横浜市立大学大学院

ナノシステム科学専攻

物理博士　ミケレット・ルジェロ

知覚情報科学

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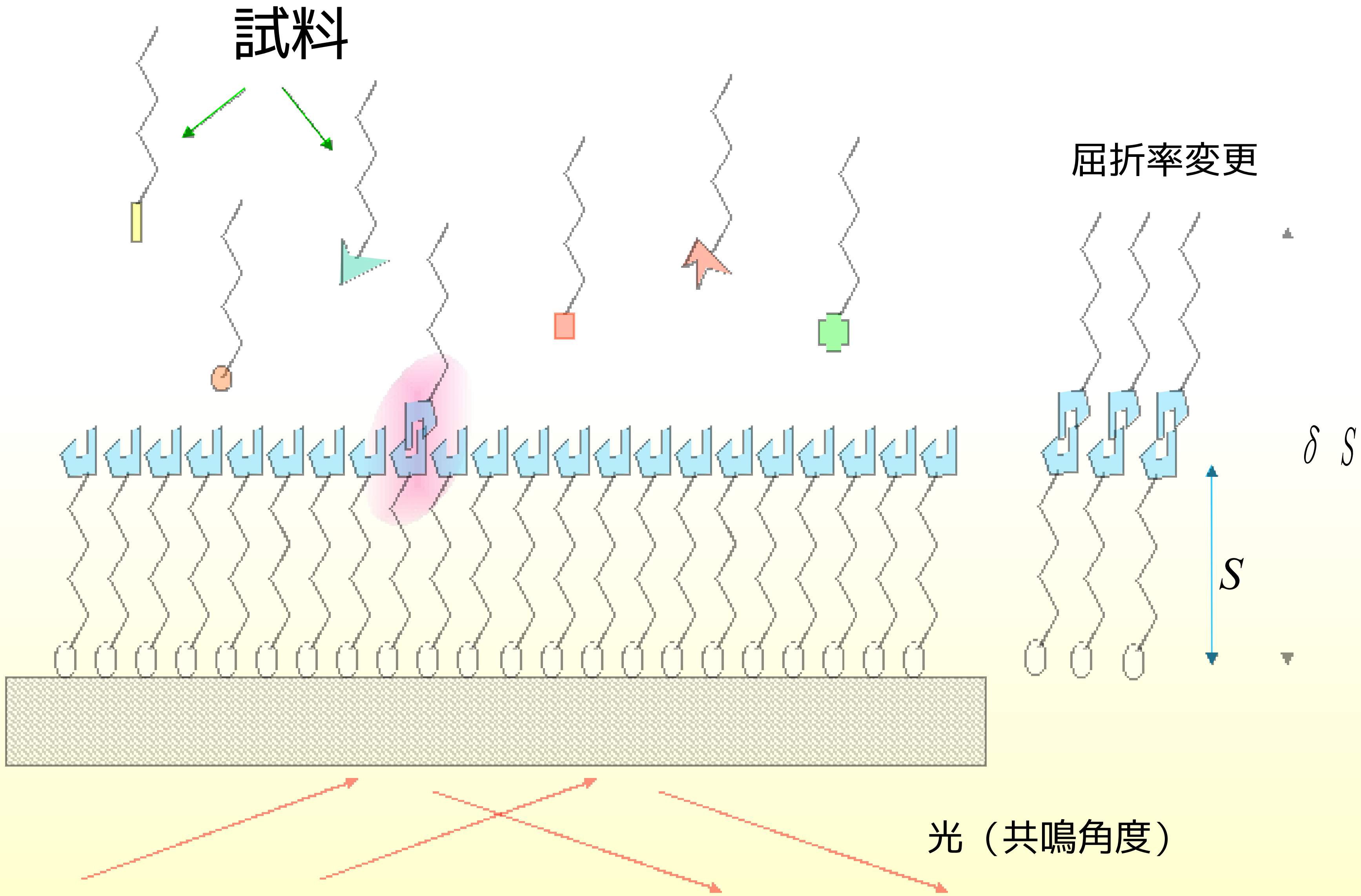
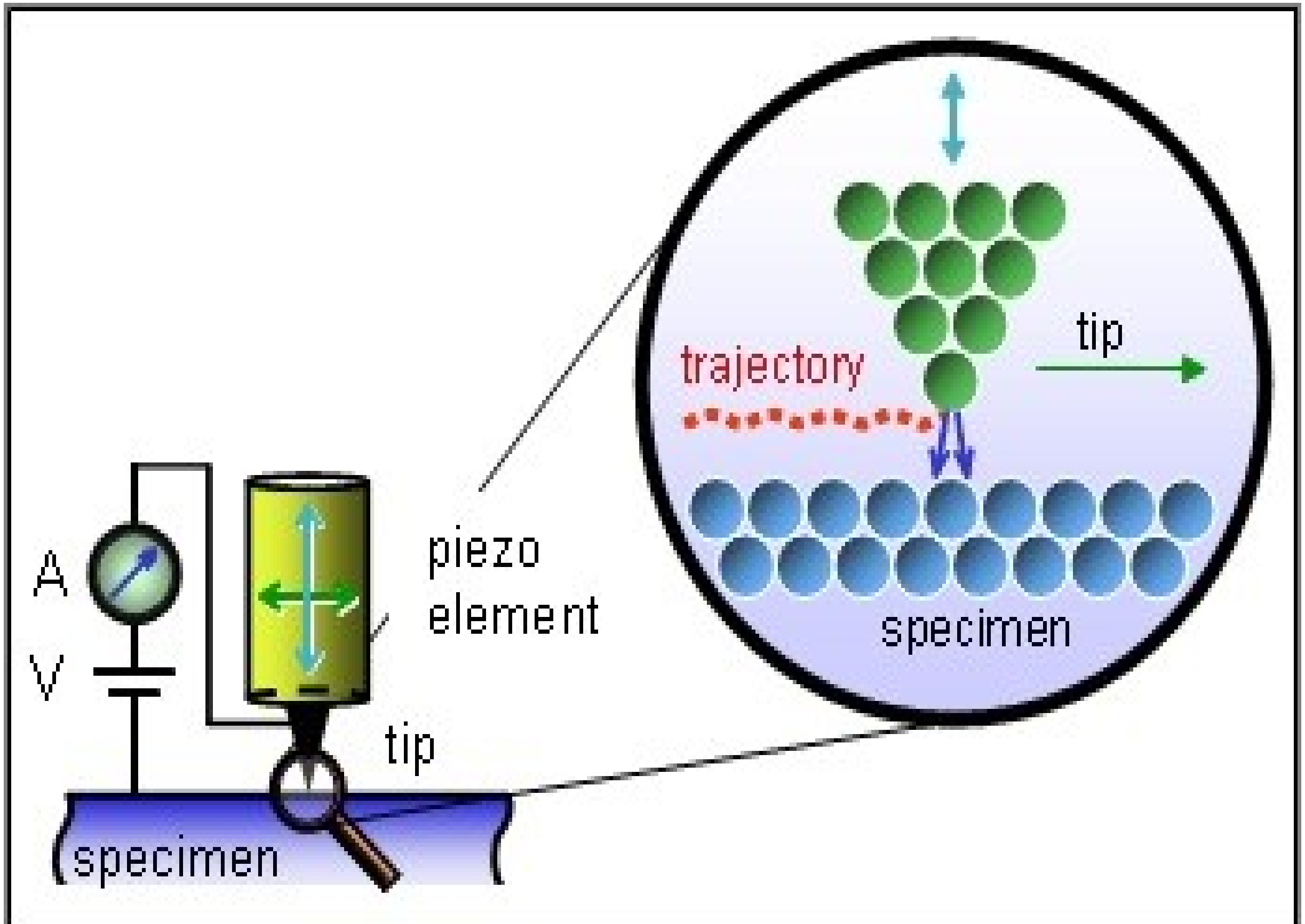
(3)

後期２０１０年

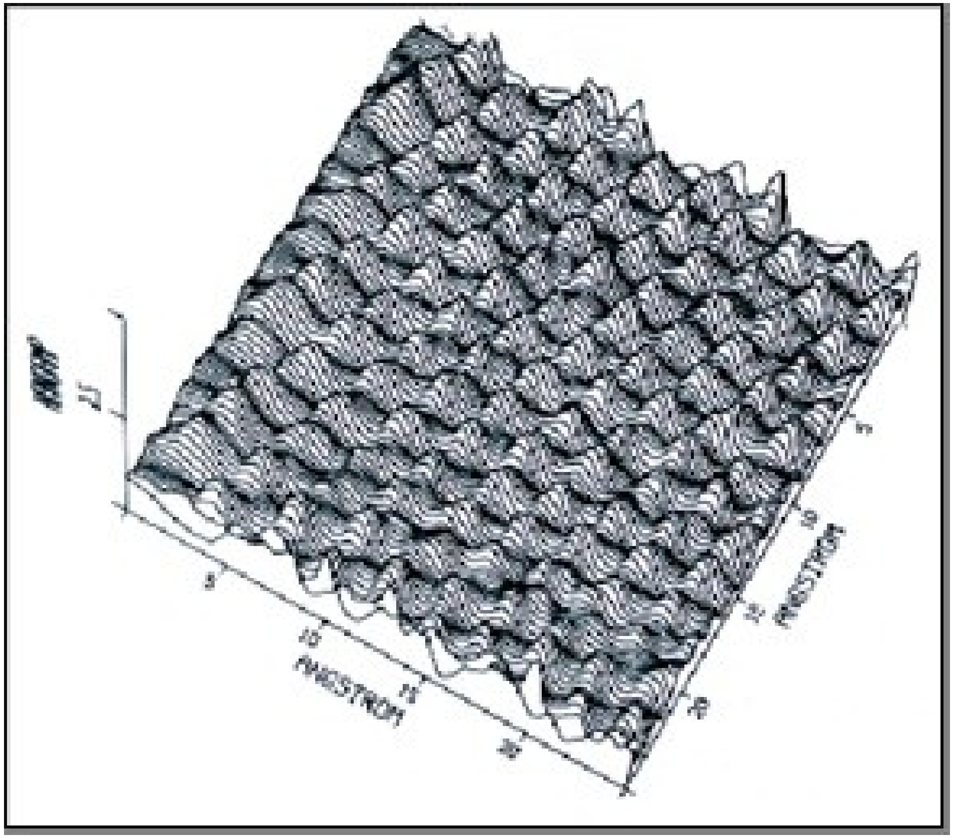
表面プラズモン共鳴を用いたバイオセンシング技術の観念

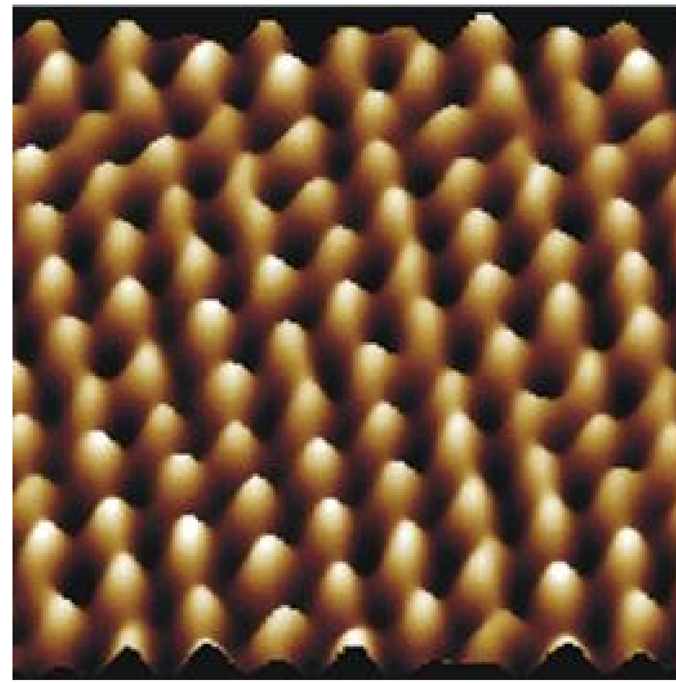


Scanning Tunneling Microscope (STM)
電子トンネル顕微鏡



原子を見ました！

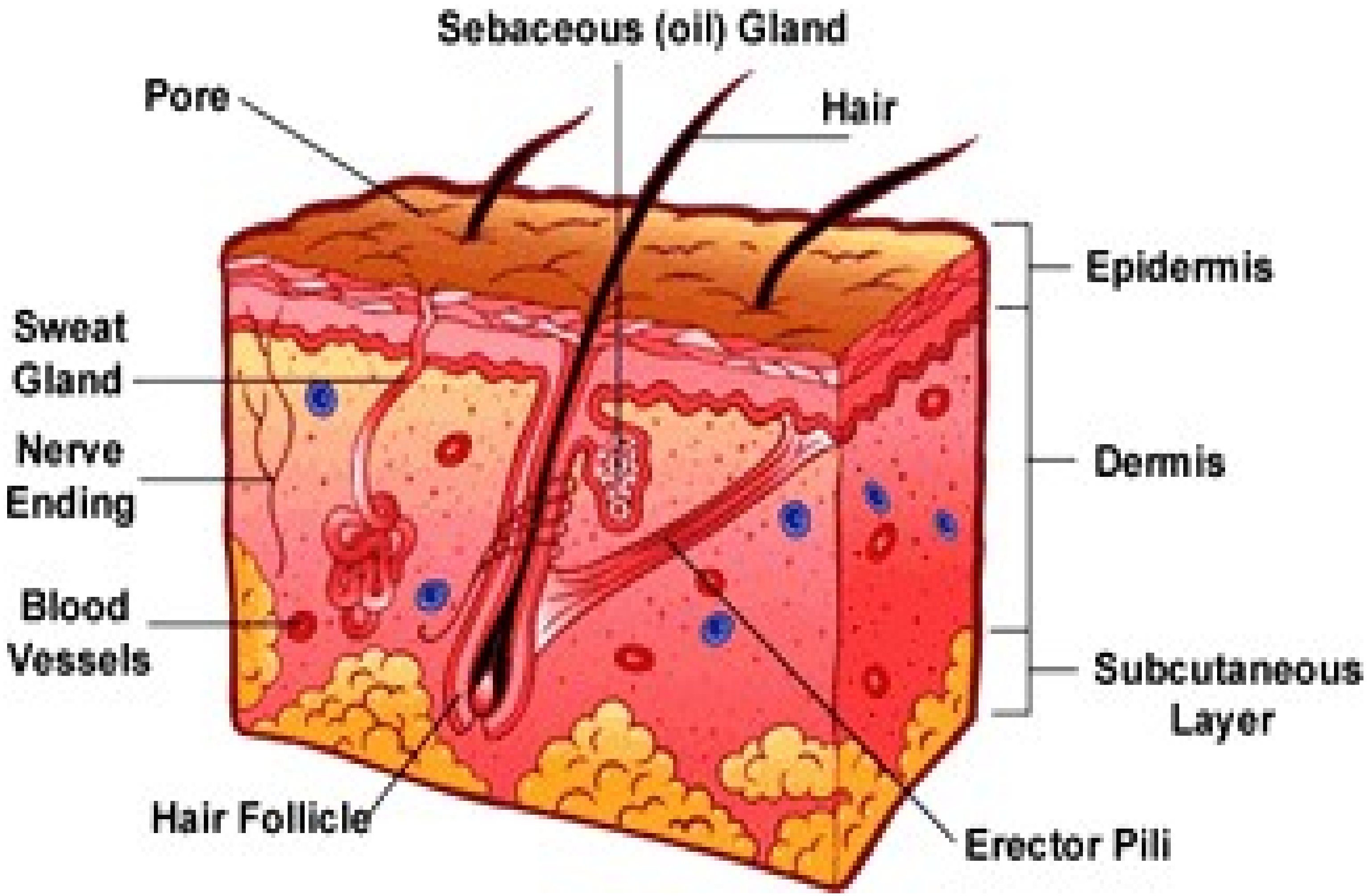


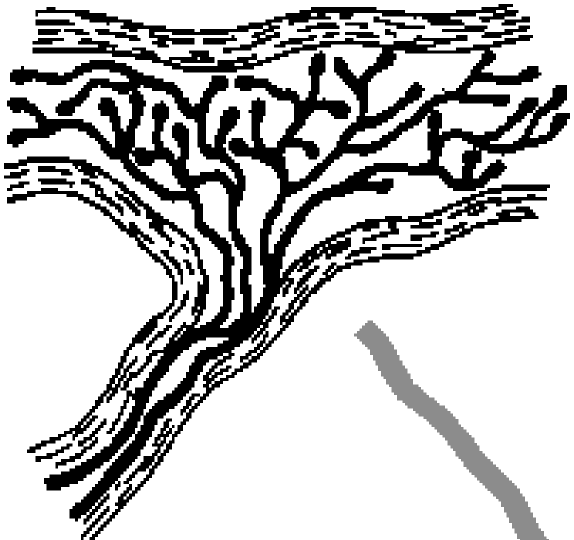


Graphite　HOPG

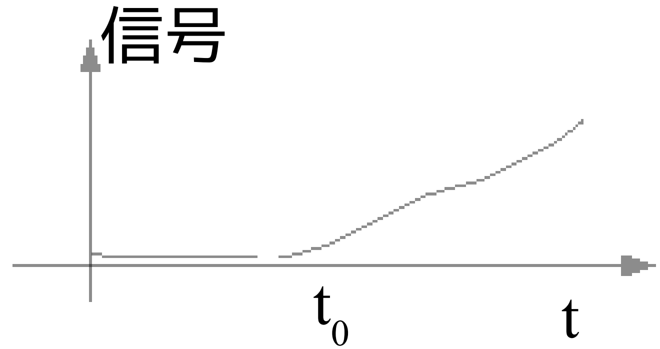
THE SKIN: the TOUCH sense （触覚）

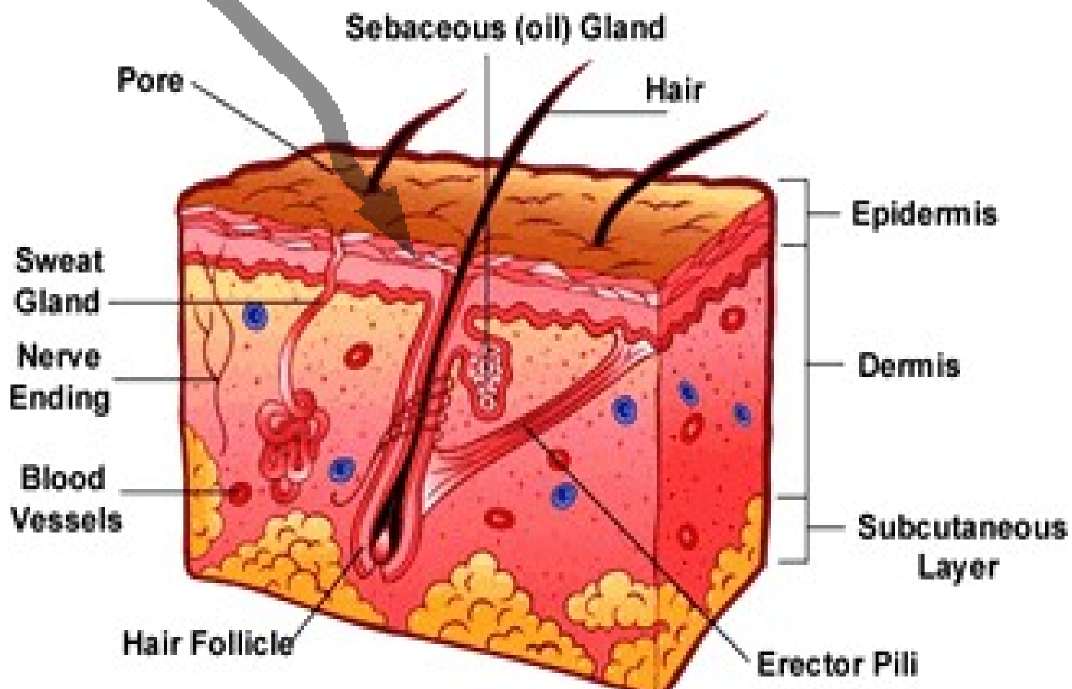
THE SKIN: the TOUCH sense　（触覚）



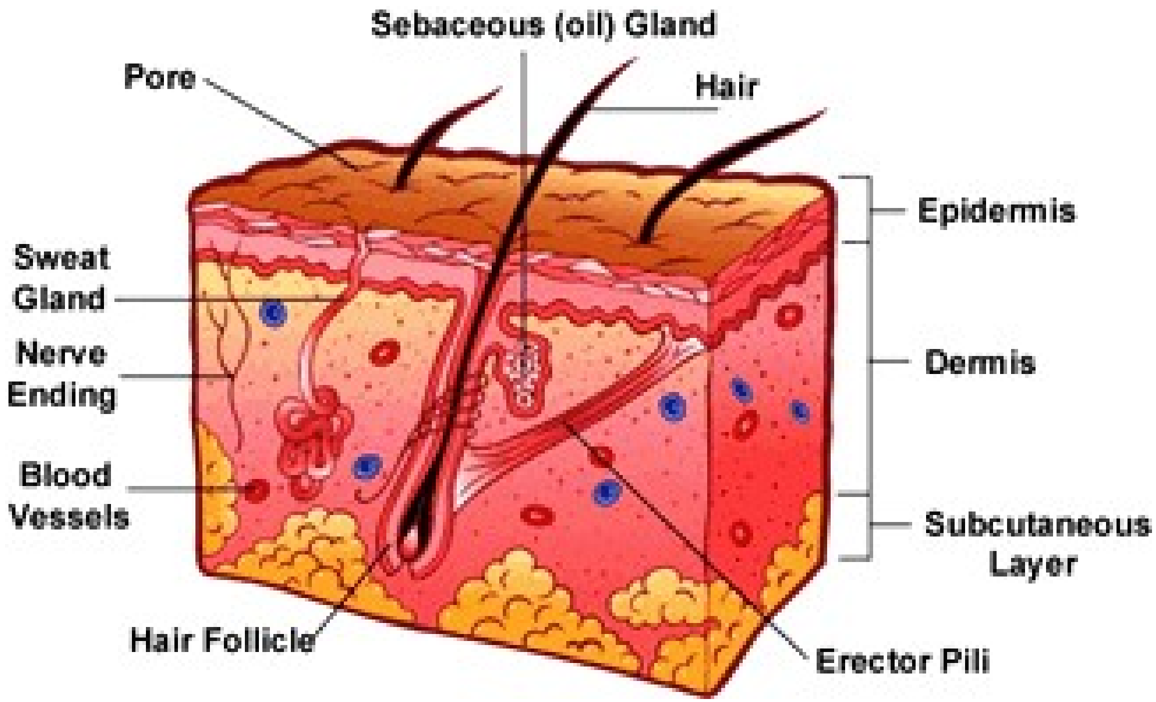


Ruffini Endings



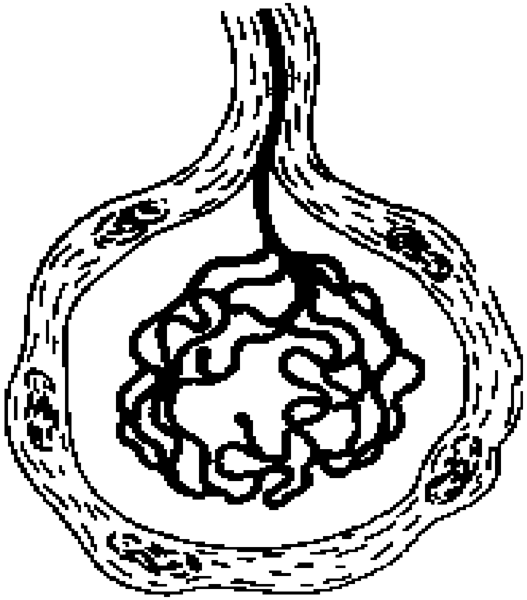


スロー
圧力センサー

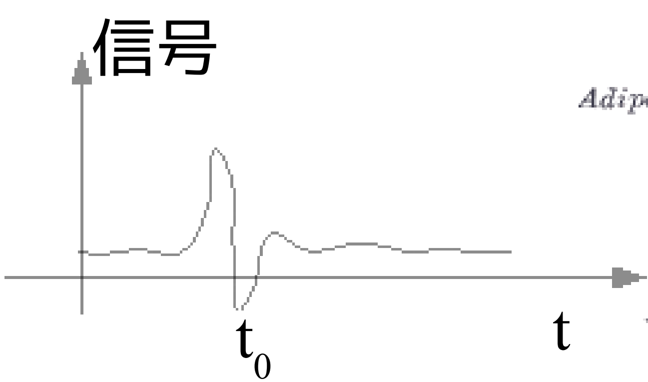


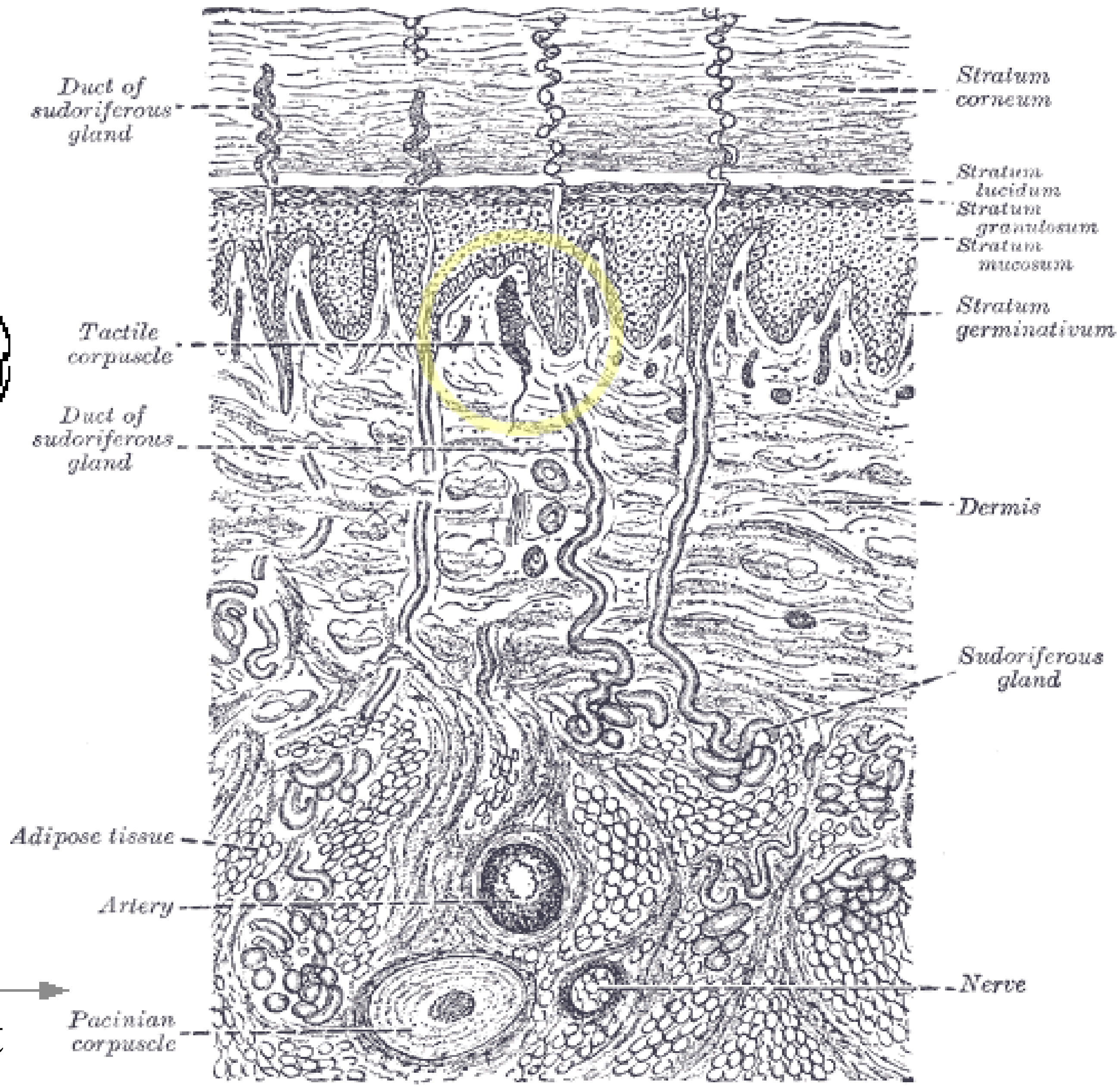
A mechanical *deformation* of the sensory dendrite causes a *depolarization* to occur within the dendrite. This dendrite is at the tip of a unipolar neuron; The sensory dendrite is embedded within the sensor corpuscle. Any depolarization that is large enough in the dendrite itself will cause an *action 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

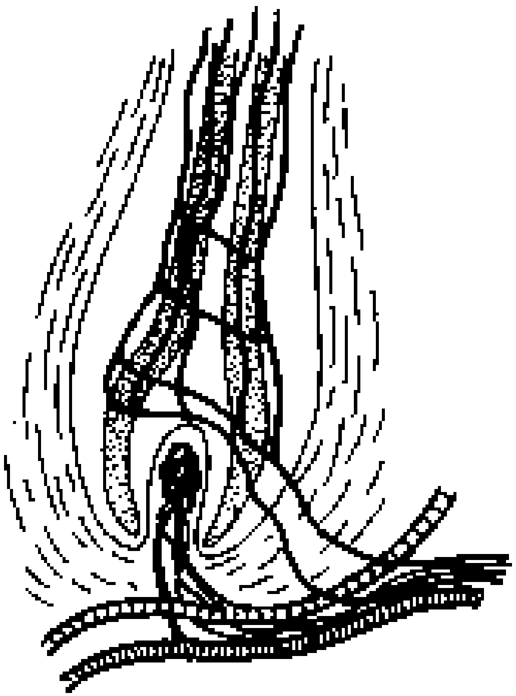




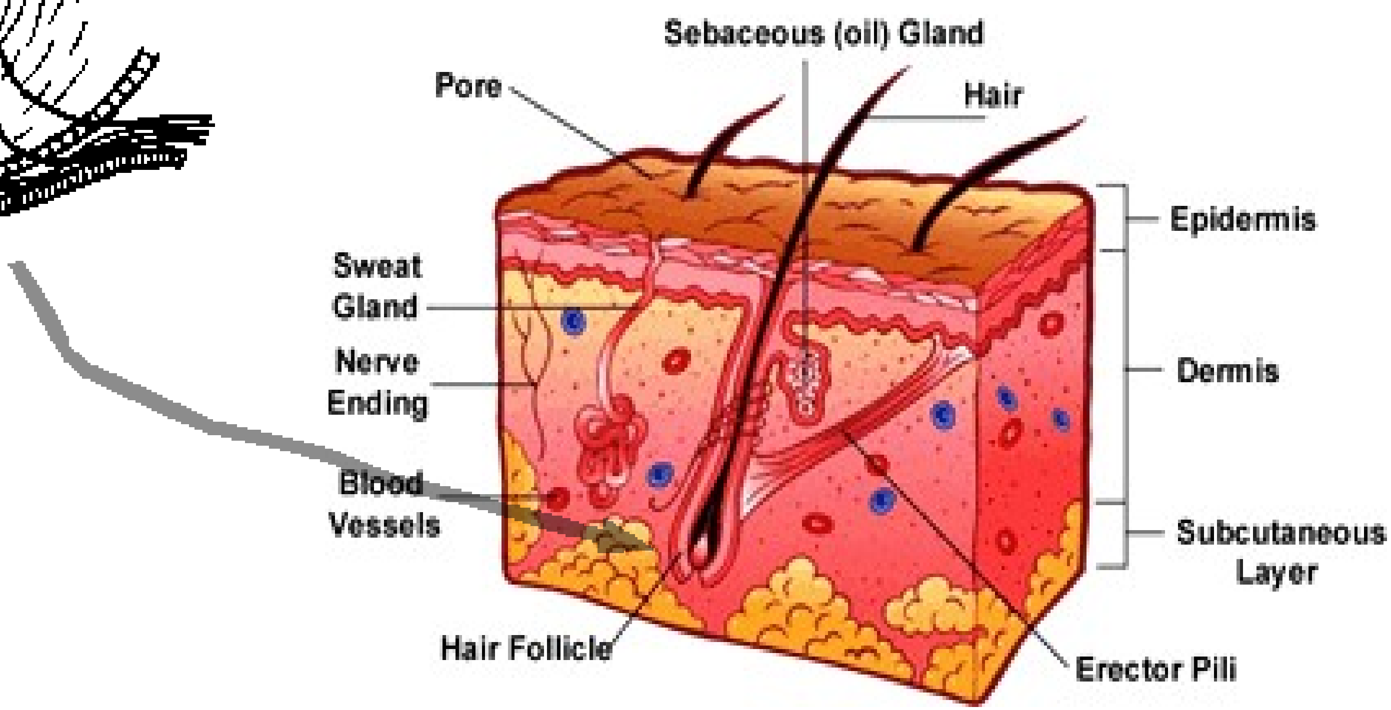
Responds to hair displacement.

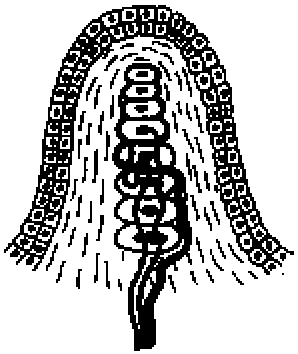
Wraps around hair follicle in, of course, hairy skin.

____



Hair Follicle Ending





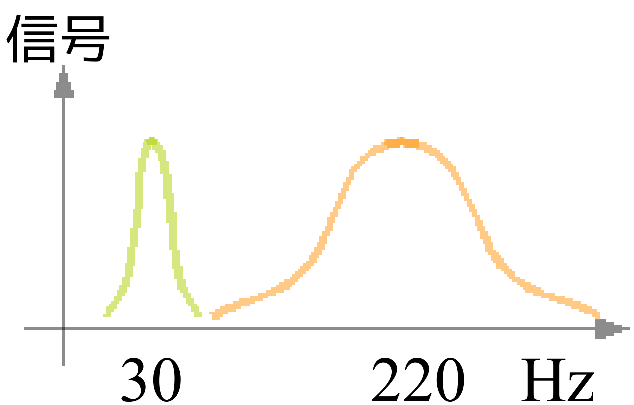
最大感度：20-40 Hz

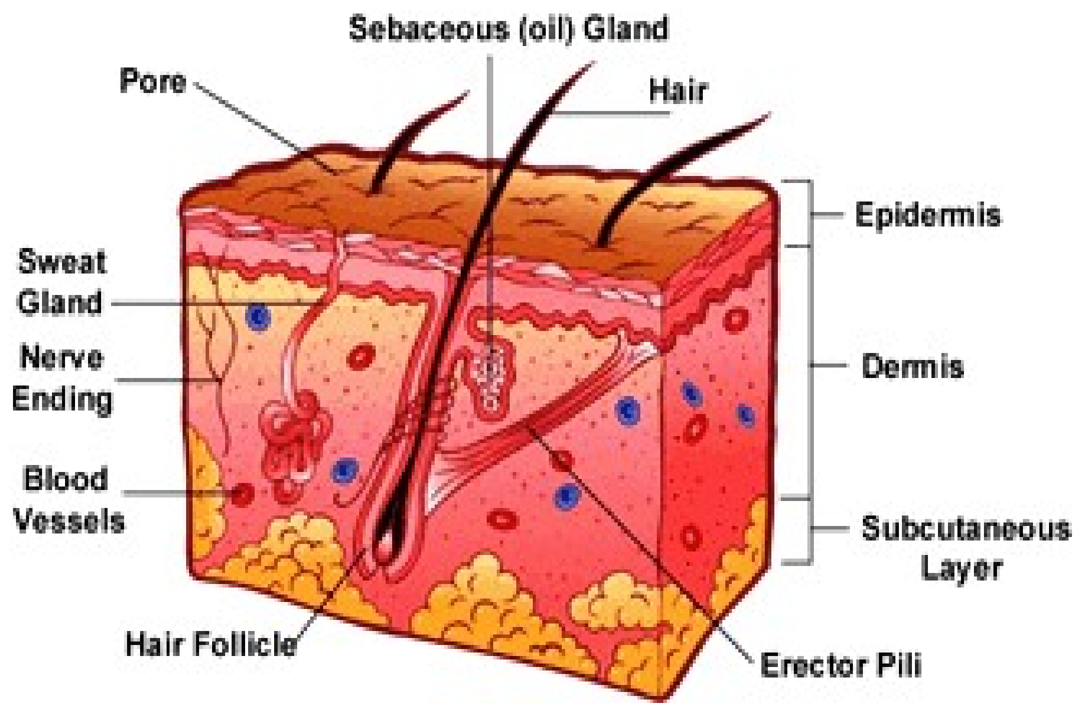
Meissner corpuscole

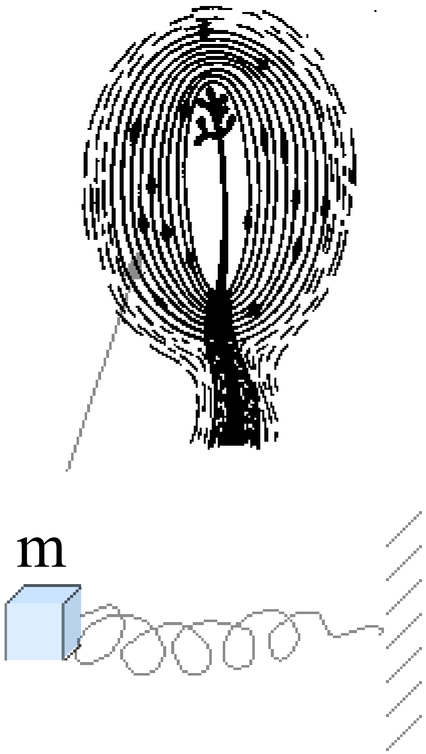
最大感度：150-300 Hz

Pacinian corpuscole

振動センサー







$$F = -kx$$

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

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

Wave equation

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

Wave function

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

pulsation

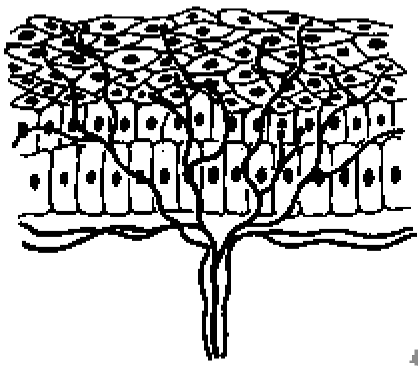
$$\omega = \sqrt{\frac{k}{m}} = (2\pi f)$$

Frequency depends on material “m” and “k”

温度センサー

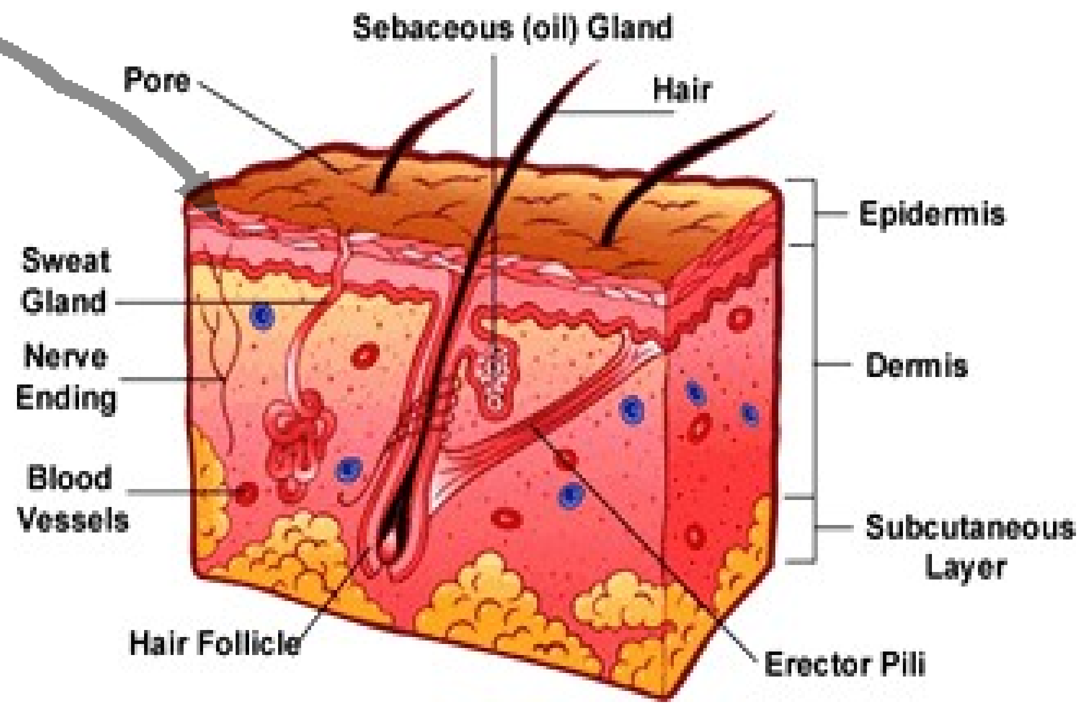
圧力センサー

化学センサー



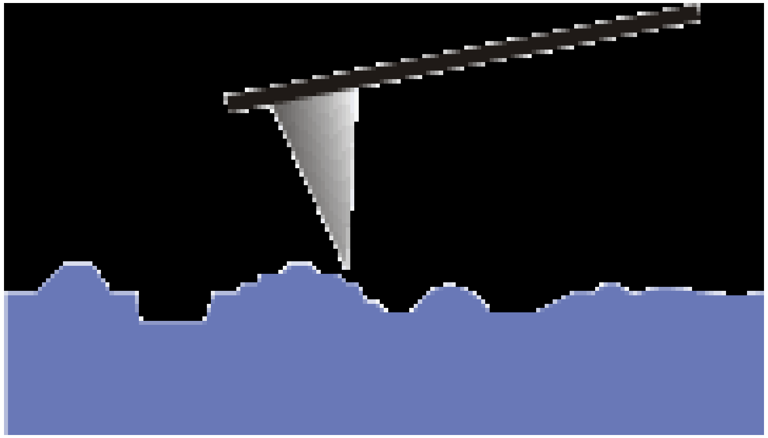
Free nerve endings

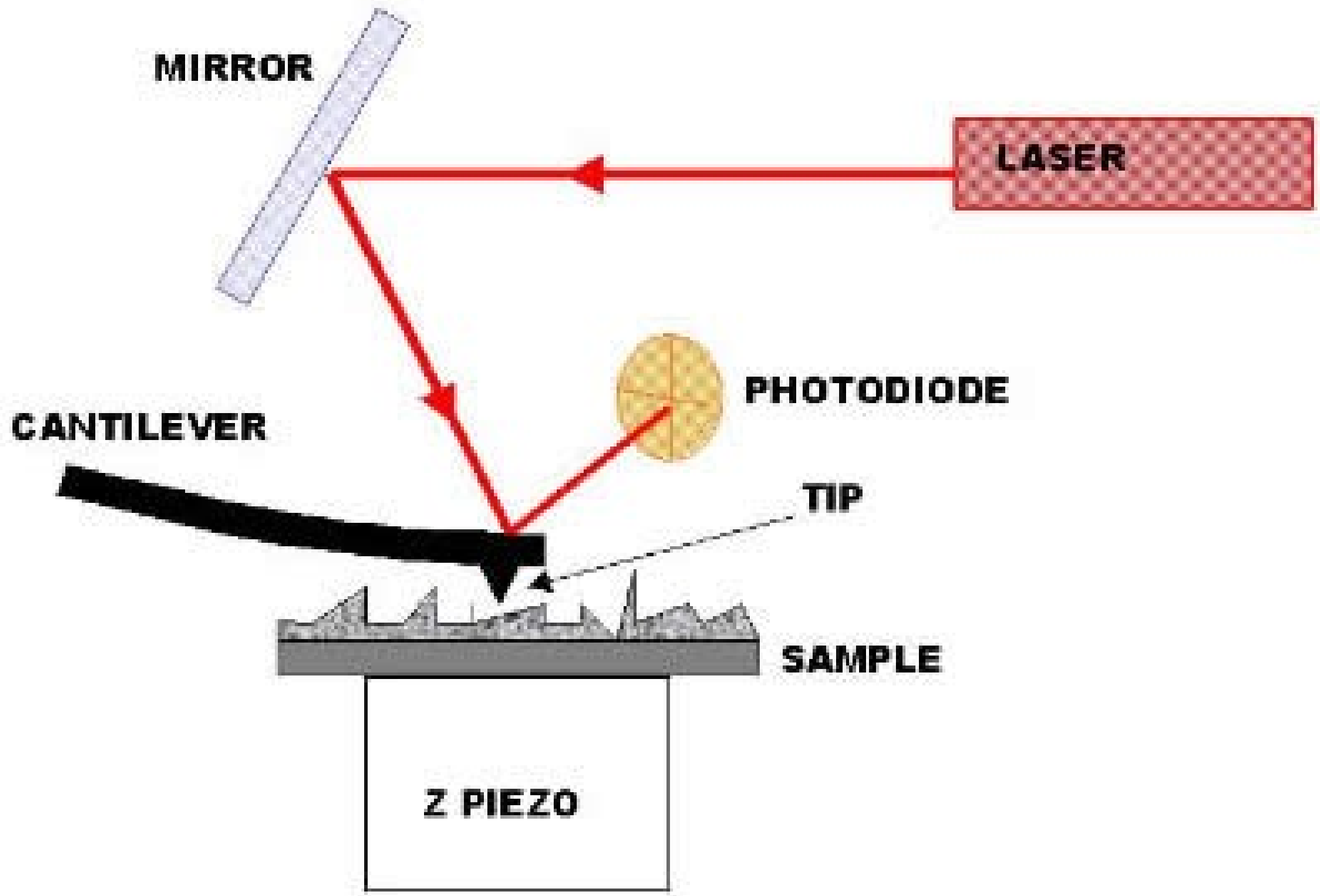
Different types of free nerve endings that respond to mechanical, thermal or noxious stimulation.

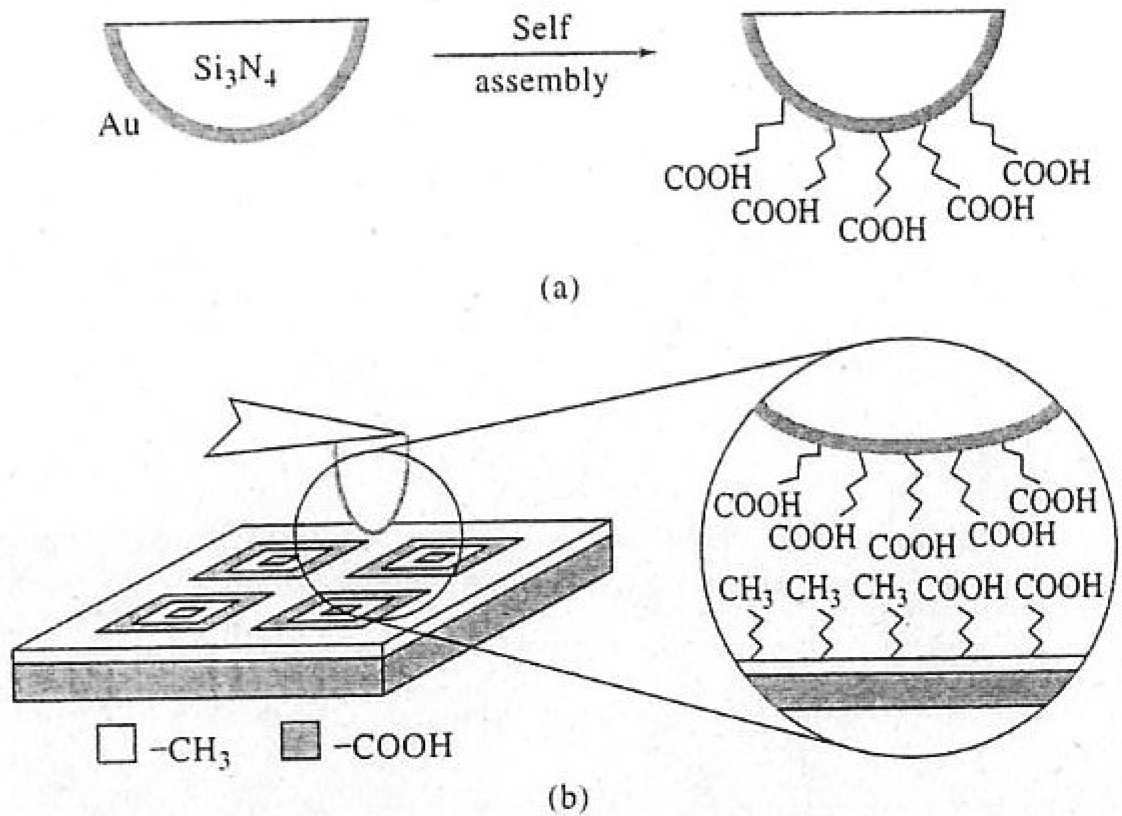


先端人工触覚センサー：原子間力顕微鏡

(AFM: Atomic Force Microscope)




MIRROR
LASER
PHOTODIODE
CANTILEVER
TIP
SAMPLE
Z PIEZO



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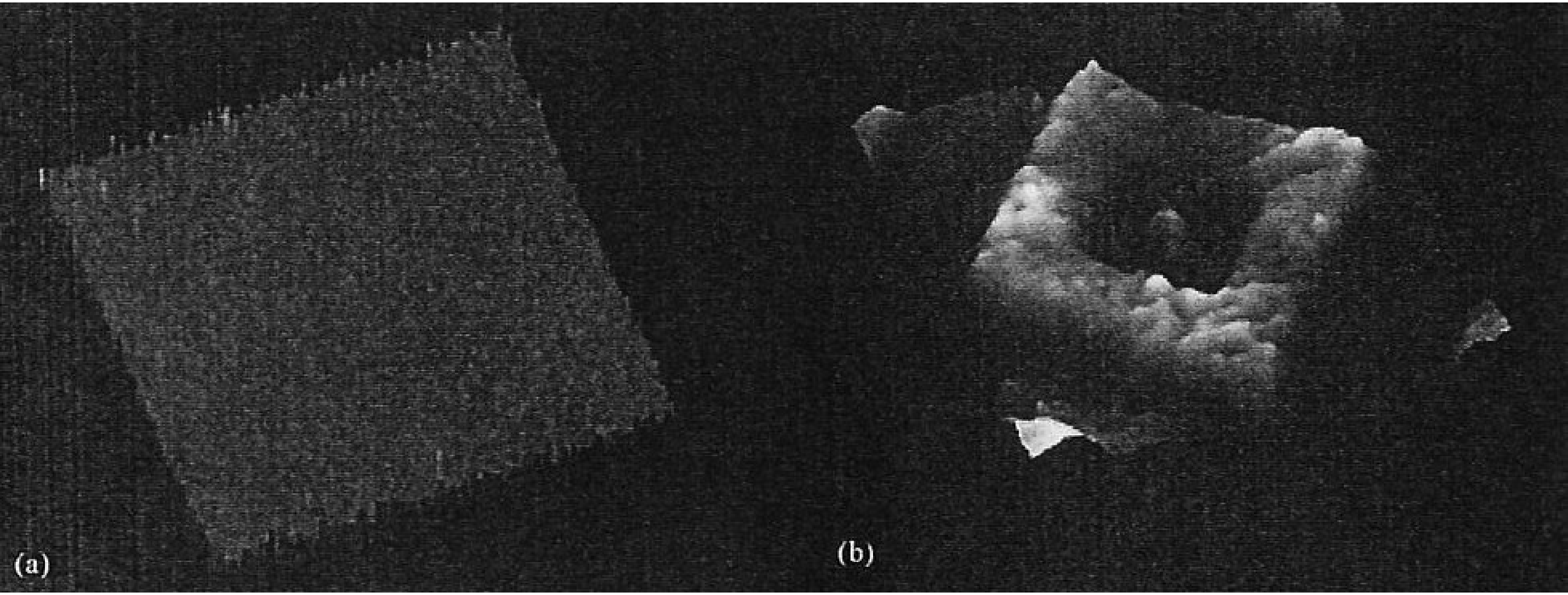
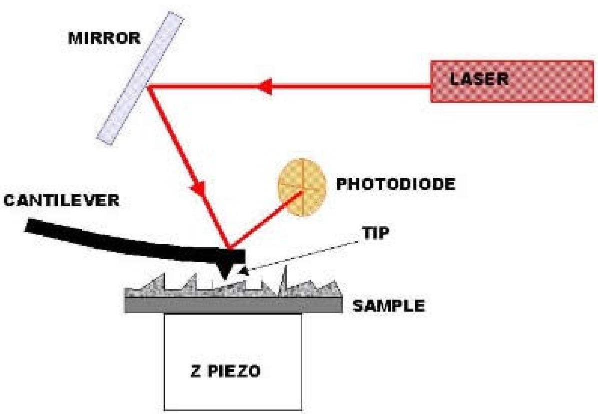
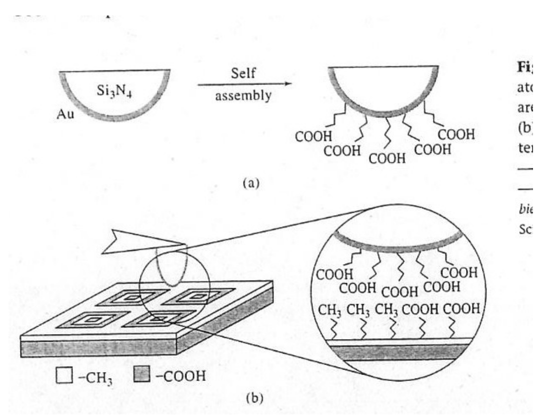
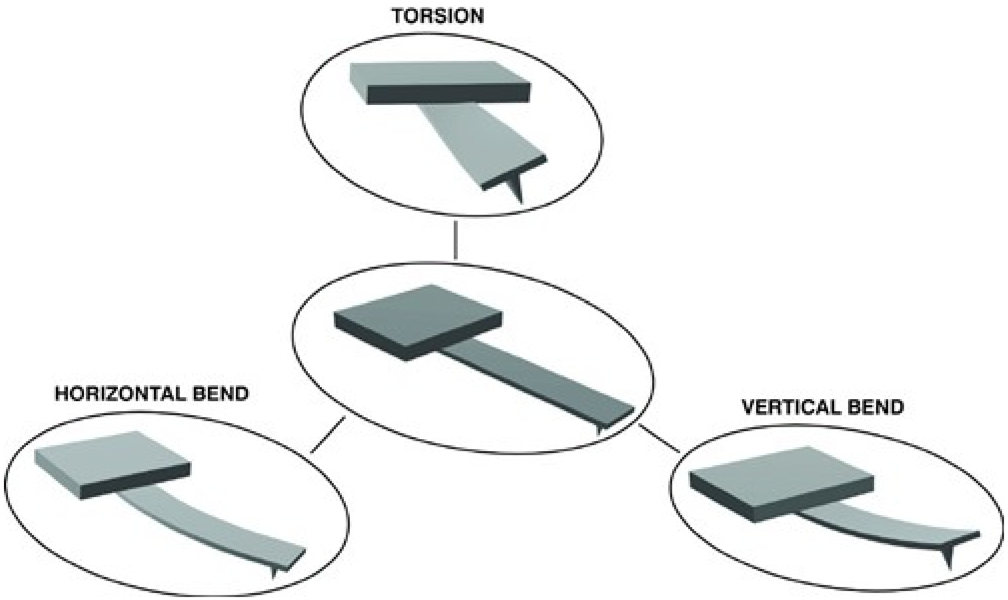
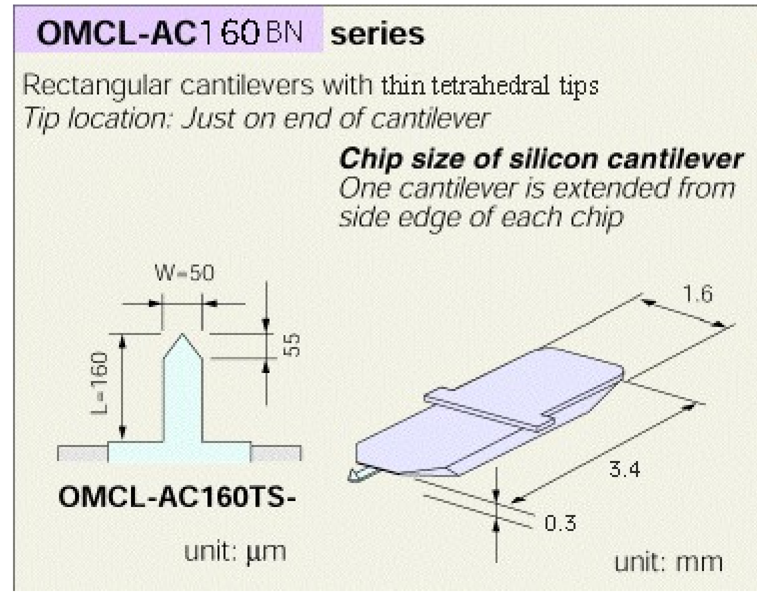
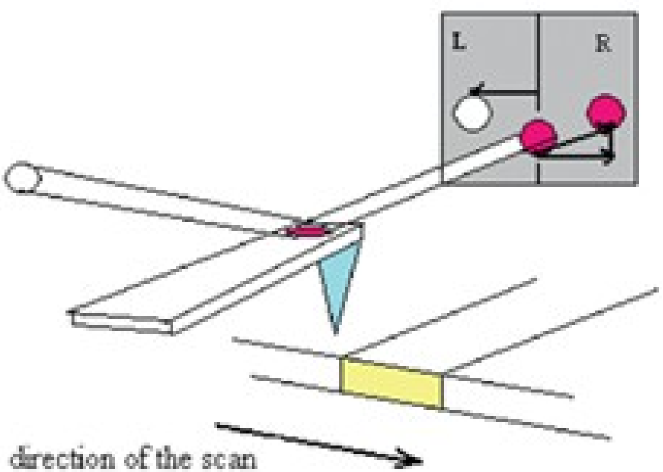

(a)
(b)


MIRROR
LASER
PHOTODIODE
CANTILEVER
TIP
SAMPLE
Z PIEZO

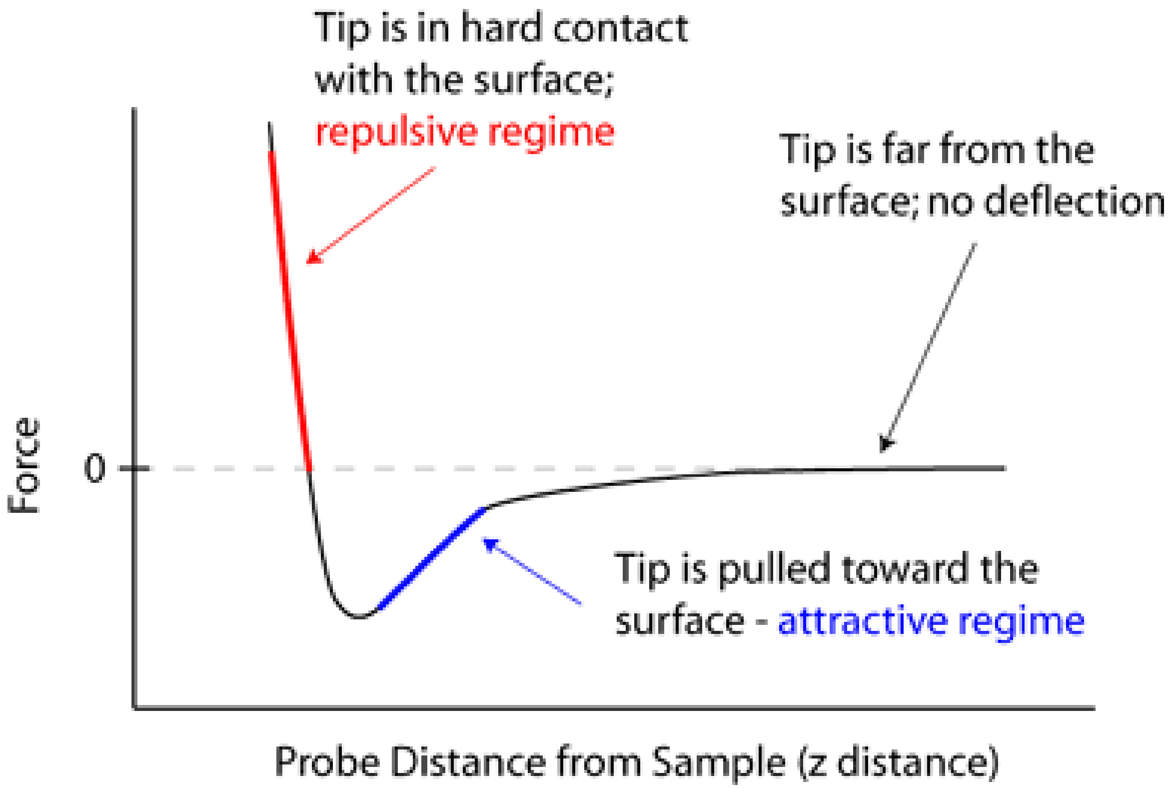

Au
Si3N4
Self assembly
COOH COOH COOH COOH COOH
(a)
COOH COOH COOH COOH COOH
CH3 CH3 CH3 COOH COOH
–CH3
–COOH
(b)

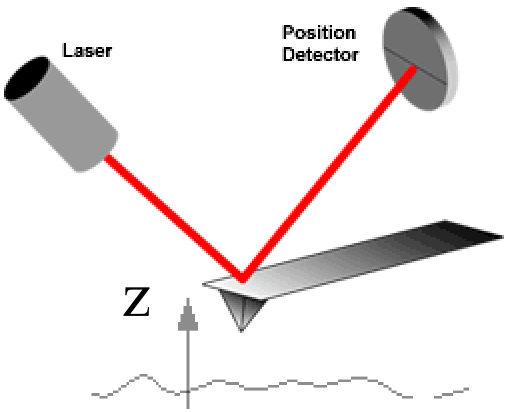

TORSION
HORIZONTAL BEND
VERTICAL BEND

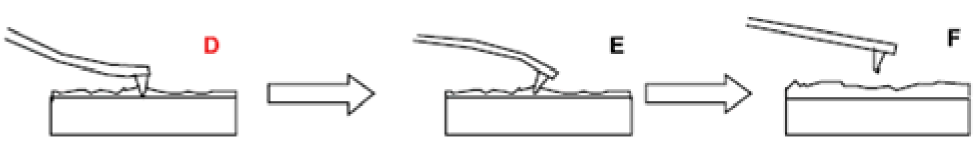

OMCL-AC160BN series
Rectangular cantilevers with thin tetrahedral tips
Tip location: Just on end of cantilever
Chip size of silicon cantilever
One cantilever is extended from side edge of each chip
W=50
55
L=160
OMCL-AC160TS-
unit: µm
1.6
3.4
0.3
unit: mm


L
R
direction of the scan

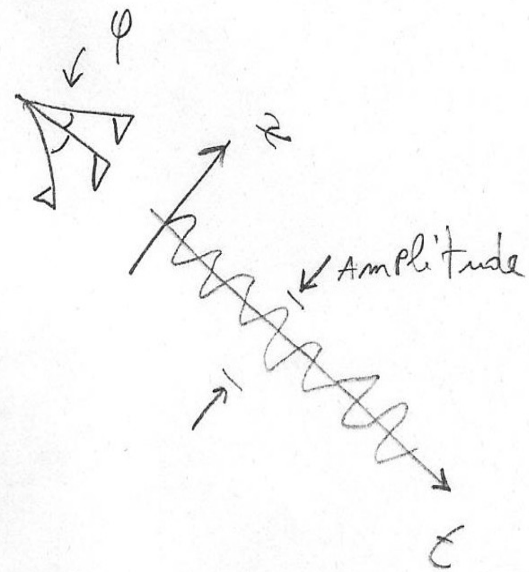
Operational Modes: CONTACT-MODE

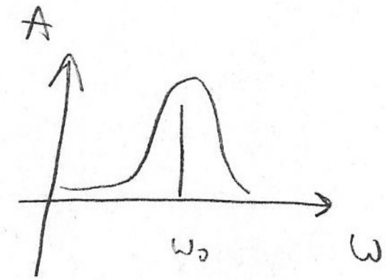






The cantilever vibration Physics:





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

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

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

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

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

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

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

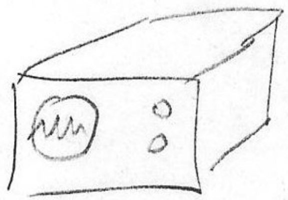
WAVE EQUATION $\rightarrow$ SOLUTION

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

$$\left\{ \begin{array}{l} \varphi(t) = A \sin(\omega_0 t) \\ \omega_0^2 = \dfrac{k}{m\ell} \end{array} \right.$$

How to measure the cantilever Force:

(1) OBSERVE ω_0 on oscilloscope



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

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

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

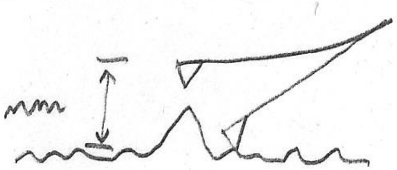
$$\boxed{\vec{F}_{(\text{over } 1mm)} = -k^*\,tg^{-1}\,\frac{10^{-9}}{\ell[m]}}$$

$m = 0.01\,[g]$ $\quad \ell = 0.001\,[m]$

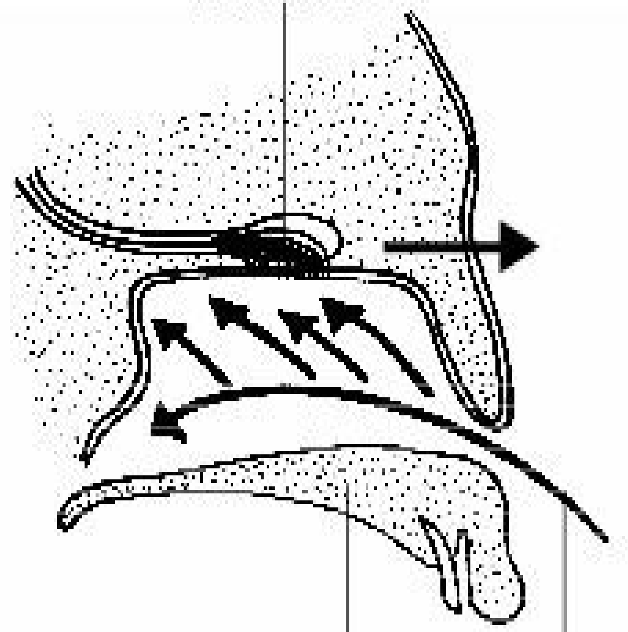
$f = 50\,kHz$

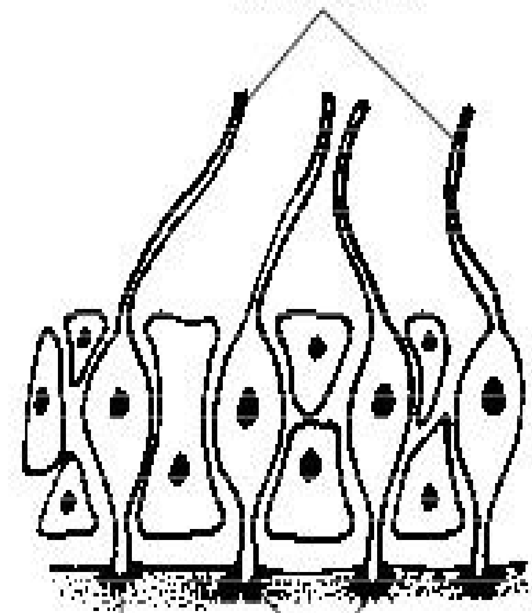
$k^* = ?$ $\quad F\big|^{1mm} = ?$

1mm

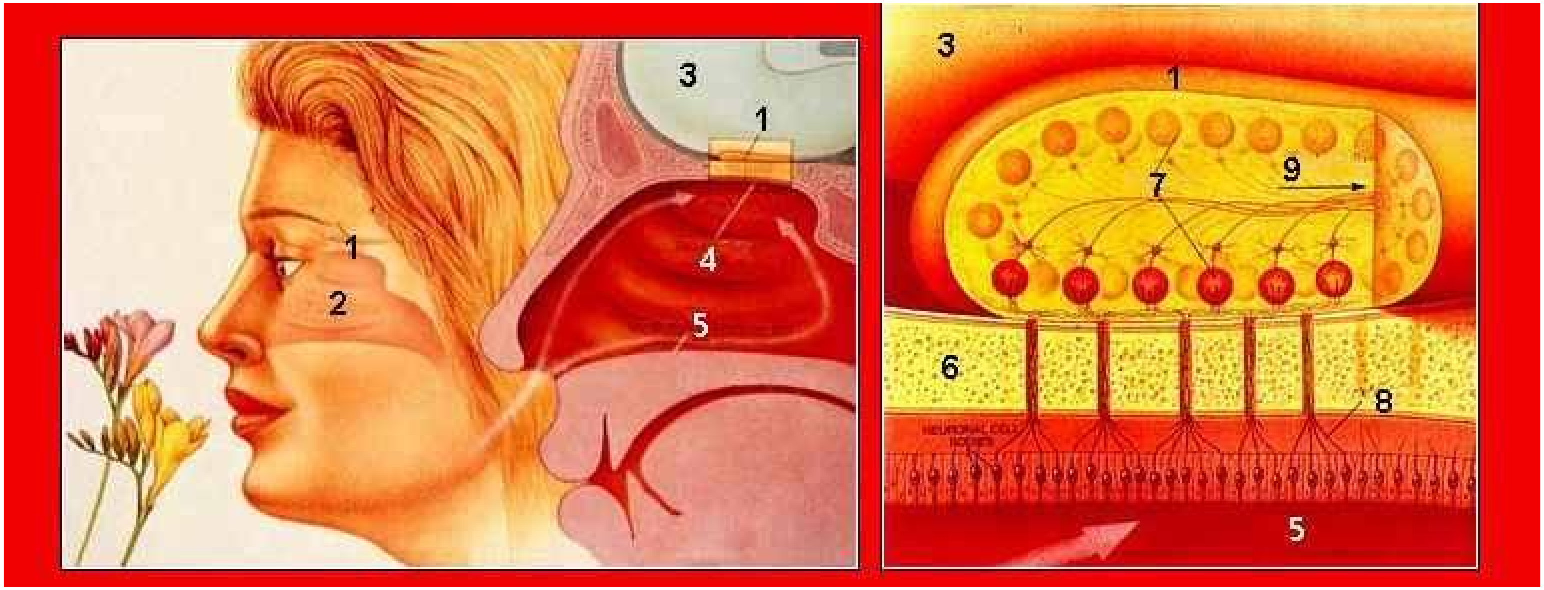


THE NOSE: the OLFACTORY sense　（嗅覚、きゅうかく）

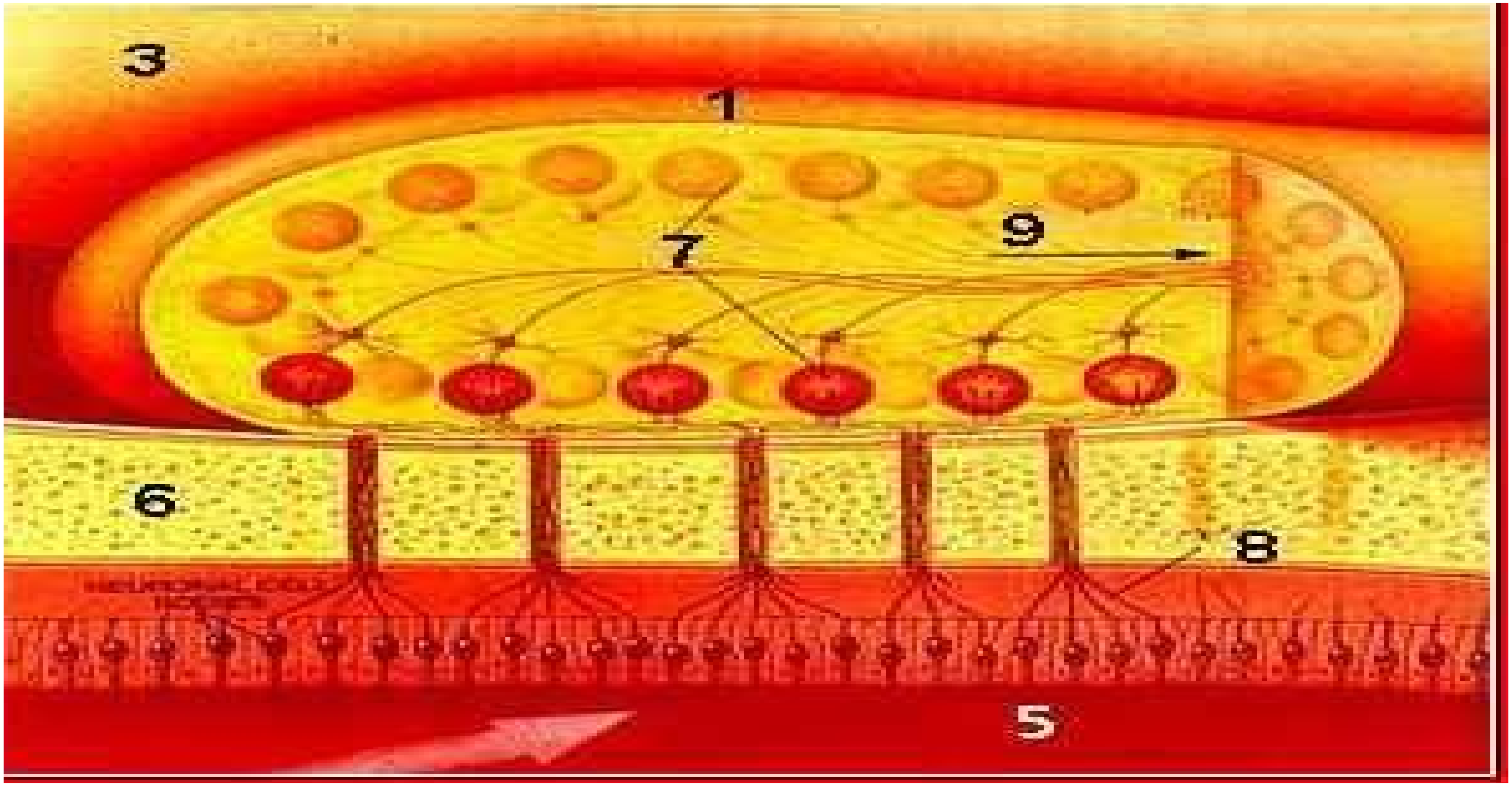




magnification of part of
olfactory organ



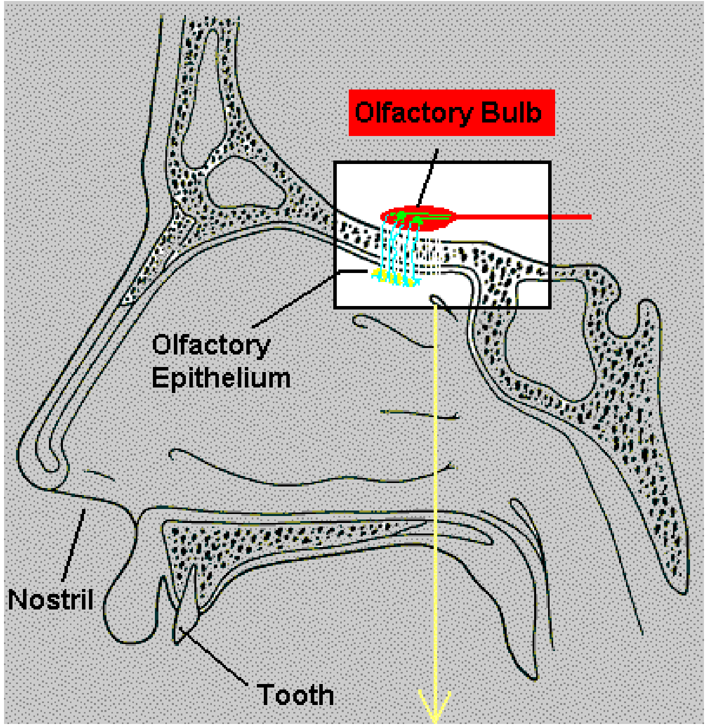
The olfactory sensors are located in yellow pigmented areas on each side of the inner nose. These areas are about 2.5 cm^2 in area each, and contain chemoreceptors, which are nerve cells responding to certain chemicals that are carried to the sensors as gases. The detailed functioning of these cells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

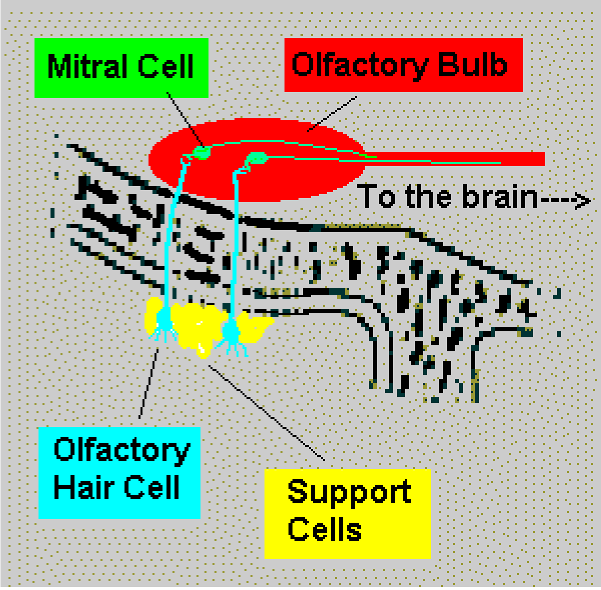


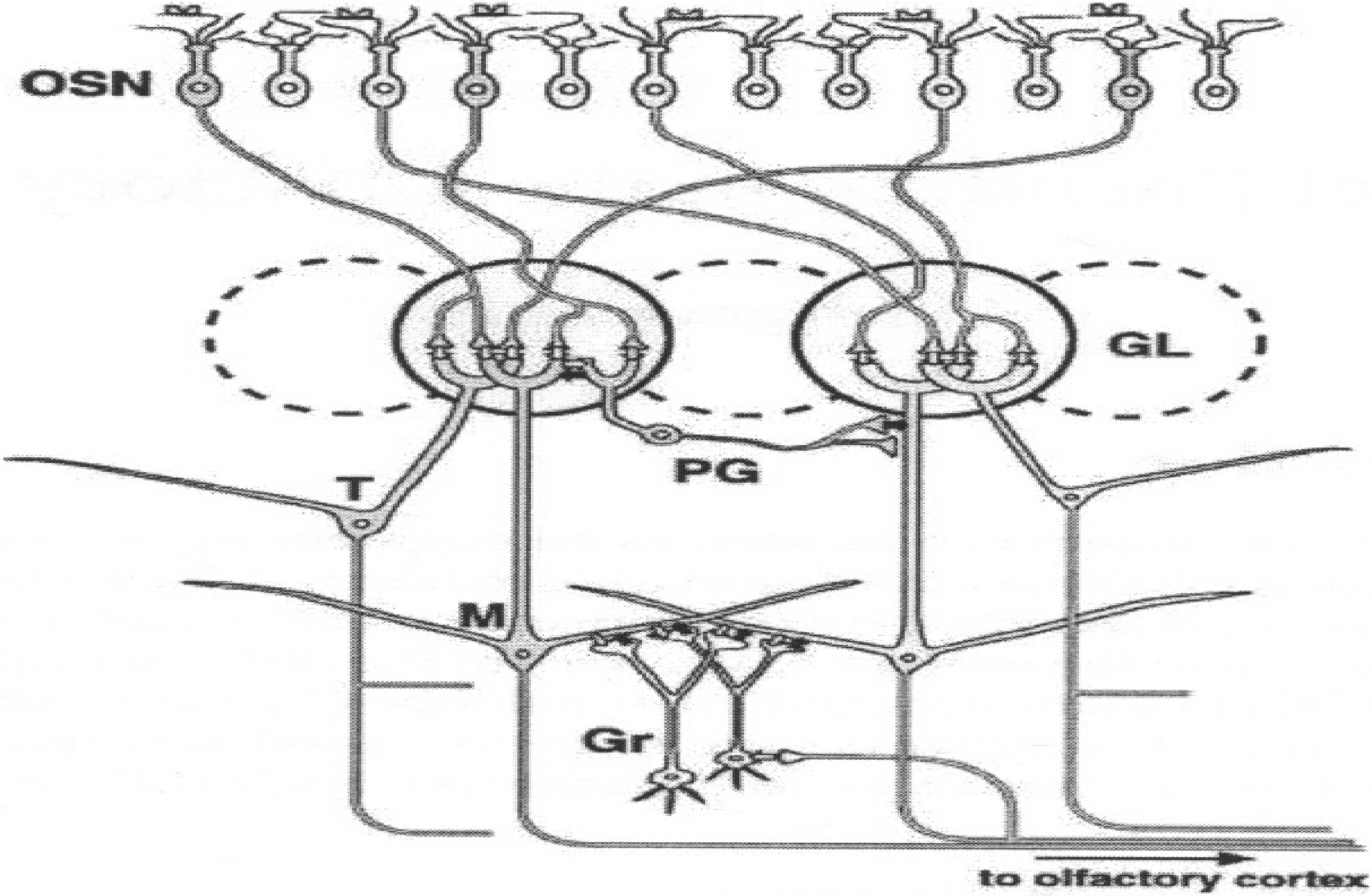
The glomeruli, each receiving signals from some 26 000 receptors. The olfactory bulbs on either side are cross-connected. Finally nerve fibres reach the olfactory areas in the anterior lobes of the brain.

- 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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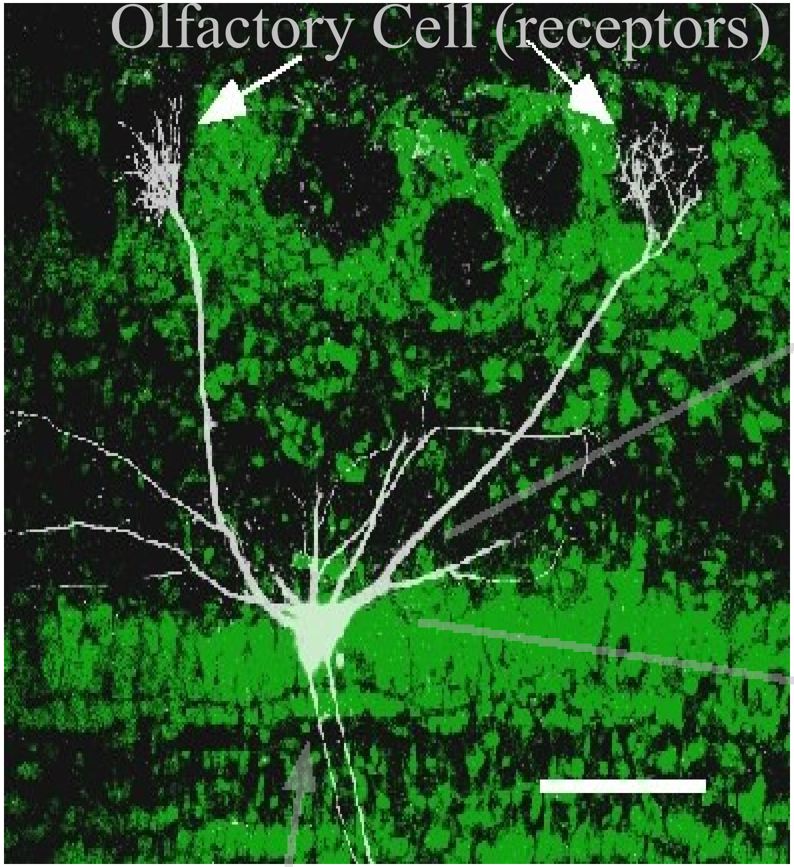
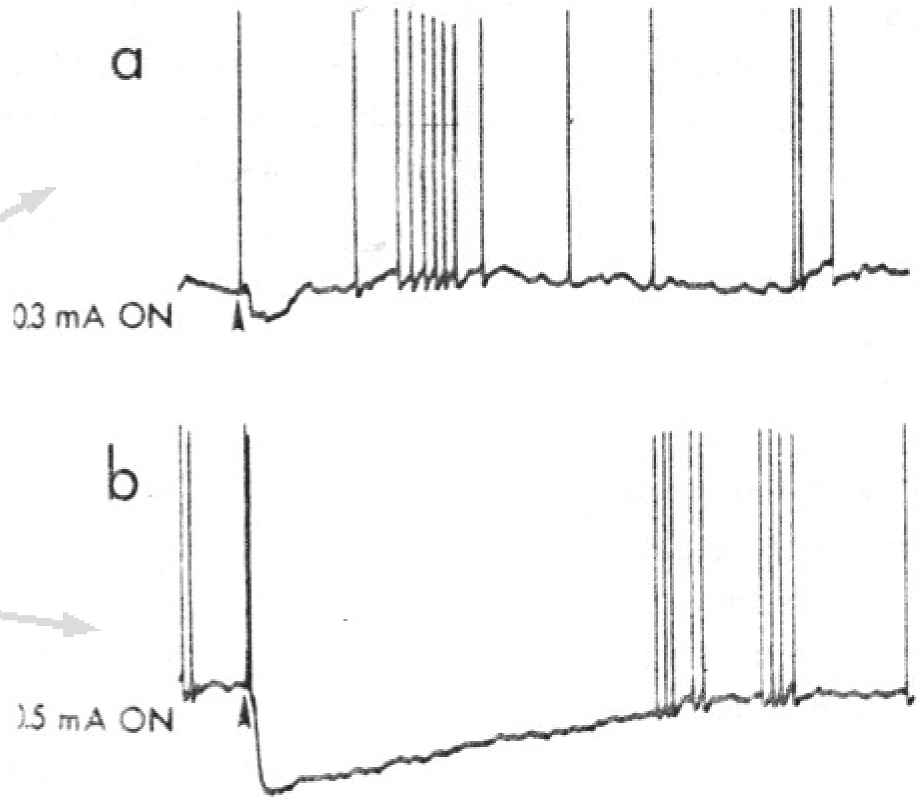
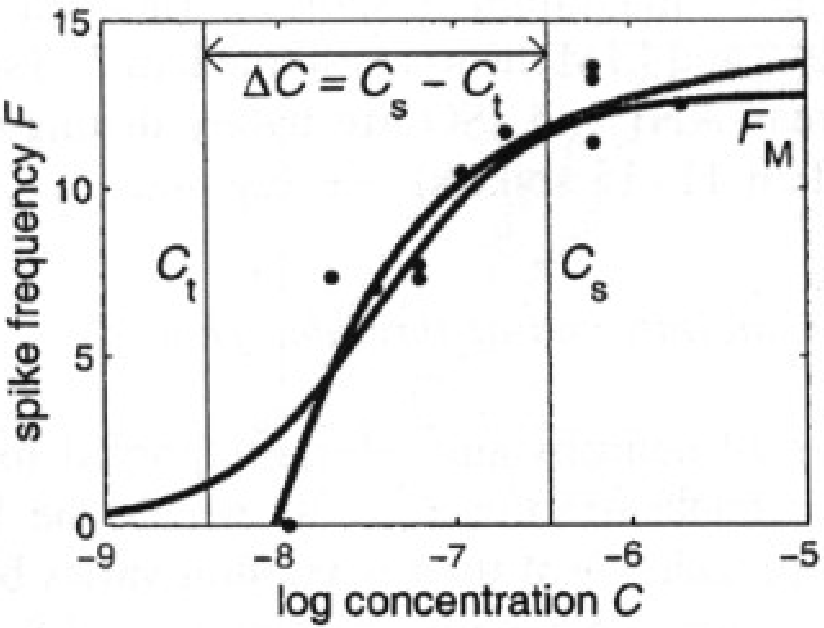


Mitral Cell

Signal from Mitral Cells

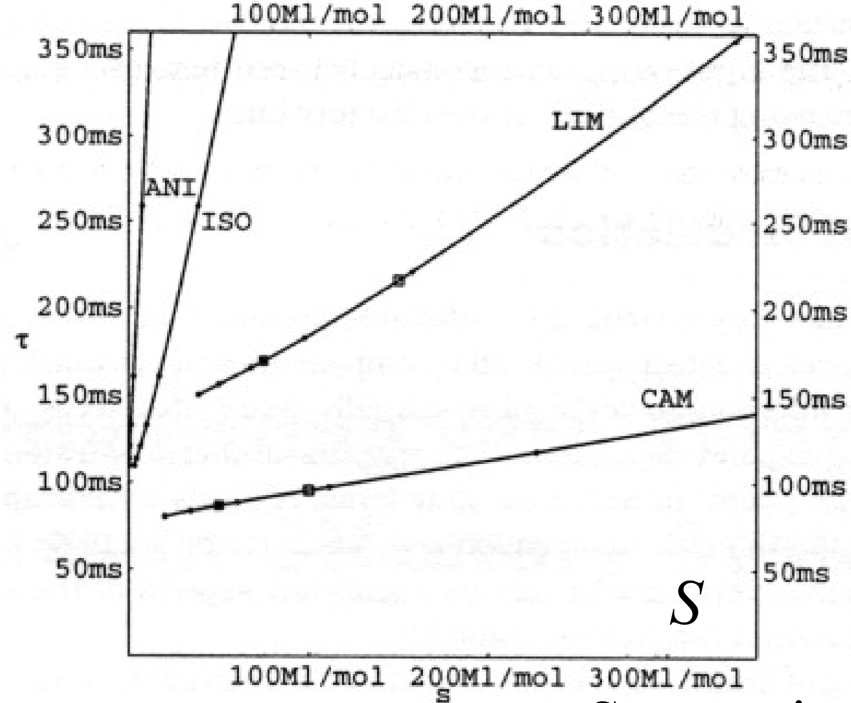


スパイク周波数



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。

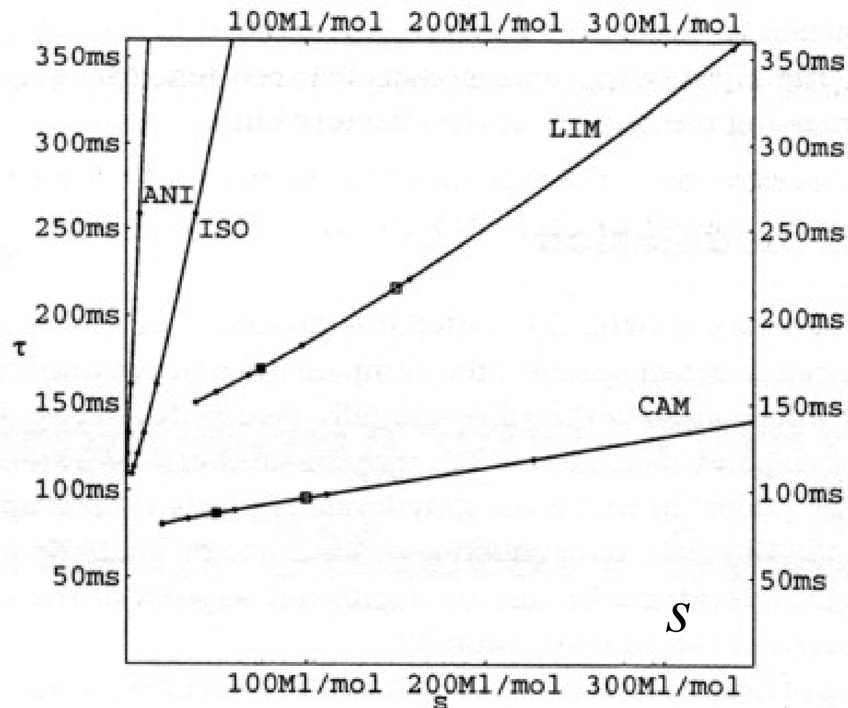
香科によってGは違います。

例：$G_{camphor}$=1.0

G_{lemon}=2.5

$G_{anisole}$=20

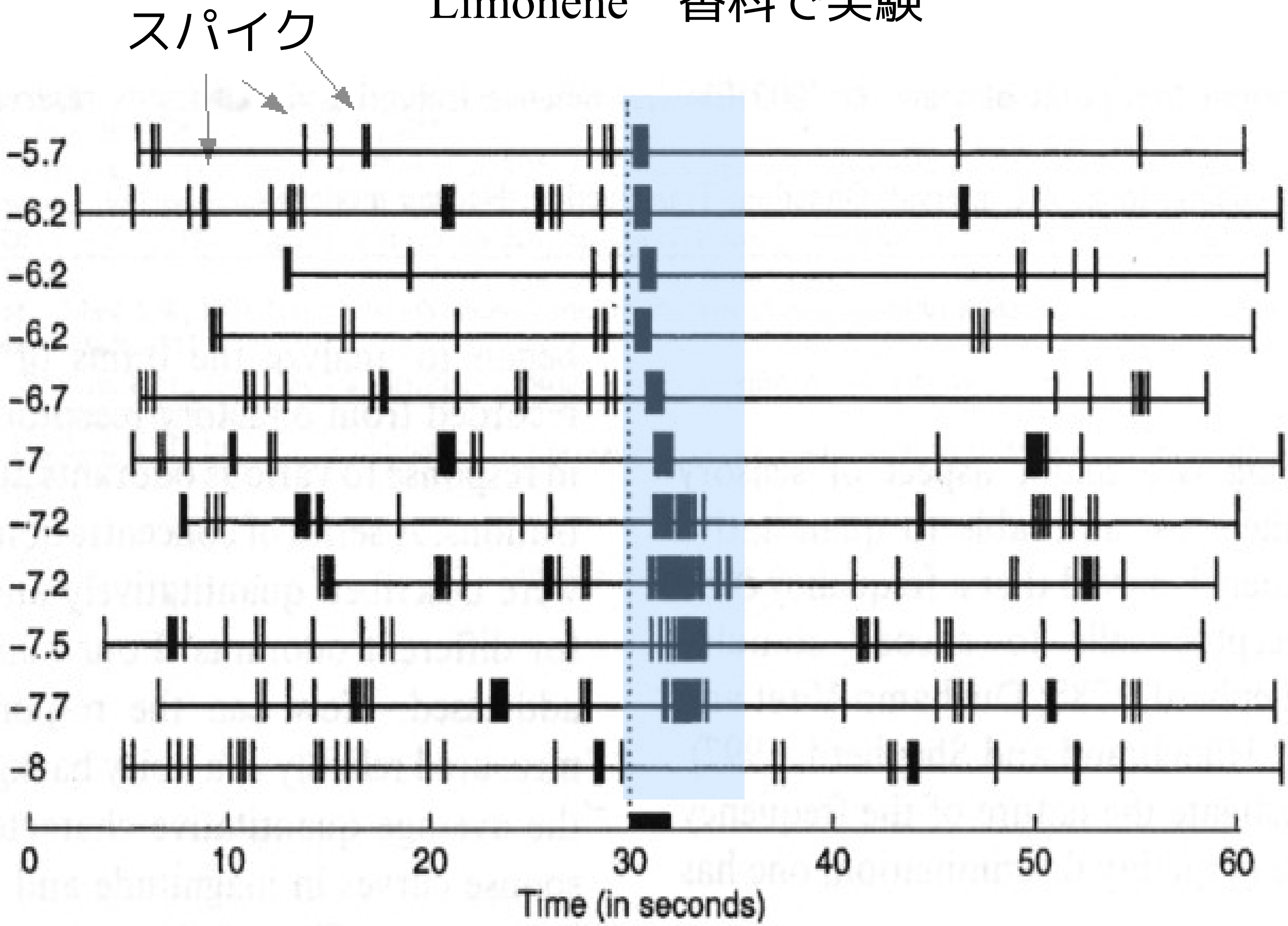
スパイクの時間間隔



香科密度

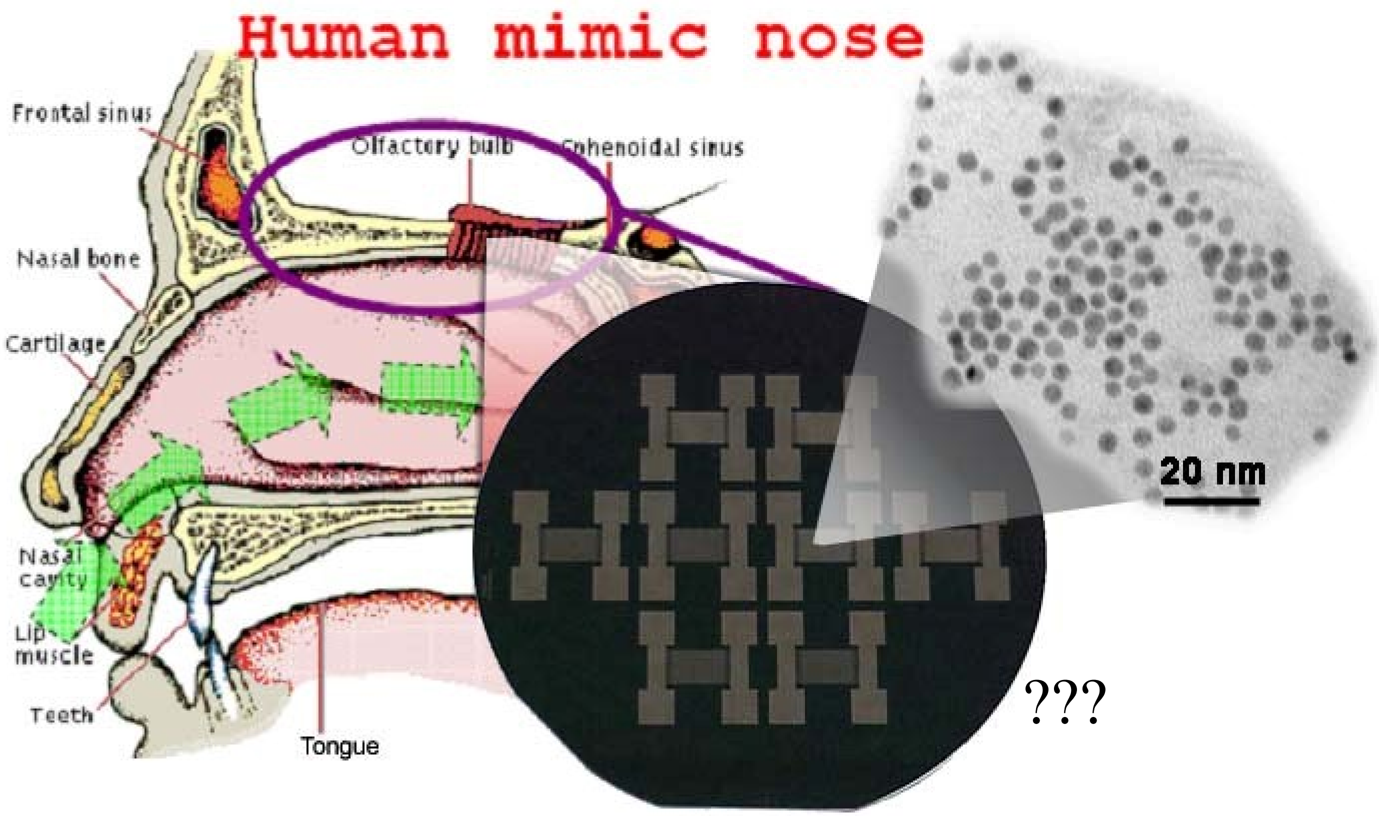
s=sparsity

Limonene　香料で実験

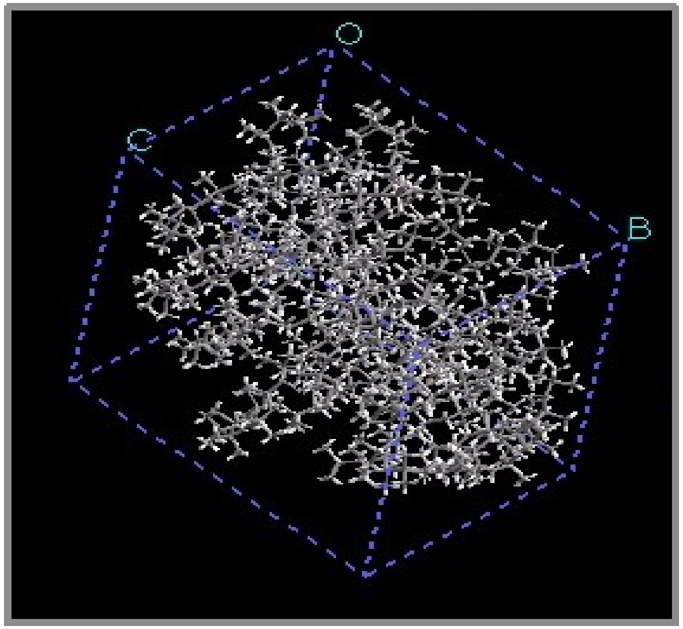


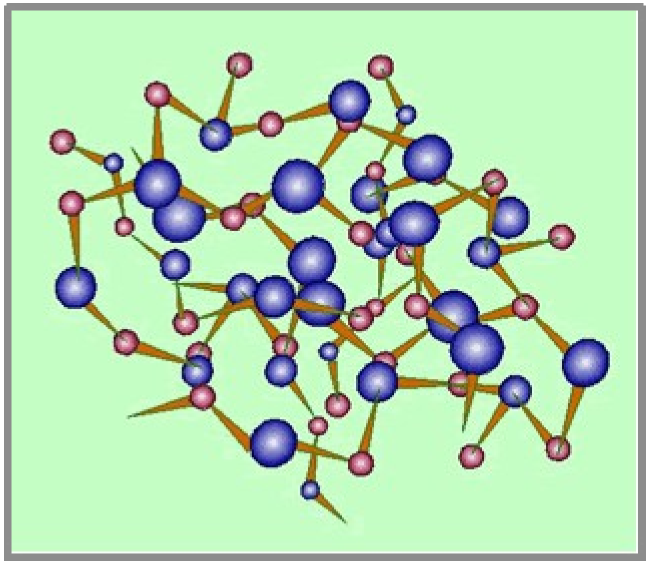
人工嗅覚

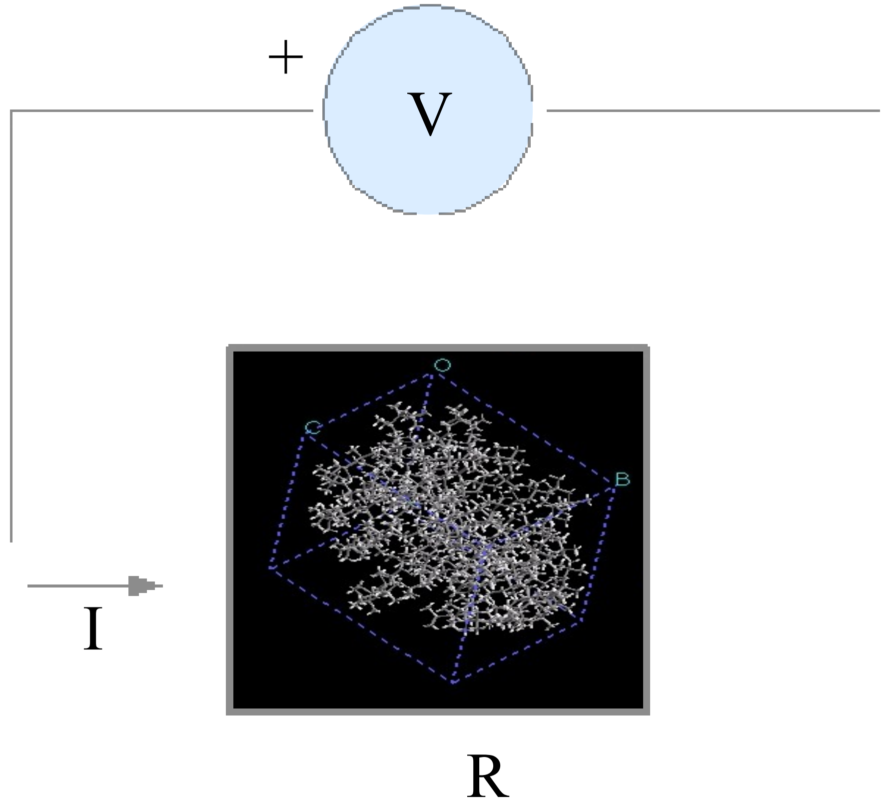
JPL 人工嗅覚デバイス


Human mimic nose
Frontal sinus
Olfactory bulb
Sphenoidal sinus
Nasal bone
Cartilage
Nasal cavity
Lip muscle
Teeth
Tongue
20 nm
???

Polymers complex structure



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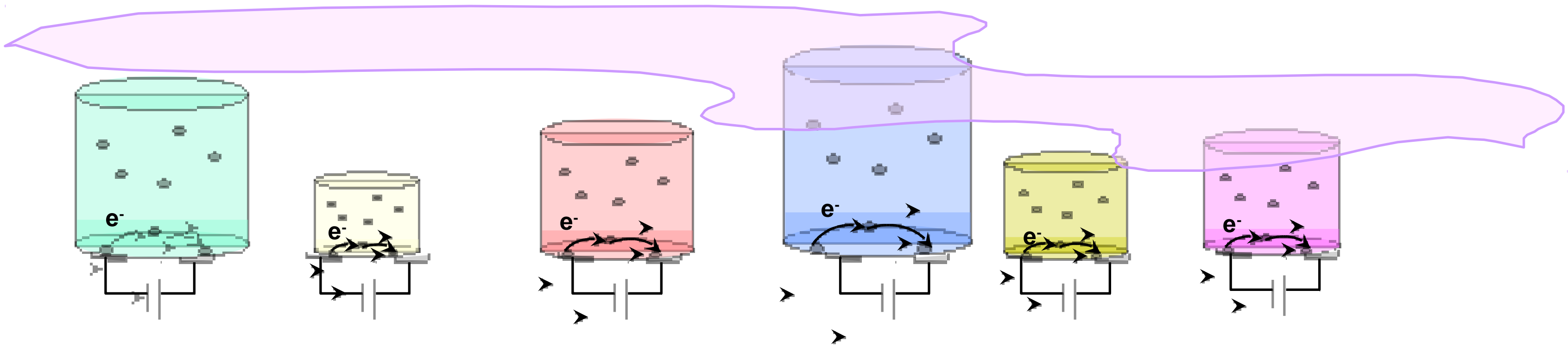
THE ELECTRONIC NOSE SMELLS SOMETHING

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:

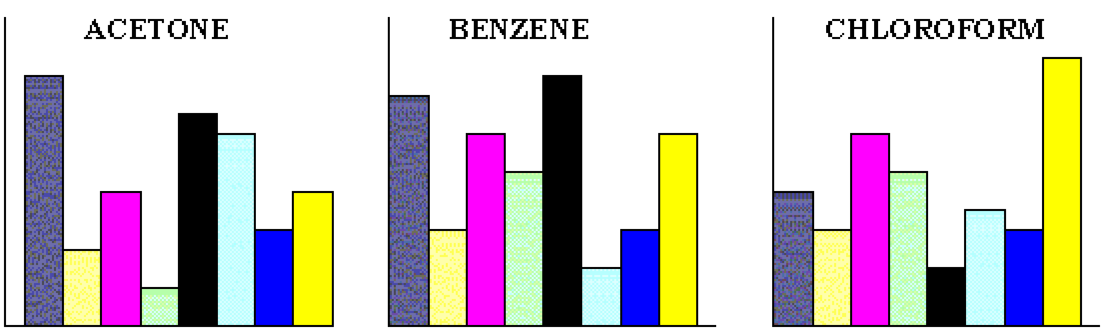
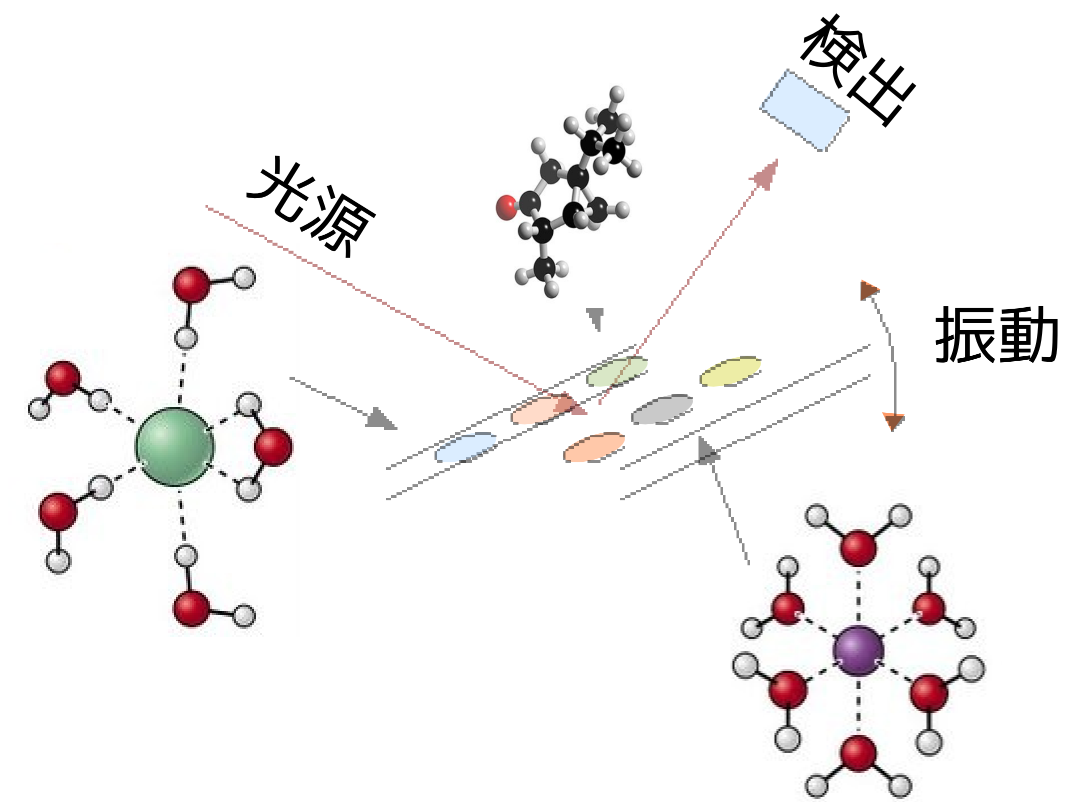


Figure 1.

AFM NOSE



結合する分子によって振動のパターンが異なる。