国際総合科学・基盤科学

物理博士　ミケレット・ルジェロ

物質機能科学**IIb**

知覚情報科学

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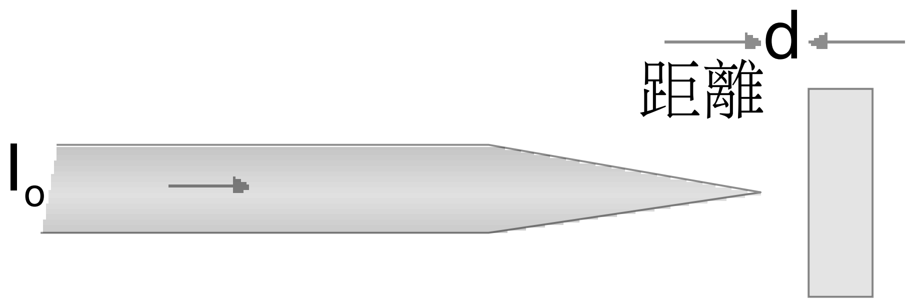
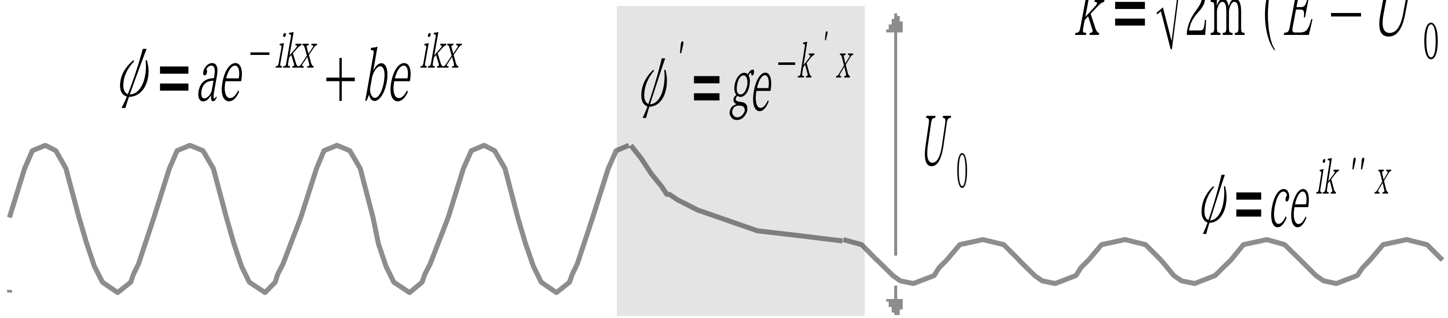
(5)

後期２００
９年

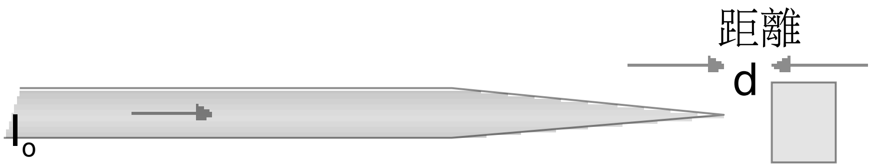


電流の値は距離に従って指数関数的に
減衰します

$$k = \sqrt{2m\,(E - U_0)/h^2}$$



One dimensional model



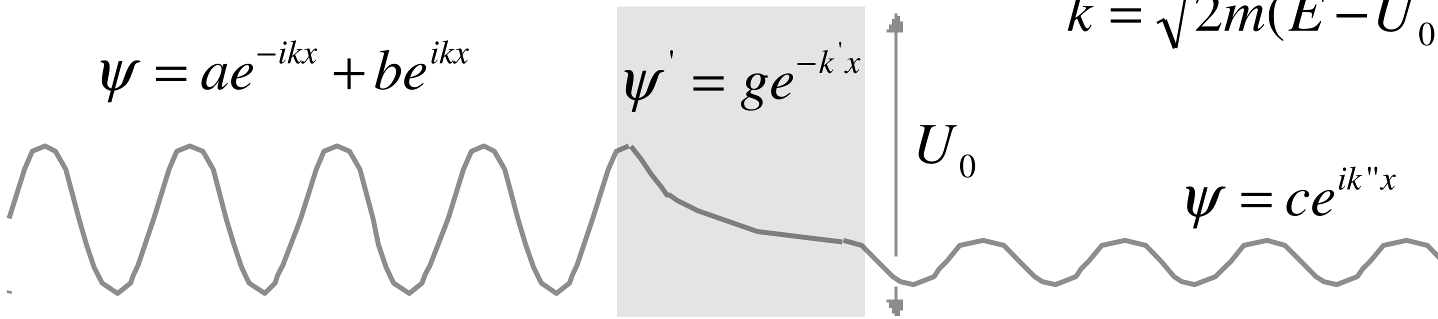
電流の値は距離に従って指数関数的に
減衰します

$$k = \sqrt{2m(E - U_0)/h^2}$$

$$\psi = ae^{-ikx} + be^{ikx}$$

$$\psi' = ge^{-k'x}$$

$$\psi = ce^{ik''x}$$

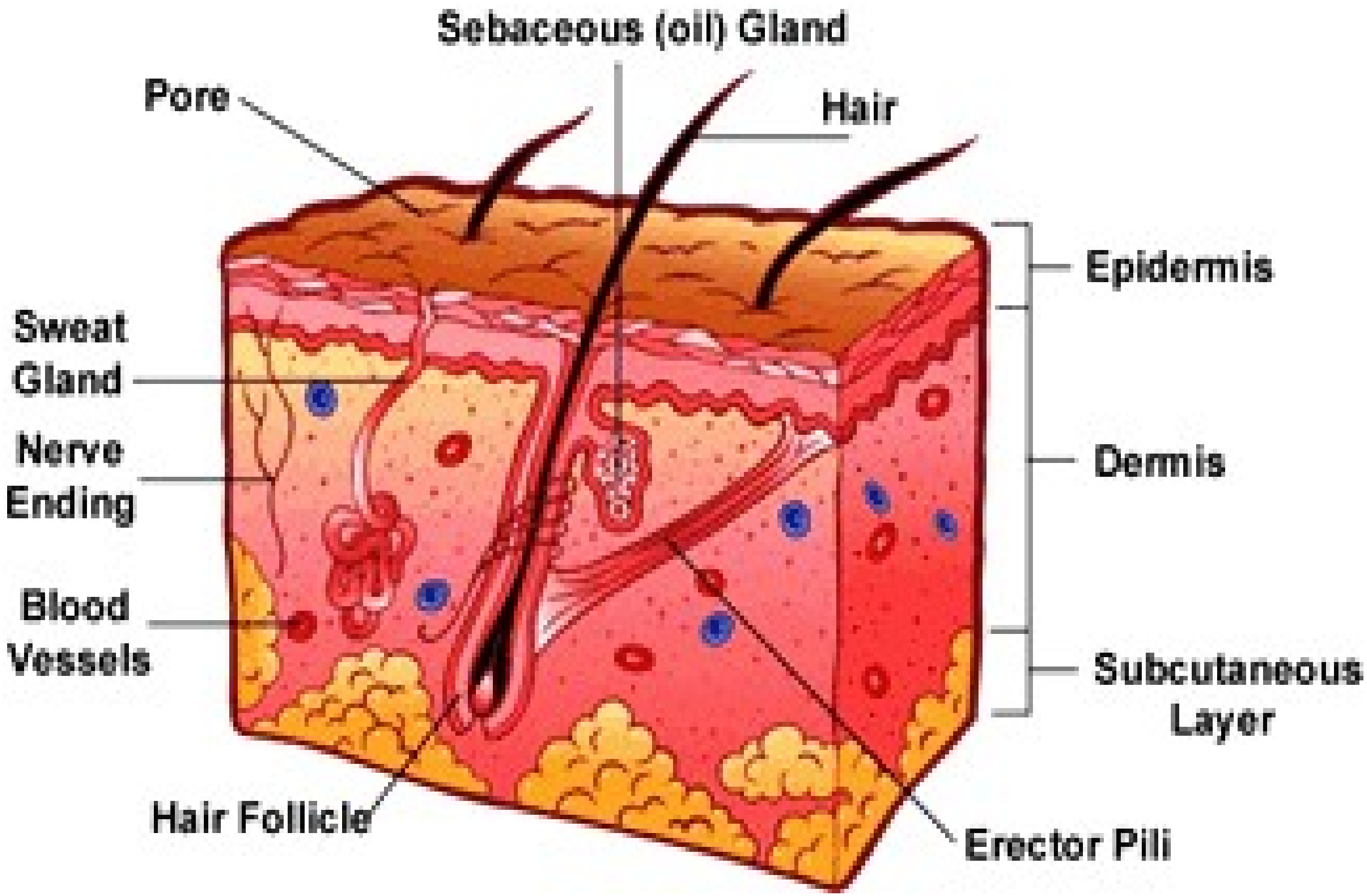


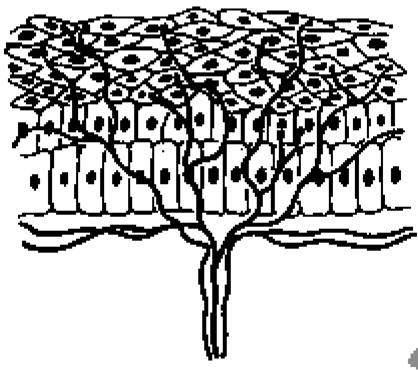
The signal measured is Exponentially dependent to the morphology in “Z”

The intensity is function of the gap distance

THE SKIN: the TOUCH sense　（触覚）

THE SKIN: the TOUCH sense （触覚）





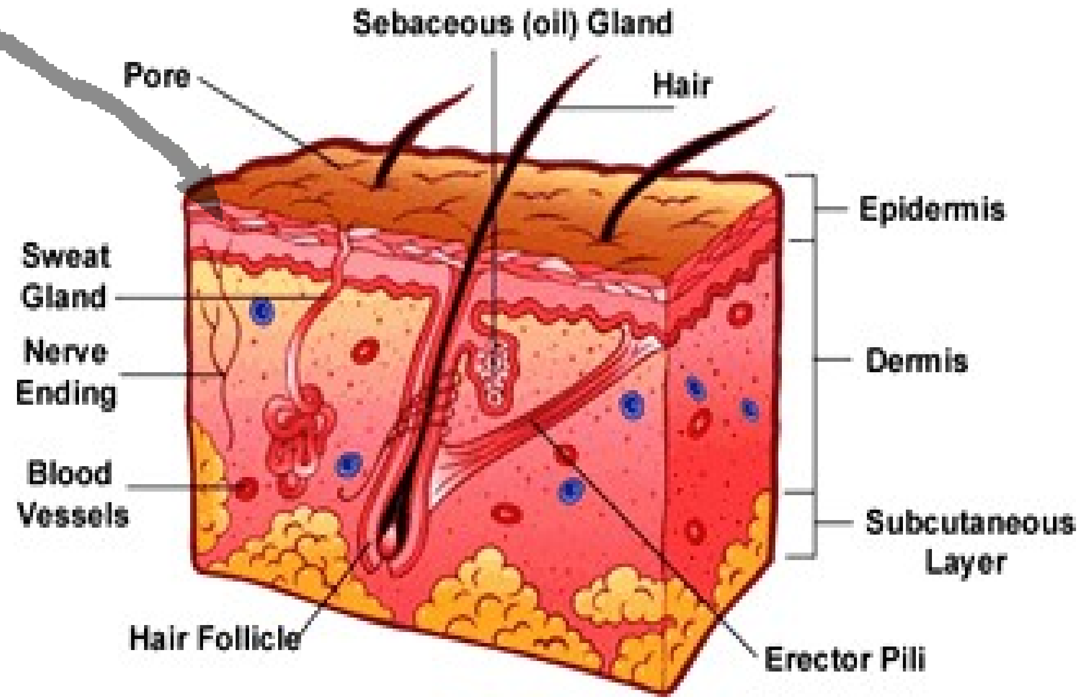
Free nerve endings

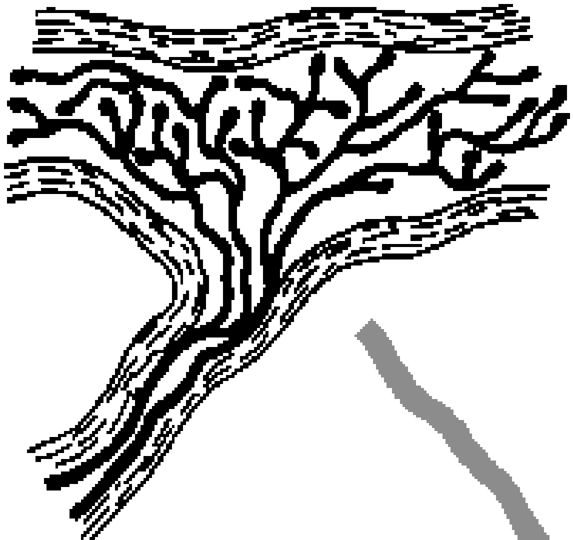
温度センサー

[illegible]力センサー

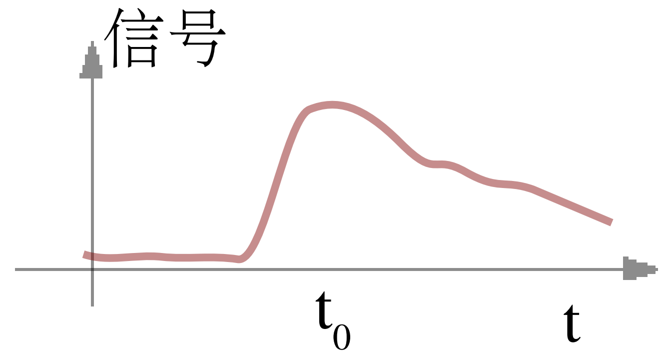
化学センサー

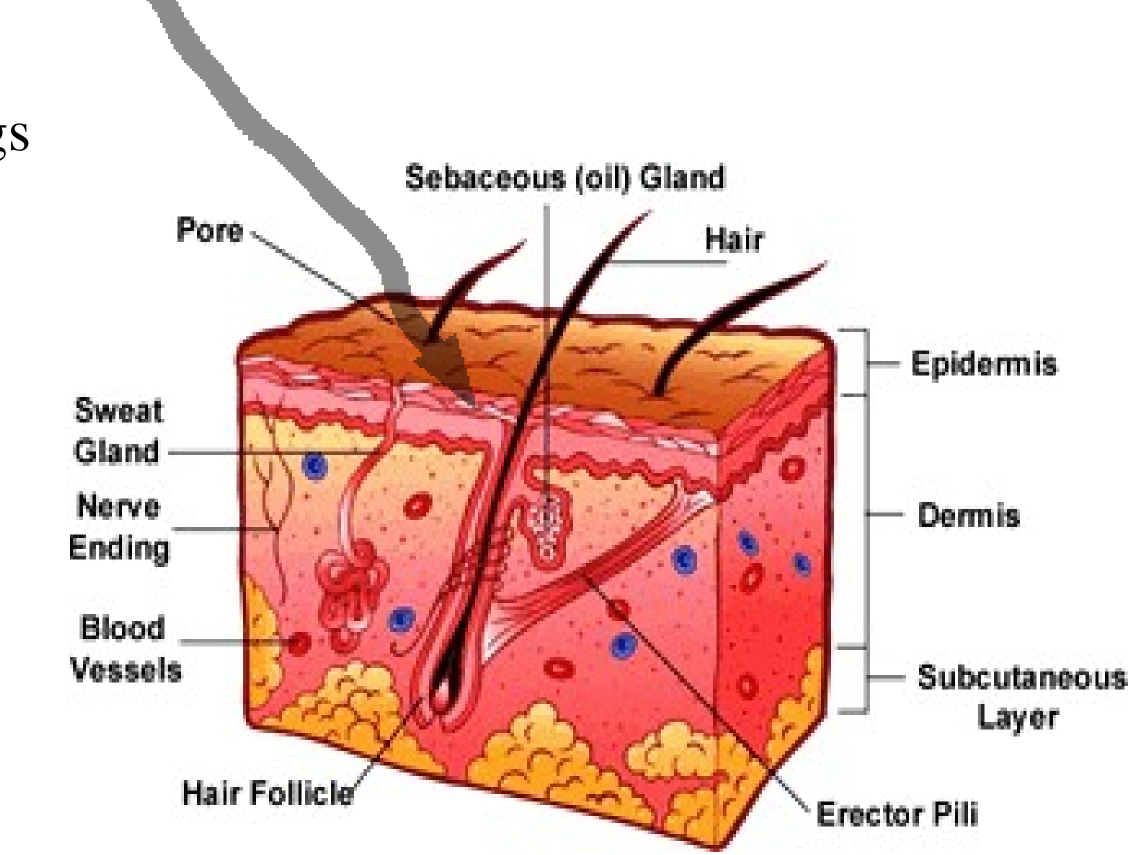
Different types of free nerve endings that respond to mechanical, thermal or noxious stimulation.



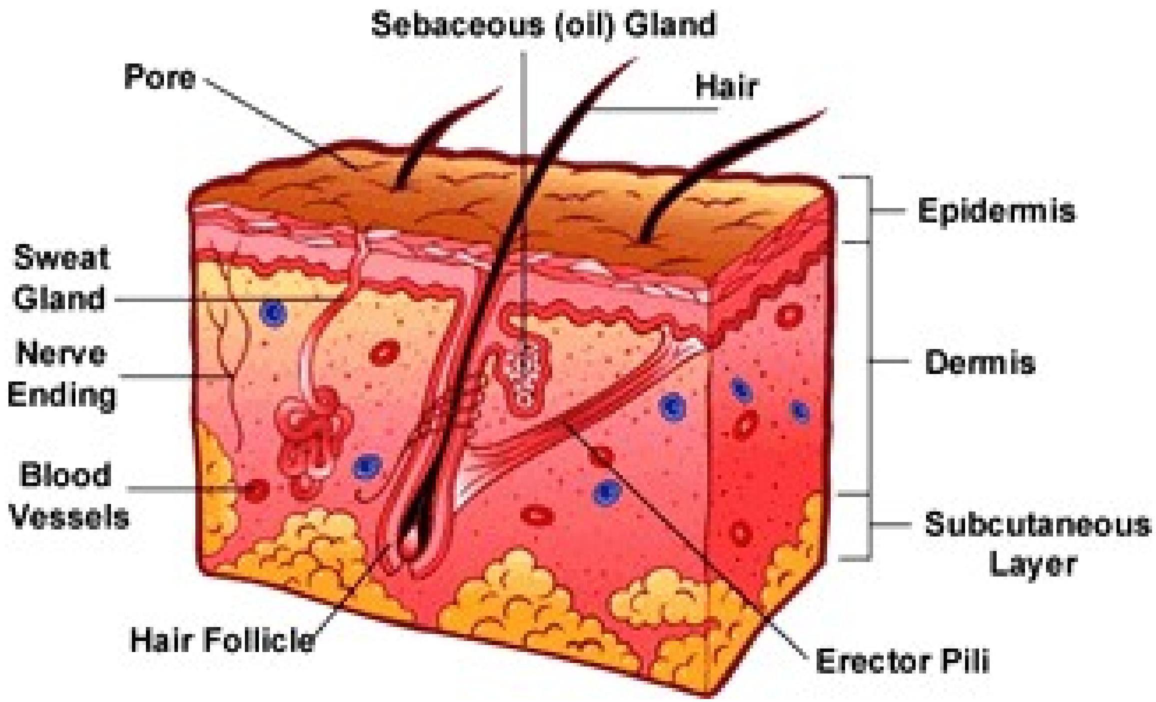


Ruffini Endings





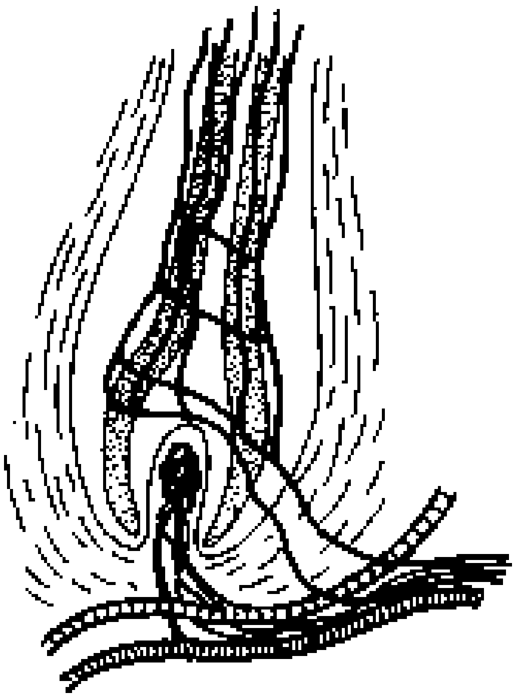
スロー
圧力センサー



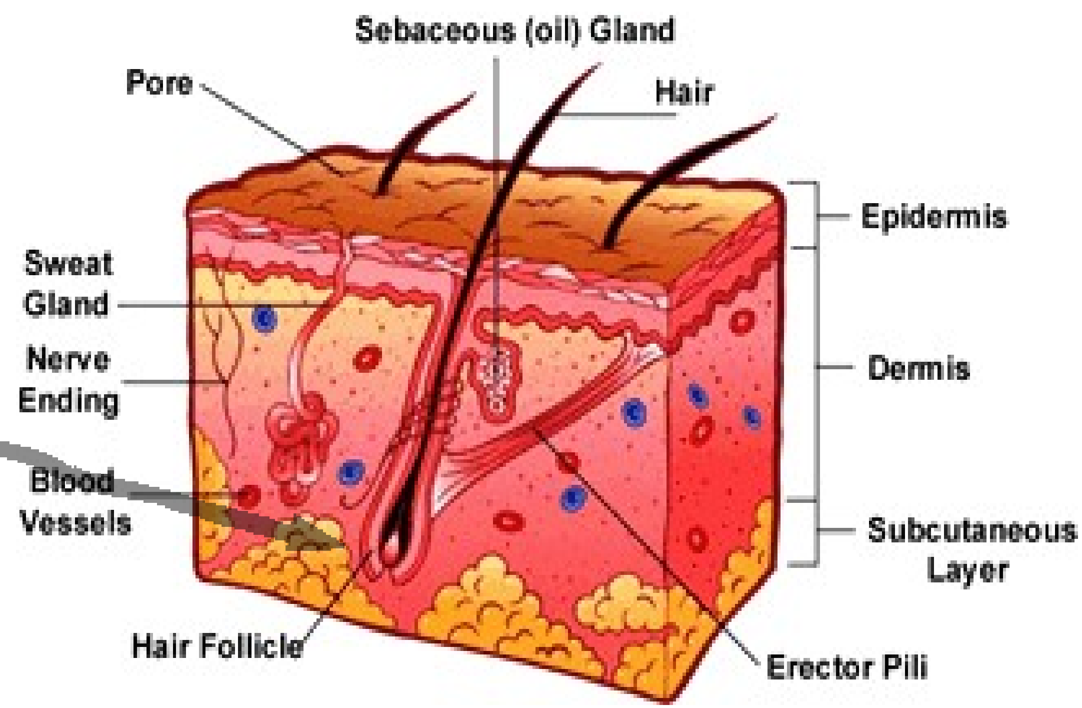
A mechanical *deformation* of the sensory dendrite causes a *depolarization* to occur within the dendrite. This dendrite is at the tip of a unipolar neuron; The sensory dendrite is embedded within the sensor corpuscle. Any depolarization that is large enough in the dendrite itself will cause an *action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

Responds to hair displacement.

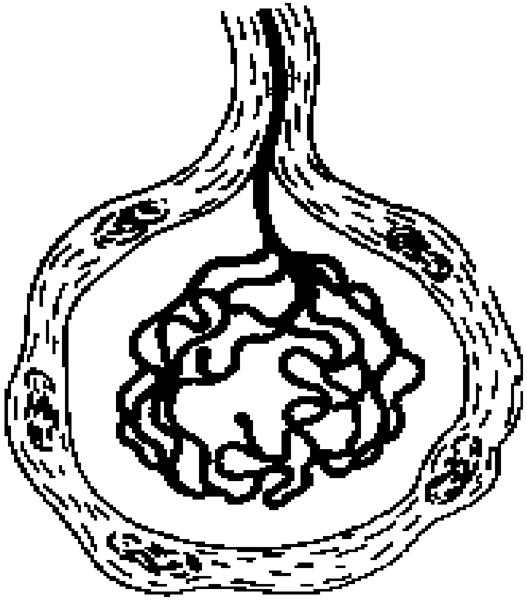
Wraps around hair follicle in, of course, hairy skin.



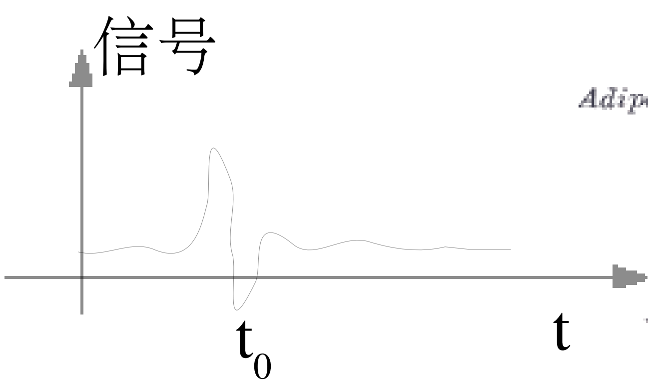
Hair Follicle Ending

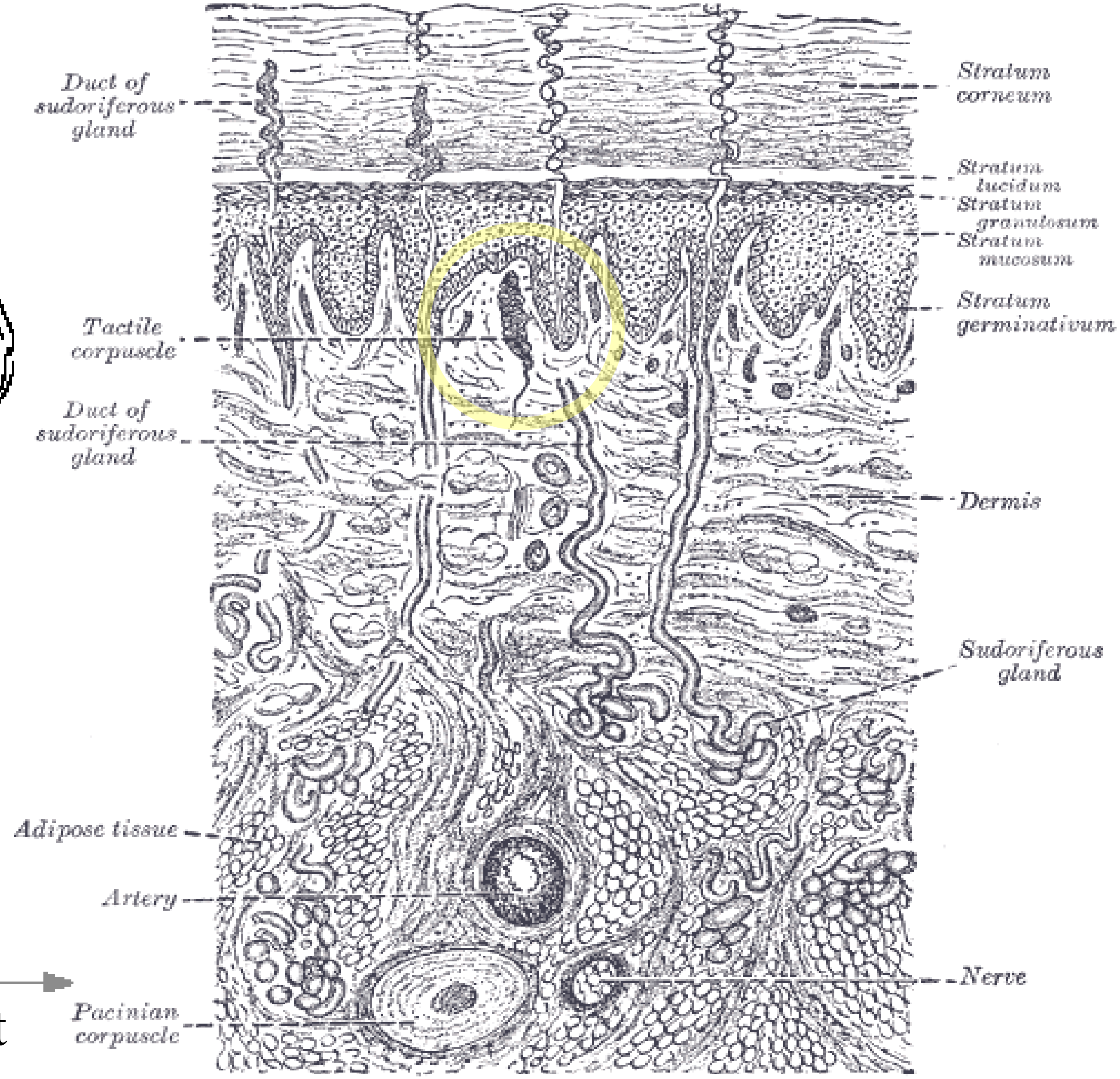


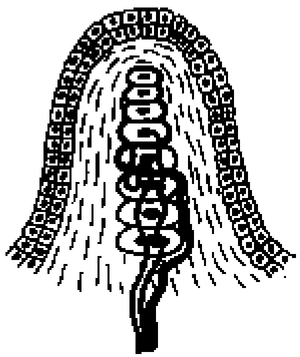
圧力センサー



Krause corpuscole

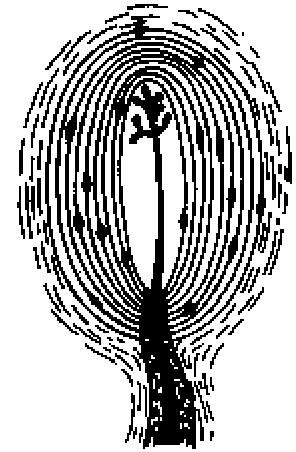






最大感度：20-40 Hz

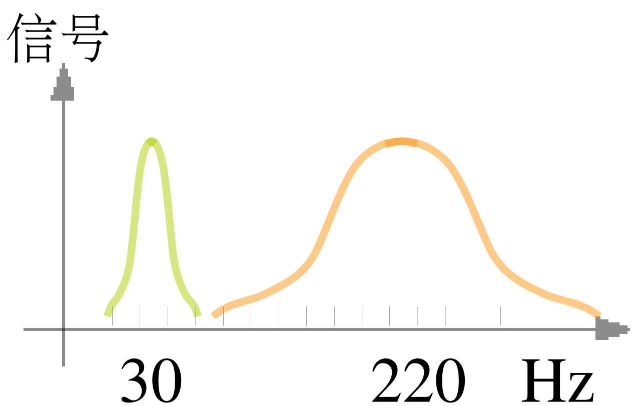
Meissner corpuscole

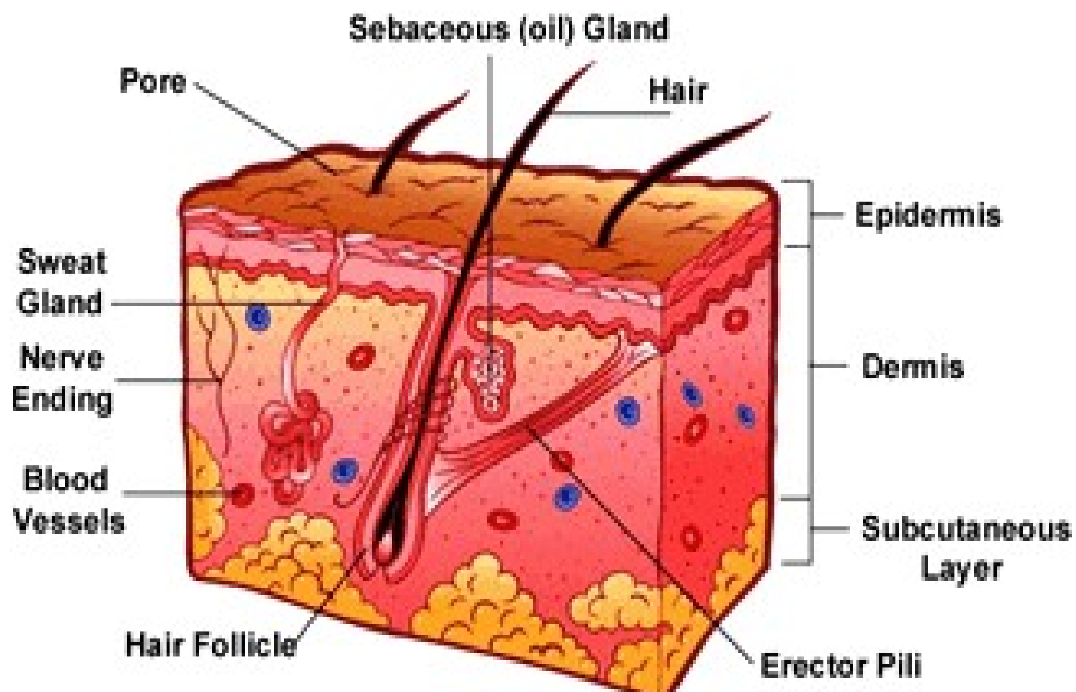


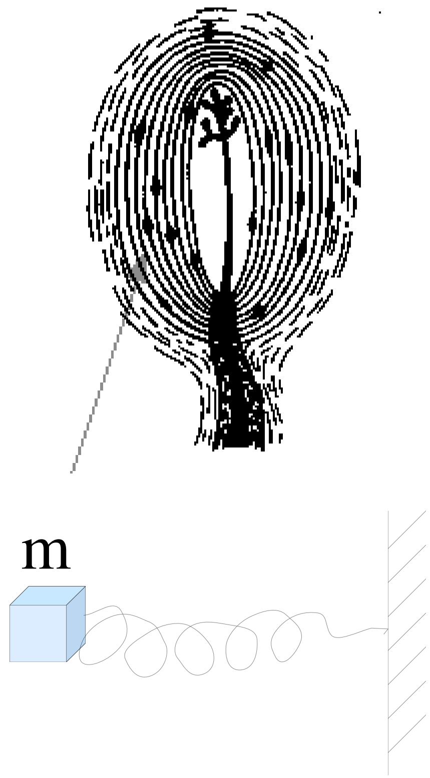
最大感度：150-300 Hz

Pacinian corpuscole

振動センサー







$$F = -kx$$

$$ma = -kx$$

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

Wave equation

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

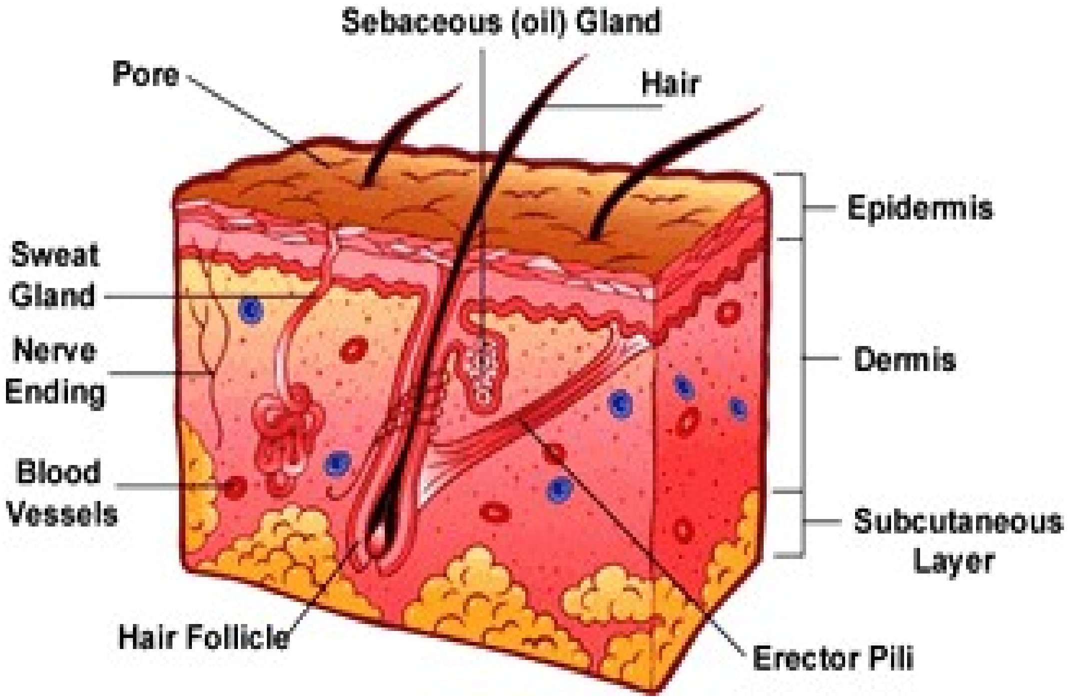
Wave function

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

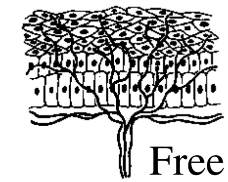
pulsation

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

Frequency depends on material “m” and “k”

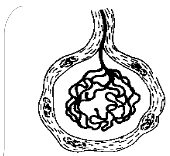


温度センサー
圧力センサー
化学センサー

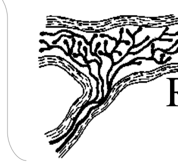


Free nerves

圧力センサー

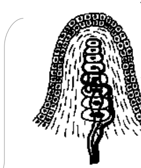


Krause (fast)



Ruffini （slow ）

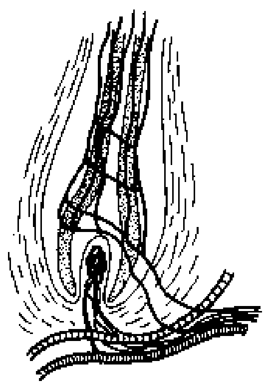
振動センサー



Meissner (20Hz)

Pacinian (220Hz)

空気の動きセンサー



Hair Follicle

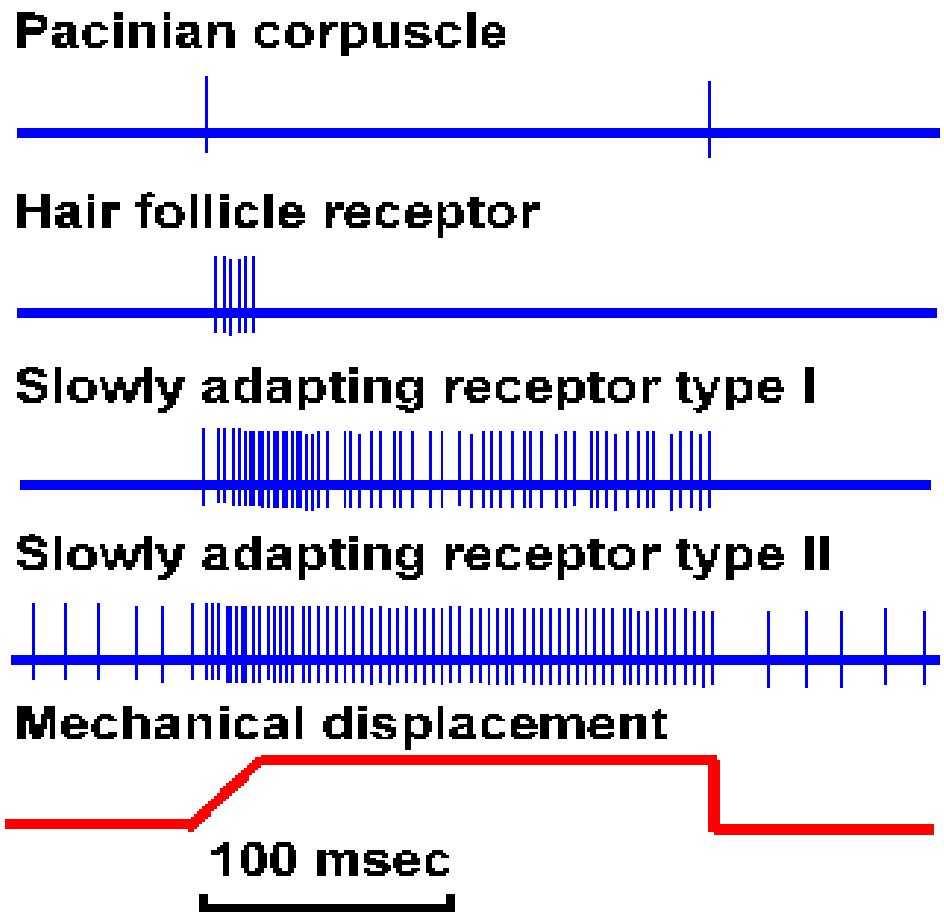
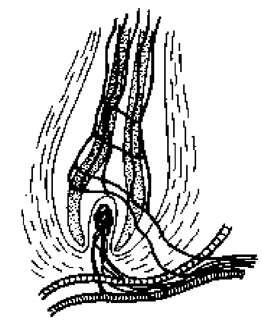


Fig. 5-2. Responses of cutaneous primary afferent fibers. A mechanical indentation or displacement was applied to four different types of receptors, the monitor of the movement being shown in trace 5 (numbered from the top down). The action potential responses of two rapidly adapting fibers are shown in traces 1 and 2: They respond only at the onset or offset of the stimulus. Responses of the two slowly adapting fibers are shown in traces 3 and 4: They discharge throughout the stimulus. A 100-msec time base is shown in trace 6.

Pacinian
(220Hz)

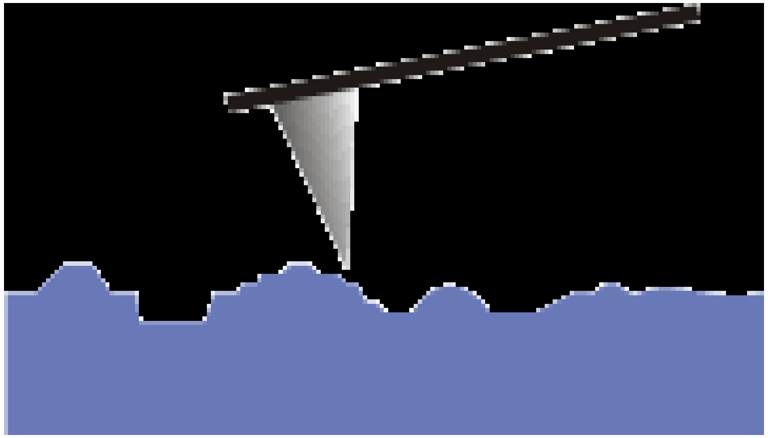


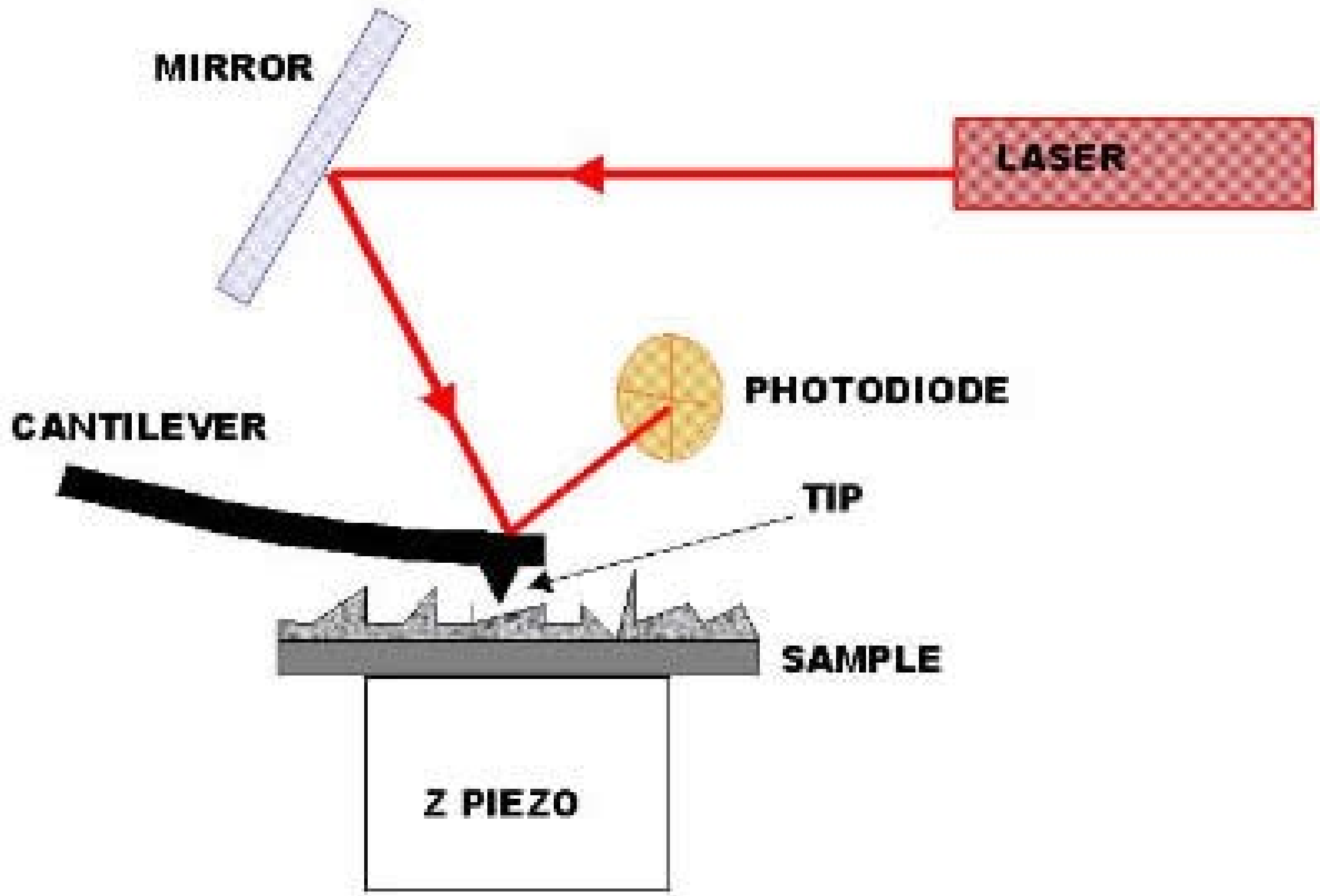
Hair
Follicle

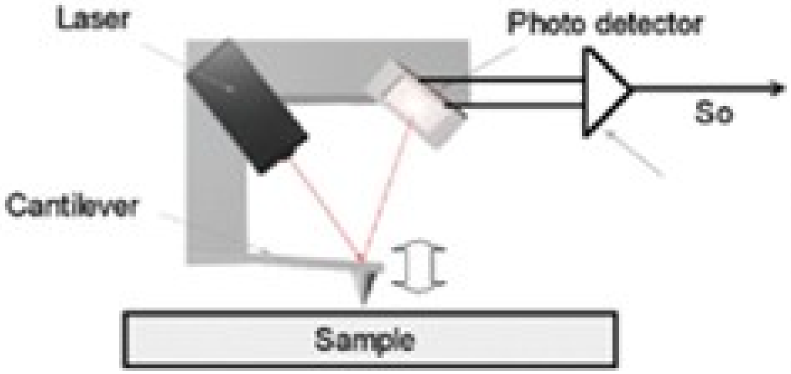
Ruffini（slow
）

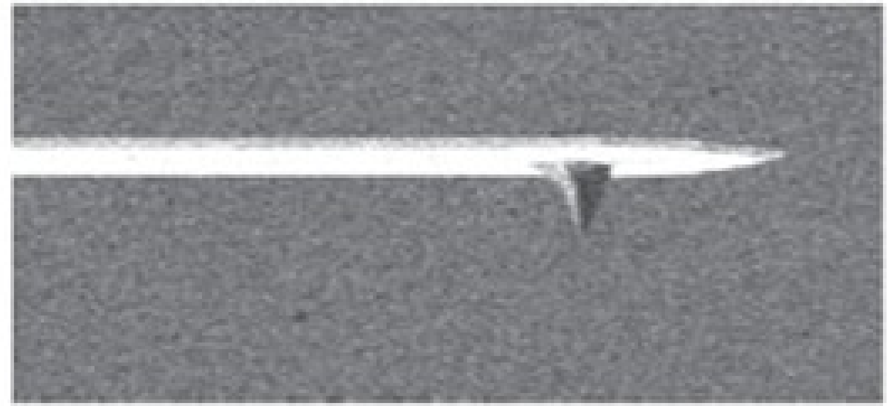
先端人工触覚センサー：原子間力顕微鏡

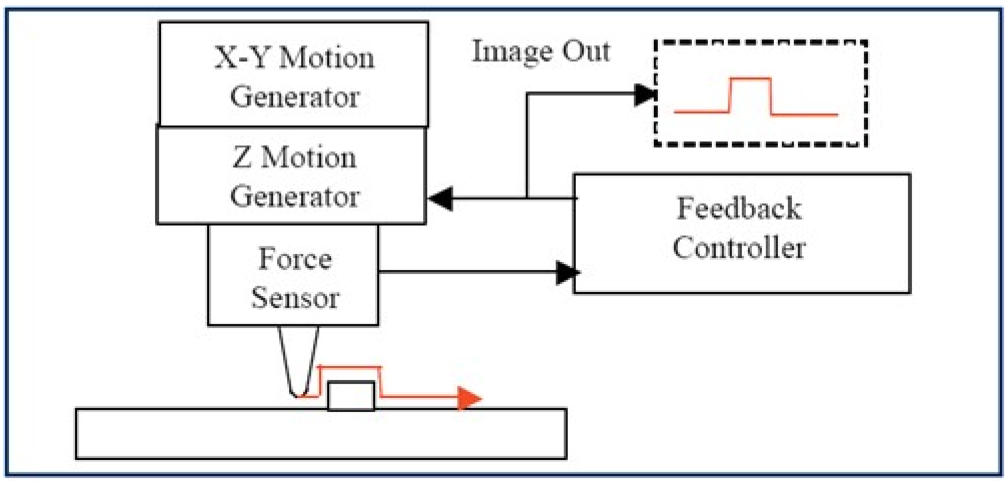
(AFM: Atomic Force Microscope)

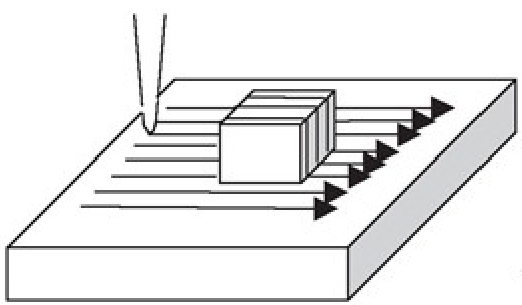


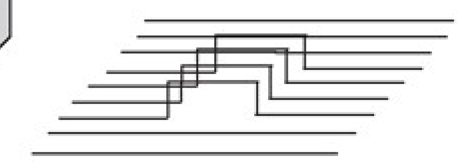

MIRROR
LASER
PHOTODIODE
CANTILEVER
TIP
SAMPLE
Z PIEZO

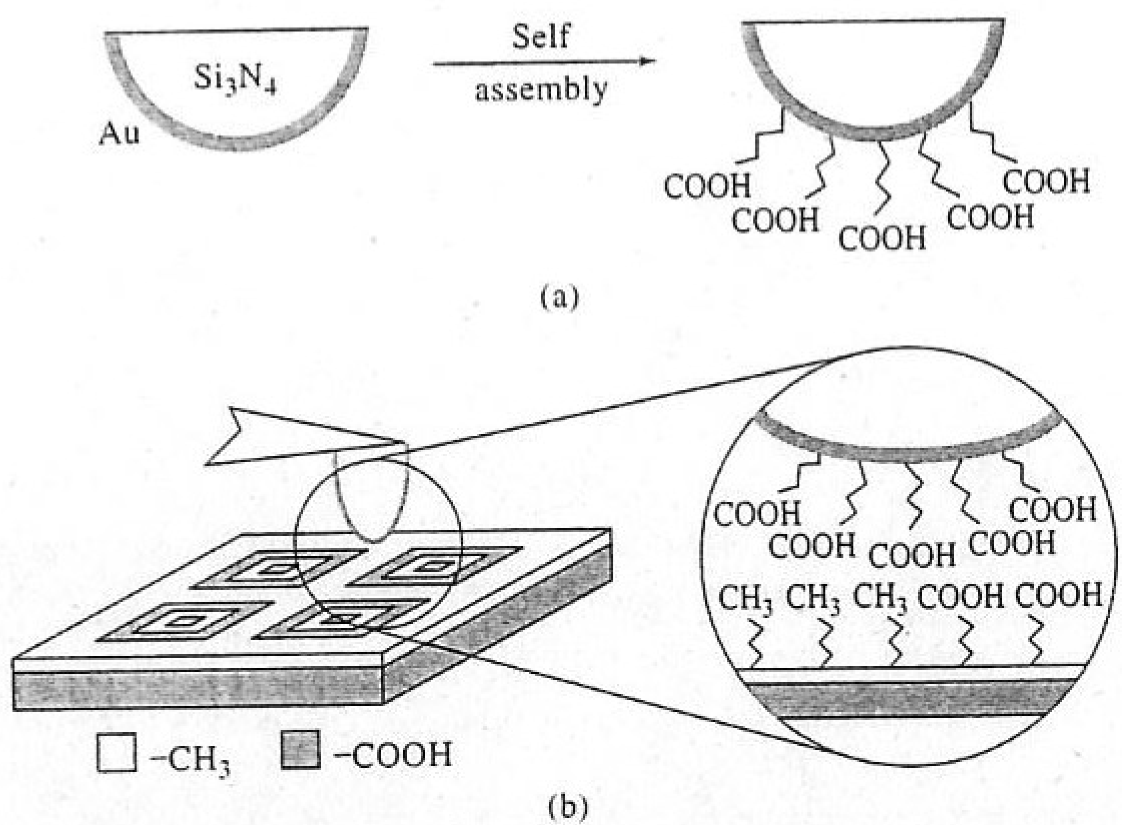

Laser
Photo detector
So
Cantilever
Sample




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







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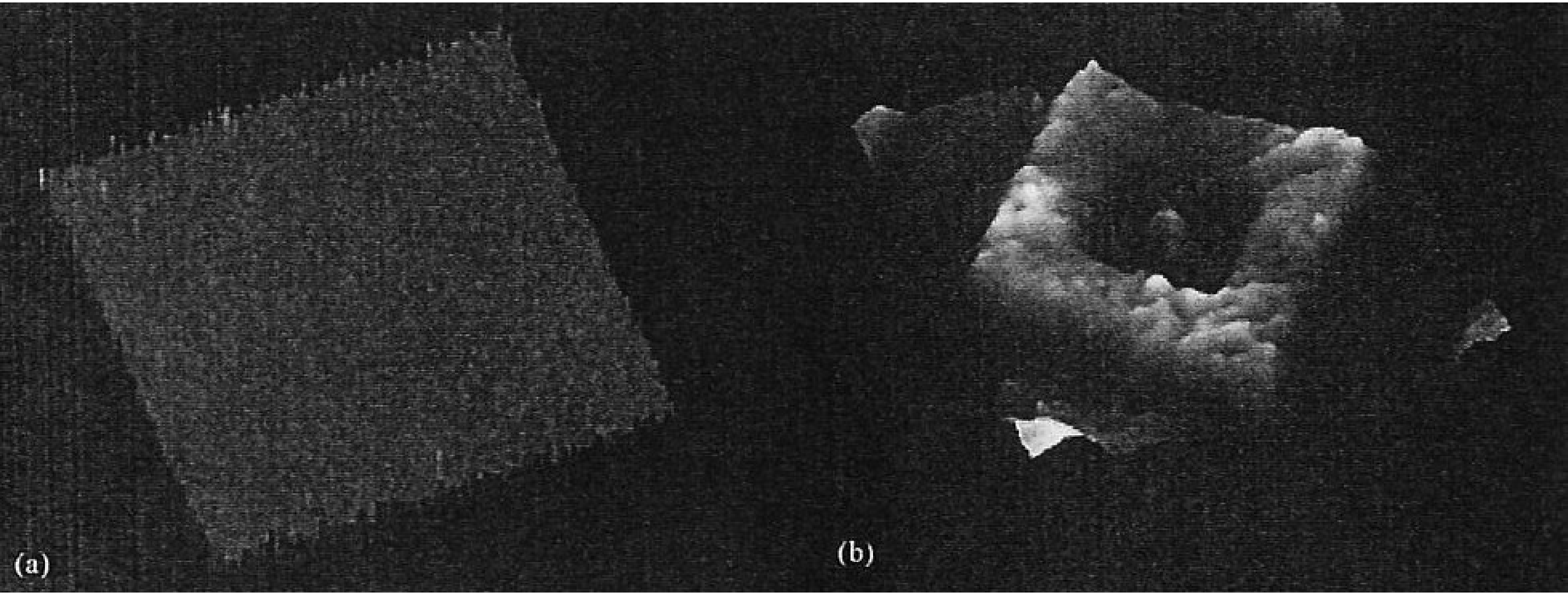
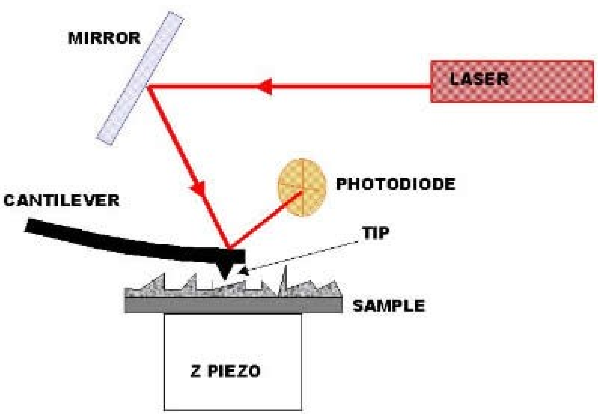
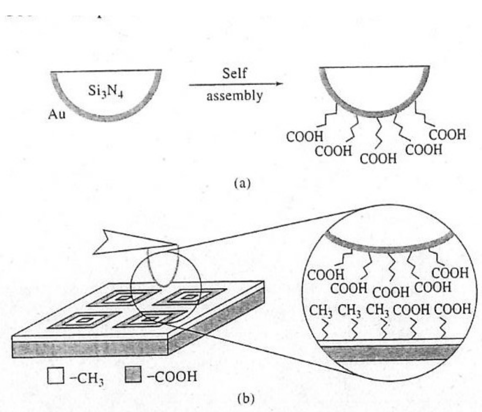
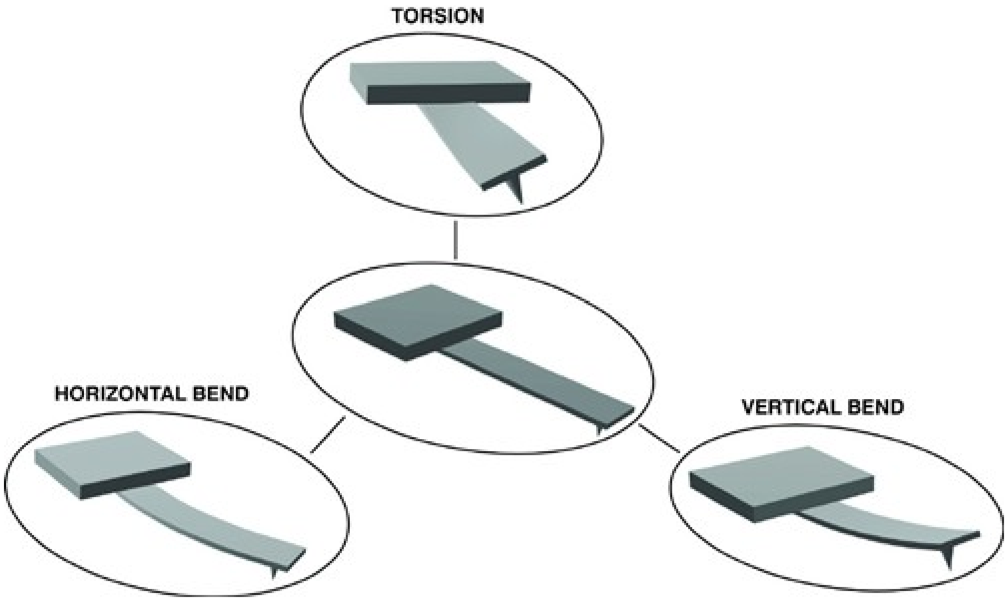
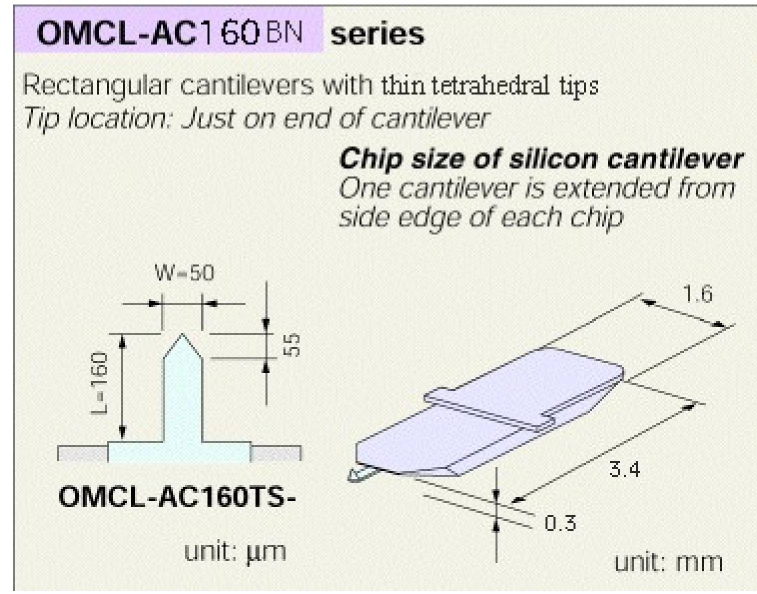
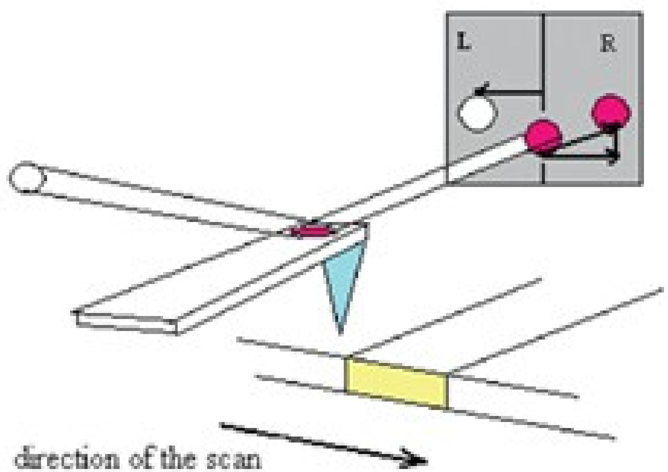

(a)
(b)


MIRROR
LASER
PHOTODIODE
CANTILEVER
TIP
SAMPLE
Z PIEZO

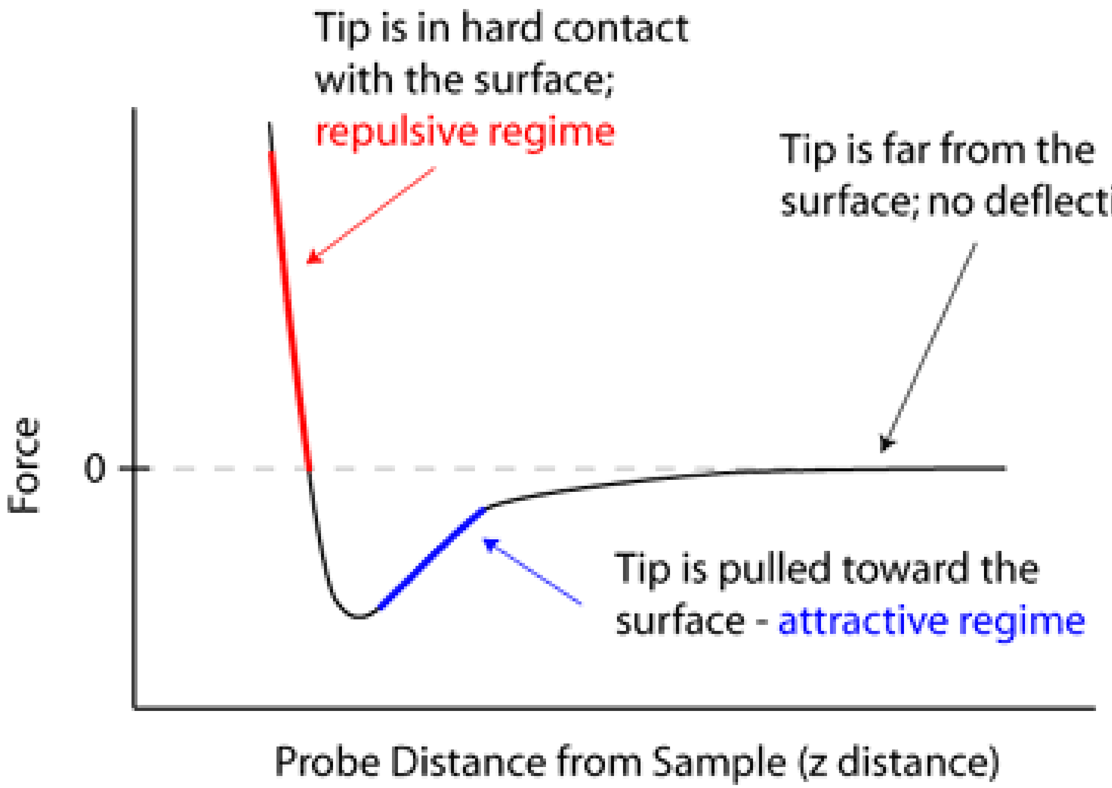

Si3N4
Au
Self
assembly
COOH
COOH
COOH
COOH
COOH
(a)
COOH
COOH
COOH
COOH
COOH
CH3 CH3 CH3 COOH COOH
–CH3
–COOH
(b)

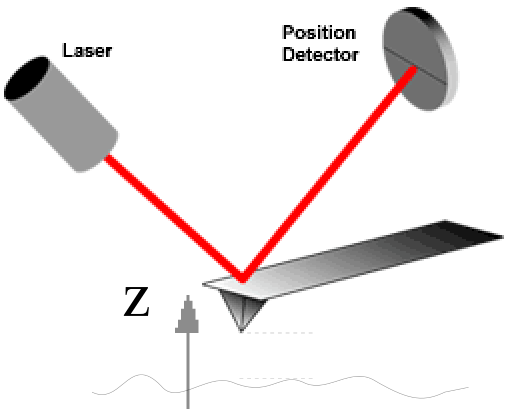

TORSION
HORIZONTAL BEND
VERTICAL BEND

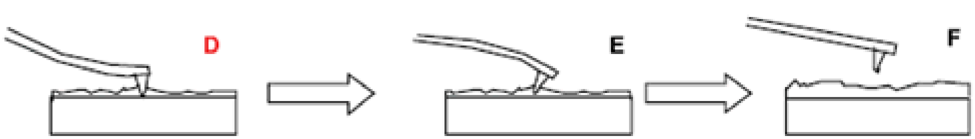

OMCL-AC160BN series
Rectangular cantilevers with thin tetrahedral tips
Tip location: Just on end of cantilever
Chip size of silicon cantilever
One cantilever is extended from side edge of each chip
W=50
L=160
55
OMCL-AC160TS-
unit: µm
1.6
3.4
0.3
unit: mm


L
R
direction of the scan

Operational Modes: CONTACT-MODE

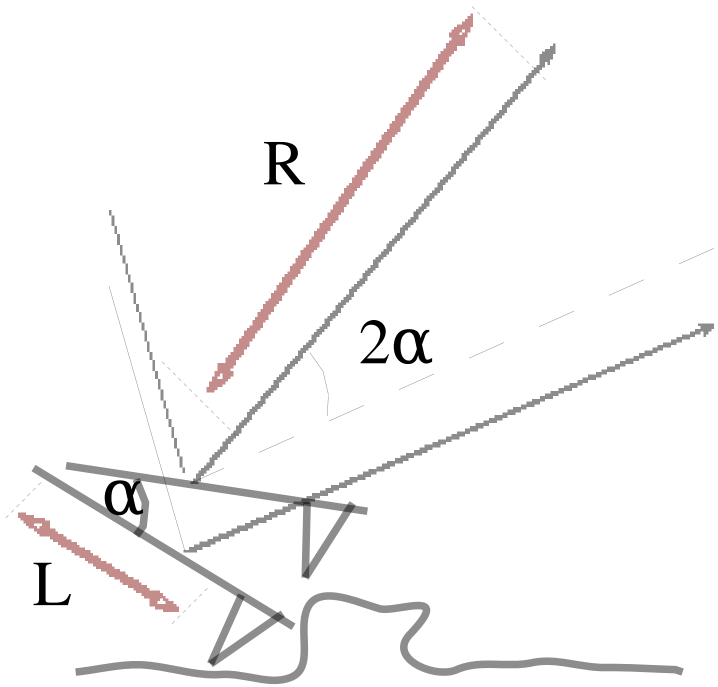






F= - k*D

F= force
k= force constant
D= Deflection distance

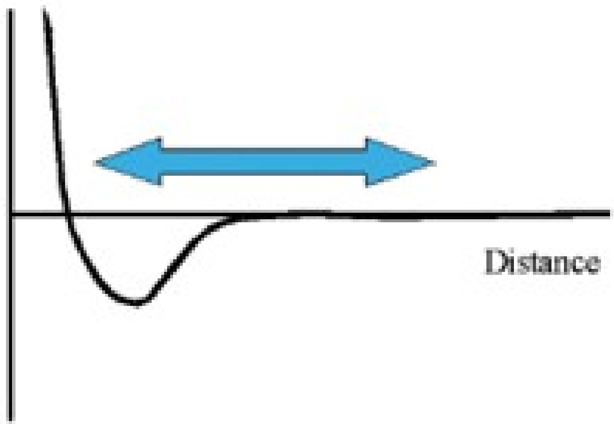


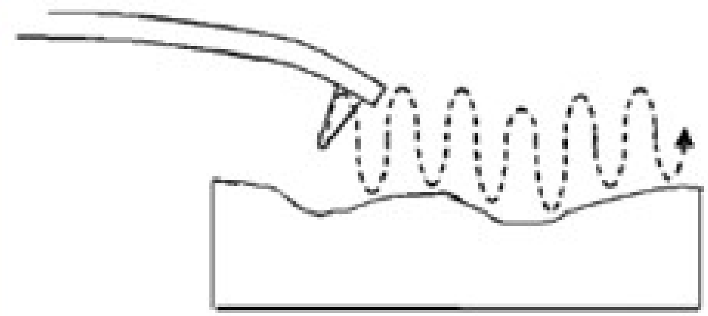
$$L = 1\ mm$$
$$\Delta z = 1\text{nm}$$

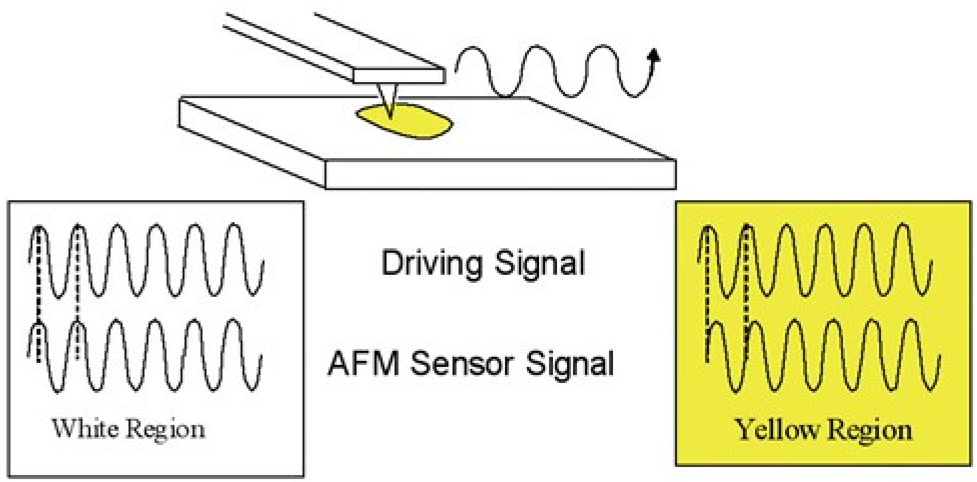
$$\alpha = \arctan\left(\Delta \frac{z}{L}\right)$$

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

Operational Modes: VIBRATING-MODES





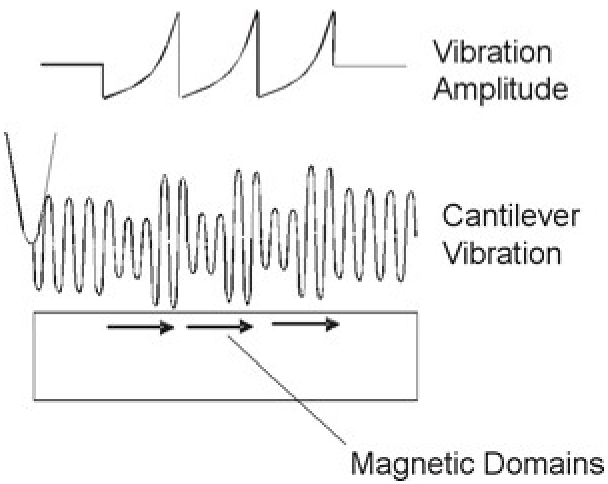


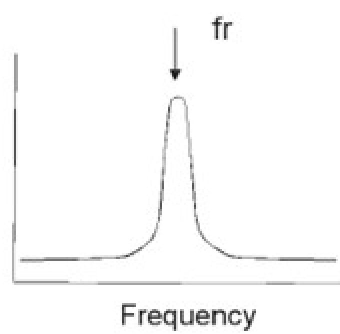
- Phase Changes
- Amplitude Changes

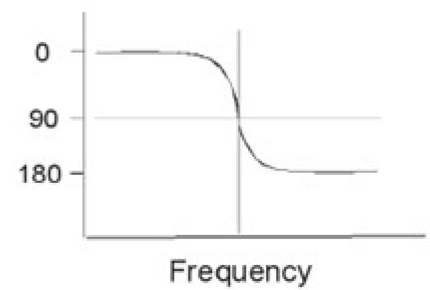
Equation 4-3: $\omega_o - \omega_o' \approx \omega_o \, f'/2k$

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

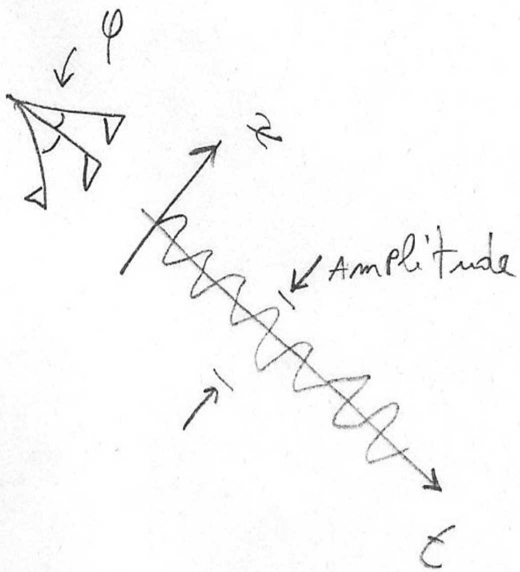
k	Force constant
ω_o	Resonance frequency
ω_o'	New resonance frequency
F	Force on probe

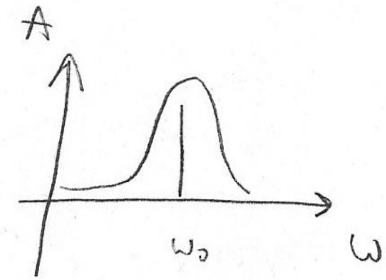






The cantilever vibration Physics:





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

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

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

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

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

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

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

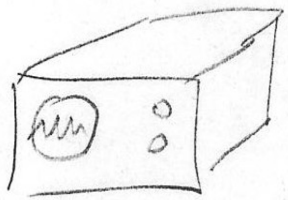
WAVE EQUATION → SOLUTION

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

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

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

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

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

$f = 50\ kHz$

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