Somatosensation

*somato*: “body”

Touch
Body position
Pain
Thermal sensation
Touch across the animal kingdom

“Finger” of trunk is densely innervated, allowing for grasping and manipulating small objects.

Control rate and pattern of whisking to acquire useful information.

Maintain tactile acuity in near-freezing water for hours.

Specialized structures along snout detect vibration in water.

Deflection of rigid spines encodes intensity of touch.
Touch in humans

You can detect bumps as small as 1 μm ($1/10,000^{th}$ cm) on a flat surface!

We need tactile feedback to execute fine motor tasks (e.g., tying shoes, fastening buttons).
Receptors in the skin

Meissner’s corpuscles
Pacinian corpuscles
Merkel’s disk
Ruffini endings

Free nerve endings

touch

Luzhnica 2019
From stimulus to action potential: mechanotransduction
From stimulus to action potential: mechanotransduction

membrane stretches

cell membrane

membrane potential (mV)

0
-40
-80
-120

?
From stimulus to action potential: mechanotransduction

L10Q1: Mechanical deformation of this channel protein will:
A) hyperpolarize the cell
B) depolarize the cell
C) have no effect on the cell voltage
From stimulus to action potential: mechanotransduction

Positive ions enter cell. Cell becomes more positive, i.e. depolarized.
From stimulus to action potential: mechanotransduction

Positive ions enter cell. Cell becomes more positive, i.e. depolarized.
Different receptor types convey different types of information

- **fine structure, shape, coarse texture**
  - Merkel’s disk

- **low-frequency vibration, slip**
  - Meissner’s corpuscles

- **high-frequency vibration, fine texture**
  - Pacinian corpuscles
Different receptor types convey different types of information

- **Merkel’s disk**
  - fine structure, shape, coarse texture
  - low-frequency vibration, slip
  - indentation
  - neural response

- **Meissner’s corpuscles**
  - high-frequency vibration, fine texture

- **Pacinian corpuscles**
  - indentation
  - neural response

Different receptor types convey different types of information.
Each receptor responds to a particular region on the skin

**receptive fields**

Merkel disks: SA1  
Meissner corpuscles: RA1  
Ruffini endings: SA2  
Pacinian corpuscles: RA2

*Principles of Neural Science: Kandel, Schwartz, & Jessell*
Some receptor types are more densely packed than others.
L10Q2: Based on their receptive fields and the density of receptors in the hand, which receptors allow you to most accurately identify the location of a small bump?

A) Merkel disks (SA1) & Meissner corpuscles (RA1)
B) Pacinian corpuscles (RA2) & Ruffini endings (SA2)
C) All are equally good
Two-point discrimination threshold

How far apart do 2 small points need to be for them to feel like 2 points rather than 1?

Seeing with your tongue?

Stimulate mechanoreceptors on tongue to create “image”

Pasluosta et al. 2018

Bach-y-Rita Lab, University of Wisconsin
Somatotopic organization

(a) Somatosensory cortex in right cerebral hemisphere
Cortex is organized into columns

Cells within a cortical column have similar response properties
- Same receptive field location
- Same type of information encoded

Discovered 1955 by Vernon Mountcastle. According to David Hubel in his Nobel Prize acceptance speech:

*The “discovery of columns in the somatosensory cortex was surely the single most important contribution to the understanding of cerebral cortex since Ramón y Cajal”*
Cortex can remap

Rosenzweig, Leiman, & Breedlove. Biological Psychology.
Cortex can remap quickly!

Perceptually relevant remapping of human somatotopy in 24 hours

James Kolasinski, Tamar R Makin, John P Logan, Saad Jbabdi, Stuart Clare, Charlotte J Stagg, Heidi Johansen-Berg
University of Oxford, United Kingdom; University College, United Kingdom; University College London, United Kingdom

SHORT REPORT Dec 30, 2016
Phantom limb syndrome
Phantom limb syndrome

Kandel, Schwartz, & Jessell. Principles of Neural Science
Phantom limb syndrome

Proprioception

Sense of body position
Deep receptors detect stretch

- **muscle stretch**
  - muscle spindle
  - Meissner’s corpuscles
- **tendon stretch**
  - Gogli tendon organ
  - Ruffini endings
- **skin stretch**
  - Pacinian corpuscles
  - Merkel’s disk
Sudden muscle stretch triggers a reflex

muscle spindle

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Pinocchio illusion

Vibration on biceps stimulates stretch receptors and gives impression arm is extending.

This creates an illusion that the nose is growing.
Proprioception in insects

Small, domed structures detect deformations on wings, halteres, and parts of exoskeleton

Andrew Mountcastle

Deora et al. 2015

Dickerson et al. 2014

Agrawal et al. 2017
Pain

“Nociception”
Latin *nocere*: “to harm or hurt”
Nociceptors

- **Thermal nociceptors** are activated by extreme temperatures

- **Mechanical nociceptors** are activated by intense pressure
Different types of nerve fibers convey different information

- **A-beta-fibers**
  - Light touch
  - Pressure
  - Vibration
  - Diameter: 6-12 μm

- **Type I A-delta-fibers**
  - Gross touch
  - Fast pain
  - High heat (>53°C)
  - Capsaicin-insensitive
  - Diameter: 1-5 μm

- **Type II A-delta-fibers**
  - Gross touch
  - Fast pain
  - Low heat (>43°C)
  - Capsaicin-sensitive
  - Diameter: <1 μm

- **C-fibers**
  - Slow pain
  - Low pH
  - Heat
  - Capsaicin-sensitive

*Source: Tender et al. 2008*
Rank the speed of signal propagation in these nerve fibers:

A) A-beta → A-delta → C
B) C → A-delta → A-beta
C) A-delta → A-beta → C
D) C → A-beta → A-delta
E) A-delta → C → A-beta

Tender et al. 2008

- Diameter:
  - A-beta-fibers: 6-12 μm
  - Type I A-delta-fibers: 1-5 μm
  - Type II A-delta-fibers: <1 μm
  - C-fibers: <1 μm

- Speed:
  - A-beta-fibers: 35-75 m/s
  - Type I A-delta-fibers: 5-30 m/s
  - Type II A-delta-fibers: <1 m/s
  - C-fibers: <1 m/s
Different nerve fibers convey information at different speeds

How does this map onto our experience when we feel pain, like burning a finger?
Withdrawal reflex

1. Thermal pain receptor in finger

2. Afferent pathway

3. Integrating center (spinal cord)

4. Efferent pathways

5. Effectors

6. Ascending pathway to brain

Components of a reflex arc:
- Receptor
- Afferent pathway
- Integrating center
- Efferent pathway
- Effector

KEY:
- + = Stimulates
- - = Inhibits
- = Synapse
- = Excitatory interneuron
- = Inhibitory interneuron
- = Neuromuscular junction

A-delta & C fibers
Different nerve fibers convey information at different speeds

![Diagram of nerve fibers showing different types and their properties.](image)

Different nerve fibers convey information at different speeds:

- **A-beta-fibers**
  - Diameter: 6-12 μm
  - Convey information up to 35-75 m/s
  - Light touch, pressure, vibration

- **Type I A-delta-fibers**
  - Diameter: 1-5 μm
  - Convey information up to 5-30 m/s
  - Gross touch, fast pain, high heat (>53°C), capsaicin-insensitive

- **Type II A-delta-fibers**
  - Diameter: <1 μm
  - Convey information <1 m/s
  - Gross touch, fast pain, low heat (>43°C), capsaicin-sensitive

- **C-fibers**
  - Diameter: <1 μm
  - Convey information <1 m/s
  - Slow pain, low pH, heat, capsaicin-sensitive

Different nerve fibers convey information at different speeds:

- 1) Withdraw hand
- 2) Feel sharp pain
- 3) Feel dull pain

Anything you might do to soothe the pain?
Touch can inhibit pain sensation

*gate control theory*

Kandel, Schwarz, & Jessell. *Principles of Neural Science*

**TENS**
transcutaneous electrical nerve stimulation
L10Q4: After touching your finger to a hot stove, you immediately grab your burned finger. This helps reduce the pain because:

A) Touch desensitizes pain receptors in your fingertips so that they stop sending pain signals
B) Touch-sensitive neurons activate inhibitory neurons in the spinal cord that reduce or eliminate the pain signal
C) Touching your finger distracts you from the pain so that you notice it less
Referred pain

*Convergence* of multiple nociceptors onto the same projection neurons can lead to a misplaced sense of pain.
Congenital insensitivity to pain

› Very rare genetic mutation in \( \text{Na}_v^{1.7} \) channels

  – Other mutations in this channel can lead to different pain disorders (e.g., hypersensitivity)

› Investigated as possible alternative to opioids for treating pain, with little success so far
Multisensory integration/illusions
Presenting mismatched stimuli

Feels higher frequency than it is

Sounds lower frequency than it is

...even when you tell people to ignore the other sense
Parchment skin illusion

- Amplify high frequencies: Skin feels rough/dry
- Amplify low frequencies: Skin feels wet