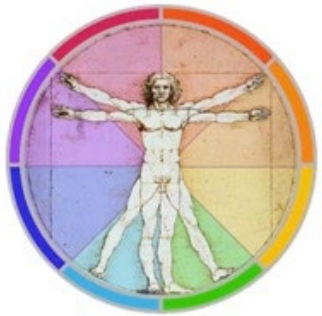
HUBS 191 Lecture Material

This pre-lecture material is to help you prepare for the lecture and to assist your note-taking within the lecture,
it is NOT a substitute for the lecture !



Please note that although every effort is made to ensure this pre-lecture material corresponds to the live-lecture there may be differences / additions.

HUBS 191

Jeff Erickson – Department of Physiology

Lecture 23
Neurophysiology 3: Sensory Receptors

Example exam question

Which of the following statements about neurotransmitters is NOT correct?

A. Neurotransmitters are stored in synaptic vesicles.
B. Neurotransmitters are released into the synaptic cleft when calcium levels rise.
C. Neurotransmitters are degraded by enzymes to terminate synaptic transmission.
D. Neurotransmitters are transported into the post-synaptic cell through chemically-gated channels.

Objectives and Study Guide

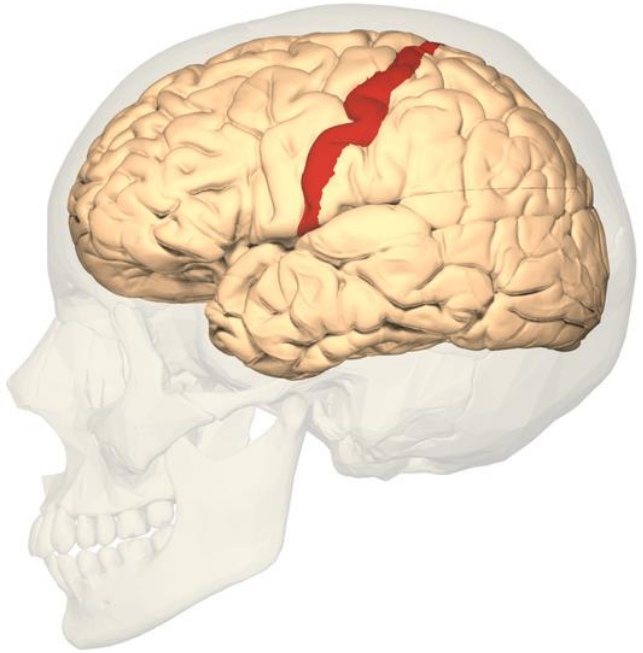
After this lecture you should be able to:

- Describe the three types general types of sensation
- Understand the difference between tonic and phasic receptors
- Summarize the functions and features of sensory receptors
- Describe how the intensity and location of a stimulus affects your perception of that stimulus

Related reading: Martini et al. Modules **13.2** (p. 532), **13.16-13.17** (p. 539-541), and **13.19** (p. 545)

Afferent vs. Efferent Signals

Afferent



Efferent

Afferent signals are sent to the central nervous system to give us information about our environment and our body homeostasis

Once you've processed this information, the central nervous system sends instructions to the rest of the body using **efferent signals**.

Afferent information is transmitted via sensory signals

Somatic senses:

- Perception of physical senses, like touch and temperature
- Can provide information about external or internal environment
- Tend to be highly specific in terms of location/direction
- Typically sensed by the skin, muscle, and joints

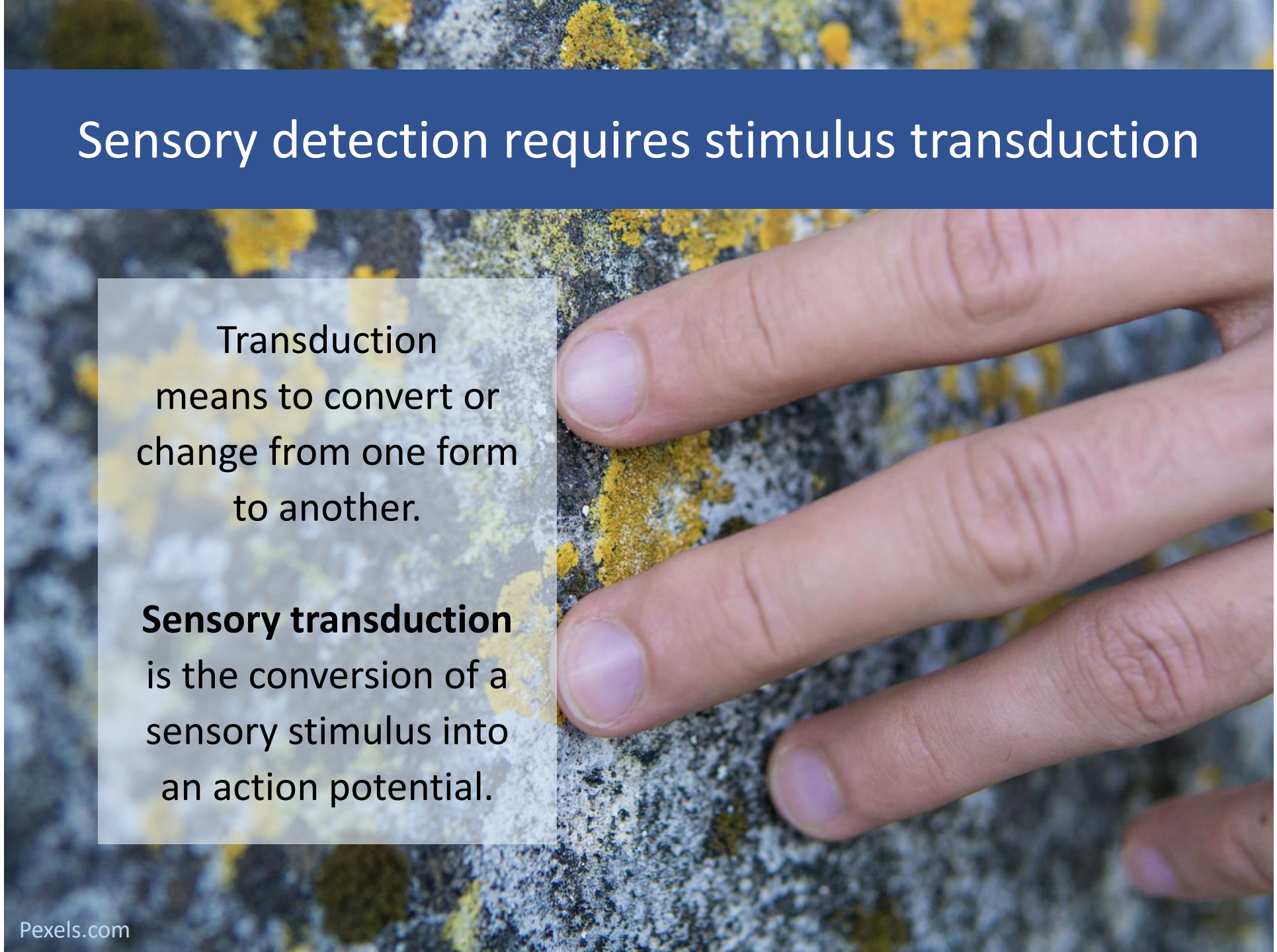
Visceral senses:

- Visceral means “deep down”…refers to senses that monitor your internal organs
- Often difficult to pinpoint a precise location, instead more of a generalized sense of well-being (or not)
- Examples are feeling full after a big meal, or feeling nauseous when ill

Special senses:

- Detected by highly specialized organs or structures
- Examples are vision (eyes), smell (nose), and taste (tongue & nose)

Sensory detection requires stimulus transduction

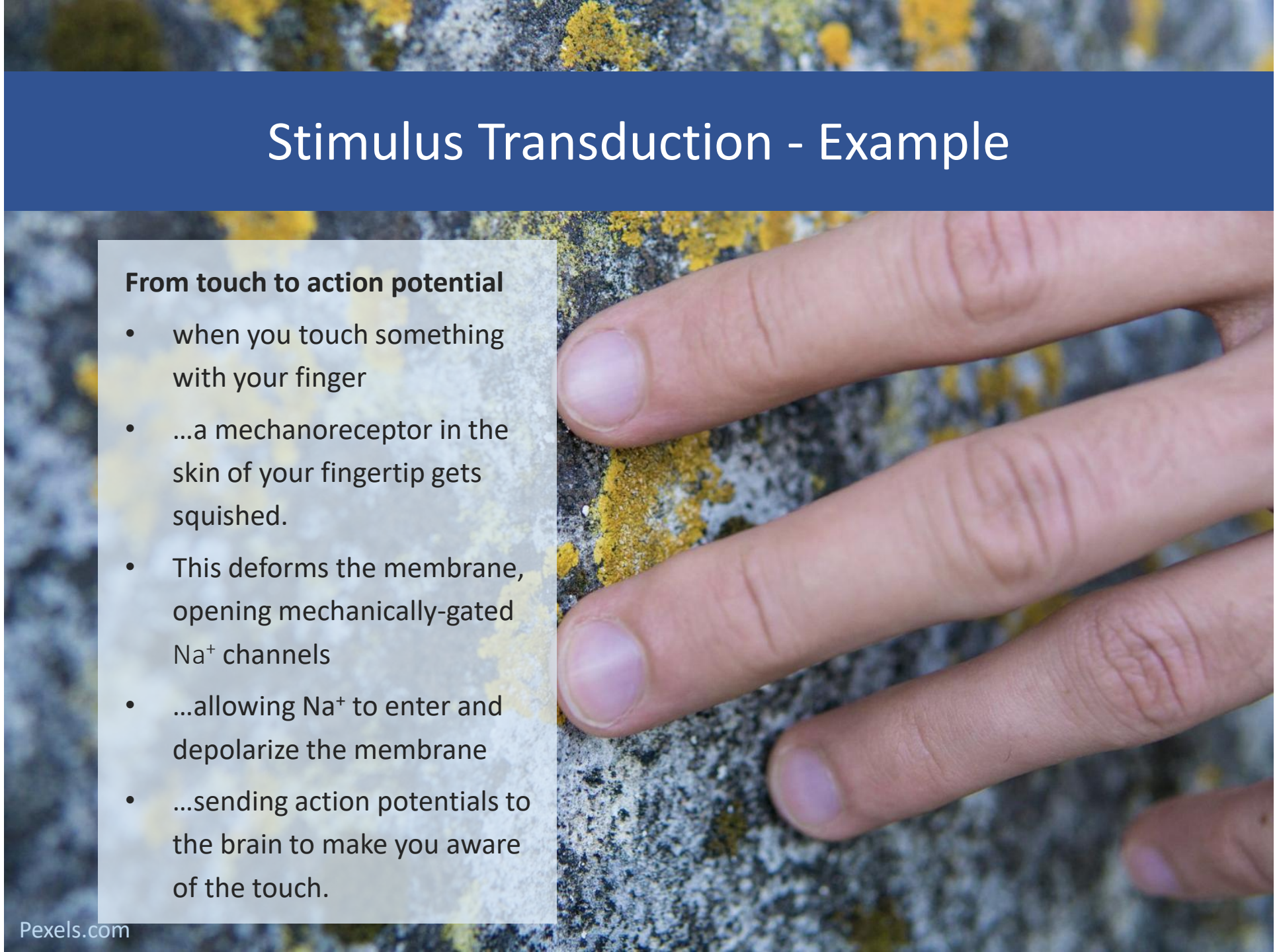


Transduction means to convert or change from one form to another.

Sensory transduction is the conversion of a sensory stimulus into an action potential.

Pexels.com

Stimulus Transduction - Example



From touch to action potential

- when you touch something with your finger
- …a mechanoreceptor in the skin of your fingertip gets squished.
- This deforms the membrane, opening mechanically-gated Na^+ channels
- …allowing Na^+ to enter and depolarize the membrane
- …sending action potentials to the brain to make you aware of the touch.

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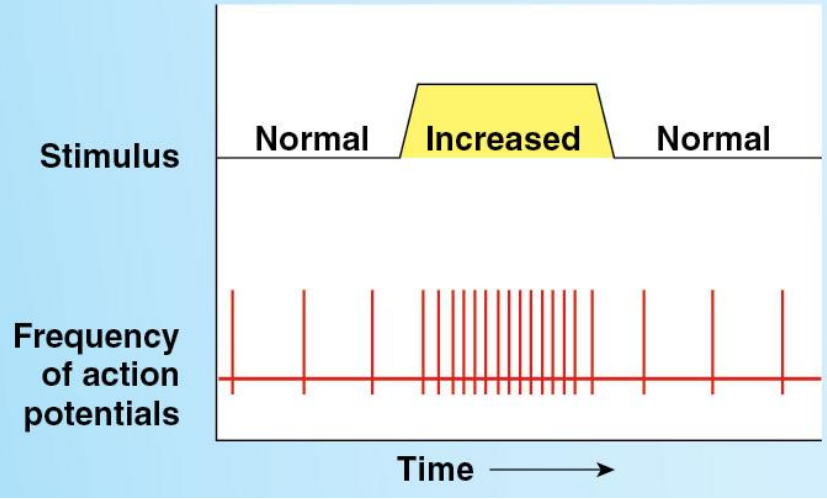
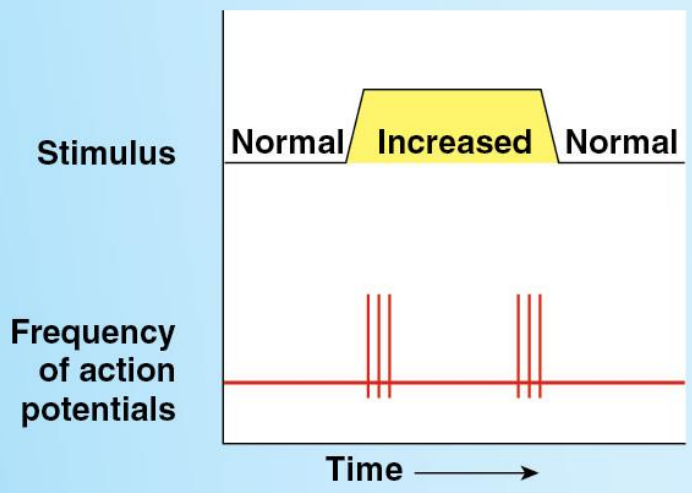
Tonic (slow-adapting) vs Phasic (fast-adapting) Receptors

Tonic Receptors



- Continually active to reflect background level of stimulation
- AP frequency changes when stimulus intensity changes
- Example: proprioceptors (body position)
- Slow adapting

Phasic Receptors



- Normally silent (No APs)
- Send APs with change but stop quickly
- Example: temperature receptors
- Fast adapting

What's the benefit of adaptation?

Sensory receptor types: Thermoreceptors

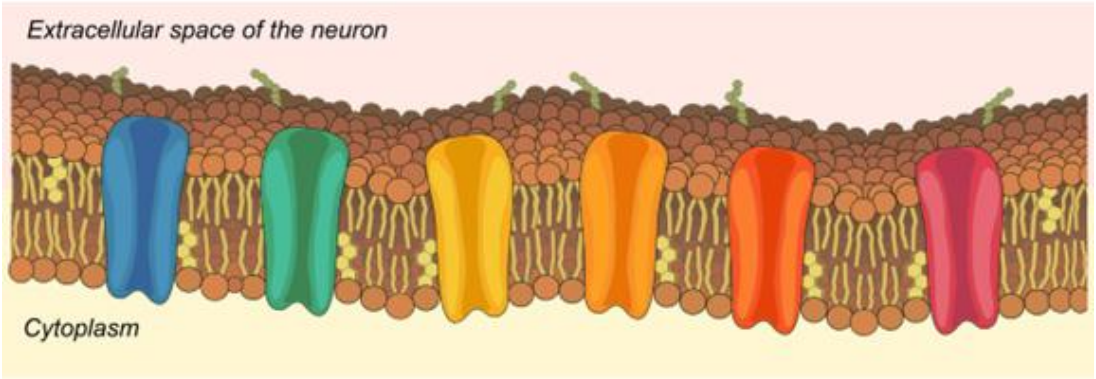
Thermoreceptors:

- are nerve endings with temperature-gated ion channels
- respond to different temperatures and also changes in temperature
- are phasic (fast-adapting)

Transduction of temperature stimuli:

- Temperature stimuli open temperature-gated Na^+ channels
- Allowing Na^+ to enter and depolarize the membrane
- If threshold is reached in the thermoreceptor, an AP will fire and propagate to the brain

Temperature-gated ion channels

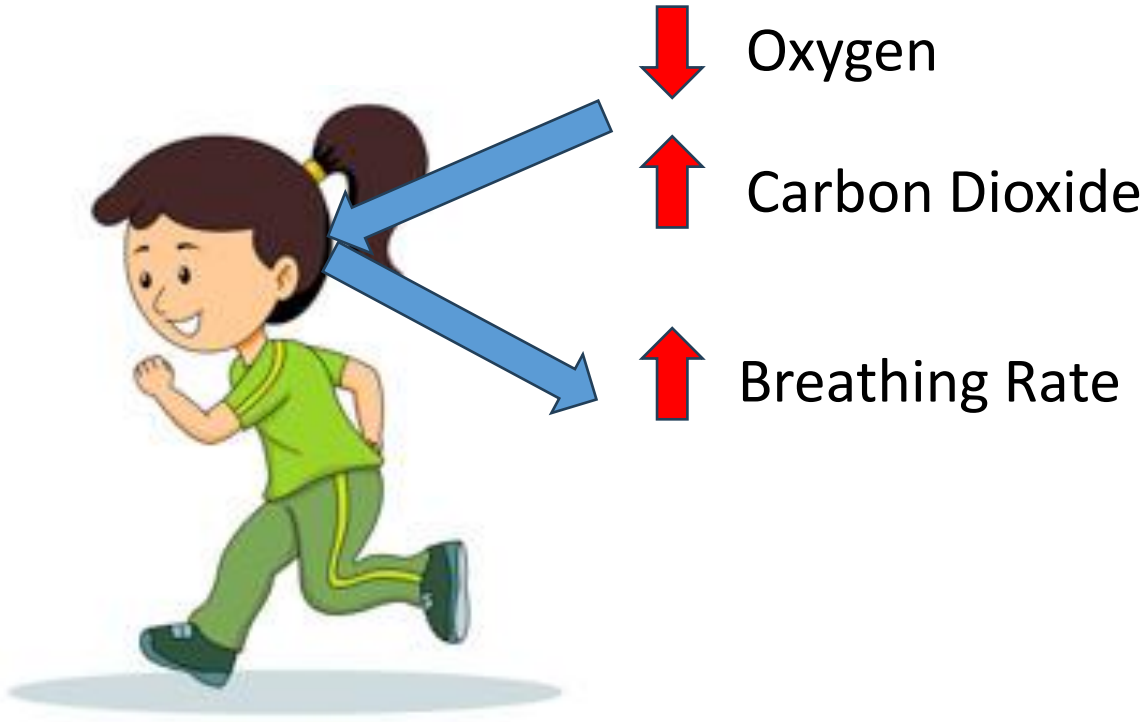


Details of this image are to show concept, and are NOT testable

Sensory receptor types: Chemoreceptors

Chemoreceptors:

- are specialized receptor cells with chemically-gated ion channels
- translate changes in chemical concentration to action potentials
- can be fast or slow-adapting depending on the chemical and location
- examples include oxygen, CO_2, and acid receptors
- more about this in HUBS192



Sensory receptor types: Mechanoreceptors

Mechanoreceptors:

- are nerve endings with mechanically-gated ion channels
- respond to physical forces that distort the plasma membrane (deformation)
- light touch receptors are typically phasic (fast-adapting), while proprioceptors and baroreceptors are tonic (slow-adapting)

Tactile Sensation

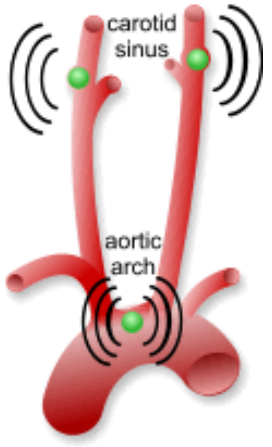
Sense of touch, including pressure and stretch of the skin

Proprioception

Sense of body position and movement in space, which comes from stretch receptors in muscles, tendons and joints

Baroreception

Detect pressure/stretch in vessels within the body



Sensory receptor types: Nociceptors

Nociceptors:

- are nerve endings that respond to noxious stimuli (harmful, painful) typically caused by tissue damage
- have either temperature-gated, chemically-gated or mechanically-gated ion channels responding to extreme stimuli (e.g. excess heat or cold; chemical or membrane deformation)
- tend to be tonic (slow-adapting), though some are phasic (fast-adapting)

Cheat sheet for sensory receptors

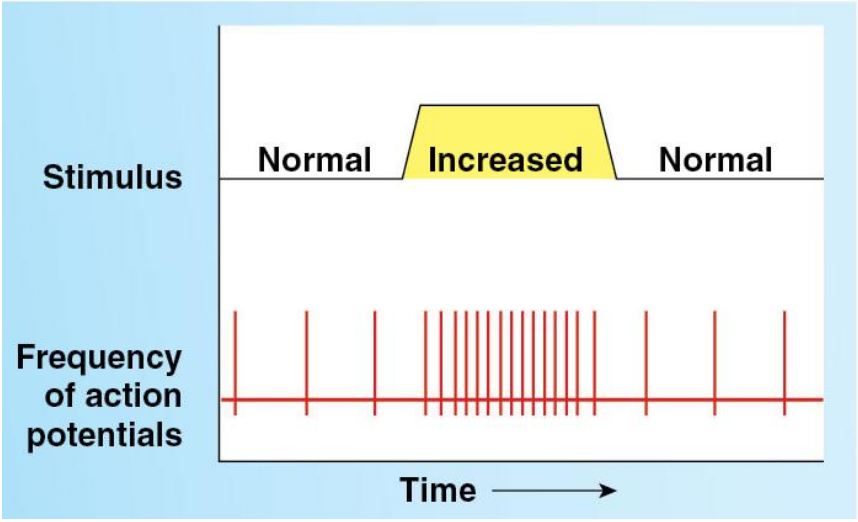
Receptor	Sense	Stimulus examples	Tonic or phasic?
1. **Thermoreceptor**	Temperature	Relative temperature (ranges)	Phasic
2. **Chemoreceptor**	Chemicals	CO_2, O_2, H^+ concentration in blood	Tonic/Phasic
3. **Mechanoreceptor** Sub-type: **Tactile receptors**	Skin touch	Light touch, pressure, texture, vibration, stretch	Mostly phasic
3. **Mechanoreceptor** Sub-type: **Proprioceptor**	Proprioception (limb position related to the torso/trunk)	Stretch or tension in muscle, tendons and joints	Tonic
3. **Mechanoreceptor** Sub-type: **Baroreceptor**	Pressure	Stretch of visceral tubes (e.g. blood vessels, airways, intestines)	Tonic
4. **Nociceptor**	Pain	Excess temperature, chemical or mechanical stimuli	Mostly tonic

Each type of receptor is stimulated by a specific type of stimulus

Example exam question

If a receptor responds to stimuli with the pattern of action potentials seen in the figure to the right, which of the following is most likely to be CORRECT?

A. It is slow adapting.
B. It is a phasic receptor.
C. It is a thermoreceptor.
D. It is normally silent.



The intensity of sensation is determined by action potential frequency and number of neurons activated

The brain interprets stimulus intensity based on the # of action potentials (APs) arriving from afferent neurons

- No APs = no sensation
- Some APs = some sensation
- More APS = more intense sensation

Examples:

- Mild stimuli (e.g. soft light, warm surface) causes few APs
- Intense stimuli (e.g. bright light, hot surface) causes many APs

The intensity of sensation is determined by action potential frequency and number of neurons activated

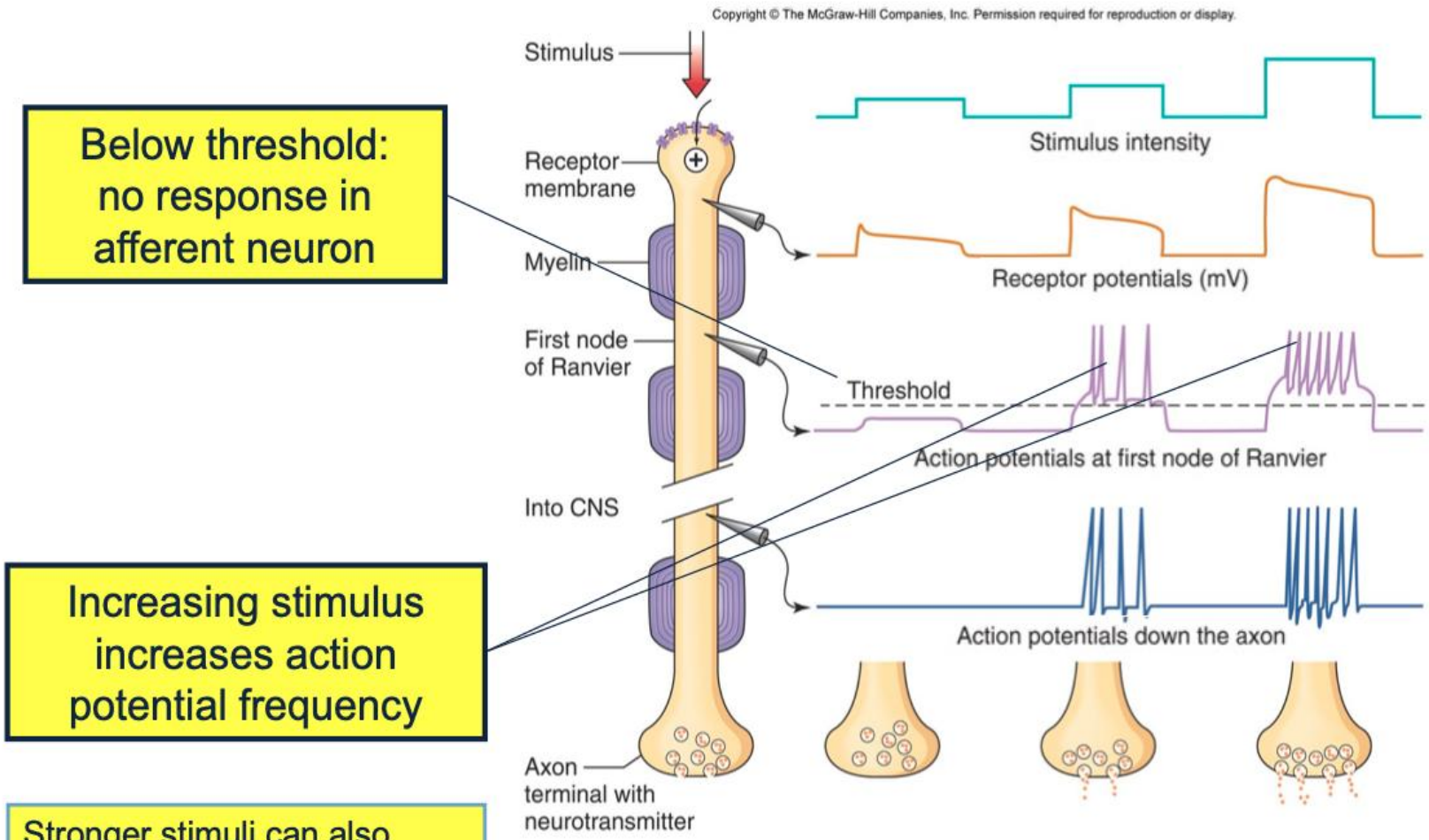
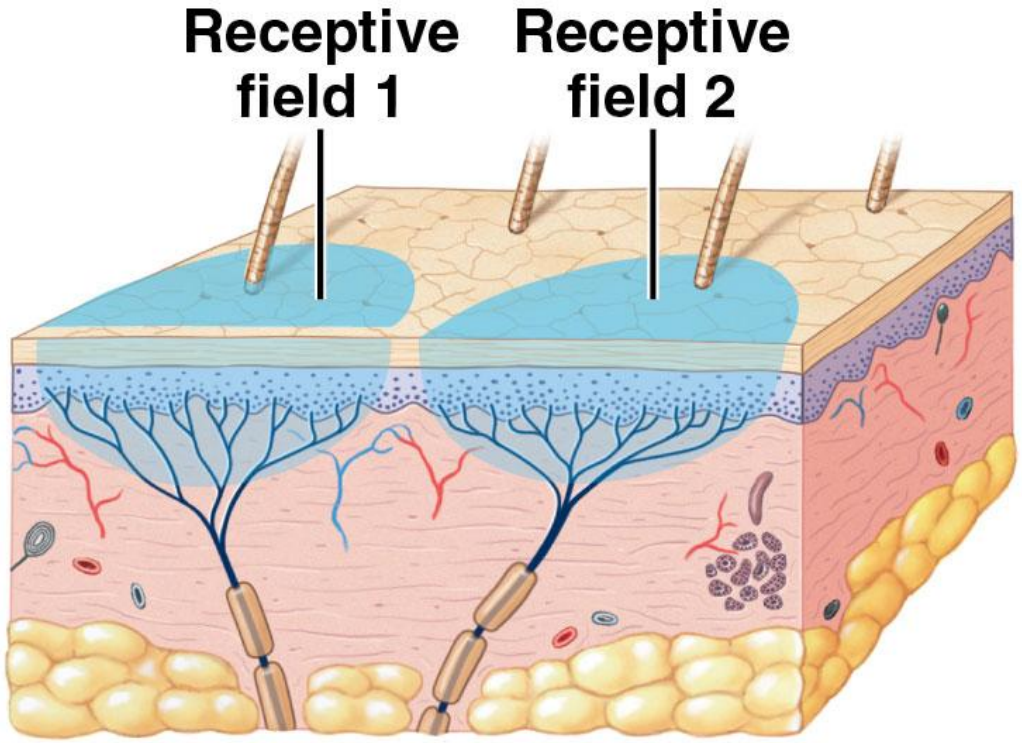


Figure 7.02. Vander's Human Physiology (11th ed.)

The receptive field is the area encompassed by nerve endings for a single sensory neuron

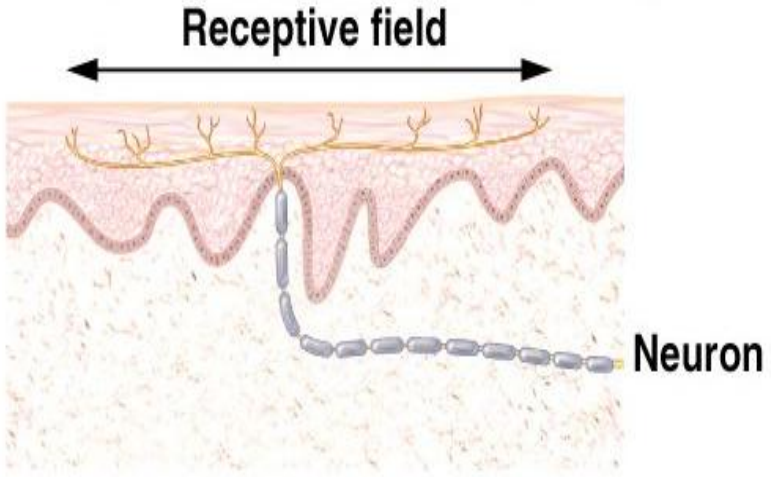
- The area of skin with receptive endings for a single sensory neuron
- Each sensory neuron has its own receptive field
- Size and density of receptive fields affect discriminatory touch (sensitivity) and ability to localize a stimulus.



The number and size of receptive fields determines the localization accuracy of sensation

Large and more widely spaced receptive fields provide:

- less sensitivity and
- less accurate localization
- e.g. in arms, legs, torso



Small and densely packed receptive fields provide:

- More sensitivity (better two-point discrimination)
- more accurate localization
- e.g. hand, fingers and lips

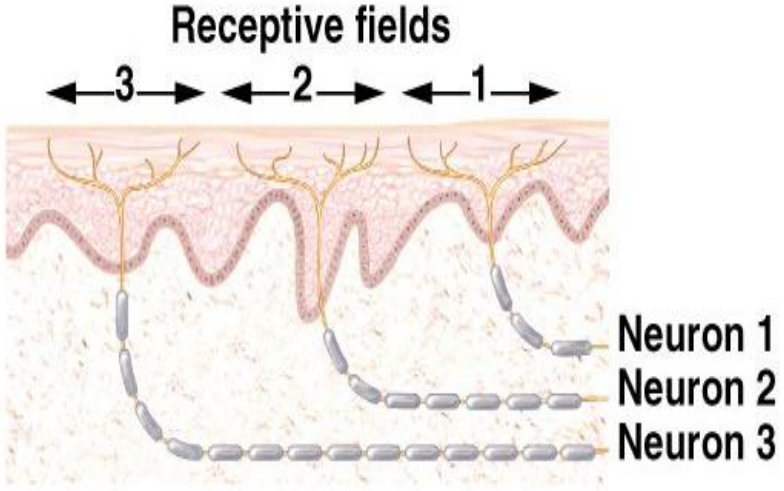
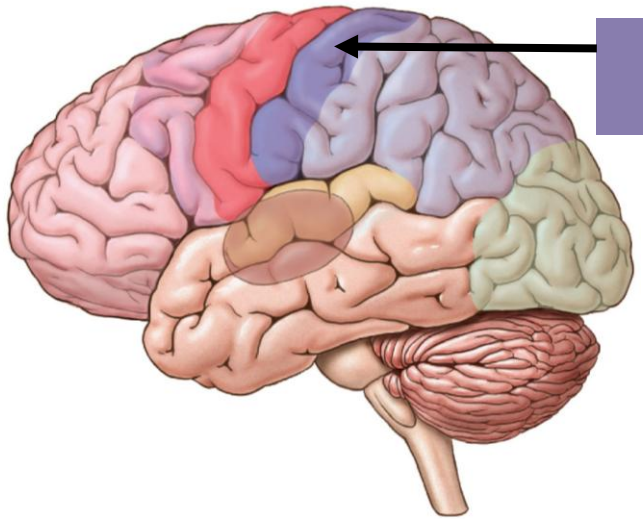


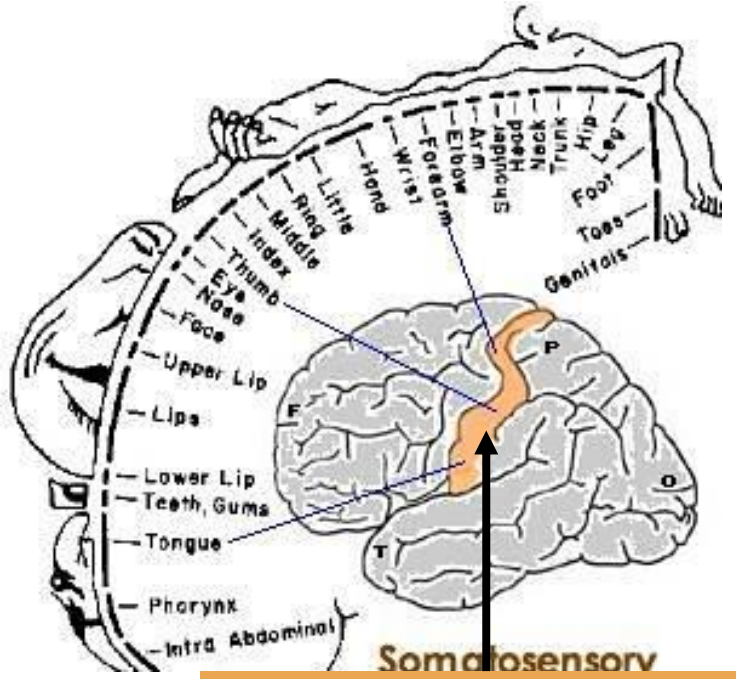
Fig 16-01, Saladin, 3rd. Edn, 2004 p587.

Somatic signals are largely interpreted by the somatosensory cortex of the brain

- Somatic sensory neurons send signals from different parts of the body
- Up axons within the dorsal column pathway
- to the somatosensory cortex of the brain
- Creating a somatotopic map



Primary somatosensory cortex (Post-central gyrus)



Primary somatosensory cortex (Post-central gyrus)

Photo credits: Brain Flickr.com,

Receptive fields and the somatotopic map

Example 1: Trunk/torso and limbs

- Areas of skin with **larger** receptive fields
- have **less** representation in the brain because there are **fewer** neurons involved
- Remember: 1 sensory neuron per receptive field

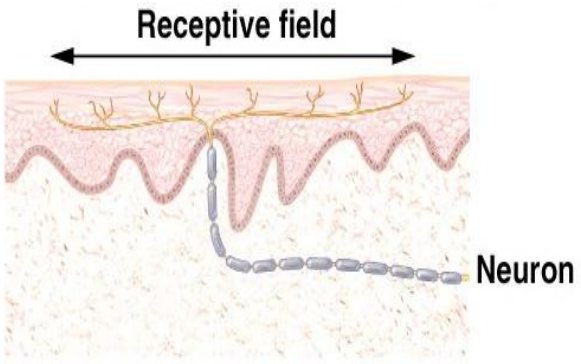


Fig 16-01, Saladin, 3rd. Edn, 2004 p587.

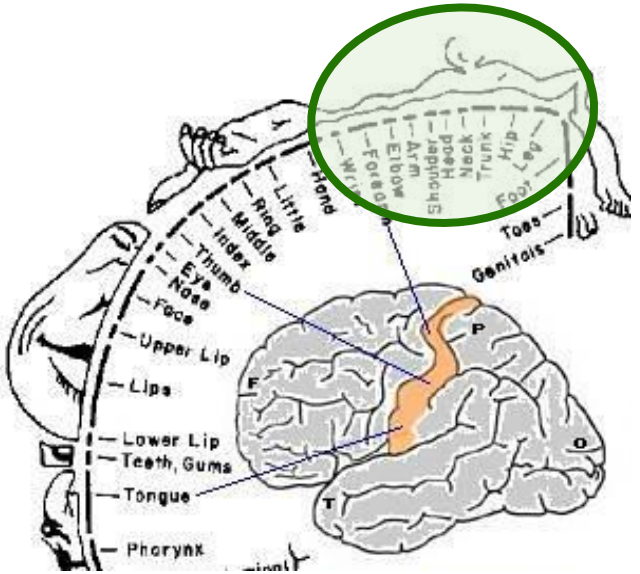


Photo credits: Brain Flickr.com, Humunculus man Wikipedia.org

Receptive fields and the somatotopic map

Example 2: Lips and hands

- Areas of skin with **smaller** receptive fields
- have **more** representation in the brain because there are **more** neurons involved
- Remember: 1 sensory neuron per receptive field

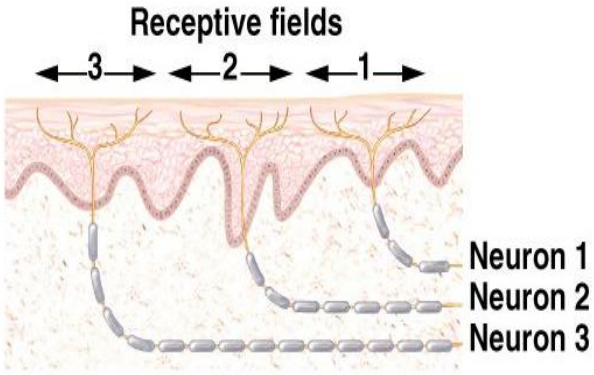


Fig 16-01, Saladin, 3rd. Edn, 2004 p587.

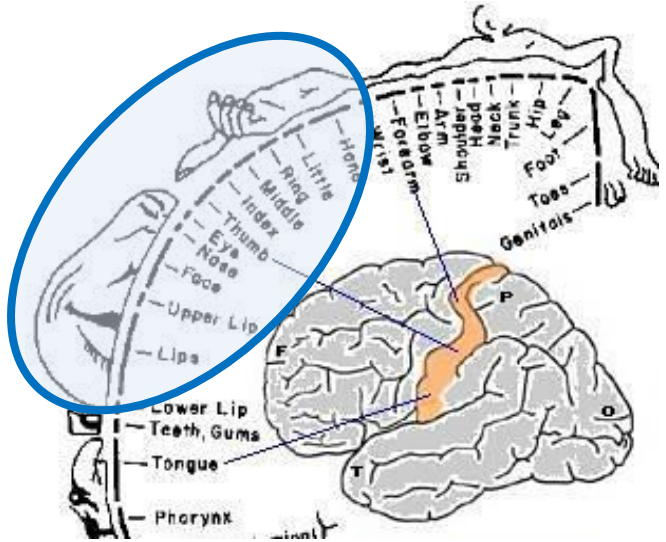


Photo credits: Brain Flickr.com, Humunculus man Wikipedia.org

Wrapping up…

- Sensation can be broadly classified into somatic, visceral, and special senses
- Tonic receptors (slow-adapting) send a constant signal that speeds up and slows down, while phasic receptors (fast-adapting) are silent in normal conditions and send signals when stimulated
- Thermoreceptors, chemoreceptors, mechanoreceptors, and nociceptors are key examples of receptors that contribute to sensory transduction
- The intensity of sensation is determined by action potential frequency, while the localization of sensation is determined by the size and number of receptive fields

Example exam question

Areas of skin with large and widely-spaced receptive fields:

A. always yield very intense stimuli.
B. are associated with visceral sensation.
C. provide a low accuracy of signal localization.
D. are common in the fingers, hands, and lips.

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