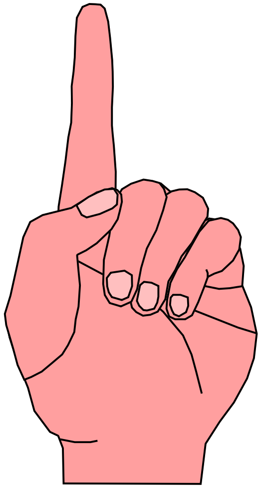
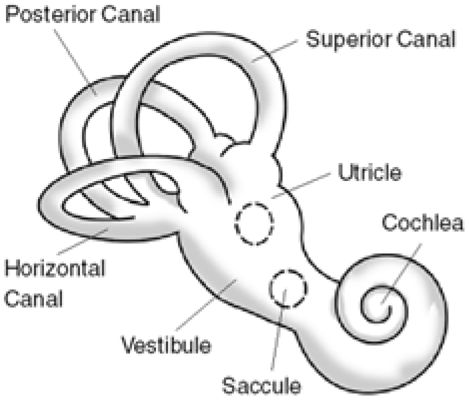
ACTIVE SENSING

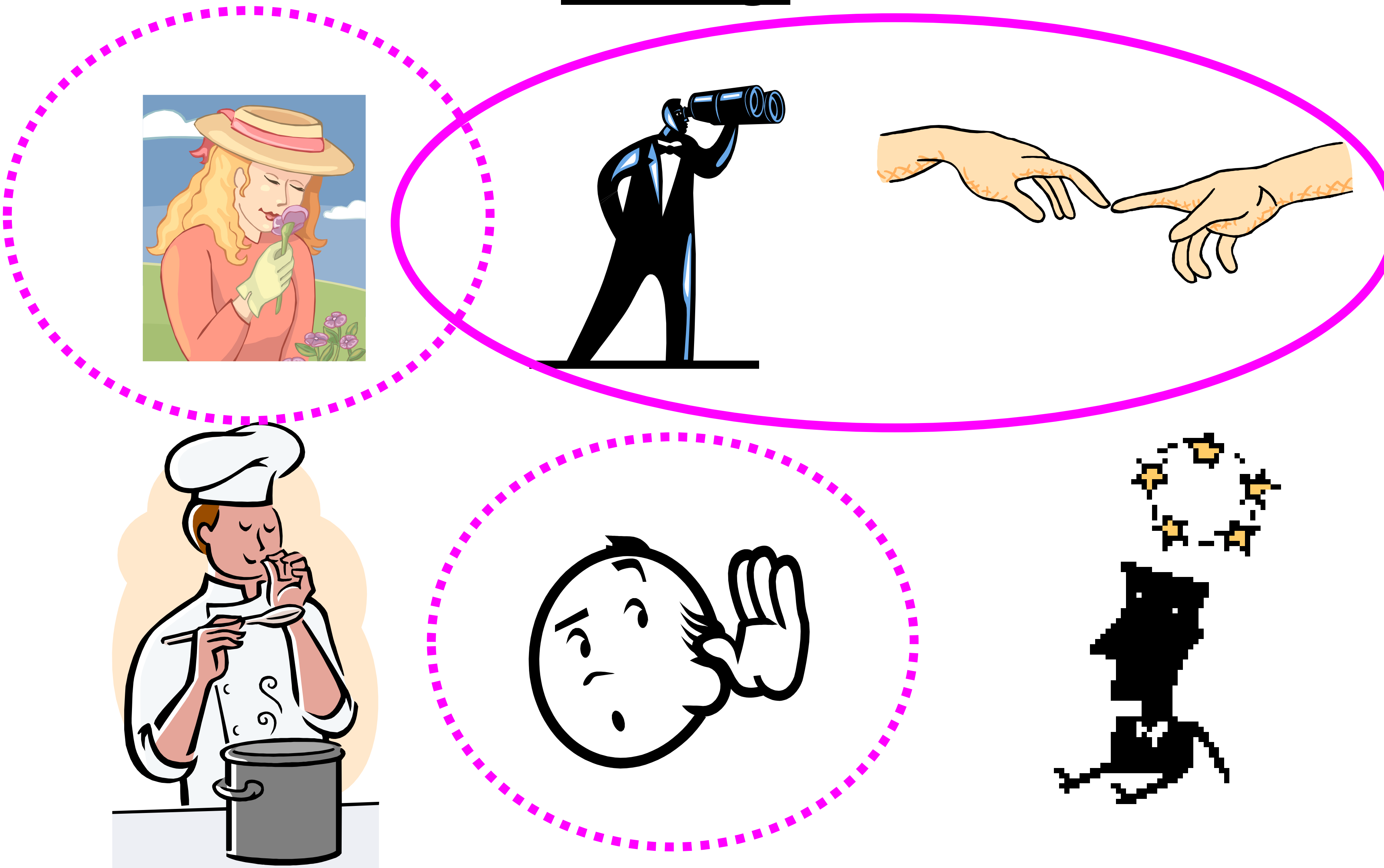
Lecture 1: The Senses

The senses:




Posterior Canal
Superior Canal
Utricle
Cochlea
Horizontal Canal
Vestibule
Saccule

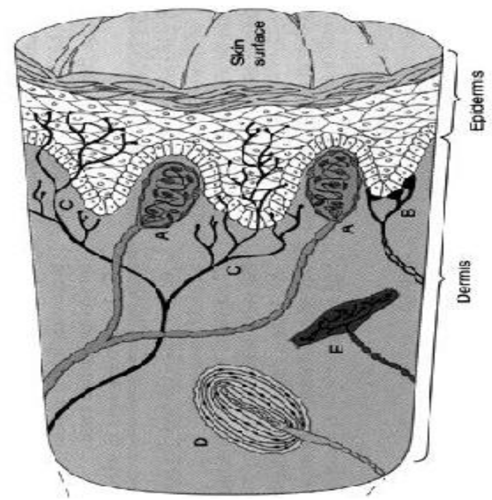
Sensing:



Sensory encoding: *What receptors tell the brain*

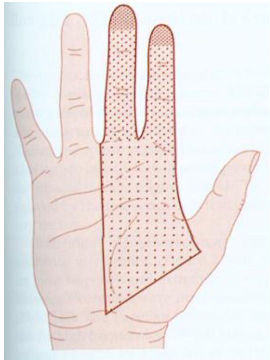
Sensory organs consist of **receptor arrays**:

somatosensation



~200 µm

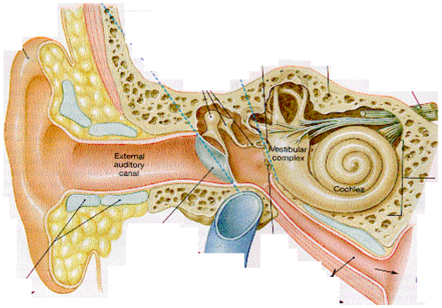
Finger pad



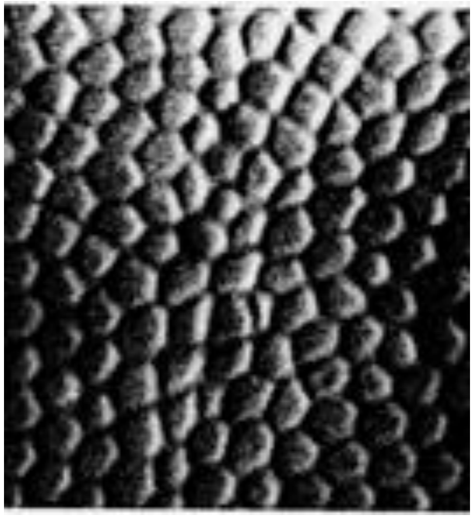
audition

10 µm

cochlea

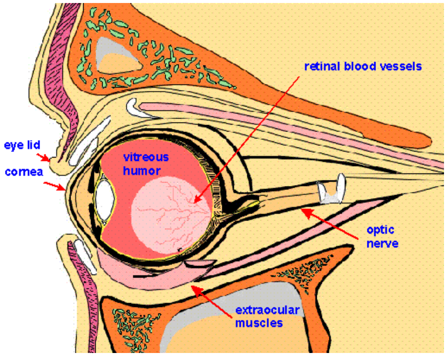


vision



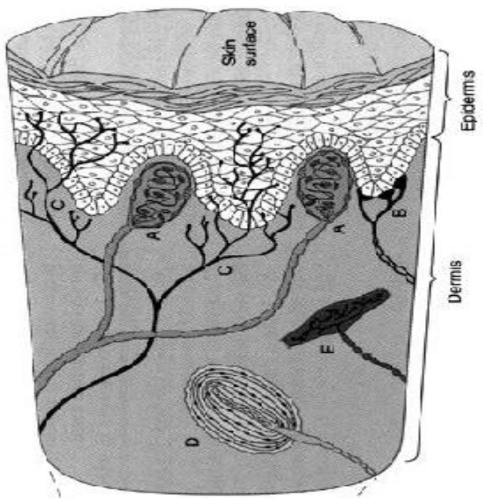
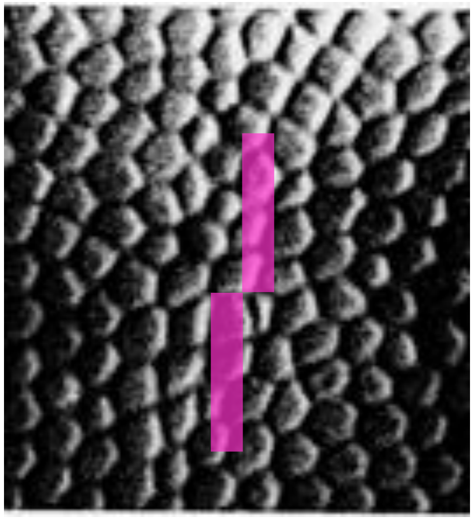
10 µm

retina



Sensory encoding: What receptors tell the brain

Sensory organs consist of **receptor arrays**:

somatosensation	**audition**	**vision**
		
~200 µm	10 µm	10 µm
Finger pad	*cochlea*	*retina*

Spatial organization => Spatial coding (“*which* receptors are activated”)

Spatial coding (via passive sensing) would be sufficient had the world being continuously

flashing on us

and sensory sheets were u n i f o r m

Passive sensing metaphors

one could think of:

*the **eye** as a **camera***

light is

Imprinted on the retina
via photo-receptors

*the **skin** as a **carbon paper***

Pressure is

Imprinted on the skin
via mechano-receptors

Imprinted on paper
via carbon particles

However

1. The world is not flashing

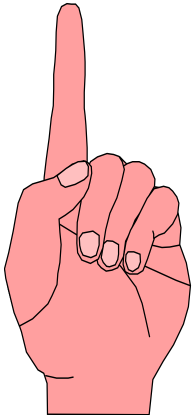
and receptors are mostly sensitive to changes

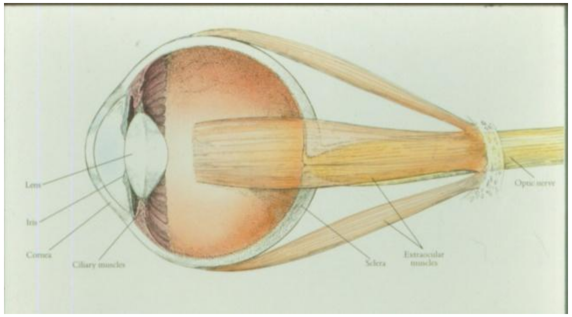
⇓

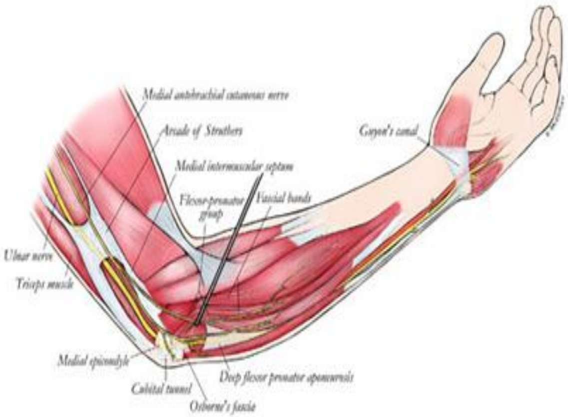
Receptors must move

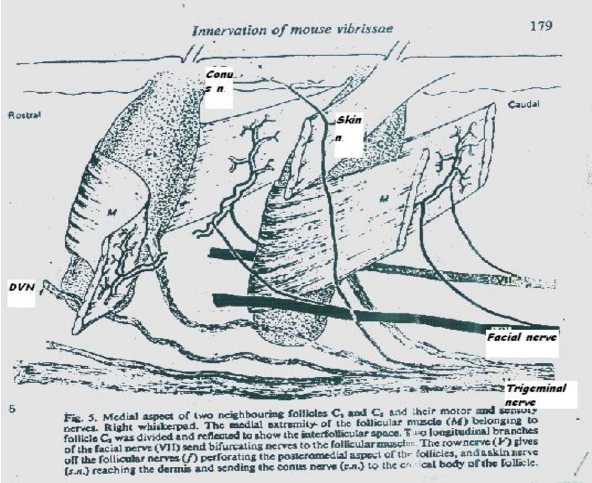
Active Sensing:

Sensor organs MOVE in order to obtain information









However

1. The world is not flashing

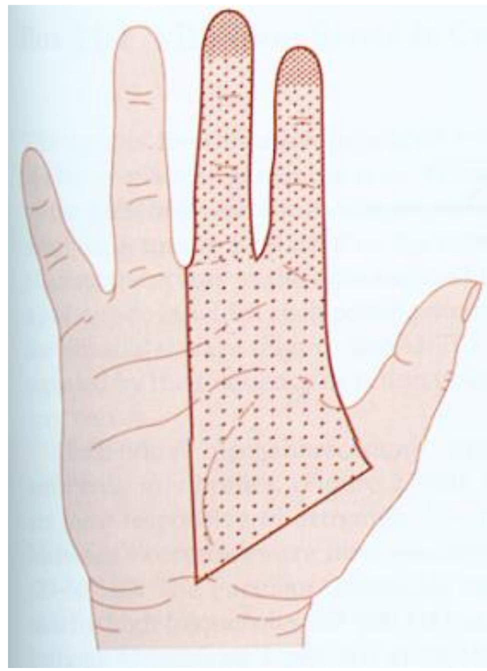
2. sensory sheets are not uniform

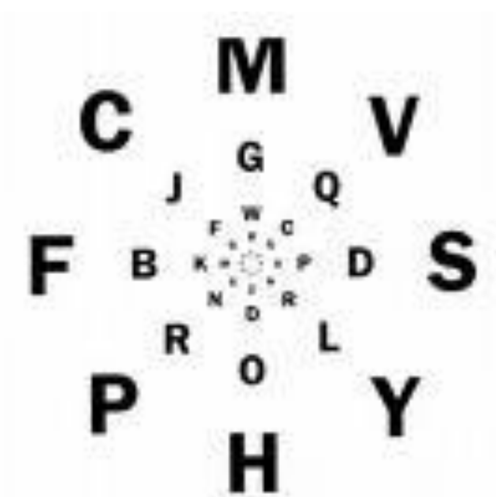
Fovea

eye

finger

whisker





Fovea => macro movements of the sensory organ

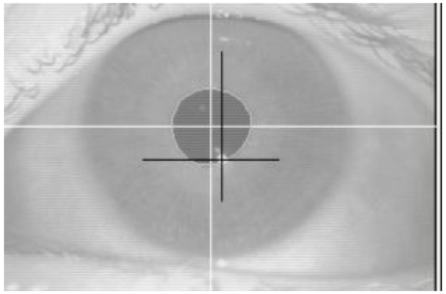
Fovea => macro movements of the sensory organ

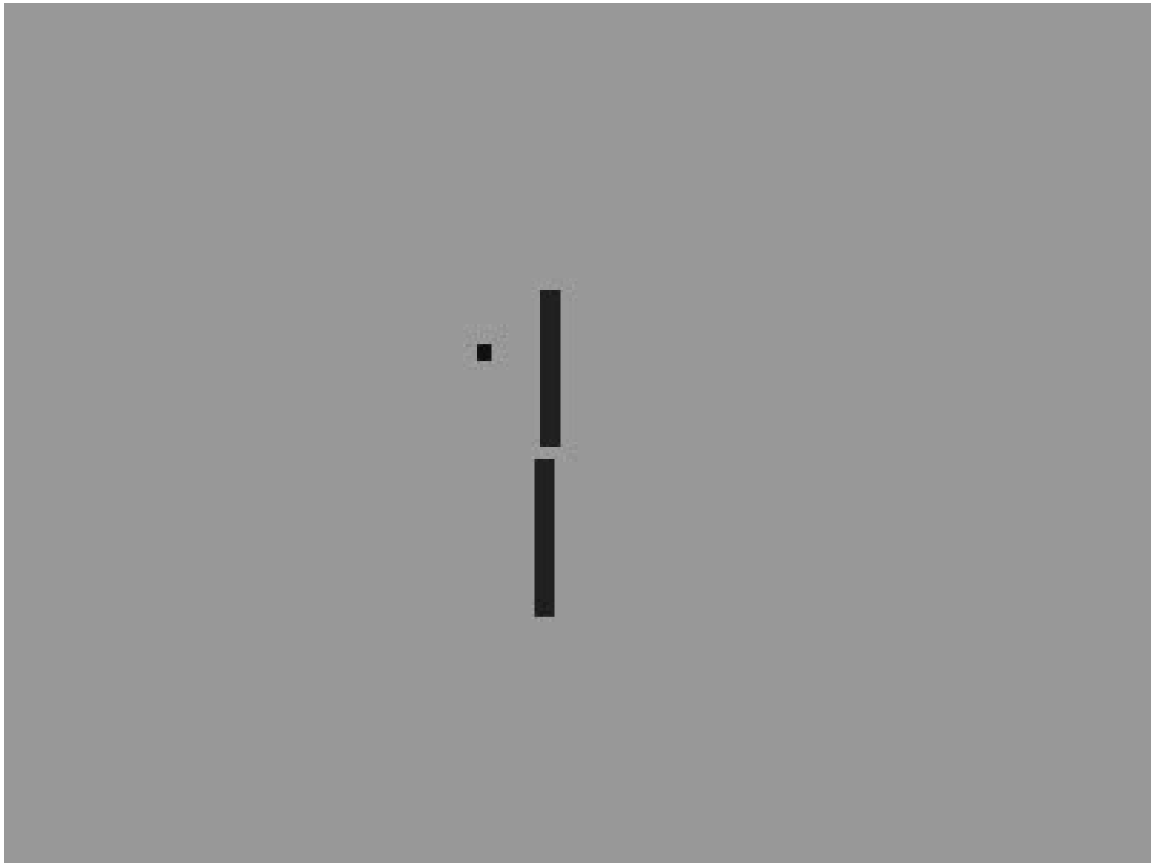
Sensitivity to changes => micro movements of the sensory organ

Without sensor motion sensation is limited to moving or flashing objects

How sensor motion constrains sensory coding?

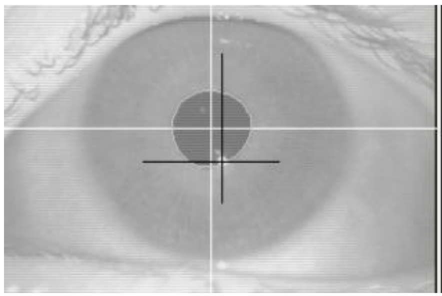
Eye movements during fixation

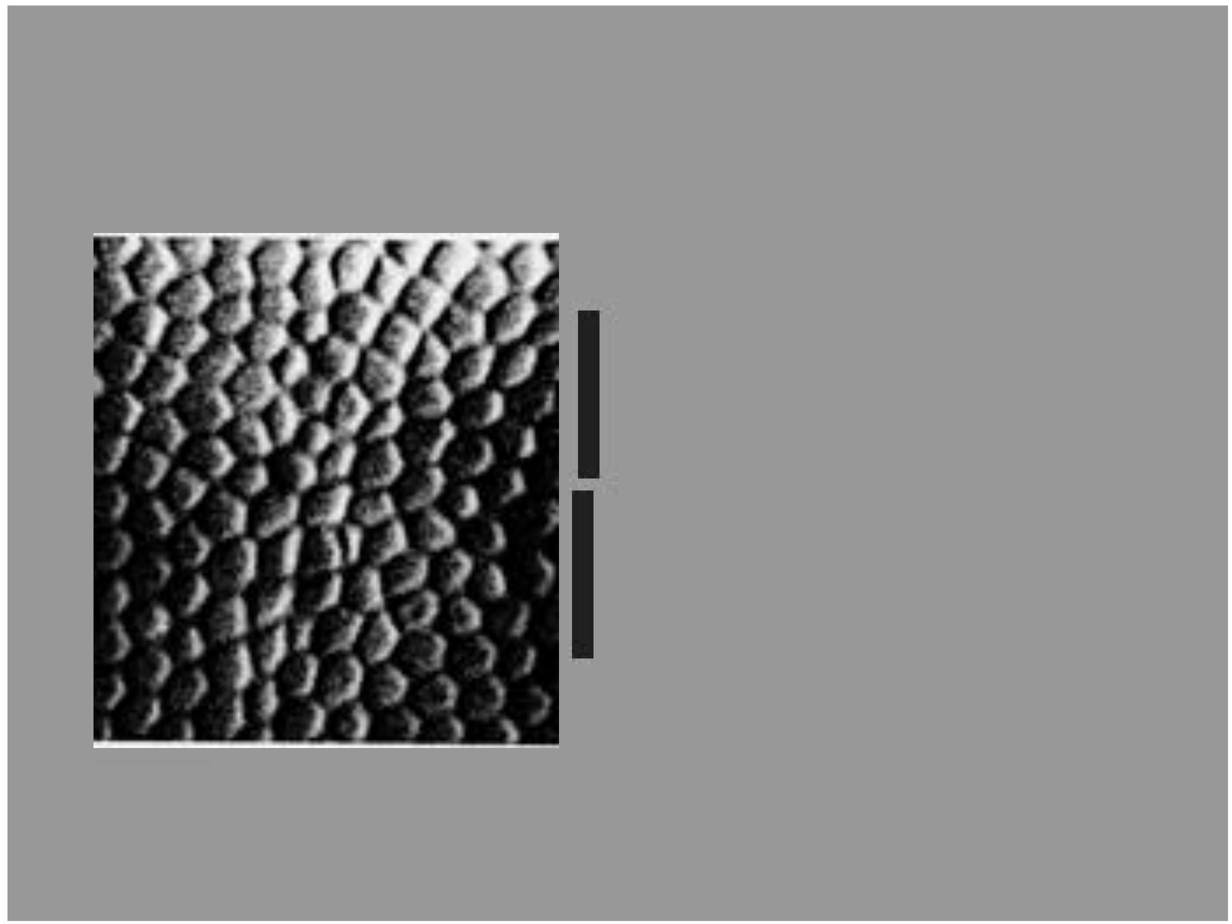




backward!

Eye movements during fixation

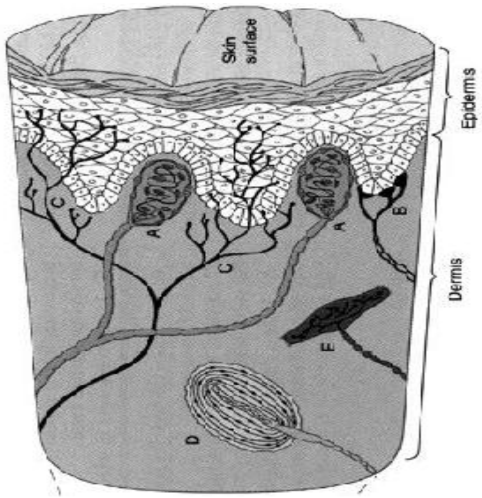




sensory encoding: *What receptors tell the brain*

Sensory organs consist of **receptor arrays**:

somatosensation



~200 μm

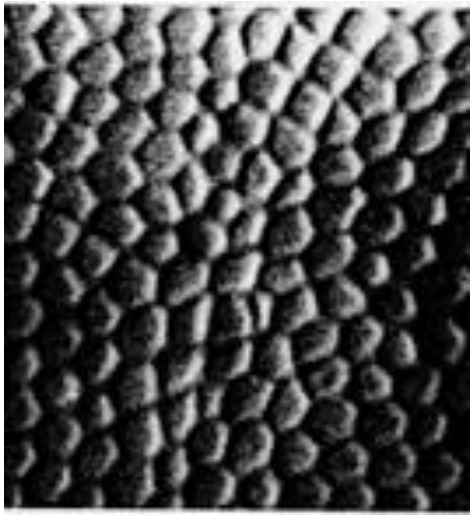
Finger pad

audition

10 μm

cochlea

vision



10 μm

retina

Spatial organization => Spatial coding ("*which* receptors are activated")

Movements => Temporal coding ("*when* are receptors activated")

Temporal coding in action

Coding space by time

1. Spatial frequency
2. Spatial phase

Touch: Temporal encoding of spatial features

Darian-Smith & Oke,
J Physiol, 1980

anesth. monkey,
MR fibers

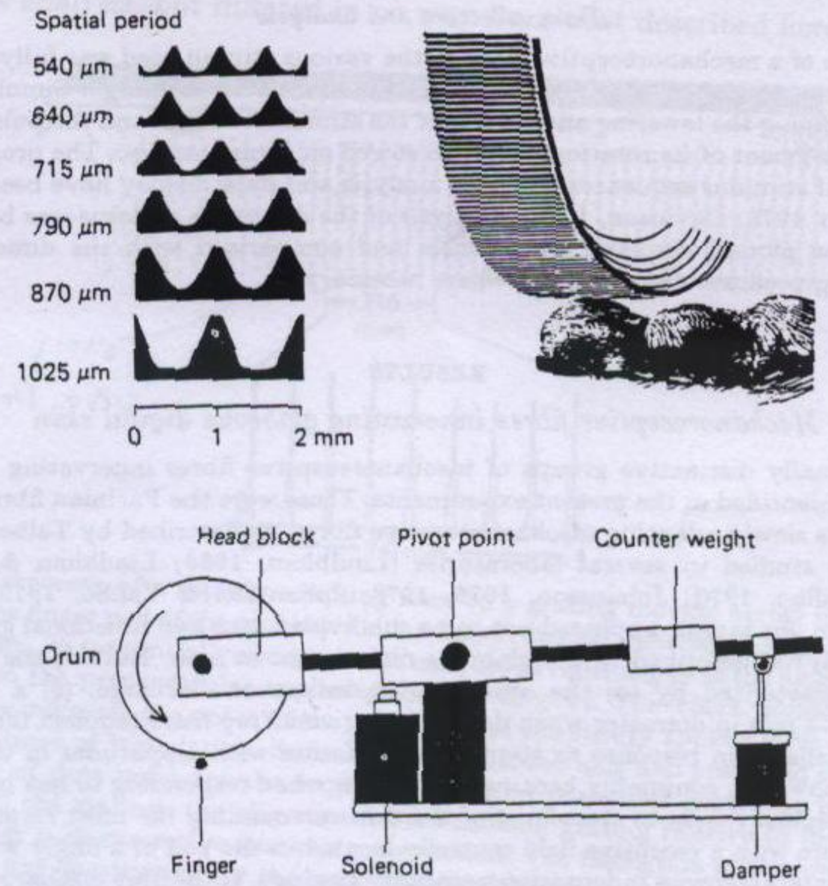


Fig. 1. Details of the stimulator used for presenting gratings to finger pad skin. The grating was mounted on a rotating drum 100 mm in diameter (upper right). The profile of each of the six gratings used is shown (upper left), along with its spatial period. The lower diagram illustrates the mechanisms for controlling the period of contact of the grating moving across the finger pad skin. *The drum was mounted at one end of a* counter-poised *lever* and *rotated* at a *preset velocity.* This drum was positioned *1 mm above the skin surface:* an actuated solenoid held the drum off the skin except for the required contact period. The perpendicular force at which the moving grating was applied to the skin during this contact period was determined by the counter-weight: this could be set in the range 20–100 g wt.

RA fiber

Vel - constant

$f = SF * V$

$dt = dx / V$

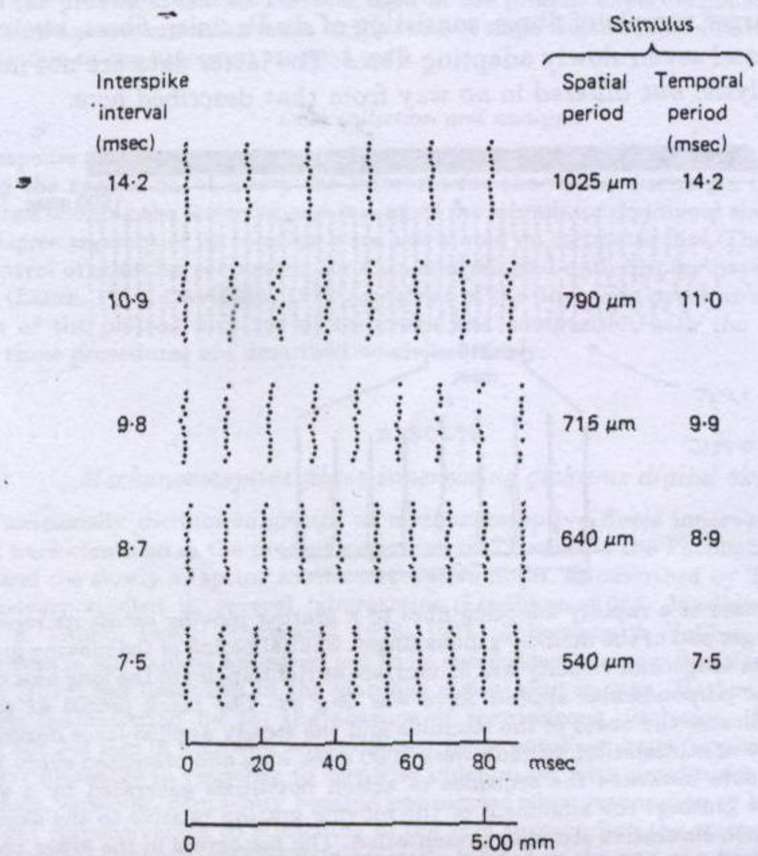
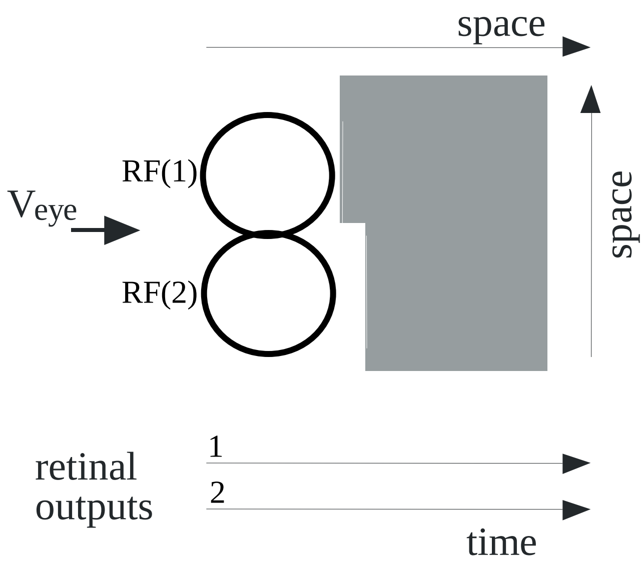


Fig. 3. Responses of a rapidly adapting fibre to different gratings moving across its receptive field on the ridged glabrous skin of terminal phalanx of thumb. The tangential velocity was 72 mm/sec in a direction at right angles to the long axis of the finger and the applied force was 60 g wt. for all records; successive stimuli were presented every 3 sec. Each row of dots indicates the occurrence of action potentials in response to a single passage of the grating across the skin; twelve successive responses are illustrated for each grating; spatial periods of these gratings are indicated on the right. The 80 msec response segment illustrated had its onset at approximately 500 msec after the beginning of stimulation, as is shown in Fig. 2. With these records there was both precise alignment of the time of occurrence of action potentials after the onset of stimulation, and also alignment relative to the instantaneous position of the grating on the skin. The stimulus spatial and temporal periods are indicated for each data block on right side of Figure. The mean interspike interval is to the left of each data block.

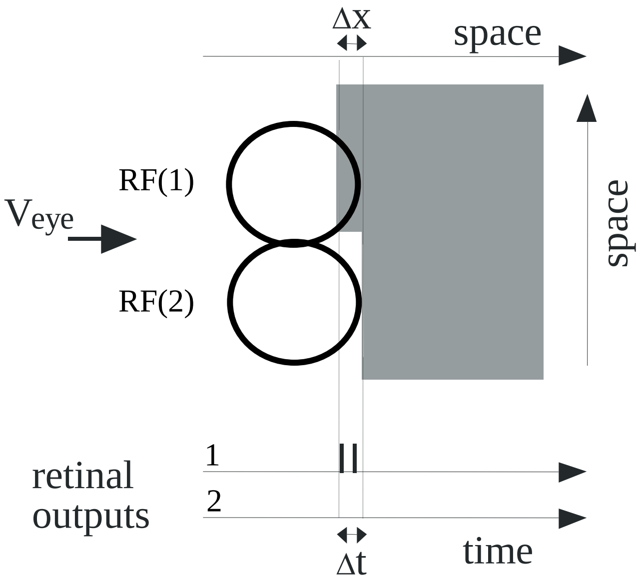
Coding space by time

1. Spatial frequency
2. Spatial phase

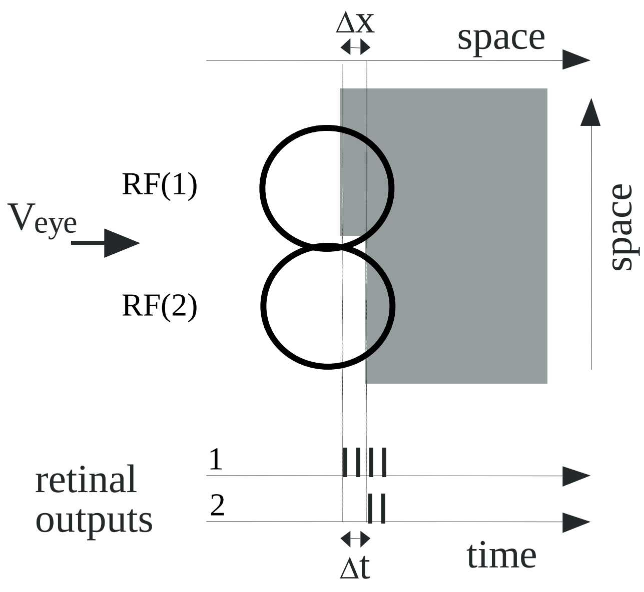
Vision: Temporal encoding due to eye movement



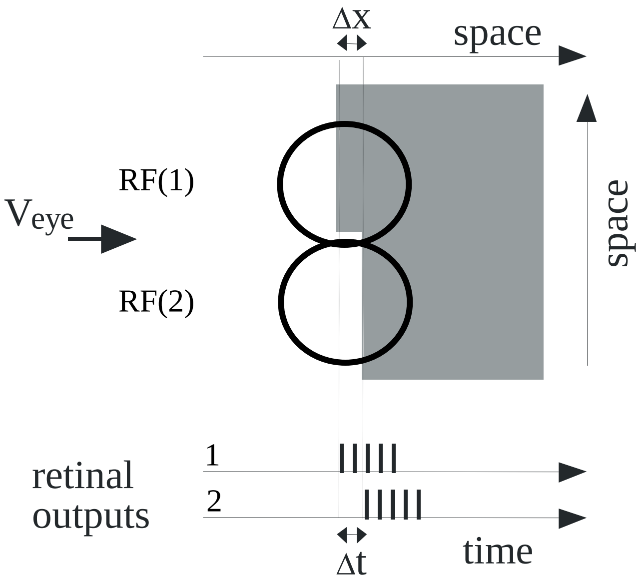
Vision: Temporal encoding due to eye movement



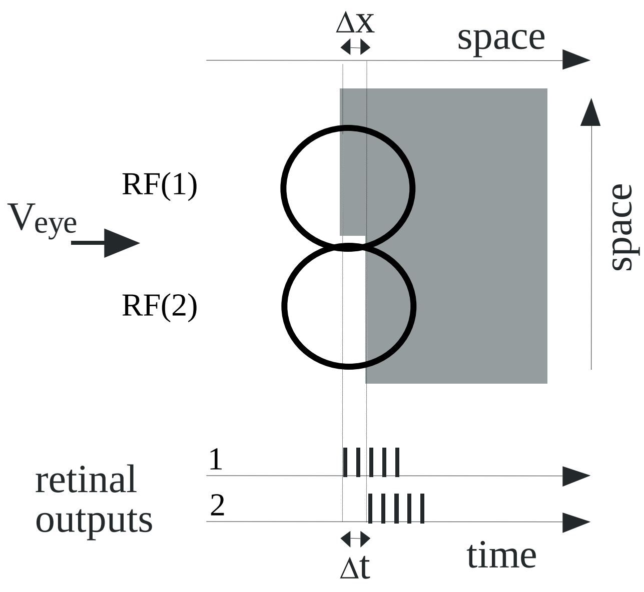
Vision: Temporal encoding due to eye movement



Vision: Temporal encoding due to eye movement



Vision: Temporal encoding due to eye movement



Spatial vs temporal coding

Spatial	**Temporal**
faster	
	better resolution

- scanning allows sensing in between receptors

End of class lecture

Passive vs Active touch

of stationary objects

Touch	Passive	Active
threshold	*low*	*high*
accuracy	*low*	*high*
Systems involved	*sensory*	*Sensory + motor*
coding	*spatial*	*Spatial + temporal*
Processing speed	*fast*	*slow*
Used in	*detection*	*Exploration* *Localization* *Identification* *…*

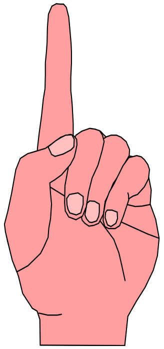
Active modes in other senses

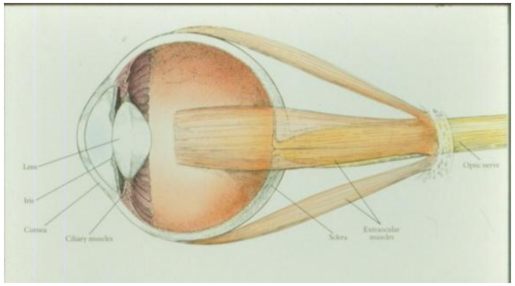
- Seeing
- Touching

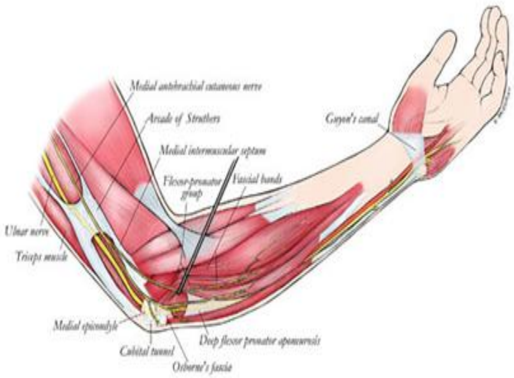
- Sniffing
- Tasting
- Hearing

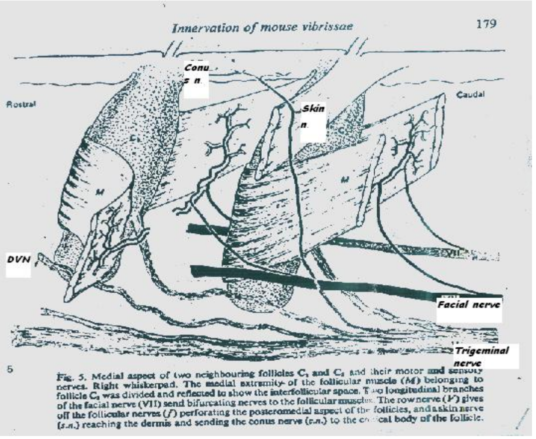
Some similarities between vision and touch sensation

Rich muscular system



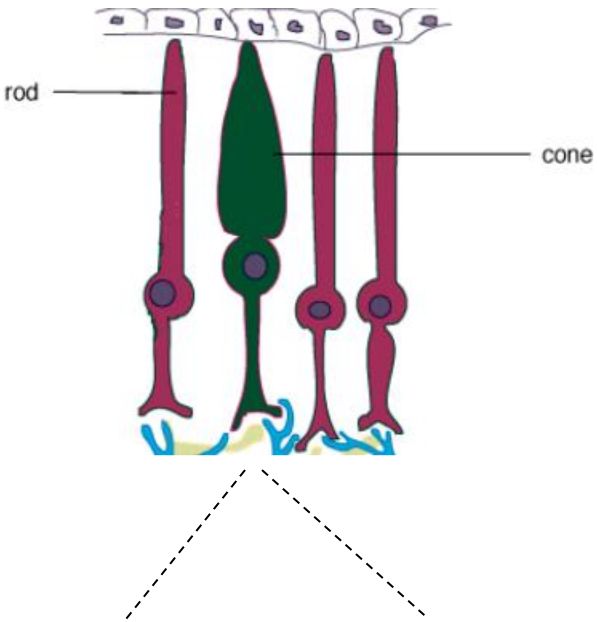






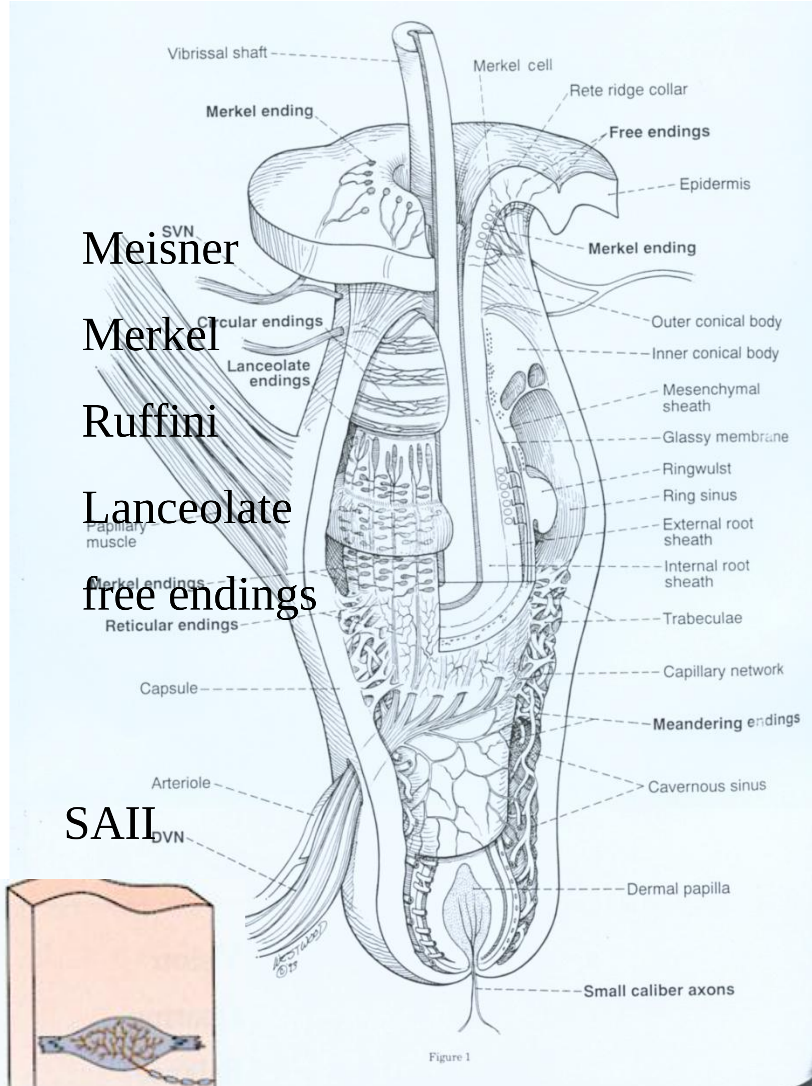
Receptor types

eye



R G B

whisker



Meisner

Merkel

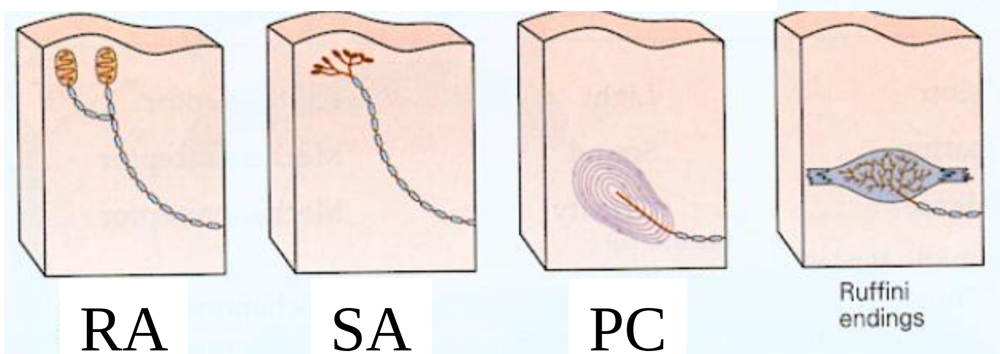
Ruffini

Lanceolate

free endings

finger

RAI SAI RAII SAII

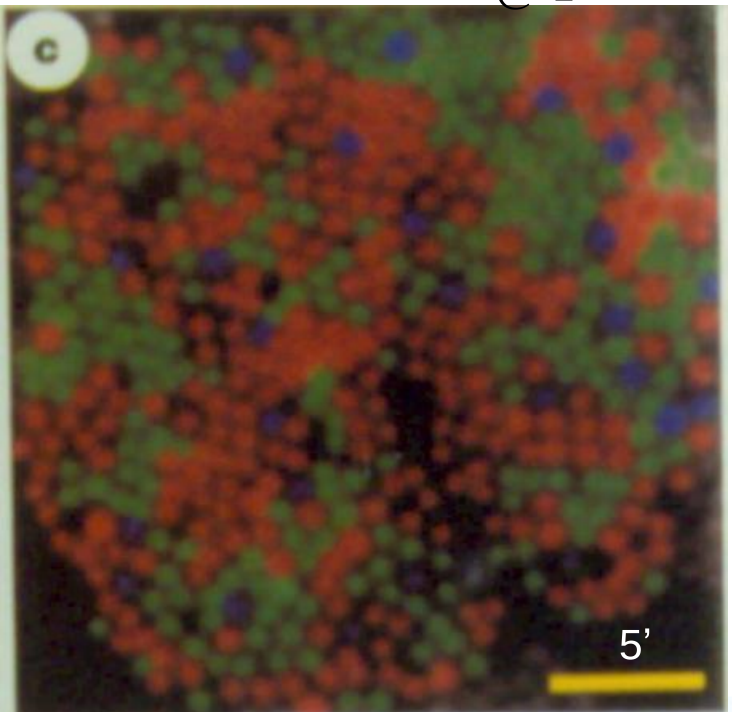


RA SA PC

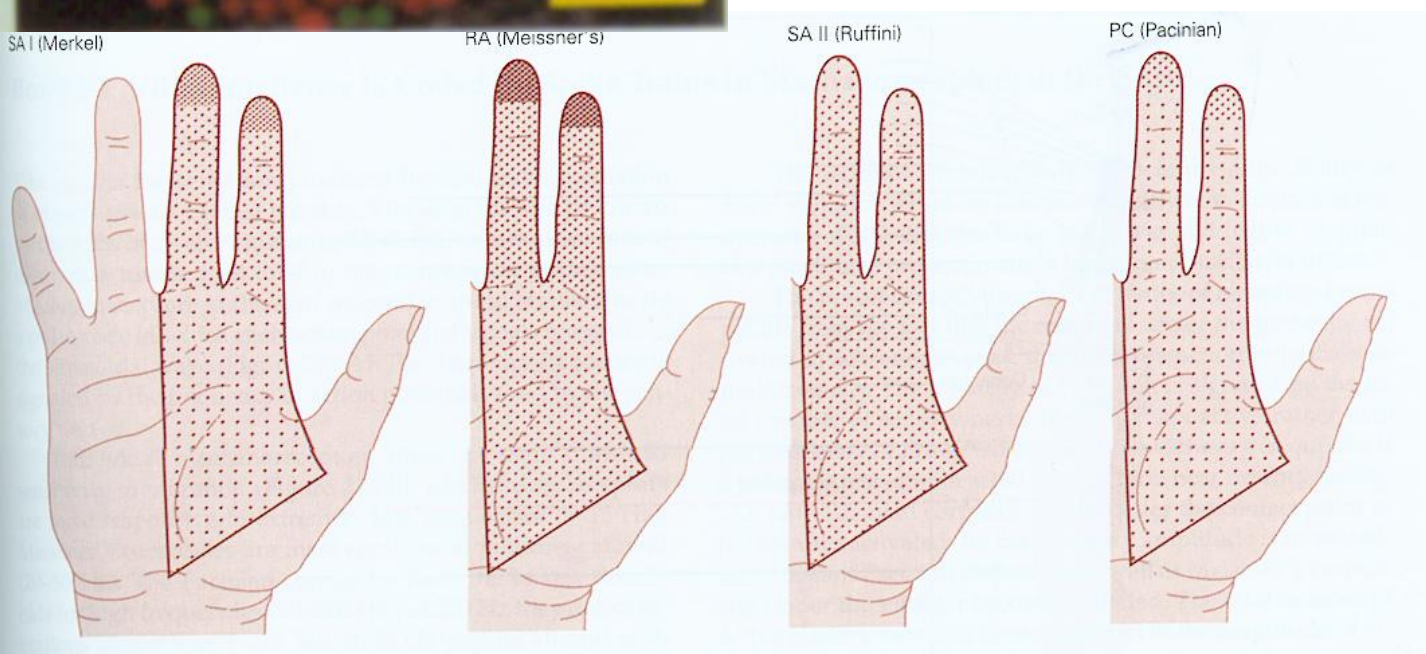
Receptors mix in clusters

eye

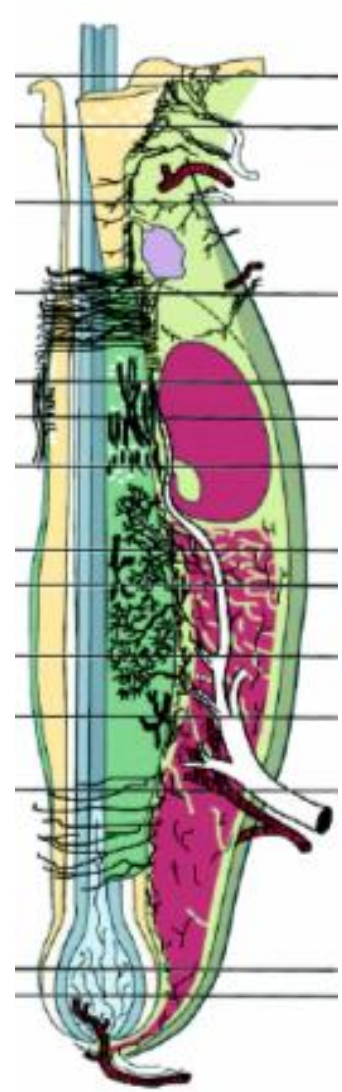
@ 1°



finger



whisker



Receptor convergence / divergence

Human eye: 5M cones (+ 120M rods) --> 1M fibers

Human skin: 2,500 receptors/cm^2 --> 300 fibers / cm^2

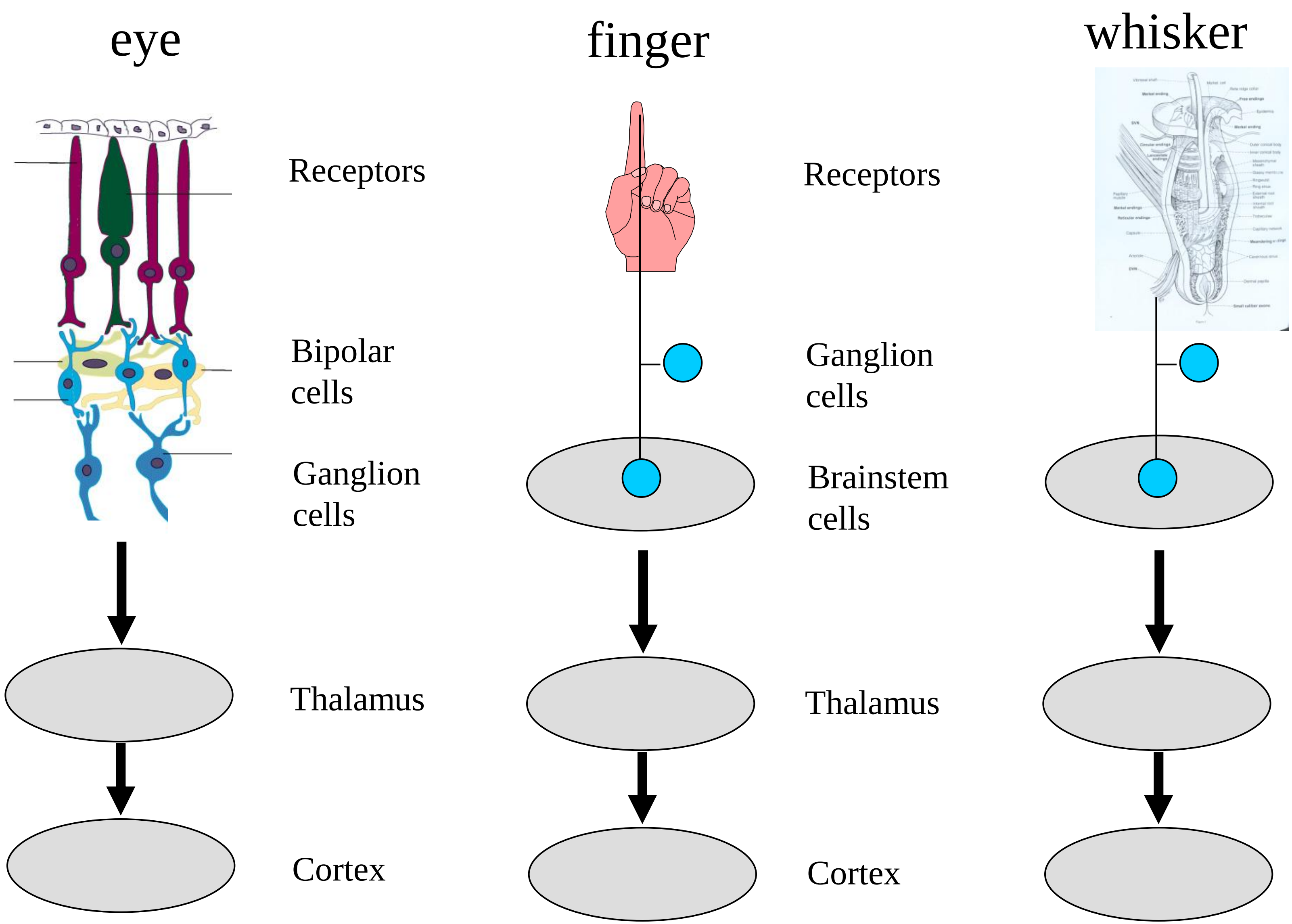
Rat whisker: 2,000 receptors --> 300 fibers

~ 10 -> 1 convergence

Human ear: 3,000 hair cells --> 30,000 fibers

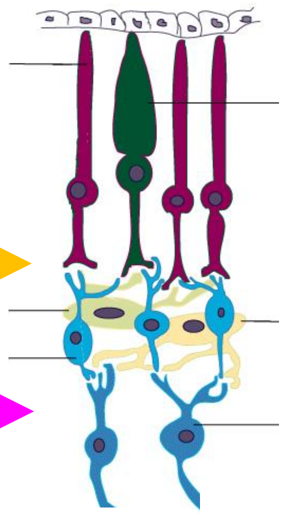
~ 1 -> 10 divergence

Processing stations



Spatial processing (by Lateral inhibition)

eye

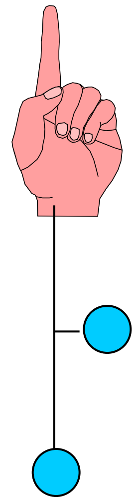


Receptors

Bipolar cells

Ganglion cells

finger



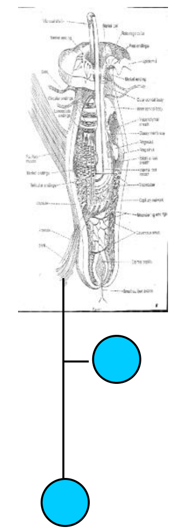
?

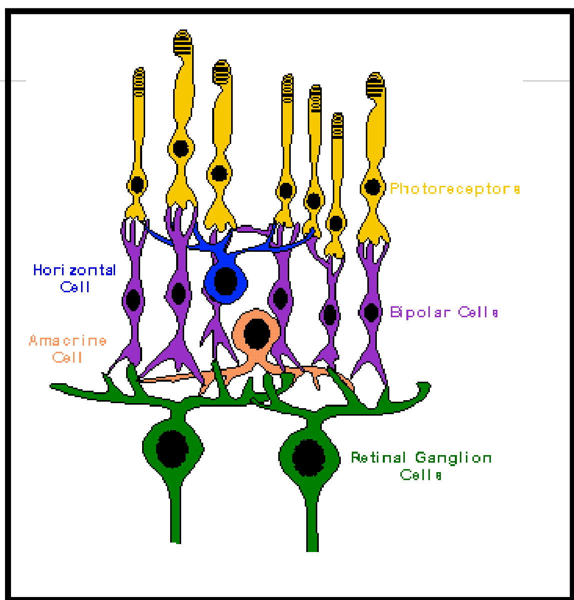
Receptors

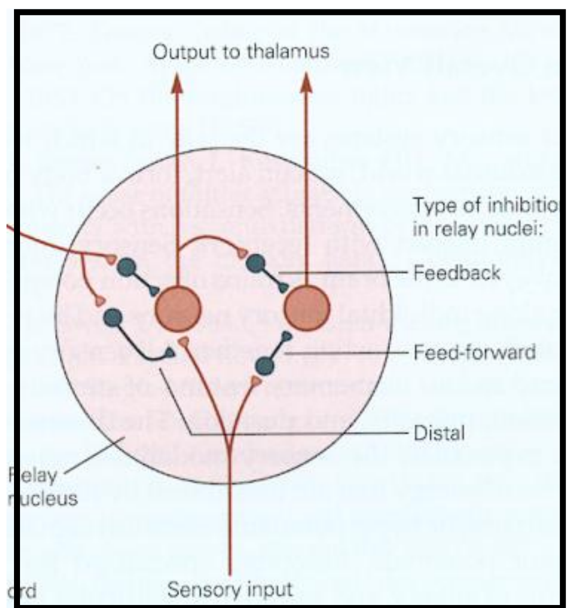
Ganglion cells

Brainstem cells

whisker







Efficient coding

(by coding changes only)

Changes in time:

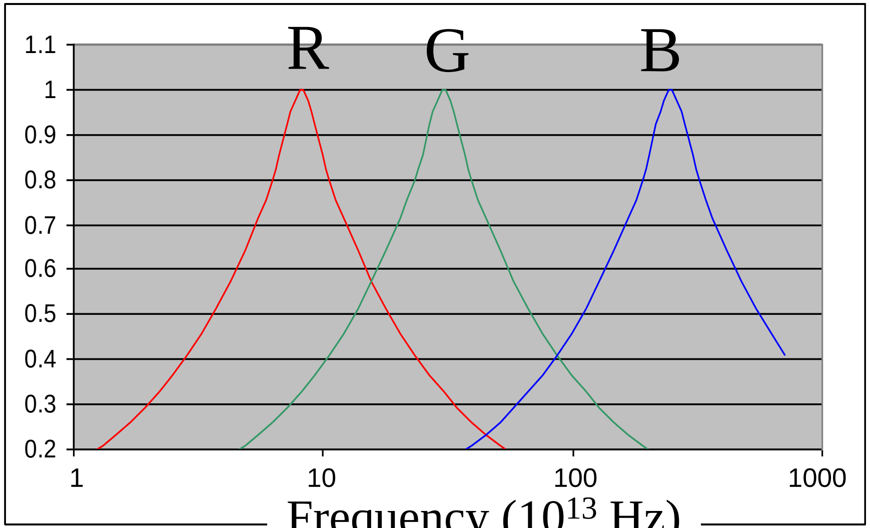
- Intrinsic in individual neurons
- Starting at the receptor level

Changes in space:

- Circuits of neurons
- Starting after lateral inhibition

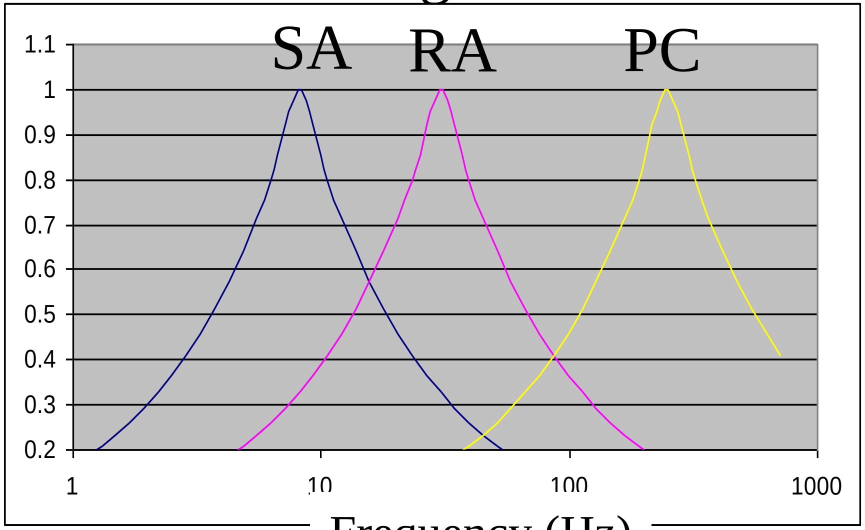
Temporal filtering (by intrinsic factors)

eye



whisker

finger



Some similarities between vision and touch sensation

Spatial Encoding

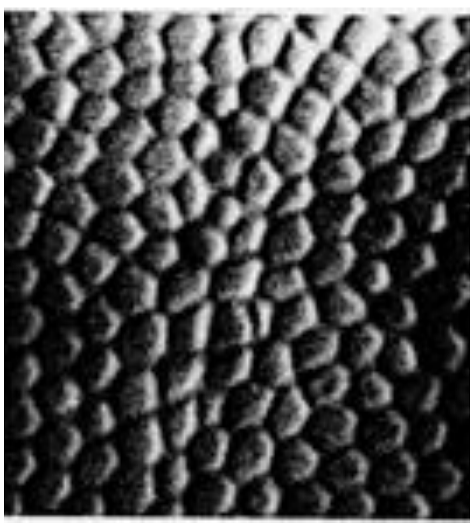
retina – 2D matrix of photorecetors sensitive to light changes

finger tip – 2D array of mechanoreceptors sensitive to skin movement

Whisker pad – 2D array of hairs sensitive to movement

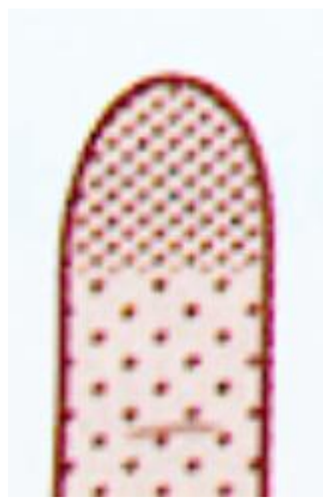
vision

somatosensation



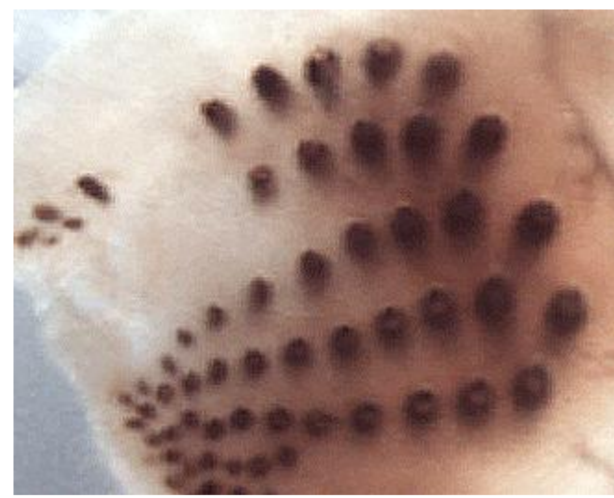
10 µm

retina



~10 mm

Finger pad

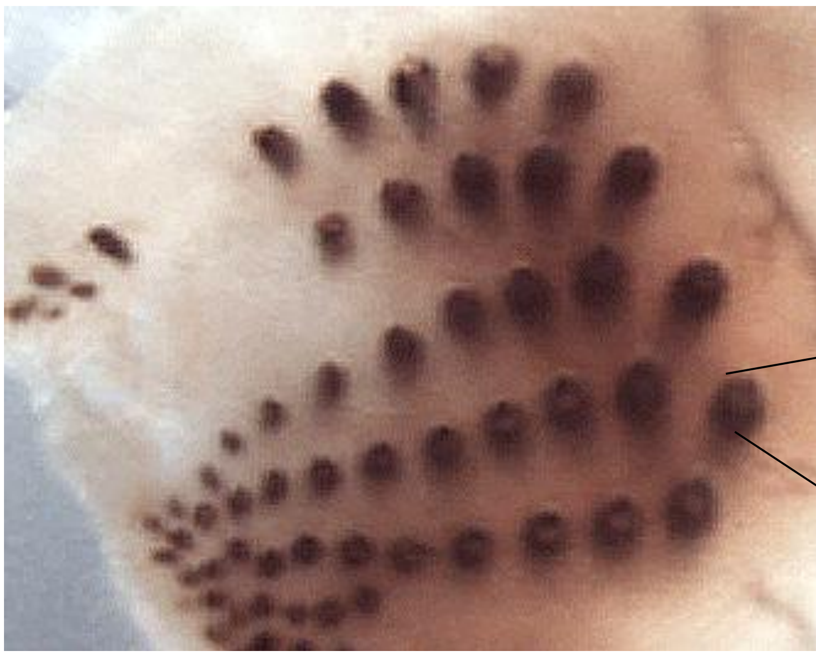


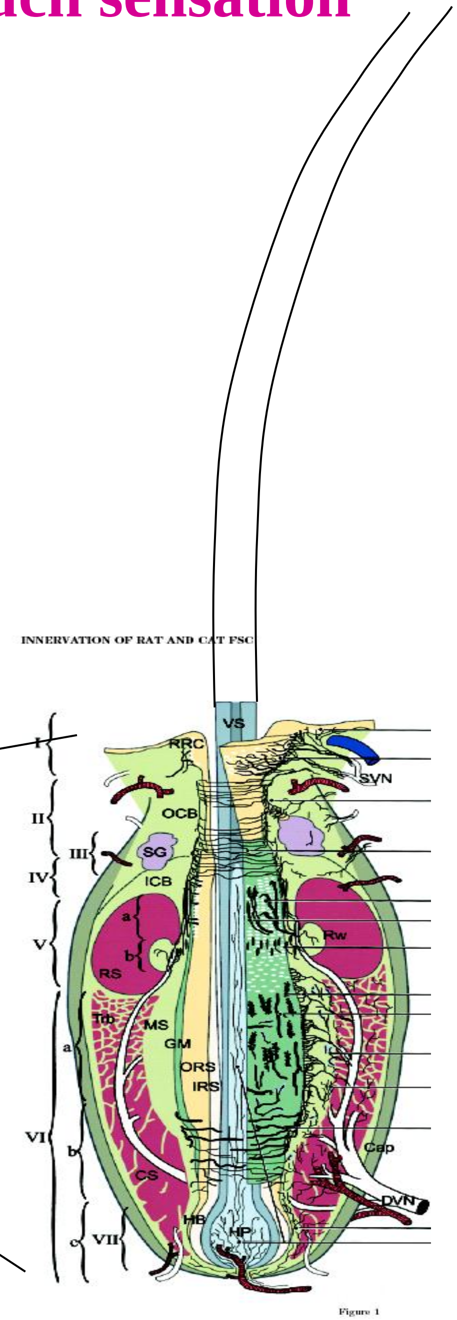
Some similarities between vision and touch sensation

Spatial Encoding

whiskers – 2D array of whiskers

but ...

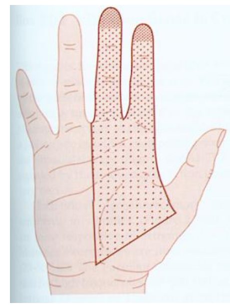




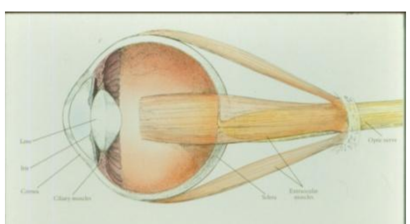
Some similarities between vision and touch sensation

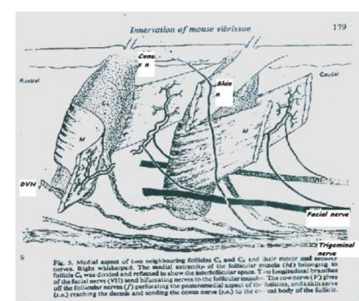
Analogies

Fovea: retinal fovea - finger pad - whisker pad



Sensor motion: an eye - a finger - a whisker





Course outline

#	date	topic	lecturer
1	13.3	sensory systems	ehud
2	20.3	motor principles	ehud
3	27.3	on-going activity	amos
4	3.4	sniffing	noam
5	10.4	proprioception	ehud
6	17.4	echolocation	nachum
	24.4	------ passover	
7	1.5	sensory coding	ehud
8	8.5	closed loops & electrolocation	ehud
9	15.5	whiskolocation	ehud
	22.5	------ lag baomer	
10	29.5	visuolocation	ehud
11	5.6	Active info	tali
12	12.6	active learning	goren
13	19.6	summary	ehud