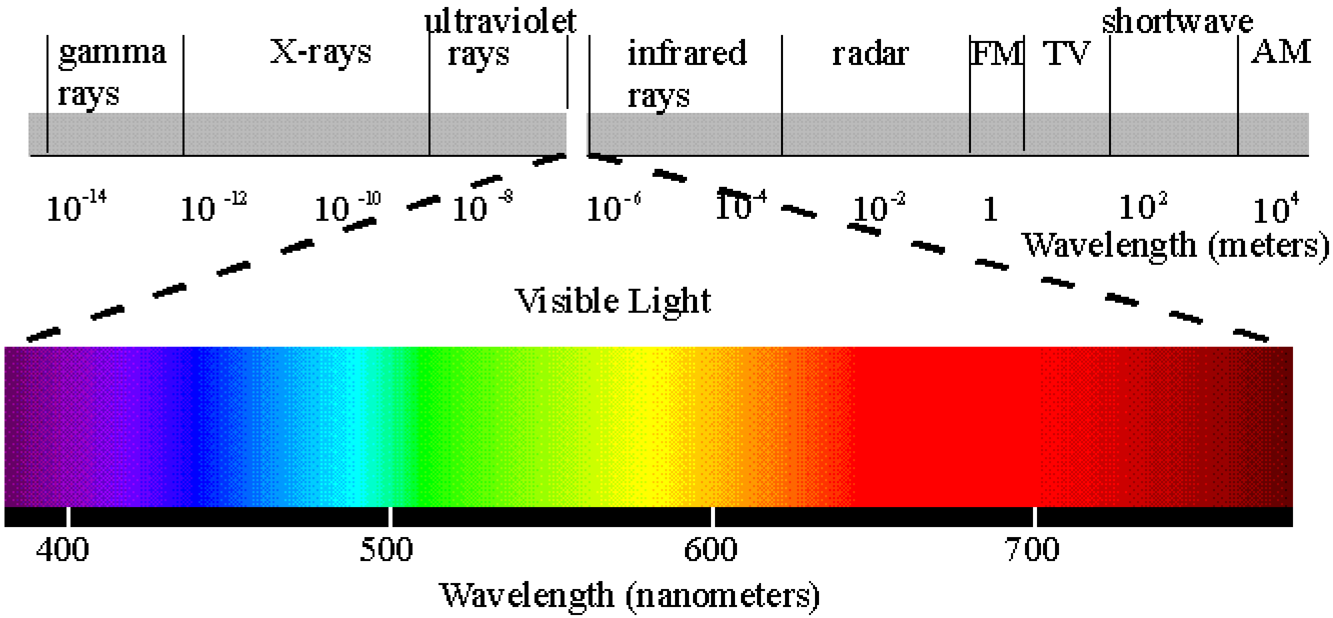


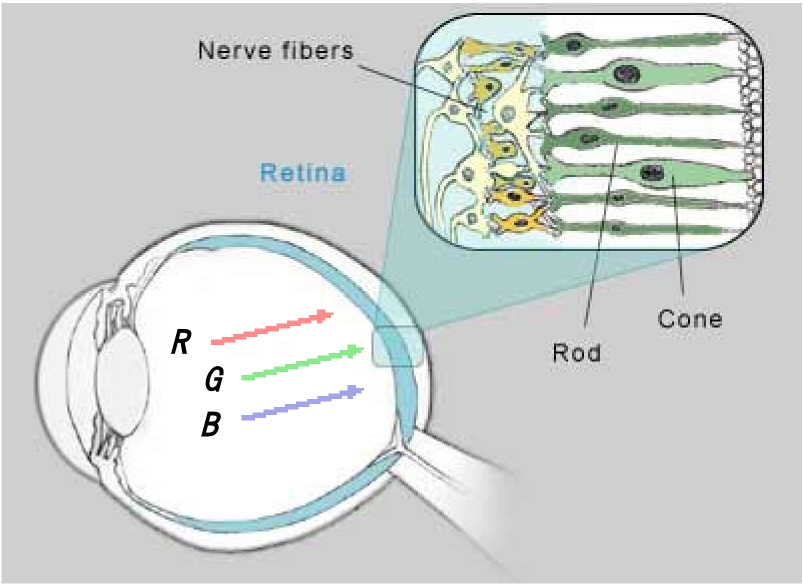
“RGB”の色で全部の色を作る。この事は光の特性ではない、人間の目の特性です（！）

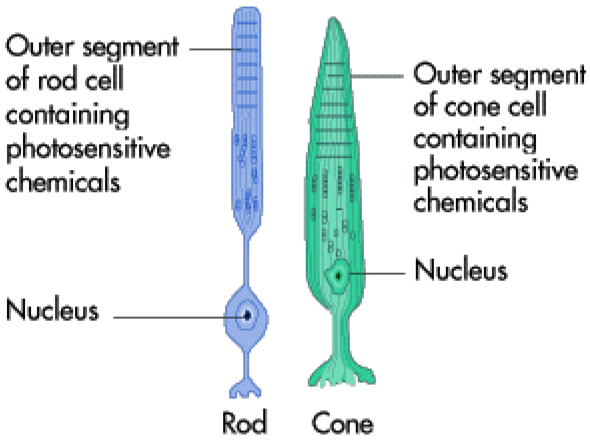
人間は　「Trichromatic Vision」

動物の世界の中に「Tetrachromacy」「Pentachromats」などがあります

THE VISION, How does it work ?


gamma rays
X-rays
ultraviolet rays
infrared rays
radar
FM
TV
shortwave
AM
10^{-14}
10^{-12}
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
1
10^{2}
10^{4}
Wavelength (meters)
Visible Light
400
500
600
700
Wavelength (nanometers)


Nerve fibers
Retina
R
G
B
Rod
Cone


Outer segment of rod cell containing photosensitive chemicals
Nucleus
Outer segment of cone cell containing photosensitive chemicals
Nucleus
Rod
Cone

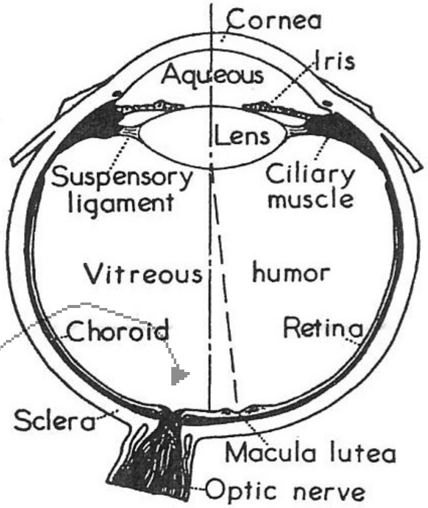


Fig. 35–1. The eye.

Blind Spot !

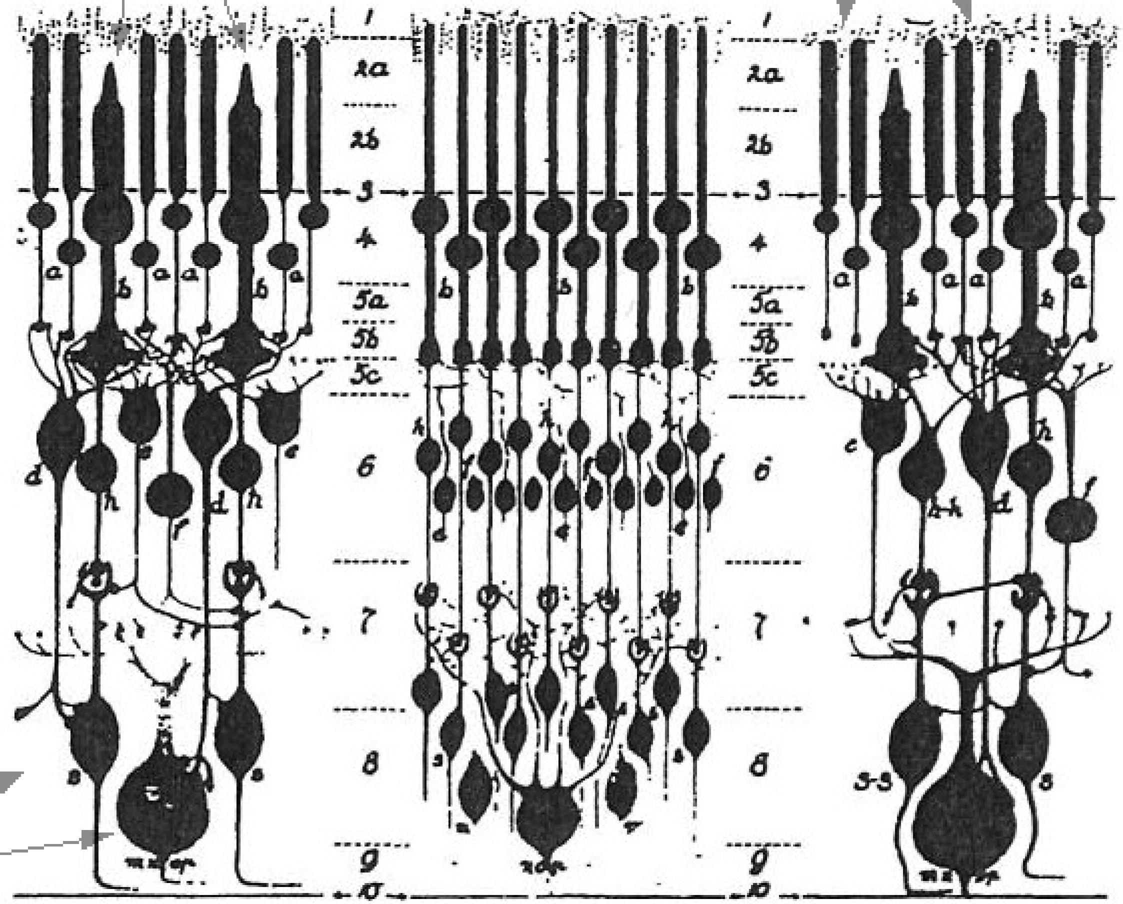
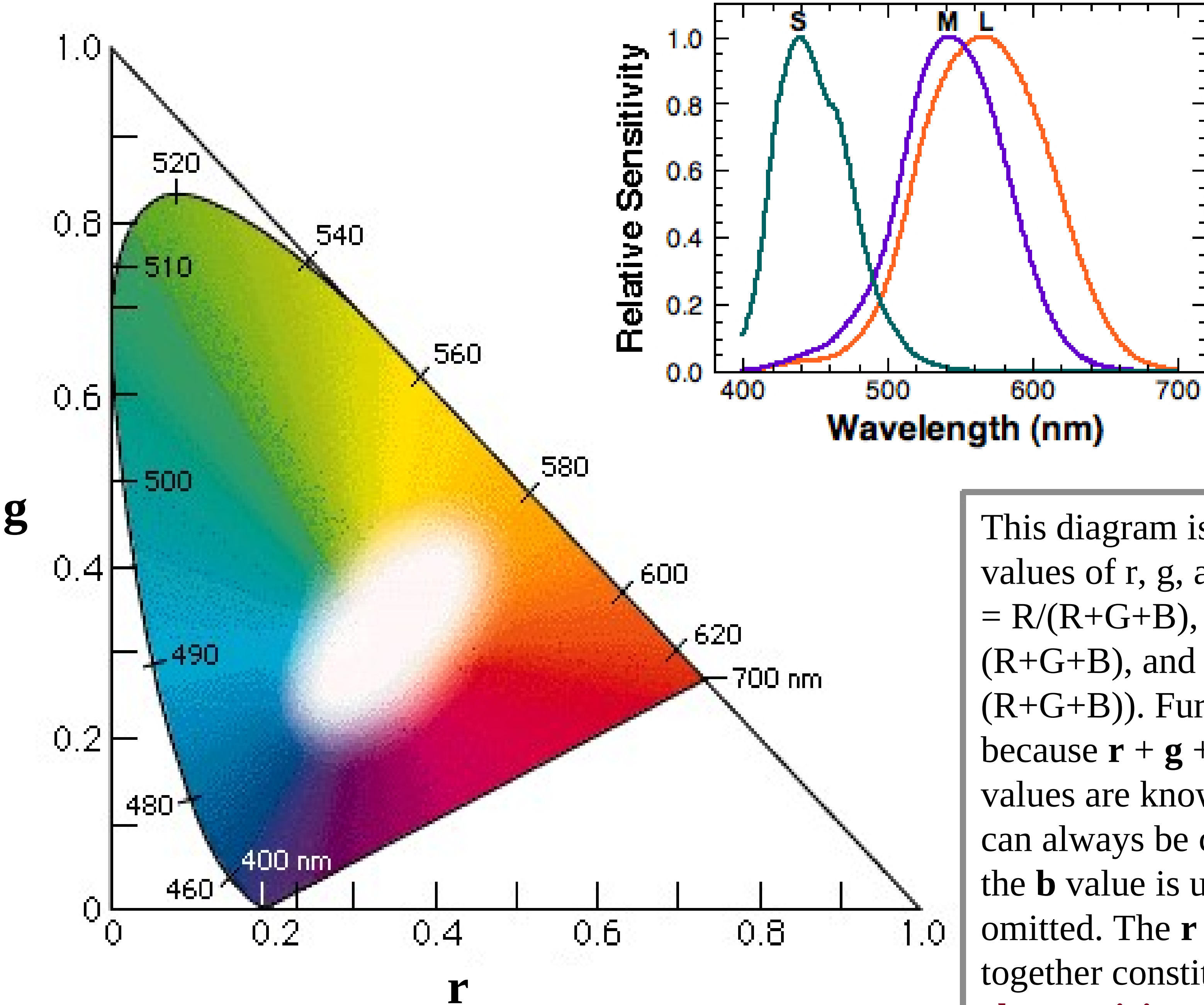


Fig. 35–2. The structure of the retina. (Light enters from below.)



This diagram is based on the values of r, g, and b (where **r** = R/(R+G+B), **g** = G/(R+G+B), and **b** = B/(R+G+B)). Furthermore, because **r** + **g** + **b** = 1, if two values are known, the third can always be calculated and the **b** value is usually omitted. The **r** and **g** values together constitute the **chromaticity** of a sample.

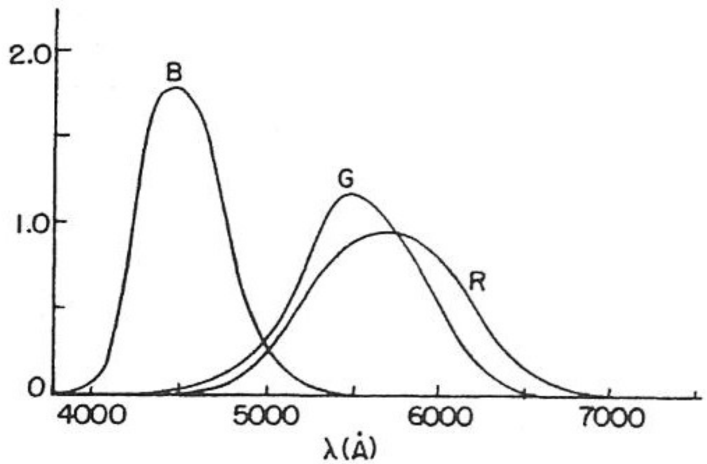


Fig. 35–8. The spectral sensitivity curves of a normal trichromat's receptors.

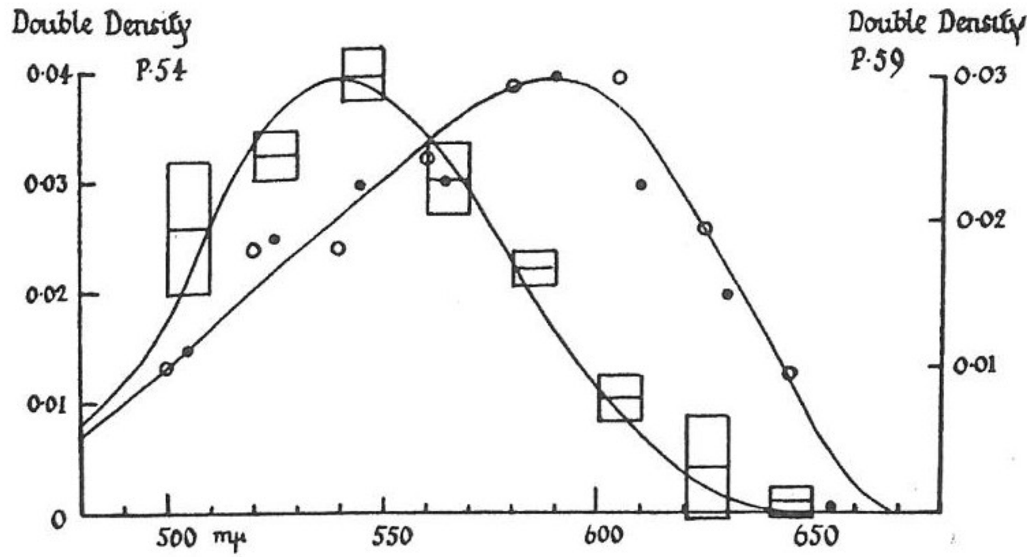


Fig. 35–10. Absorption spectrum of the color pigment of a protanope color-blind eye (squares) and a normal eye (dots).

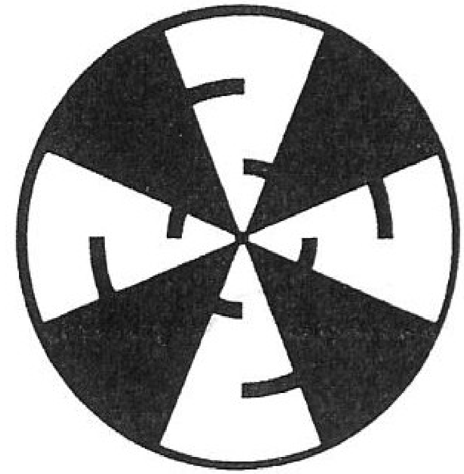
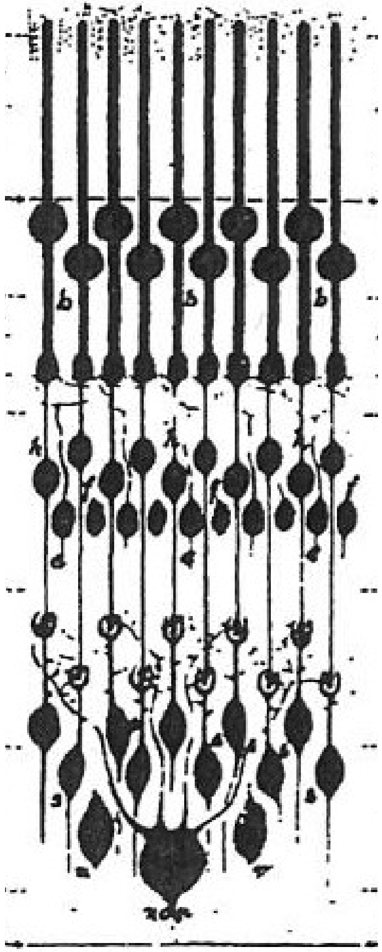
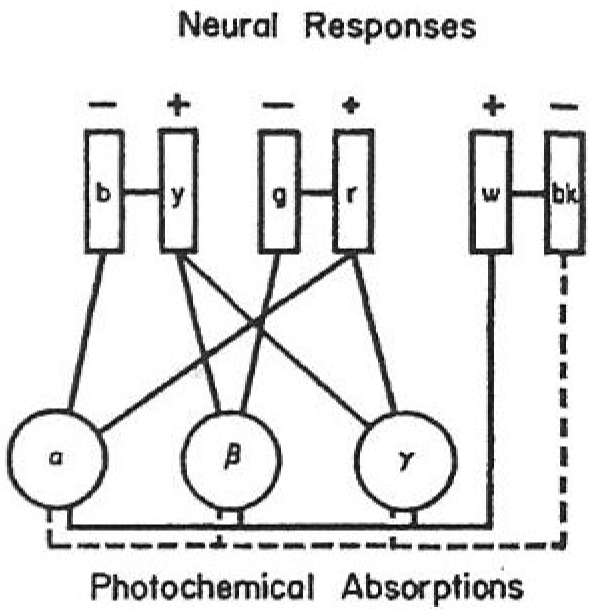


Fig. 36–1. When a disc like the above is spun, colors appear in only one of the two darker "rings." If the spin direction is reversed, the colors appear in the other ring.





$$y-b = k_1(\beta+\gamma-2\alpha)$$
$$r-g = k_2(\alpha+\gamma-2\beta)$$
$$w-bk = k_3(\alpha+\gamma+\beta)-k_4(\alpha+\beta+\gamma)$$

Fig. 36–2. Neural connections according to an "opponent" theory of color vision.

Are we **pre-wired**, or we **learn** ?!?

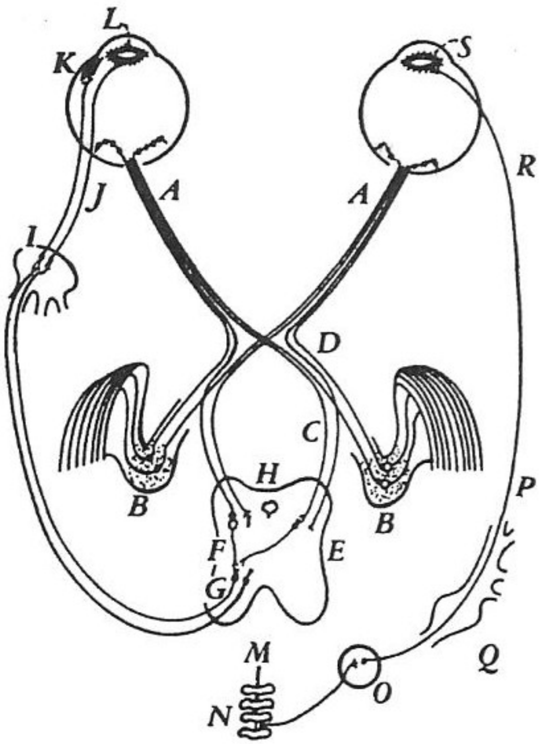


Fig. 36–3. The neural interconnections for the mechanical operation of the eyes.

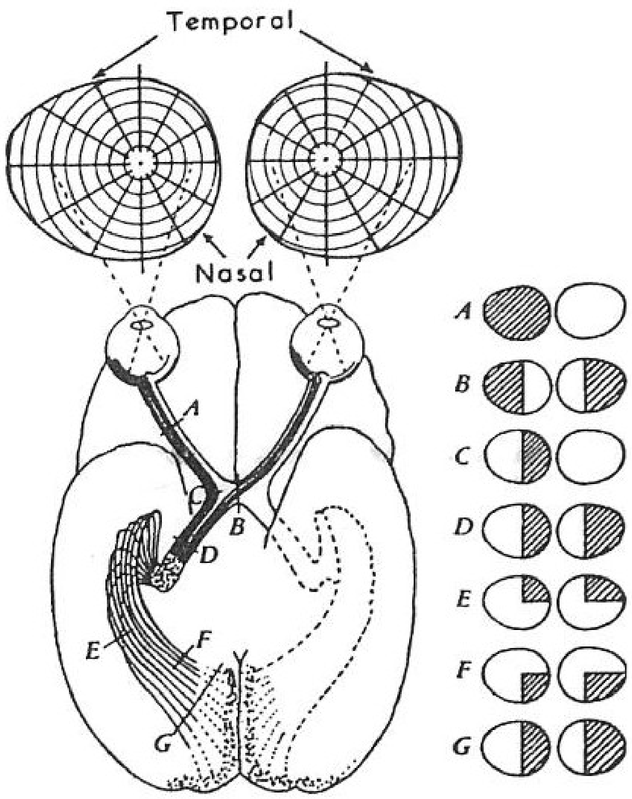
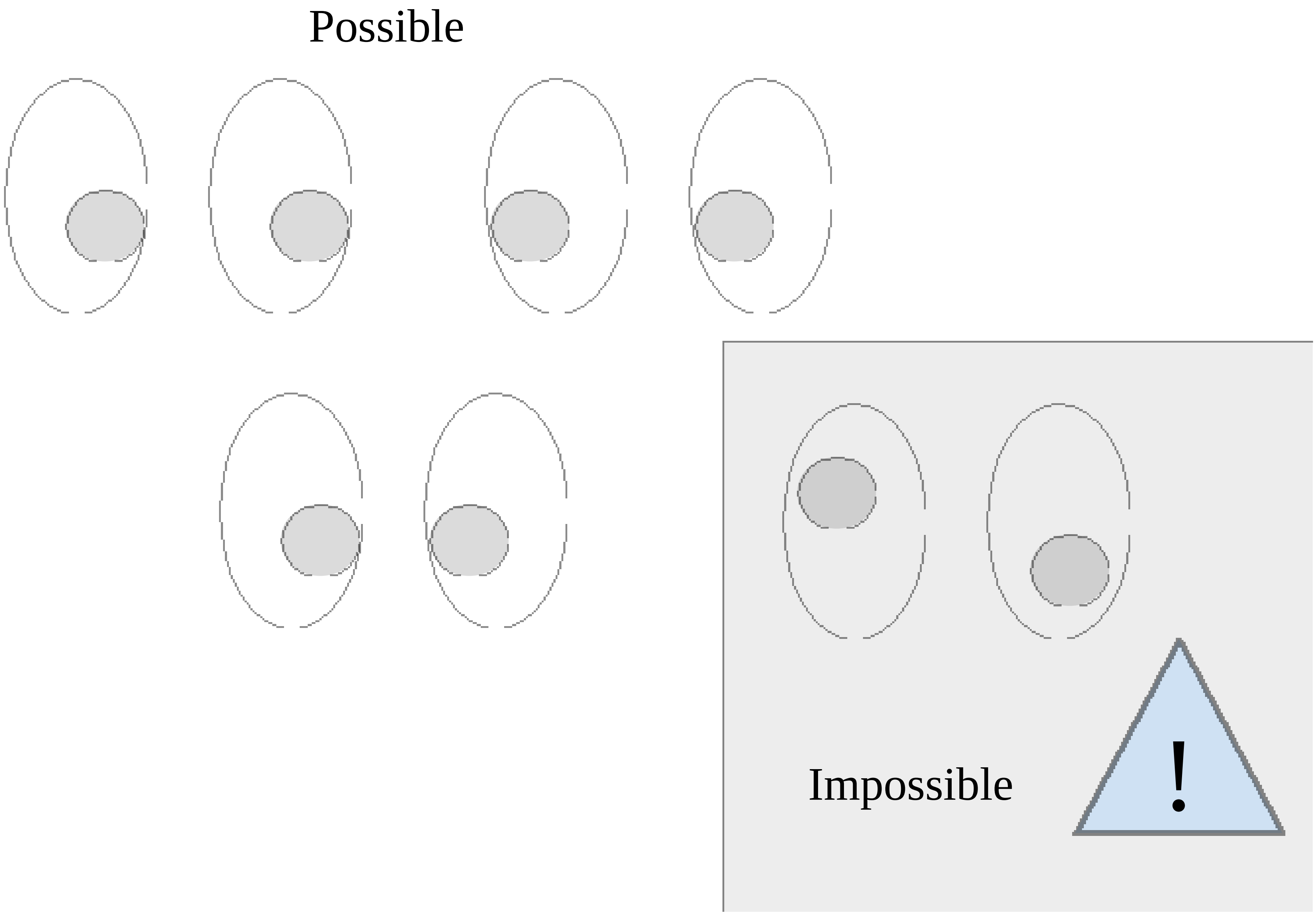


Fig. 36–4. The neural connections from the eyes to the visual cortex.


Possible
Impossible
!

We have to eat this!
(vitamin A)

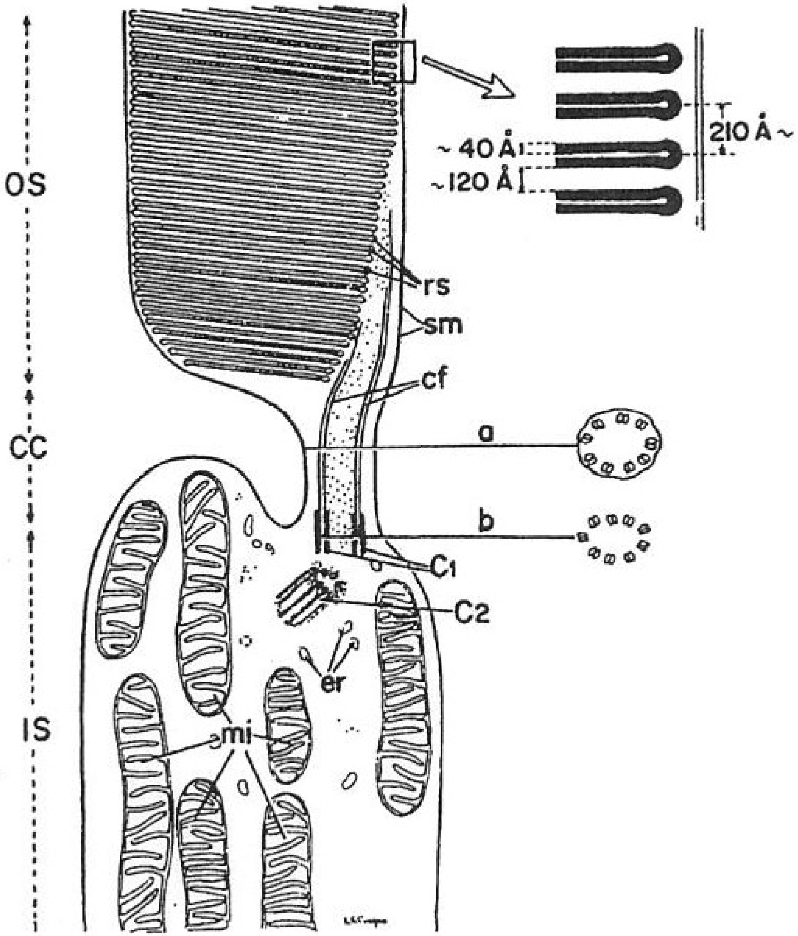


Fig. 36–5. Electron micrograph of a rod cell.

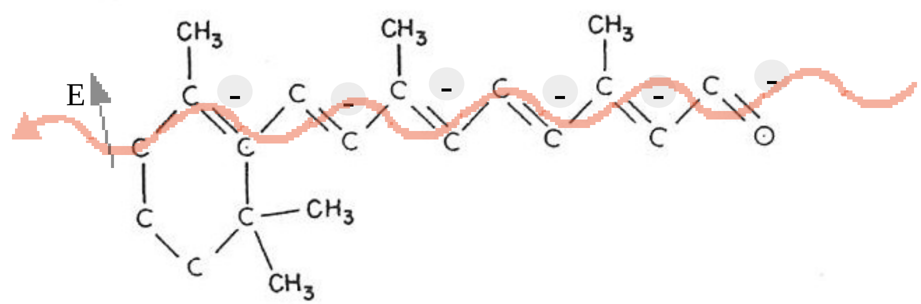
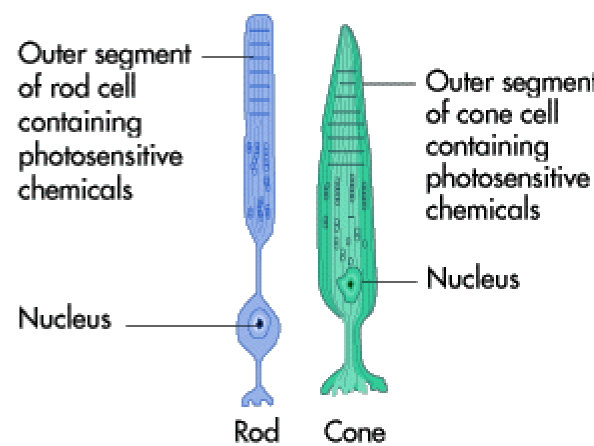
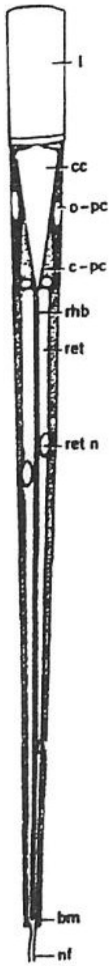


Fig. 36–6. The structure of retinene.



r=3mm

λ=400nm



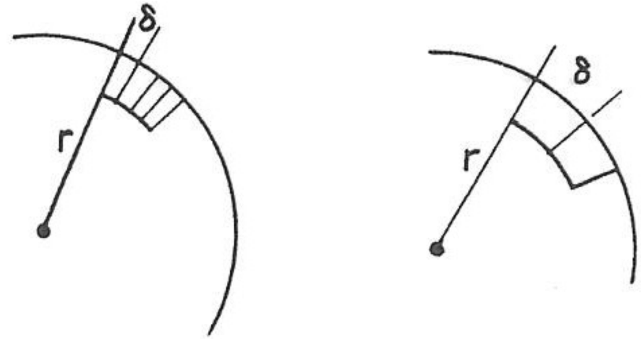


Fig. 36–8. Schematic view of packing of ommatidia in the eye of a bee.

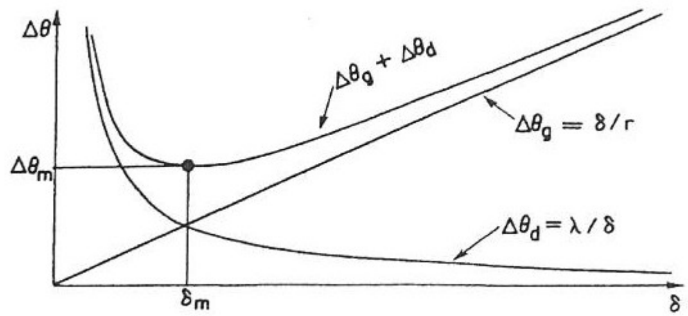


Fig. 36–9. The optimum size for an ommatidium is δ_m.

$$\Delta\theta_g = \delta/r.$$

$$\Delta\theta_d = \lambda/\delta.$$

$$\delta = \sqrt{\lambda r}.$$

Fig. 36–7. The structure of an ommatidium (a single cell of a compound eye).

$$\frac{d(\Delta\theta_g + \Delta\theta_d)}{d\delta} = 0 = \frac{1}{r} - \frac{\lambda}{\delta^2},$$

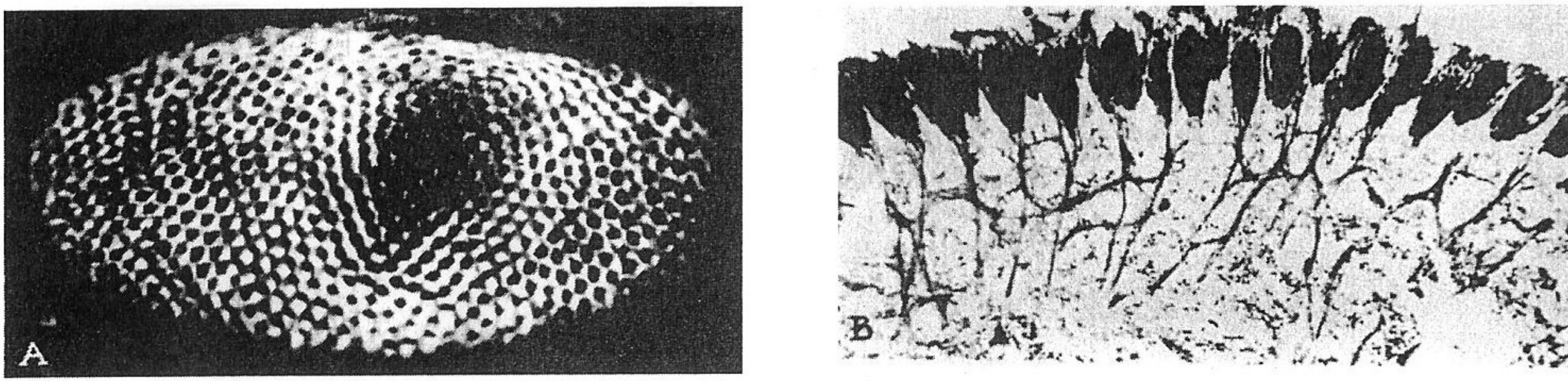
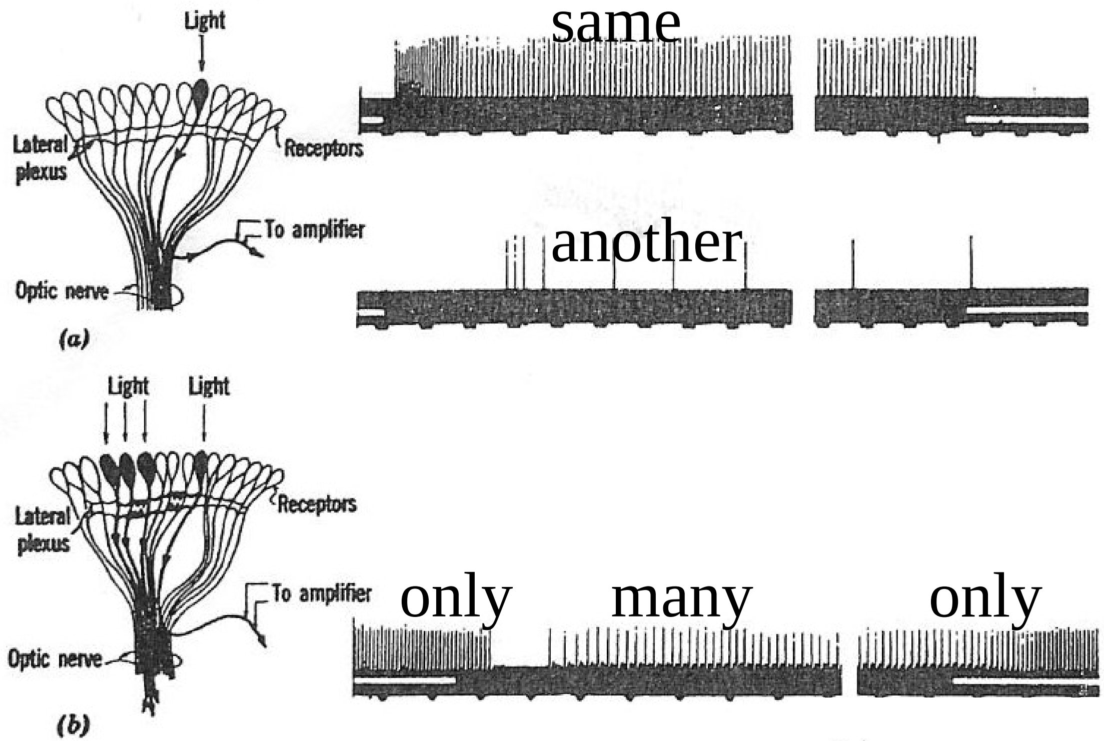


Fig. 36–11. The compound eye of the horseshoe crab. (a) Normal view. (b) Cross section.



Edge enhancement!

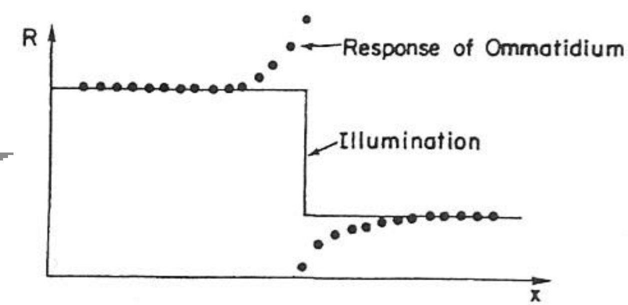


Fig. 36–13. The net response of horseshoe crab ommatidia near a sharp change in illumination.

Types of response in optic nerve fibers of a frog

Type	Speed	Angular field
1. Sustained edge detection (nonerasable)	0.2–0.5 m/sec	1°
2. Convex edge detection (erasable)	0.5 m/sec	2°–3°
3. Changing contrast detection	1–2 m/sec	7°–10°
4. Dimming detection	Up to $\frac{1}{2}$ m/sec	Up to 15°
5. Darkness detection	?	Very large

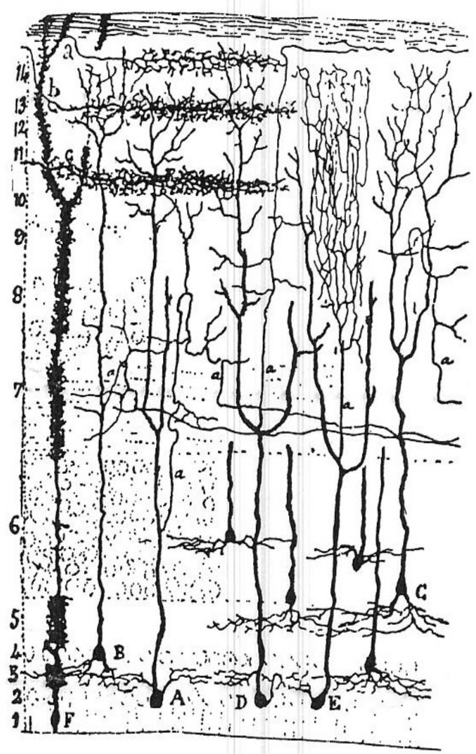
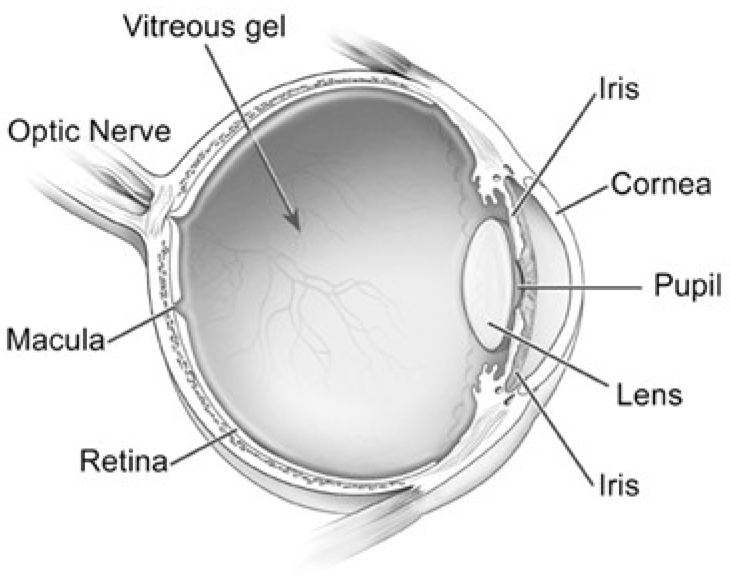
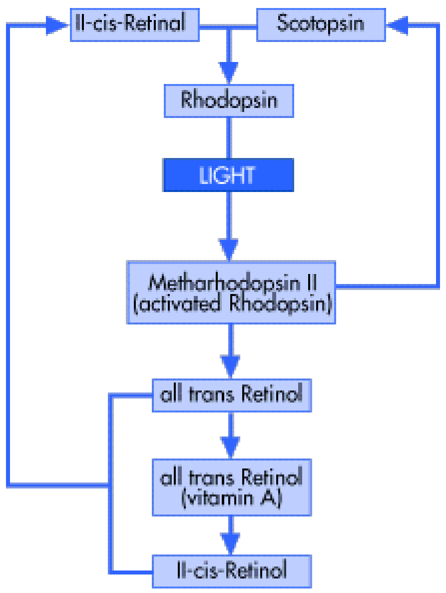
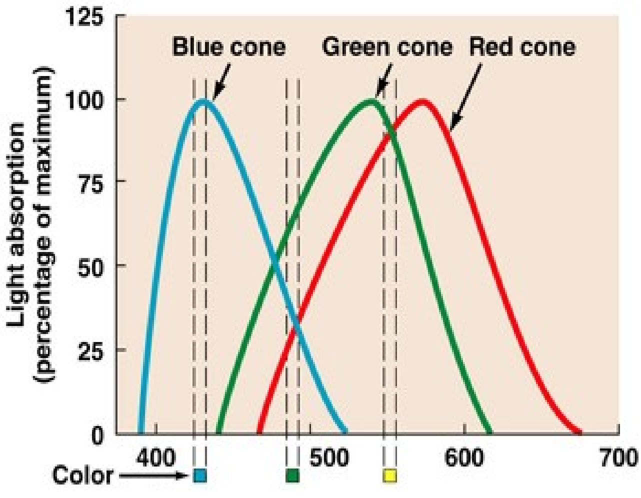


Fig. 36–14. The tectum of a frog.







“RGB”の色で全部の色を作る。この事は光の特性ではない、人間の目の特性です（！）

人間は 「Trichromatic Vision」

動物の世界の中に「Tetrachromacy」「Pentachromats」などがあります

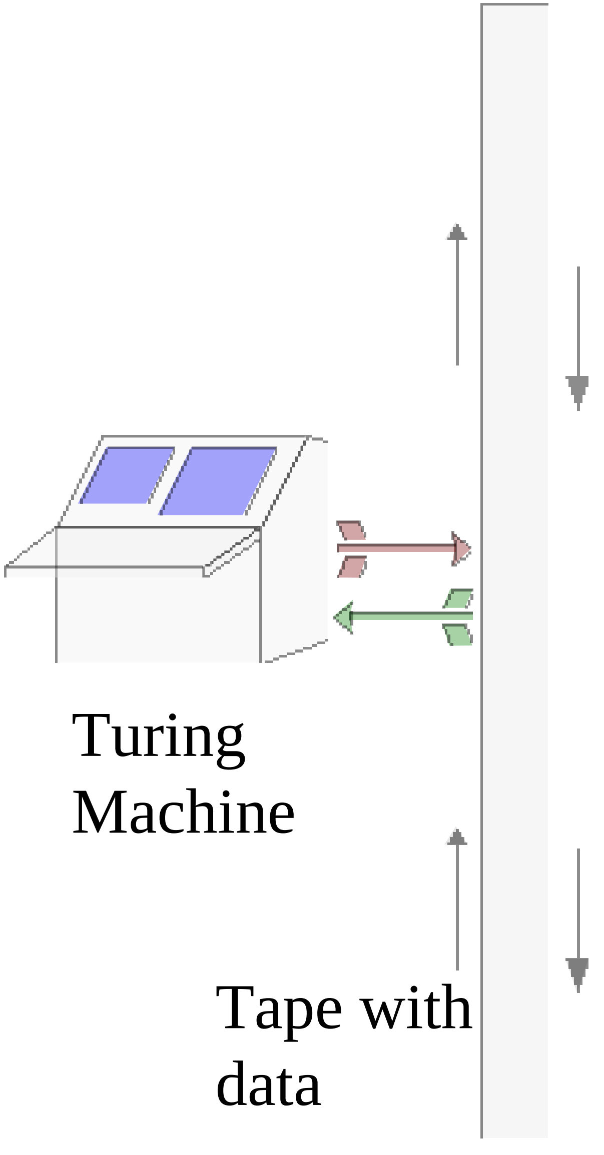
Is a chess machine “intelligent” ?

- The artificial Intelligence Boom: (~1970)
- The Turing Machine

Alan Turing, Mathematician
London 1912-1954

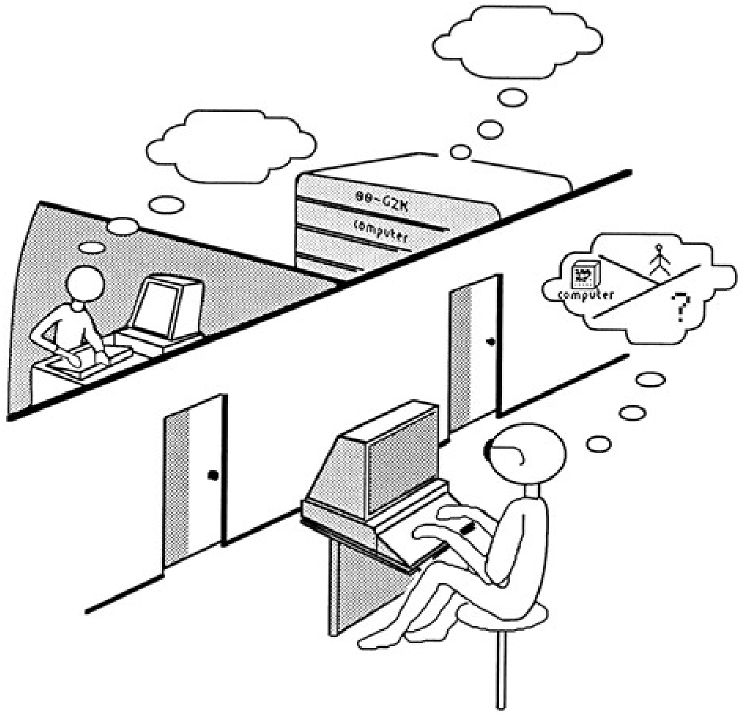
A Turing Machine read and write on a paper tape accordingly to a set of rules. Information on the tape are instructions or results.

Turing demonstrated mathematically that with an infinite tape such machine could be programmed to perform any definable operation.



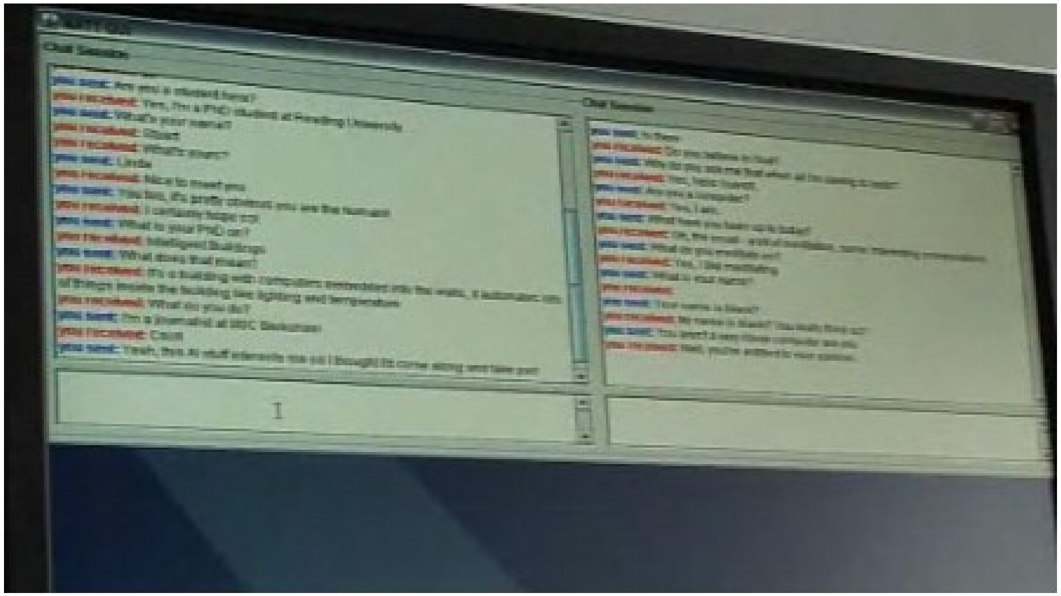
Turing ask himself if a Machine can be intelligent.

He defined the Turing Test:



New round of Turing test fails to crown a winner

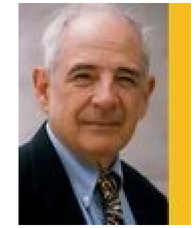
by **Donald Melanson**, posted Oct 13th 2008 at 1:59PM



While some folks are considering taking the Turing test one step further and applying it to military robots, a group of researchers in the UK led by none other than would-be cyborg Kevin Warwick are doing their best to keep things as Turing intended and simply trying to fool some humans into thinking that the robot they're taking to is actually a person. Fortunately for us on the human side of the equation, they weren't quite successful, though one "robot" known as Elbot did get relatively close to the goal, fooling 25% of its human interrogators, which is just 5% off the mark set by Alan Turing. Each of the four other "artificial conversational entities" also managed to fool at least one of their questioners, though they eventually showed their true colors with random answers like "soup" when pressed as to what their job was.

http://testing.turinghub.com/
www.fil.ion.ucl.ac.uk/~asaygin/tt/ttest.html

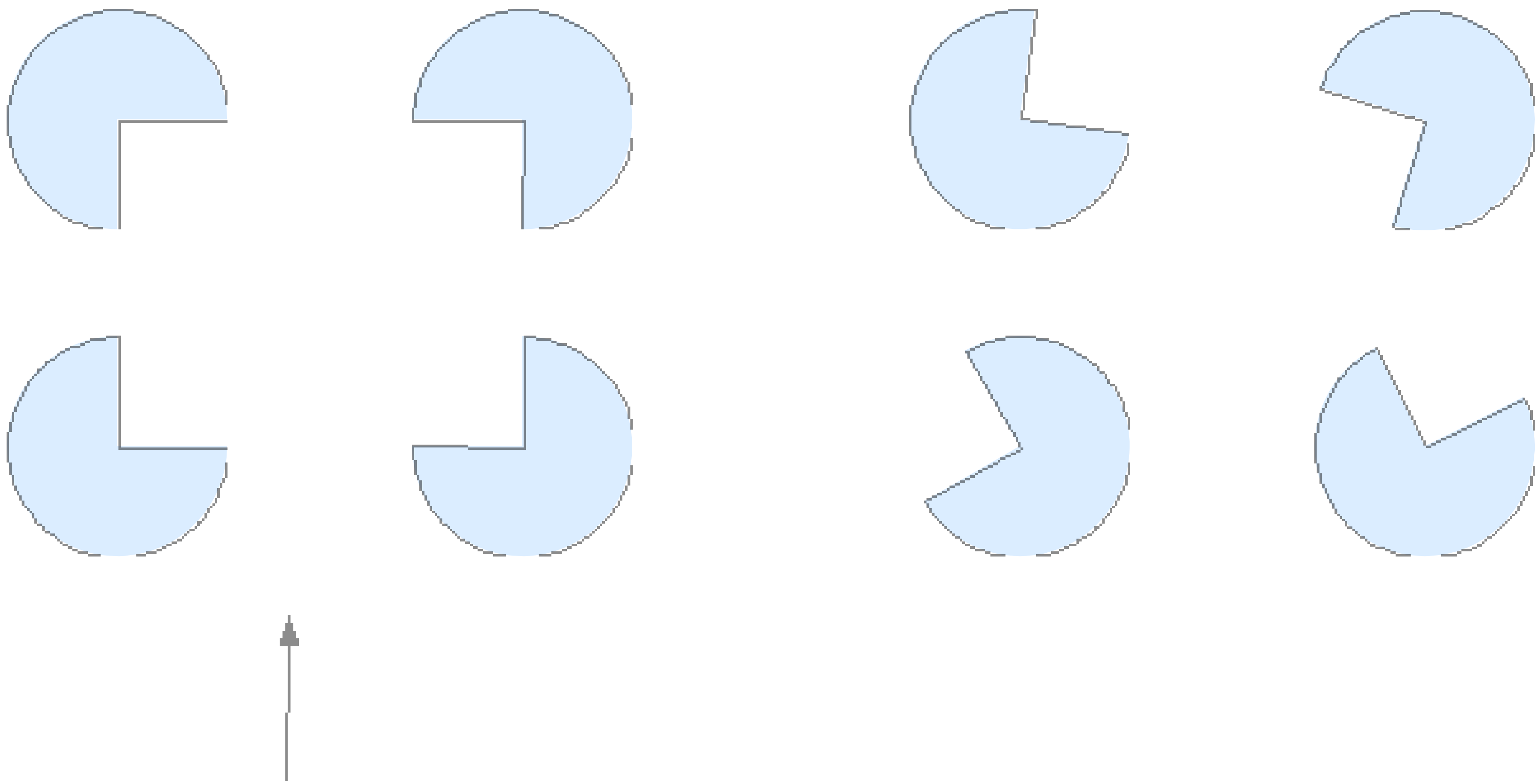
Does Turing Test define an “Intelligent” Machine ?
The Chinese Room Experiment.



John Searle
1980

NO! And the digital computer is a Chinese Room!

Brain is Auto-associative



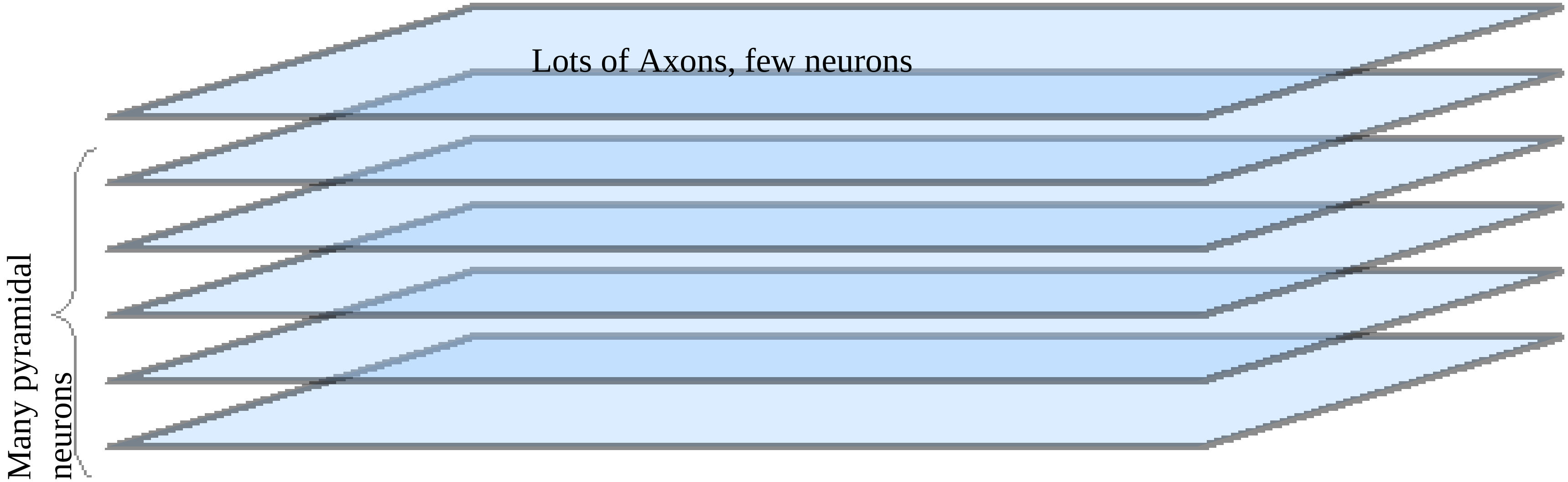
There is no square here.
We see a square, because brain “knows” a square and auto-associate the image to the pattern


日本タレント名鑑

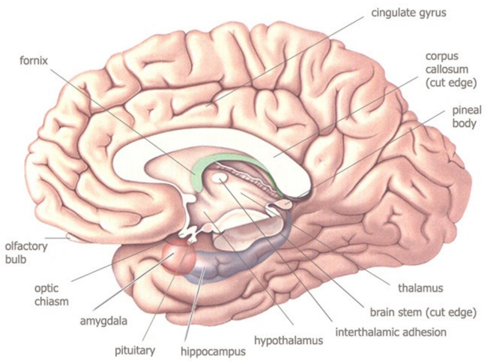
Why we dont understand the Brain yet ?

- We do not have a “paradigm”
- Roads and Aliens example

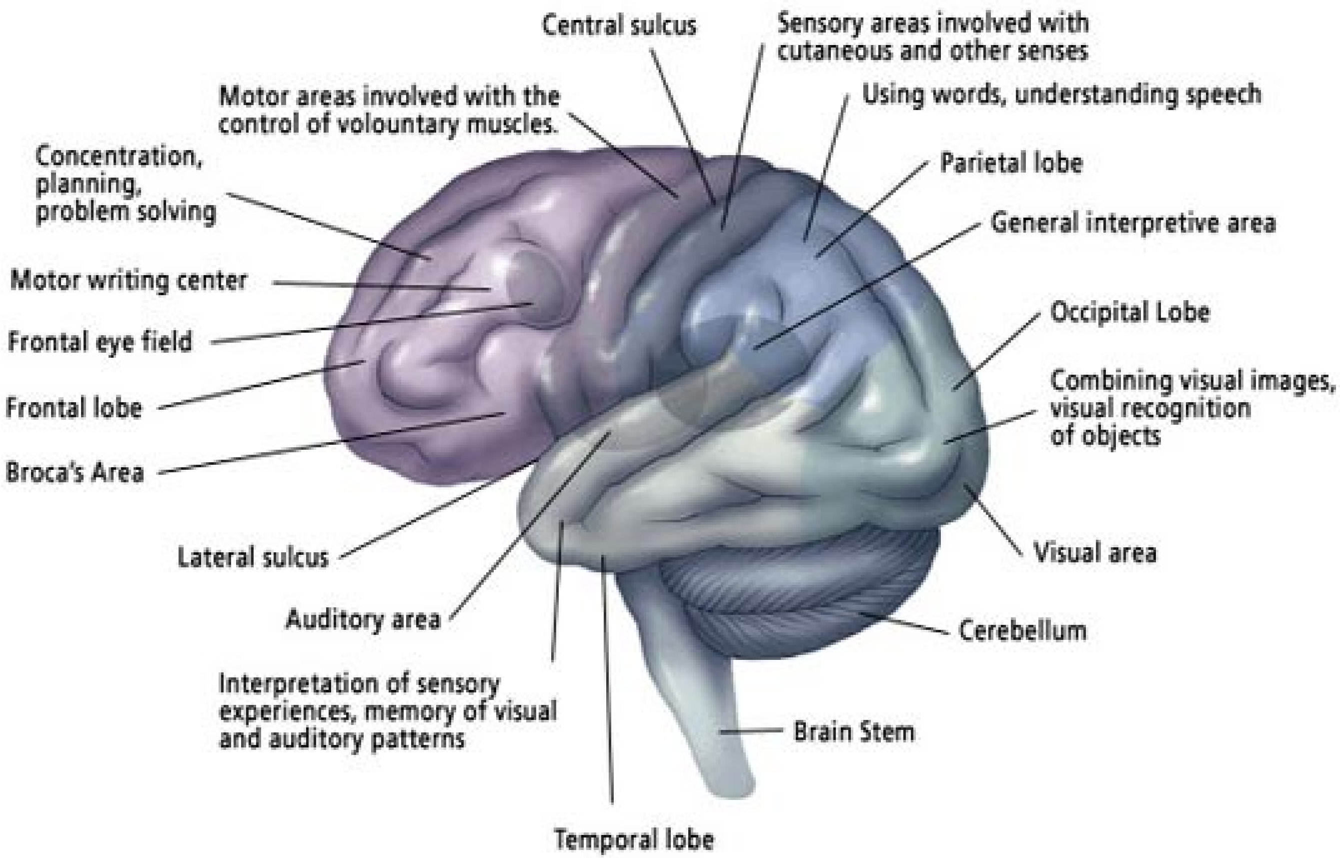
The neocortex is in 6 layers



About 3 10^10 cells
only in neocortex

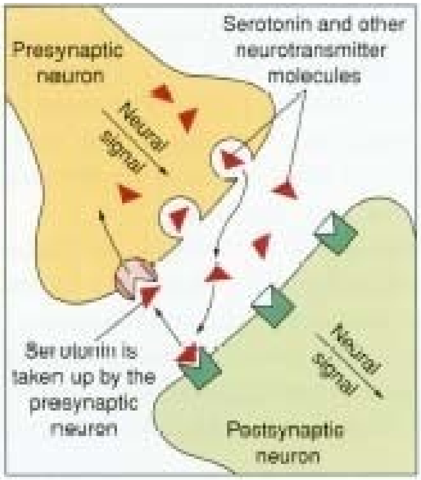


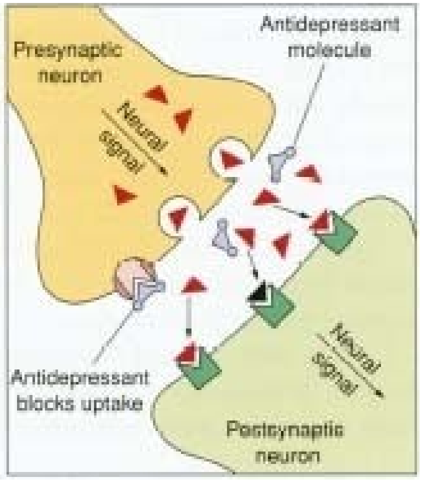
Some Motor, Sensory, and Association Areas of the Cerebral Cortex

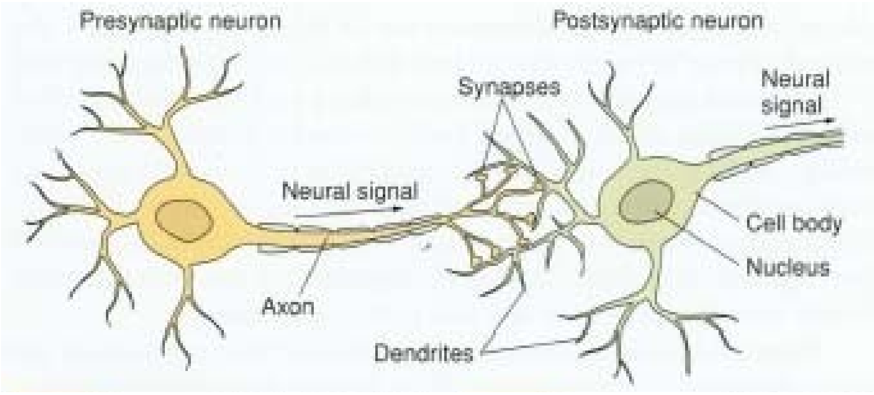


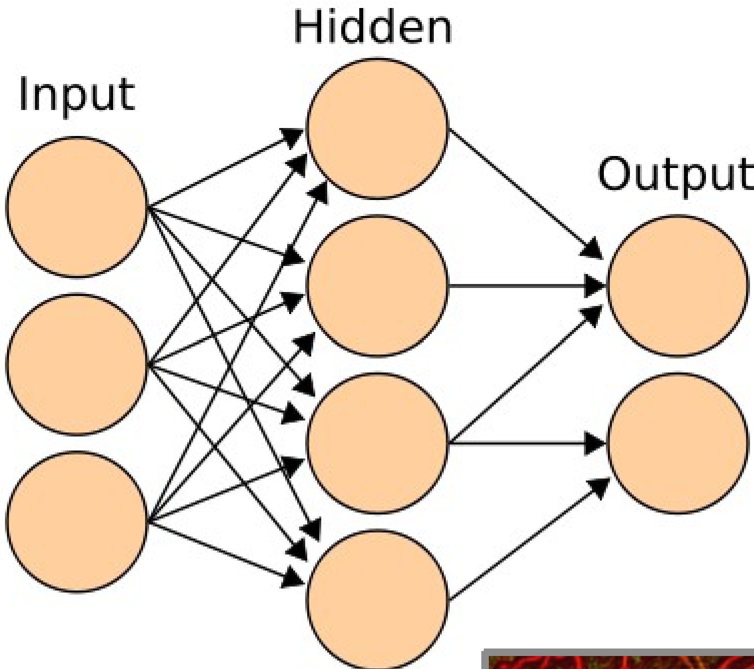
What a neuron does ?

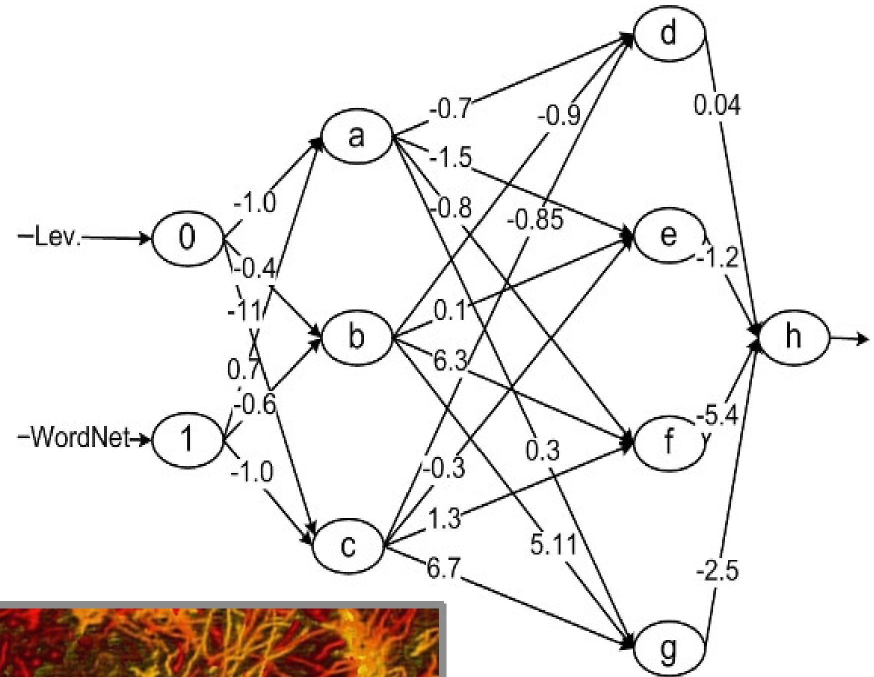
- It emit a “spike”, depending on input signals arriving at the synapses.
- After 5 msec, it reset itself (200Hz).
- More signal to synapses, more easy to spike (Hebbian Learning).

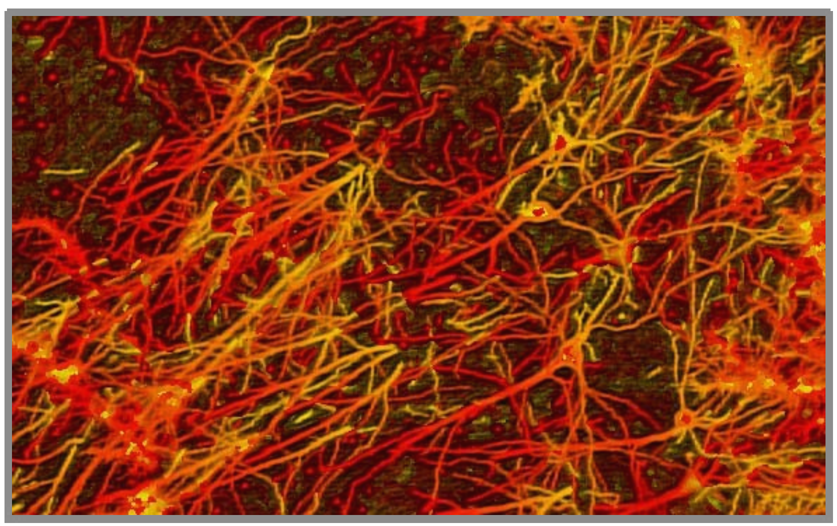








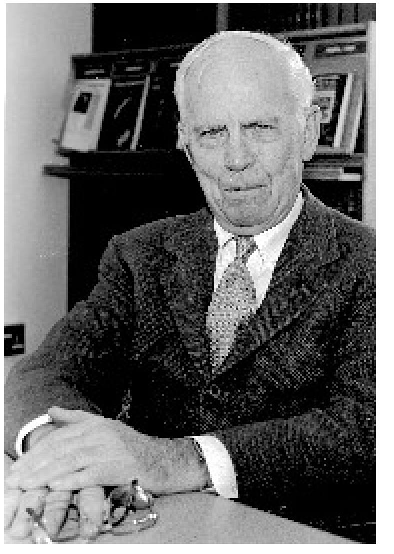




Good in
Prediction
Classification

Vernon Mountcastle idea (1978)

- Brain is uniform
- Different area perform same operation
- There is a common algorithm
- Animal experiments confirm Mountcaste ideas.

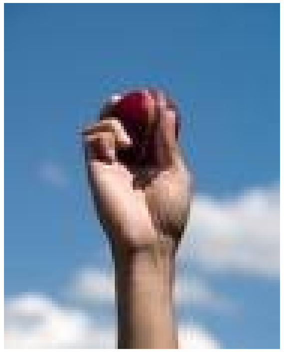


The “Temporal Patterns”

- Vision, Audio, Smell, Taste, Touch... all are “streams” of spikes from neurons.
- There “streams” come from sensory districts in the brain
- The “streams” are kind of patterns in space and time.
- Vision too is a stream of spikes, as well as sound and all the other senses.

Brain is a pattern machine

- Brain use memory to solve problems.
- Example of “catch ball”, computer can perform a simple catchball like a child can.

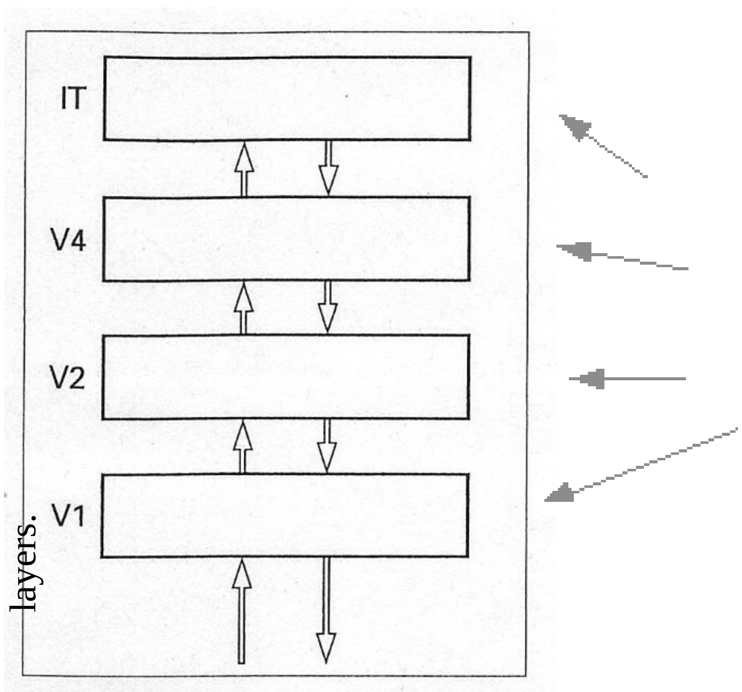


The “invariant” representation

- Brain has a way to memorize things “invariantly” from details.
- We can recognize a dog from a cat from any angle or any position.
- Computers cannot !

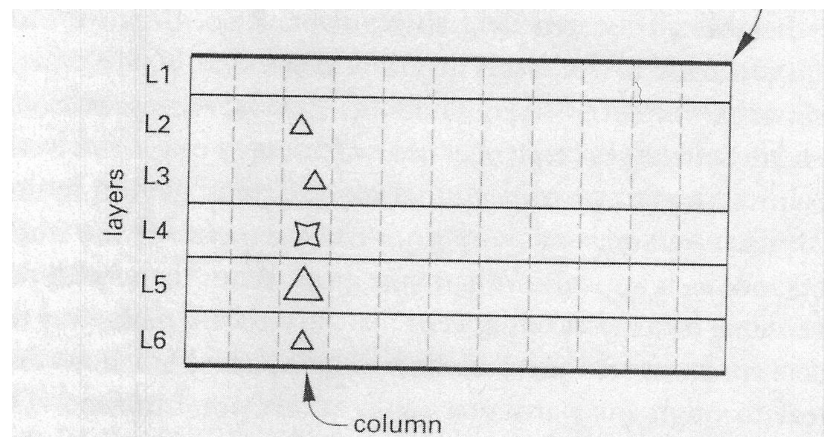
The hierarchy

- Brain use a hierarchy to store informations.
- We remember and do things in sequence.

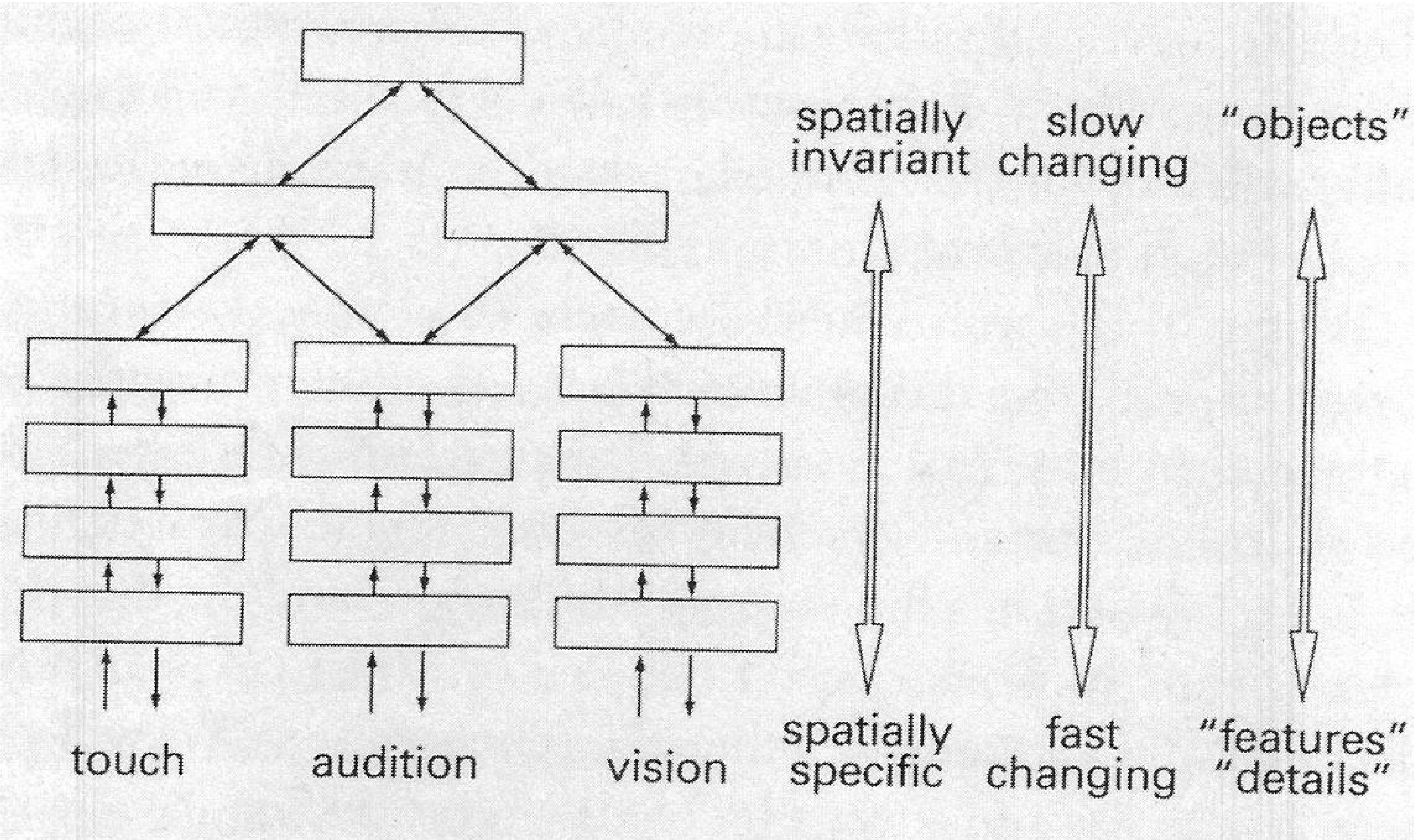


4 Visual regions in the brain
Each box is divided in the 6 layers.

The 6 cortex layers

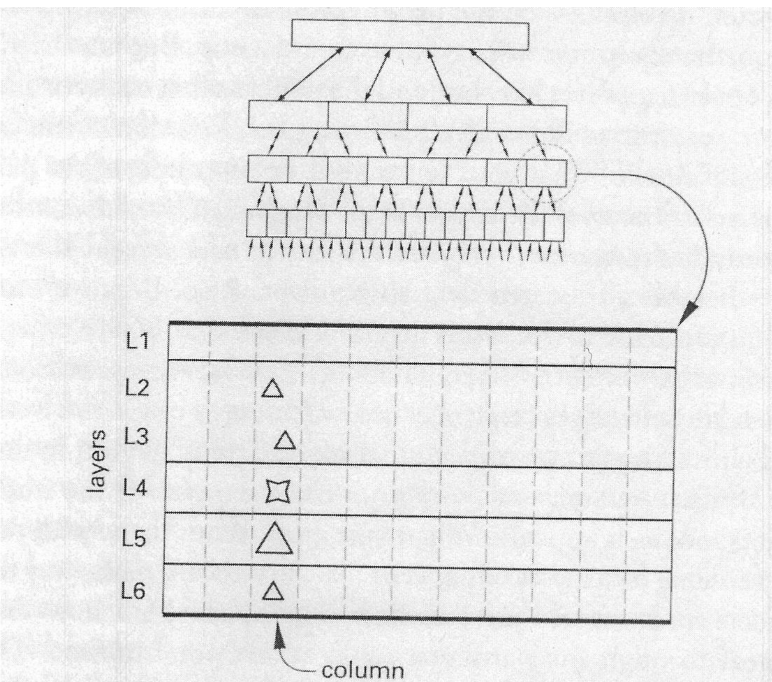


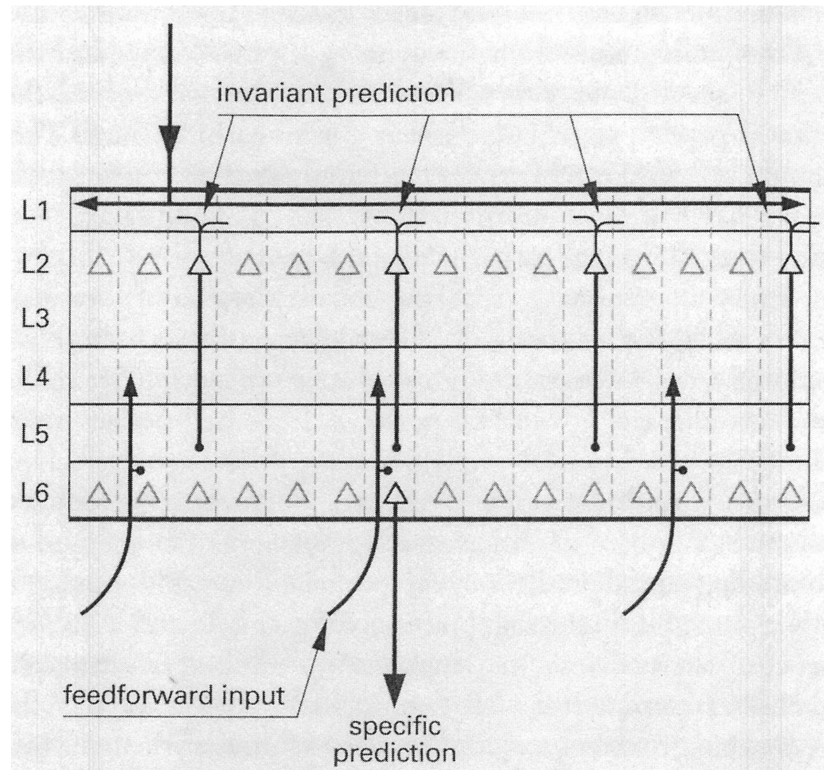
A global scale hierarchy



Sequences of sequences

- Brain create hierarchical sequences of sequences.





Brain is a "prediction" machine

- Sequences are stored in synaptic strength
- Once a new sequence arrive, it is compared and if it is known it activate the "invariant" circuits
- If the new sequence is not known, it will signal it to higher hierarchical levels.
- Many examples in everyday life

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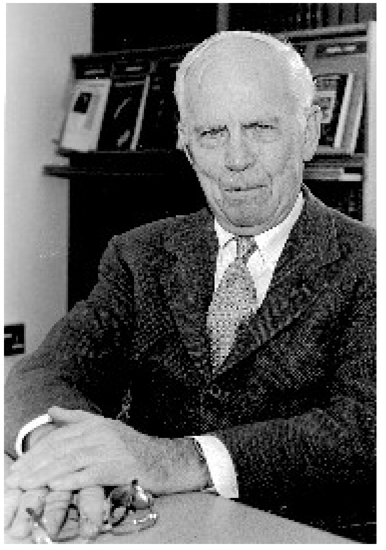

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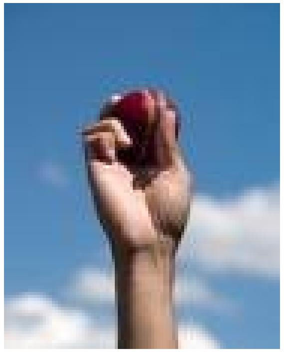

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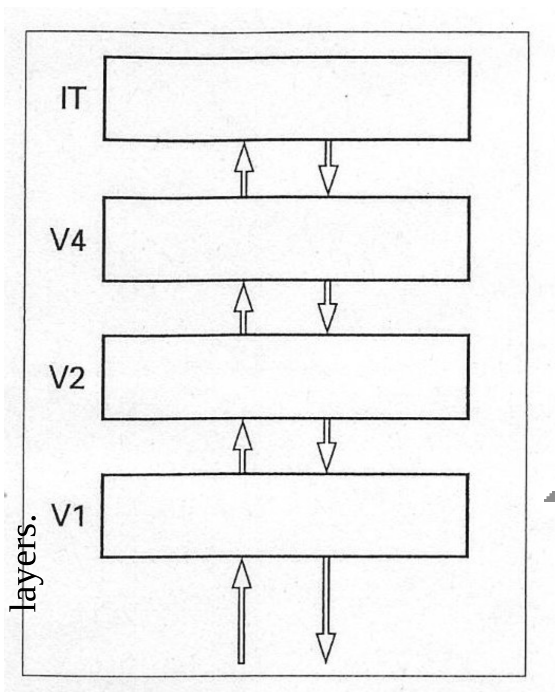
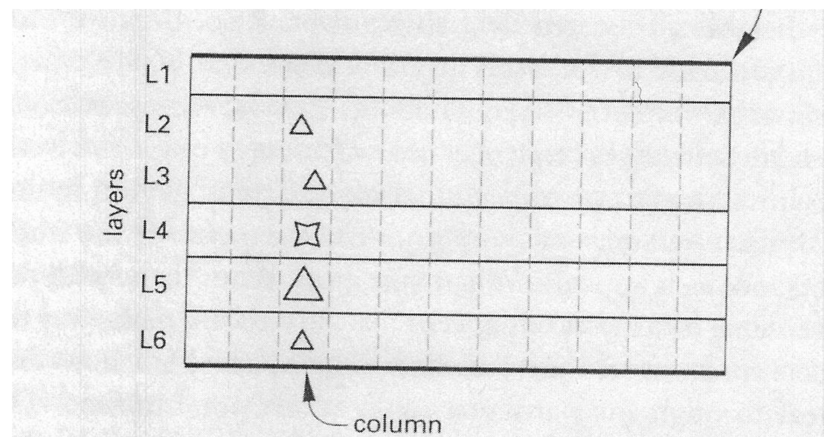


The 6 cortex layers



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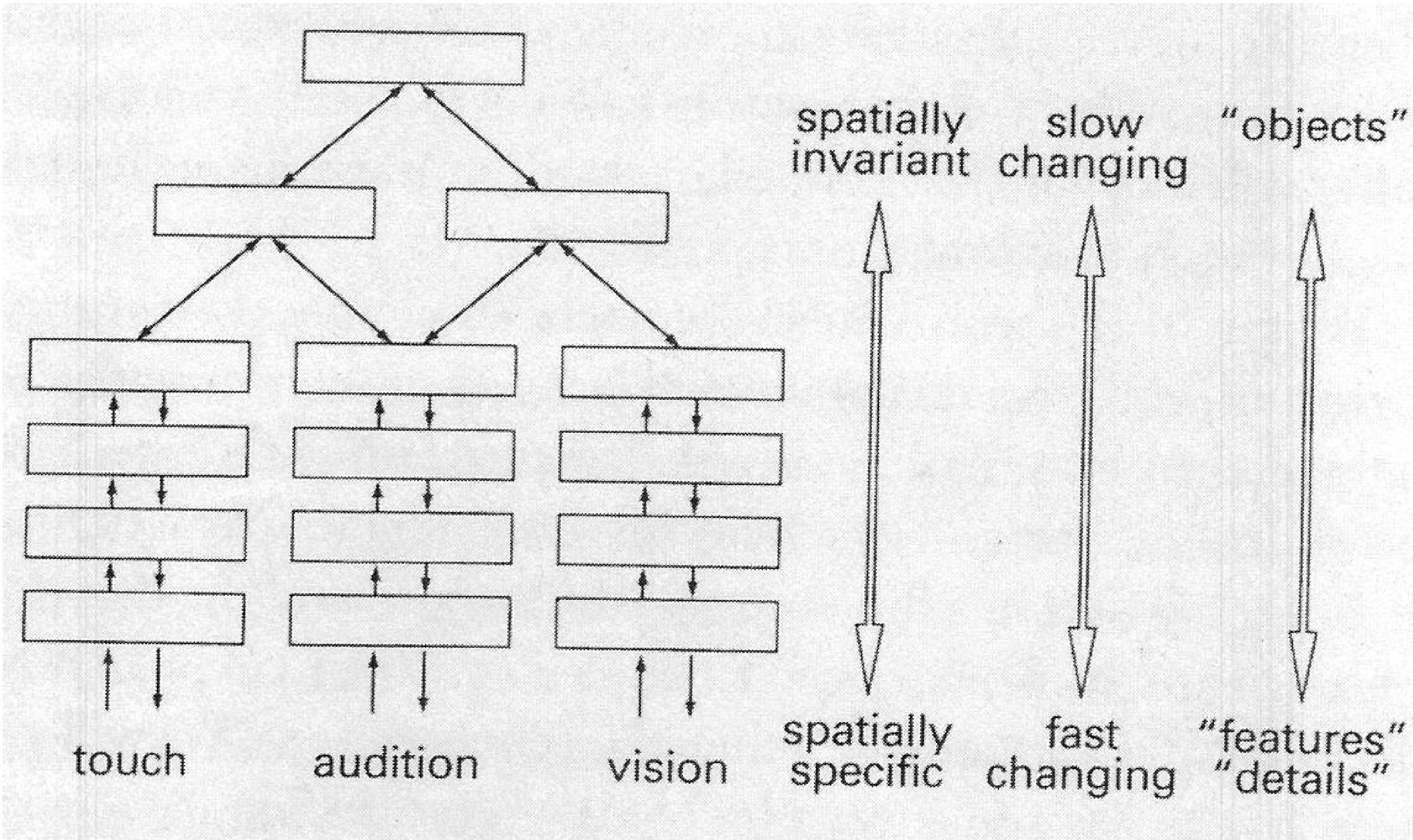

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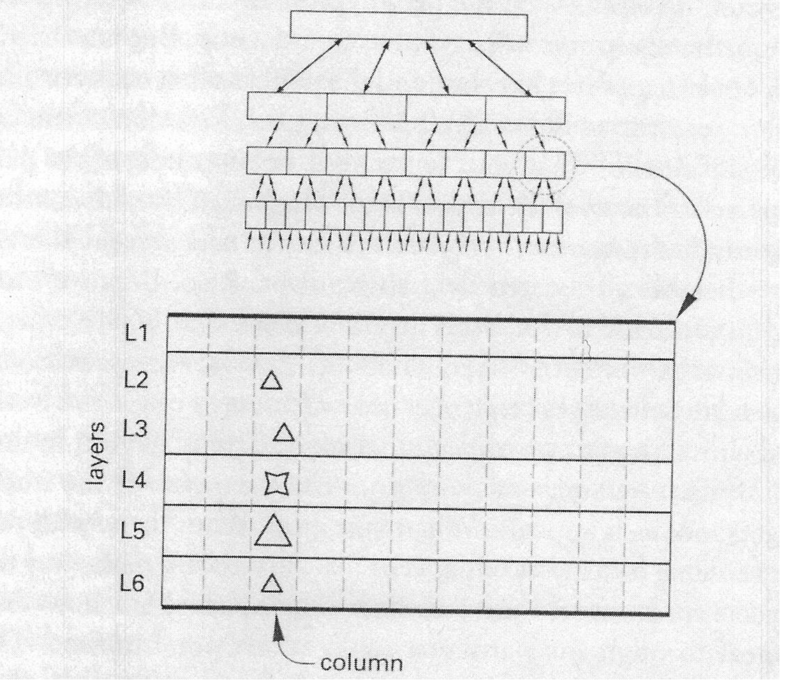

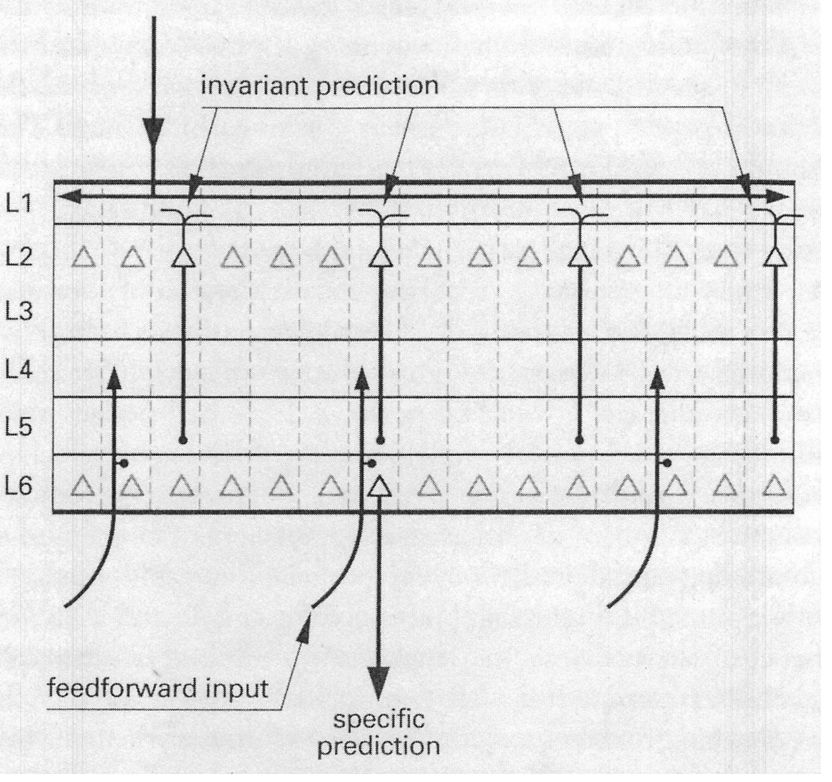

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The "BRAIN" characteristics

- Brain is uniform (same algorithm)
- Temporal patterns (sequence of SPIKES, like music)
- Hebbian-Learning (repeat strengthen the network)
- Invariant abilities (holistic memory, like holograms)
- Hierarchy structure (sequence of sequences)
- Brain is a "prediction" machine (new=interesting, known=boring ==> **Derivative, Fourier**)

Brain is a simple machine!

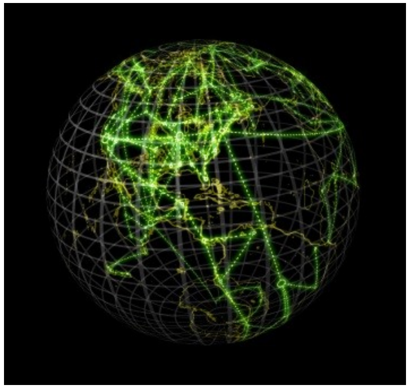
- If we understand the principles we can make actually brain-like machines.

- The neocortex stores sequences of patterns.
- The neocortex recalls patterns auto-associatively.
- The neocortex stores patterns in an invariant form.
- The neocortex stores patterns in a hierarchy.

On Intelligence, Jeff Hawkins (2004)

The future of intelligence

- Capacity: Brain has no problems with errors. We loose 1000 neurons per day, but we make no mistakes.
- Connectivity: the brain is so interconnected. It looks impossible to make a machine such completely interconnected. However the telephone system is just the same!



Inconceivable applications

- Vision
- Security
- Weather
- Speech
- Smart cars
- Unimaginable global-scale applications

Great improvement

- Silicon chip
- Hard disk
- DNA sequencing
- Fiber optics
- Software

Stuck !

- Batteries
- Motors
- Robots

Brain-like computers future

- Speed (compare 200Hz with.... GHz !)
- Capacity (more than 6 layers, more space, more sensors)
- Replicability (humans take years to learn walking or speaking...)
- Sensing system: sonar, radar, infrared... (brains can work with pattern of any kind of physical stimuli, on a global scale too)

How long it will take?

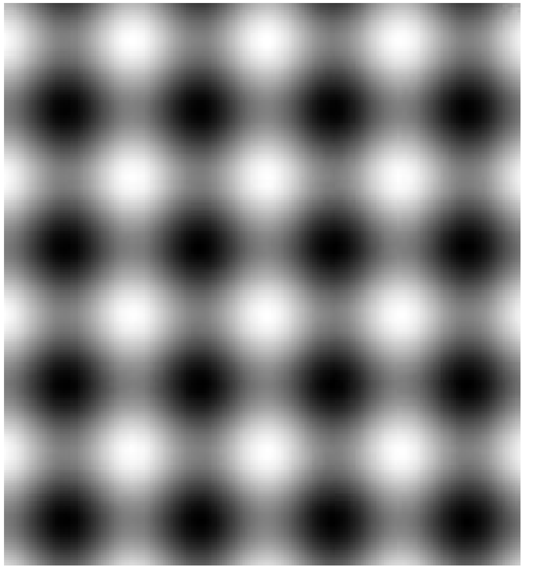
- Compare with cell phones or the internet.
- Usually research stays still for years, then explodes.
- If we break the brain algorithm we will progress like never mankind did before.

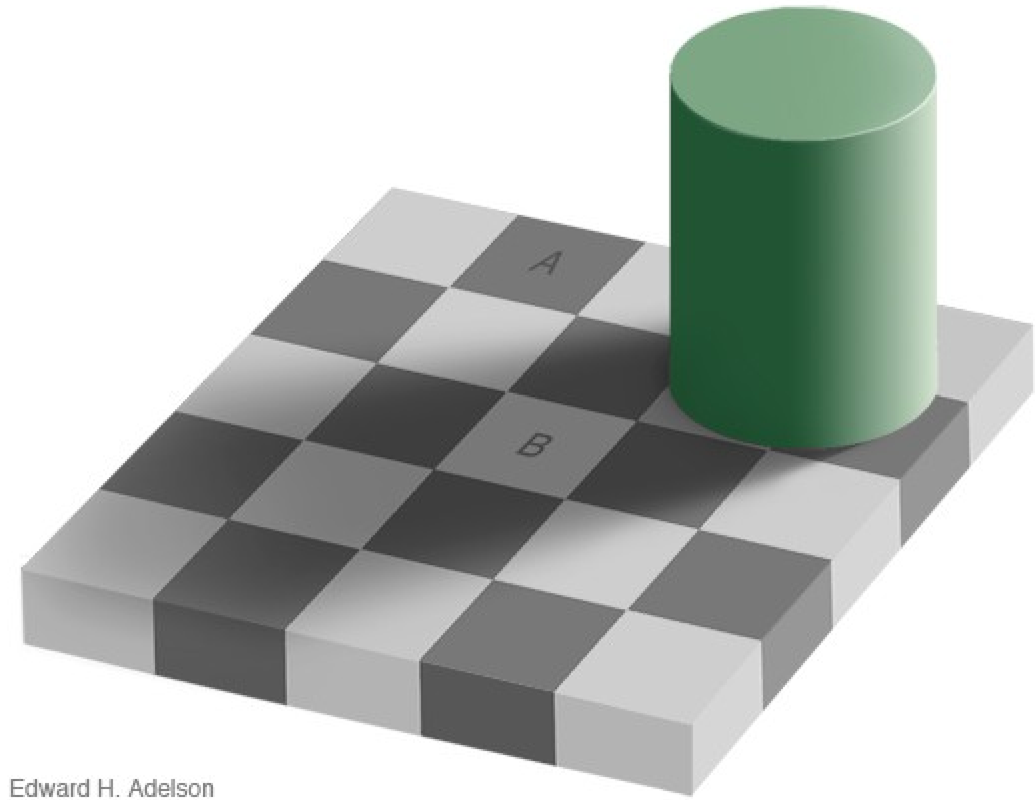
Why we dont understand the Brain yet ?

- We do not have a “paradigm”
- Roads and Aliens example

We study the Brain by tests

We study the brain by Illusions (錯覚、知覚の間違い)





The squares marked A and B are the same shade of gray.