Overview of Questions

- What are the sensors in the skin, what do they respond to and how is this transmitted to the brain?
- How does the brain represent touch information?
- What is the system for sensing pain? How is pain signaled to the brain?
- How does knowledge and experience modulate touch and pain perception?

Somatosensory System

There are three parts:

1. Cutaneous senses - perception of touch and pain from stimulation of the skin
2. Proprioception - ability to sense position of the body and limbs
3. Kinesthesis - ability to sense movement of body and limbs

Skin

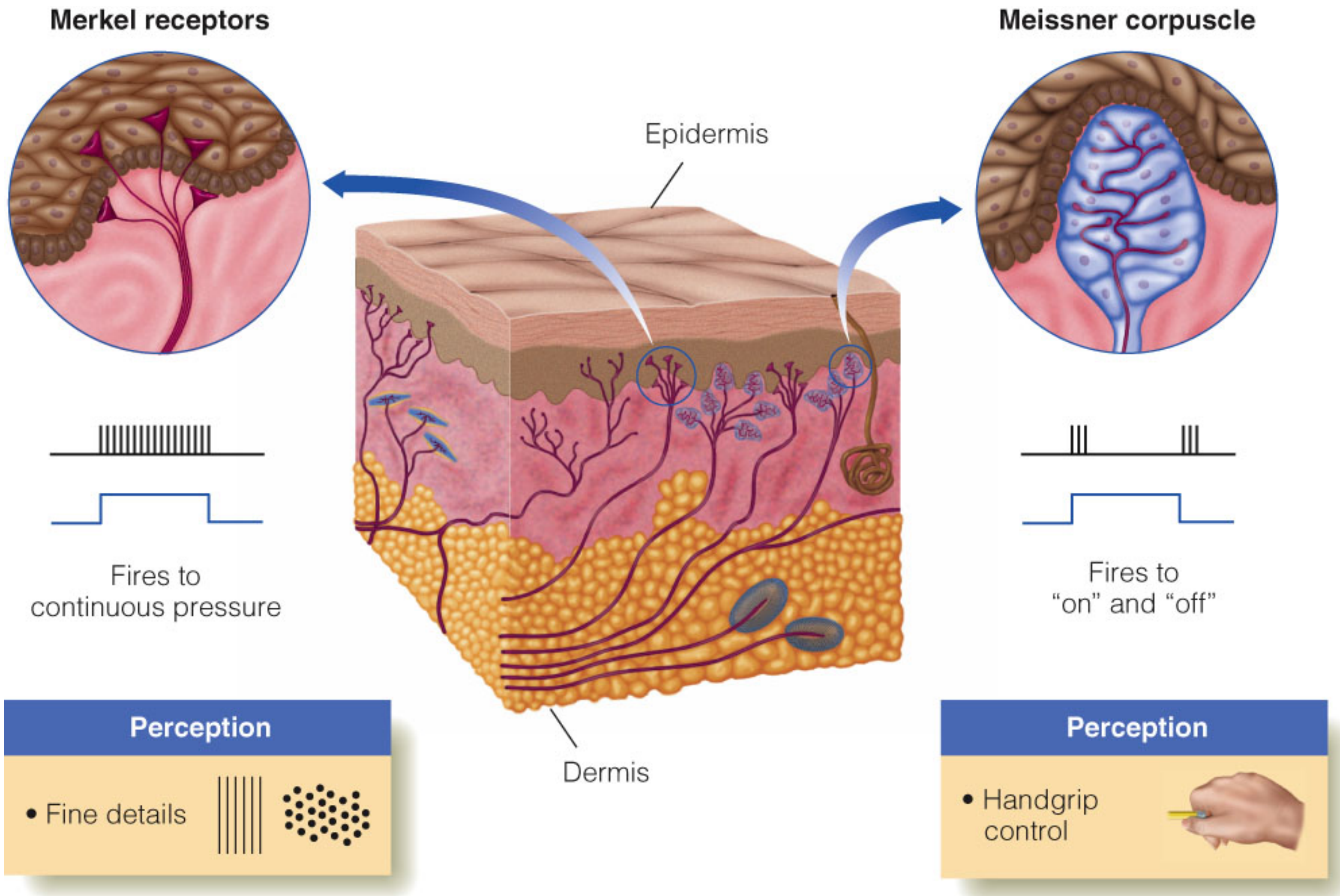
- Protects the organism by keeping damaging agents from penetrating the body.
- Epidermis is the outer layer of the skin, which is made up of dead skin cells.
- Dermis is below the epidermis and contains *mechanoreceptors* that respond to stimuli such as pressure, stretching, and vibration.

Mechanoreceptors

Two types located close to surface of the skin:

1. Merkel receptor fires continuously while stimulus (pressure) is present.
   Involved in sensing fine details.

2. Meissner corpuscle fires only when a stimulus is first applied and when it is removed.
   Involved in controlling hand-grip.

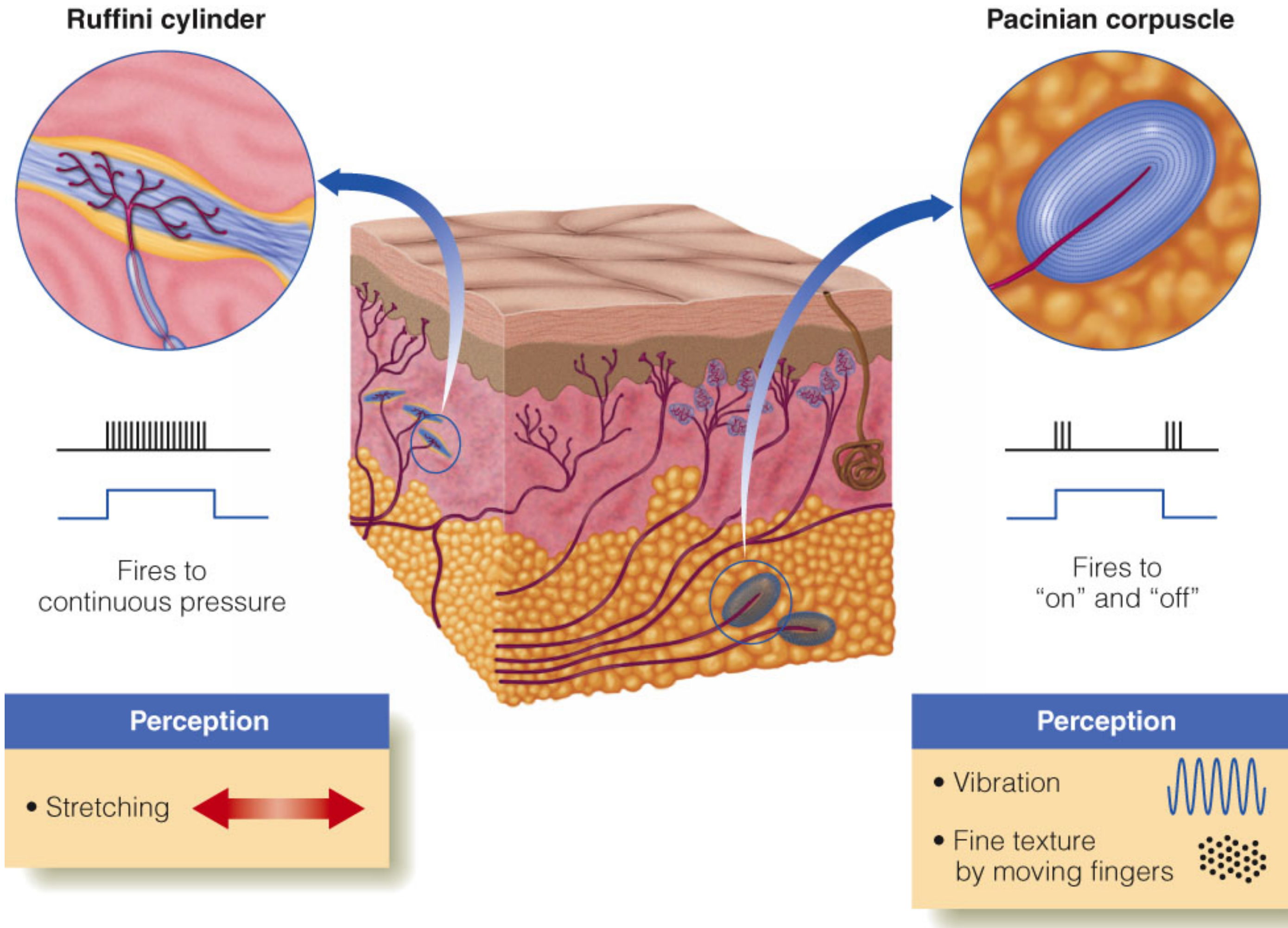

Merkel receptors
Meissner corpuscle
Epidermis
Fires to
continuous pressure
Fires to
"on" and "off"
Dermis
Perception
• Fine details
Perception
• Handgrip
control

Mechanoreceptors - continued

Two types located deeper in the skin:

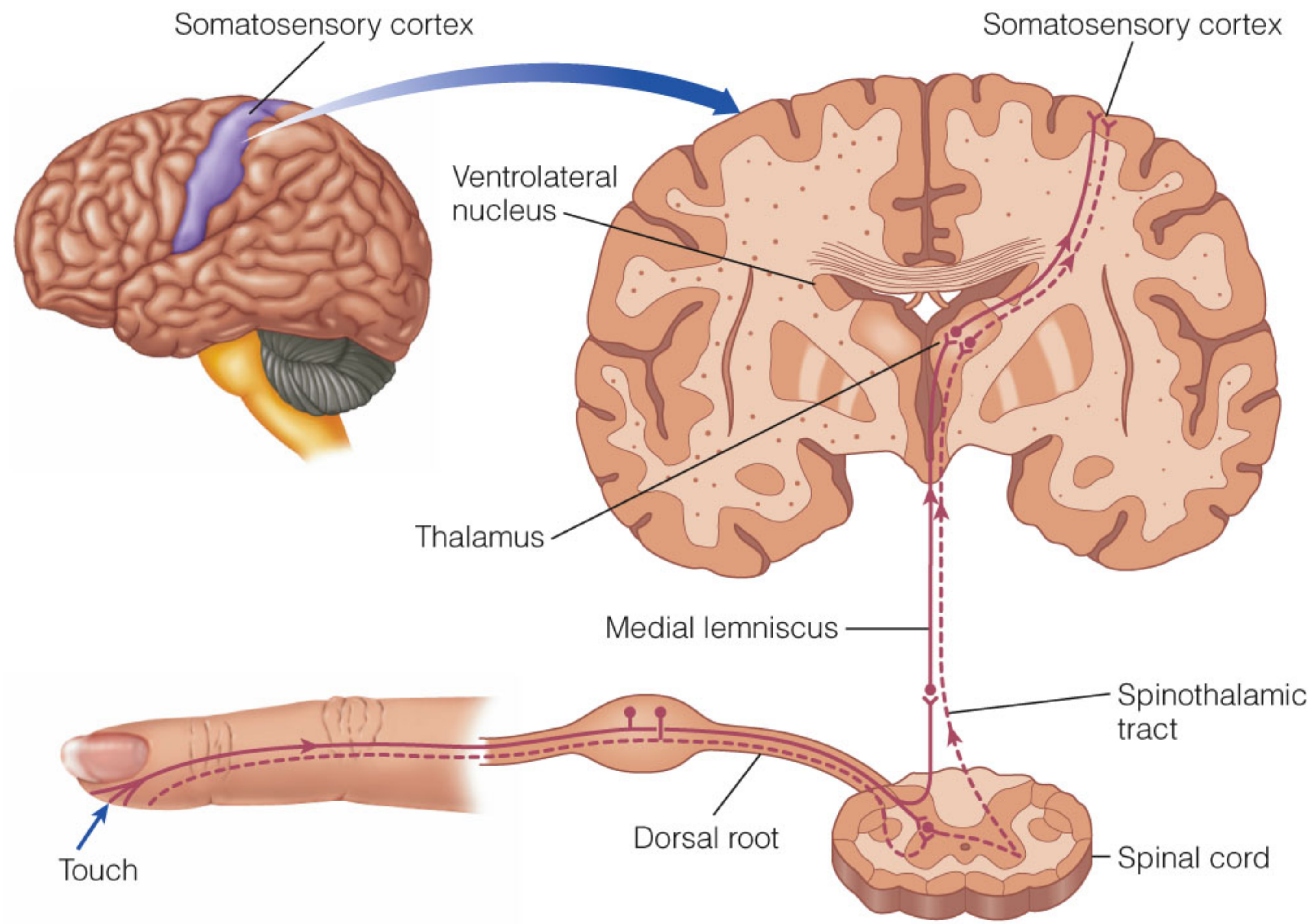
3. Ruffini cylinder fires continuously to stimulation.
   Associated with perceiving stretching of the skin.

4. Pacinian corpuscle fires only when a stimulus is first applied and when it is removed.
   Associated with sensing rapid vibrations and fine texture.


Ruffini cylinder
Pacinian corpuscle
Fires to
continuous pressure
Fires to
"on" and "off"
Perception
• Stretching
Perception
• Vibration
• Fine texture
by moving fingers

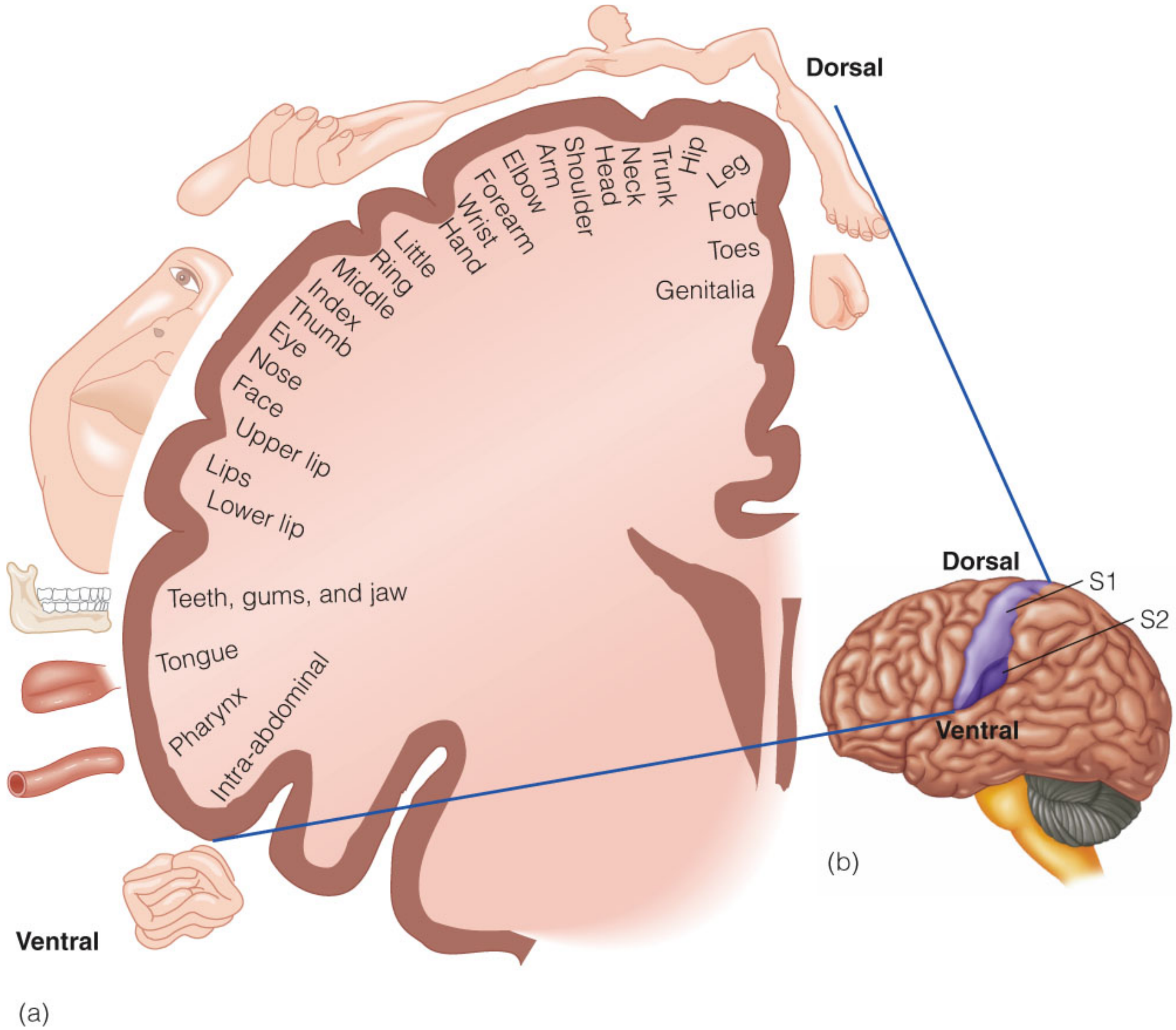
Pathways from Skin to Cortex

- Nerve fibers travel in bundles (peripheral nerves) to the spinal cord.
- Two major pathways in the spinal cord:
  - Medial lemniscal pathway consists of large fibers that carry *proprioceptive* and *“touch”* information.
  - Spinothalamic pathway consists of smaller fibers that carry *temperature* and *pain* information.
  - These pathways cross over to the opposite side of the body and synapse in the thalamus.


Somatosensory cortex
Somatosensory cortex
Ventrolateral nucleus
Thalamus
Medial lemniscus
Spinothalamic tract
Touch
Dorsal root
Spinal cord

Maps of the Body on the Cortex

- Signals travel from the thalamus to the somatosensory receiving area (S1) and the secondary receiving area (S2) in the parietal lobe.
- Body map (homunculus) on the cortex in S1 and S2 shows more cortical space allocated to parts of the body that are responsible for detail.
- Plasticity in neural functioning leads to multiple homunculi and changes in how cortical cells are allocated to body parts.


Dorsal
Hip
Leg
Trunk
Neck
Head
Shoulder
Arm
Elbow
Forearm
Wrist
Hand
Little
Ring
Middle
Index
Thumb
Eye
Nose
Face
Upper lip
Lips
Lower lip
Teeth, gums, and jaw
Tongue
Pharynx
Intra-abdominal
Foot
Toes
Genitalia
Ventral
(a)
Dorsal
S1
S2
Ventral
(b)

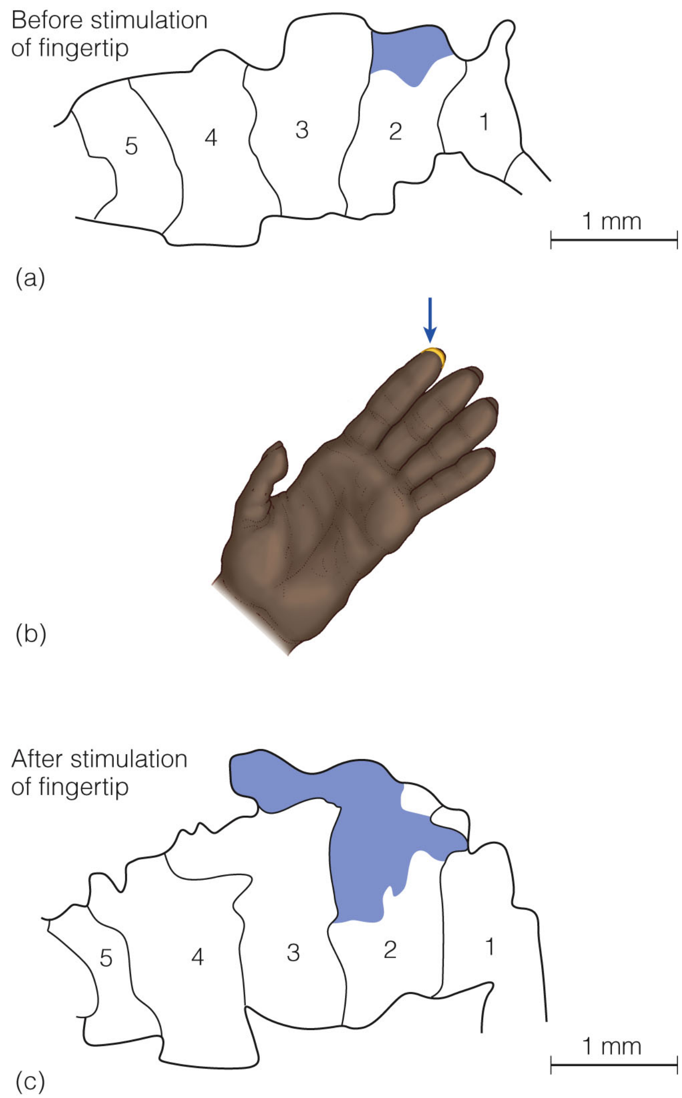
Influence of Experience

Experience with touch can lead to changes in the region of the cortex (e.g. S1) that represents parts of the body.

Merzenich et. al. showed that the part of the cortex representing the tip of the index finger in the monkey increased in area after two months of extensive use of the finger tip.

fMRI data of musicians shows expanded cortical areas related to their use of the hands in playing their instrument (e.g. left hand fingers for a violinist).

From Merzenich et. al., 1988



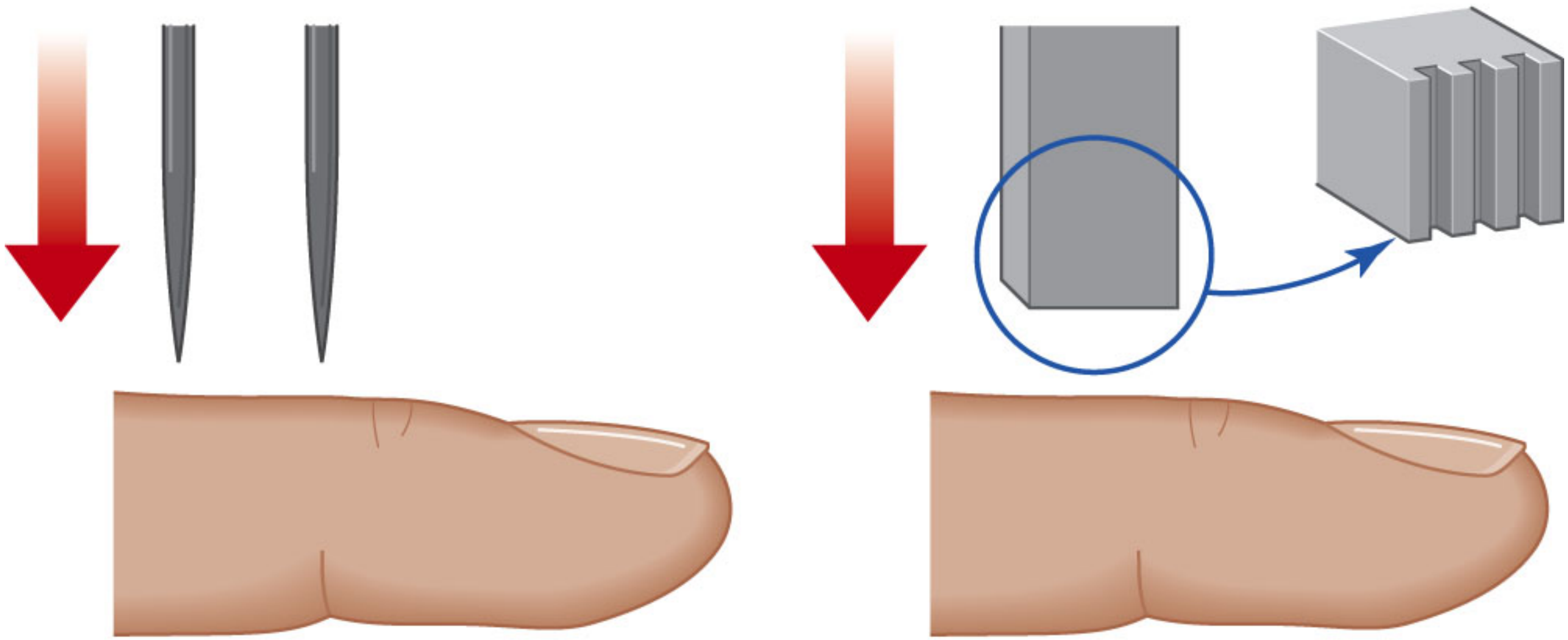
Perceiving Details

Measuring tactile acuity:

1. Two-point threshold - minimum separation needed between two points to perceive them as two units.

2. Grating acuity - placing a grooved stimulus on the skin and asking the participant to indicate the orientation of the grating (grooves).

3. Raised pattern identification - using such patterns (e.g. the dot patters of Braille) to determine the smallest size that can be identified.



(a) One point or two?

(b) Grating vertical or horizontal?

Receptor Mechanisms for Tactile Acuity

There is a (relatively) high density of Merkel receptors in the fingertips. This is similar to the higher density of cones in the fovea in the visual system.

Both two-point thresholds and grating acuity studies show that fine detail perception is better (lower threshold) on the fingertips.

Areas with higher acuity also have smaller receptive fields.

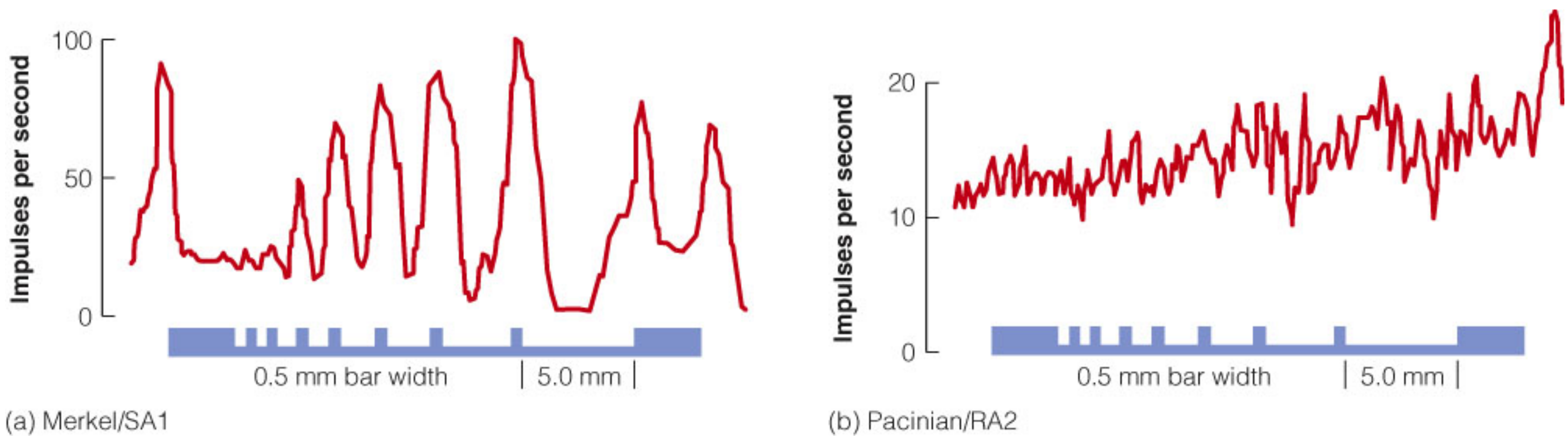


Figure 14.8 (a) The firing of the fiber associated with a Merkel receptor to the grooved stimulus pattern. (b) The firing of the fiber associated with a Pacinian corpuscle to the same grooved pattern. Results such as these indicate that the Merkel receptor signals details *(Johnson, 2002). (Adapted from Phillips & Johnson, 1981.)*

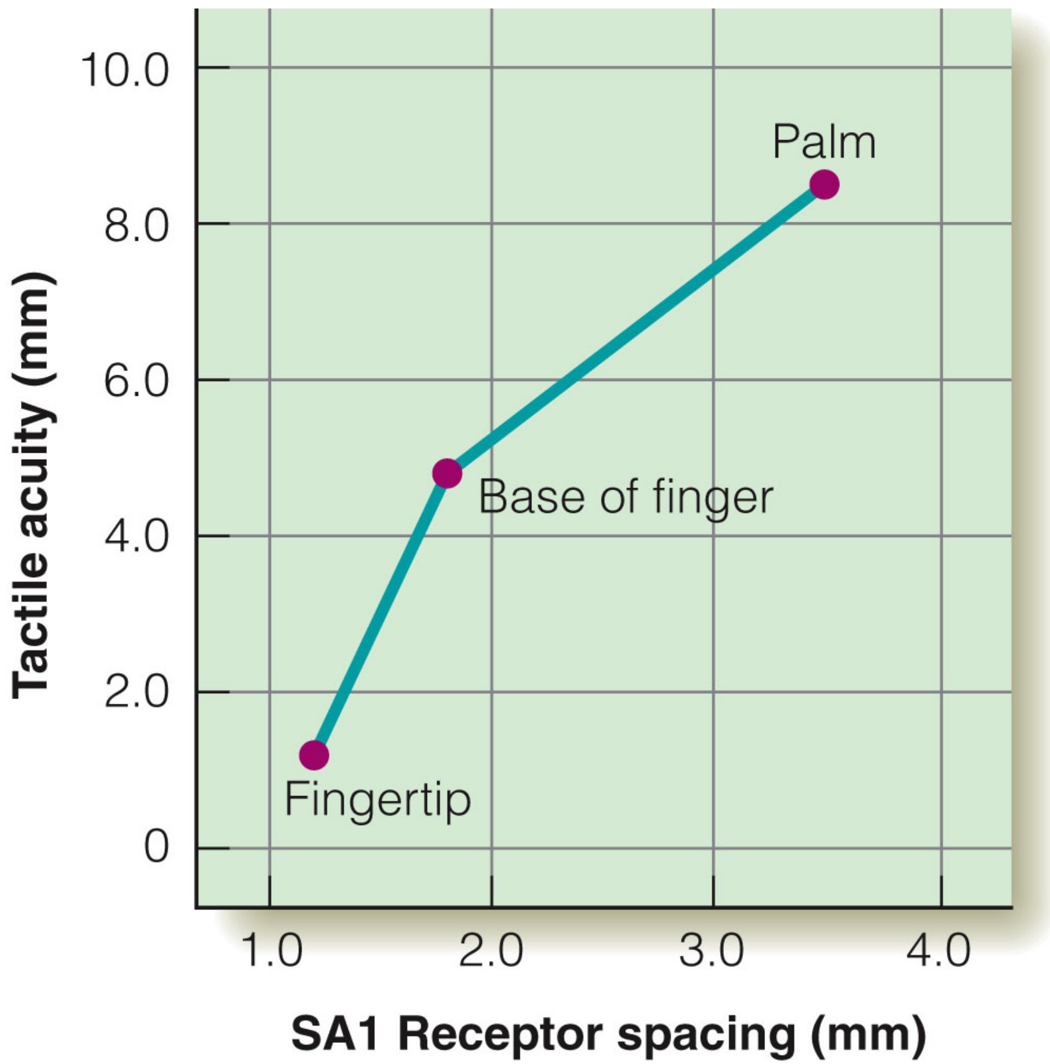


Figure 14.9 Correlation between density of Merkel receptors density and tactile acuity. (*From Craig & Lyte, 2002.*)

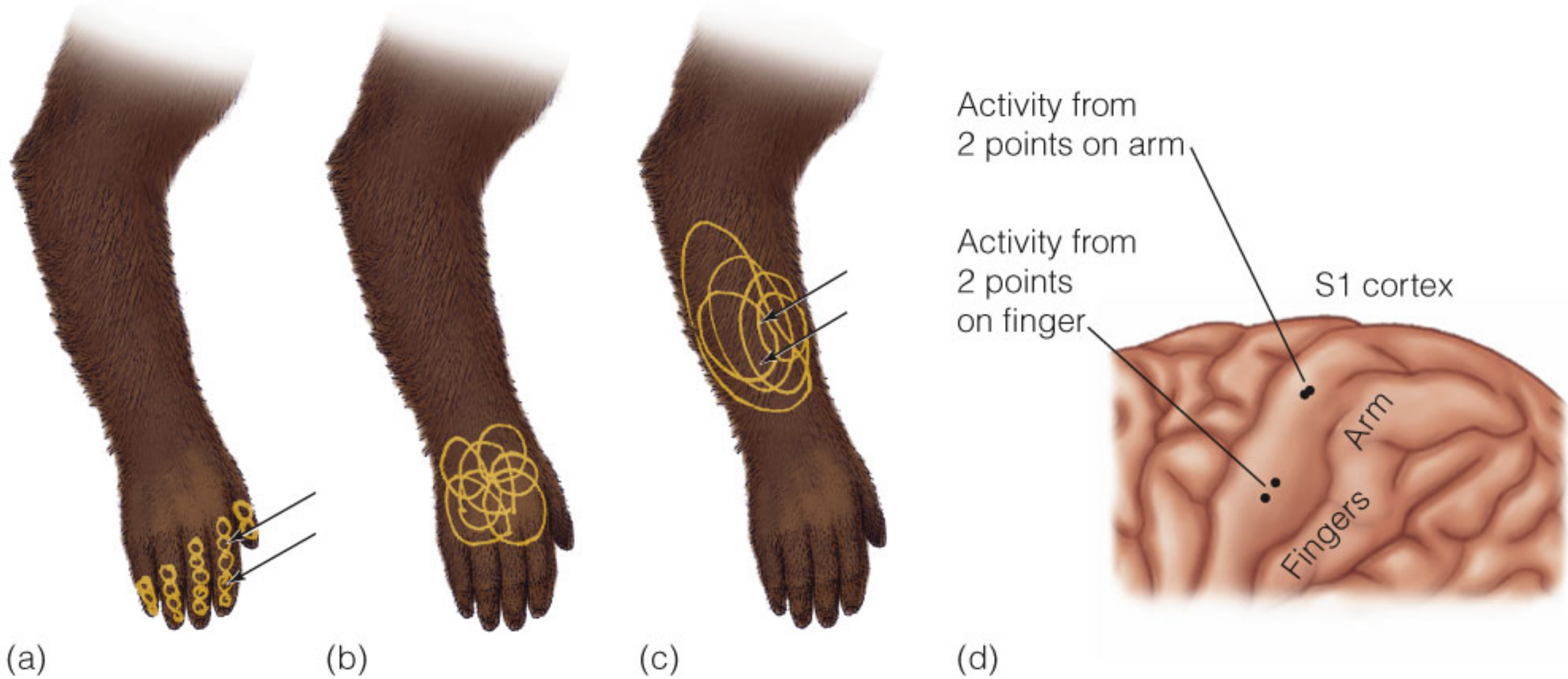


Figure 14.11 Receptive fields of monkey cortical neurons that fire (a) when the fingers are stimulated; (b) when the hand is stimulated; and (c) when the arm is stimulated. (d) Stimulation of two nearby points on the finger causes separated activation on the finger area of the cortex, but stimulation of two nearby points on the arm causes overlapping activation in the arm area of the cortex. (From Kandel & Jessell, 1991 (a-c).

Perceiving Vibration

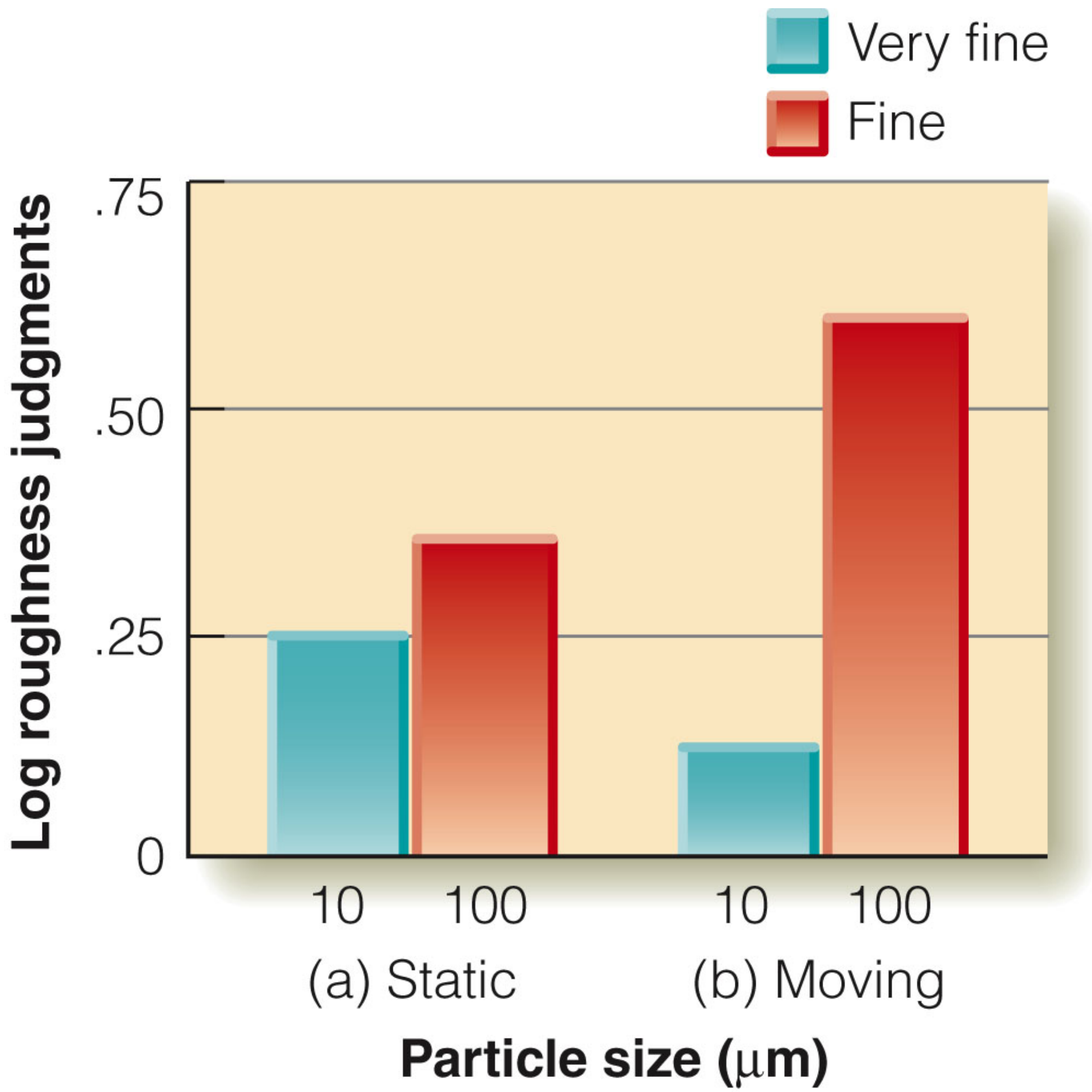
Pacinian corpuscle (PC) is primarily responsible for sensing vibration. Nerve fibers associated with PCs respond best to high rates of vibration.

Perceiving Texture

- Katz (1925) proposed that perception of texture depends on two cues:
  - Spatial cues are determined by the size, shape, and distribution of surface elements.
  - Temporal cues are determined by the rate of vibration as skin is moved across finely textured surfaces.
- Two receptors may be responsible for this process - called the *duplex theory of texture perception.*

Perceiving Texture - continued

- Past research showed support for the role of spatial cues.
- Recent research by Hollins and Reisner shows the influence of temporal cues.
  - In order to detect differences between fine textures such as small differences in the roughness of a surface, participants needed to move their fingers across the surface.


Very fine
Fine
Log roughness judgments
.75
.50
.25
0
10
100
10
100
(a) Static
(b) Moving
Particle size (μm)

Perceiving Objects

- Humans use *active* rather than passive touch to interact with the environment.
- Haptic perception is the active exploration of 3-D objects with the hand.
  - It uses three distinct systems:
    - Sensory system
    - Motor system
    - Cognitive system

Perceiving Objects - continued

- Psychophysical research shows that people can identify objects haptically in one to two seconds.
- Klatzky et al. have shown that people use various types of movement *(exploratory procedures):*
  - Lateral motion
  - Contour following
  - Pressure
  - Enclosure

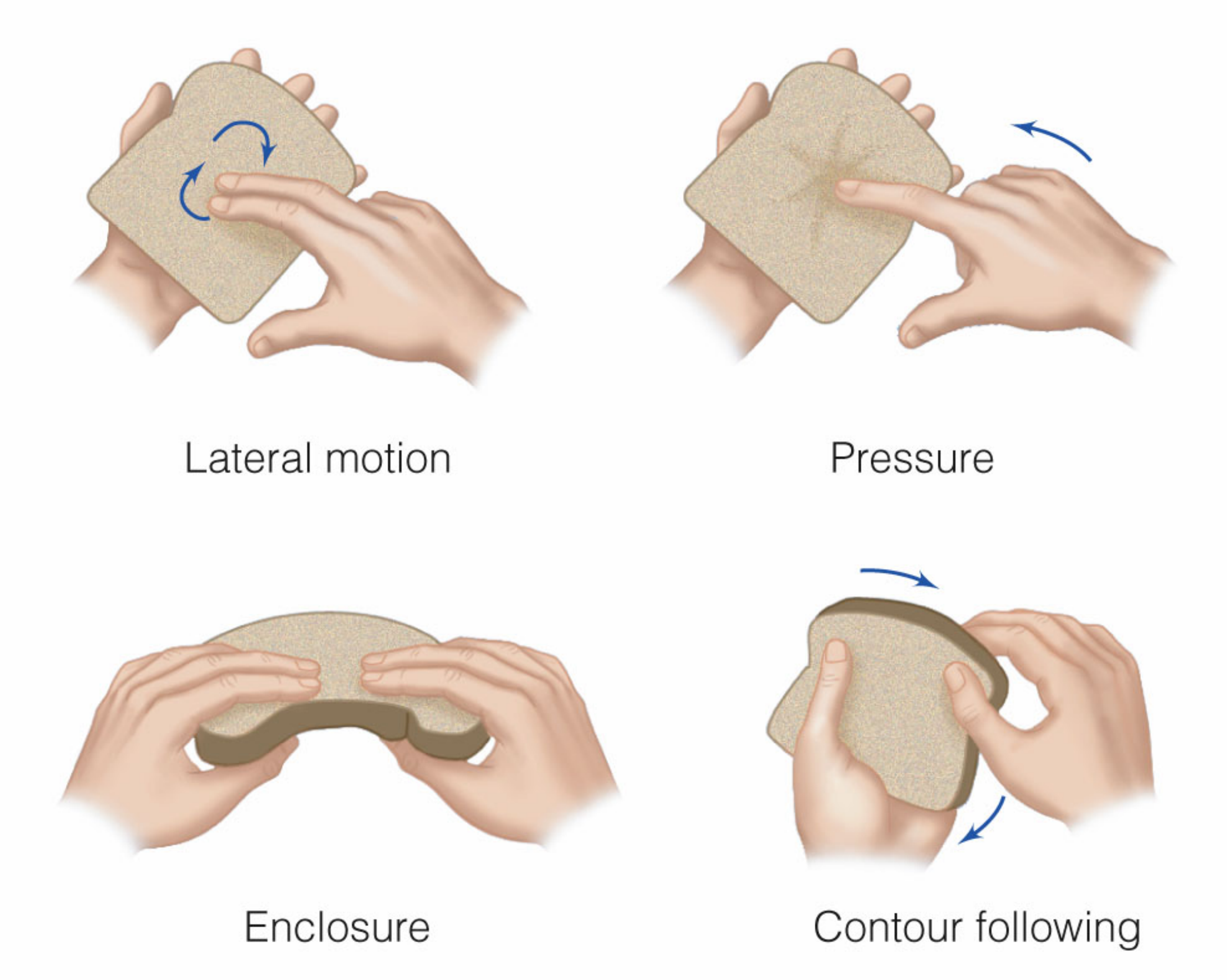


Figure 14.15 Some of the exploratory procedures (EPs) observed by Lederman and Klatzky as participants identified objects. (From Lederman & Klatzky, 1987)

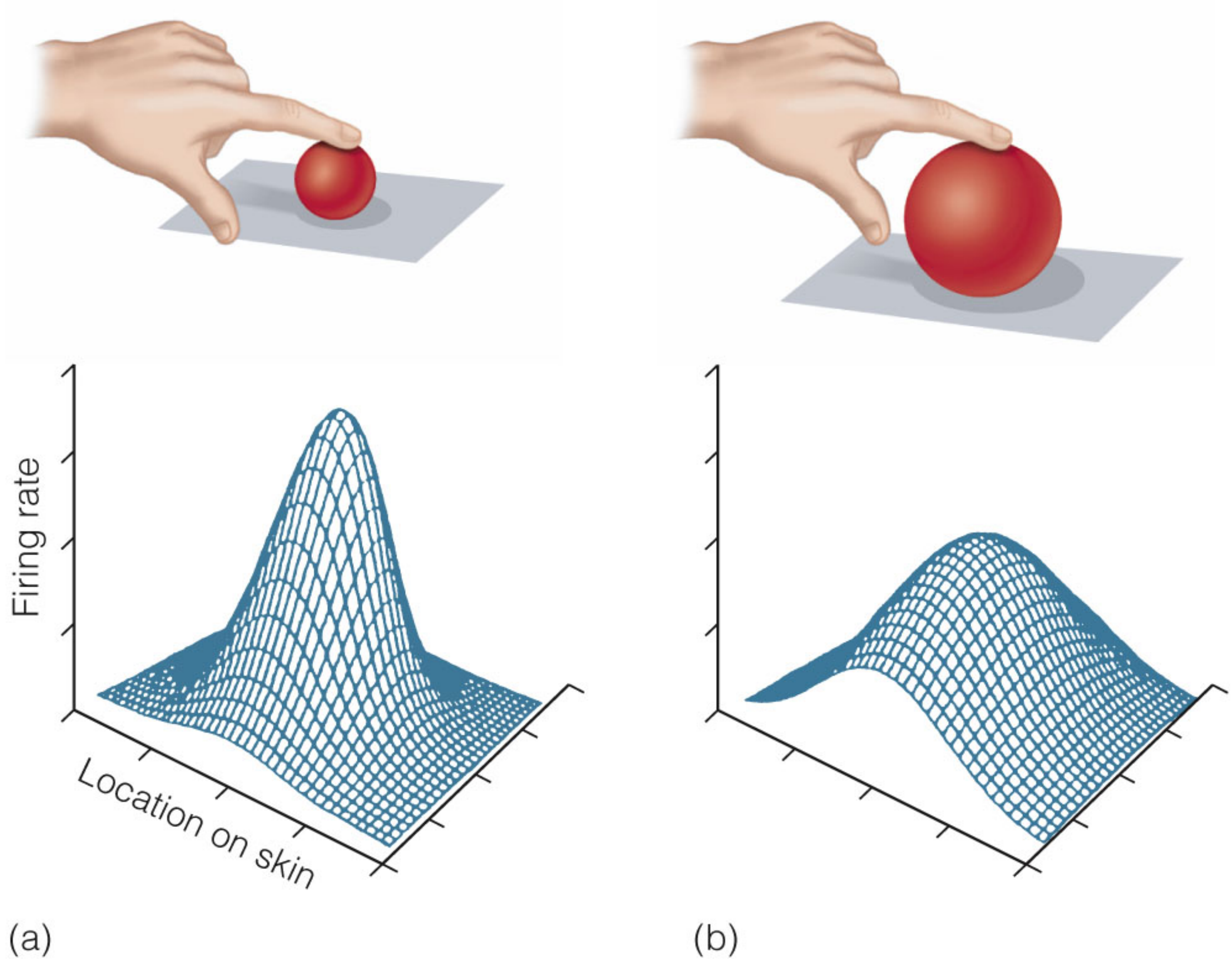
The Physiology of Tactile Object Perception

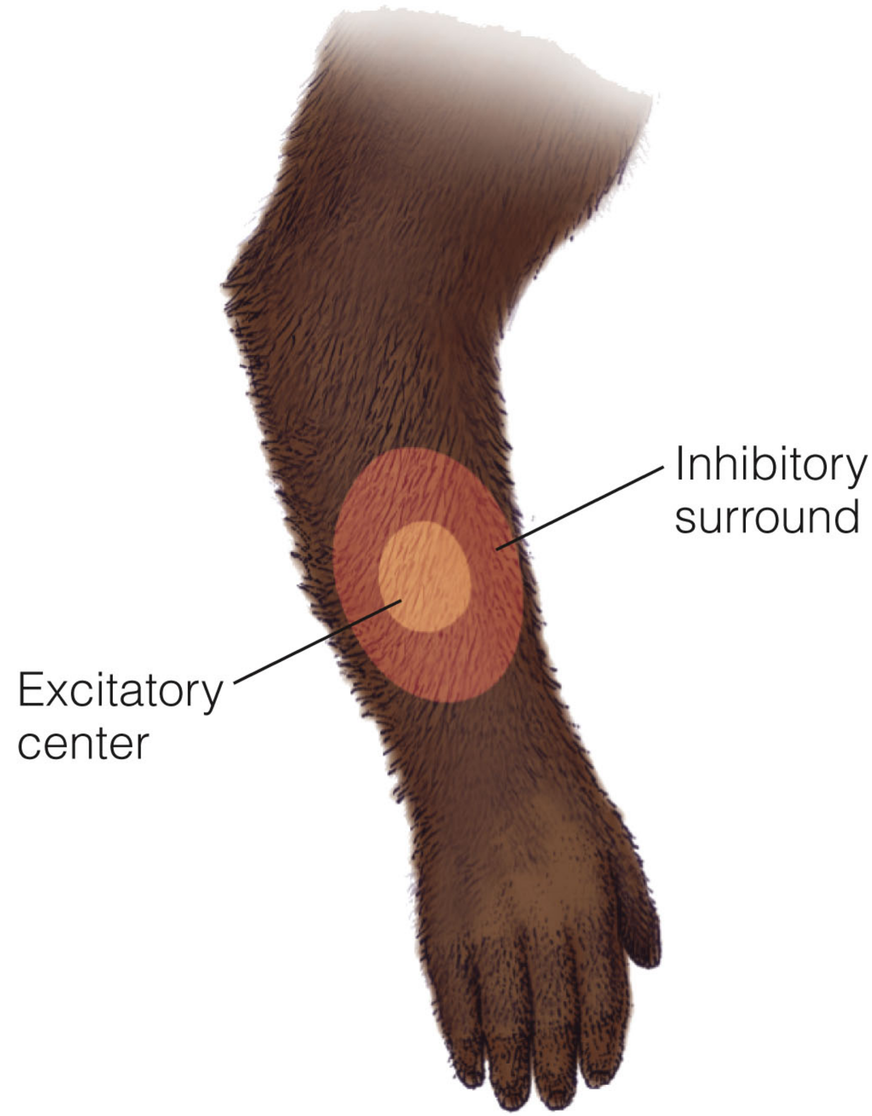
The firing pattern of groups of mechanoreceptors signals shape, such as the curvature of an object.

Neurons further upstream become more specialized:

Monkey’s thalamus shows cells that respond to center-surround receptive fields.

Somatosensory cortex shows cells that respond maximally to orientations and direction of movement.


Firing rate
Location on skin
(a)
(b)


Inhibitory
surround
Excitatory
center

The Physiology of Tactile Object Perception - continued

Monkey's somatosensory cortex also shows neurons that respond best to:

1. Grasping specific (shaped) objects.

2. Paying attention to the task.

Neurons may respond to stimulation of the receptors, but attending to the task increases the response.

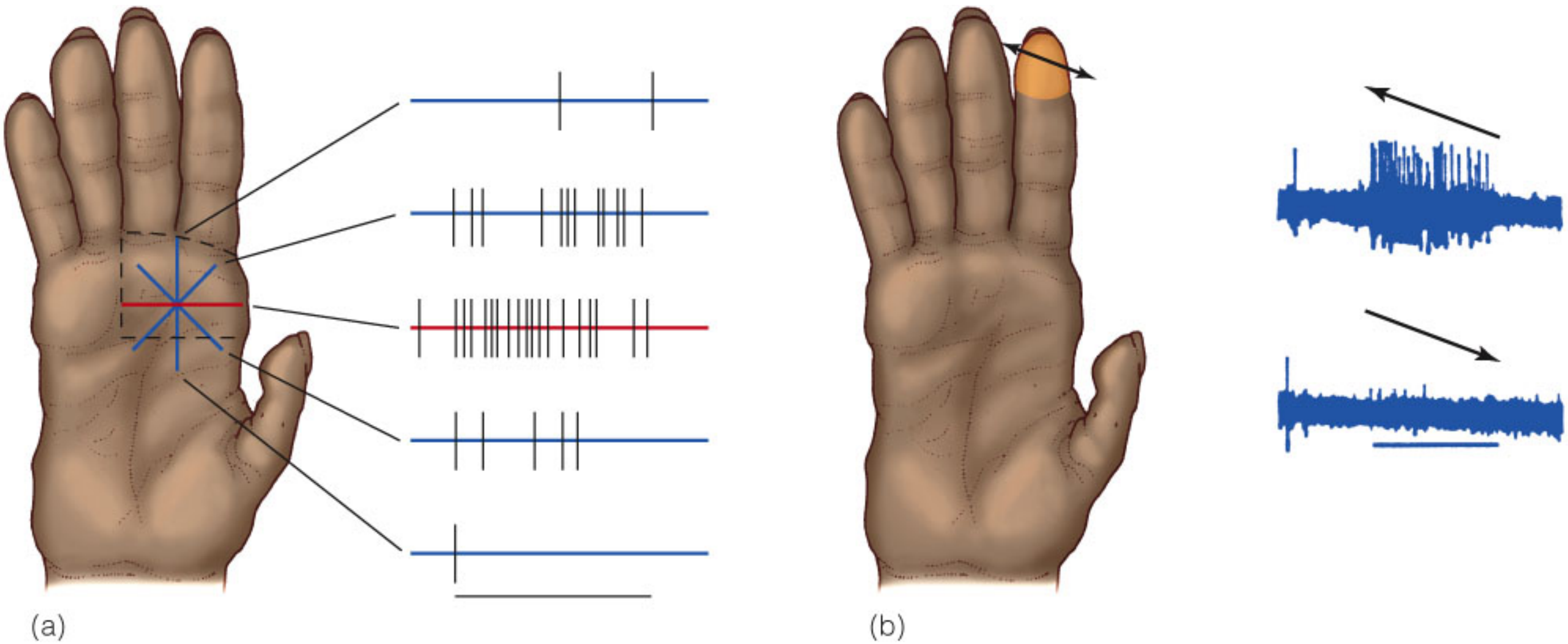
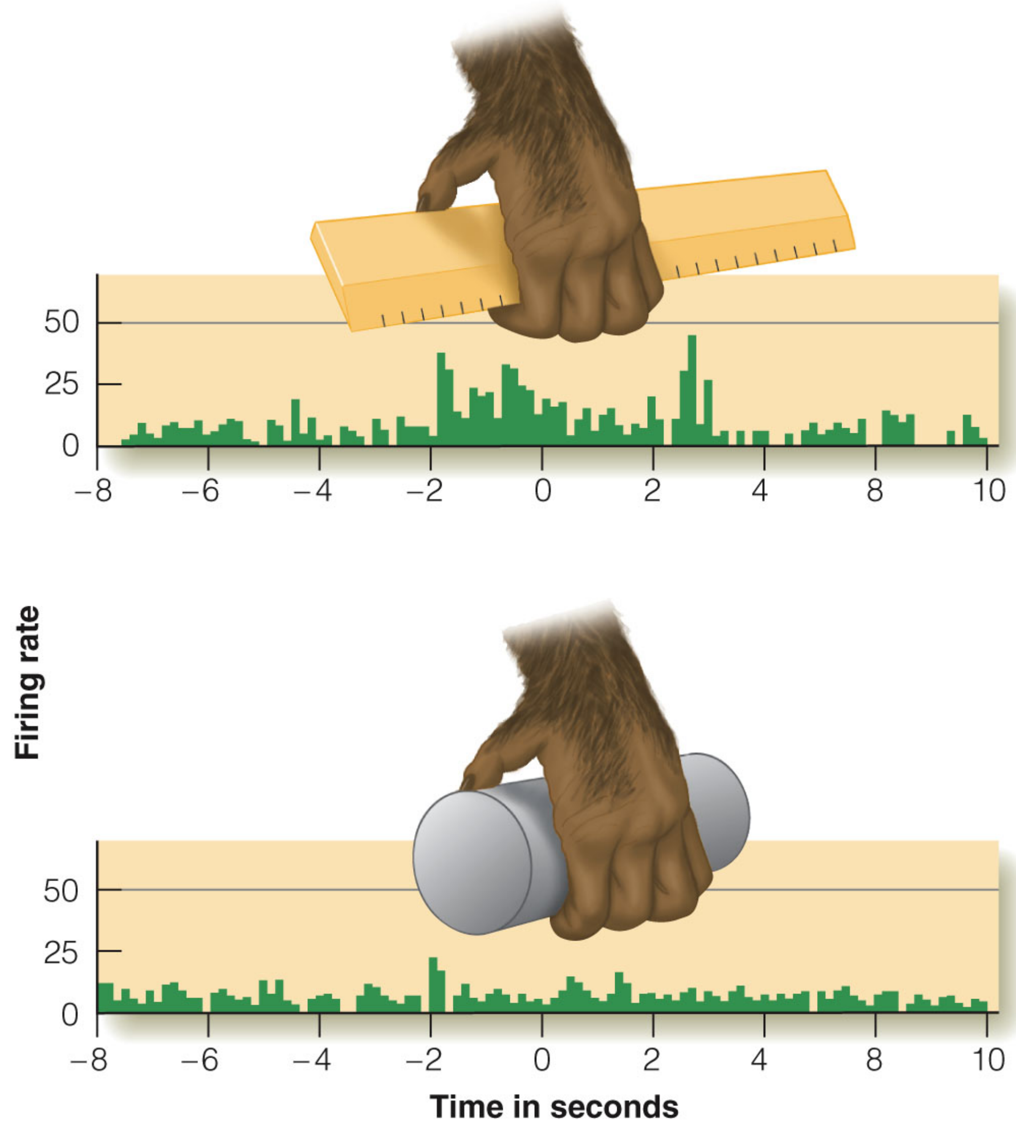


Figure 14.18 Receptive fields of neurons in the monkey's somatosensory cortex. (a) This neuron responds best when a horizontally oriented edge is presented to the monkey's hand. (b) This neuron responds best when a stimulus moves across the fingertip from right to left. (From Hyvarinin & Poranen, 1978)



Firing rate
50
25
0
−8
−6
−4
−2
0
2
4
8
10
50
25
0
−8
−6
−4
−2
0
2
4
8
10
Time in seconds

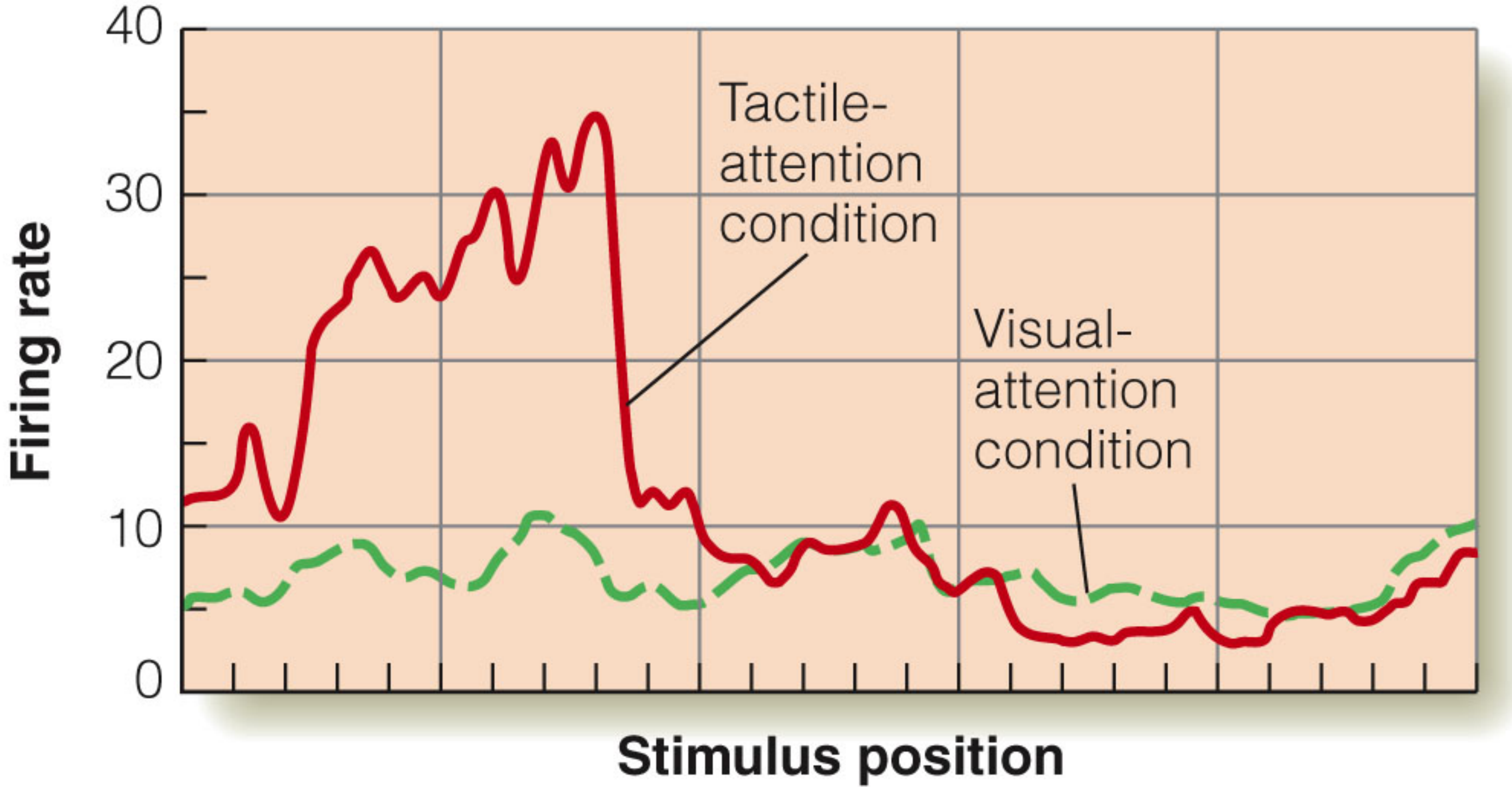


Figure 14.20 Firing rate of a neuron in area S1 of a monkey's cortex to a letter being rolled across the fingertips. The neuron responds only when the monkey is paying attention to the tactile stimulus. (From Hsiao, O'Shaughnessy, & Johnson, 1993)

Pain Perception

Pain is a multimodal phenomenon containing a sensory component and an affective or emotional component.

Three types of pain:

1. Nociceptive - signals impending damage to the skin. Different nociceptors respond to heat, chemicals, severe pressure, and cold.

Threshold of eliciting receptor response balanced to warn of damage, but not be affected by normal activity.

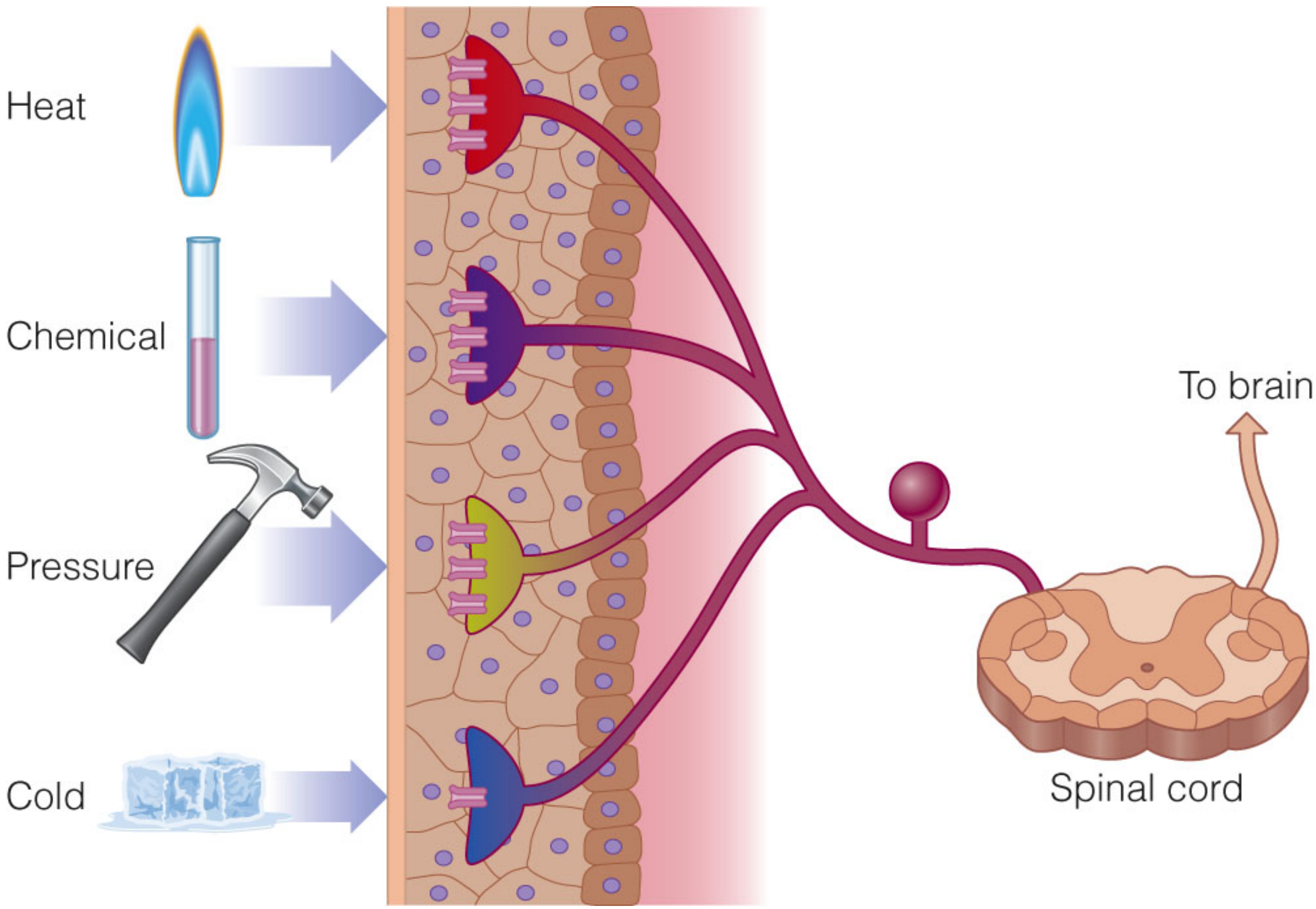
Types of Pain (cont.)

2. Inflammatory pain - caused by damage to tissues and joints or by tumor cells.

3. Neuropathic pain - caused by damage to the central nervous system, such as:

    Brain damage caused by stroke.

    Repetitive movements which cause conditions like carpal tunnel syndrome.


Heat
Chemical
Pressure
Cold
To brain
Spinal cord

Direct Pathway Model of Pain Perception

Early model stated nociceptors are stimulated and send signals to the brain.

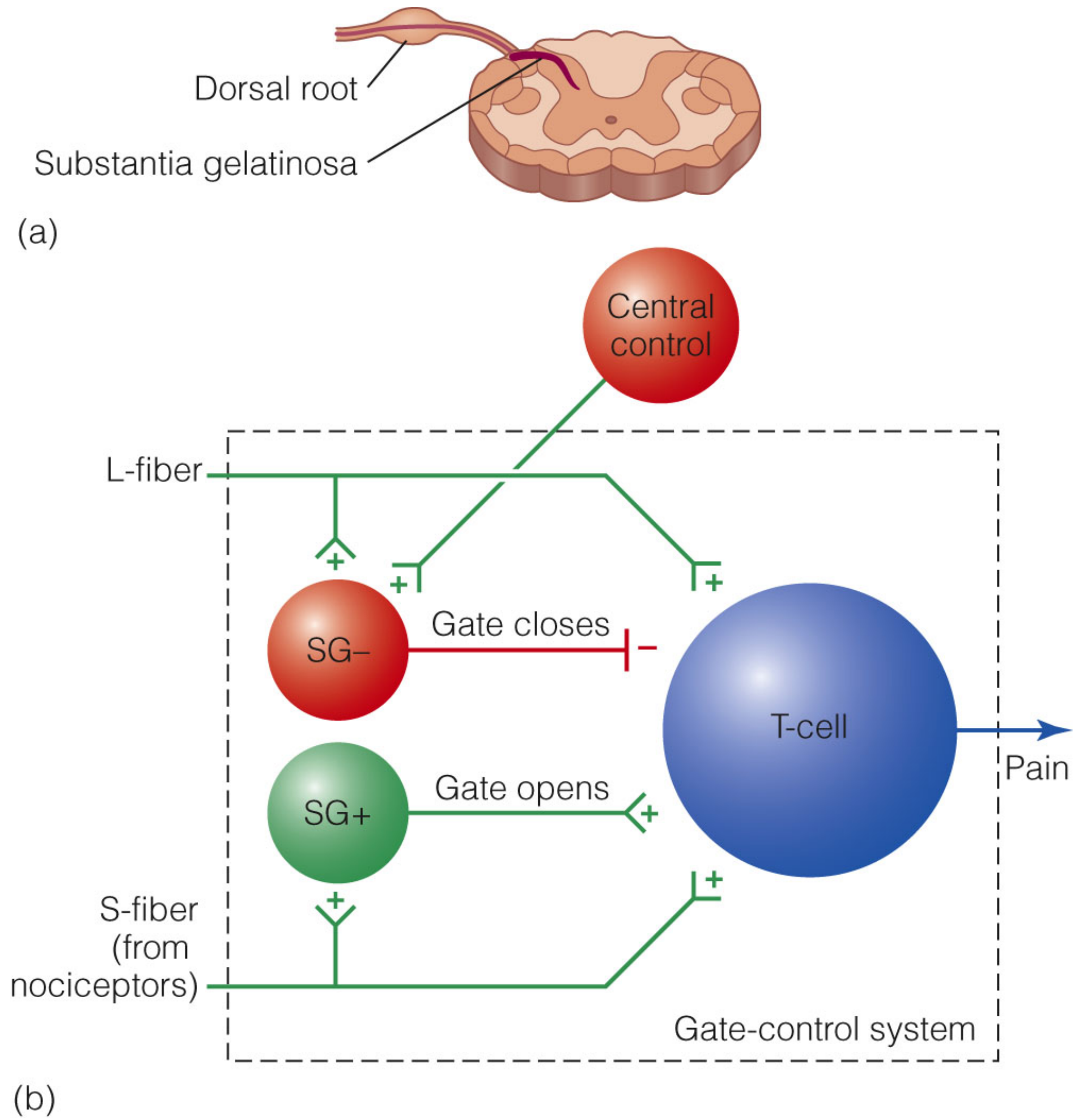
Problems with this model:

- Pain can be affected by a person's mental state.
- Pain can occur when there is no stimulation of the skin.
- Pain can be affected by a person's attention.

Gate Control Model of Pain Perception

- The "gate" consists of substantia gelatinosa cells in the spinal cord (SG- and SG+).

- Input into the gate comes from
  - Large diameter (L) fibers - information from tactile stimuli.
  - Small diameter (S) fibers - information from nociceptors.
  - Central control - information from cognitive factors from the cortex.


Dorsal root
Substantia gelatinosa
(a)
Central control
L-fiber
SG–
Gate closes
SG+
Gate opens
T-cell
Pain
S-fiber (from nociceptors)
Gate-control system
(b)

Gate Control Model of Pain Perception - continued

- Pain does not occur when the gate is closed by stimulation into SG- from central control or L-fibers into the T-cell.

- Pain does occur from stimulation of the S-fibers into the SG+ into the T-cell.

- Actual mechanism is more complex than this model suggests.

Cognitive and Experiential Aspects of Pain

- Expectation - when surgical patients are told what to expect, they request less pain medication and leave the hospital earlier.
  - Placebos can also be effective in reducing pain.

- Content of emotional distraction - participants could keep their hands in cold water longer when pictures they were shown were positive.

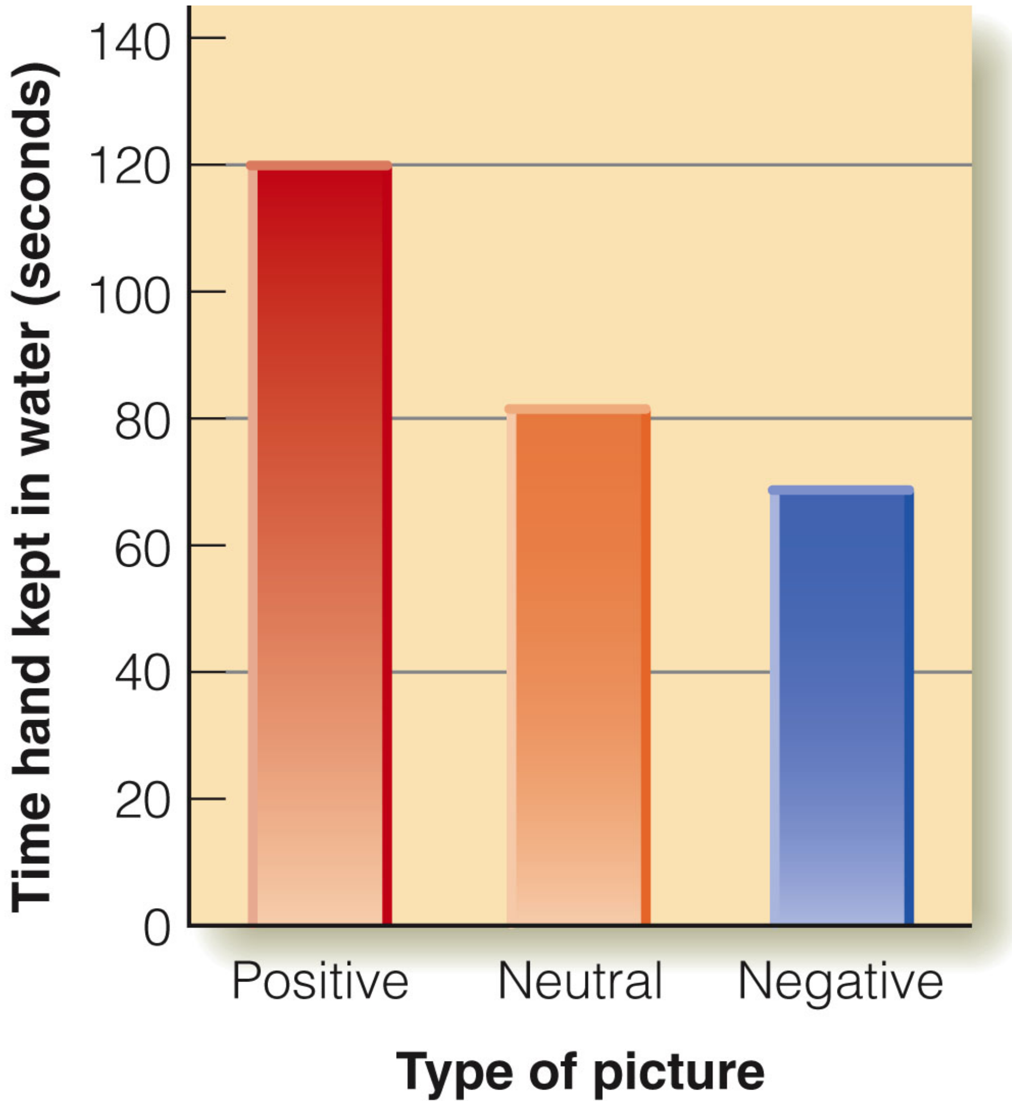


Figure 14.24 The results of deWied and Verbaten's (2001) experiment showing that participants kept their hands in cold water longer when looking at positive pictures than when looking at neutral or negative pictures.

Cognitive and Experiential Aspects of Pain - continued

Experiment by Derbyshire to investigate hypnotically induced pain.

Participants had a thermal stimulator attached the to palm of their hand. Three Conditions:

1. Physically induced pain
2. Hypnotically induced pain
3. Participants asked to imagine pain

fMRI and subjective report show evidence of participants "feeling" pain due to hypnotic suggestion.

Brain Structures and Pain

- Subcortical areas including the hypothalamus, limbic system, and the thalamus.
- Cortical areas including S1 and S2 in the somatosensory cortex, the insula, and the anterior cingulate and prefrontal cortices.
- These cortical areas taken together are called the *pain matrix.*

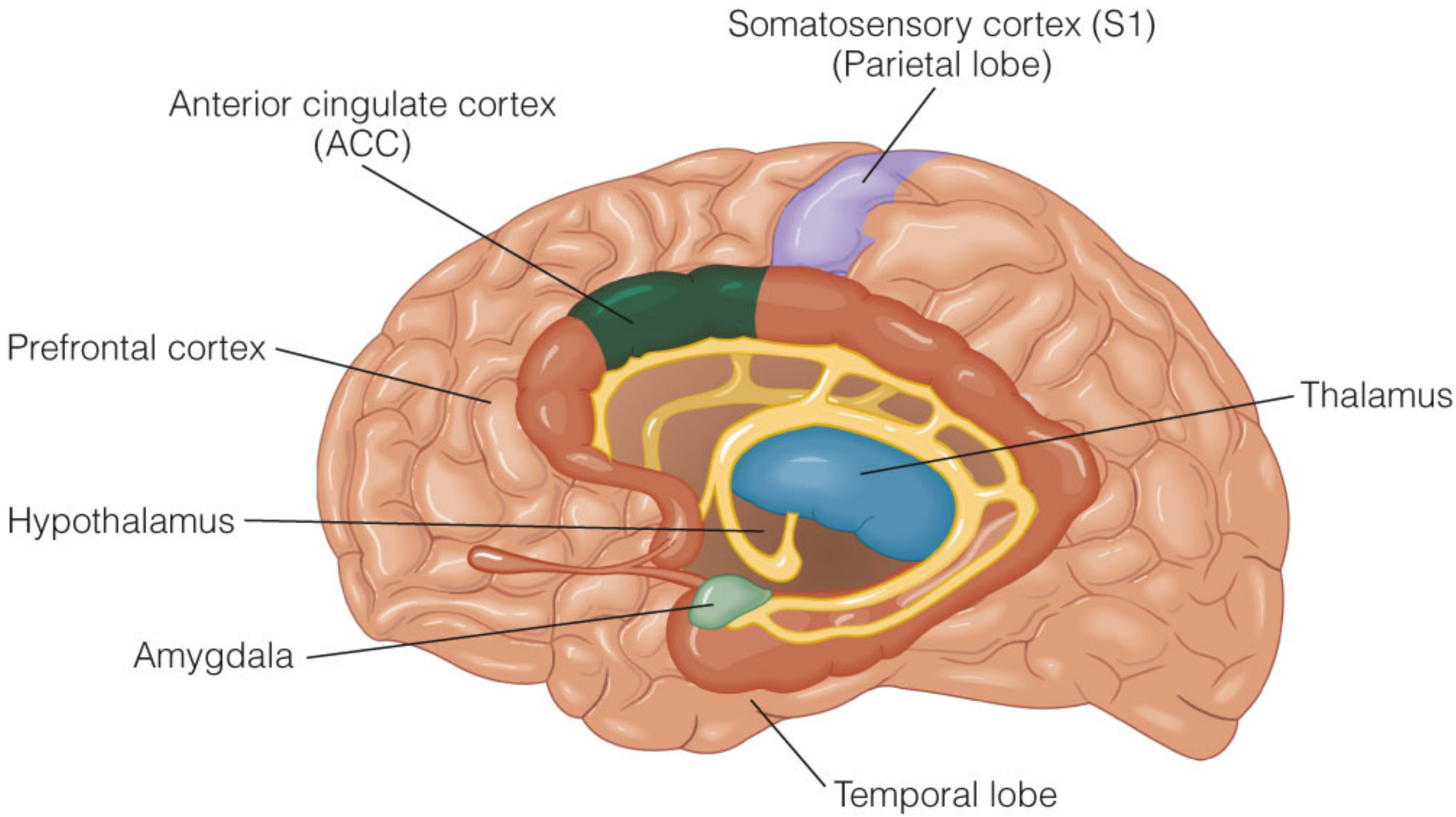


Figure 14.26 The perception of pain is accompanied by activation of a number of different areas of the brain. All of these areas, taken together, are called the pain matrix.

Sensory and Affective Components of Pain

Experiment by Hoffauer et al. Participants were presented with potentially painful stimuli and asked:

1. To rate subjective pain intensity.
2. To rate the unpleasantness of the pain.

Brain activity was measured while they placed their hands into hot water.

Hypnosis was used to increase or decrease the sensory and affective components.

Experiment by Hoffauer et al. - continued

Results showed that:

1. Suggestions to change the subjective intensity of pain led to changes in both ratings and in activity in S1.

2. Suggestions to change the unpleasantness of pain did not affect the subjective pain intensity ratings, but did change:

    Ratings of unpleasantness.

    Activation in the anterior cingulate cortex.

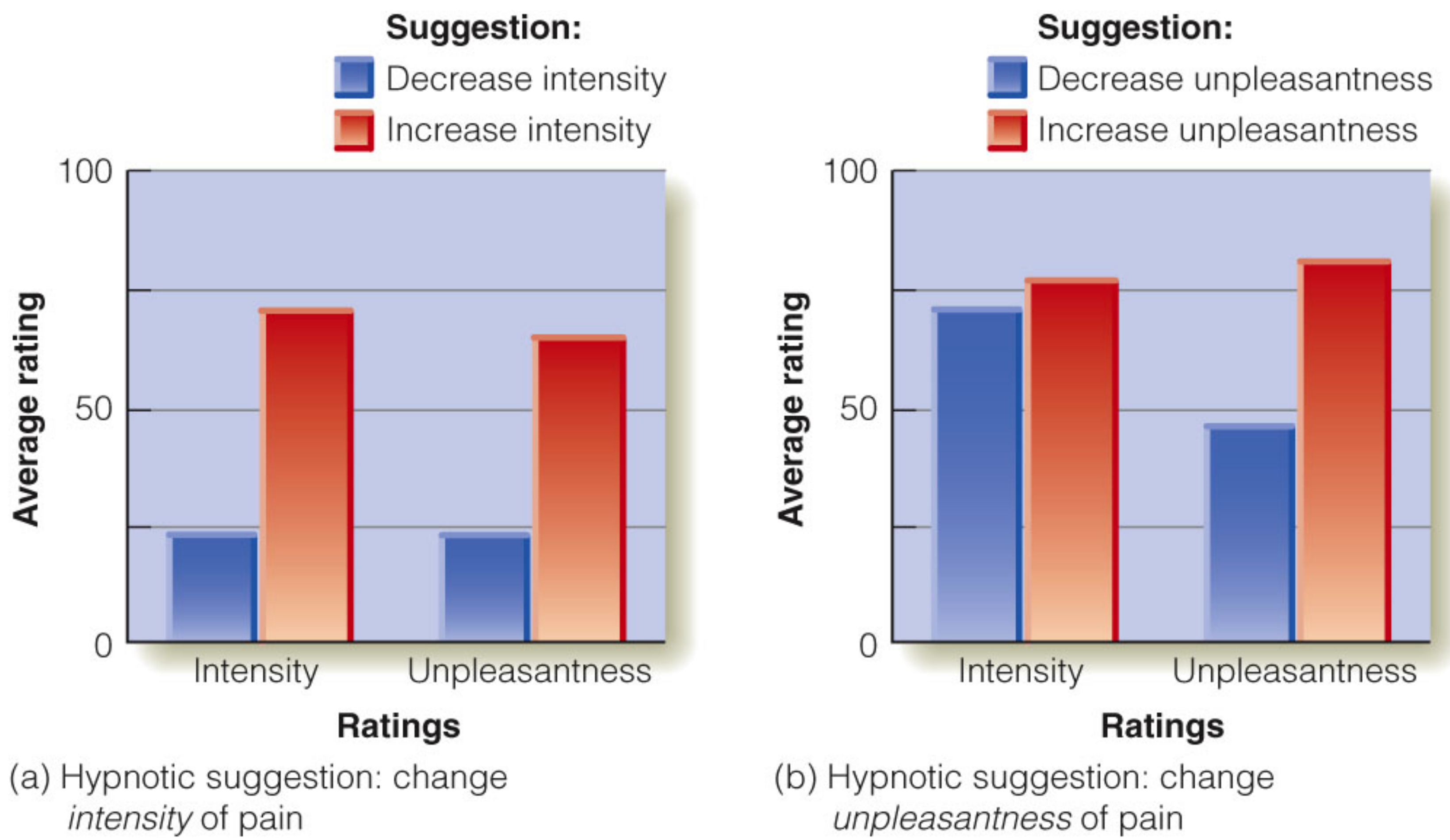


Figure 14.27 Results of Hofbauer et al.'s (2001) experiment. Participants' ratings of the intensity and the unpleasantness of pain were affected by hypnosis. (a) Results of hypnotic suggestion to decrease or increase the pain's *intensity*. (b) Results of suggestion to decrease or increase the pain's *unpleasantness*.

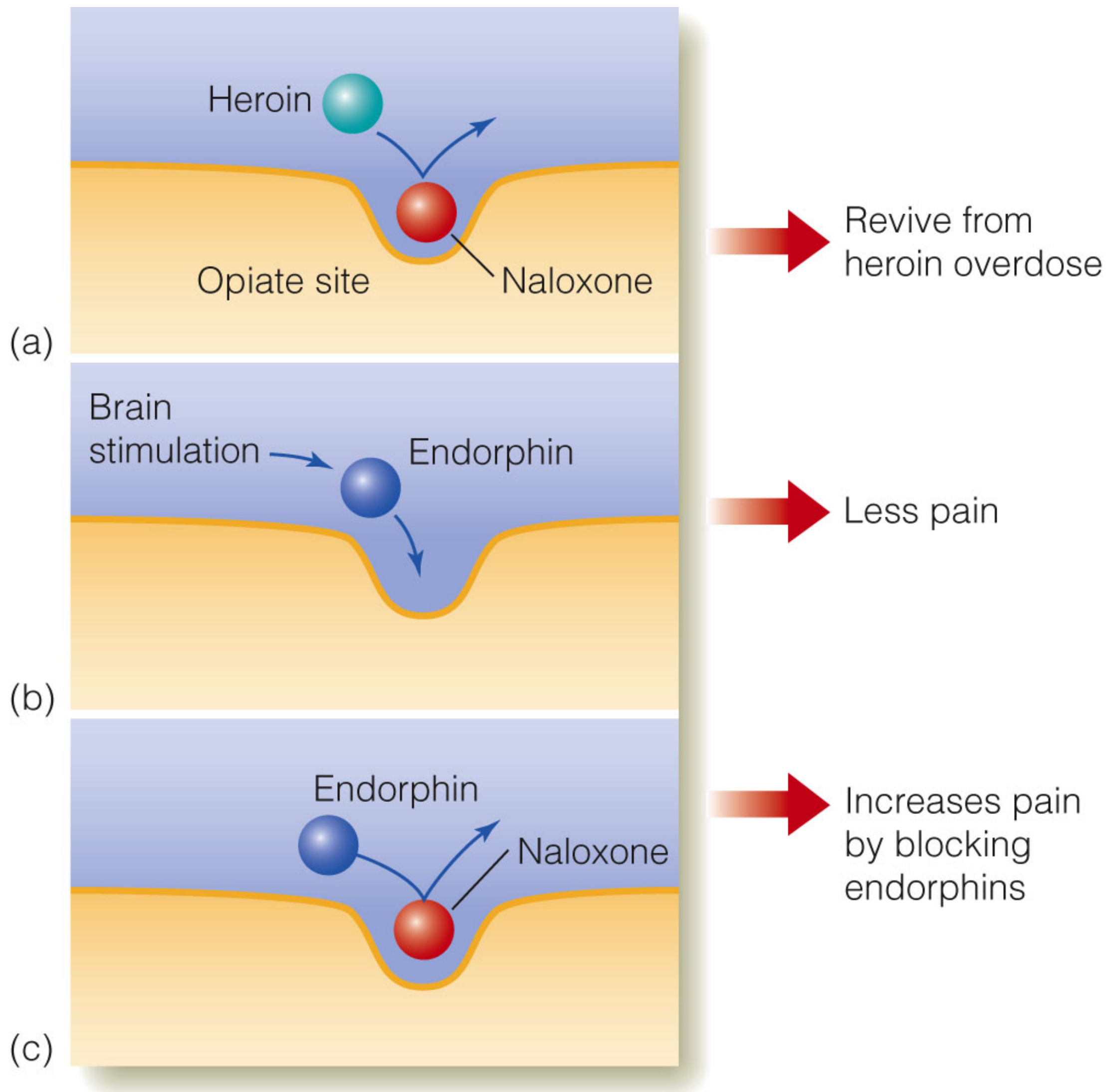
Opioids and Pain

Brain tissue releases neurotransmitters called endorphins. Evidence shows that endorphins reduce pain.

Injecting naloxone blocks the receptor sites causing more pain.

Naloxone also decreases the effectiveness of placebos.

People whose brains release more endorphins can withstand higher pain levels.


Heroin
Opiate site
Naloxone
(a)
Revive from heroin overdose
Brain stimulation
Endorphin
(b)
Less pain
Endorphin
Naloxone
(c)
Increases pain by blocking endorphins