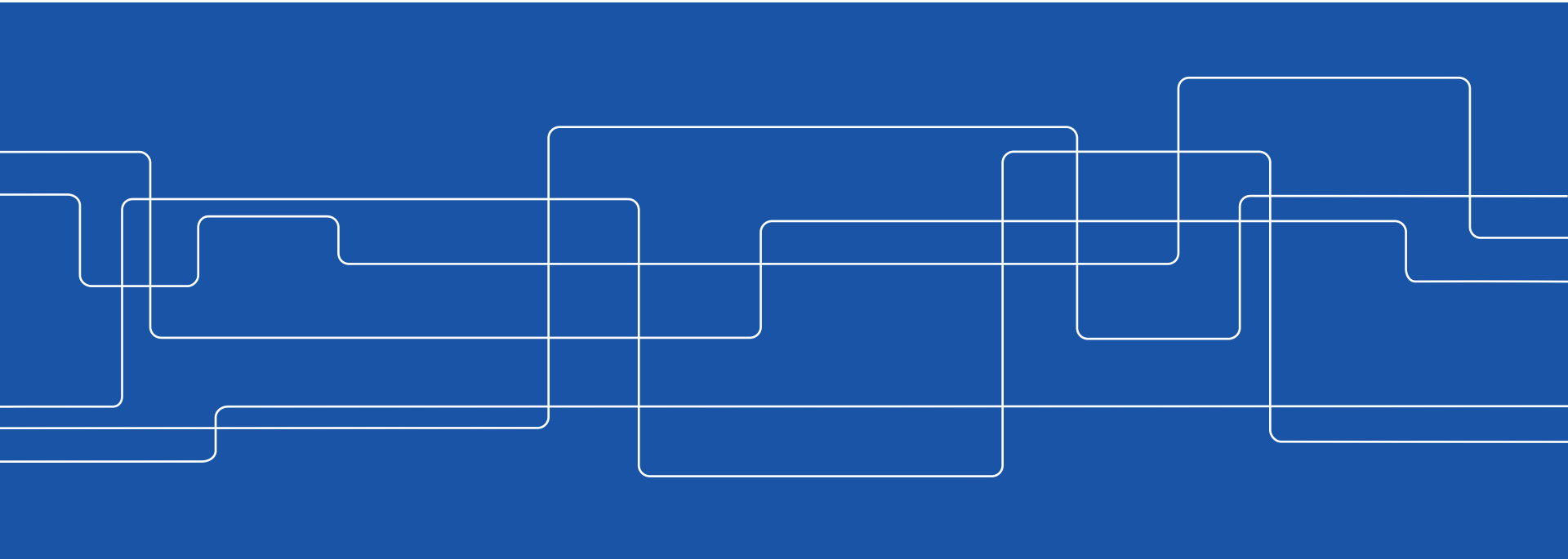
Introduction to the physiology of perception

DT2350 Human Perception for Information Technology

Pawel Herman, *paherman AT kth.se*

CST/CSC, LV 5, room 4442

HT2016



What is perception?

- The interpretation of sensory information (Hayes & Orrell, 1987)
- A dynamic search for the best interpretation of available data (Gregory, 1966)
- Perception is “the process of assembling sensations into a usable mental representation of the world” (Coon, 1983)
- The processes by which stimuli are selected, organised and interpreted (Solomon, 2006)

What is perception?

- The interpretation of sensory information (Hayes & Orrell, 1987)
- A dyn… e data (Gregor…
- Perce… a usable mental…
- The p… and interpreted (Solomon, 2006)

Perception is not a simple passive registration of sensory input, it is a process where we actively select, order and interpret information in order to understand and interact with the environment.

Sensation and perception

Sensation

- Detection of a signal in the environment through out senses
- Biochemical and neurological responses to external stimuli
- *e.g.* sensation in hearing: waves of pulsating air collected by the outer ear and transmitted through the bones of the middle ear to the cochlear nerve

Perception

- The organization, identification, and interpretation in order to represent, understand and interact with our environment
- Where is the object, what is it, is it moving, how does it affect me?

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How do physical processes get transformed to rich perceptual experiences?

Perceptual process – from stimulus to behaviour

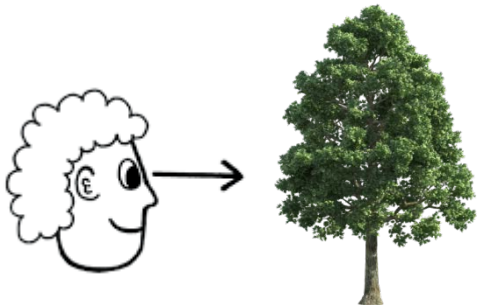
STIMULUS → *ACTION / BEHAVIOUR / RESPONSE*

Perceptual process – from stimulus to behaviour

STIMULUS → ACTION / BEHAVIOUR / RESPONSE

smile and pick another flower

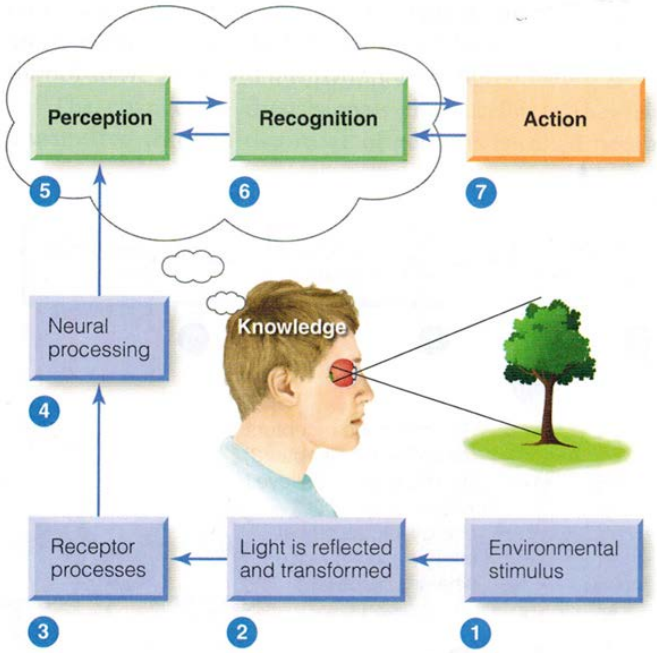
approach a tree



withdraw a foot

Perceptual process - overview

behavioural components



transduction

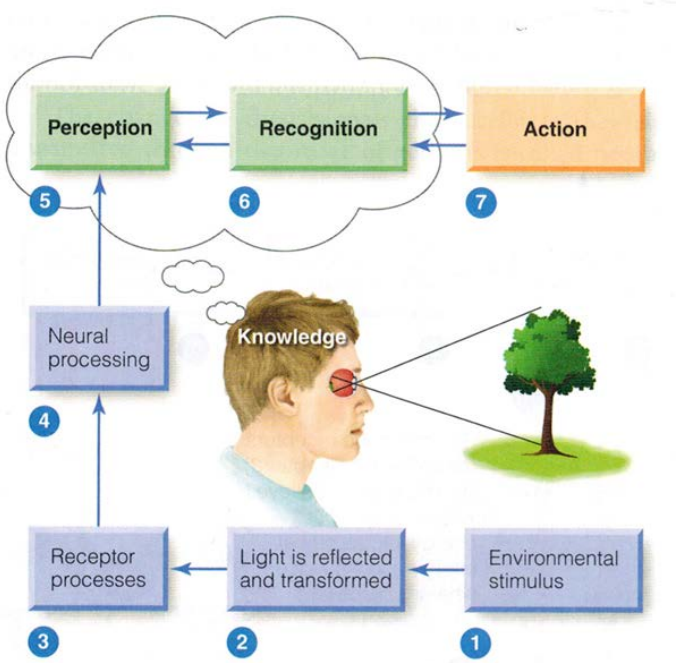
first stages of transformation

Perceptual process - overview

behavioural components

Perception vs recognition

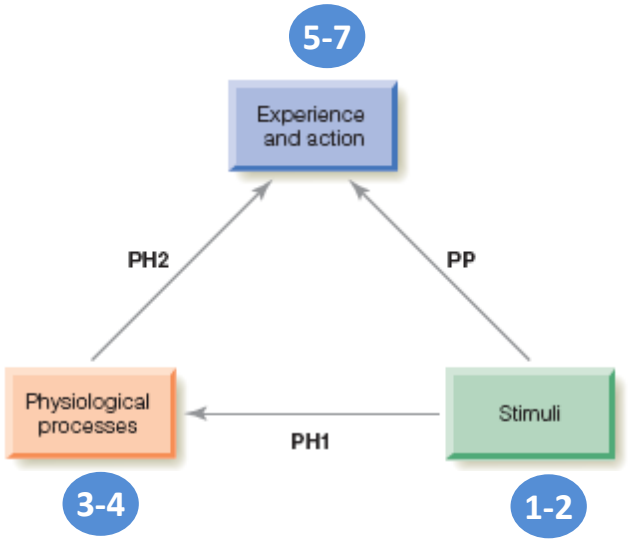
- conscious awareness of a stimulus
- stimulus identification, categorisation

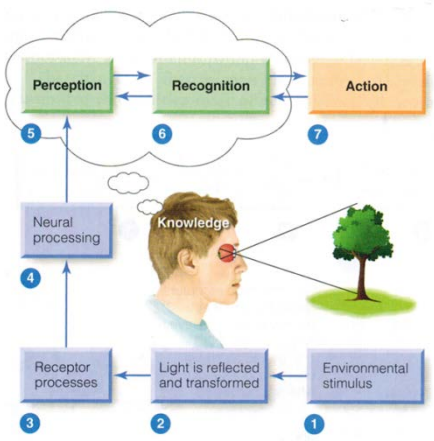


transduction

first stages of transformation

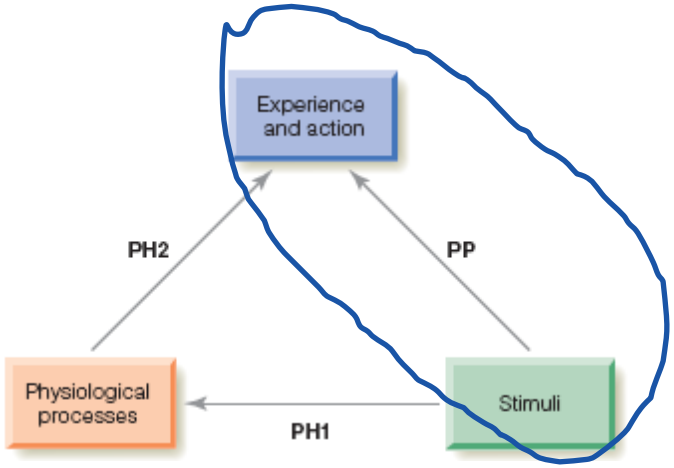
Methodological approaches to perception

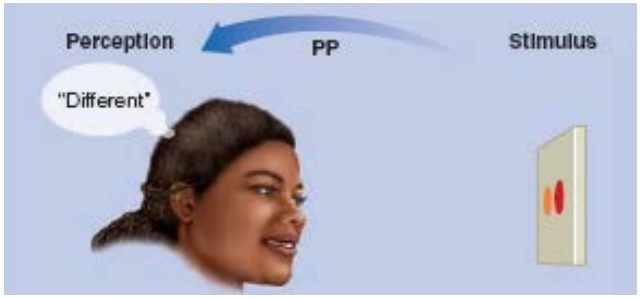




physiological (PH) vs *psychophysical* (PP)

Methodological approaches to perception





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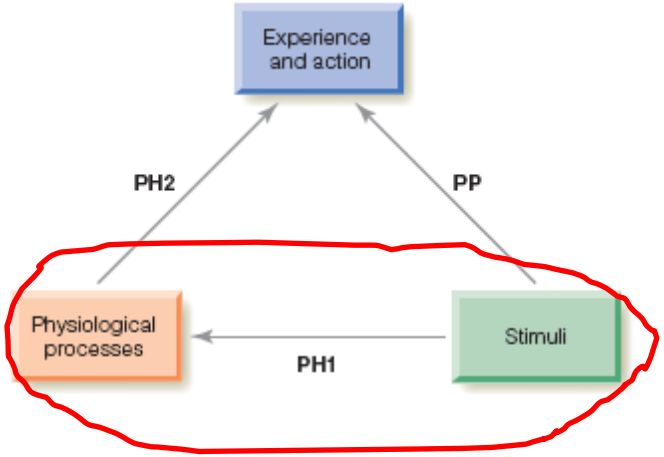

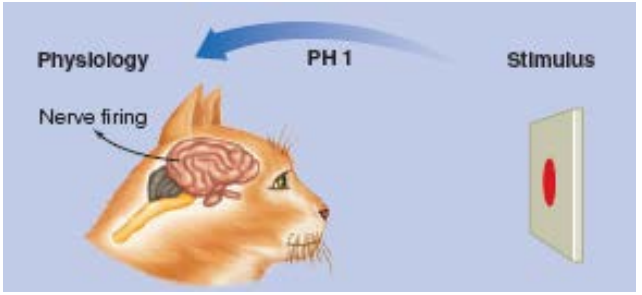

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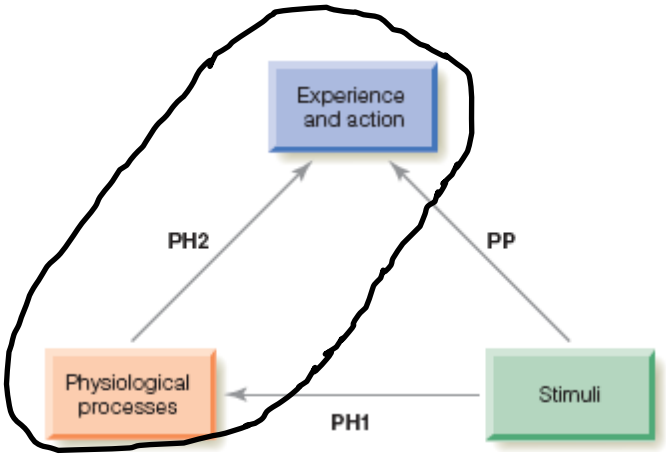
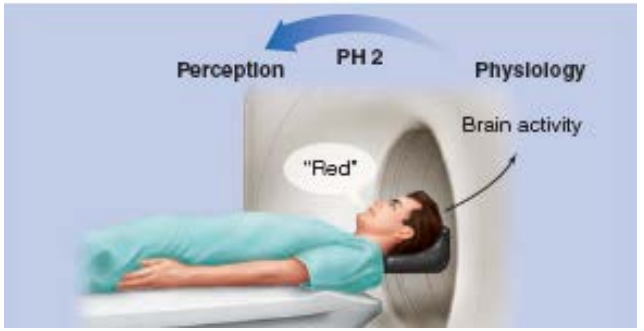
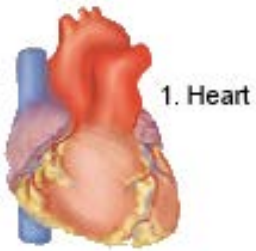




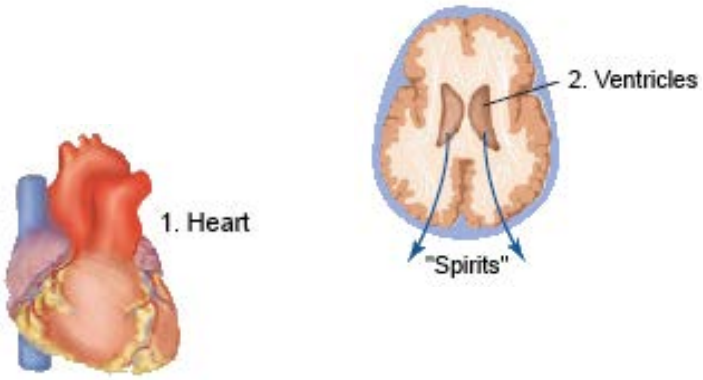
Physiological approach – historical aspects



Mind and soul in the heart
Aristotle, 4th century BC

Physiological approach – historical aspects

Thoughts and emotions
determined by ”spirits”
flowing from the ventricles
Galen, 2nd century



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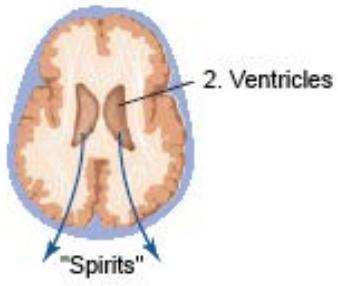
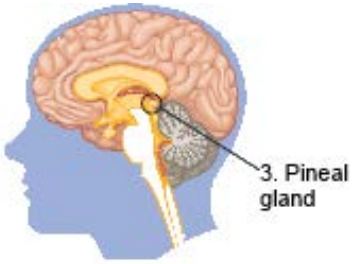
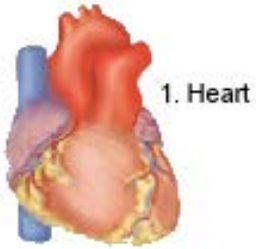




Pineal gland as the seat of soul
Descartes, 1630s



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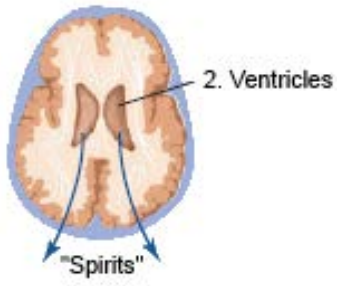

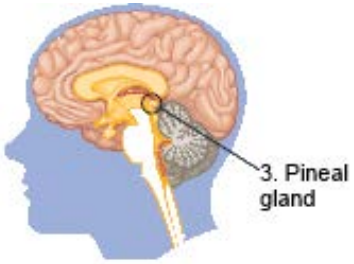

Pineal gland as the seat of soul
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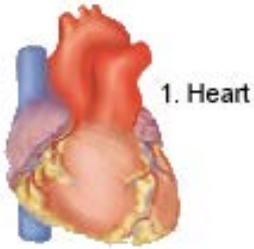
Different functions in different regions of the brain
Willis, 1664



Mind and soul in the heart
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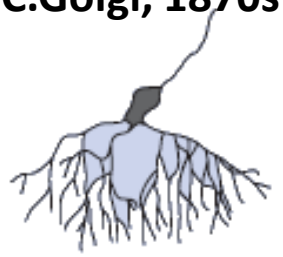
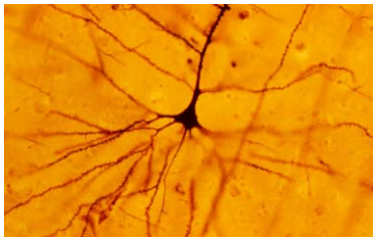
Physiological approach – historical aspects

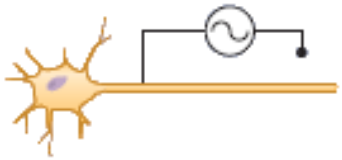
Staining to resolve the structure of the nervous system
C.Golgi, 1870s (Nobel prize in 1906)



5. Golgi stained neuron



Physiological approach – historical aspects



6. Single neuron recording

Staining to resolve the structure of the nervous system
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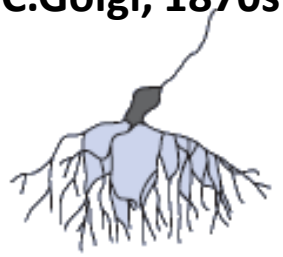

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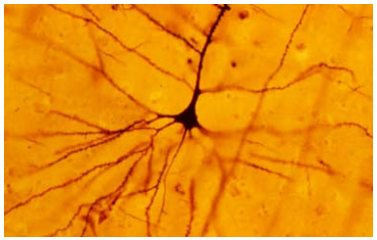
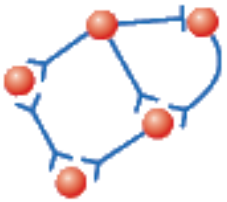


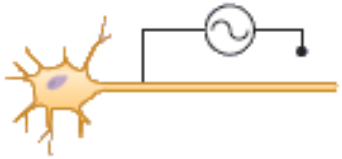
Electrophys recordings from neurons
E. Adrian, 1920s (Nobel prize in 1932)

Physiological approach – historical aspects

Network approach,
multi-unit recordings



7. Neural networks



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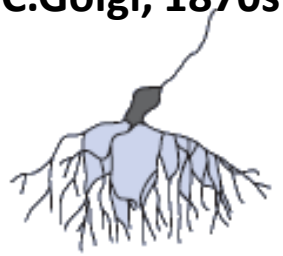

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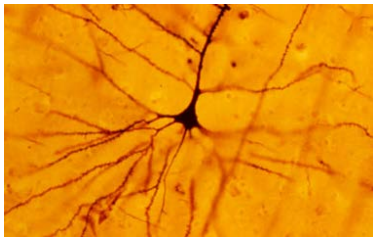

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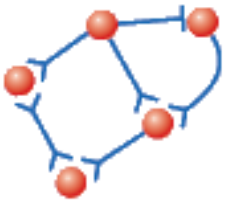
Physiological approach – historical aspects

How can electrical signals in the nervous system represent objecs in the environment?

Network approach, multi-unit recordings



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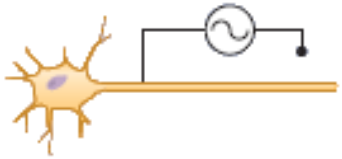

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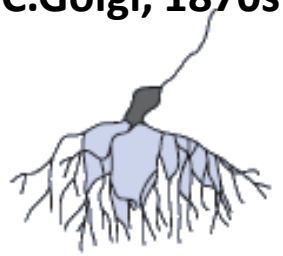

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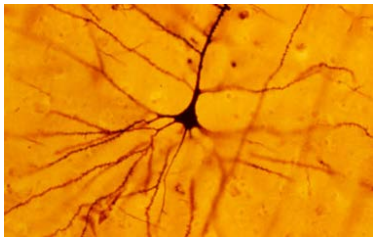

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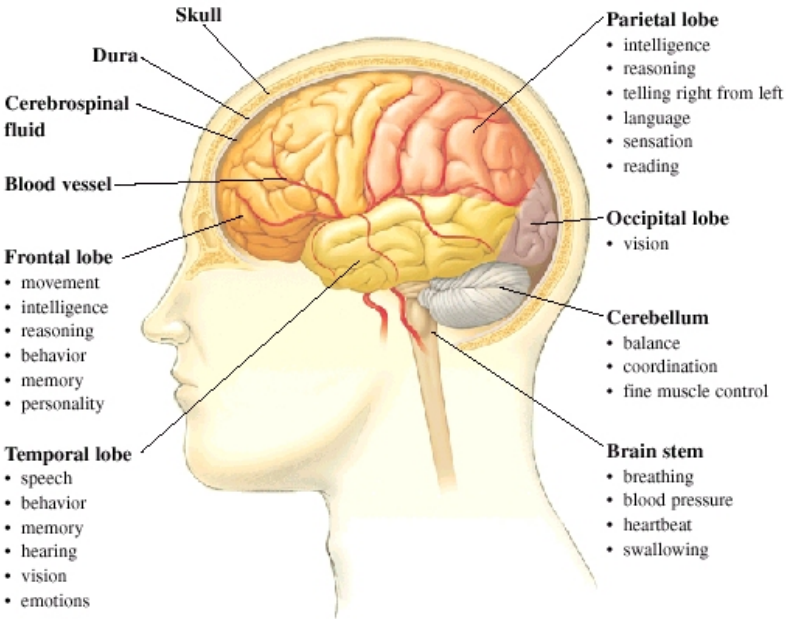
”The Brain – The Mind’s Computer”



- modular and hierarchical organization
- senses organized into primary receiving areas
- key role of cerebral cortex in perception

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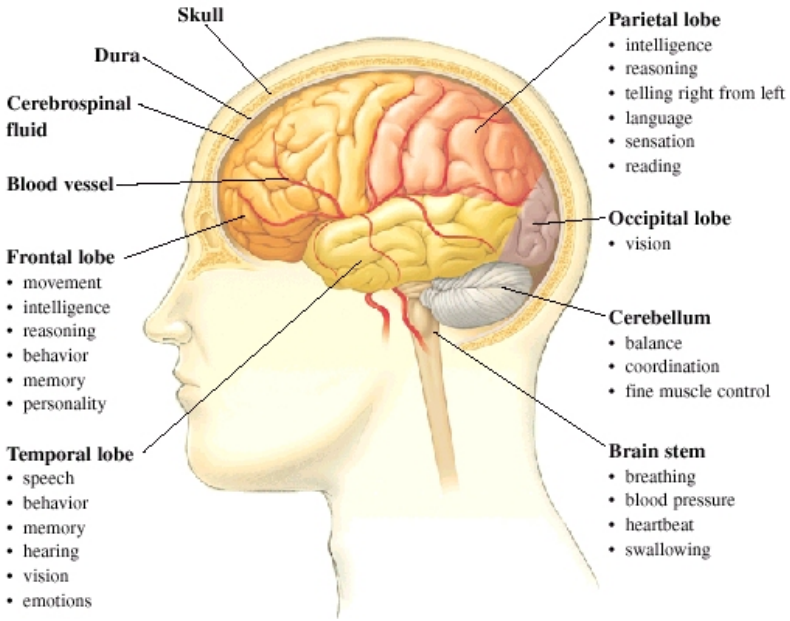

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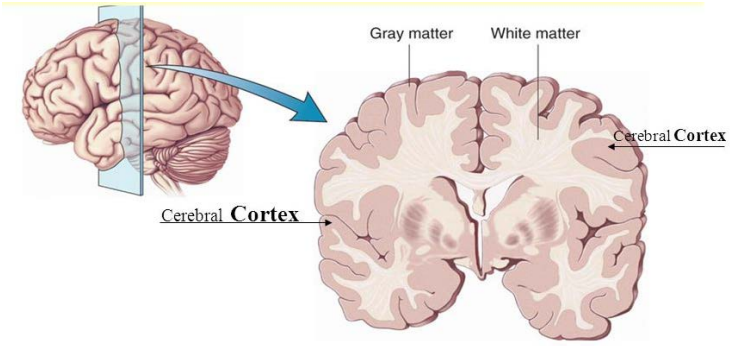
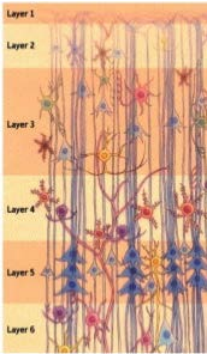
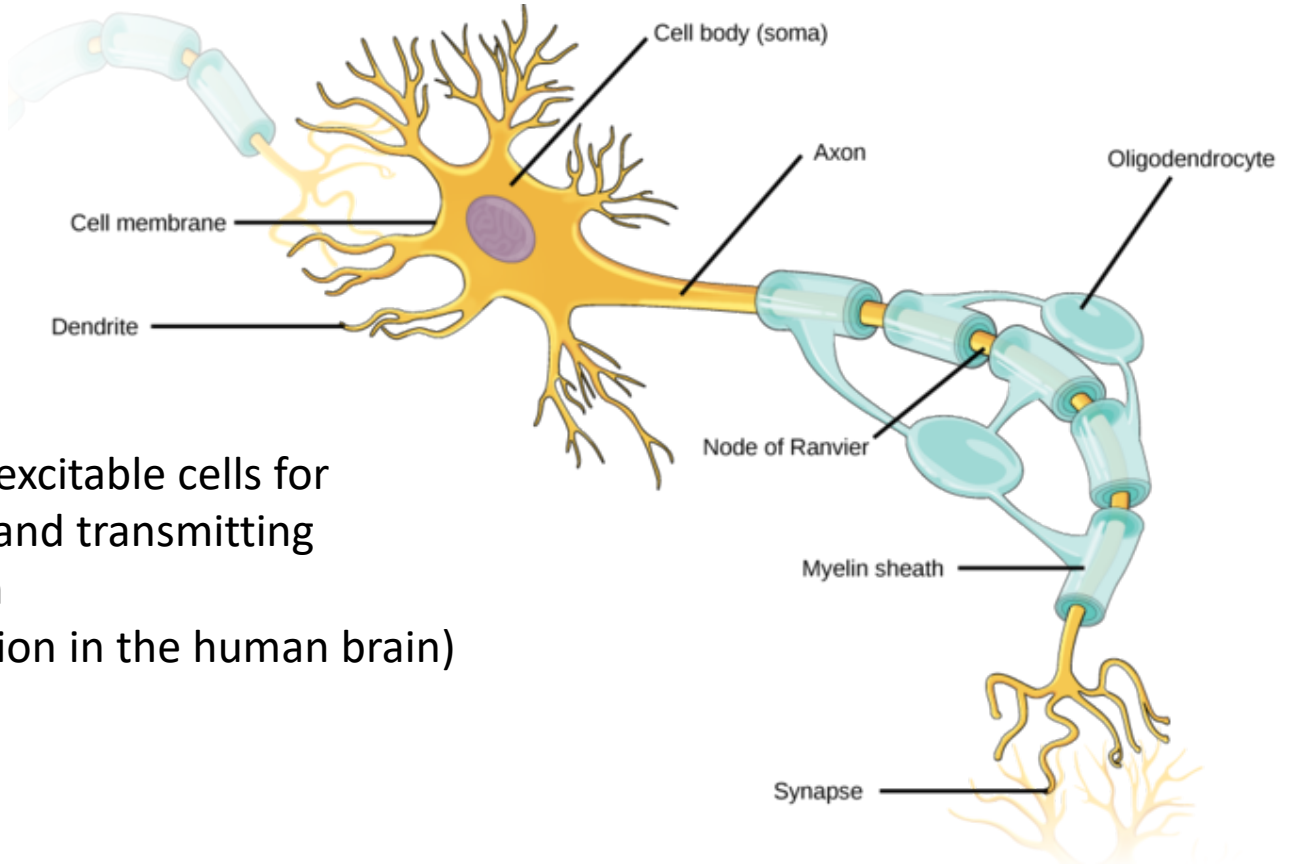


layered structure, 2-3 mm thick

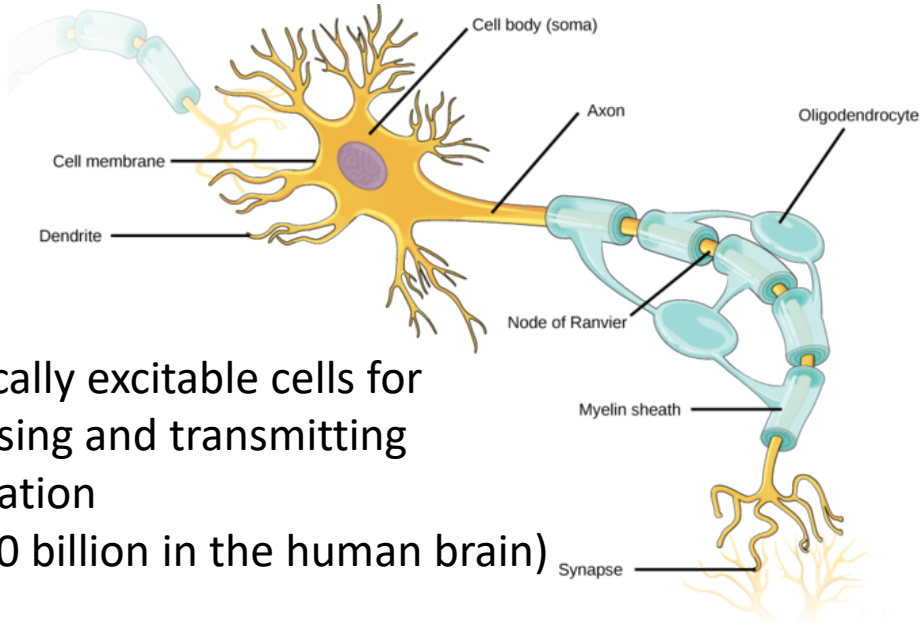


Neurons (nerve cells) as building blocks of the nervous system



electrically excitable cells for processing and transmitting information
(ca. 100 billion in the human brain)

Neurons (nerve cells) as building blocks of the nervous system



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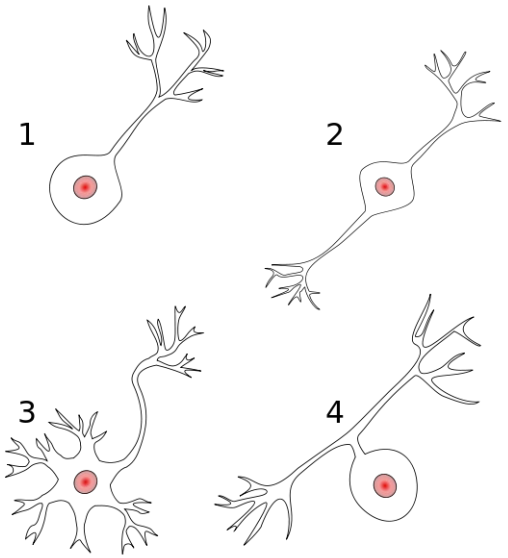
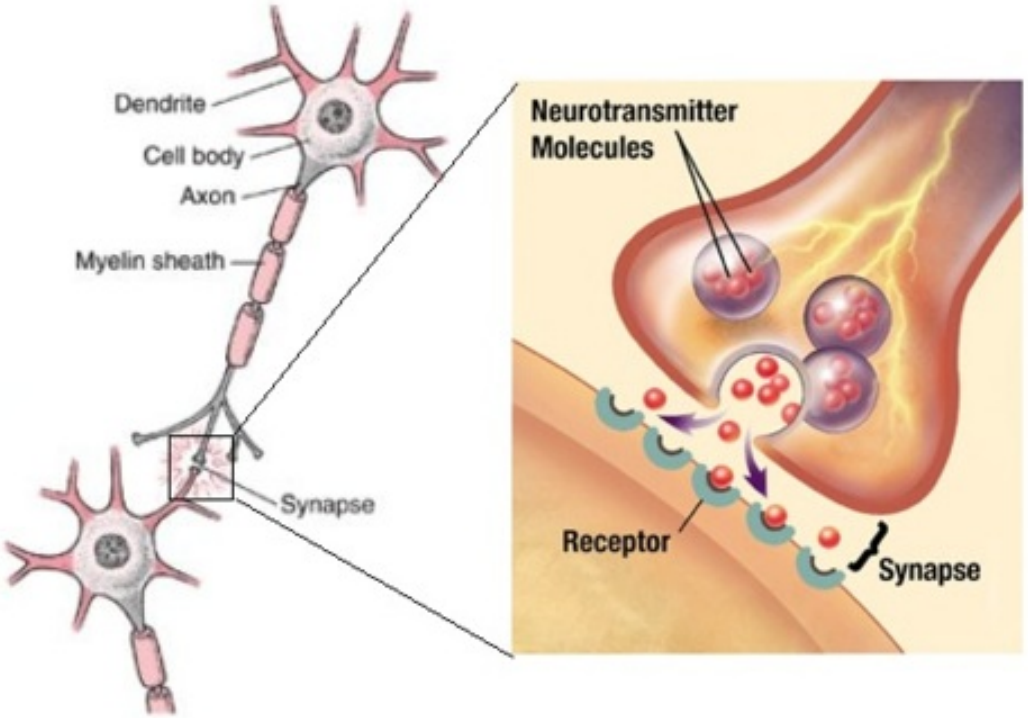
Multitude of neuron types in the brain



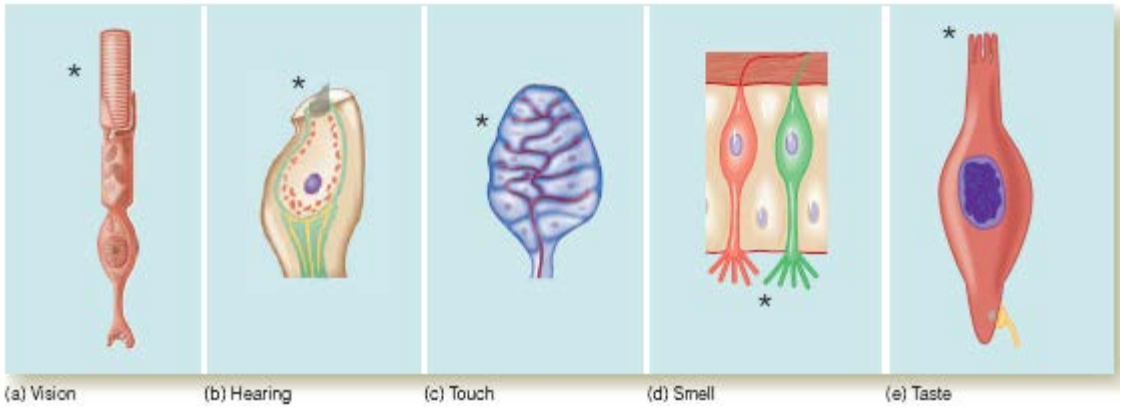
Synaptic communication



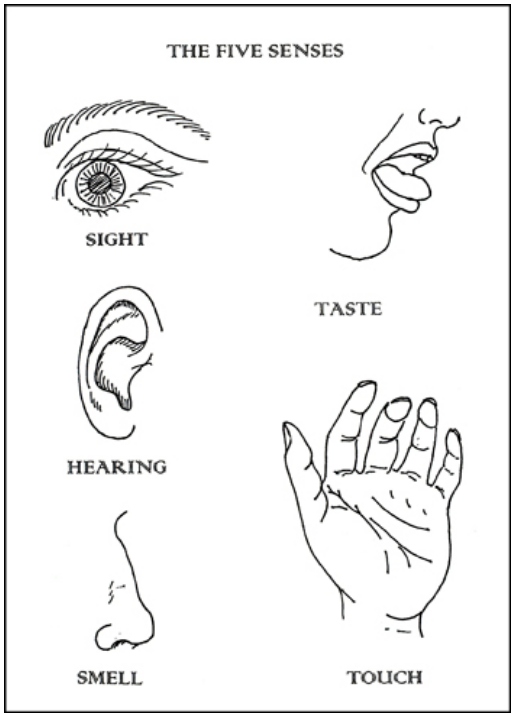
communication via chemical and electrical synapses
(ca. 100 trillion in the human brain)

Neural receptors – transduction devices

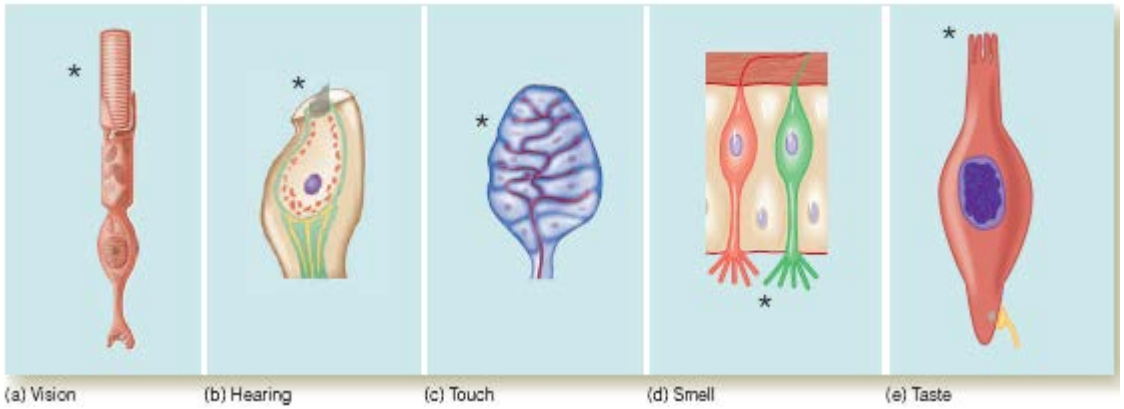
Cells that interface the nervous system with the external environment

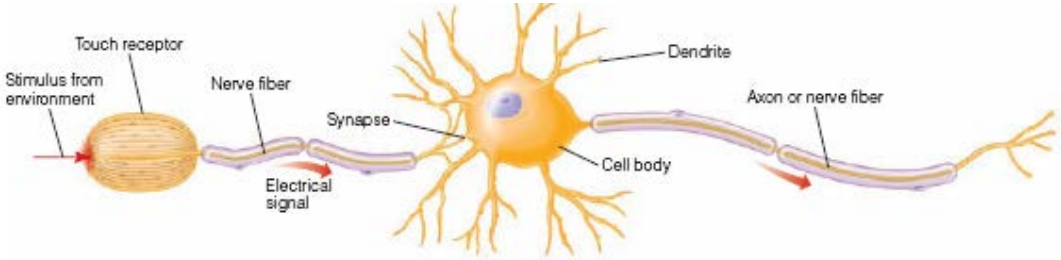


environmental stimulus → electrical signal



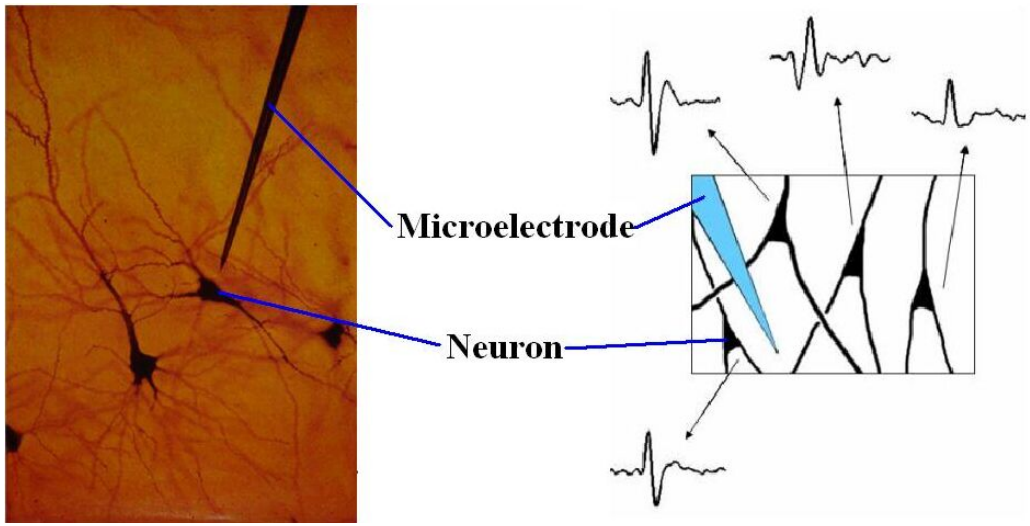
Neural receptors and sensory input transmission

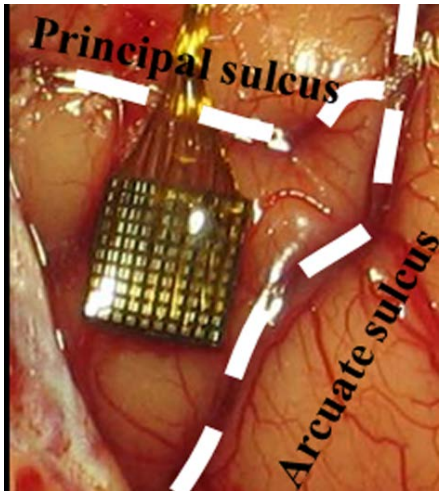




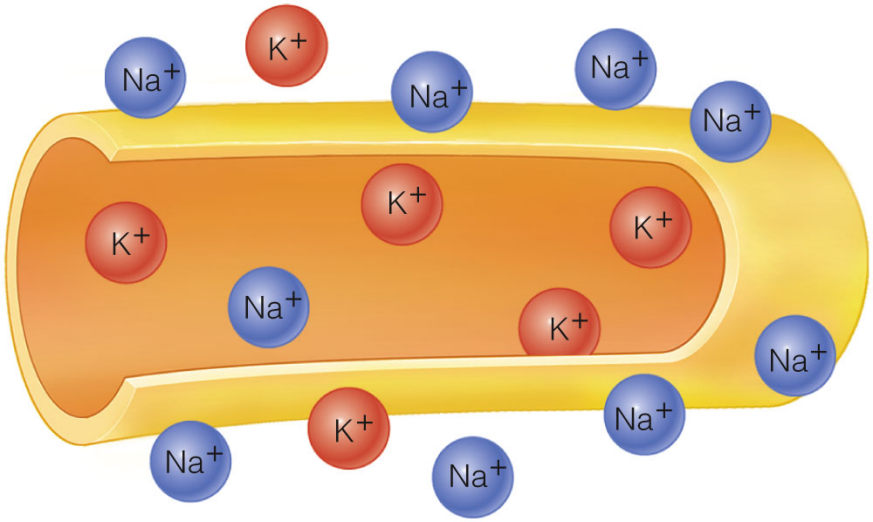
Transduction and transmission of neural information (electrical signals) for further processing & communication

Recordings of neural electrical activity

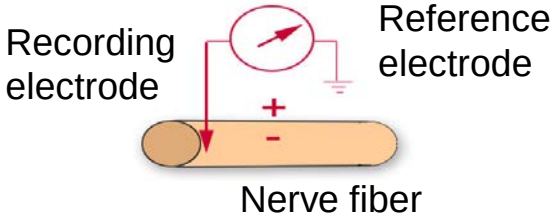




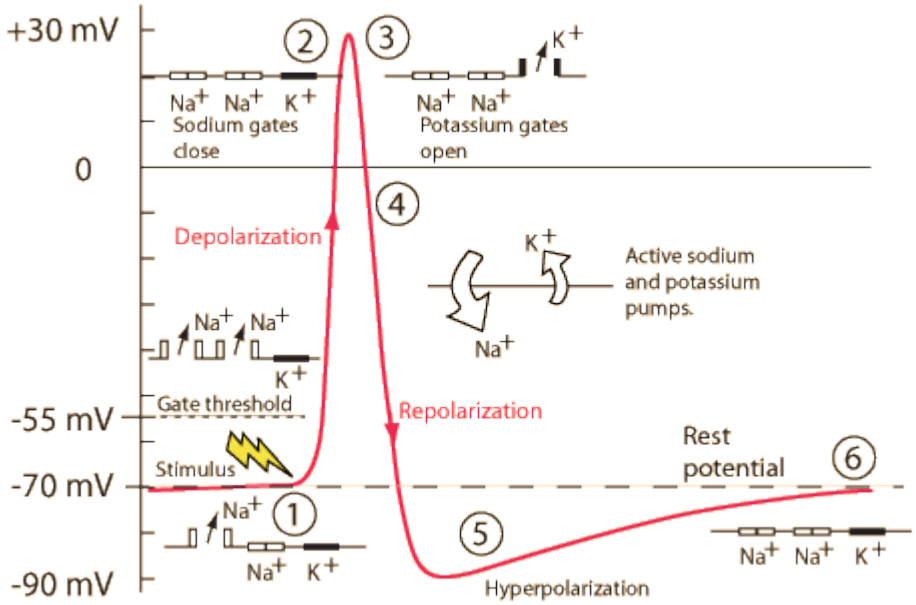
Chemical basis of neurons and spikes

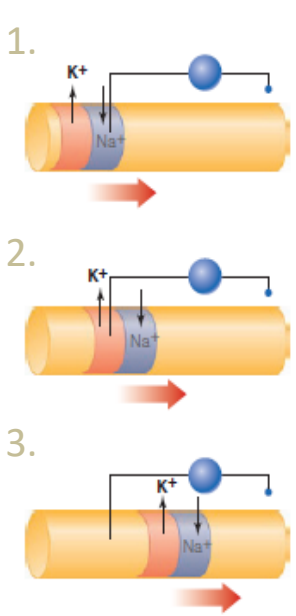


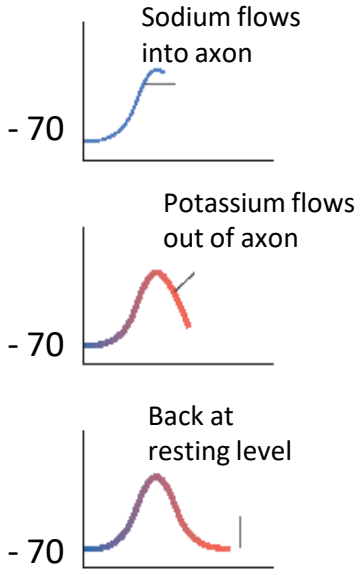
- ions carrying electrical charges as key element sof neuron's liquid environment
- ions flow through the membrane causing depolarization or hyperpolarization
- key role of ion pumps
- passive vs active transmission of action potentials



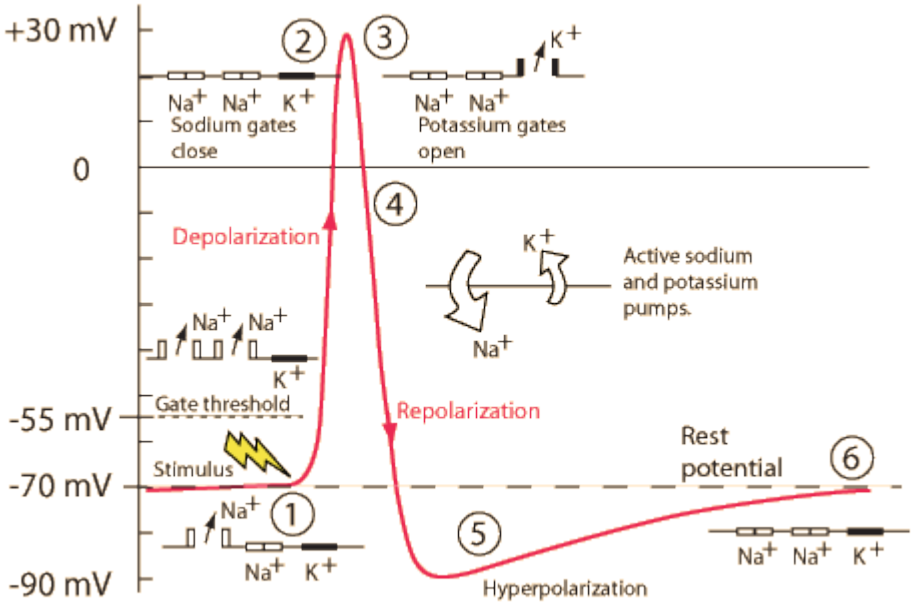
Action potentials – spike generation

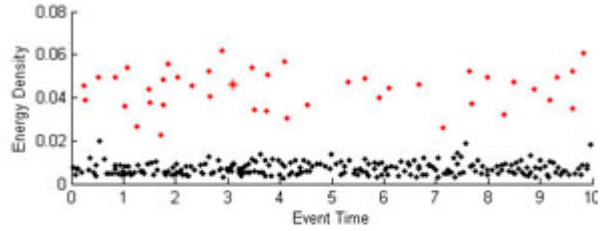


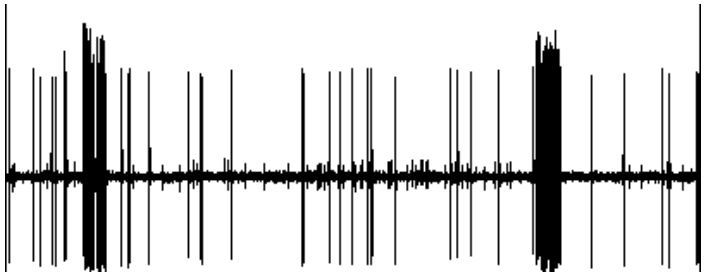




Action potentials – spike generation



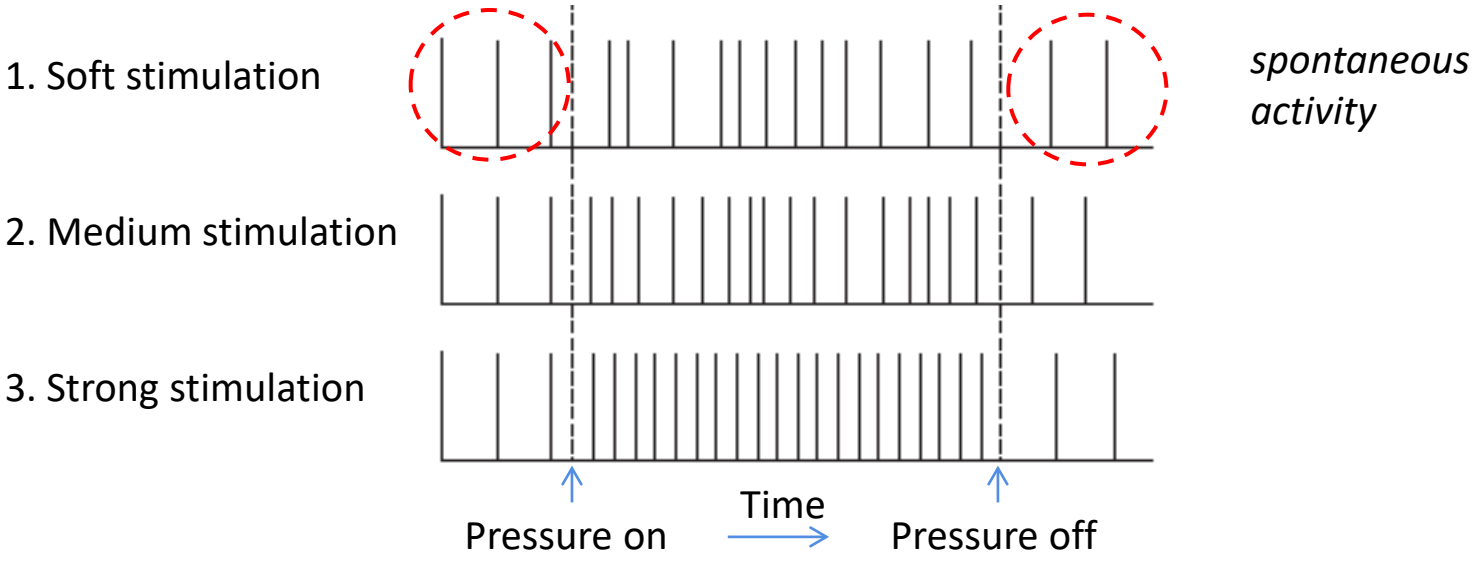




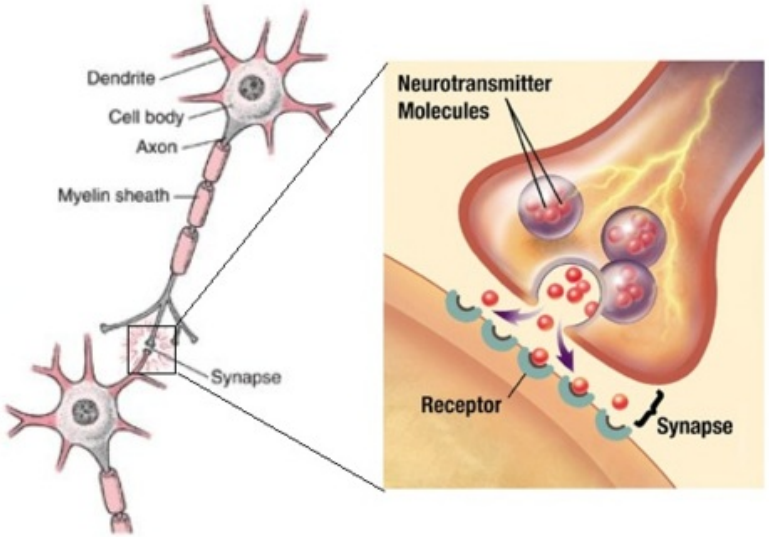
Action potentials: spike-based communication

Propagated response

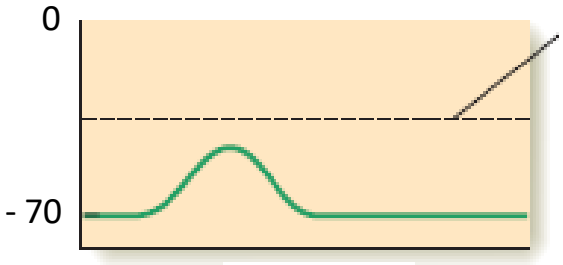
- Action potential travels long distances without decreasing in size
- The intensity of the stimulus does not affect the *size* of the action potentials, only the *rate* of firing.



Spike propagation, synaptic communication

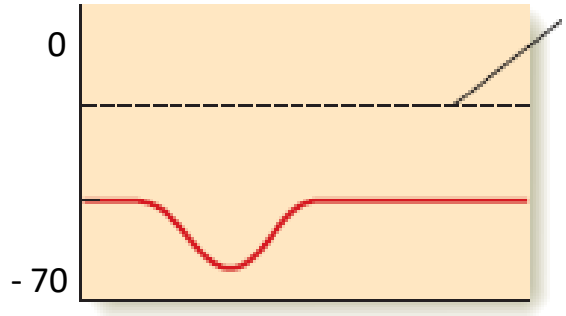


http://www.youtube.com/watch?v=HXx9qlJetSU



Level of depolarization needed to trigger an action potential

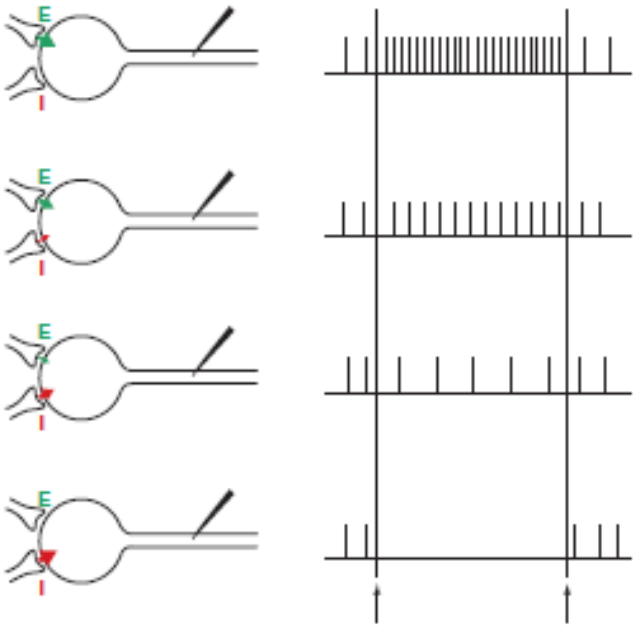
Depolarization
(Excitatory)

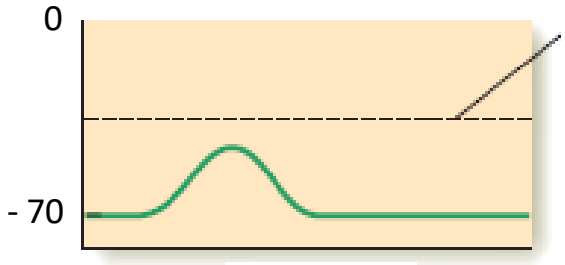


Level needed to trigger an action potential

Hyperpolarization
(Inhibitory)

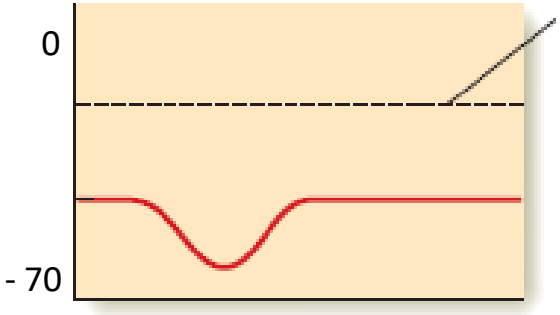
Spike propagation, synaptic communication





Level of depolarization needed to trigger an action potential

Depolarization
(Excitatory)

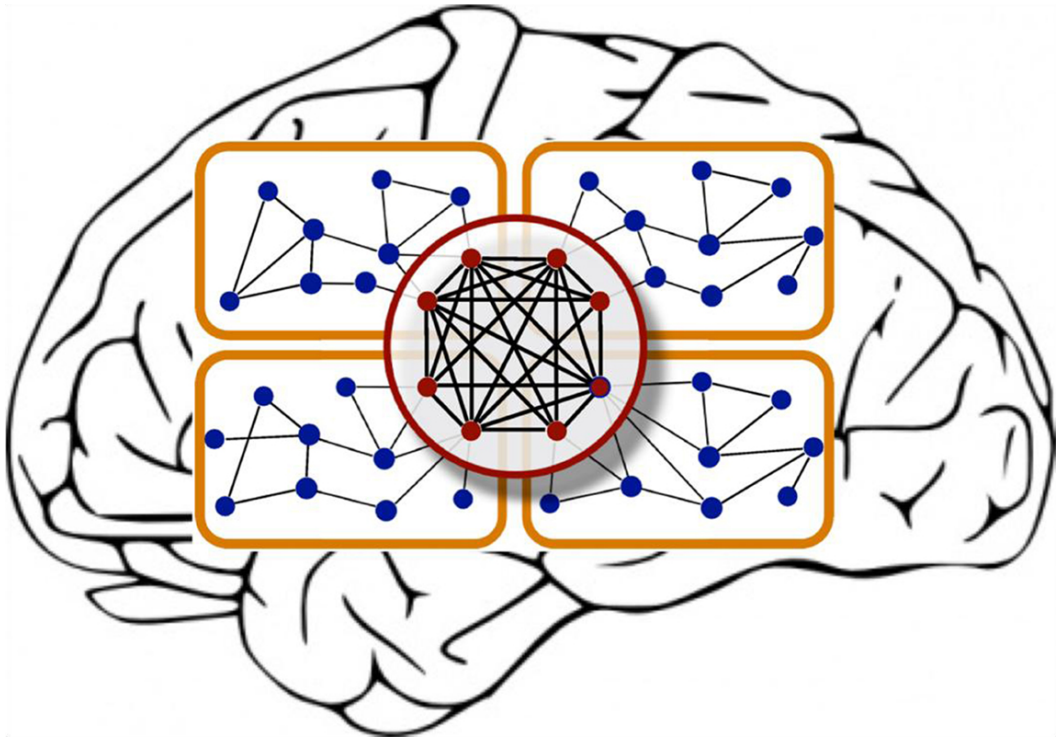


Level needed to trigger an action potential

Hyperpolarization
(Inhibitory)

Neural circuits for processing neural information

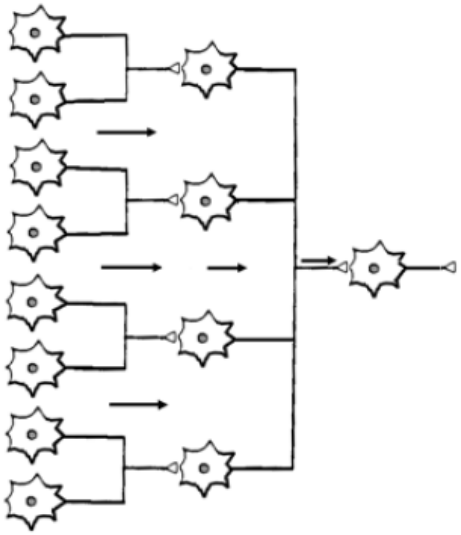
Network perspective



Fundamental principles of connectivity

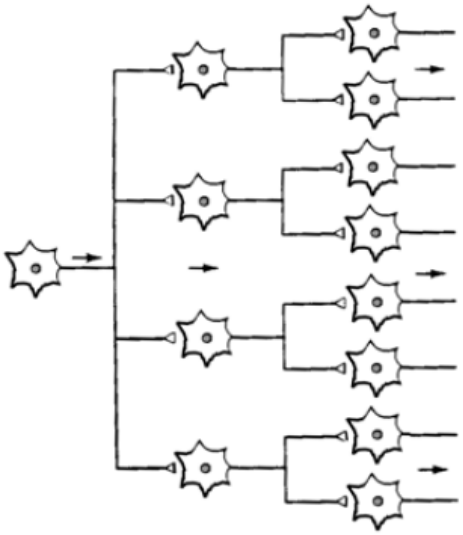
Convergence

Output from many neurons onto one

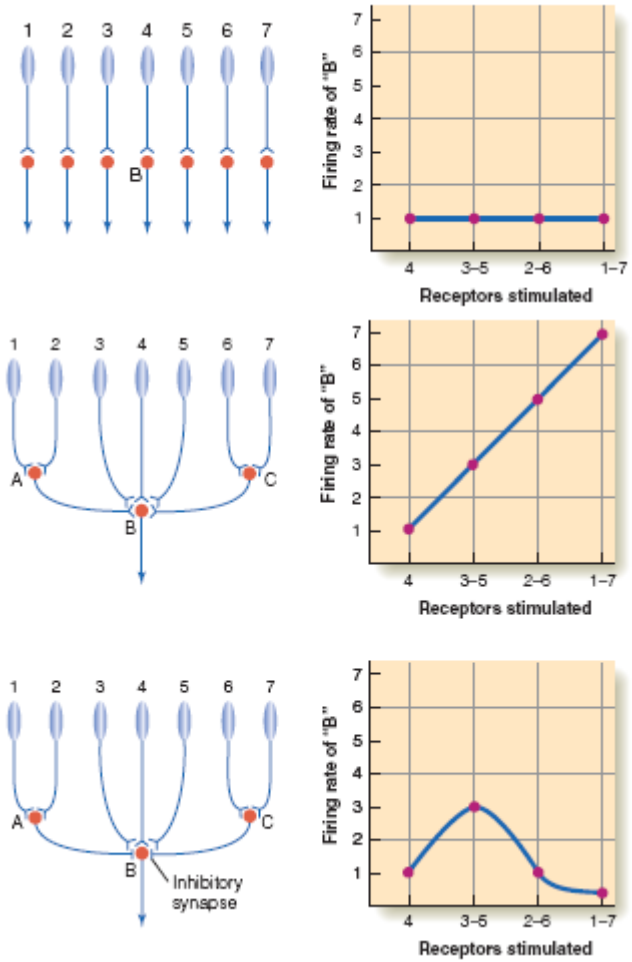


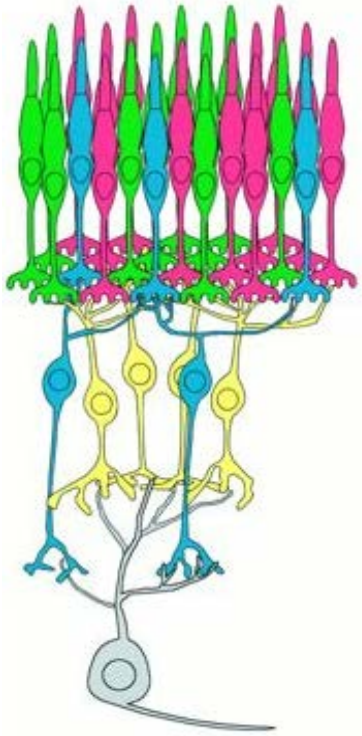
Divergence

Output from one neuron onto many



Neural circuits – basic functionality





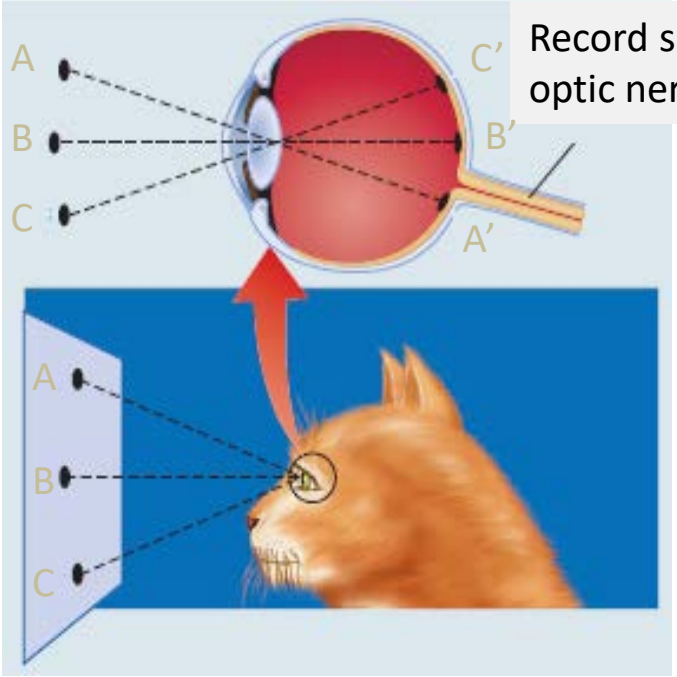
Rods and cones

Bipolar cells

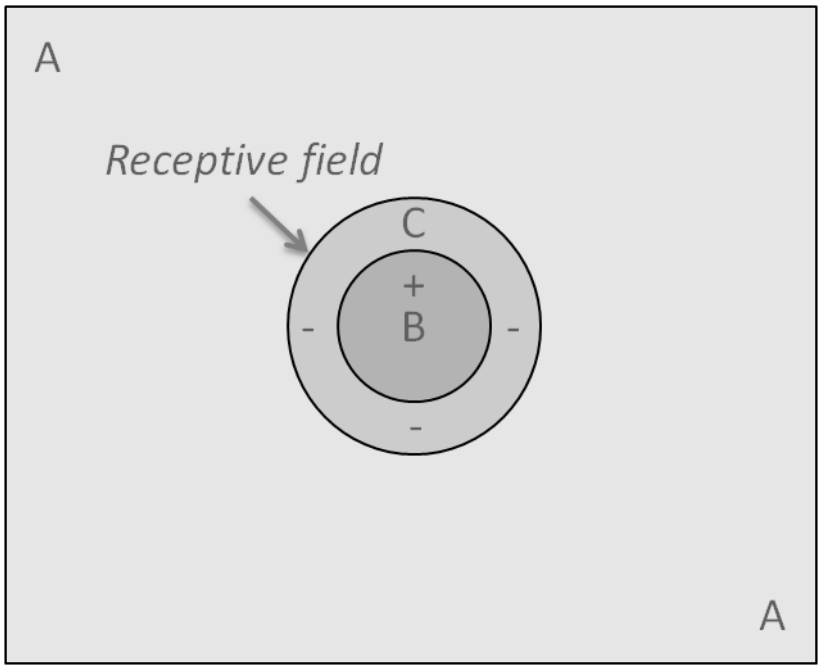
Ganglion cells

Receptive fields

An area where stimulation leads to a response of a particular sensory neuron

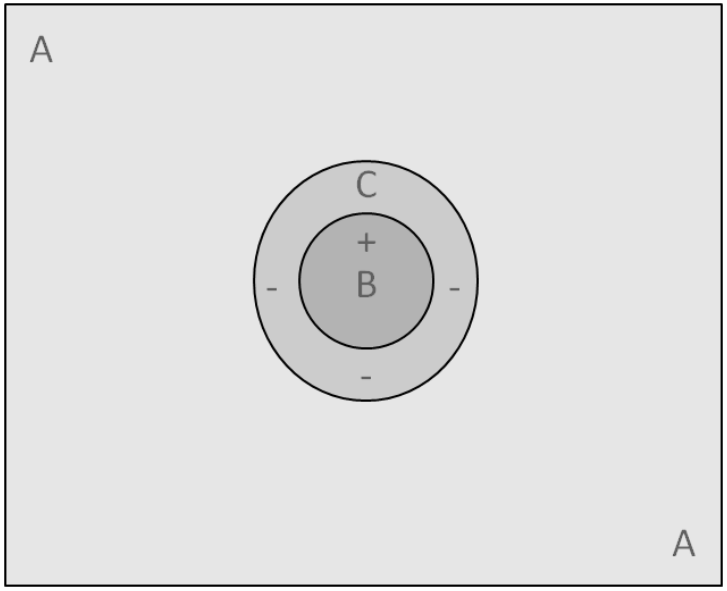


Receptive fields

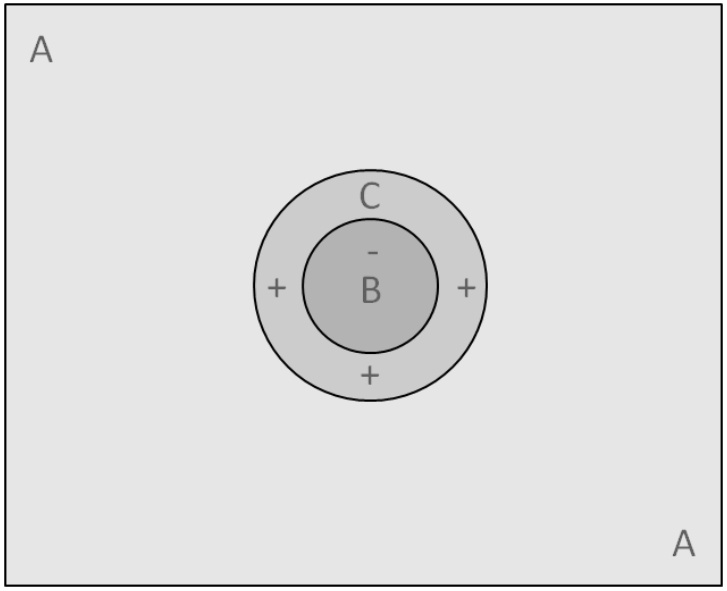


Receptive fields

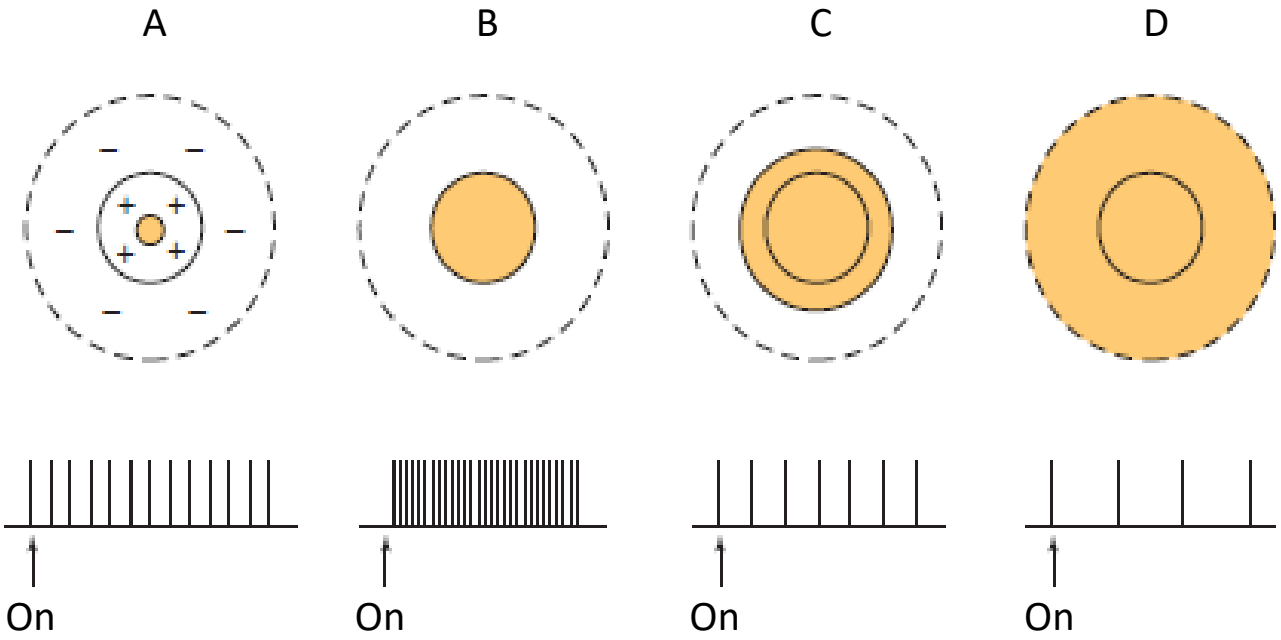
Excitatory-center-inhibitory-surround receptive field
"on center off surround"



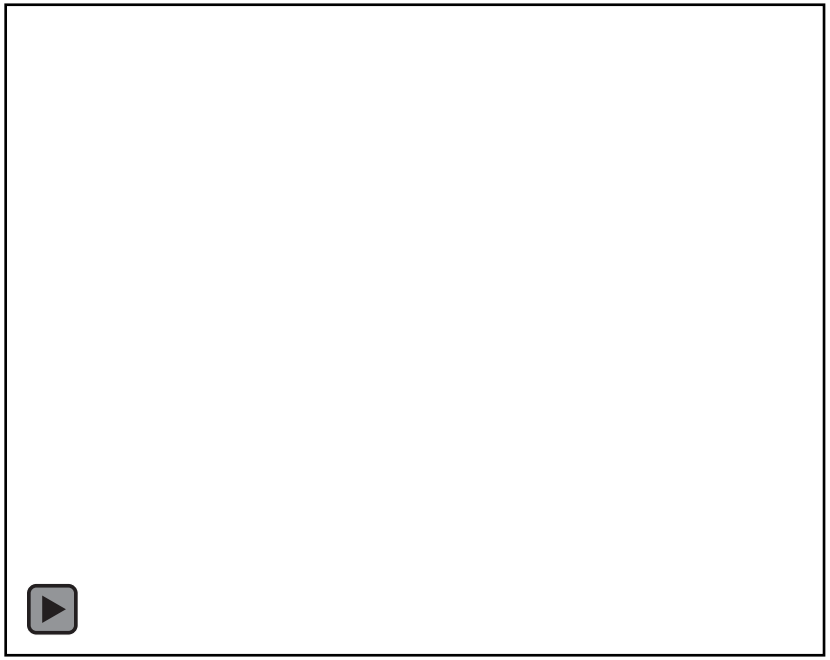
Inhibitory-center-exhibitory-surround receptive field
"off center on surround"



Center-surround antagonism



Simple Cell Receptive Field Mapping



http://www.youtube.com/watch?v=n31XBMSSSpI

Summary receptive fields

Studying a neuron's receptive field:

- Enables us to specify a neuron's response
- Indicates the area of the receptor surface that causes the neuron to respond
- Indicates the size or shape of the stimulus that causes the neuron's "best" (highest firing rate) response

The problem of sensory coding

We have now explored the electrical signals that are the link between the environment and perception.

How does the firing of neurons represent various characteristics of our environment?

- ***Specificity coding***
  - a concept is represented by the firing of a single neuron
- ***Distributed coding***
  - a concept is represented by the firing pattern of a large set of neurons
- ***Sparse coding***
  - a concept is represented by the firing pattern of a few neurons

Specificity coding

Specificity coding

Konoroski, 1967

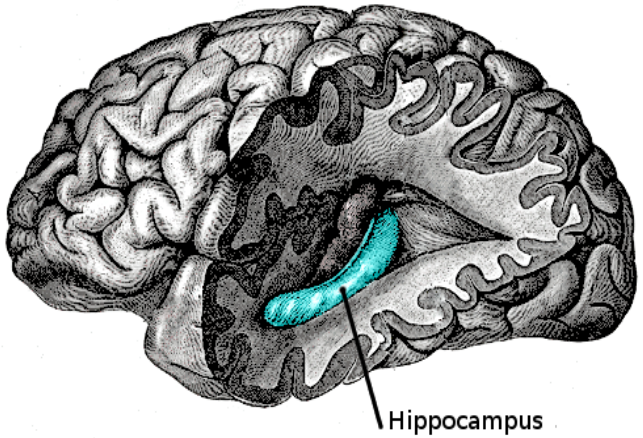
- "Gnostic units"

Lettvin, 1969

- "Grand mother cells"

Quiroga, et al 2005

- Studied the response in hippocampus in patients with epilepsy
- Specific neurons that responded to Halle Berry alone, but not to other faces of other famous people

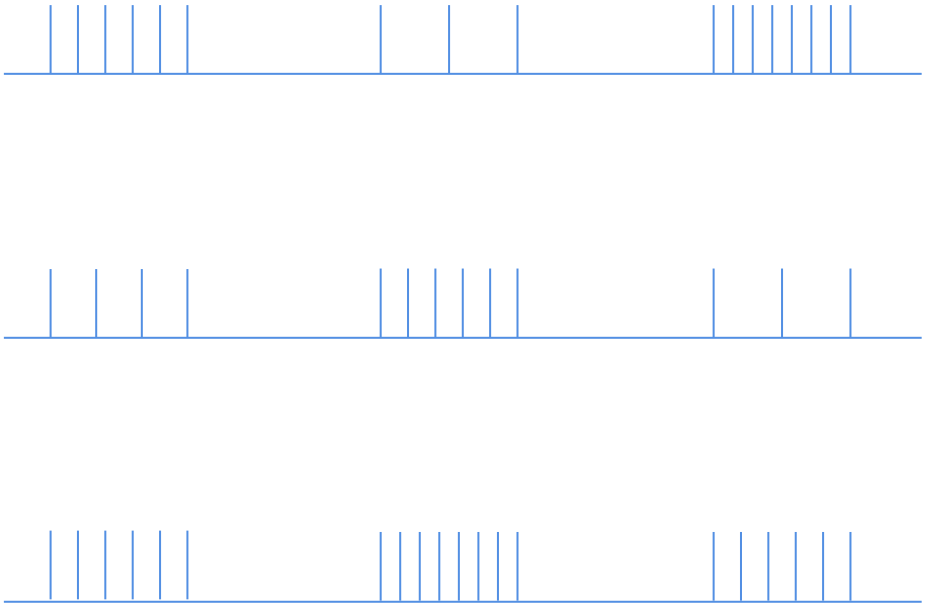


Most researchers (including Quiroga et al. 2008) agree that specificity coding is unlikely.

Distributed coding

Stimulus

Neuron 1 Neuron 2 Neuron 3



Sensory code

Distributed coding

Instead of requiring a specific neuron for each concept in the environment, *distributed coding* allows the representation of a large number of stimuli by the firing of a *large* set of neurons.

Sparse coding

- Somewhere in-between distributed coding and specificity coding
- A concept is represented by the firing of a small number of neurons
- Quiroga, (2008) suggest that their results are probably an example of sparse coding.