Information processing in the NS Principals of sensation and perception

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This presentation includes only the most important terms and facts. Its content by itself is not a sufficient source of information required to pass the Neuroscience exam.

Figures and tables re-used from:

- Principles of Neural Science (5th ed.), Kandel et al. (2013)
- Medical Physiology (2nd ed.), Boron and Boulpaep (2012)
- Neuroscience (4th ed.), Purves et al. (2008)
- Medical Neurobiology (1st ed.), Mason (2011)
- Ganong's review of medical physiology, (24th ed.),Barret (2010)
- Textbook of Medical Physiology (11th ed.), Guyton and Hall (2006)
- Color Atlas of Physiology (6th ed.), Silbernagl a Despopoulos (2009)

Information processing in the NS

- NS receives a huge amount of information from various sensory organs, processes it and integrates it to determine responses of the body.

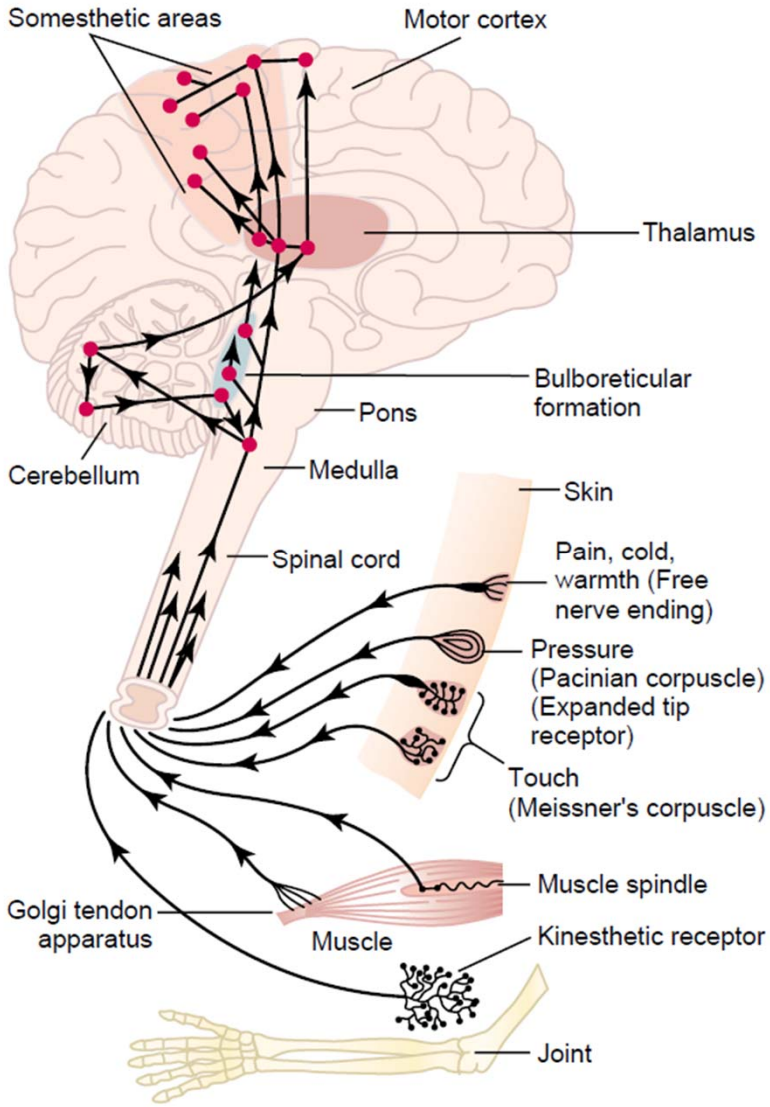
Information processing in the NS

- **Sensory part of the NS – Sensory Receptors**
- **Processing of information – Integrative function of the NS**
- **Motor part of the NS - Effectors**

- Central nervous system (CNS)
- Peripheral nervous system (PNS)

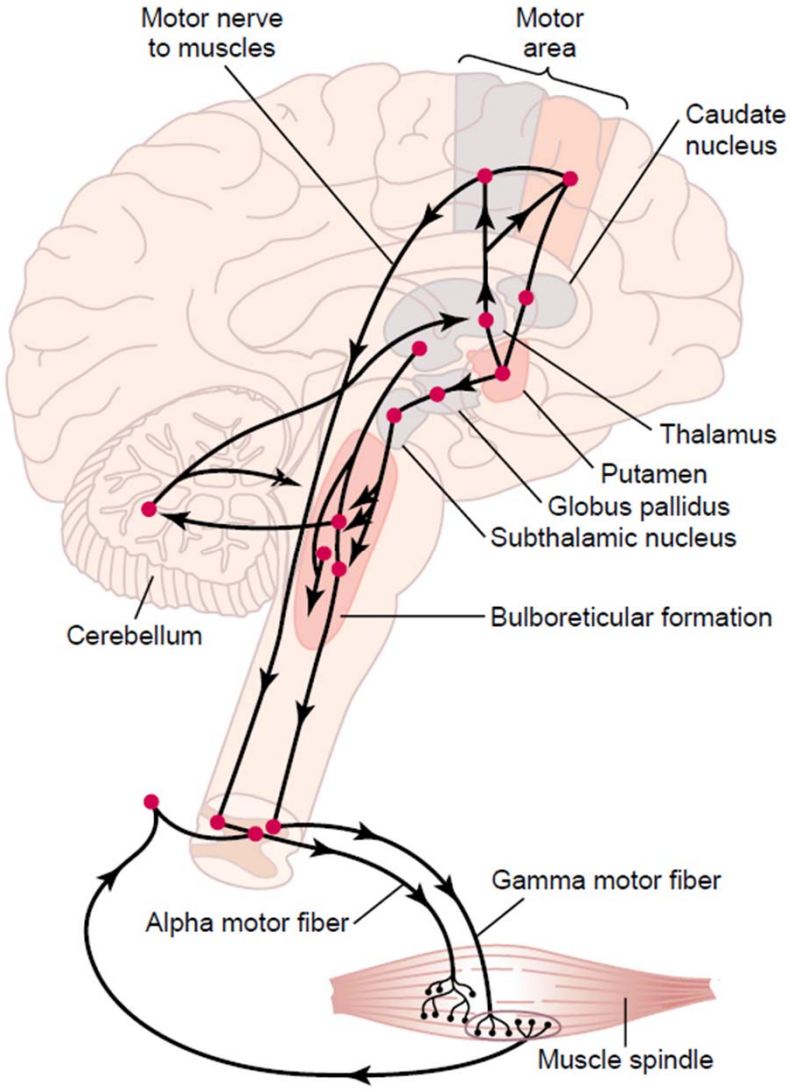
Information processing in the NS

- **Sensory part of the NS – Sensory Receptors**
- initiation by excitation of sensory receptors (visual, auditory, tactile, *etc.*) – peripheral nerves – multiple sensory areas of the CNS
- either cause immediate action of the brain,
- or memories are stored in the brain and determine future reactions



Information processing in the NS

- **Motor part of the NS - Effectors**
- control of activities of the body by:
  - contraction of appropriate skeletal muscles
  - contraction of smooth muscles in the internal organs
  - secretion of substances by glands (endocrine, exocrine)
- „skeletal“ motor nerve axis
- autonomic nervous system



Information processing in the NS

- **Processing of information – Integrative function of the NS**
- essential function of the brain
- has to process the incoming information in such a way that appropriate mental and motor responses will occur
- role of synapses

Information processing in the NS

- **Storage of information – Memory**
- much of the sensory information stored
- mostly in the cerebral cortex but also lower, even in the spinal cord (small amounts of information)

- function of synapses - **facilitation**
- Memories become a part of the brain processing mechanism for future thinking.

Information processing in the NS

- **Major levels of the CNS function**

- Spinal cord level
- Lower brain (subcortical) level
- Higher brain (cortical) level

Information processing in the NS

- **Major levels of the CNS function**
- **Spinal cord level**
- conduit for signals
- highly organized functions

- commanded by the upper levels of the NS

Information processing in the NS

- **Major levels of the CNS function**
- **Lower brain (subcortical) level**
- medulla, pons, mesencephalon, hypothalamus, thalamus, cerebellum, basal ganglia
- control most of the subconscious activities of the body

Information processing in the NS

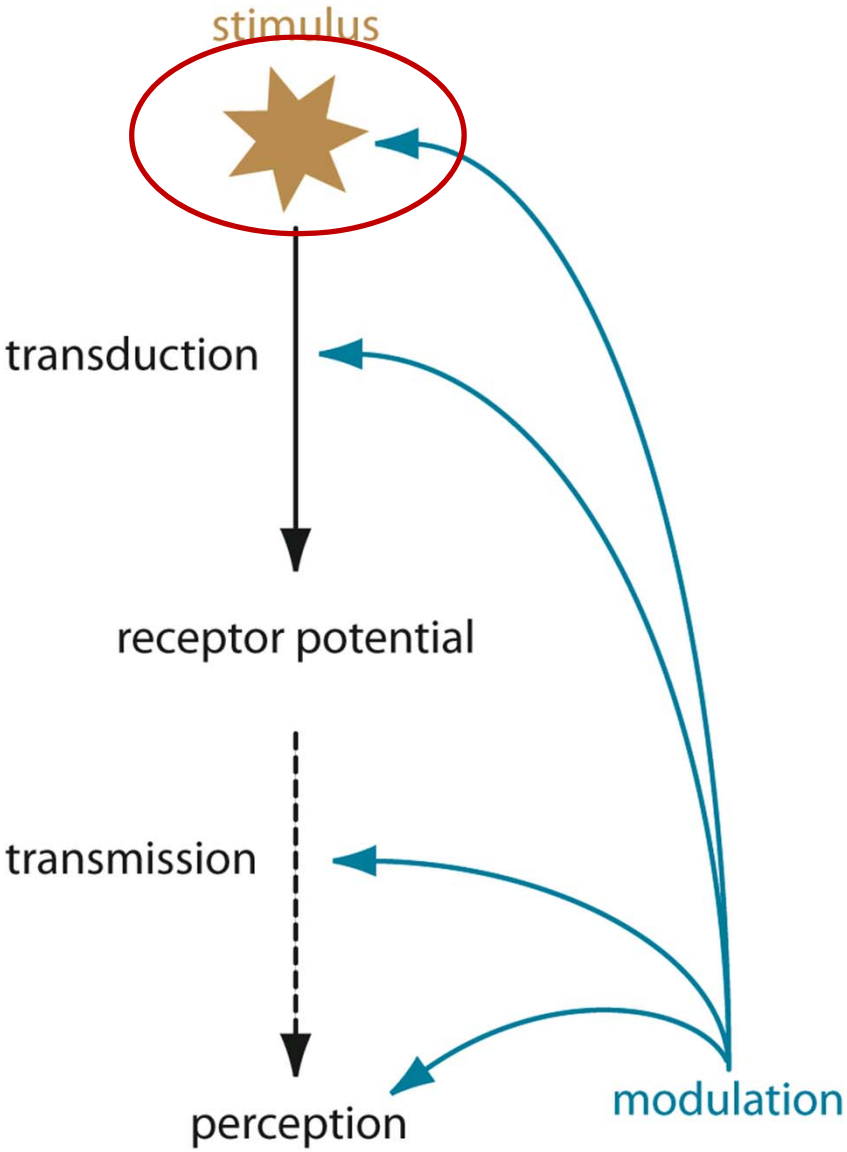
- **Major levels of the CNS function**
- **Higher brain (cortical) level**
- cerebral cortex – always works in association with the lower centers
- extremely large memory storehouse
- optimalization and coordination of the processes controlled by the lower centers
- essential for the thought processes

Principals of sensation and perception

- **Sensation** - is how the senses deliver signals about the current state of the world to the CNS

- **Perception** - is how an individual interprets these signals in terms of previous experience, knowledge of the world and expectation

Components of sensory pathways



Stimulus

- To register a stimulus, a receptor able to transduce the stimulus into neural signal has to be available.

- sensory organs steer stimuli to sensory receptors
- any change in the external environment or internal milieu

All sensory systems convey

four basic types of information:

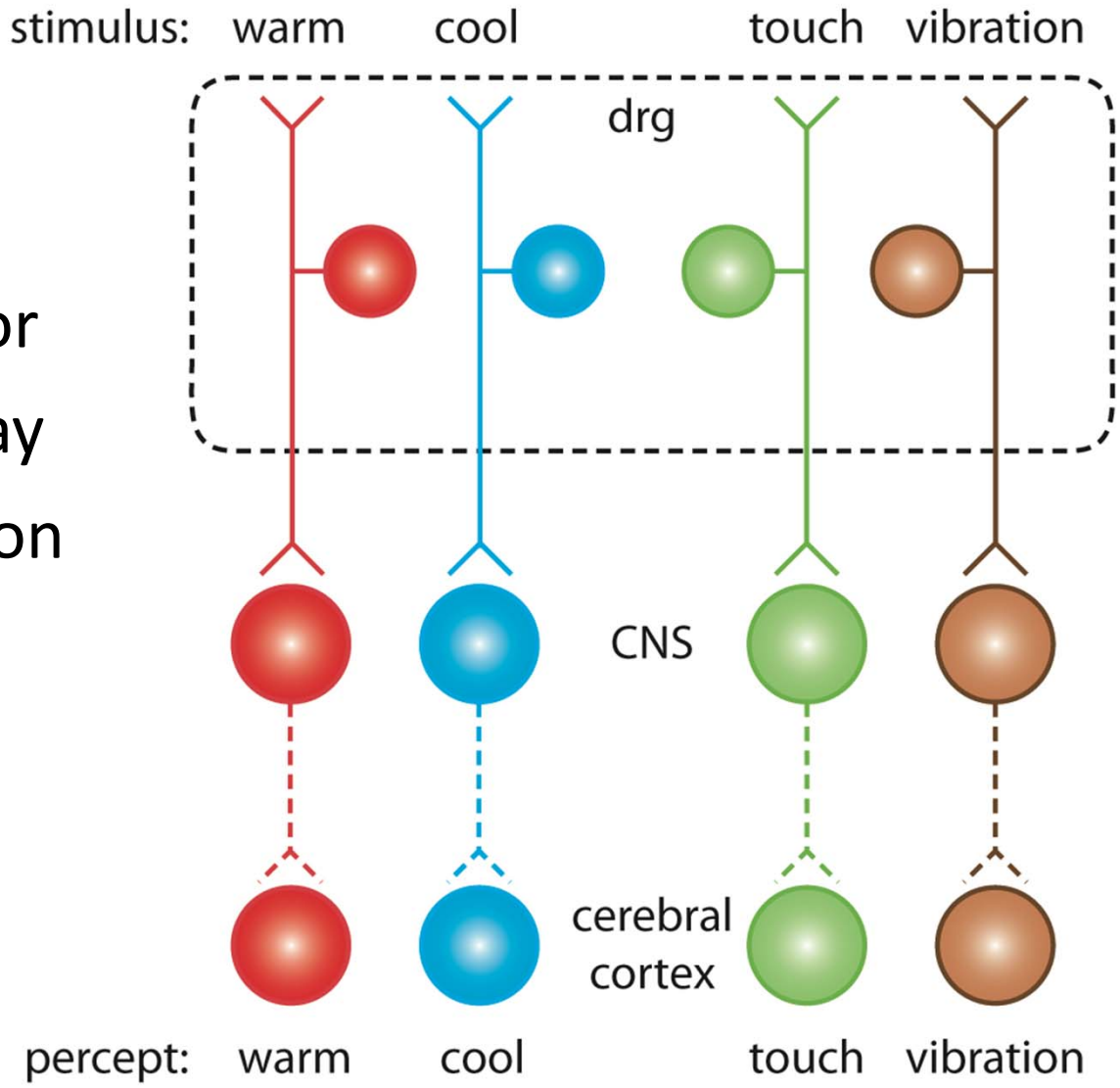
1. **modality** (what it is)
2. **location** (where)

1 and 2 - labelled line coding

Labeled line sensory pathway

Sensory systems:

- sensory receptor
- afferent pathway
- central projection



Modality

Müller`s law of specific sense energies (1826):

modality is a property of sensory nerve fibre

- is activated primarily by a certain type of stimulus

- each sensory nerve fibre makes specific connections to structures in the CNS whose activity give rise to specific sensation (labelled line coding)

All sensory systems convey

four basic types of information:

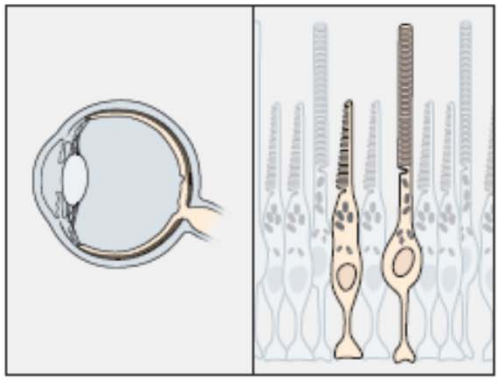
1. **modality** (what it is)
2. **location** (where)

    1 and 2 - labelled line coding

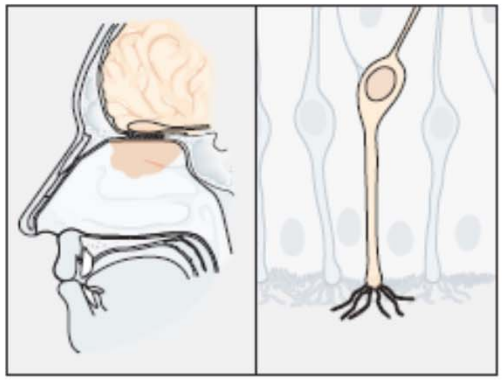
3. **intensity** (how much)
4. **timing** (when)

    3 and 4 - frequency coding

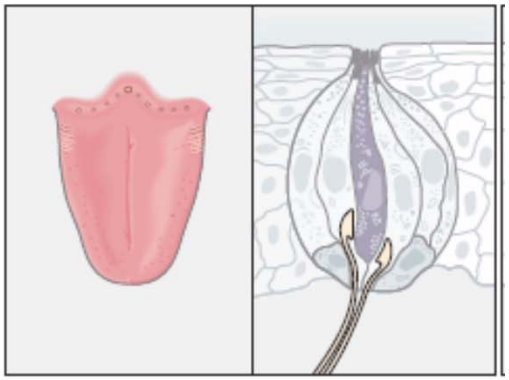
Vision



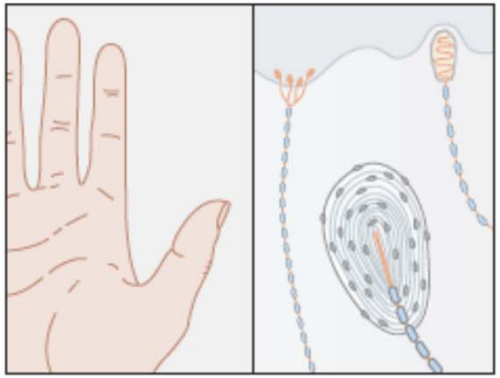
Smell



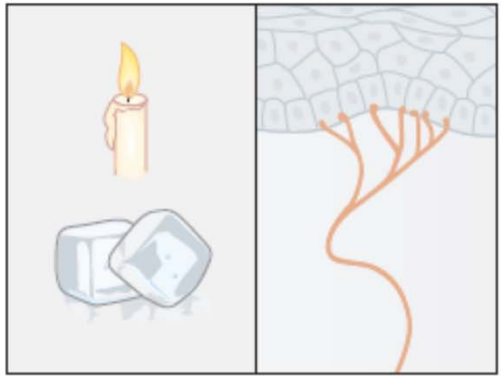
Taste



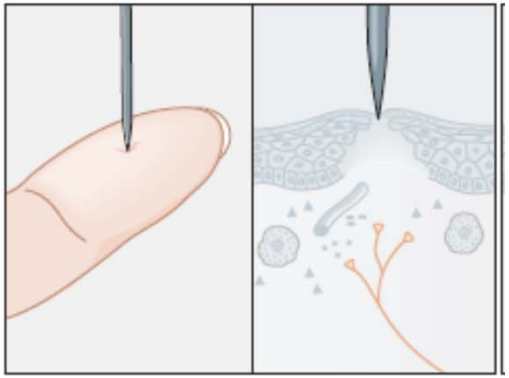
Touch



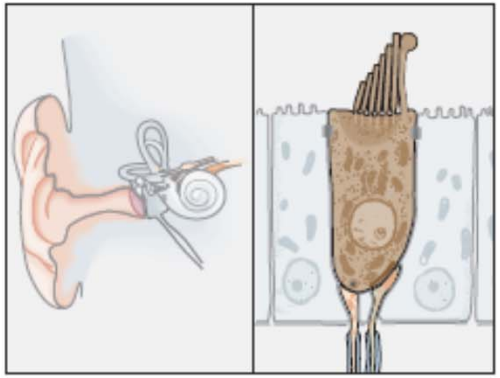
Thermal senses



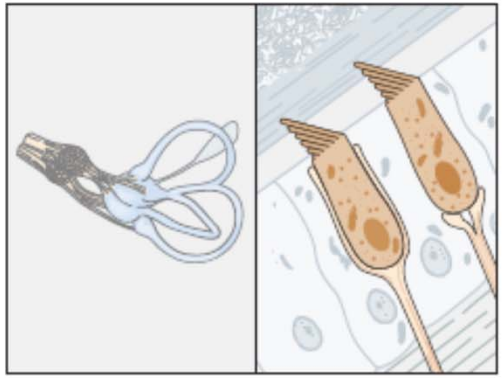
Pain



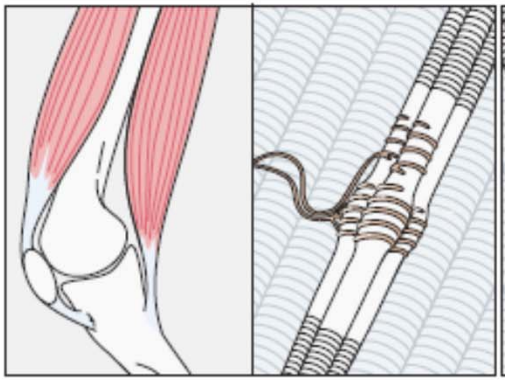
Hearing



Balance



Proprioception



Receptors - types of energy

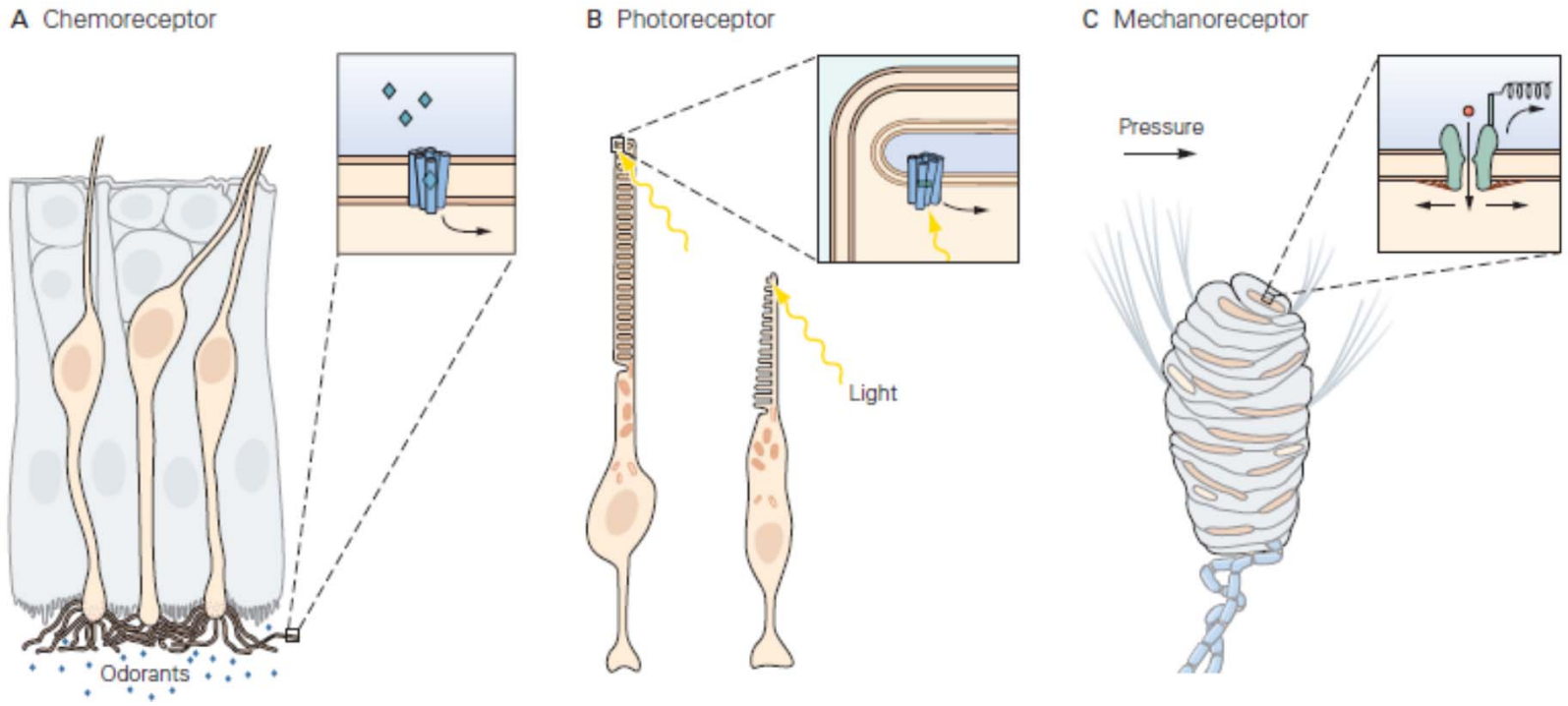
mechanical (mechanoreceptors) - touch, pressure, sound ...

chemical (chemoreceptors) - taste, smell, osmoreceptors ...

thermal (thermoreceptors) – warm, cold

electromagnetic (photoreceptors) - vision

various pain stimuli (nociceptors, pain receptors) – pain

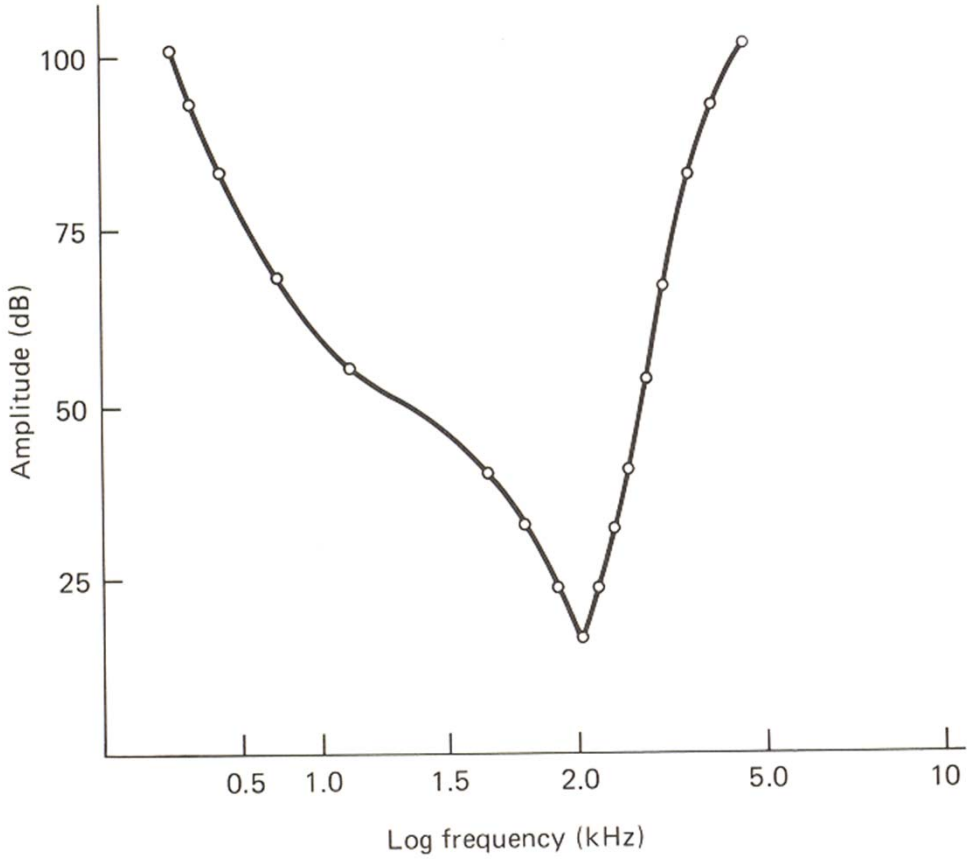


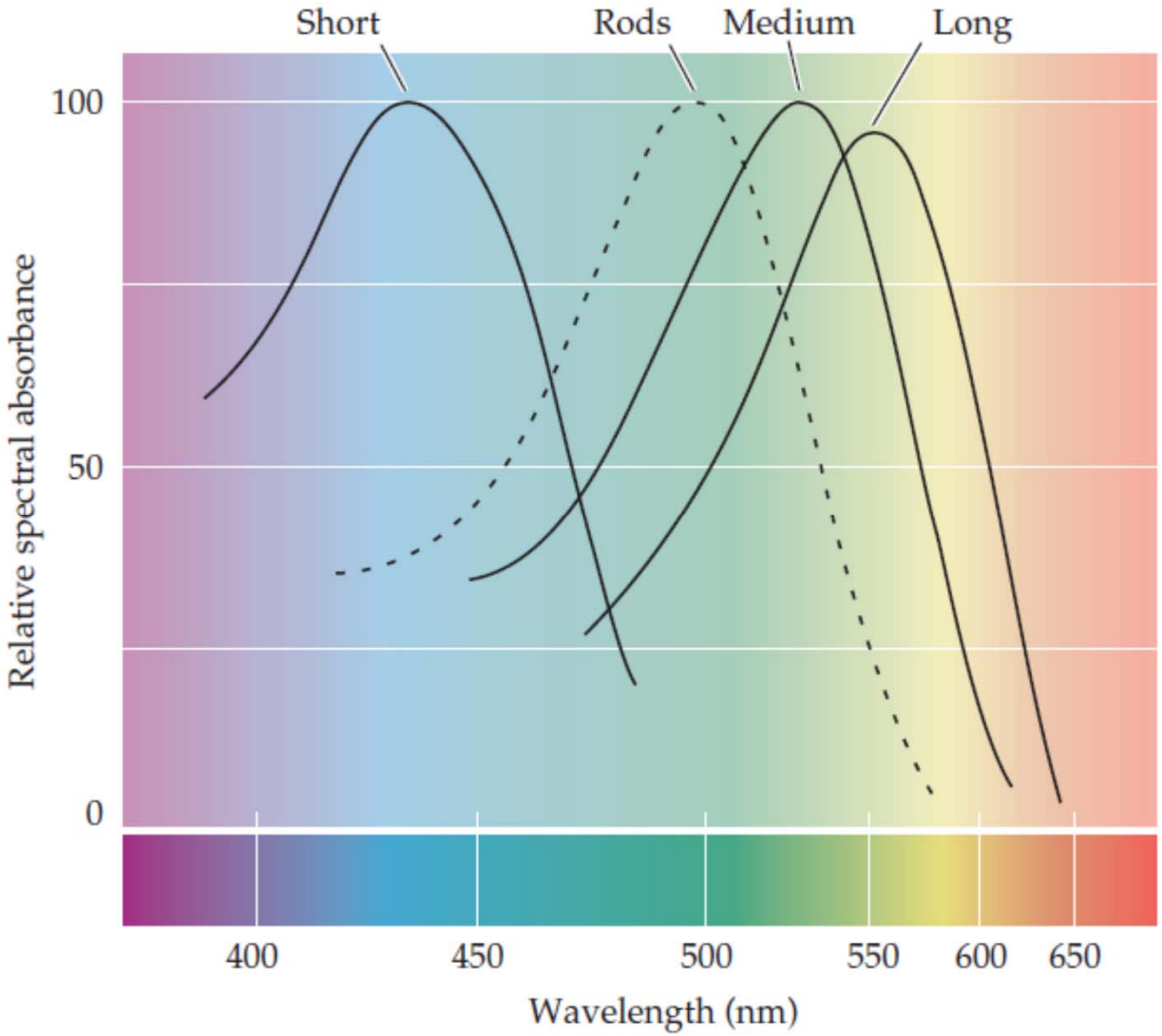
Receptors

- behave as a filter for narrow range of energy

(they are tuned to adequate stimulus)

- respond probabilistically to a range of stimuli




Short
Rods
Medium
Long
100
50
0
Relative spectral absorbance
400
450
500
550
600
650
Wavelength (nm)

Receptors – location of stimulus action

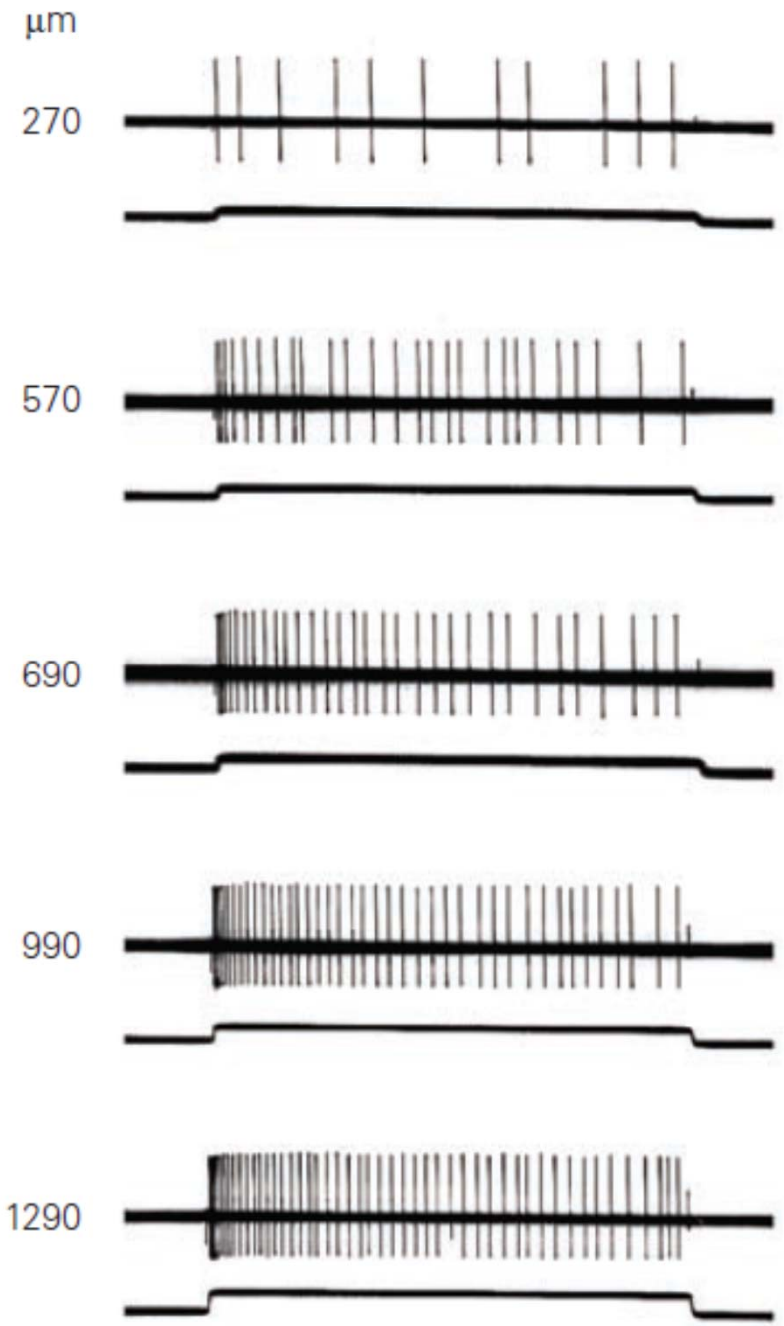
- telereceptors
- exteroreceptors
- proprioreceptors
- viscероreceptors

- low-threshold
- high-threshold

Receptors - adaptation

- **slowly adapting - tonic**

- pain receptors (nociceptors)
- baroreceptors
- chemoreceptors
- receptors of the macula in the vestibular apparatus
- muscle spindles
- Golgi tendon apparatuses, *etc.*

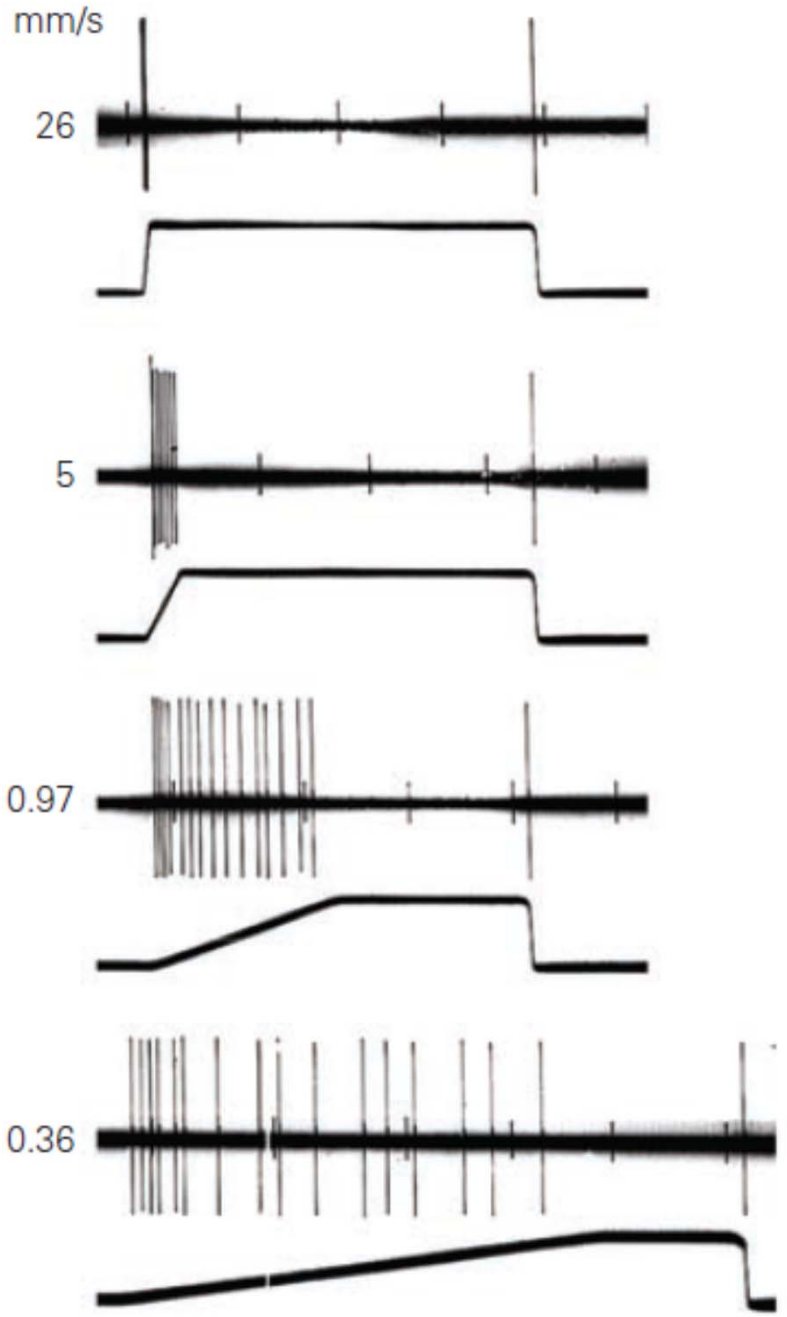


Receptors - adaptation

- **rapidly adapting - phasic**

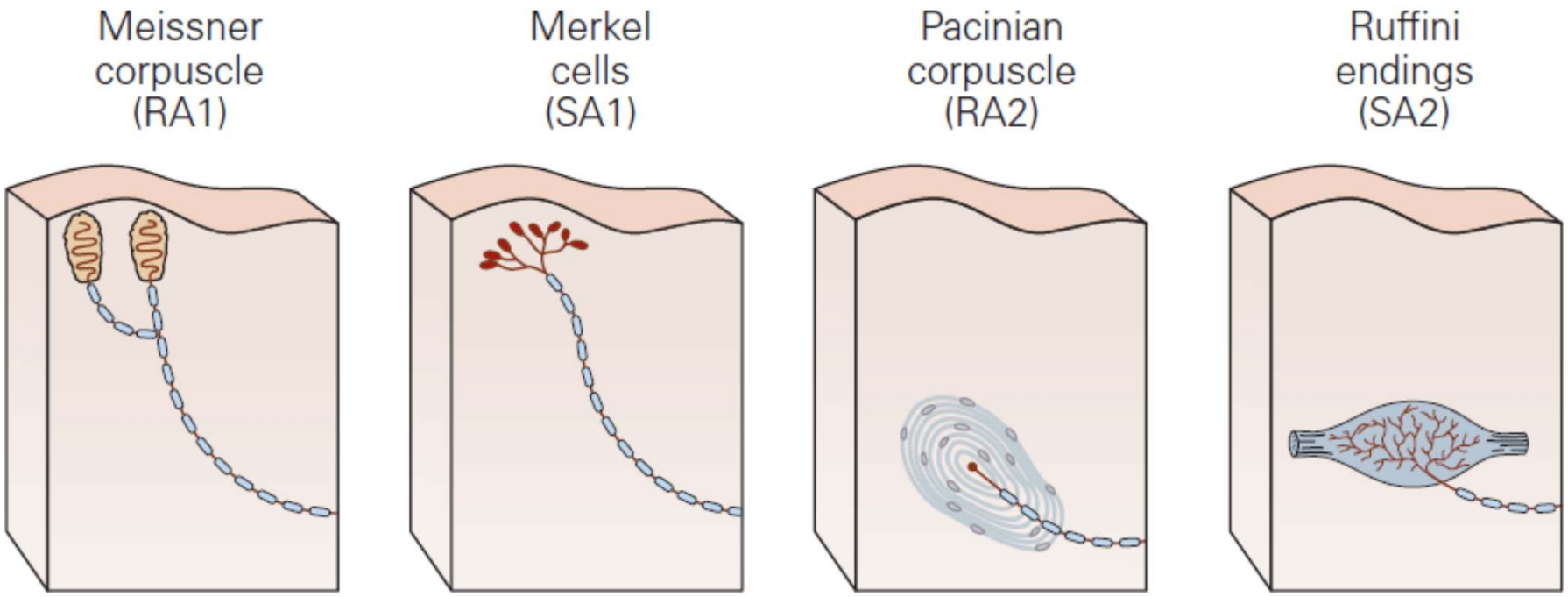
- cones in the retina
- olfactory receptors
- pacinian corpuscle, *etc.*

- predictive function



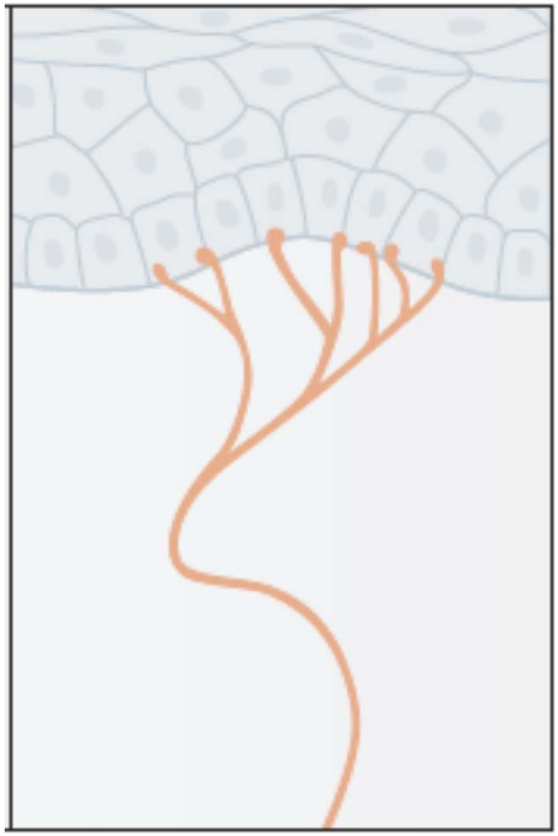
Receptors - structure

- encapsulated receptors - touch, pressure..



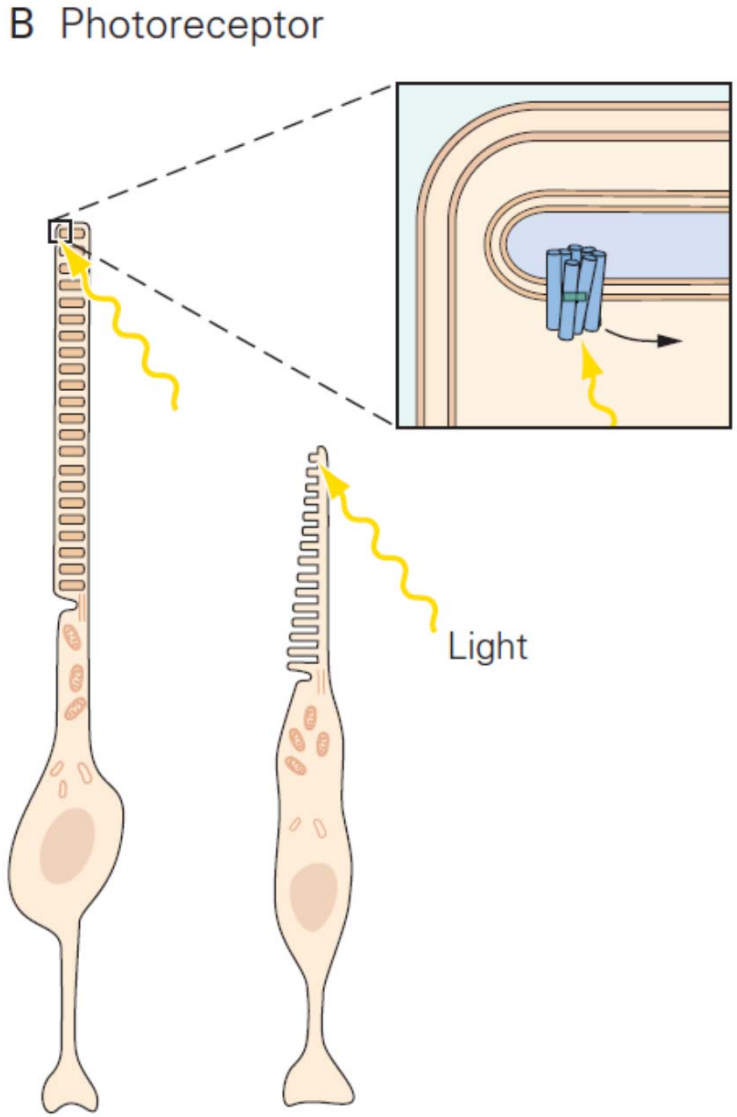
Receptors - structure

- free nerve endings – myelinated and unmyelinated – nociceptors, thermoreceptors

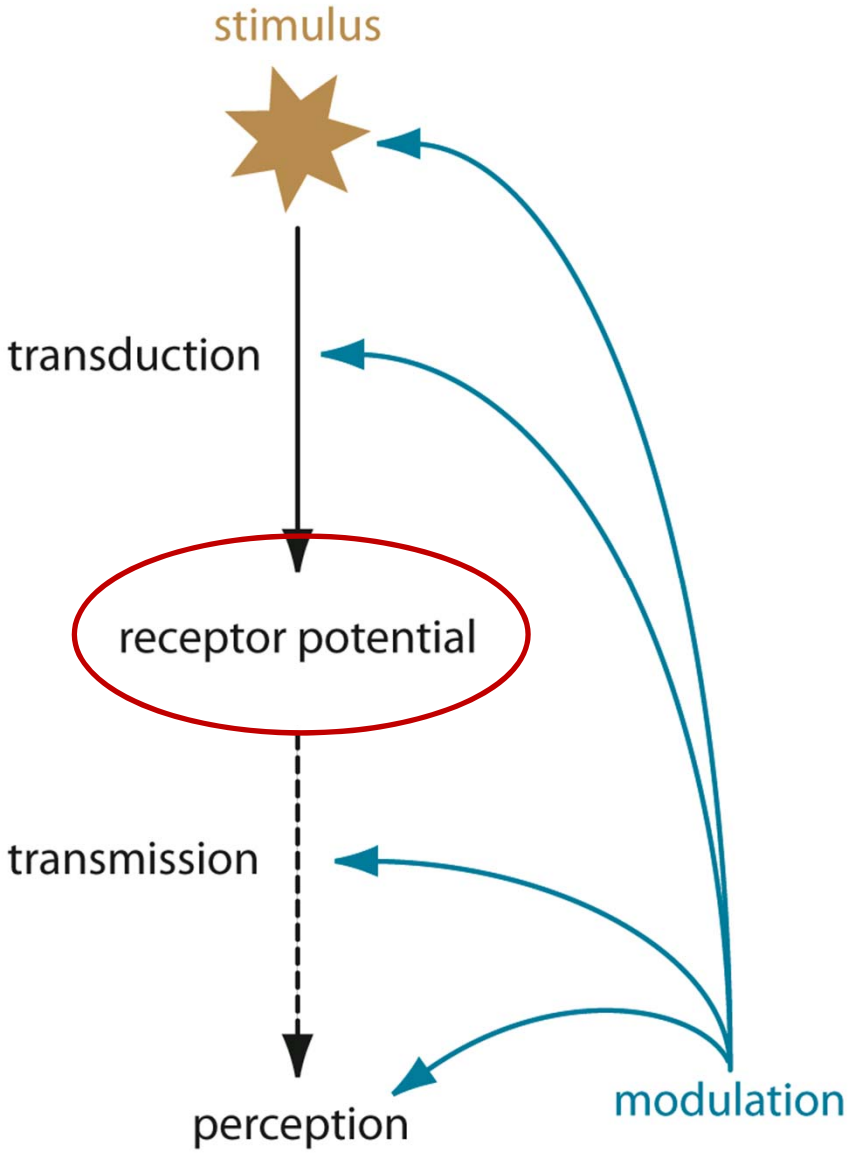


Receptors - structure

- receptor cells - coupled to G proteins, stretch sensitive ion channels .....



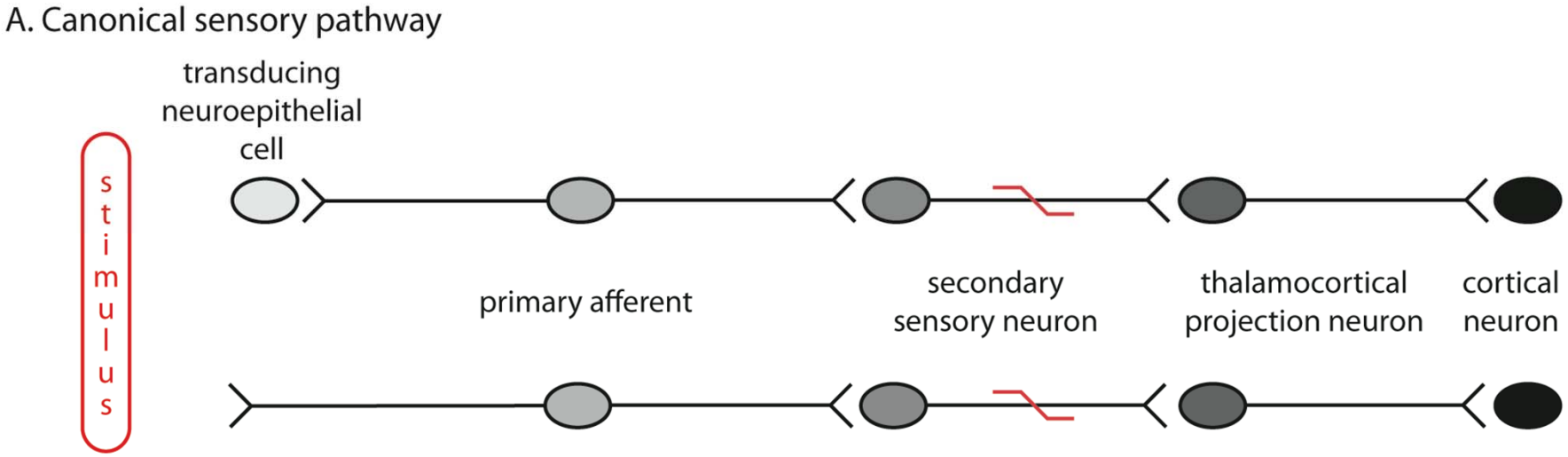
Components of sensory pathways



Stimulus processing

Receptors

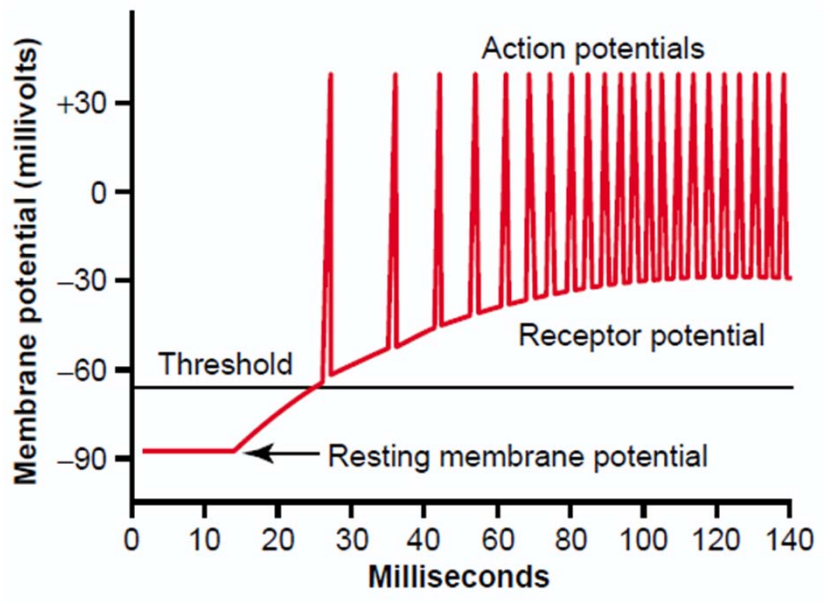
- transduce stimulus energy into a change in membrane potential



Stimulus processing

Generator (receptor) potential

- receptors may be excited by:
  1) mechanical deformation
  2) application of chemicals
  3) temperature change
  4) electromagnetic radiation



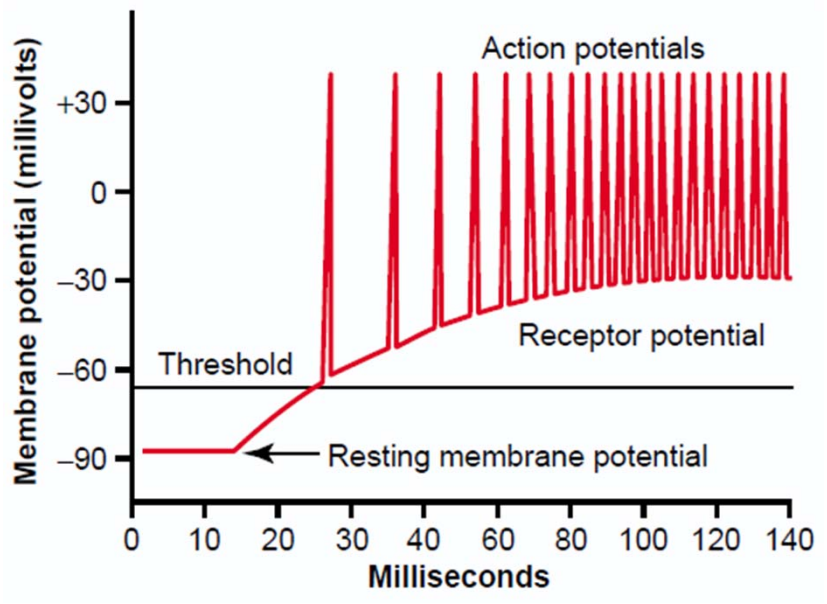
- cause opening of specific channels → change of transmembrane potential
- receptor potential above threshold → action potentials (frequency proportional to the hight of r.p.)

Stimulus processing

Generator (receptor) potential

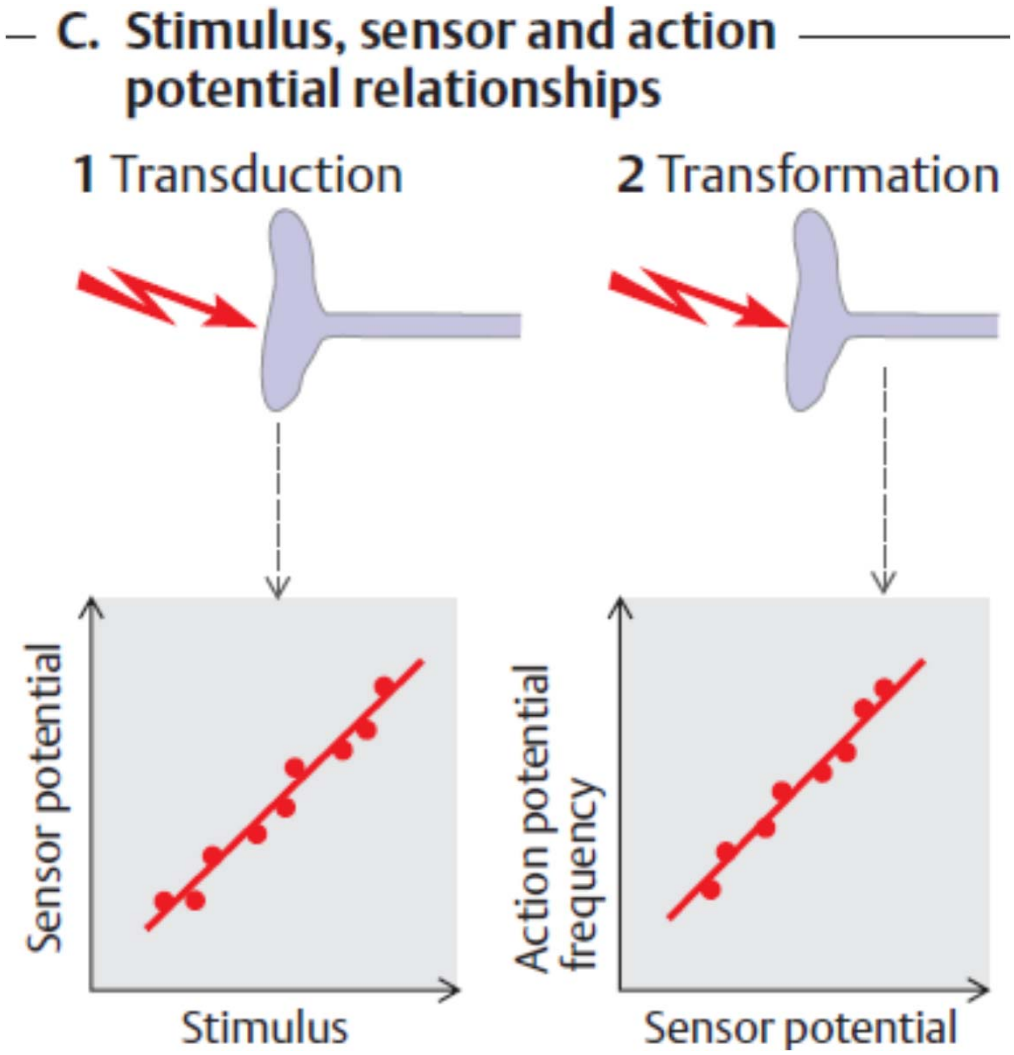
= membrane polarity change due to stimulation

- **depolarizing**: mainly influx Na^+, or Ca^{2+} ($\downarrow K^+$)
- **hyperpolarizing**: e.g. $\downarrow$influx Na^+ ($\uparrow K^+$)



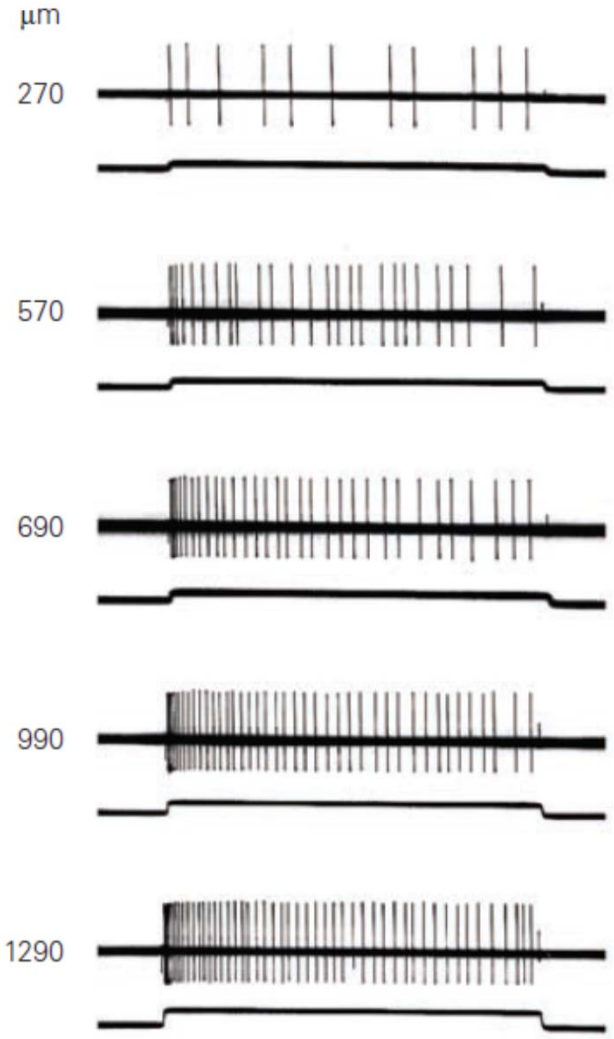
Stimulus processing

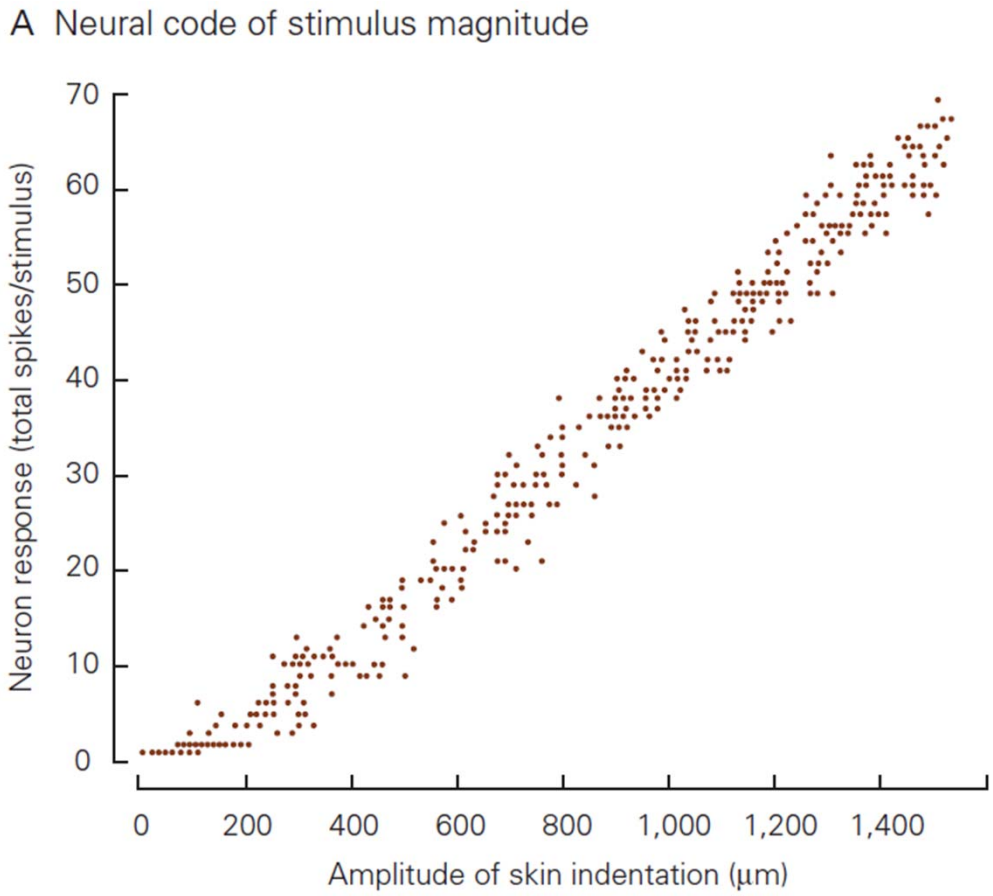
- transduction – conversion of stimulus energy into a receptor potentials
- transformation – conversion of receptor potential into action potential



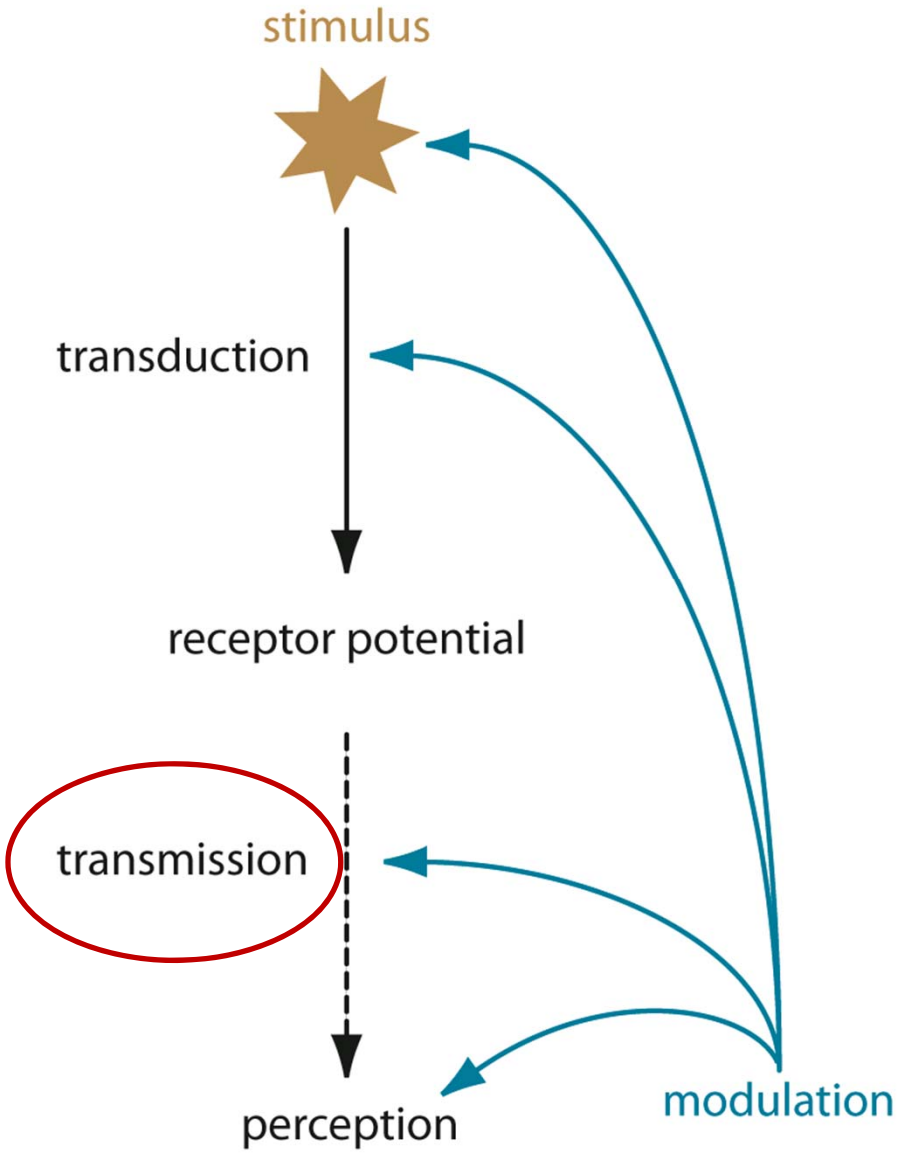
Stimulus processing

Stimulus intensity coding

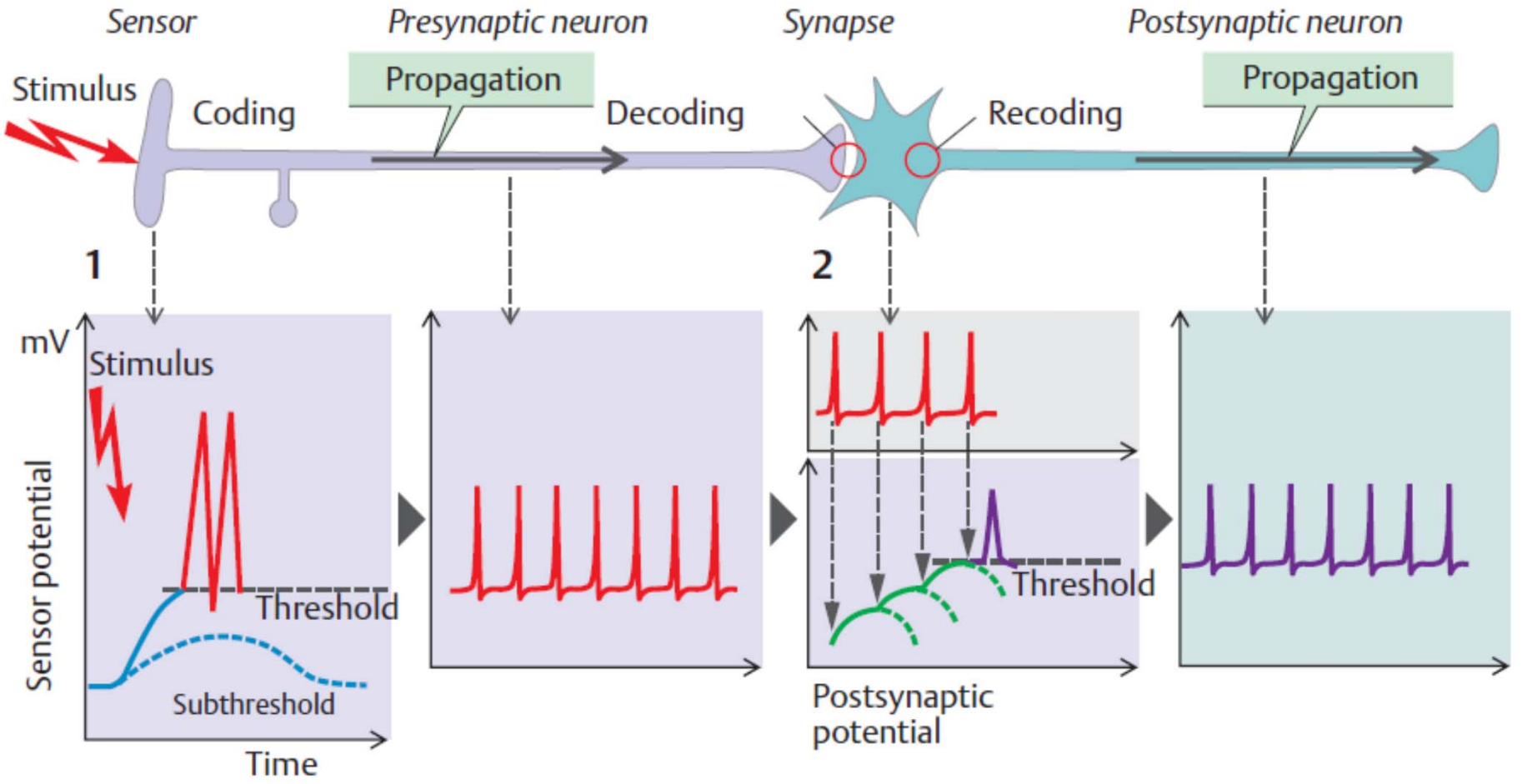




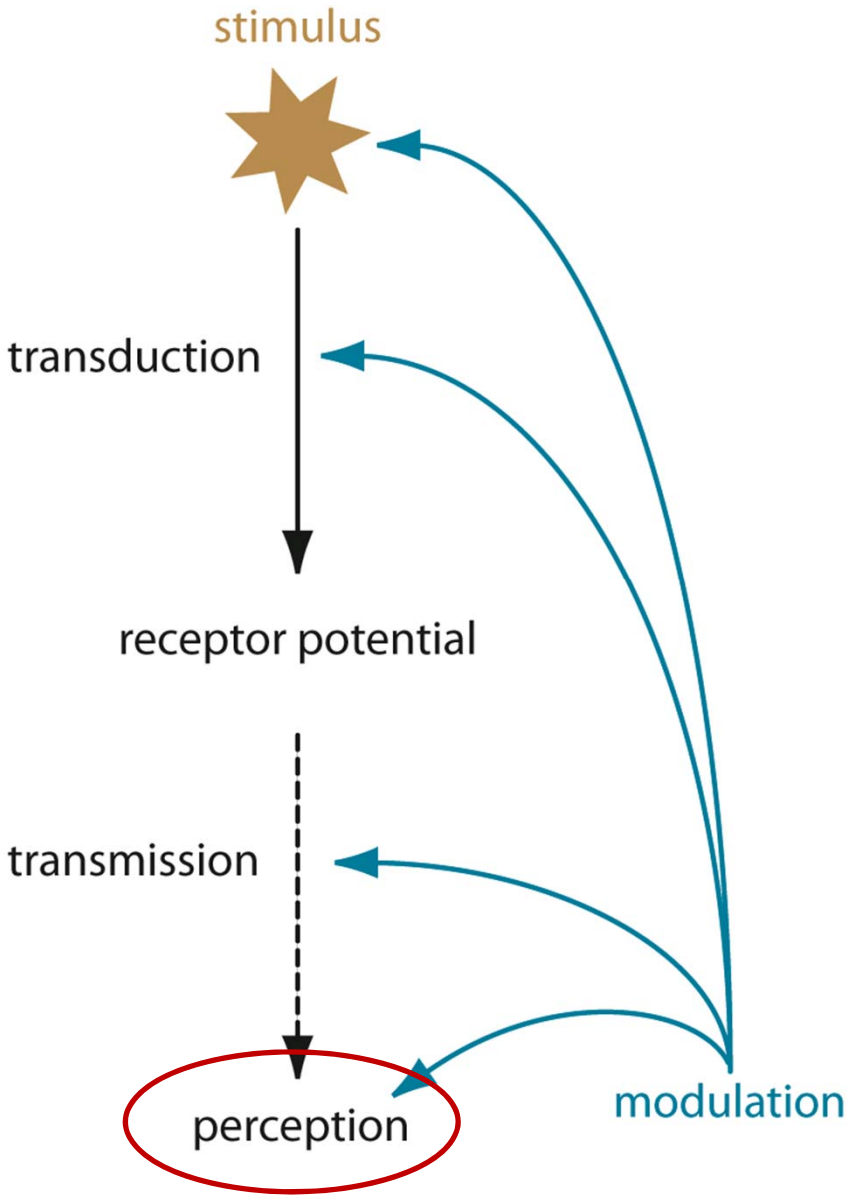
Components of sensory pathways



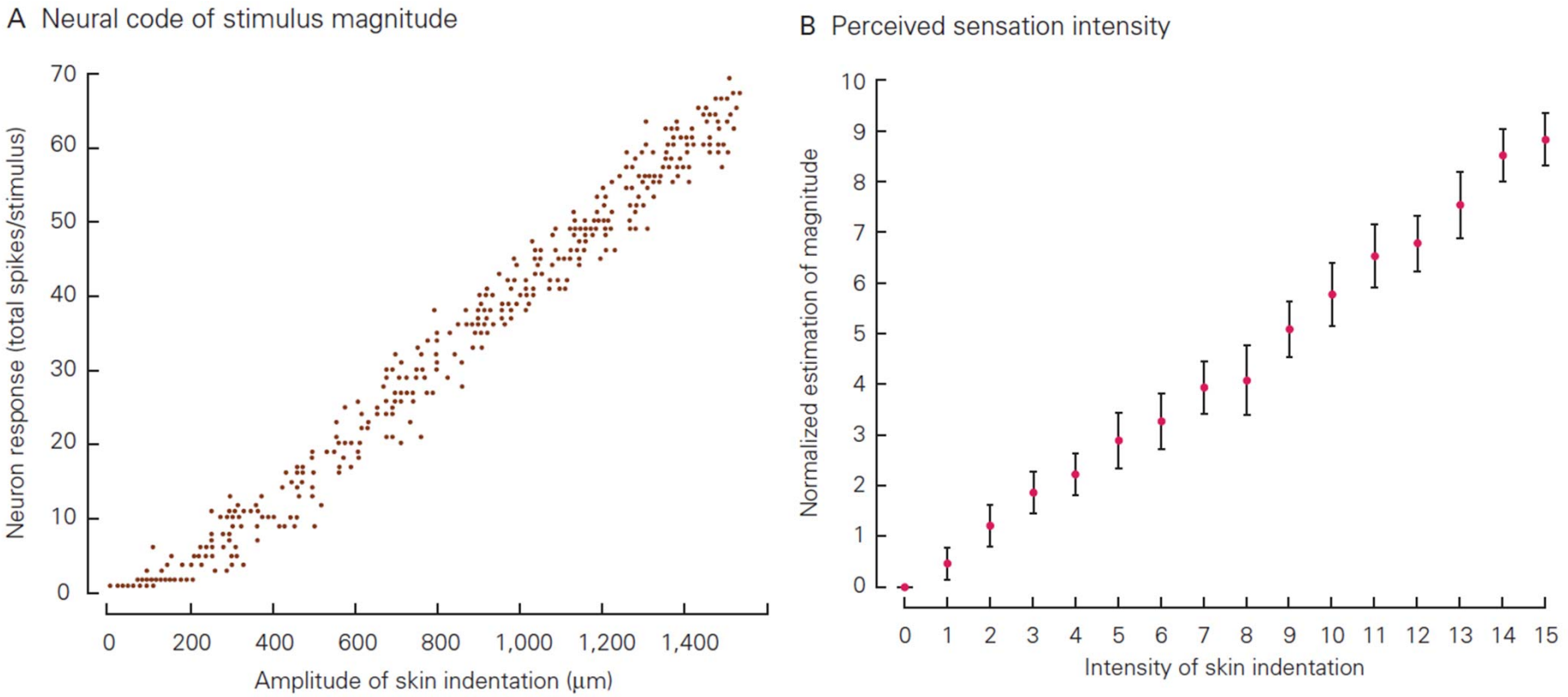
– B. Stimulus processing and information coding



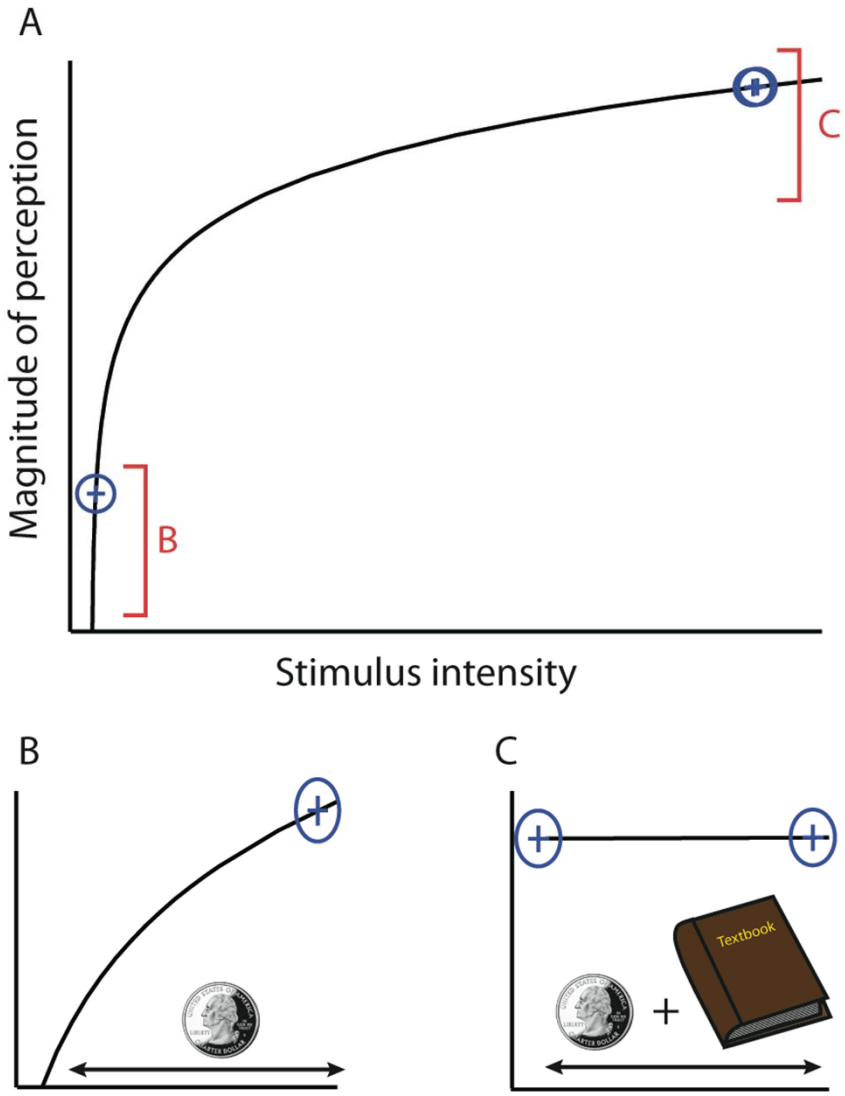
Components of sensory pathways



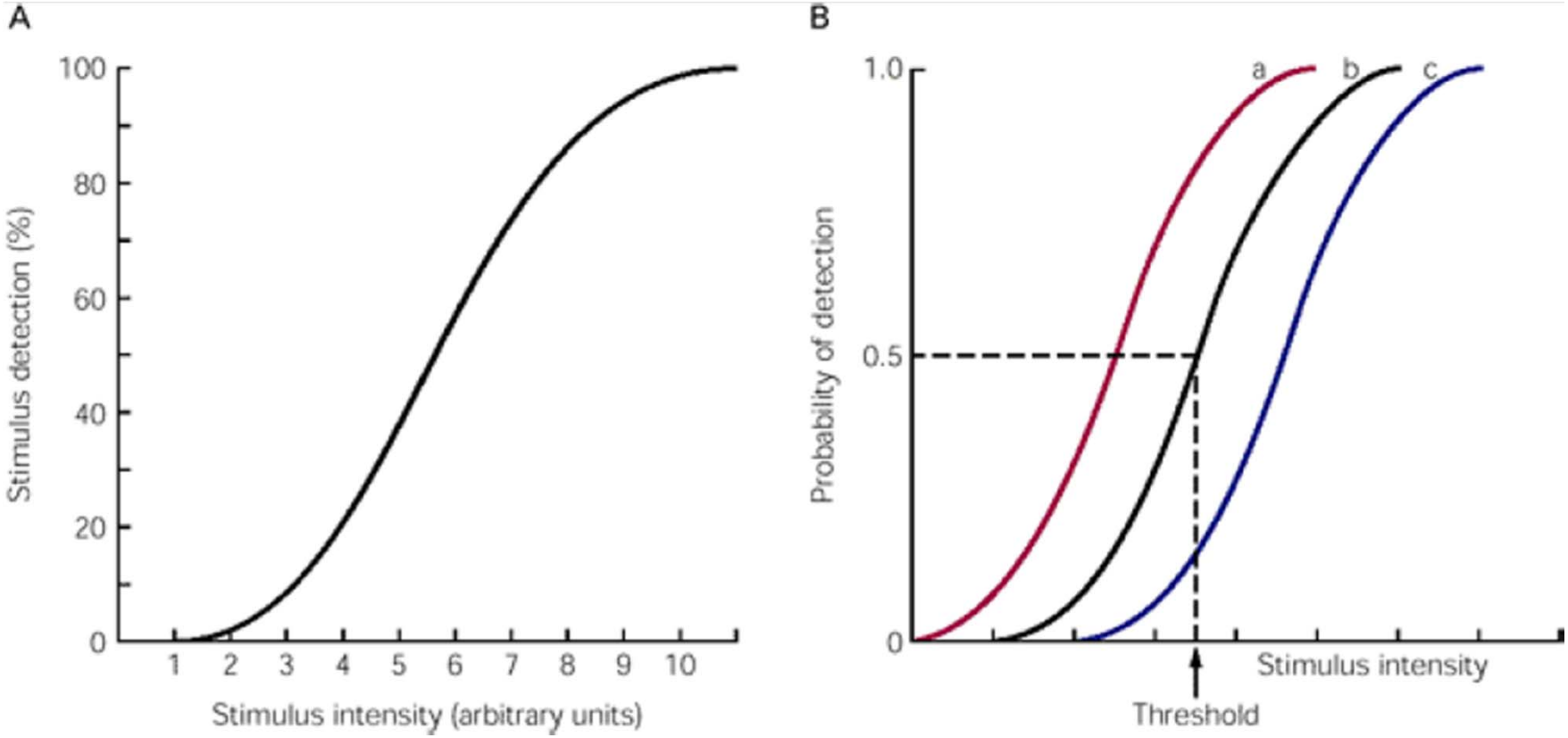
Stimulus intensity coding



Perception and stimulus intensity

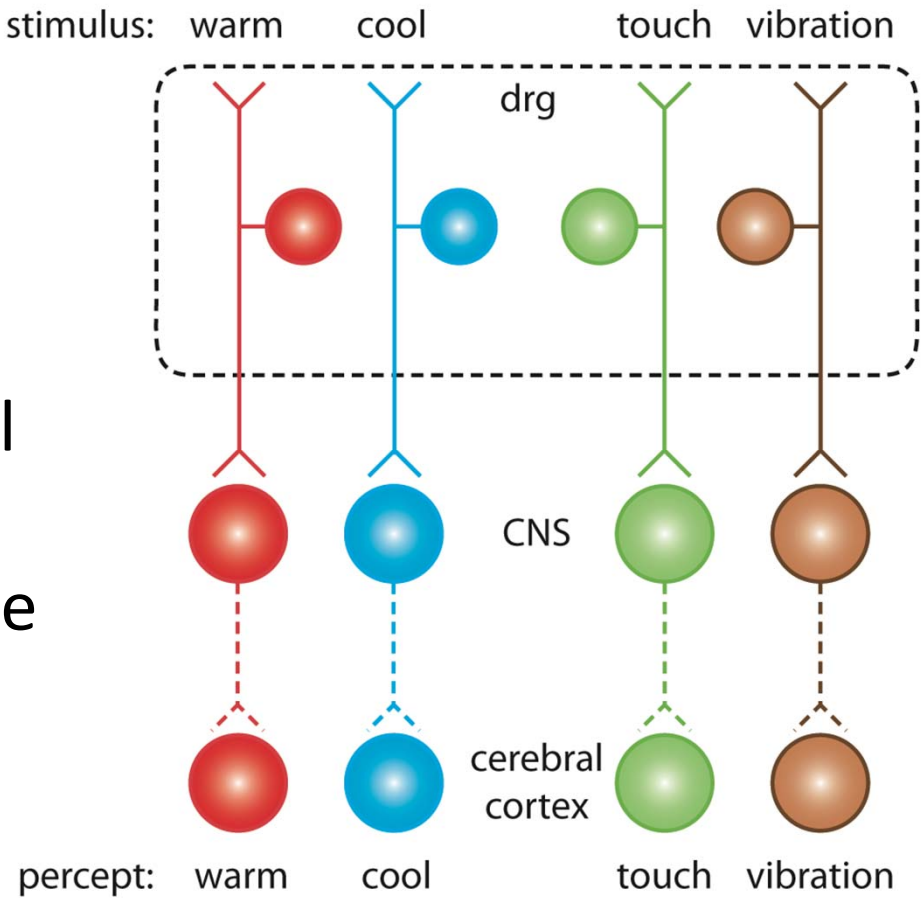


Stimulus threshold



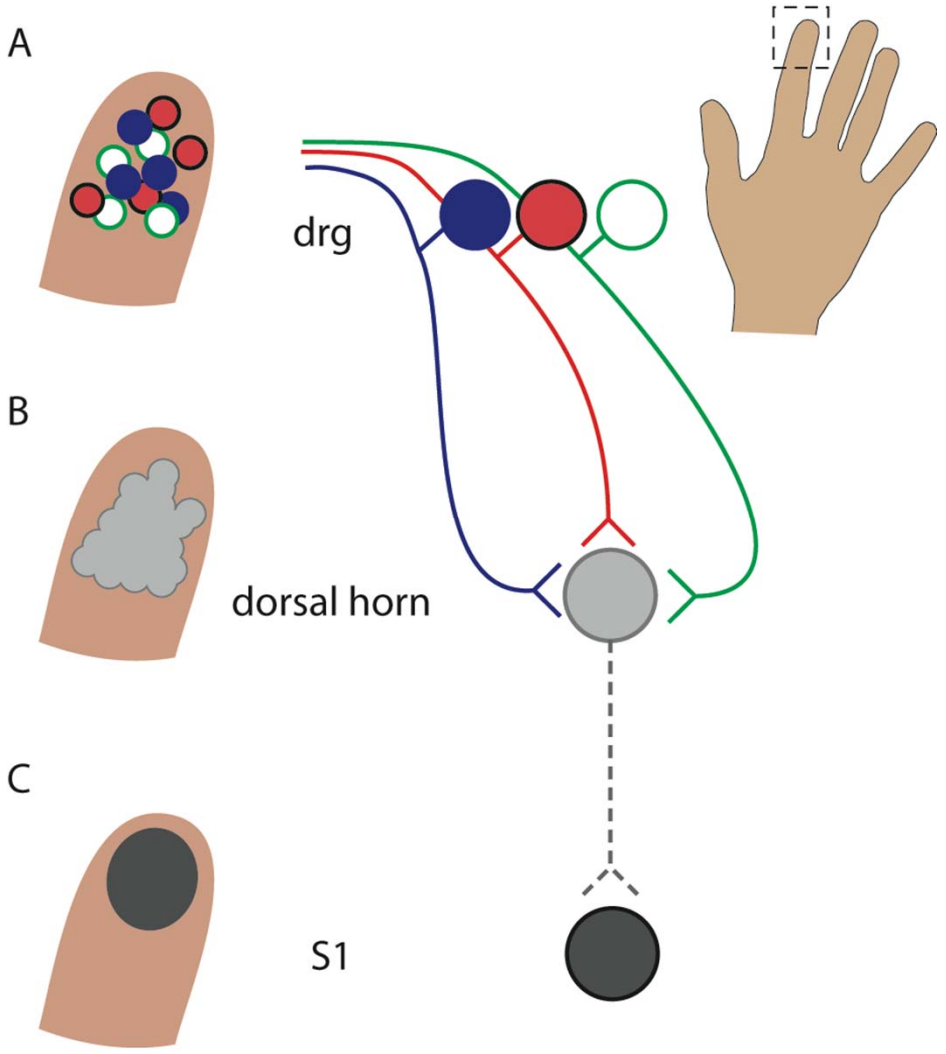
Spatial distribution of sensory neurons - stimulus location

1. receptive fields of sensory neurons (somatic sensation and vision)
2. hearing, taste and smell - receptors are spatially distributed following the energy spectrum of the modality



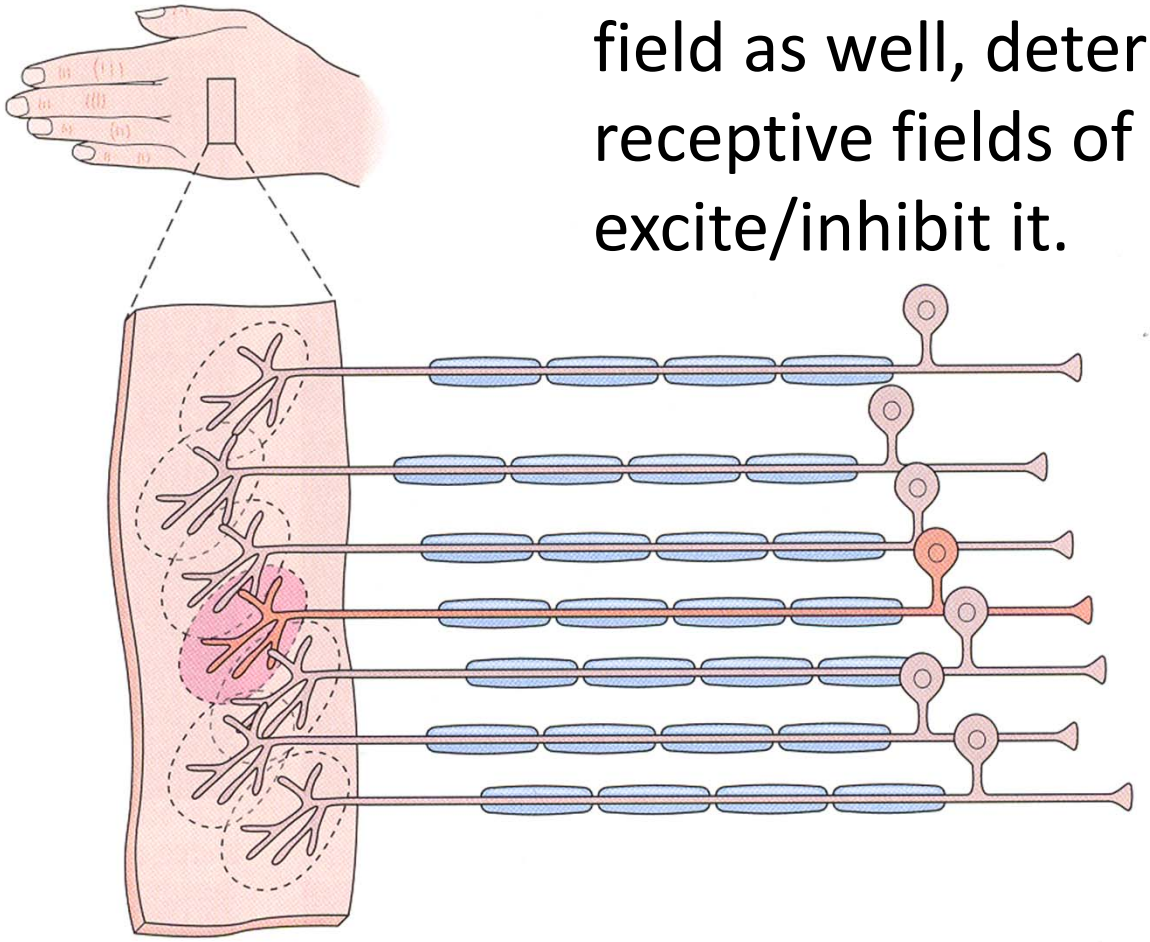
Receptive field

= the range of locations where stimulation will excite a sensory receptor

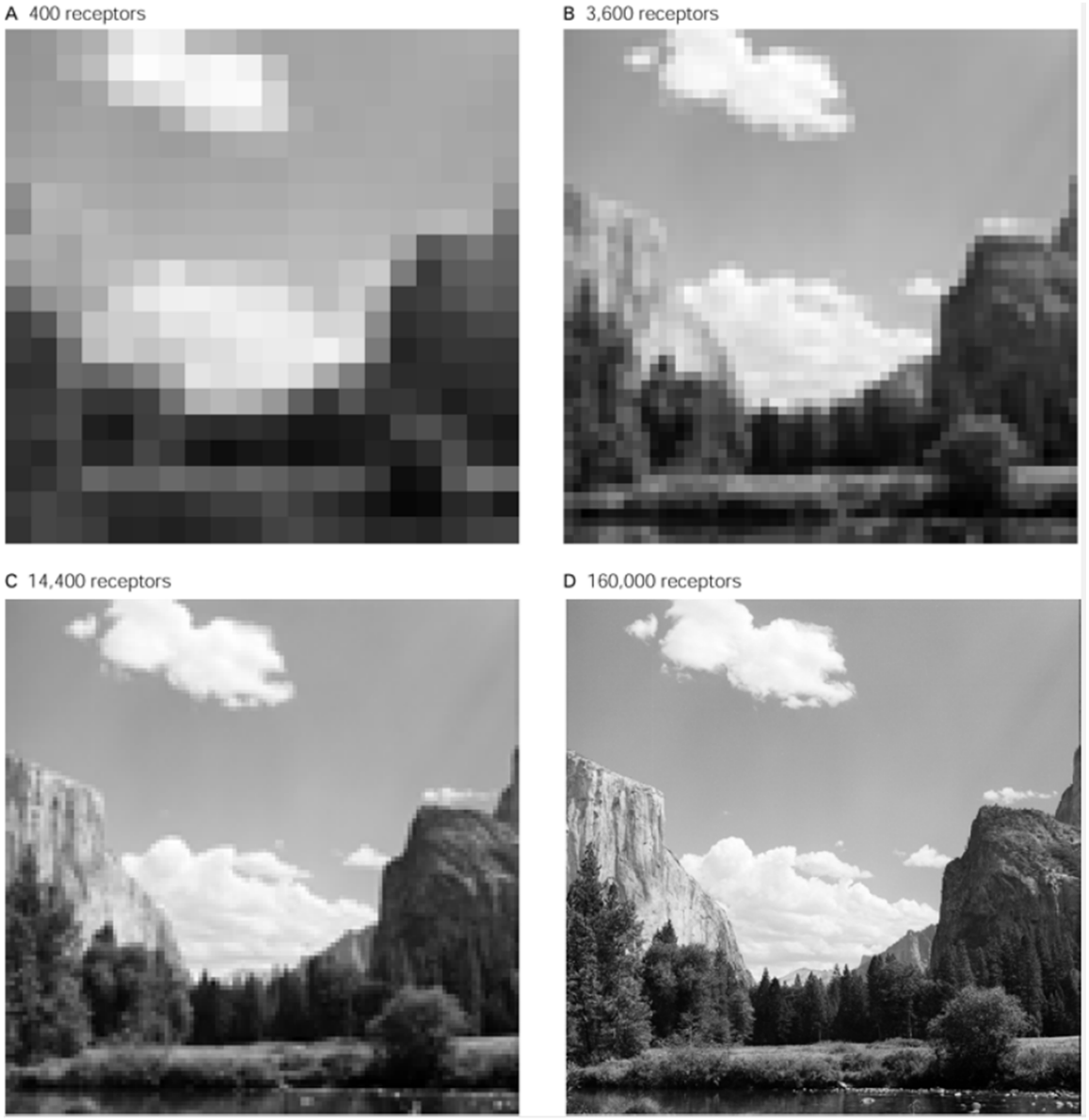


Receptive field

- dimensions of the receptive field
- The central neuron has a receptive field as well, determined by the receptive fields of the neurons that excite/inhibit it.



The spatial resolution is proportional to the total number of receptor neurons and also to the area of their individual receptive field.

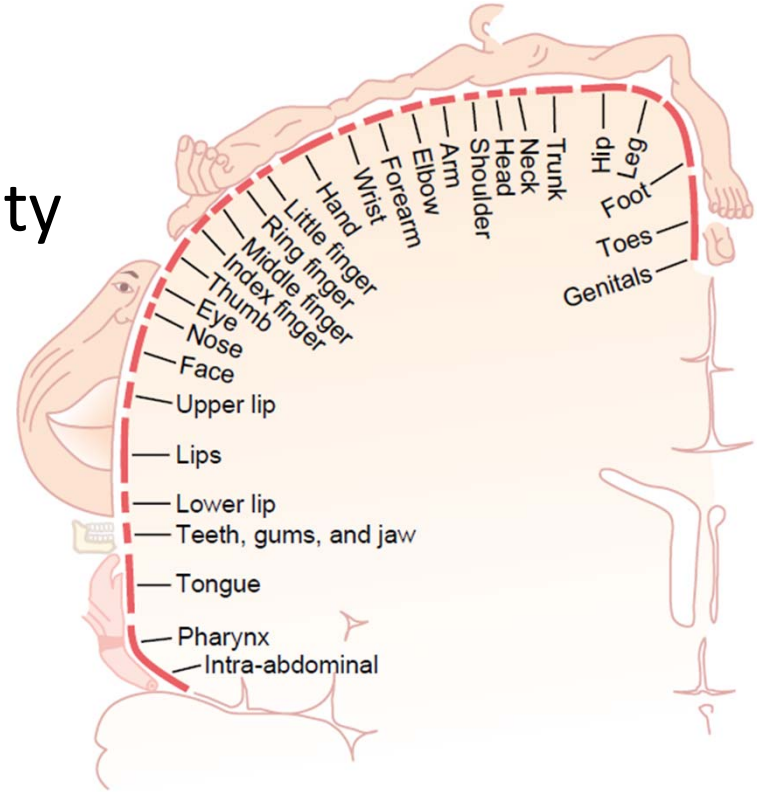


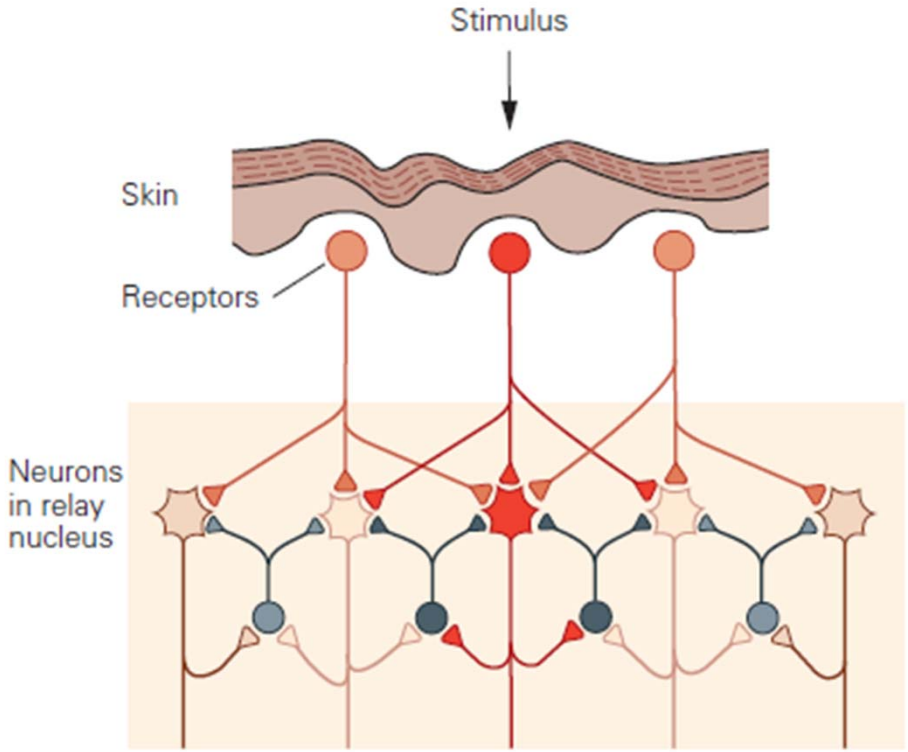
Sensory systems have a common plan

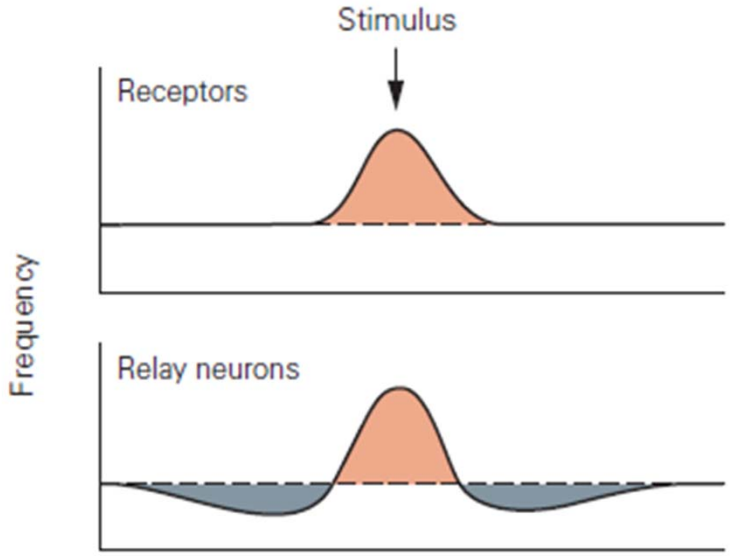
- each stimulus first fragmented into components, then, assembled within the neural networks of the brain to the internal representation of an object

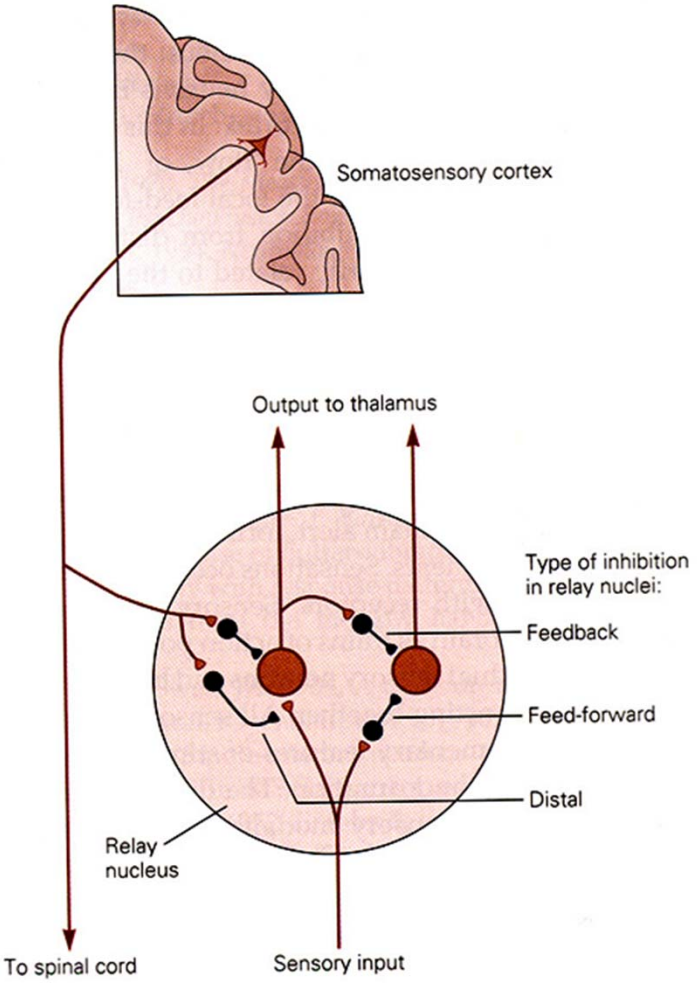
- each class of sensory receptors connected with CNS structures dedicated to one sensor modality + somatotopic organization

- hierarchy: thalamus – cortex (feedback)
- parallel and serial processing









Inhibitory interneurons

help to sharpen contrast between stimuli by various types of inhibition

Lateral inhibition