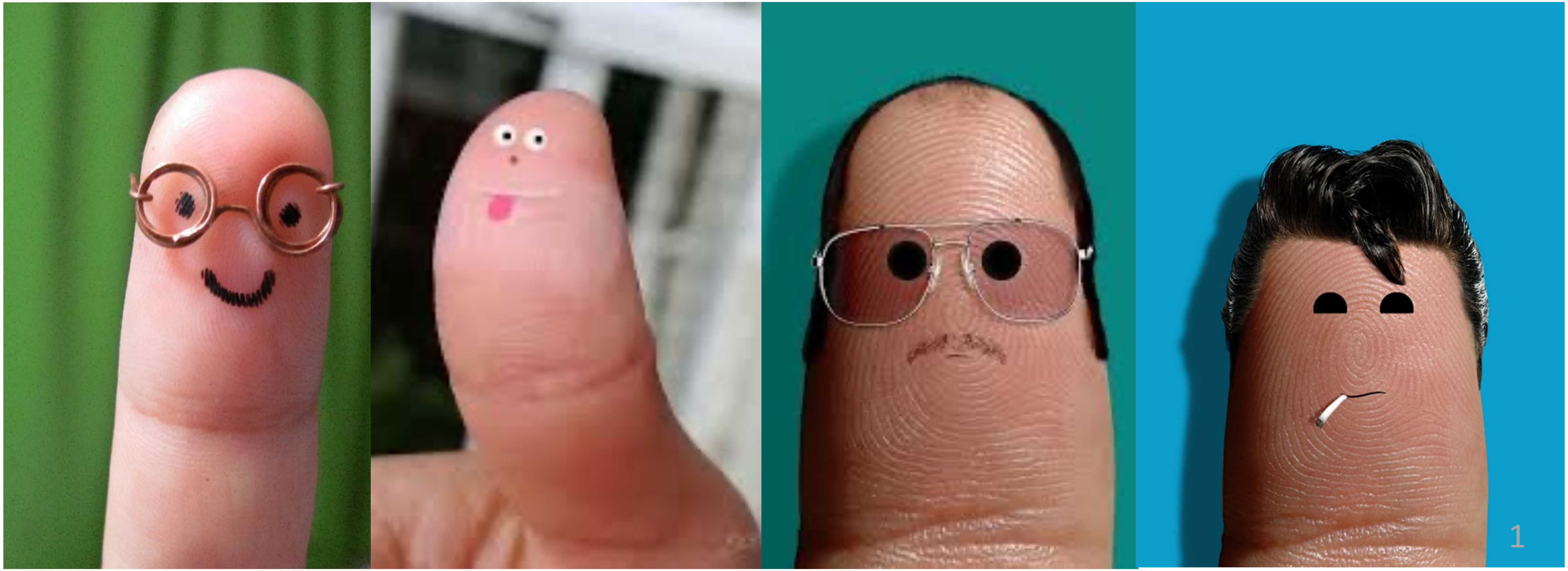
PSYC304: General Principles of Sensory Processing, Touch, and Pain

Jay Hosking, PhD

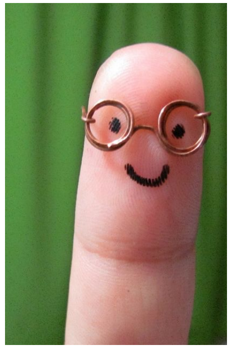


Lecture outline

- Principles of sensory processing
- Types of somatosensation
- Pain, thermosensation, and itch

Learning objectives

1. Differentiate sensation and perception.
2. Differentiate top-down from bottom-up sensory processes.
3. Do we have five senses? Justify your answer with evidence at the cellular level.
4. How do we determine whether incoming neural information reflects vision, or sound, or touch, etc.? What would happen if we wired the auditory neurons to the visual system, and vice versa?
5. Define the four main types of somatosensory receptors in sensory cells. How do they transduce the external energy into a neural signal? How is their information carried to the brain, including their axons and the pathways?
6. How does the brain code for intensity of a stimulus?
7. Why does our sensation diminish with constant stimulation? Why would this be a good thing?
8. Understand the concepts of a receptive field as well as centre-surround organization.
9. How does the brain organize sensory information?
10. What does it mean that the brain is plastic? How does this relate to damage or experience?
11. In biological terms, what is attention?
12. Why experience pain? Why not simply have the negative stimulus alter our behaviour?
13. Define some different types of nociceptors and thermoceptors, including the receptor types and pathways into the brain.
14. Describe some ways that pain can be managed, including their potential drawbacks.



Basic Concepts of Sensation and Perception (part 1)

- **Under normal circumstances, sensation and perception are parts of one continuous process.**
- **Sensation**
- **Perception**

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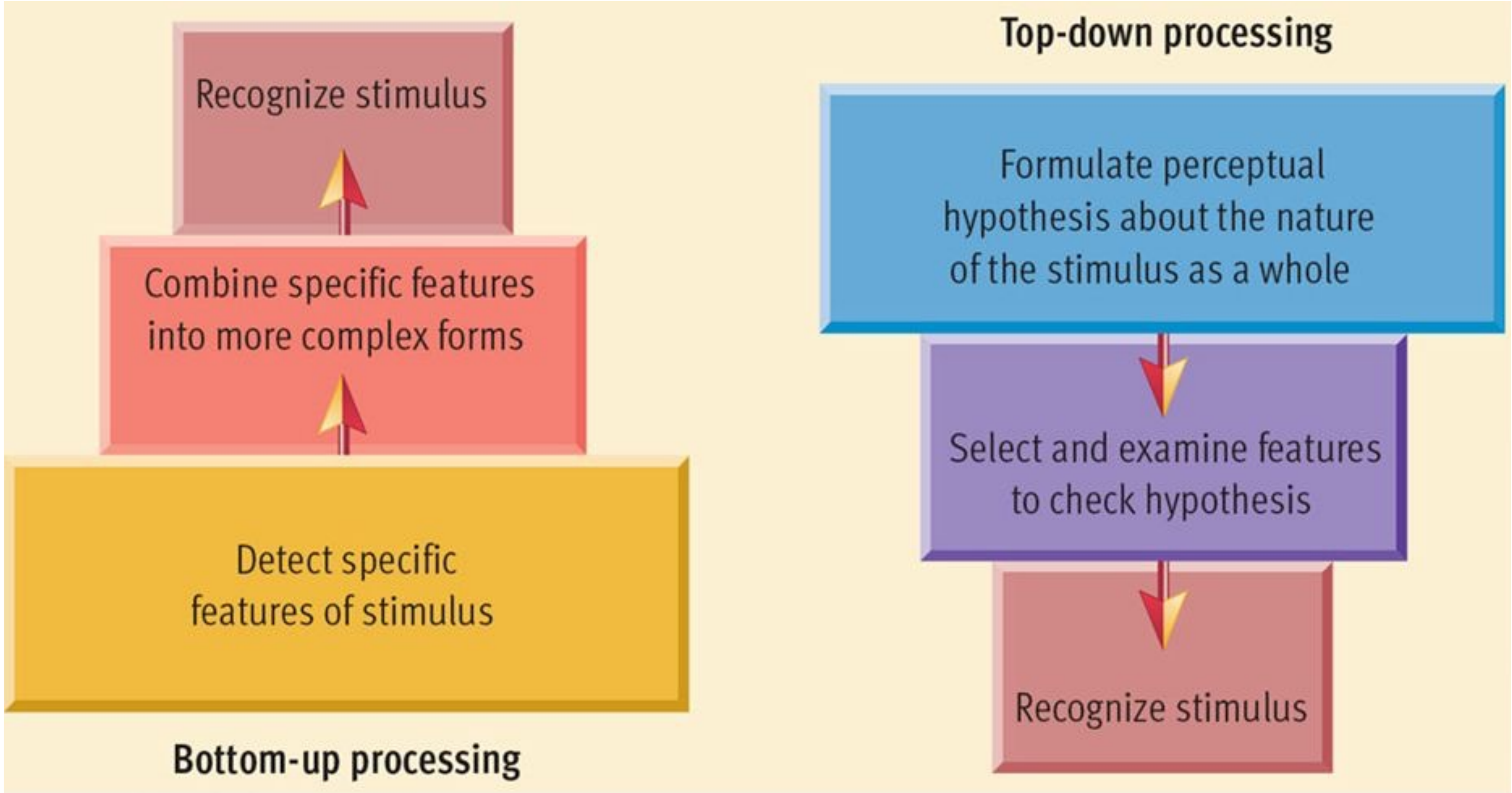
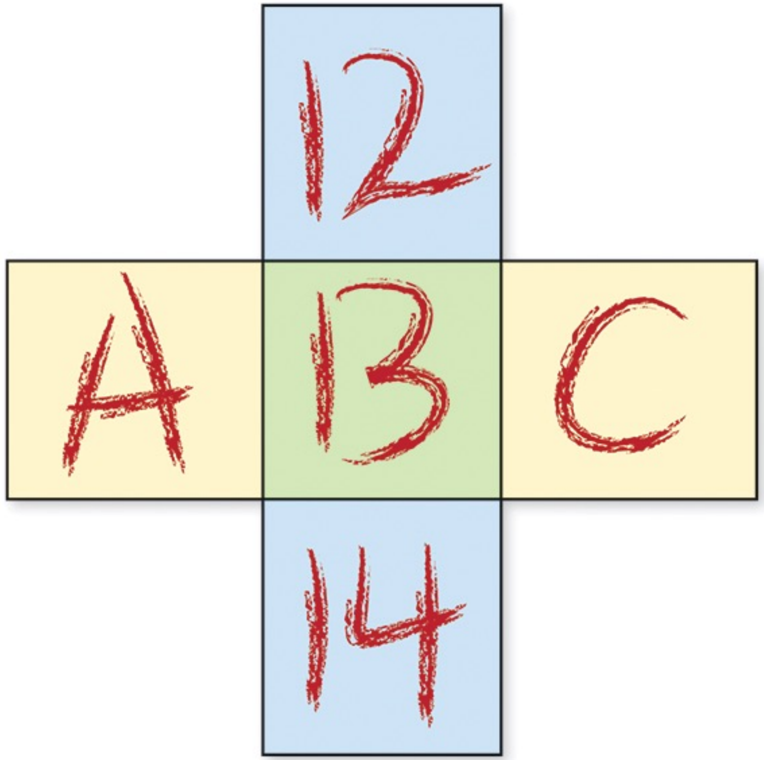
Sensory principles

Basic Concepts of Sensation and Perception (part 2)

- **Bottom-up processing**
- **Top-down processing**

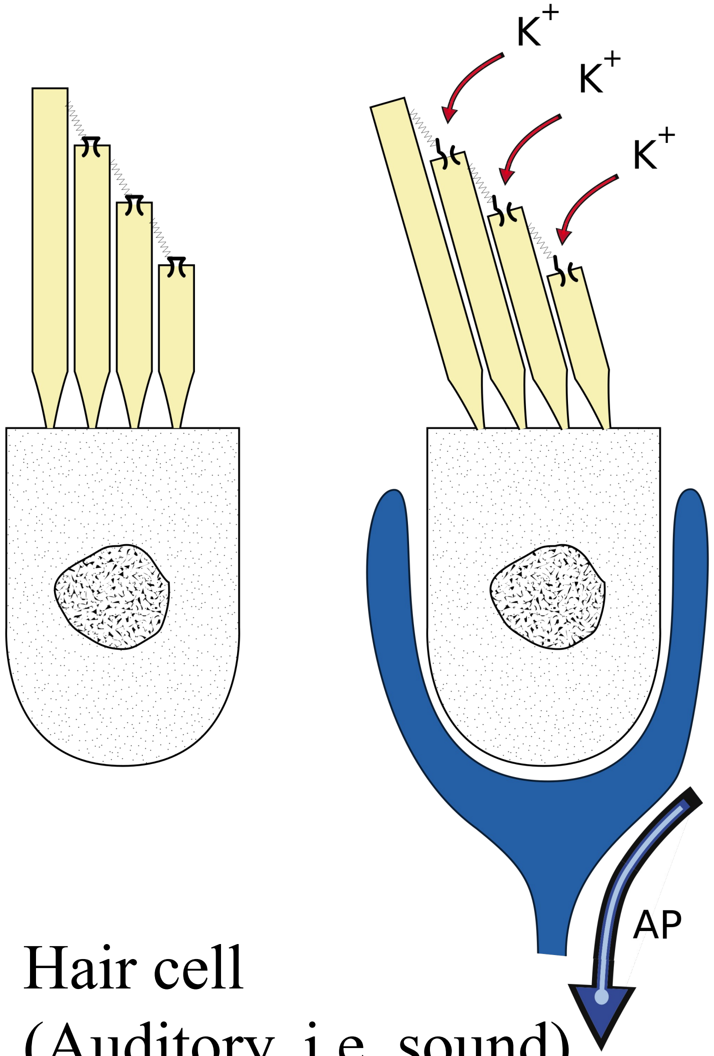




Sensory principles

Basic Concepts of Sensation and Perception (part 3)

- **Our senses**
  - Receive sensory stimulation, often using specialized receptor cells
  - **Transduction**, often into **receptor potentials** (cf. PSPs) via ionotropic receptors, can also be via metabotropic
  - Deliver the neural information to our brain



Hair cell
(Auditory, i.e. sound)

Sensory principles

The five senses?

TABLE 8.1 Classification of Sensory Systems

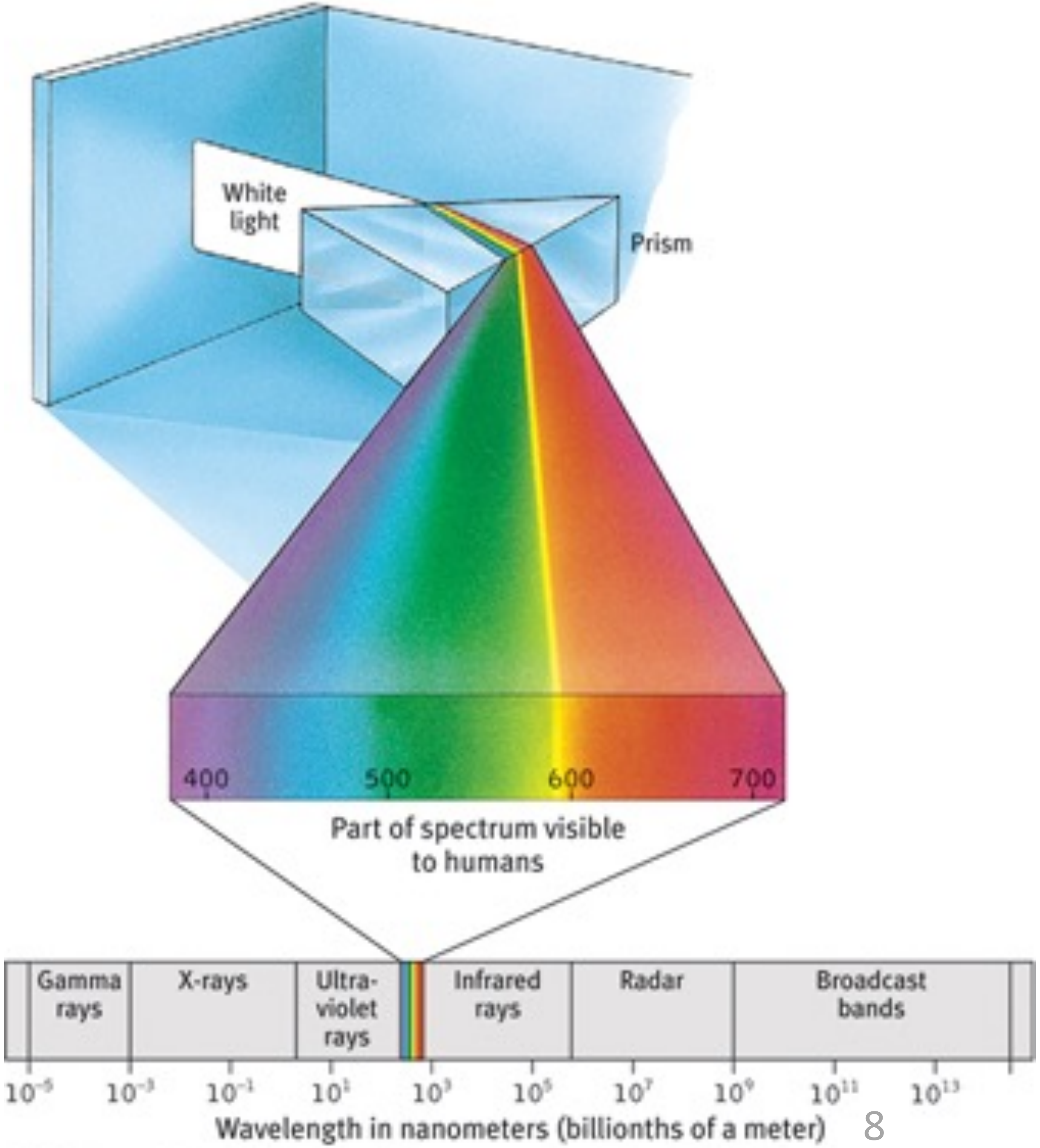
TYPE OF SENSORY SYSTEM	MODALITY	ADEQUATE STIMULI
Mechanical	Touch	Contact with or deformation of body surface
	Pain	Tissue damage
	Hearing	Sound vibrations in air or water
	Vestibular	Head movement and orientation
	Joint	Position and movement
	Muscle	Tension
Visual	Seeing	Visible radiant energy
Thermal	Cold	Decrease in skin temperature
	Warmth	Increase in skin temperature
Chemical	Smell	Odorous substances dissolved in air or water
	Taste	Substances in contact with the tongue or palate
	Common chemical	Changes in CO_2, pH, osmotic pressure
	Vomeronasal	Pheromones in air or water
Electrical	Electroreception	Differences in density of electrical currents

BEHAVIORAL NEUROSCIENCE 8e, Table 8.1

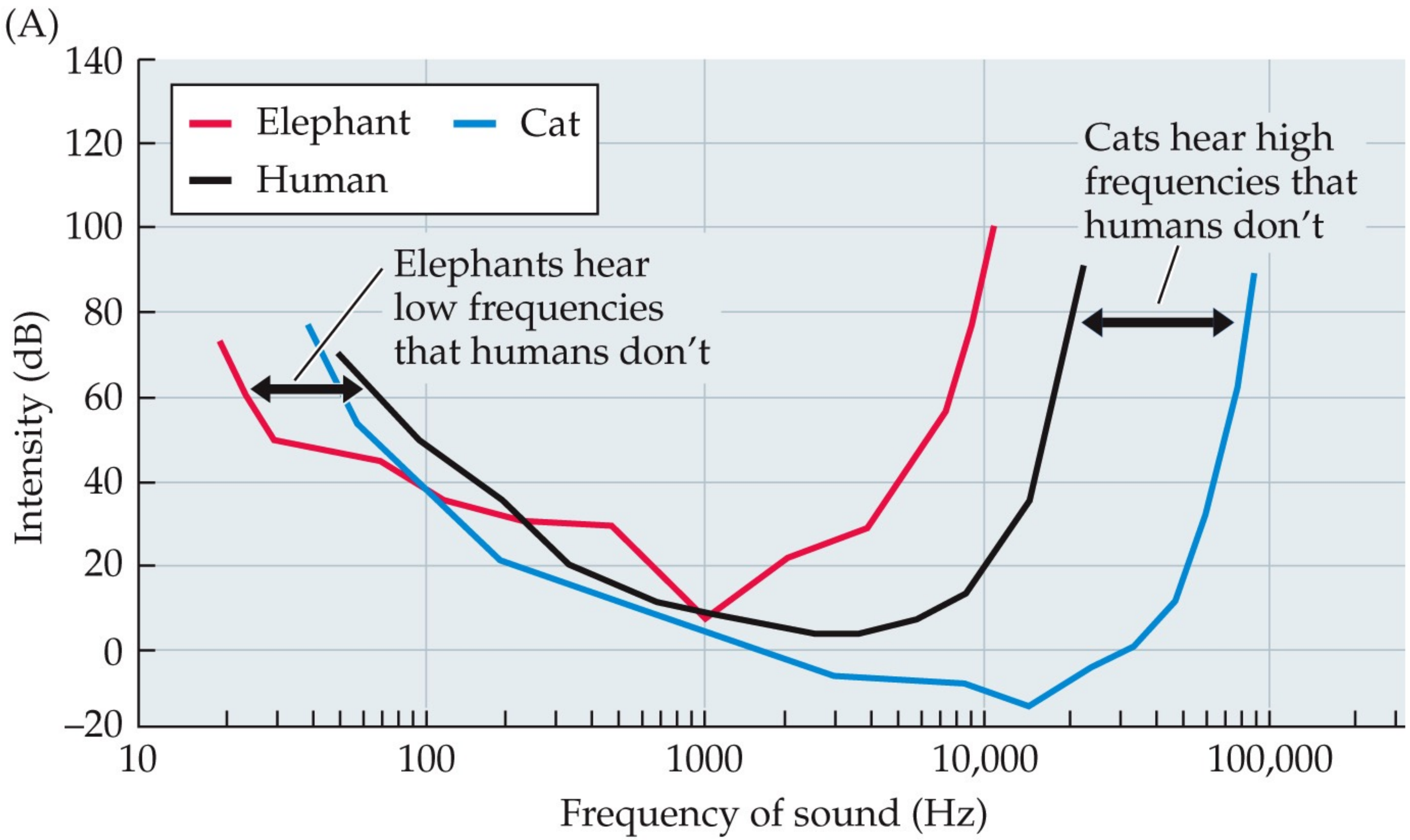
\+ Magnetic?
\+ More?

Sensory Receptor Organs Detect Energy or Substances

Sensory systems have a restricted range of responsiveness.

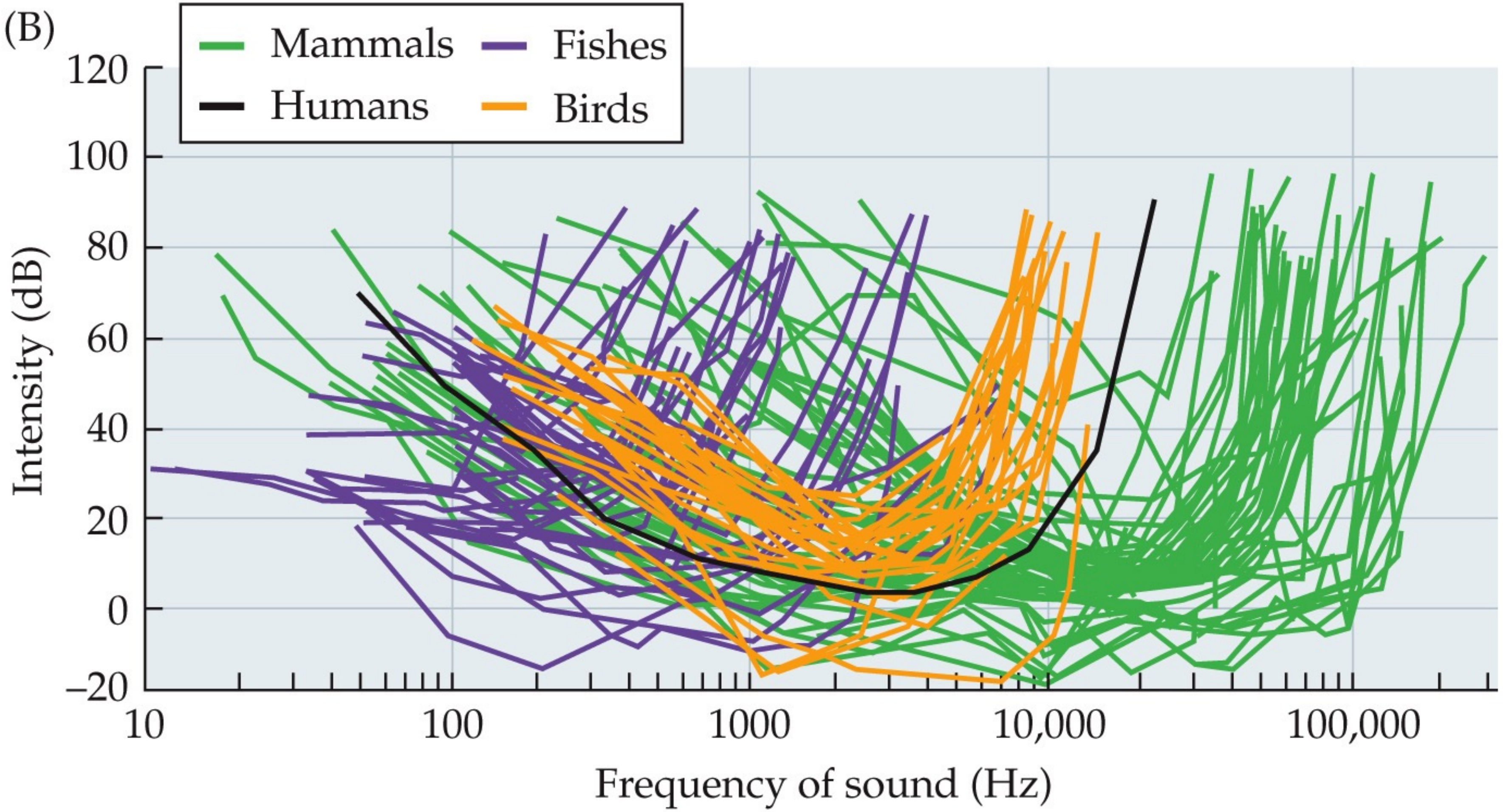


Sensory principles



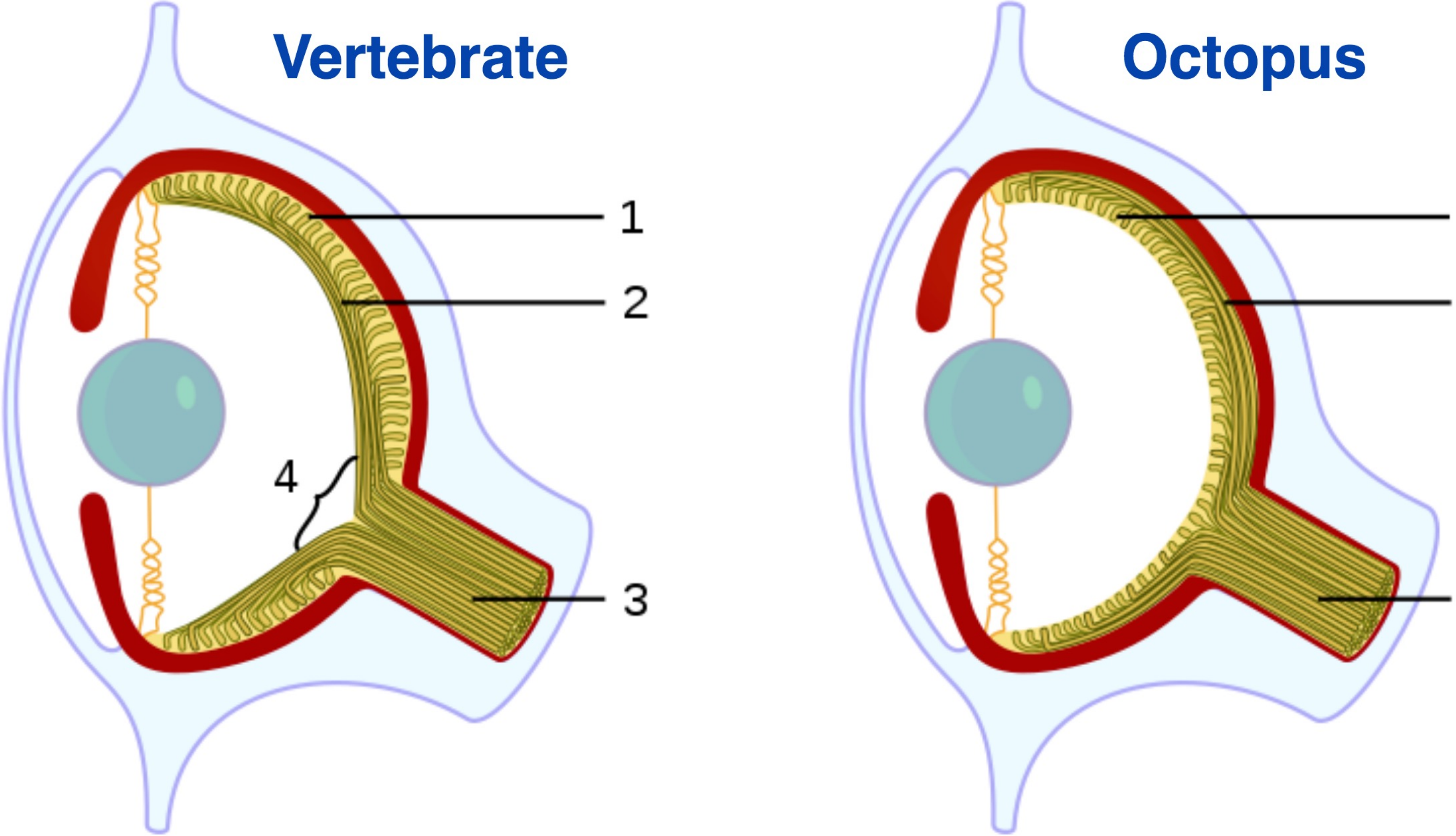
BEHAVIORAL NEUROSCIENCE 8e, Figure 8.2 (Part 1)

Sensory principles



BEHAVIORAL NEUROSCIENCE 8e, Figure 8.2 (Part 2)

Sensory principles



Sensory principles

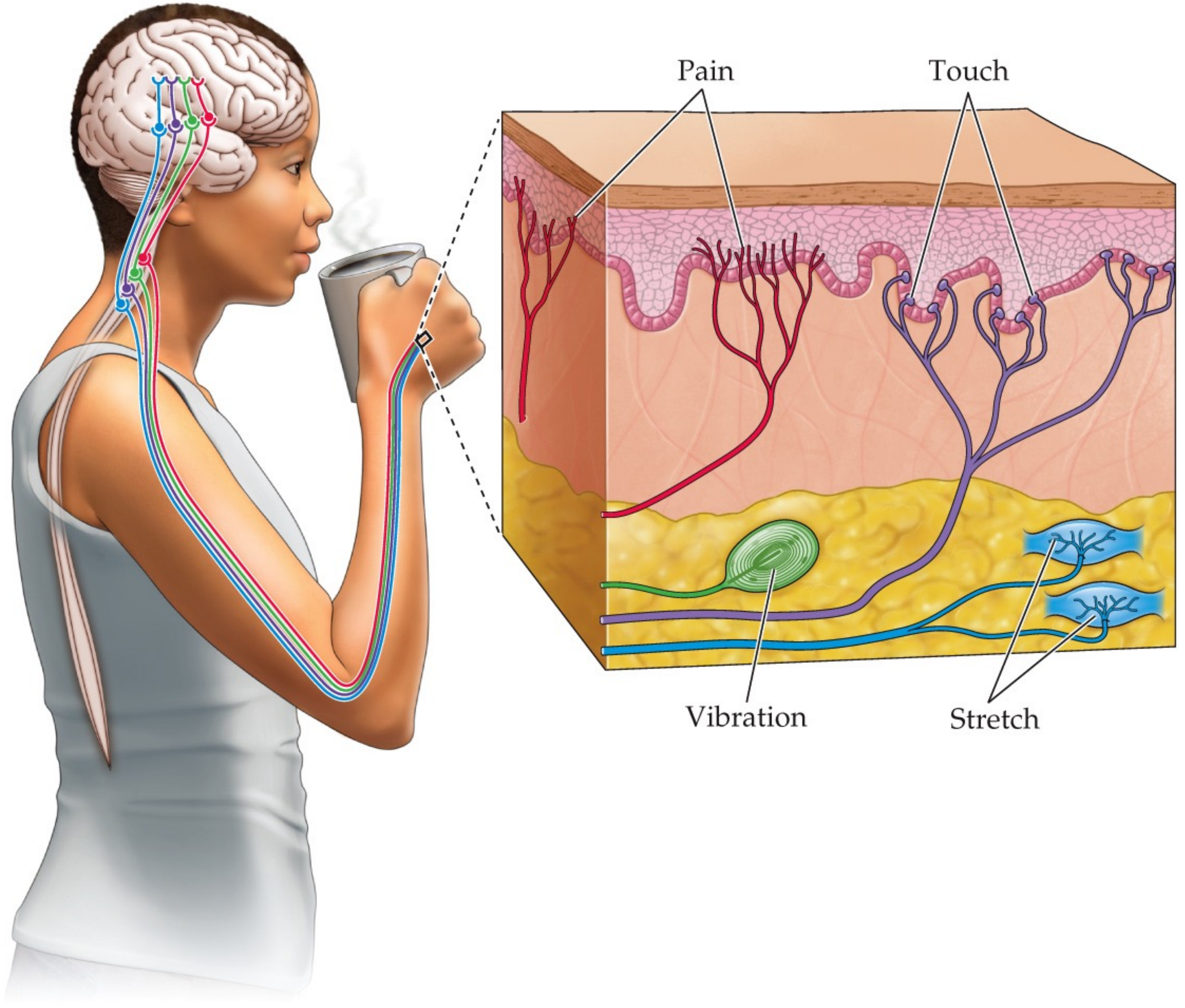
How can we decode action potentials, which are all the same, into separate senses?

The doctrine of **specific nerve energies**

The concept of **labelled lines**

What happens if the lines are crossed?

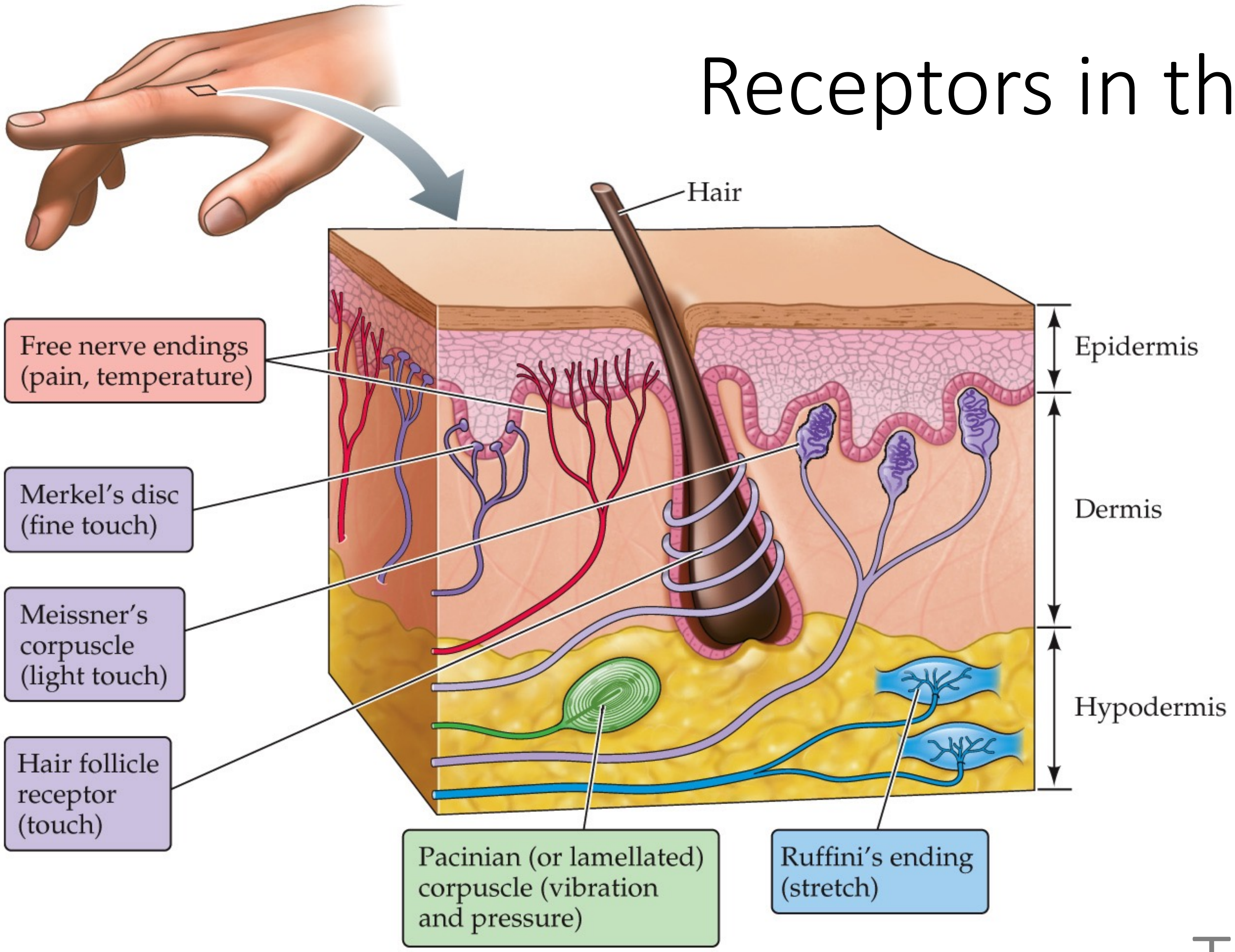
What happens if the lines are wired to different targets?



BEHAVIORAL NEUROSCIENCE 8e, Figure 8.3

Sensory principles

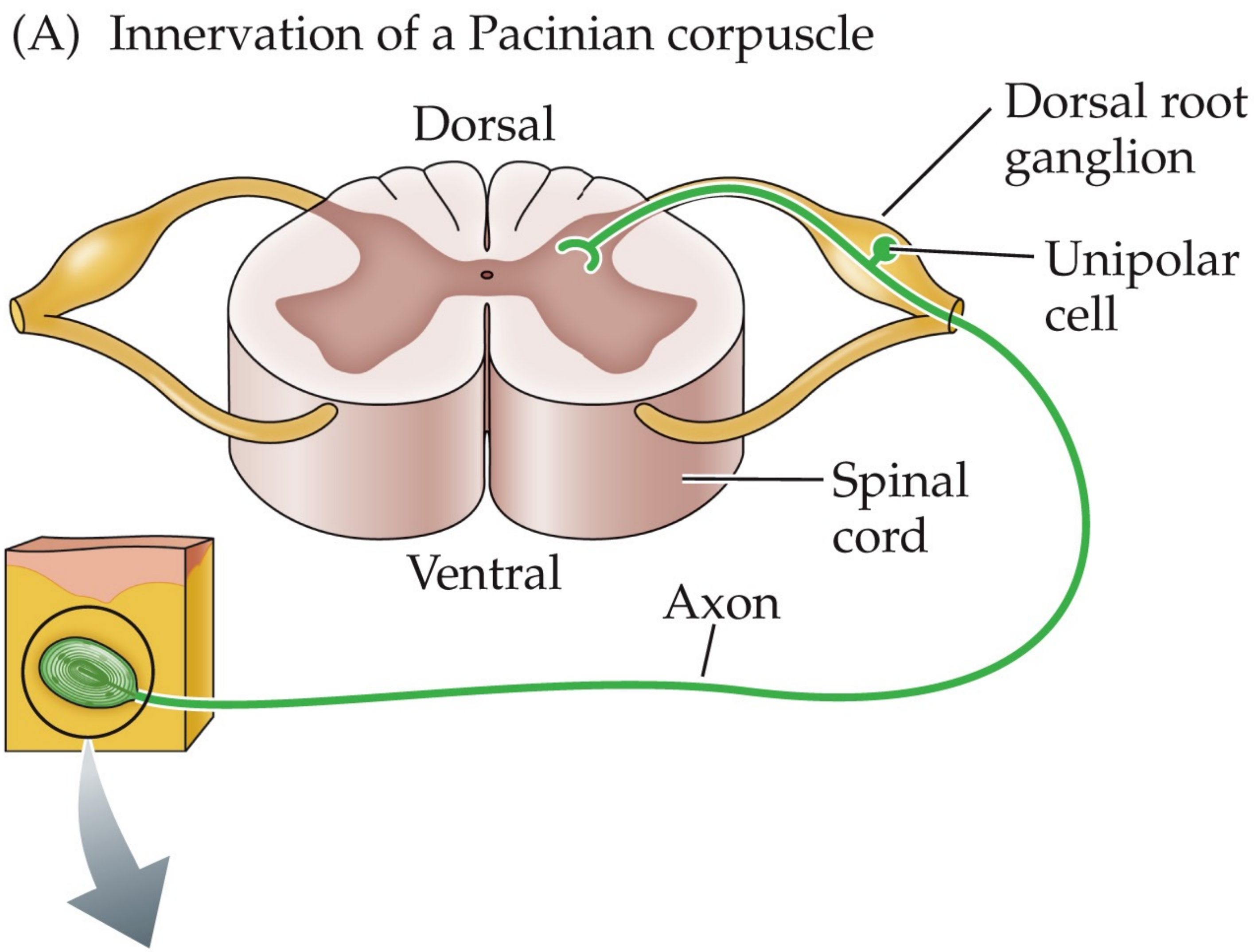
Receptors in the skin



BEHAVIORAL NEUROSCIENCE 8e, Figure 8.4

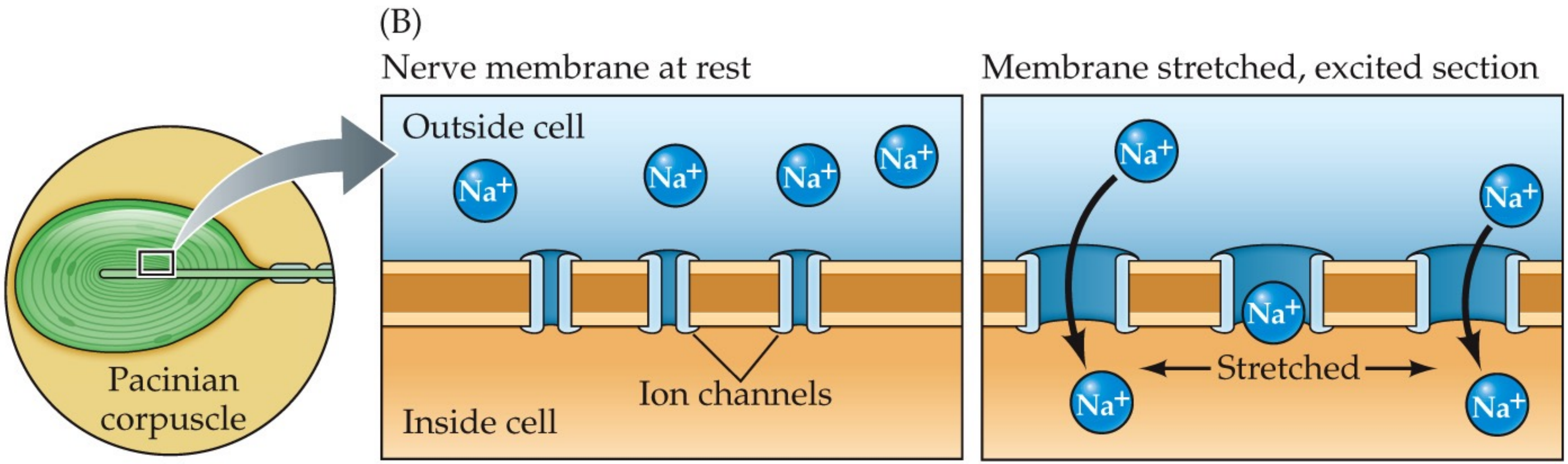
Example: the Pacinian Corpuscle (Part 1)

- AKA the *lamellated corpuscle*
- One type of skin receptor that detects vibration
- **Graded potentials**
- Action potentials
- Cell bodies in the dorsal root ganglia
  (i.e. *pseudounipolar* neurons)



BEHAVIORAL NEUROSCIENCE 8e, Figure 8.5 (Part 1)

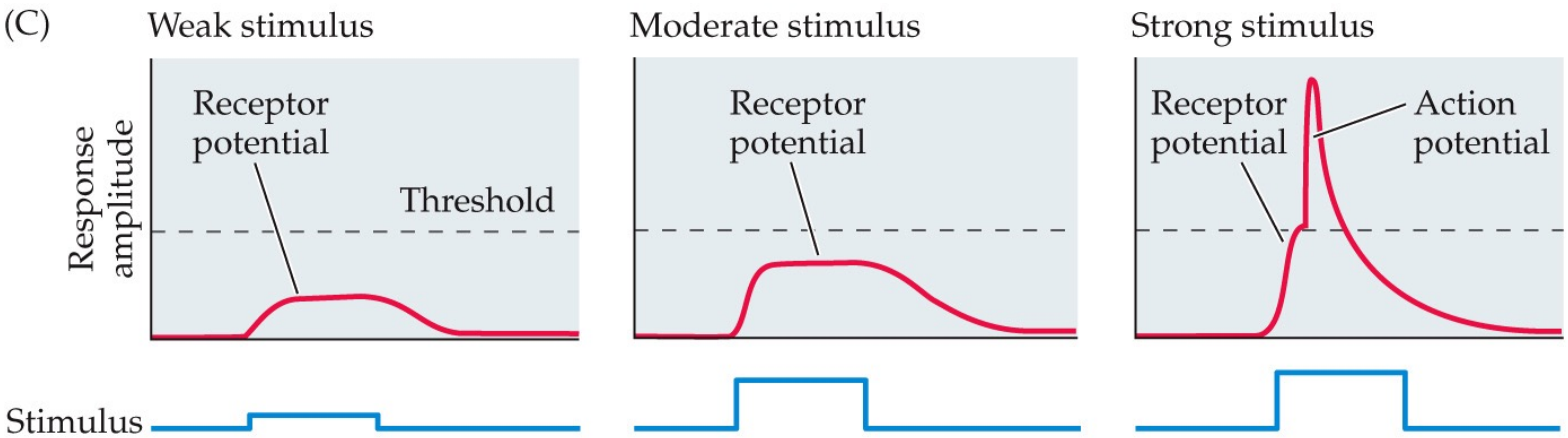
Example: the Pacinian Corpuscle (Part 2)



BEHAVIORAL NEUROSCIENCE 8e, Figure 8.5 (Part 2)

- Transduction via stretch receptors
- Similar to receptors in your muscles (for proprioception, called **muscle spindles**)

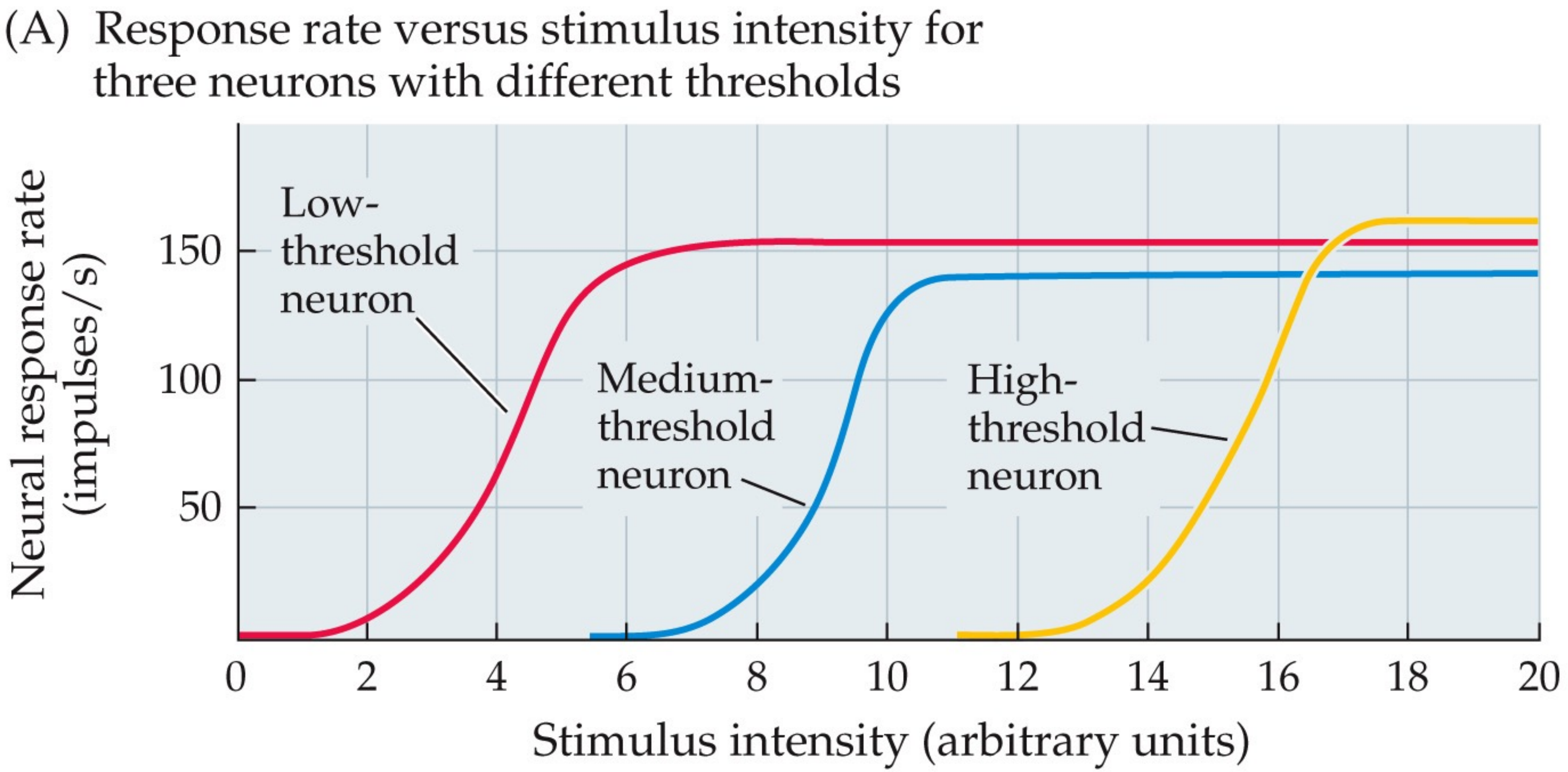
Receptor potentials and APs



BEHAVIORAL NEUROSCIENCE 8e, Figure 8.5 (Part 3)

- This should look familiar!

Intensity Coding: cells with differing thresholds



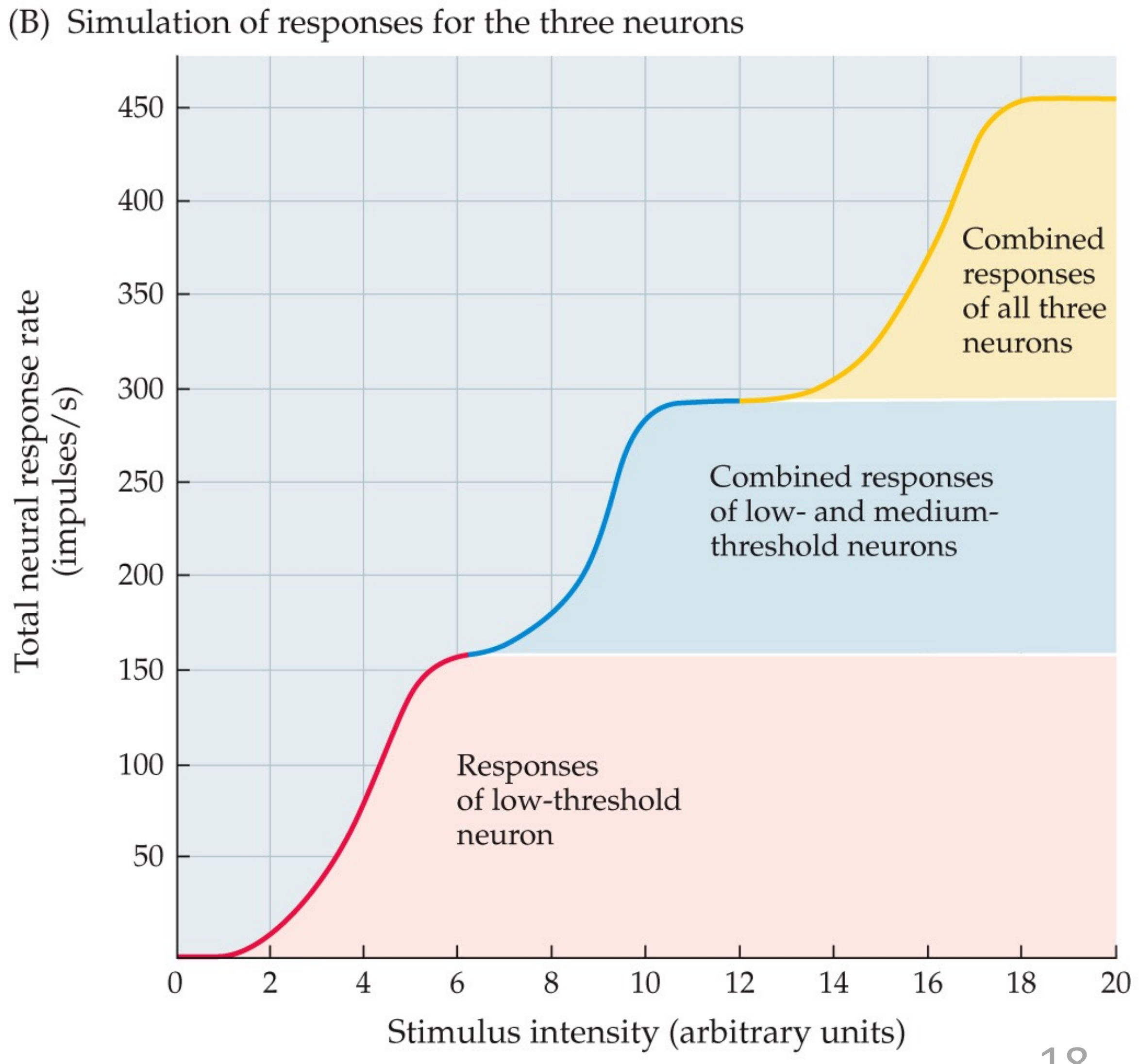
BEHAVIORAL NEUROSCIENCE 8e, Figure 8.6 (Part 1)

Intensity Coding: summation of responses

Multiple neurons act in parallel

Stimulus strengthens, more neurons recruited

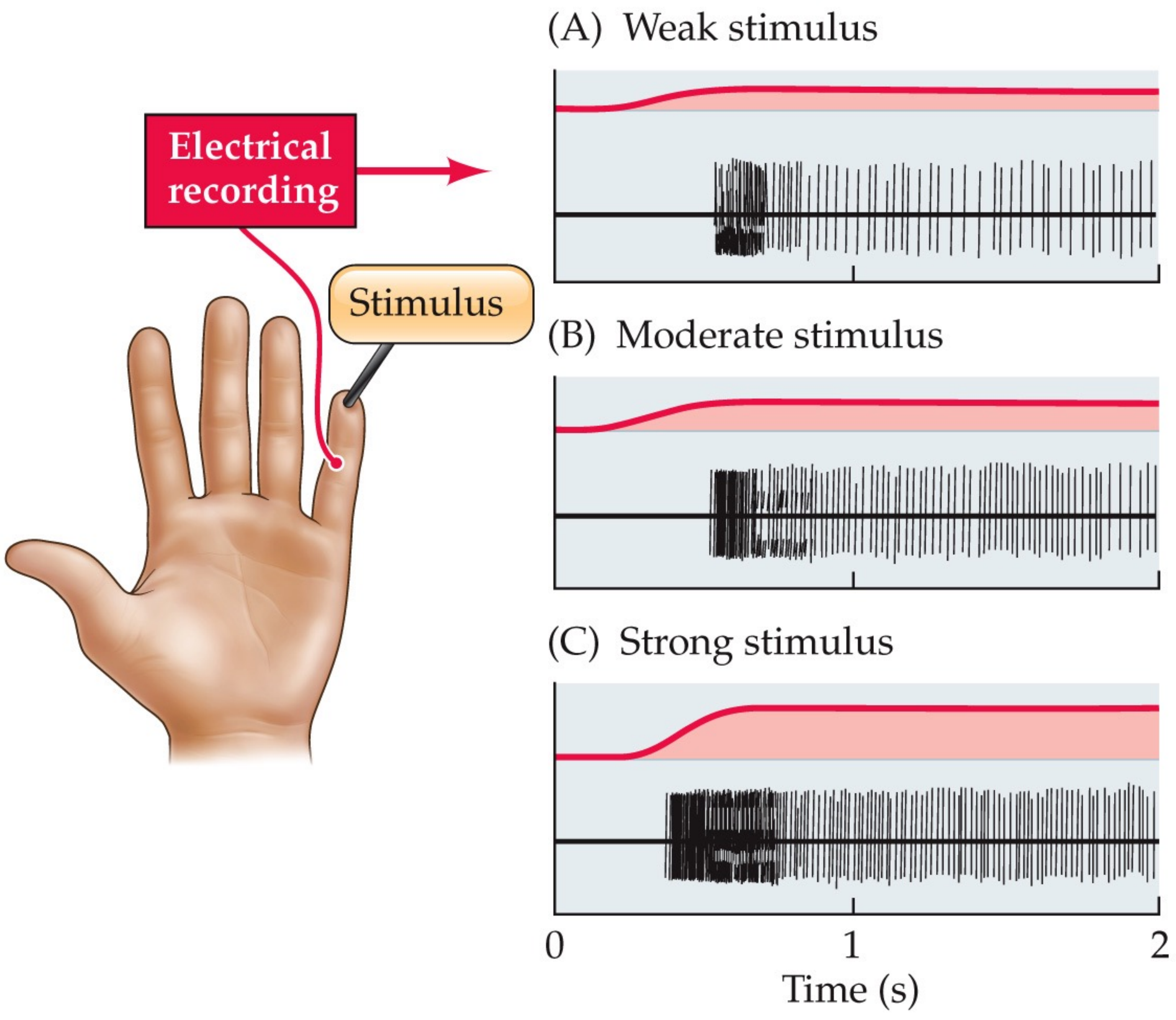
Range fractionation



BEHAVIORAL NEUROSCIENCE 8e, Figure 8.6 (Part 2)

Sensory Adaptation

- **Adaptation**: Progressive loss of response to maintained stimulus
- Why have adaptation?
- **Tonic receptors** (slow-adapting)
- **Phasic receptors** (fast-adapting)



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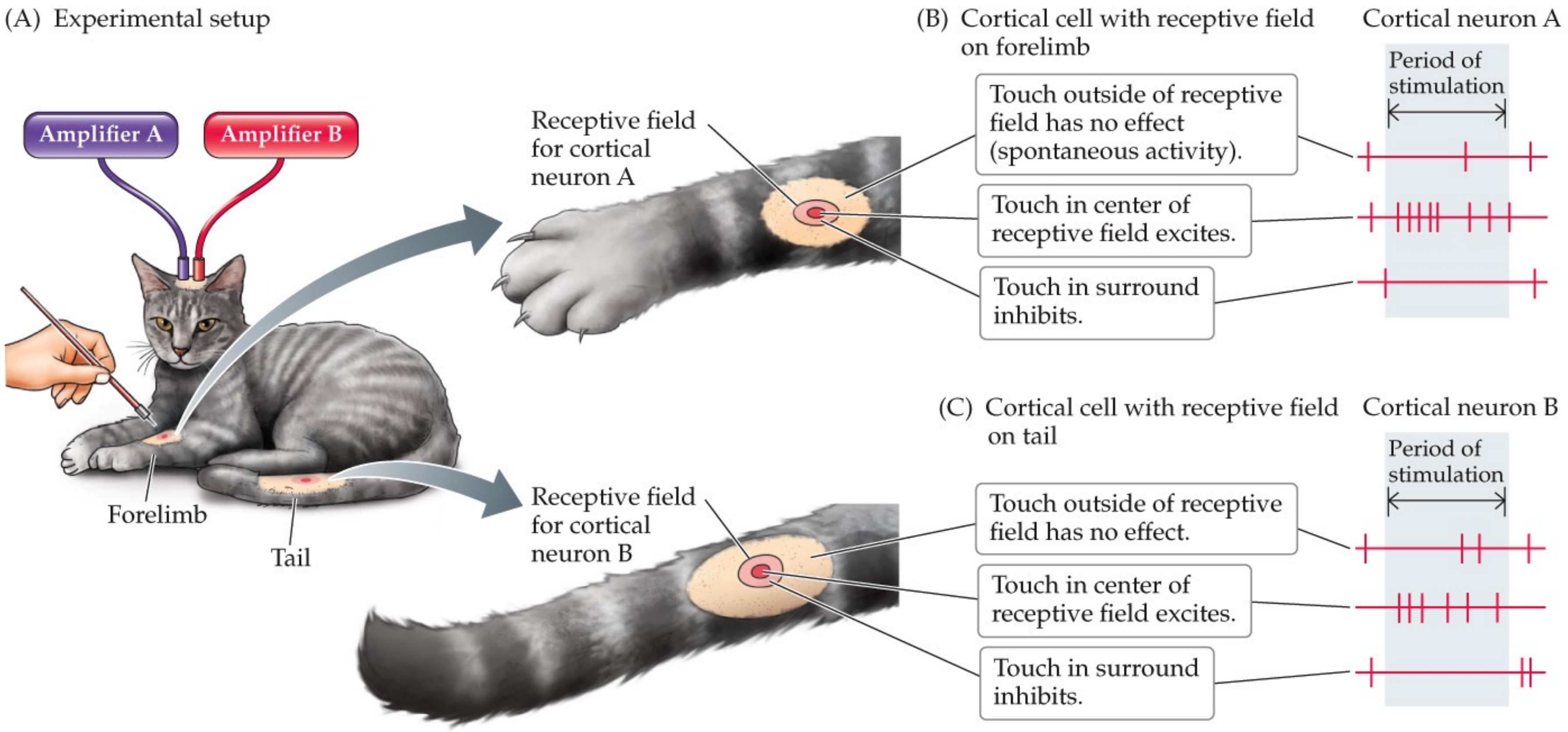
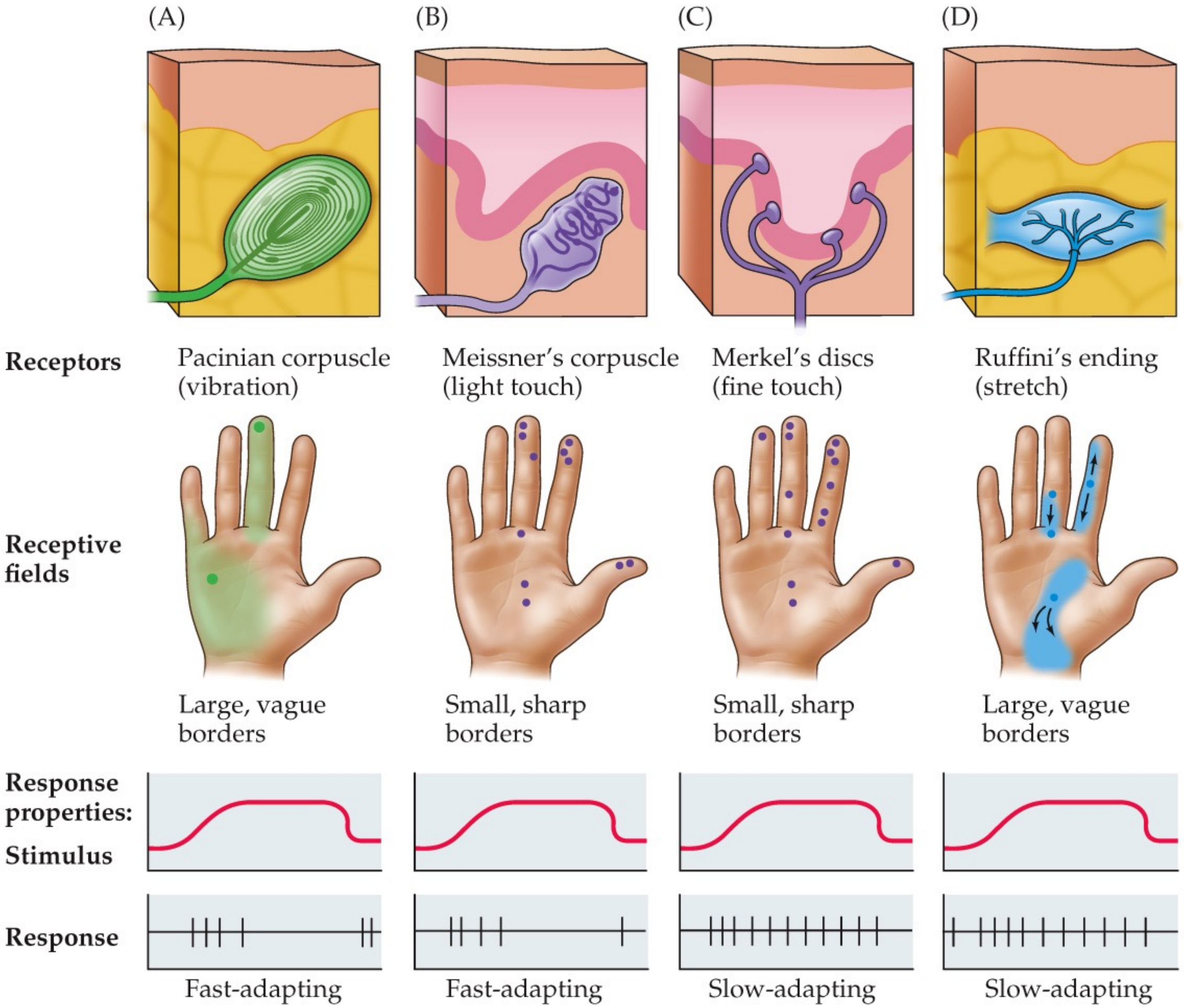
Receptive Fields



BEHAVIORAL NEUROSCIENCE 8e, Figure 8.9

Sensory principles

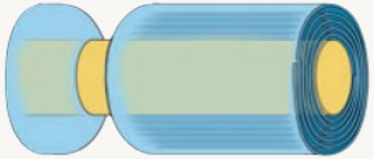
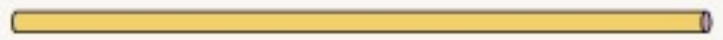
The four main skin receptors



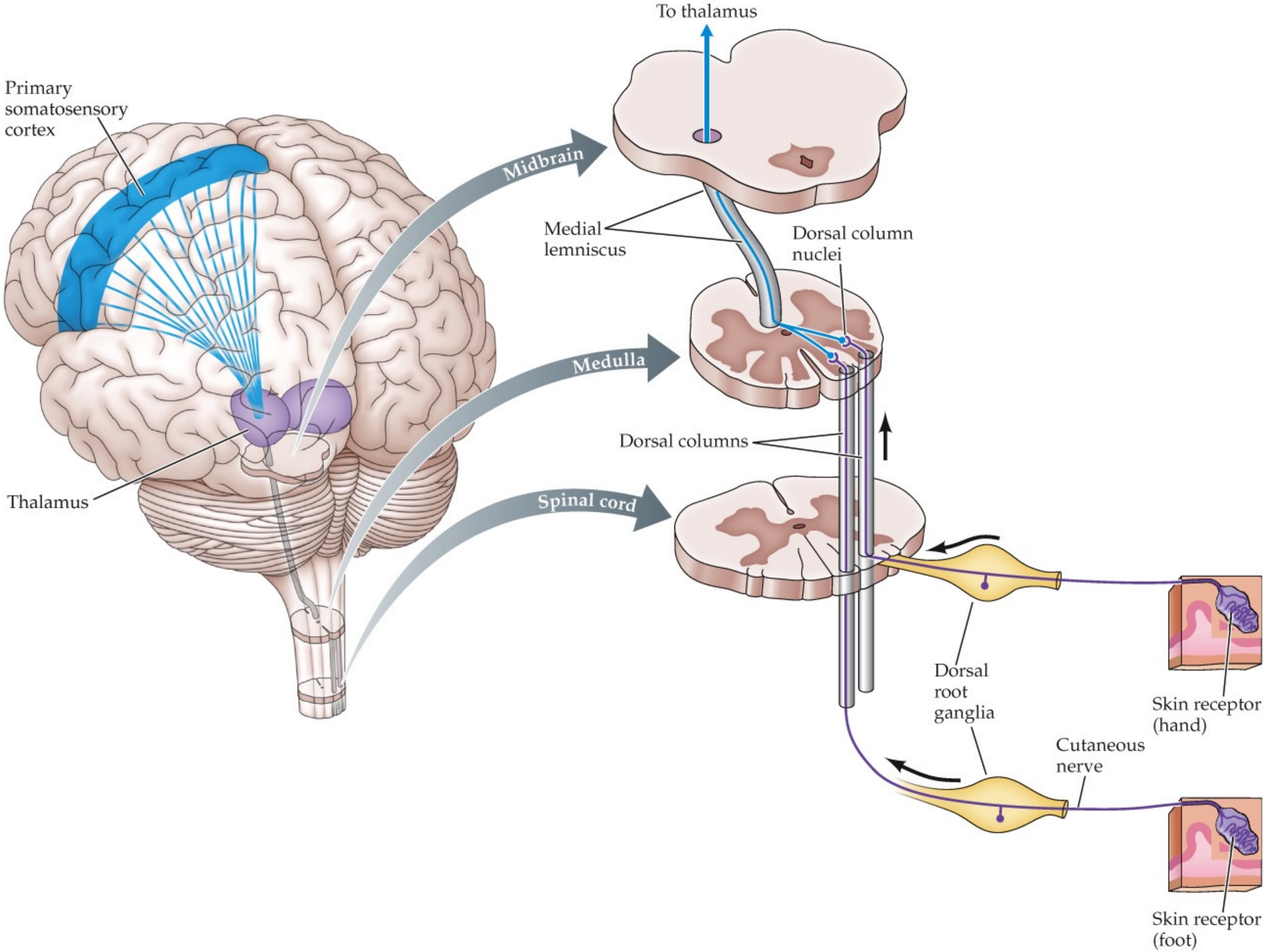
BEHAVIORAL NEUROSCIENCE 8e, Figure 8.13

Afferent axons from skin receptors

TABLE 8.2 Fibers That Link Receptors to the CNS

SENSORY FUNCTION(S)	RECEPTOR TYPE(S)	AXON TYPE	DIAMETER (μm)	CONDUCTION SPEED (M/S)
Proprioception (body sense)	Muscle spindle (see Chapter 11)	 Aα (A alpha)	13–20	80–120
Touch (see Figures 8.13 and 8.14)	Pacinian corpuscles, Ruffini's endings, Merkel's discs, Meissner's corpuscles	 Aβ (A beta)	6–12	35–75
Pain, temperature	Free nerve endings	 Aδ (A delta)	1–5	5–30
Temperature, pain, itch	Free nerve endings	 C	0.2–1.5	< 1

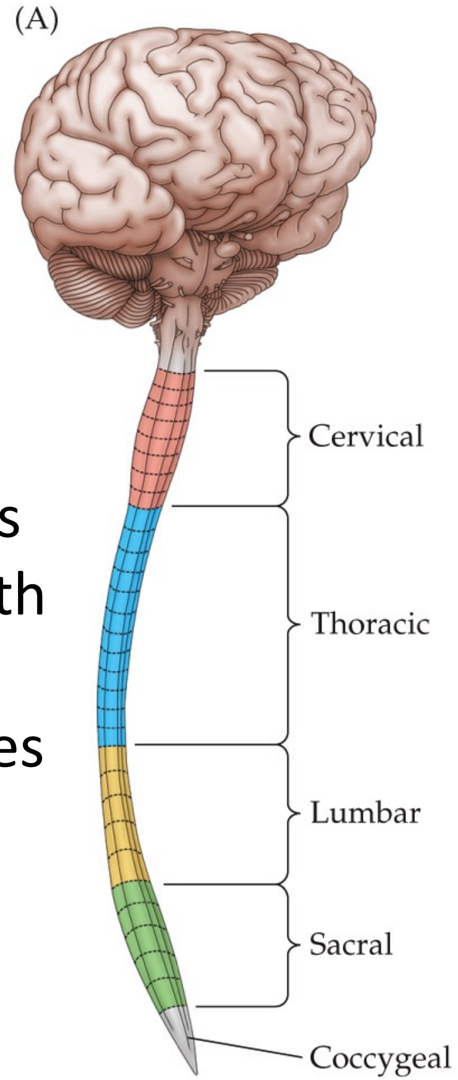
Pathways: The dorsal column system



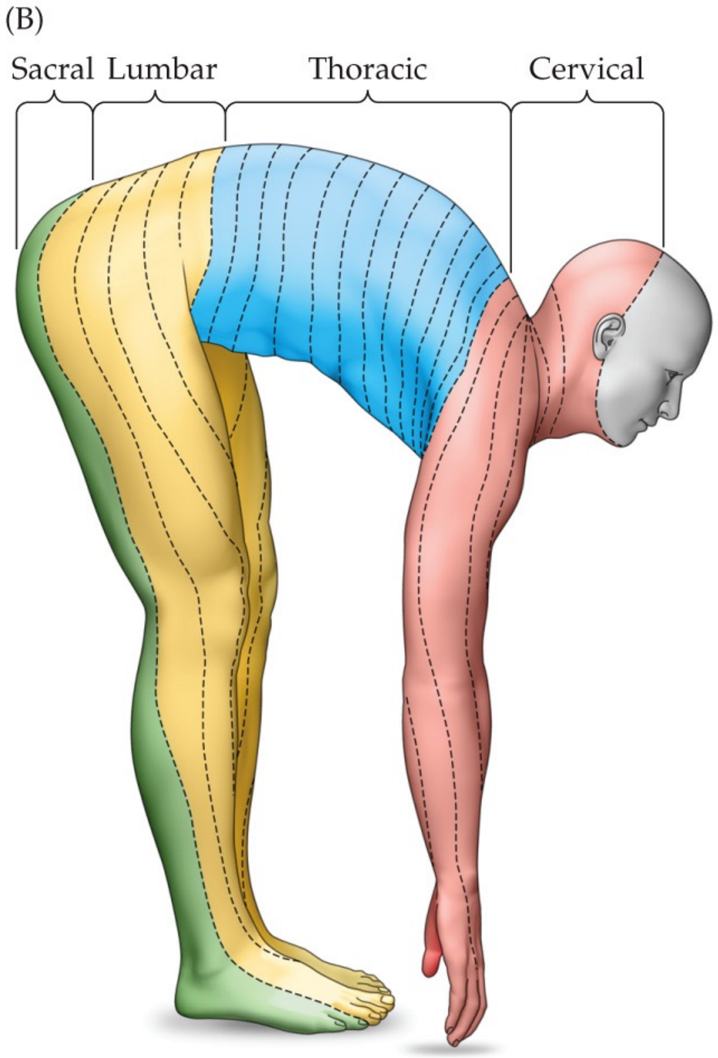
BEHAVIORAL NEUROSCIENCE 8e, Figure 8.15

Dermatomes

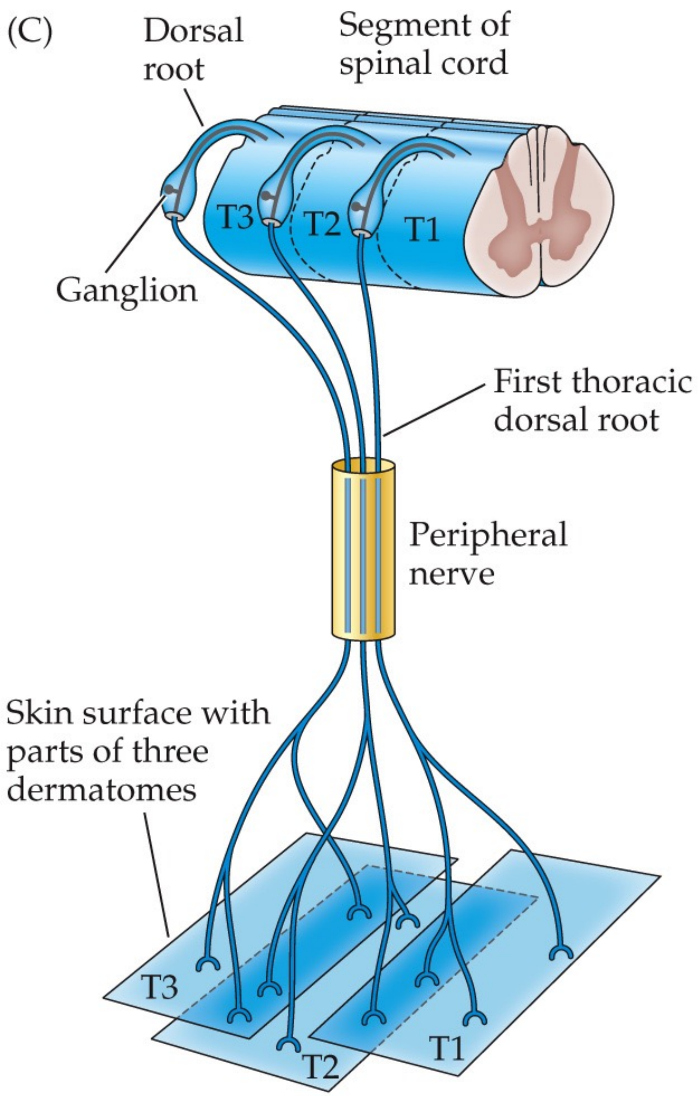
- Related to different dorsal roots
- Overlap with adjacent dermatomes



BEHAVIORAL NEUROSCIENCE 8e, Figure 8.16 (Part 1)



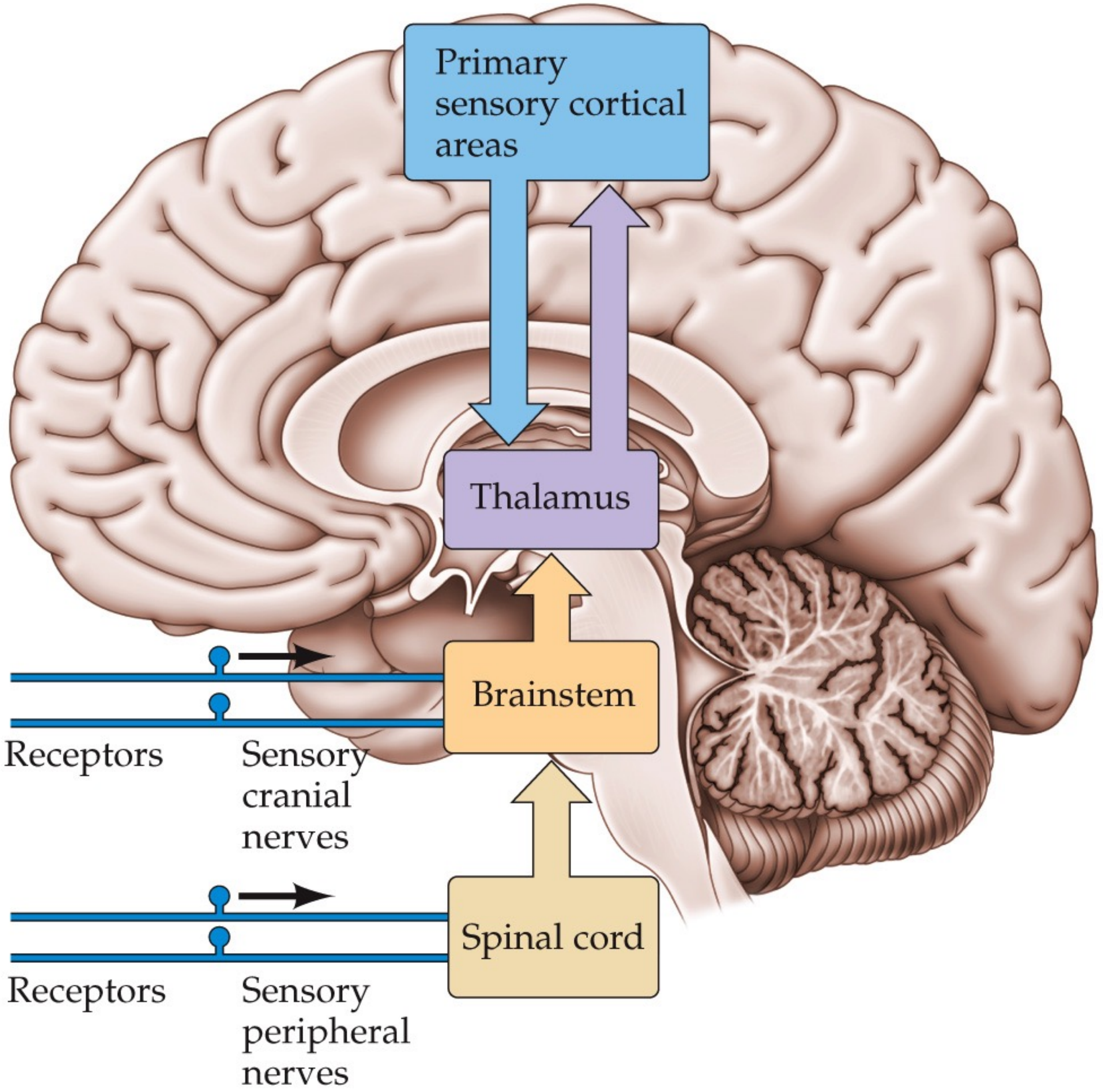
BEHAVIORAL NEUROSCIENCE 8e, Figure 8.16 (Part 2)



BEHAVIORAL NEUROSCIENCE 8e, Figure 8.16 (Part 3)

Sensory pathways

- Segregated pathways
- Arrive via nerves to spinal cord or brain stem
- Most (not all) pass through thalamus
- Terminate in the cerebral cortex



BEHAVIORAL NEUROSCIENCE 8e, Figure 8.8

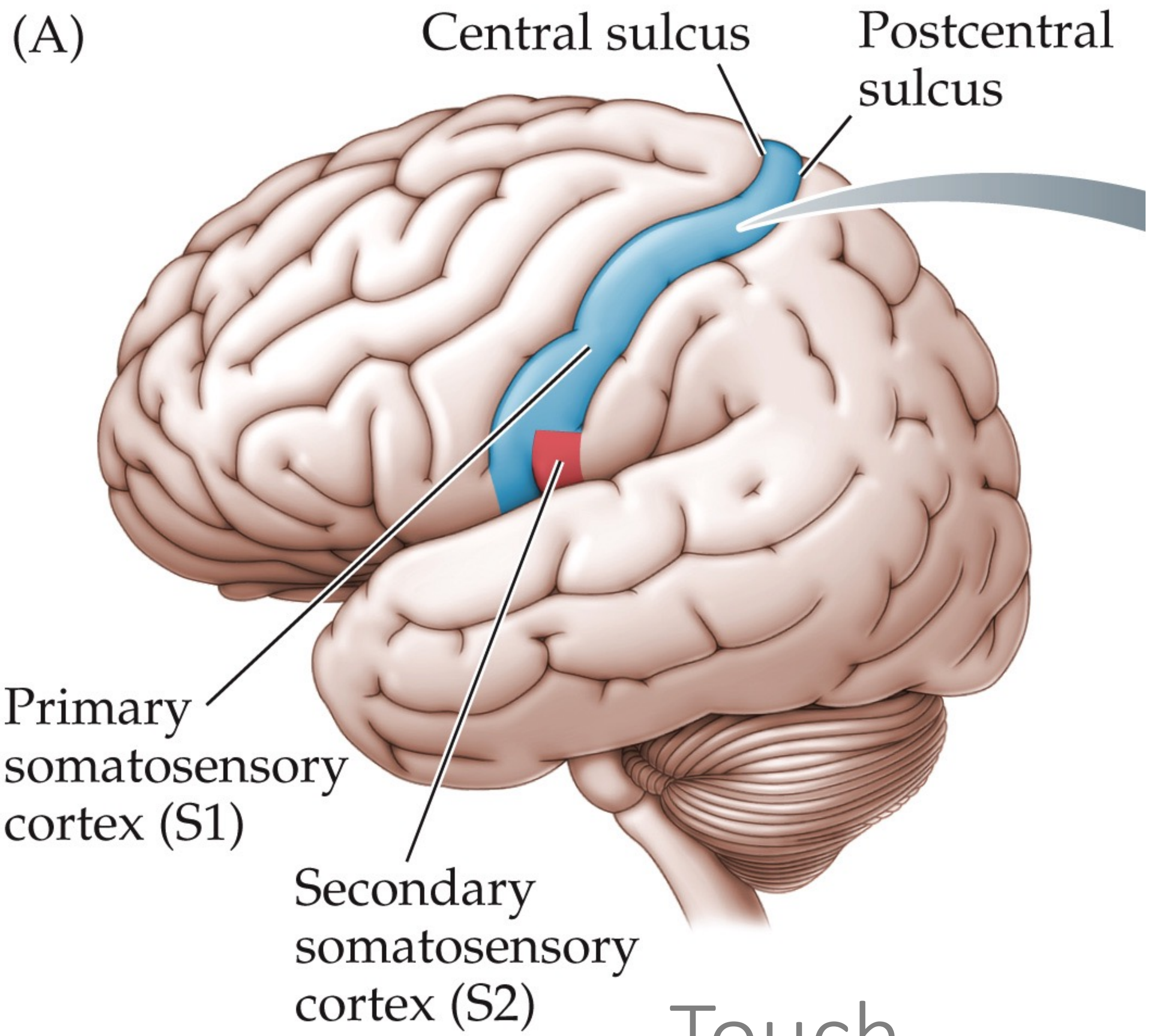
Cortical organization of sensory information

Primary somatosensory cortex (S1)

- *Contralateral* organization
- *Somatotopic* organization

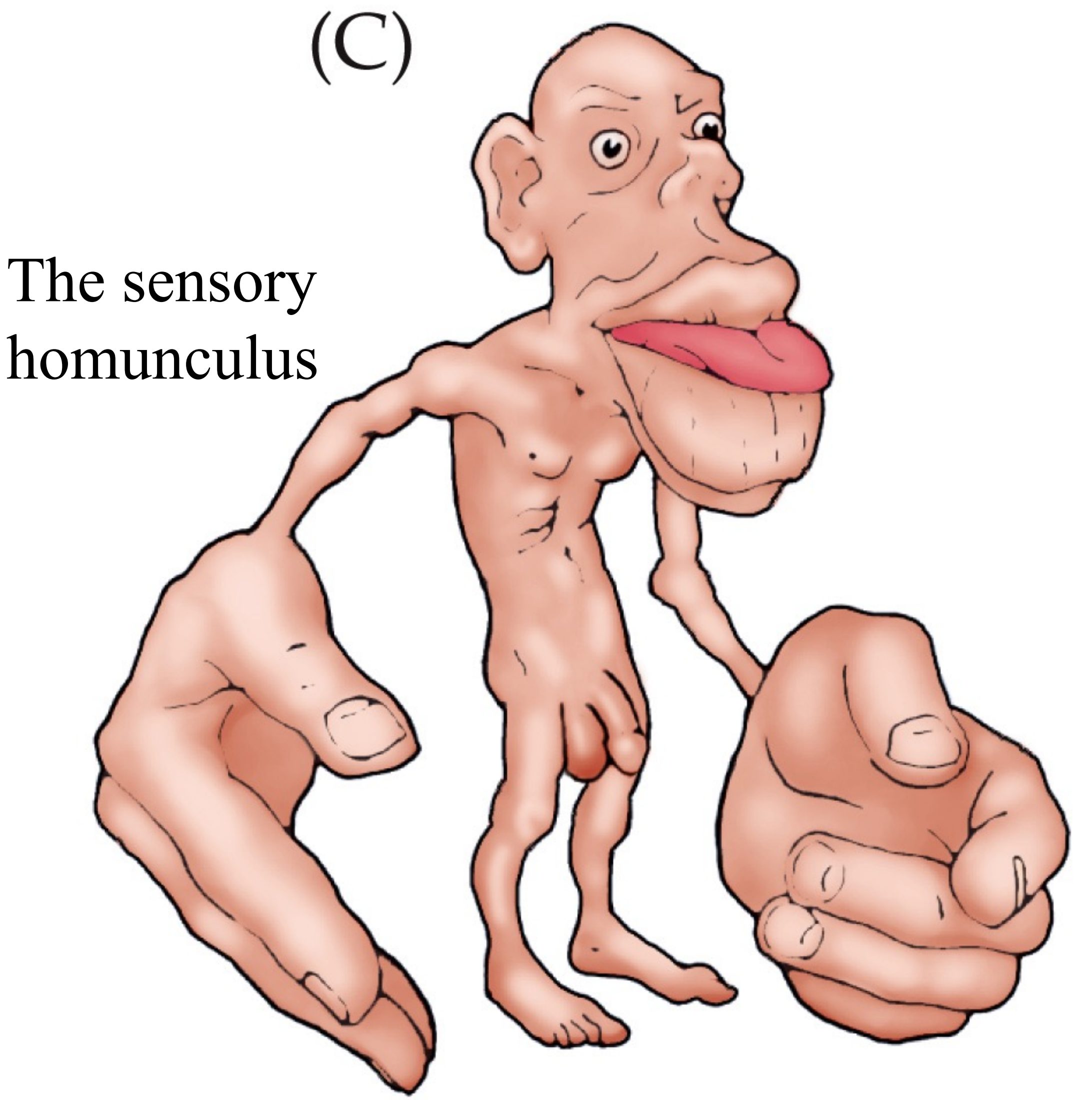
Secondary somatosensory cortex (S2)

- More sophisticated processing
  - e.g. bilateral information

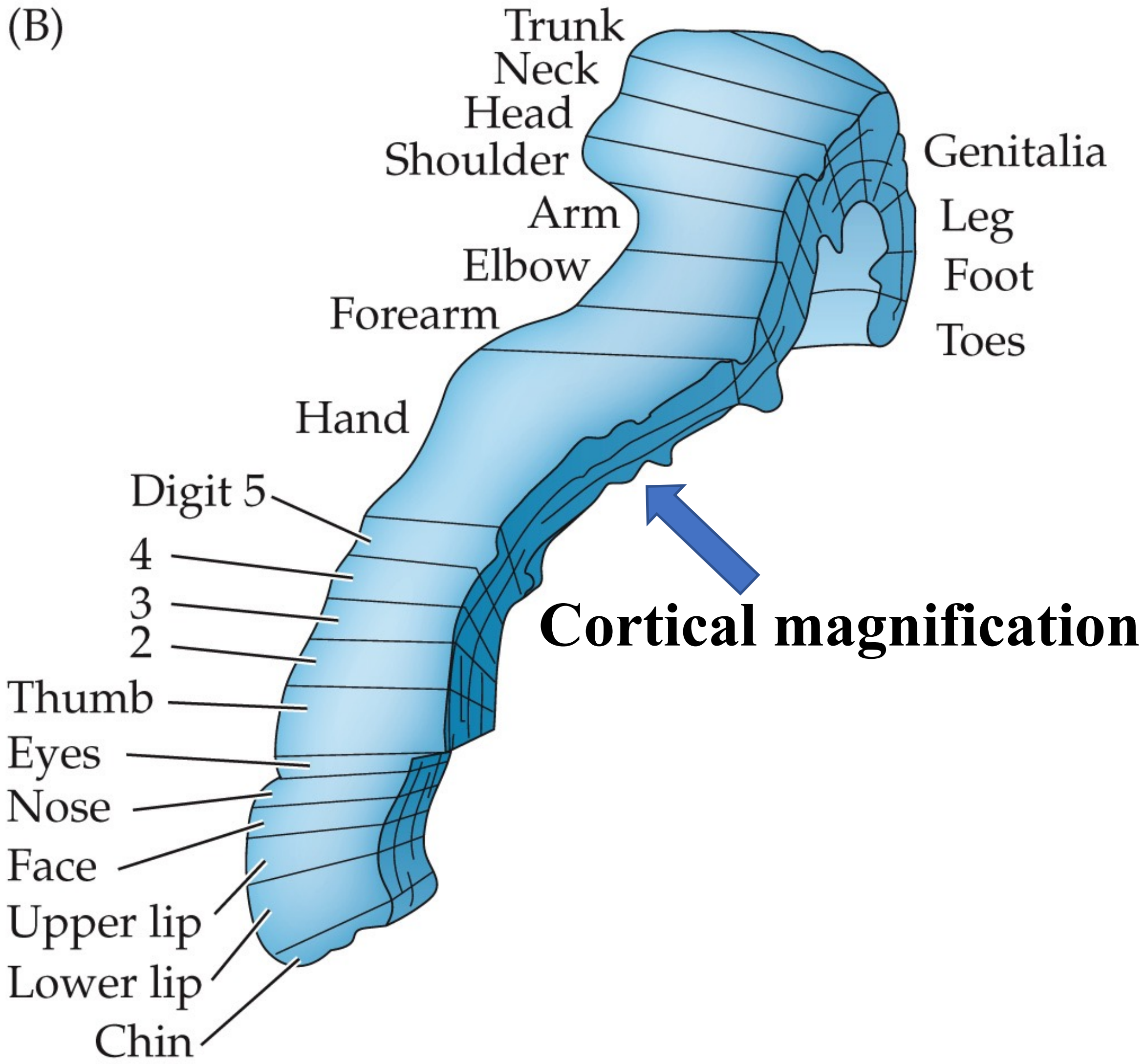


BEHAVIORAL NEUROSCIENCE 8e, Figure 8.10 (Part 1)

-topic organization (in this case, somatotopic)



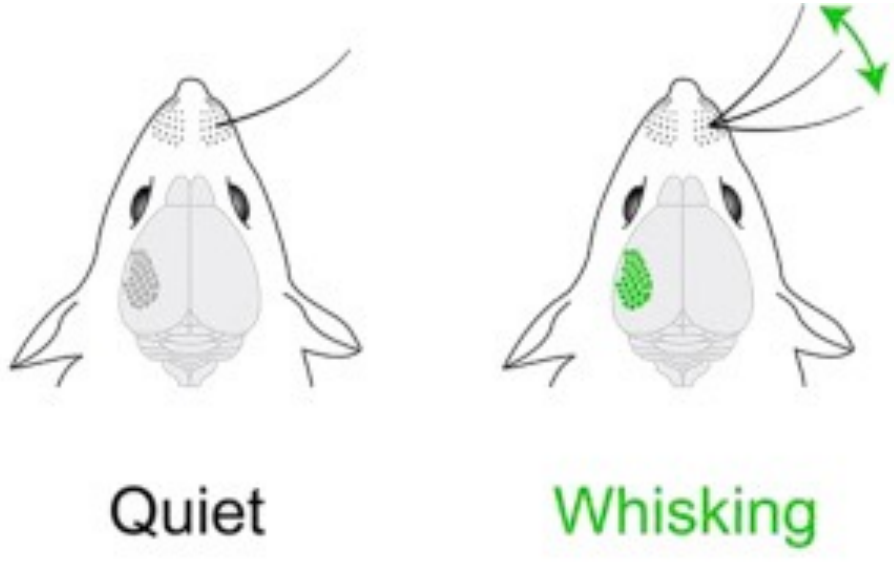
BEHAVIORAL NEUROSCIENCE 8e, Figure 8.10 (Part 3)

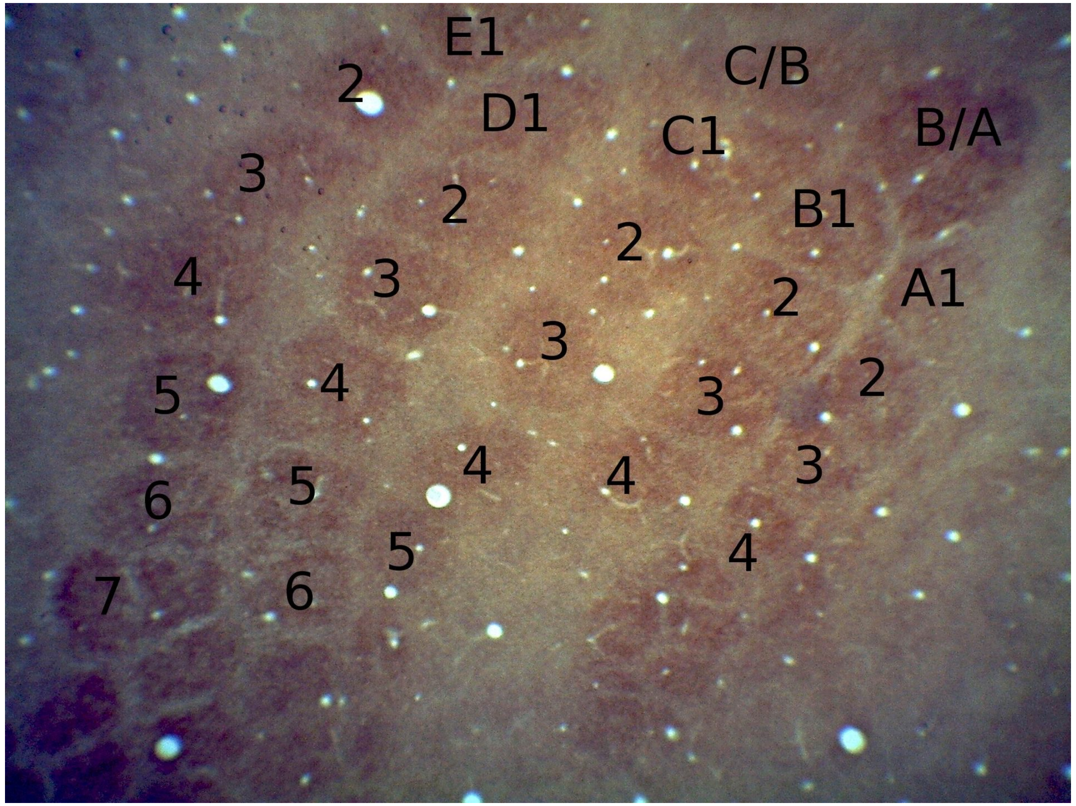


BEHAVIORAL NEUROSCIENCE 8e, Figure 8.10 (Part 2)

Special systems for special animals

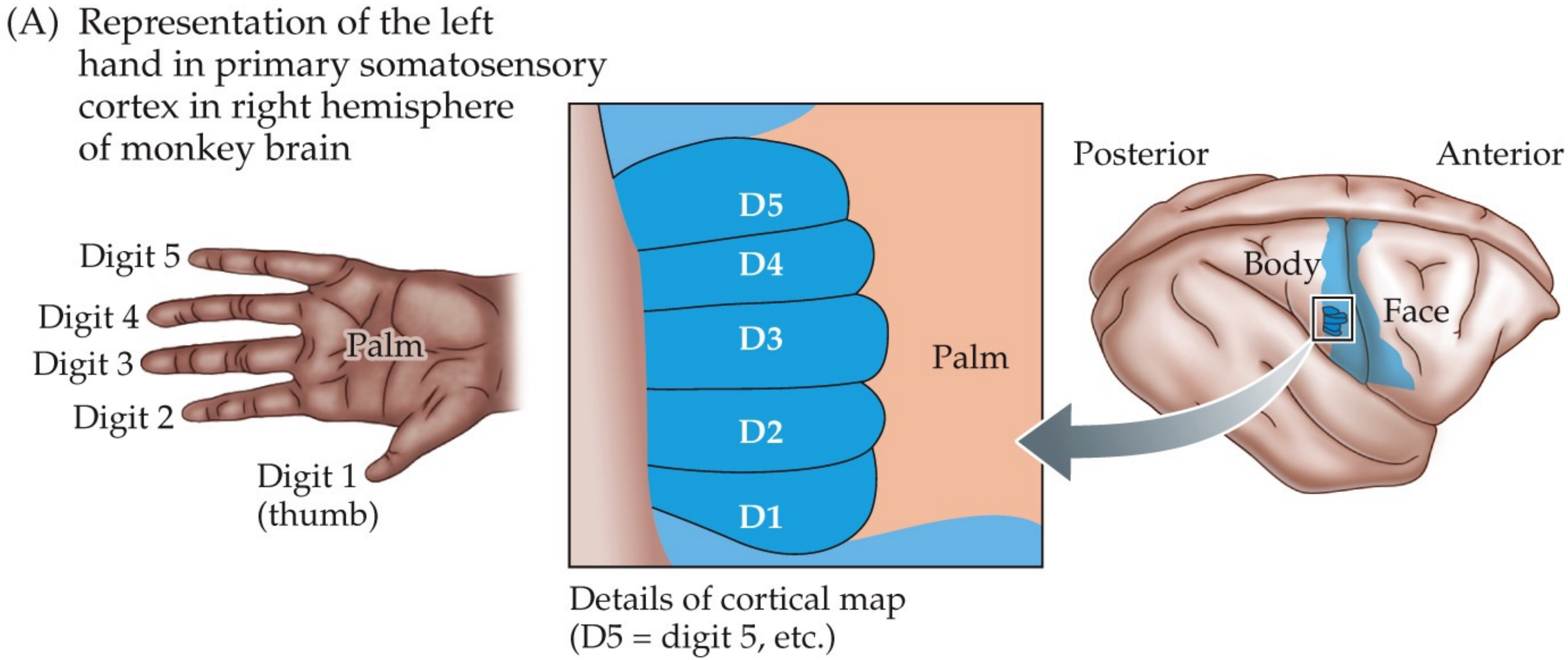
- Whiskers are for whisking!
- The barrel cortex





Touch

Cortical representation



BEHAVIORAL NEUROSCIENCE 8e, Figure 8.17 (Part 1)

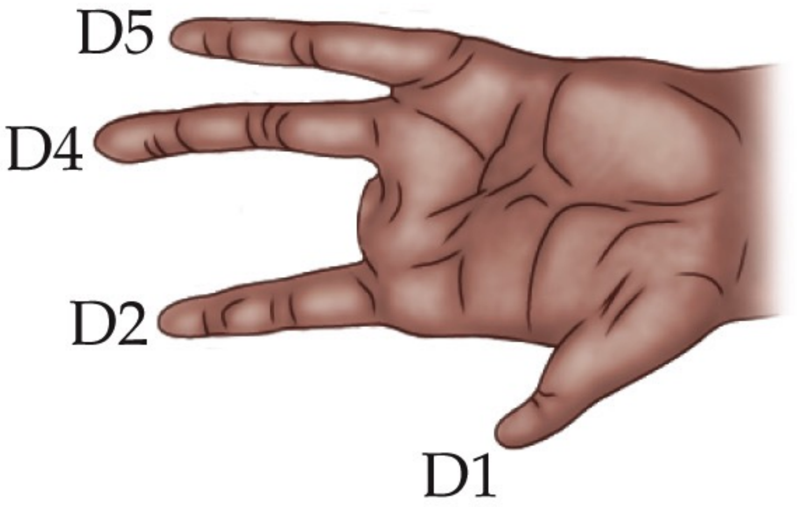
Receptive fields get larger, are flexible

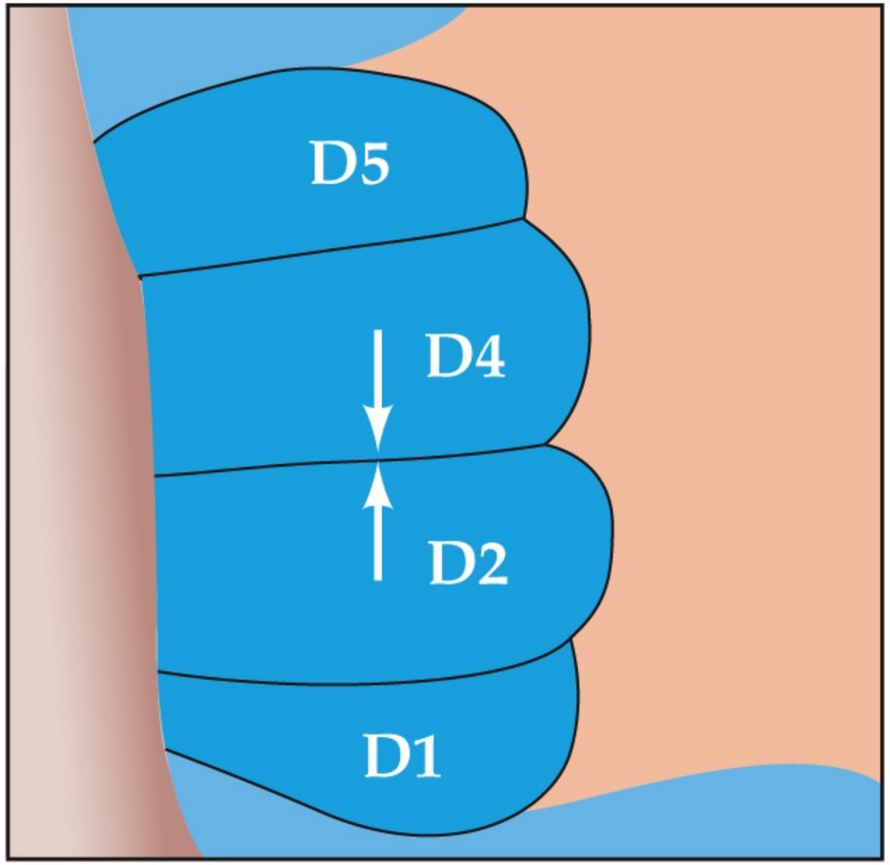
Representation is based on use

Neuroplasticity due to damage

"The brain abhors an unused neuron."

—Your teacher, last night when he was prepping these slides

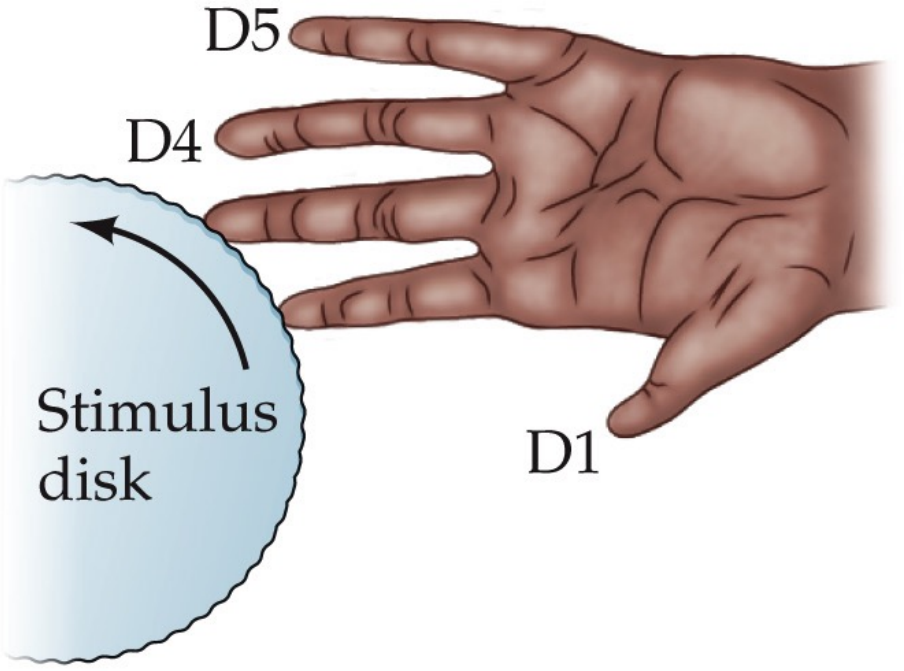


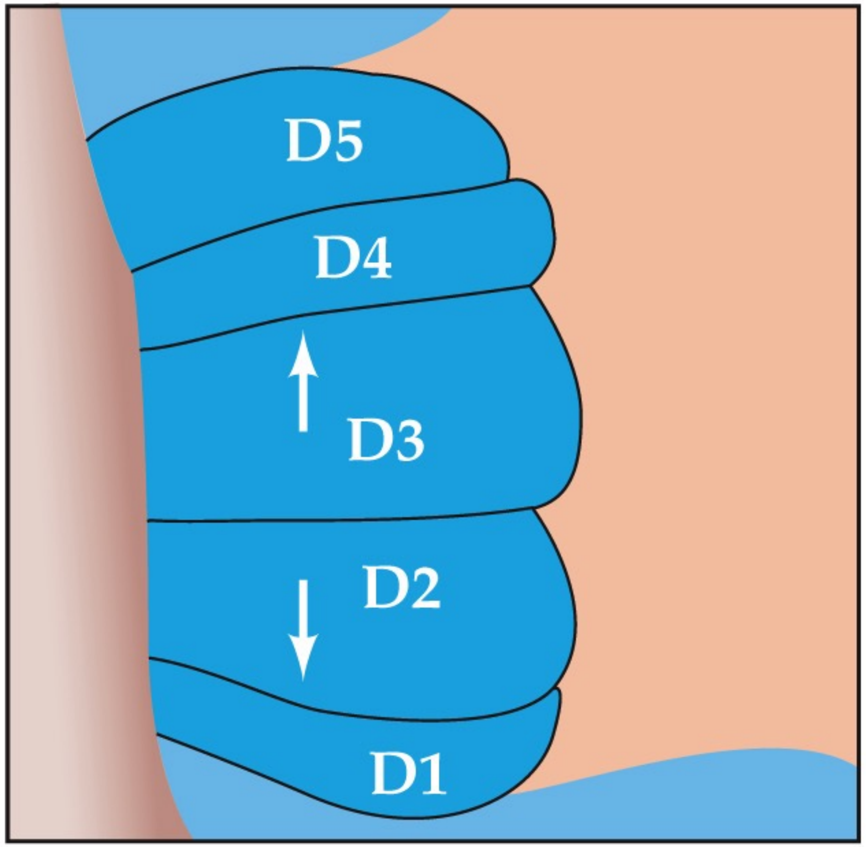


BEHAVIORAL NEUROSCIENCE 8e, Figure 8.17 (Part 2)

Neuroplasticity due to use

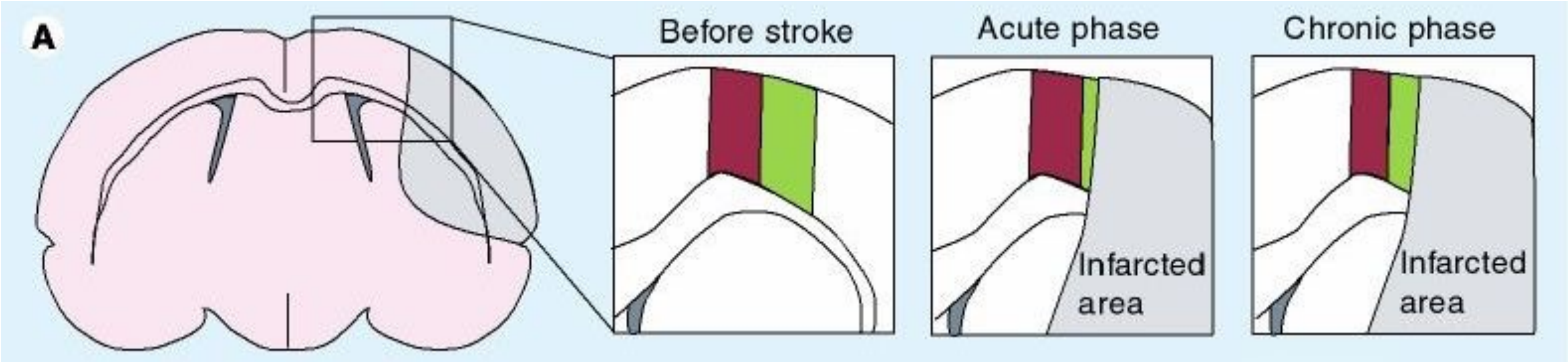
Implications for your life?





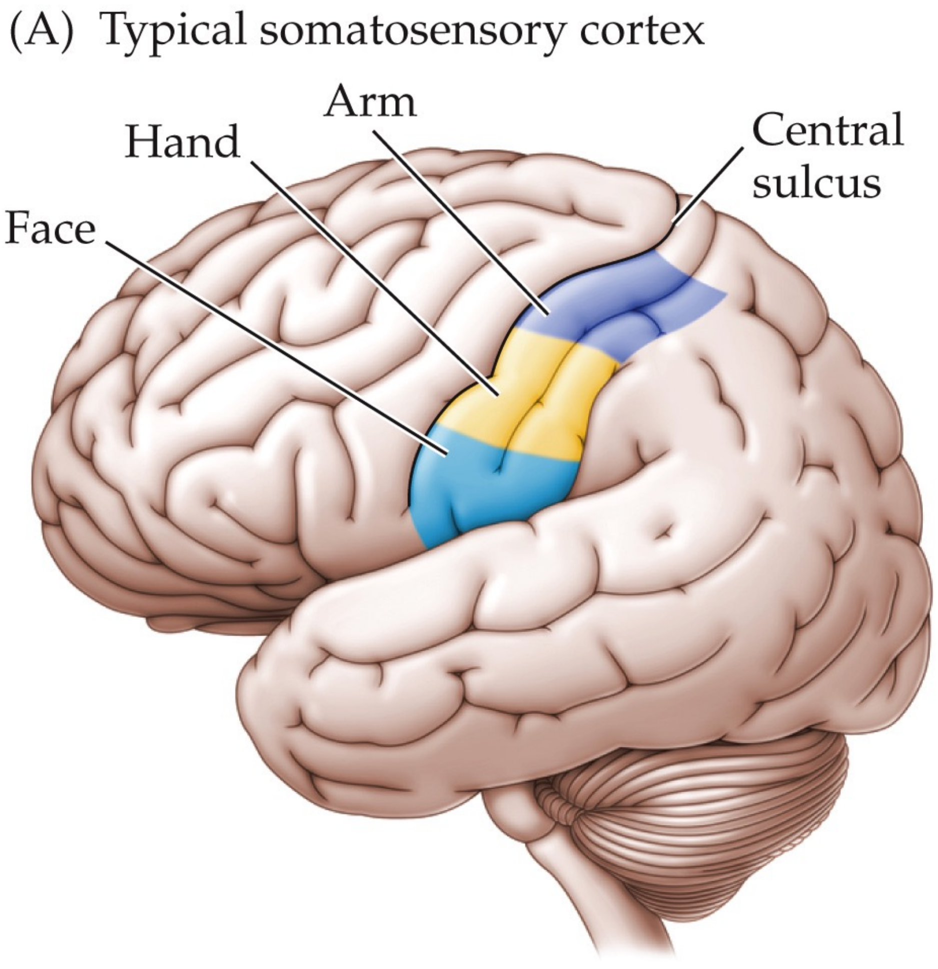
BEHAVIORAL NEUROSCIENCE 8e, Figure 8.17 (Part 3)

Neuroplasticity due to cortical damage

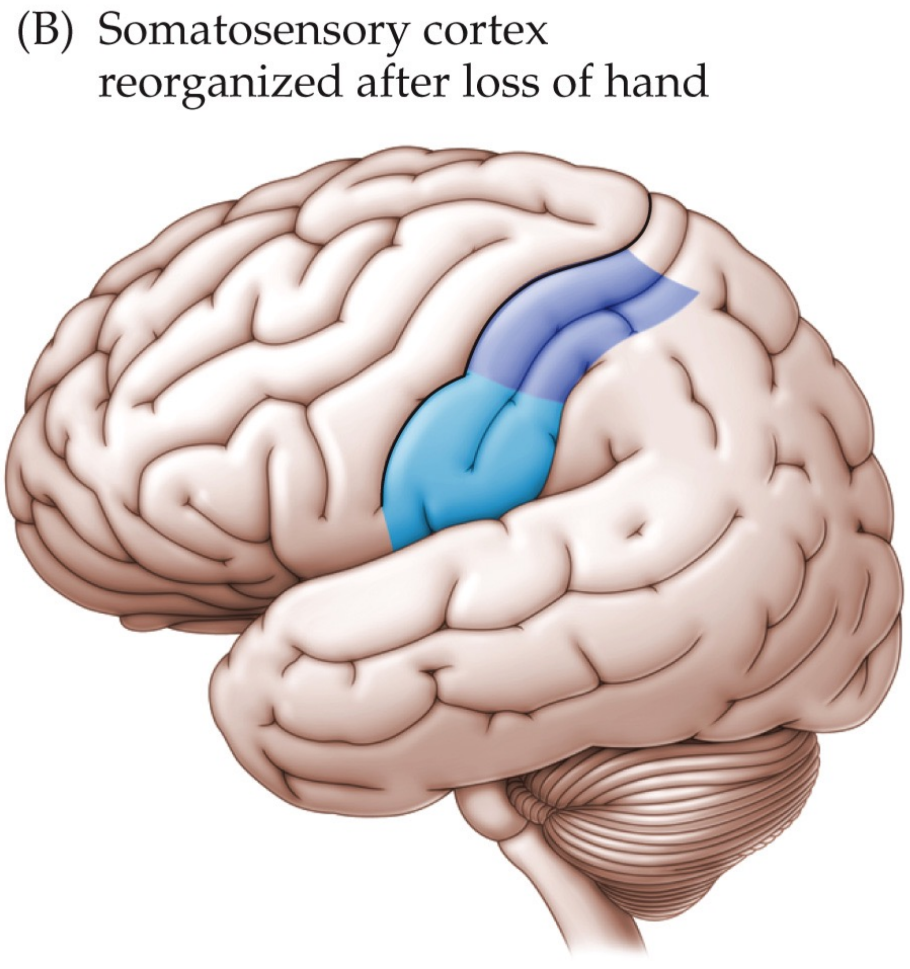


Constraint-induced therapy

Phantom limbs: a case of large-scale plasticity



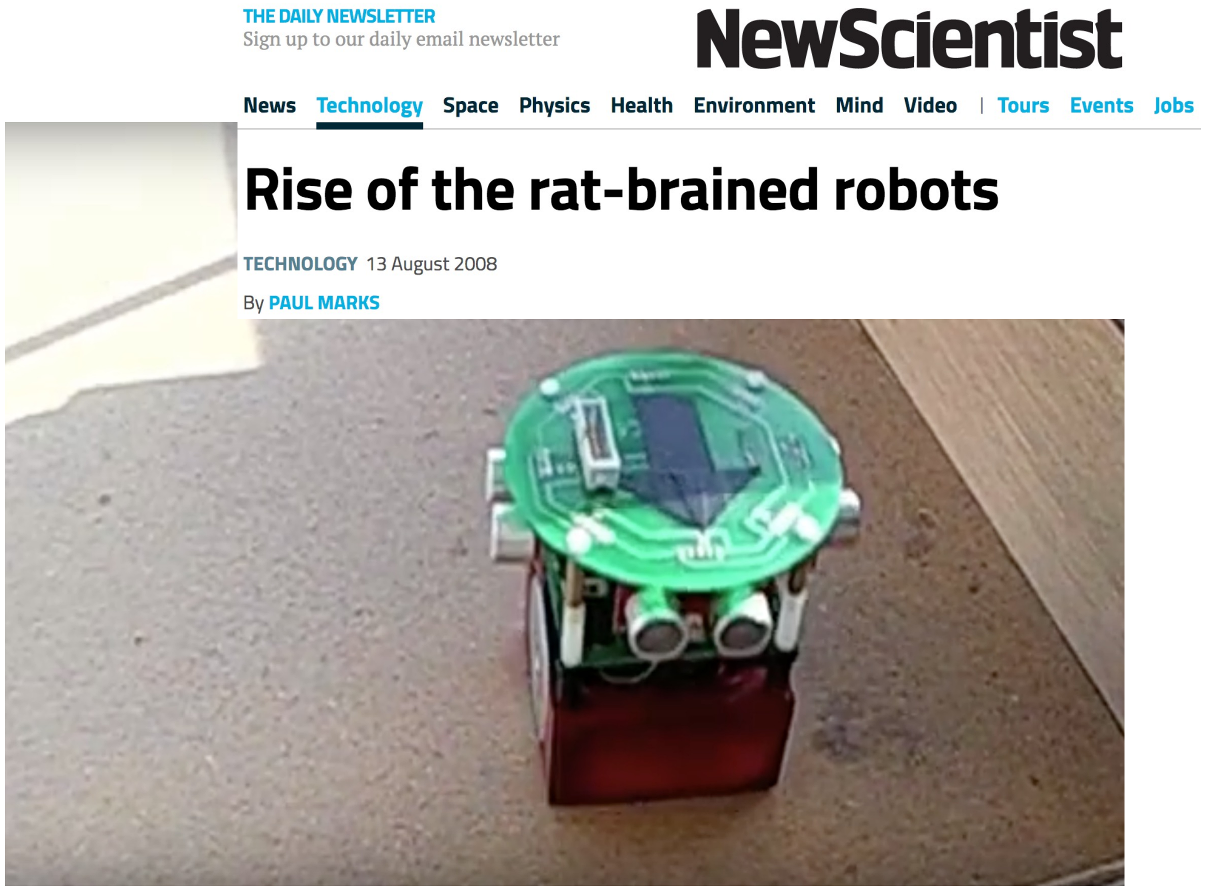
BEHAVIORAL NEUROSCIENCE 8e, Figure 8.18 (Part 1)



BEHAVIORAL NEUROSCIENCE 8e, Figure 8.18 (Part 2)

Are cortical sensory neurons specialized for their type of sensation?

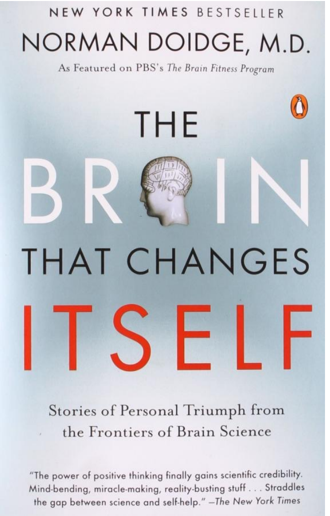
- Yes, **but** wiring also seems to be an essential feature
- Neurons can make sense of nearly any input, even artificial
- As before, the brain abhors an unused neuron



https://www.youtube.com/watch?v=1-0eZytv6Qk
Xydas *et al.* 2008

The Brain that Kind of Changes Itself (but Is Mostly Inflexible Because that Inflexibility is a Good Thing)

- BUT rewiring/activity is limited



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The Learning Brain is Less Flexible Than We Thought

NEUROSCIENCE NEWS × MARCH 13, 2018

FEATURED NEUROSCIENCE 7 MIN READ

Summary: According to researchers, when learning a new task, the brain is less flexible than previously believed.

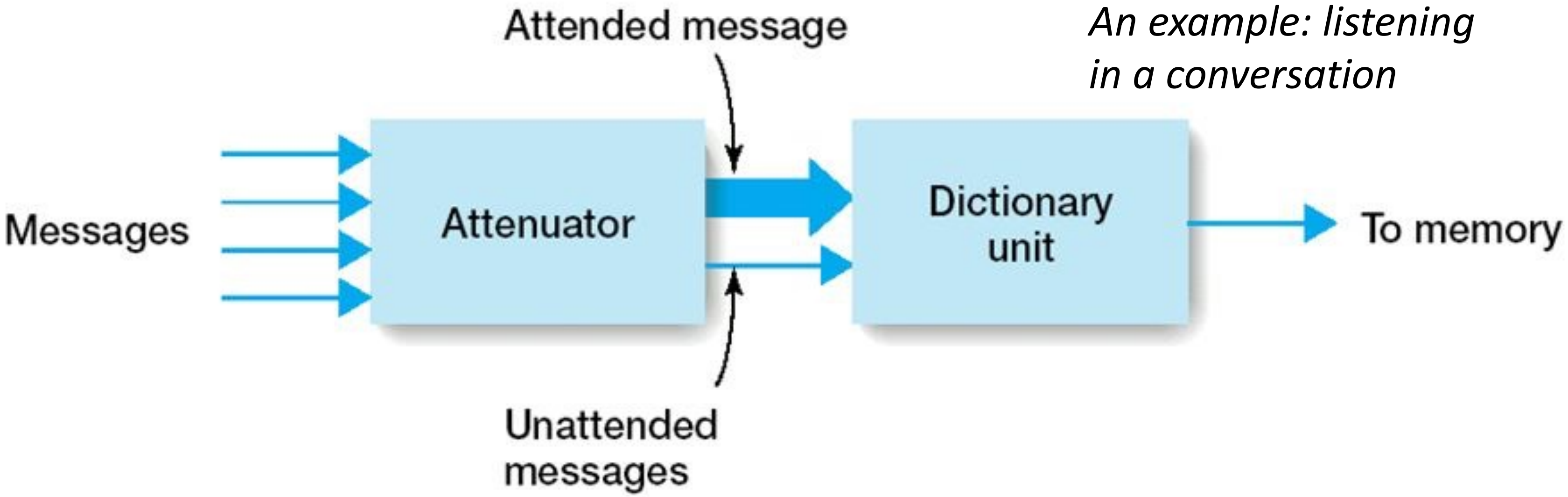
Source: Carnegie Mellon University.

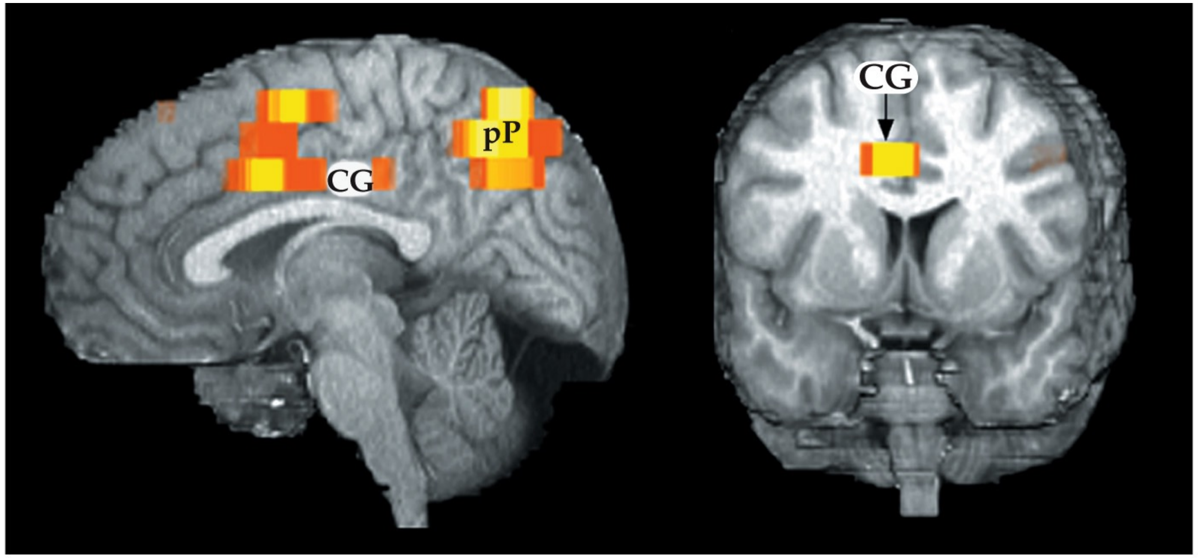
Nobody really knows how the activity in your brain reorganizes as you learn new tasks, but new research from Carnegie Mellon University and the University of Pittsburgh reveals that the brain has various mechanisms and constraints by which it reorganizes its neural activity when learning over the course of a few hours. The new research finds that, when learning a new task, the brain is less flexible than previously thought.

Attention: manipulating sensory processing

An example: listening in a conversation

- Specifically, enhanced processing
- What about unattended information?
- Important regions: posterior parietal, cingulate cortex, others (more to come!)





BEHAVIORAL NEUROSCIENCE 8e, Figure 8.12

Sensory principles

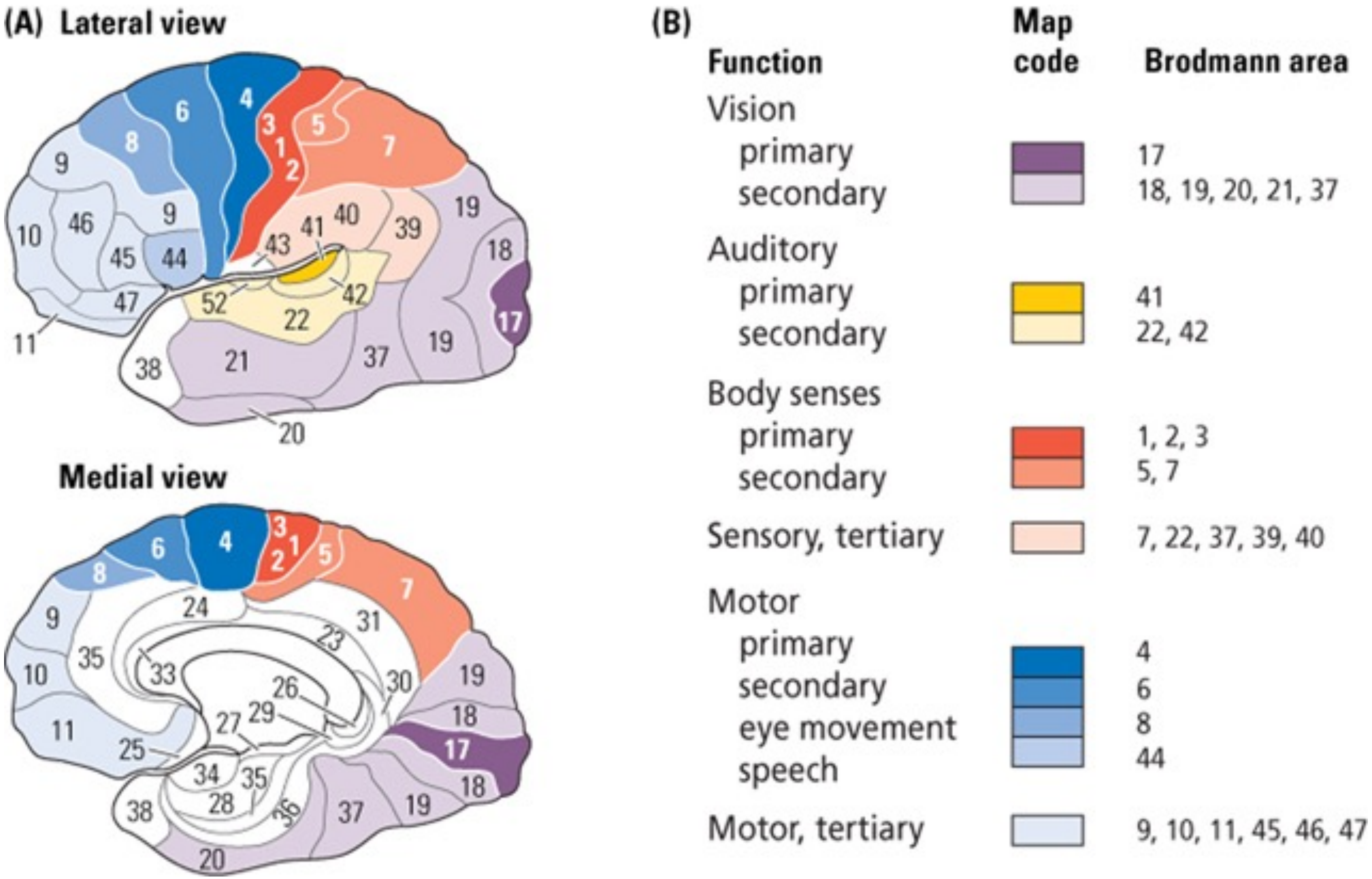
“Association” cortex?

AKA tertiary cortex

Is multimodal

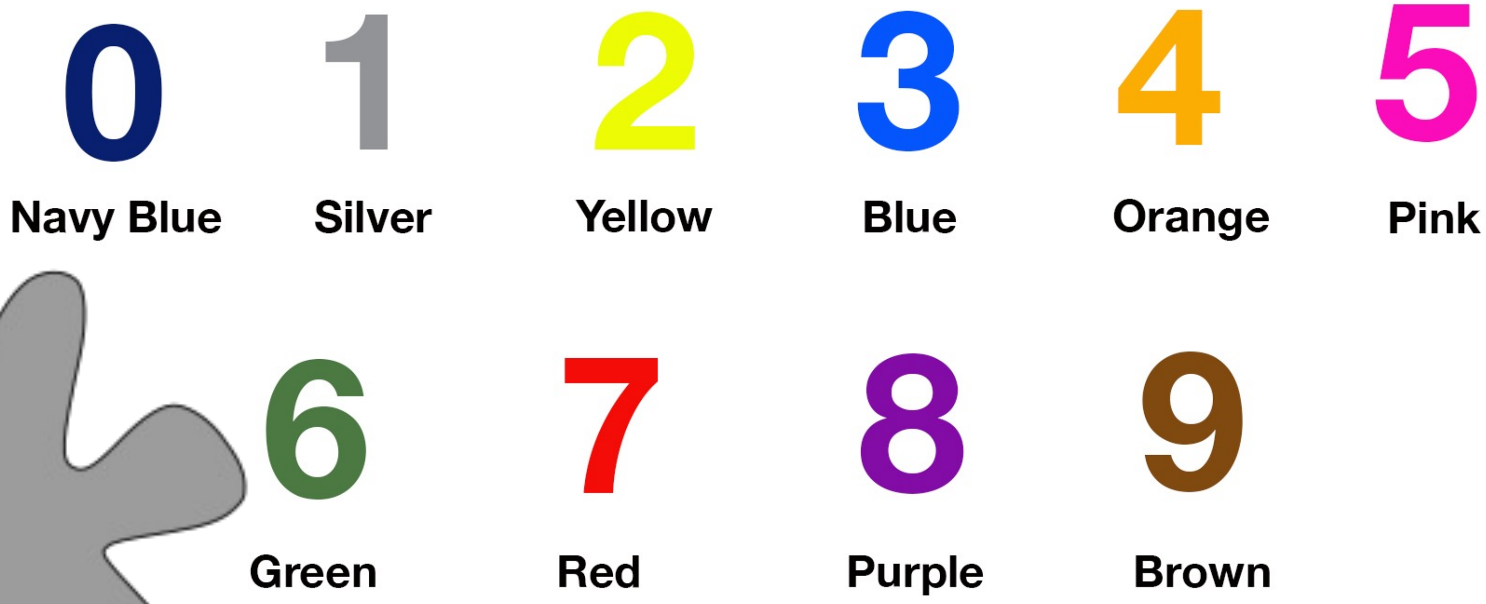
Comprises much of the brain

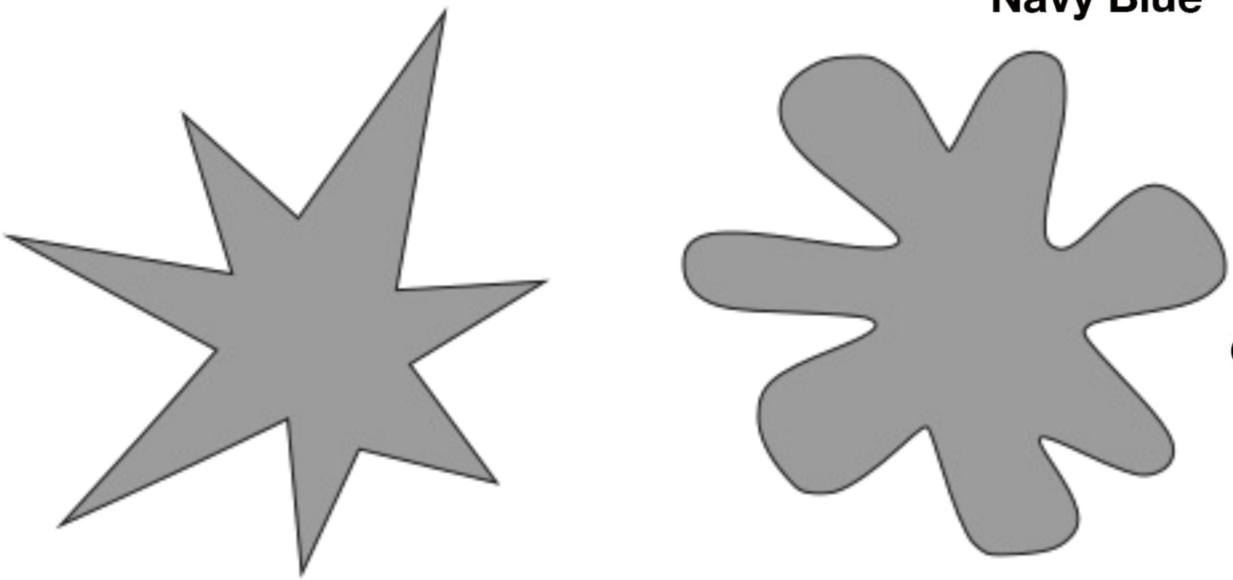
Is it truly “sensory” or “motor”?



Synesthesia: cross-modal stimulation

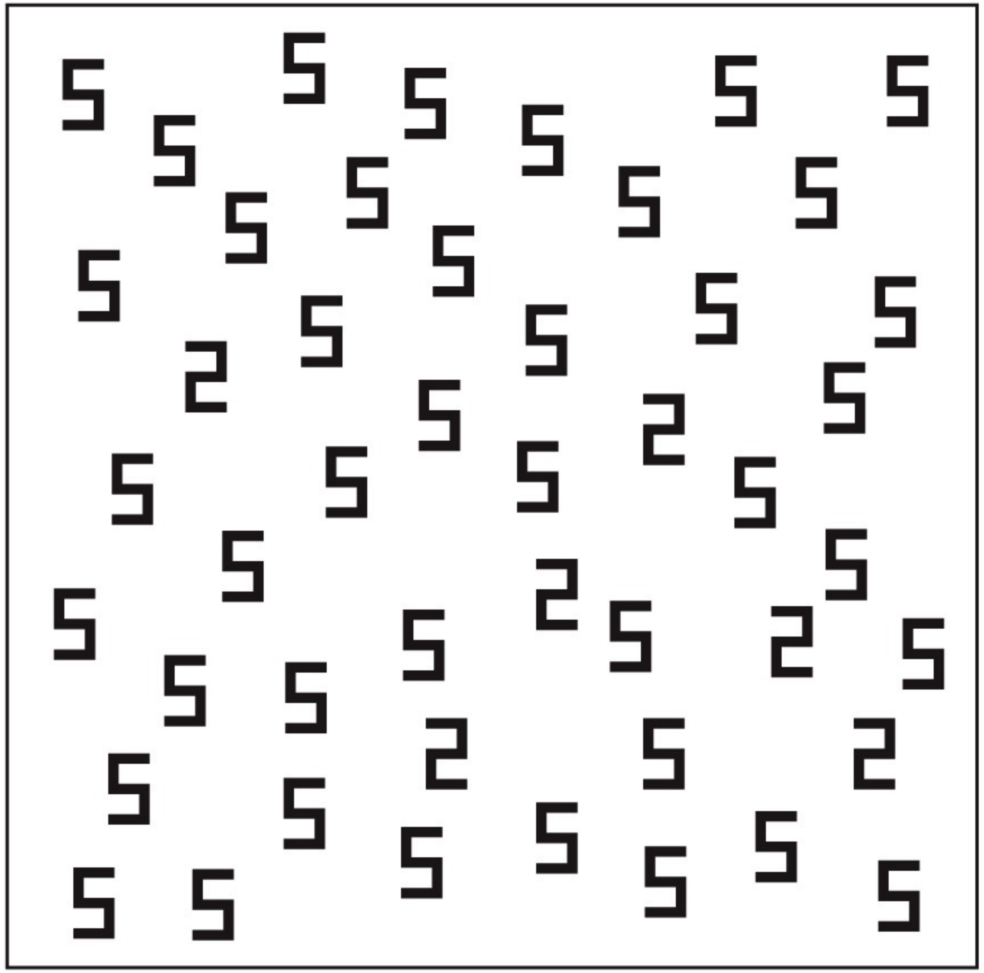
- e.g. Grapheme-colour synesthesia
- Thought to be driven by learning rules rather than specific memories
- May be related to other processes that have been evolutionarily conserved
    - e.g. bouba vs. kiki





How to test if synesthesia is real (vs. malingering)

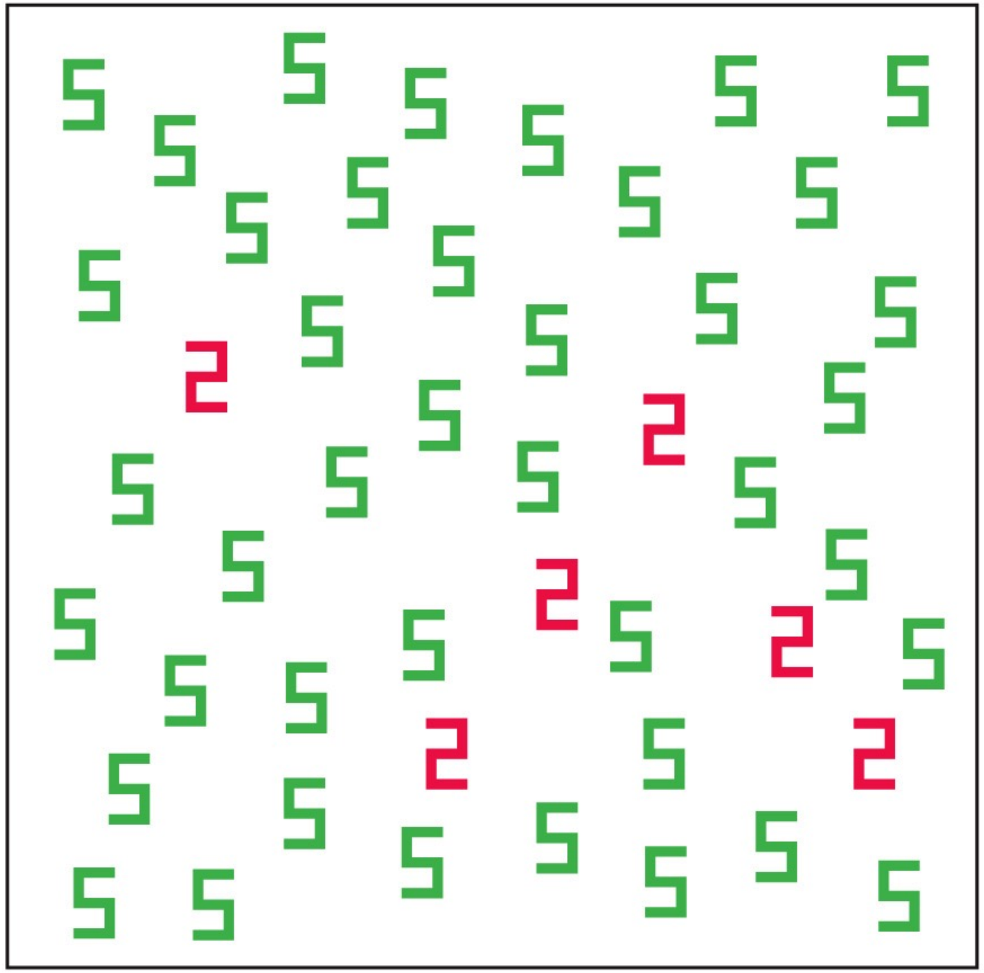
(B) Difficult search



BEHAVIORAL NEUROSCIENCE 8e, Box 8.1 (Part 2)

How to test if synesthesia is real (vs. malingering)

(C) Easy search

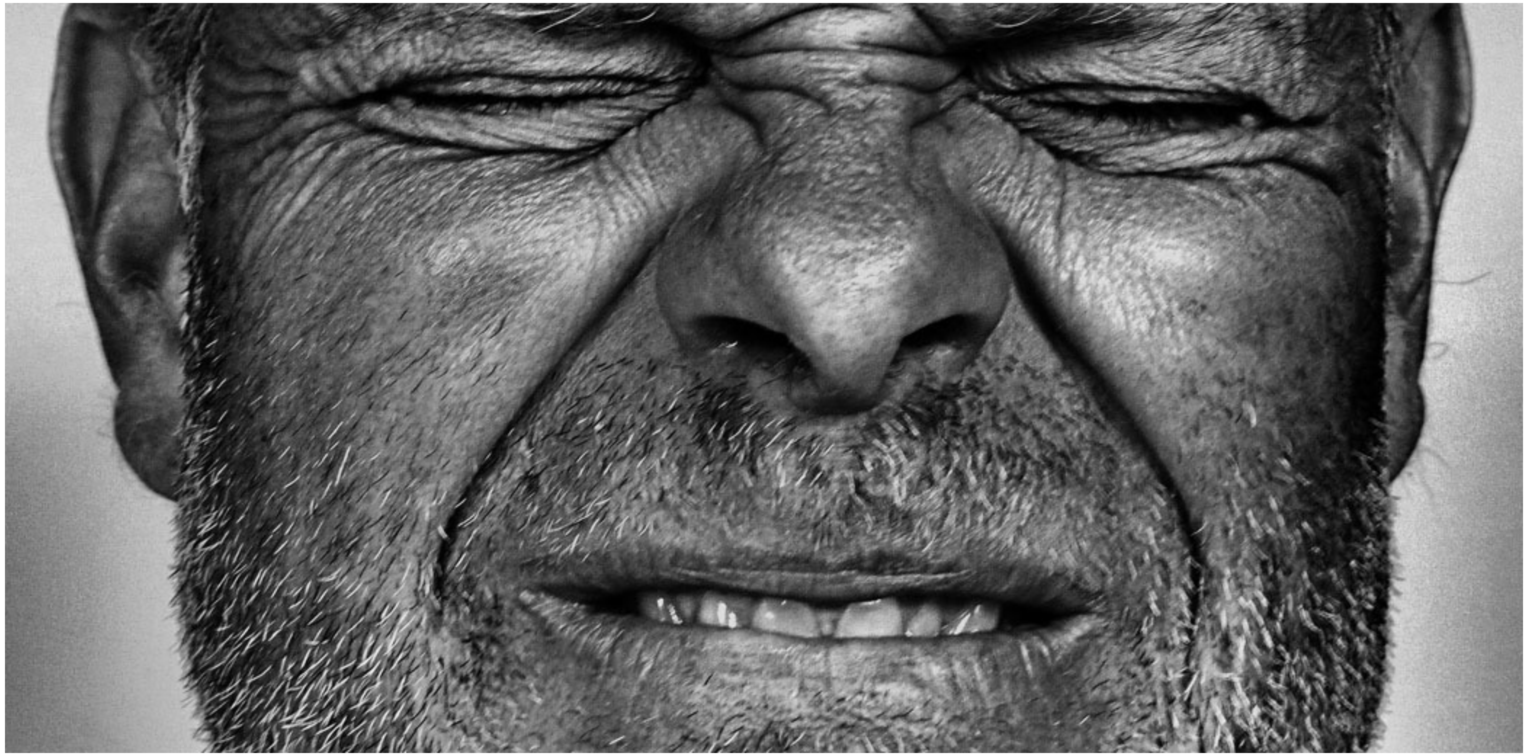


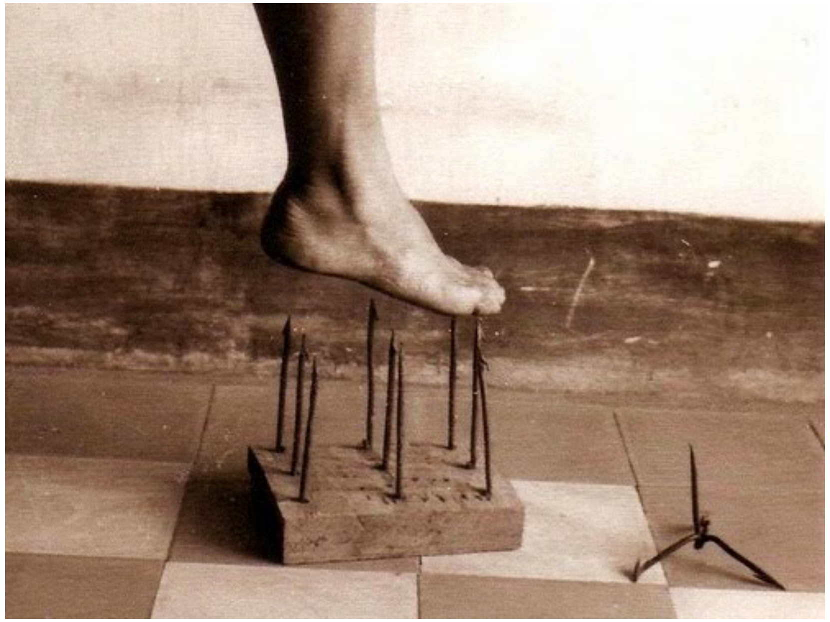
BEHAVIORAL NEUROSCIENCE 8e, Box 8.1 (Part 3)

Unpleasant but Adaptive

Pain: associated with tissue damage, an unpleasant experience

Congenital insensitivity to pain: a voltage-gated sodium channel mutation!

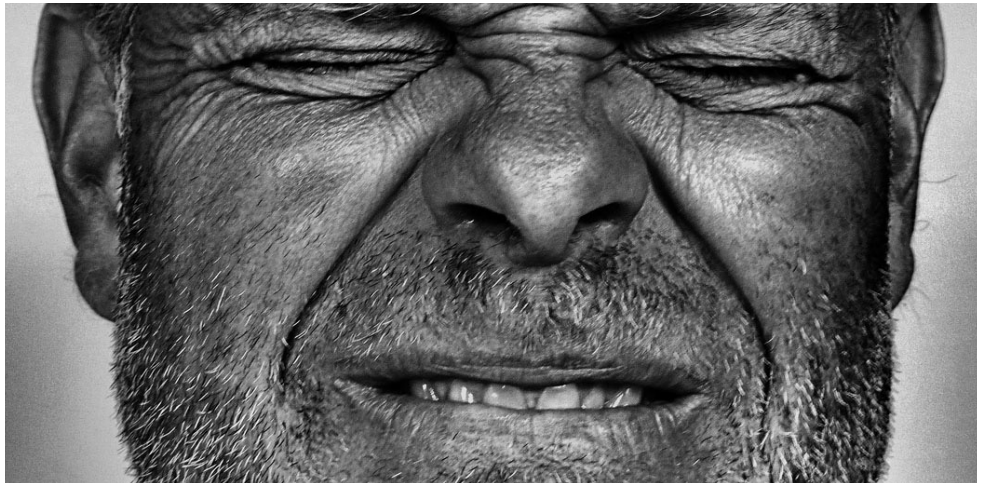




Pain serves many functions

More than simply withdrawal from a source:

- Recuperation
- Learning
- Signal to others



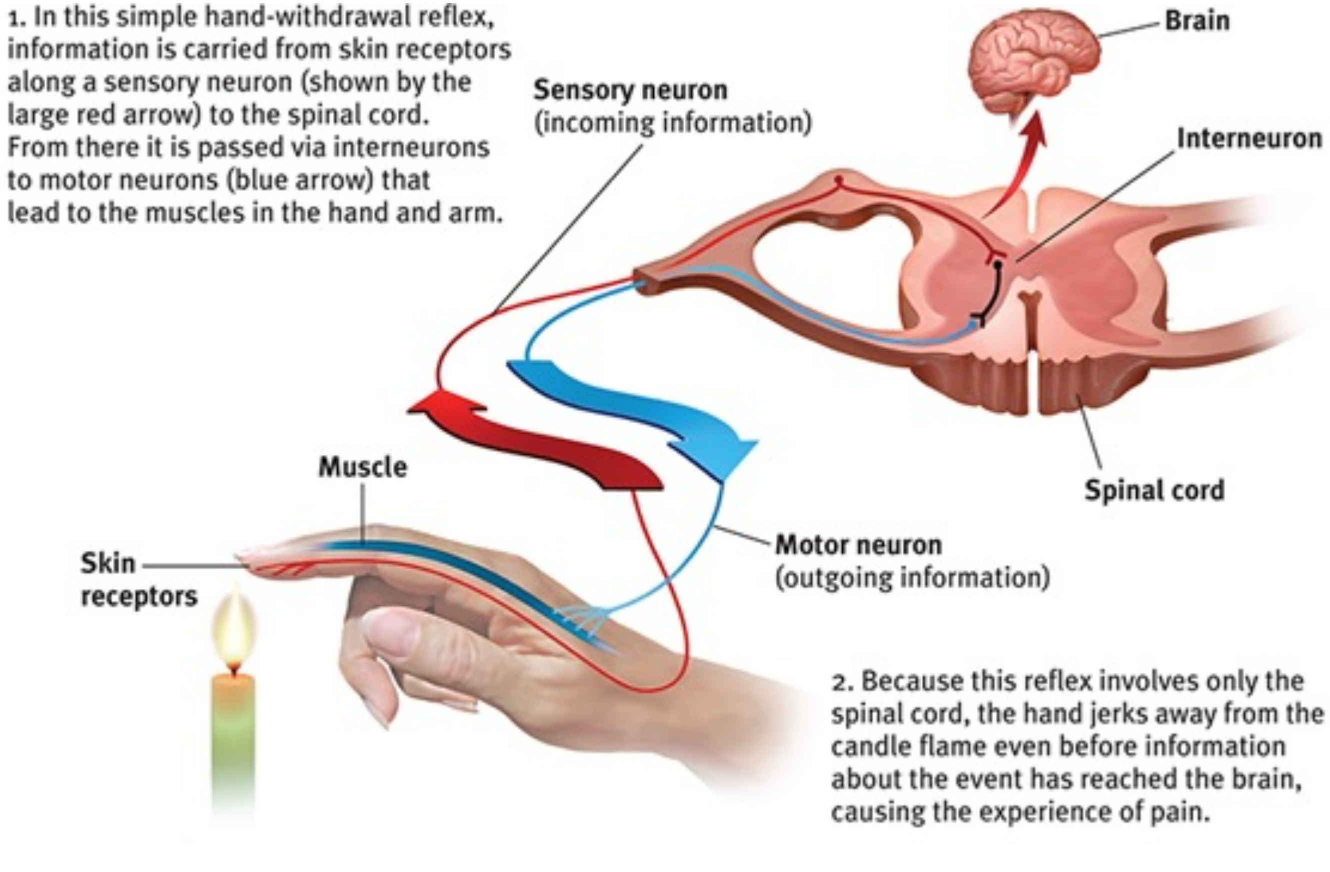
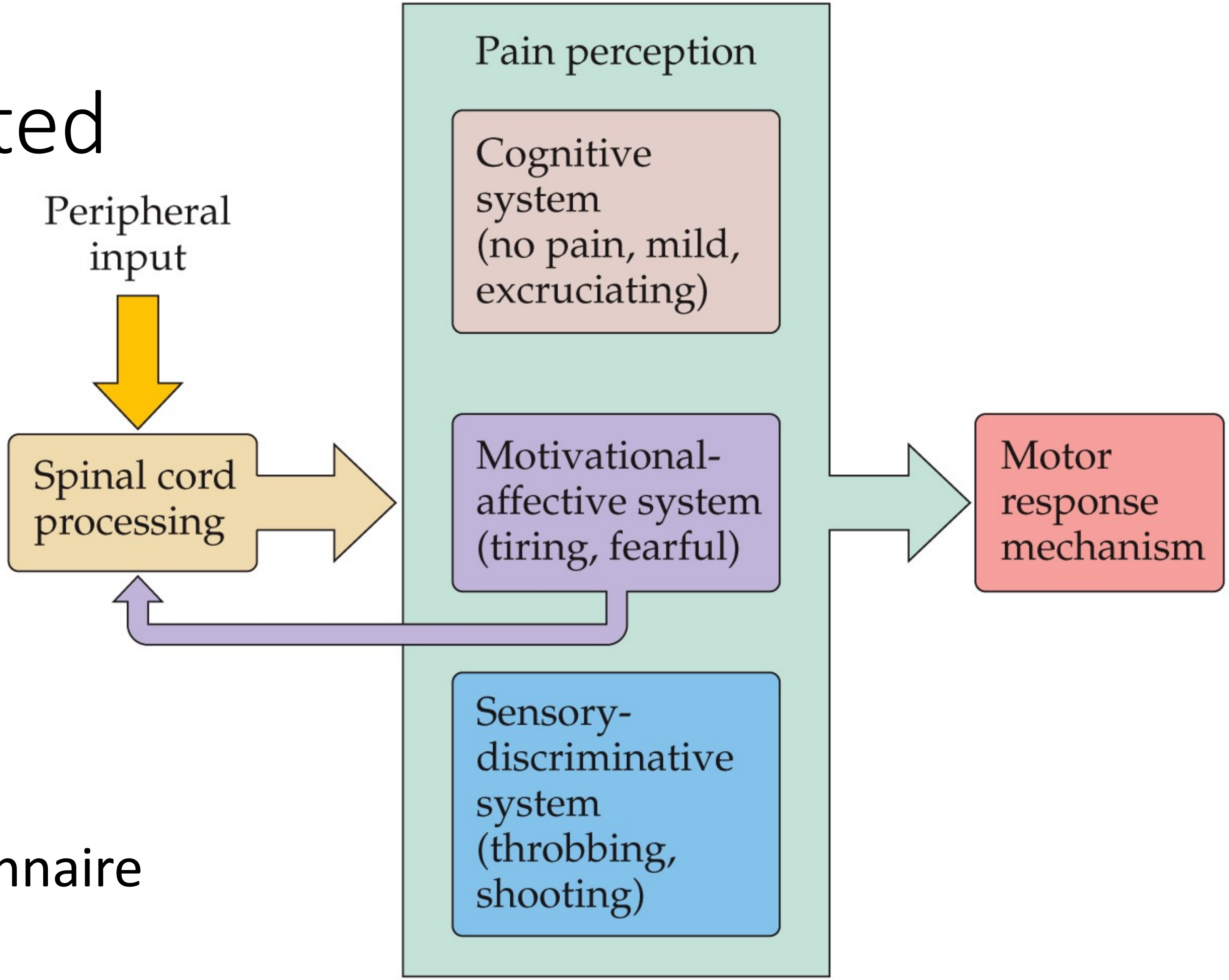


FIGURE 2.9 Myers/DeWall, *Psychology*, 12e, © 2018 Worth Publishers

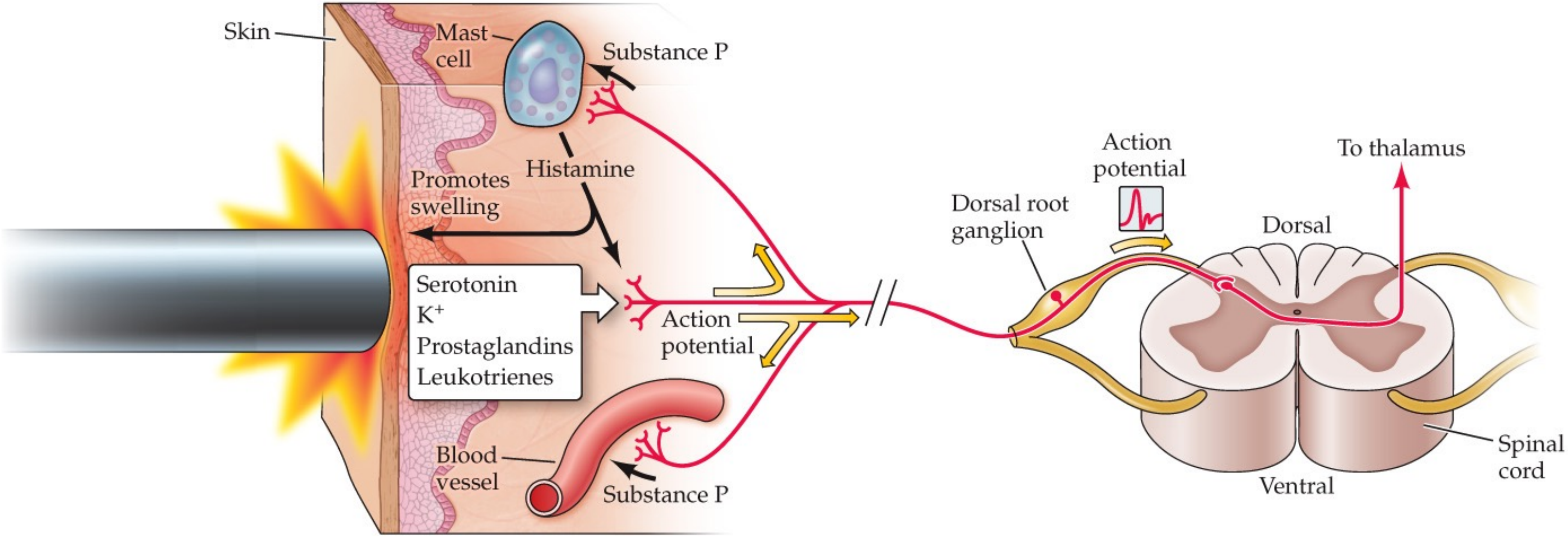
Pain is multifaceted



BEHAVIORAL NEUROSCIENCE 8e, Figure 8.20

- The McGill Pain Questionnaire

Nociceptors



BEHAVIORAL NEUROSCIENCE 8e, Figure 8.21

Sensitive to temperature, and to chemicals released by tissue damage

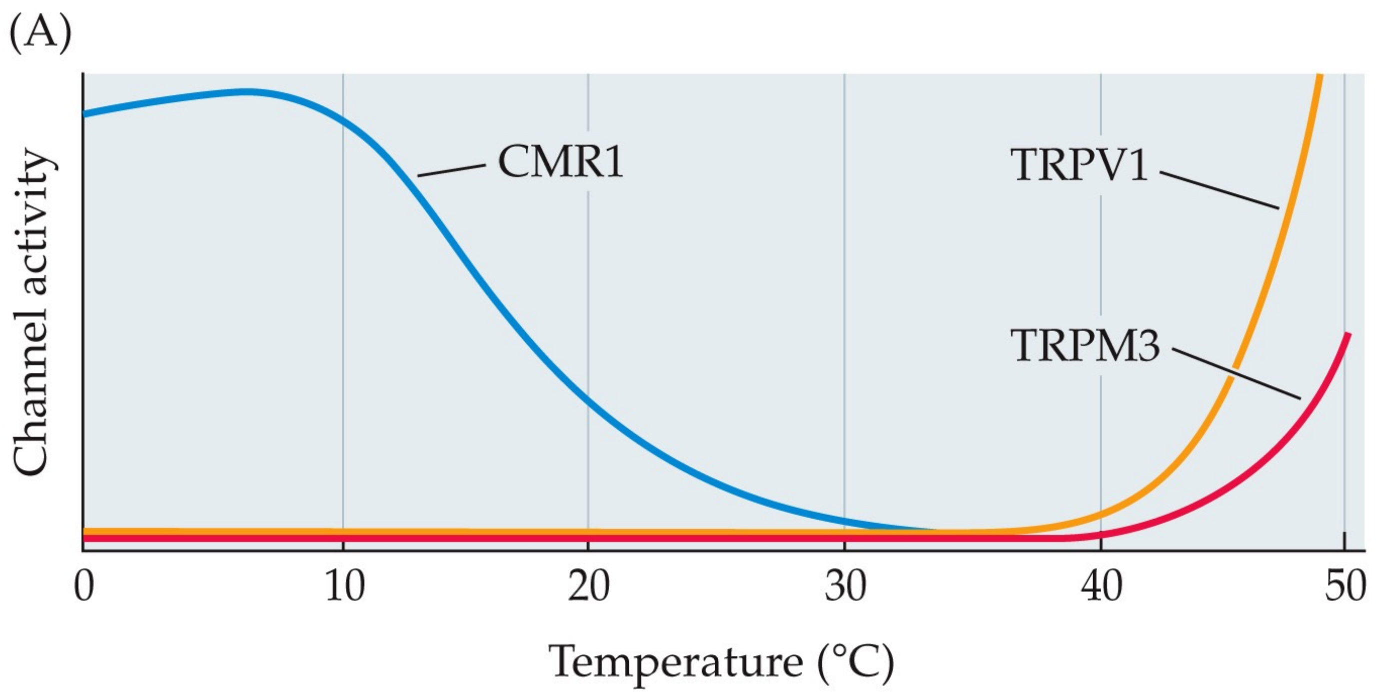
Different receptors for different temperatures

- TRPV1
  - C fibres
  - Binds to capsaicin!

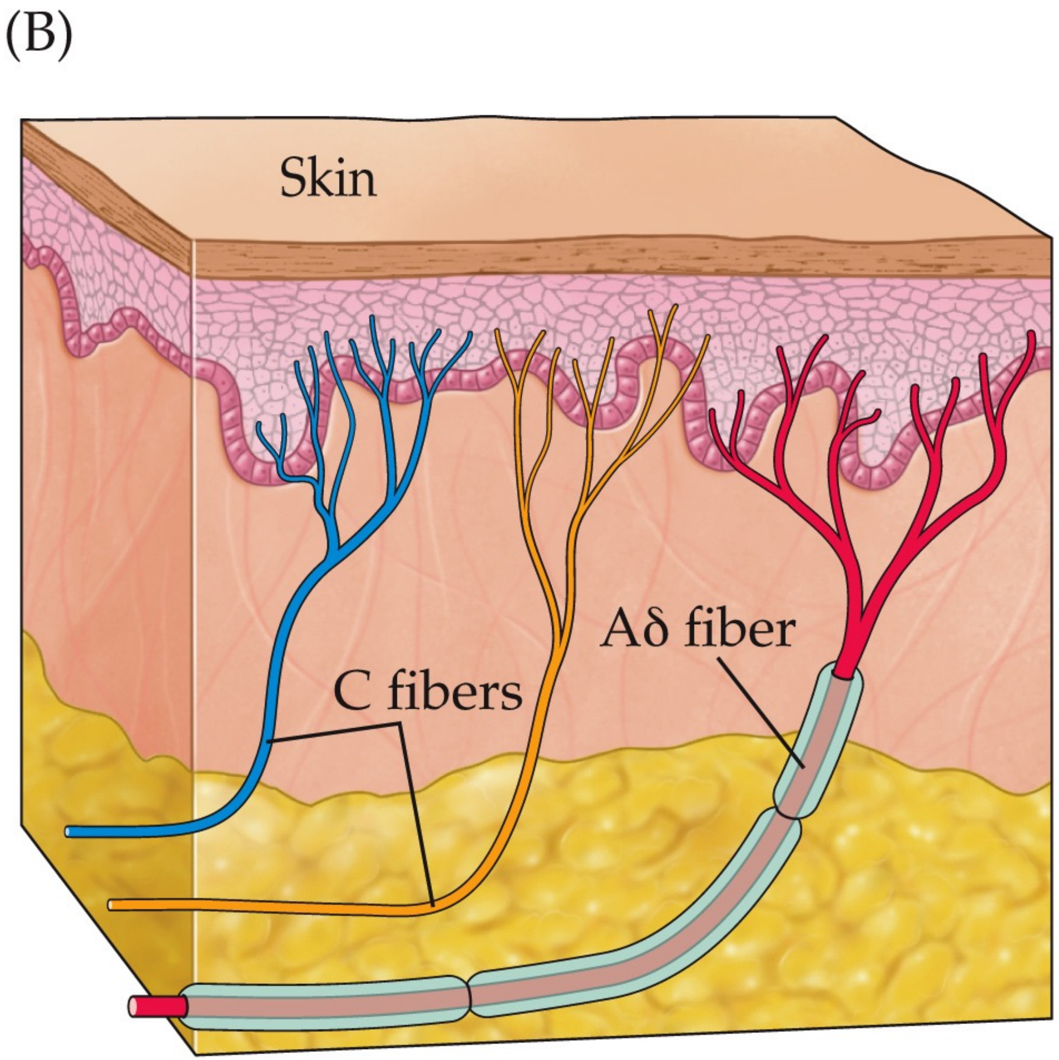
- TRPM3
  - Aδ fibres

- CMR1
  - C fibres
  - Binds to menthol!

Different receptors for different temperatures



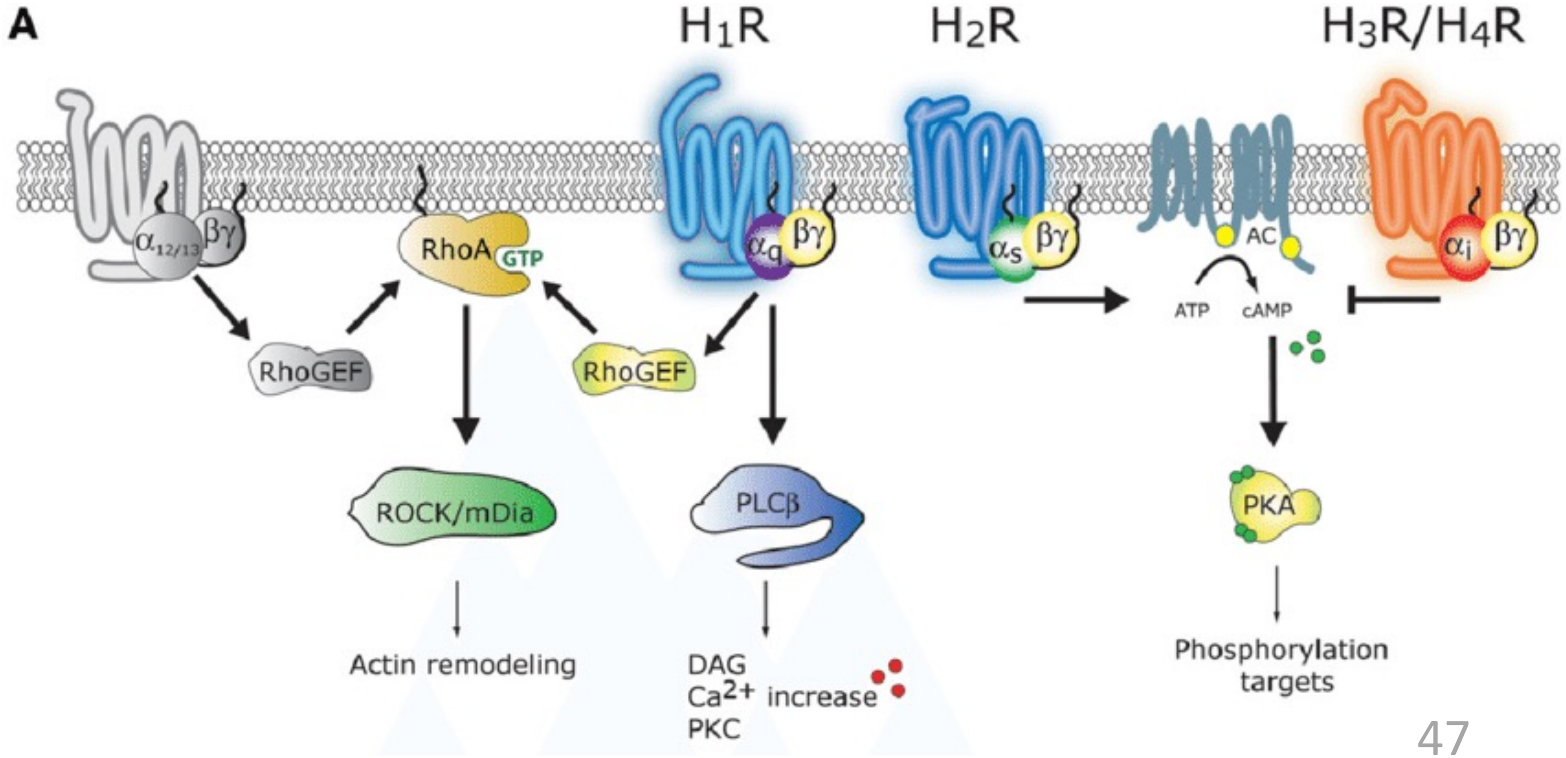
BEHAVIORAL NEUROSCIENCE 8e, Figure 8.22 (Part 1)



BEHAVIORAL NEUROSCIENCE 8e, Figure 8.22 (Part 2)

Itch: a complicated sensation

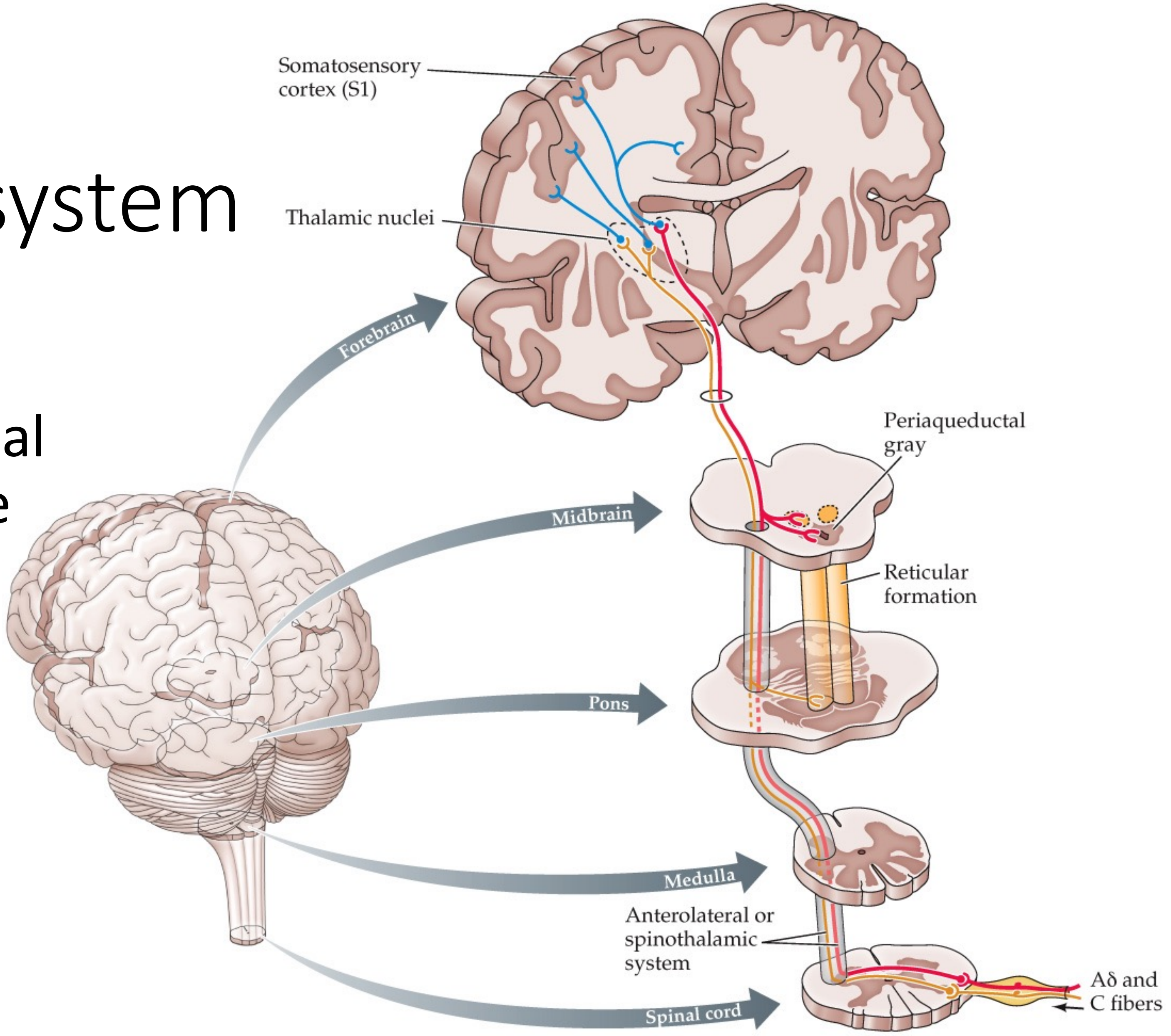
- Some itch cells have histamine receptors, some don't
- All have TRPV1
- Natriuretic polypeptide B (NPPB)?



Pathways:
The spinothalamic system

AKA the **anterolateral system**

Crosses the midline in the spinal cord, before ascending to the thalamus

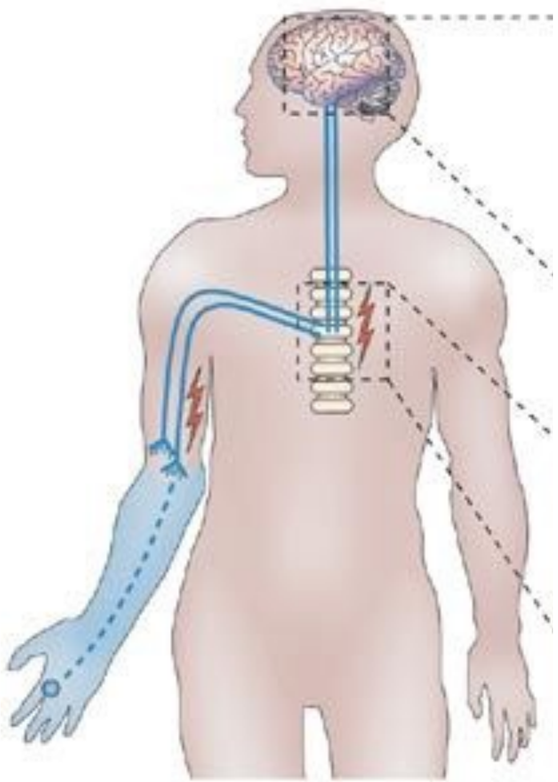


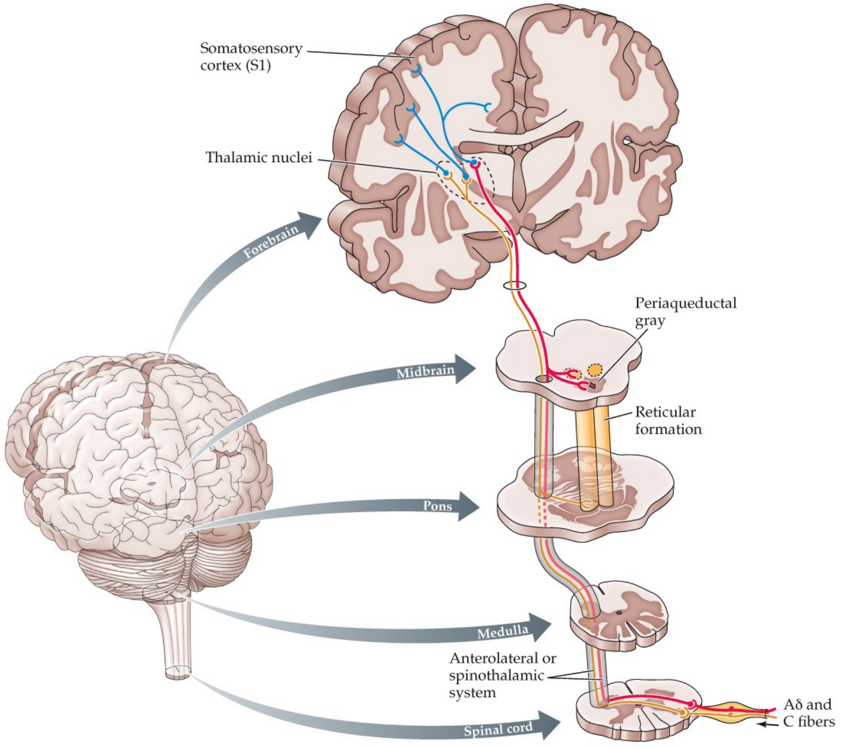
BEHAVIORAL NEUROSCIENCE 8e, Figure 8.23

Phantom limb pain

AKA **neuropathic pain**

Dorsal horn neurons can become hyperexcitable after damage

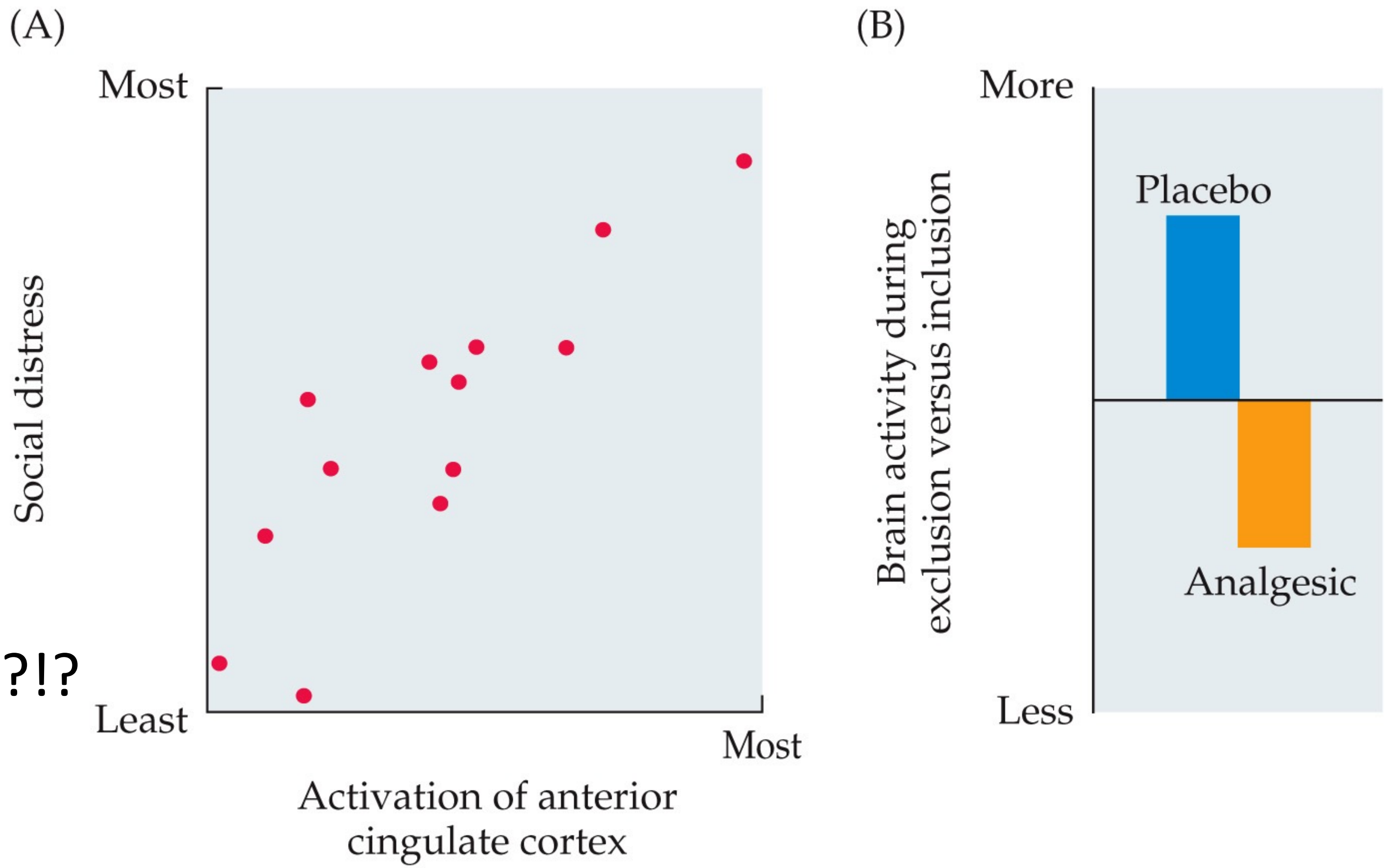




BEHAVIORAL NEUROSCIENCE 8e, Figure 8.23

Pain isn’t a physical sensation

- Social rejection experienced and described as pain
- Activates the anterior cingulate cortex
- Painkillers can lessen the pain of social rejection
- See also: existential pain?!?



Pain management

TABLE 8.3 Types of Pain Relief Intervention

MEASURE	MECHANISM	LIMITATIONS/COMMENTS
PSYCHOGENIC		
Placebo	May activate endorphin-mediated pain control system	Ethical concerns of deceiving patient
Hypnosis	Alters brain's perception of pain	Unaffected by opiate antagonists
Stress	Both opioid and non-opioid mechanisms	Clinically impractical and inappropriate
Cognitive (learning, coping strategies)	May activate endorphin-mediated pain control system	Limited usefulness for severe pain
PHARMACOLOGICAL		
Opiates	Bind to opioid receptors in periaqueductal gray and spinal cord	Severe side effects due to binding in other brain regions
Spinal block	Drugs block pain signals in spinal cord	Avoids side effects of systemic administration
Anti-inflammatory drugs	Block prostaglandin and/or leukotriene synthesis at site of injury (see Figure 8.21)	May have side effects
Cannabinoids	Act in spinal cord and on nociceptor endings	Illegal in some regions; smoke damages lungs
STIMULATION		
Acupuncture	Seems similar to placebo	Sometimes affected by opiate antagonists
Central gray	Electrical stimulation activates endorphin-mediated pain control systems, blocking pain signal in spinal cord	Inhibited by opiate antagonists; invasive surgery to implant electrodes
SURGICAL		
Cut peripheral nerve cord Rhizotomy (cutting dorsal root) Cord hemisection	Create physical break in pain pathway	Considerable risk of failure or return of pain
Frontal lobotomy	Disrupts affective response to pain	Irreversible; risky; severe effects on behavior

Pain management: drugs

Analgesia: the absence or reduction of pain

NSAIDS: acting on a different path than we've discussed

i.e. COX, prostaglandins

Opioids (endogenous and exogenous)

act at spinal cord, descending pathways, and higher brain sites

Learn more in a class on drugs!

Pain management: PAG

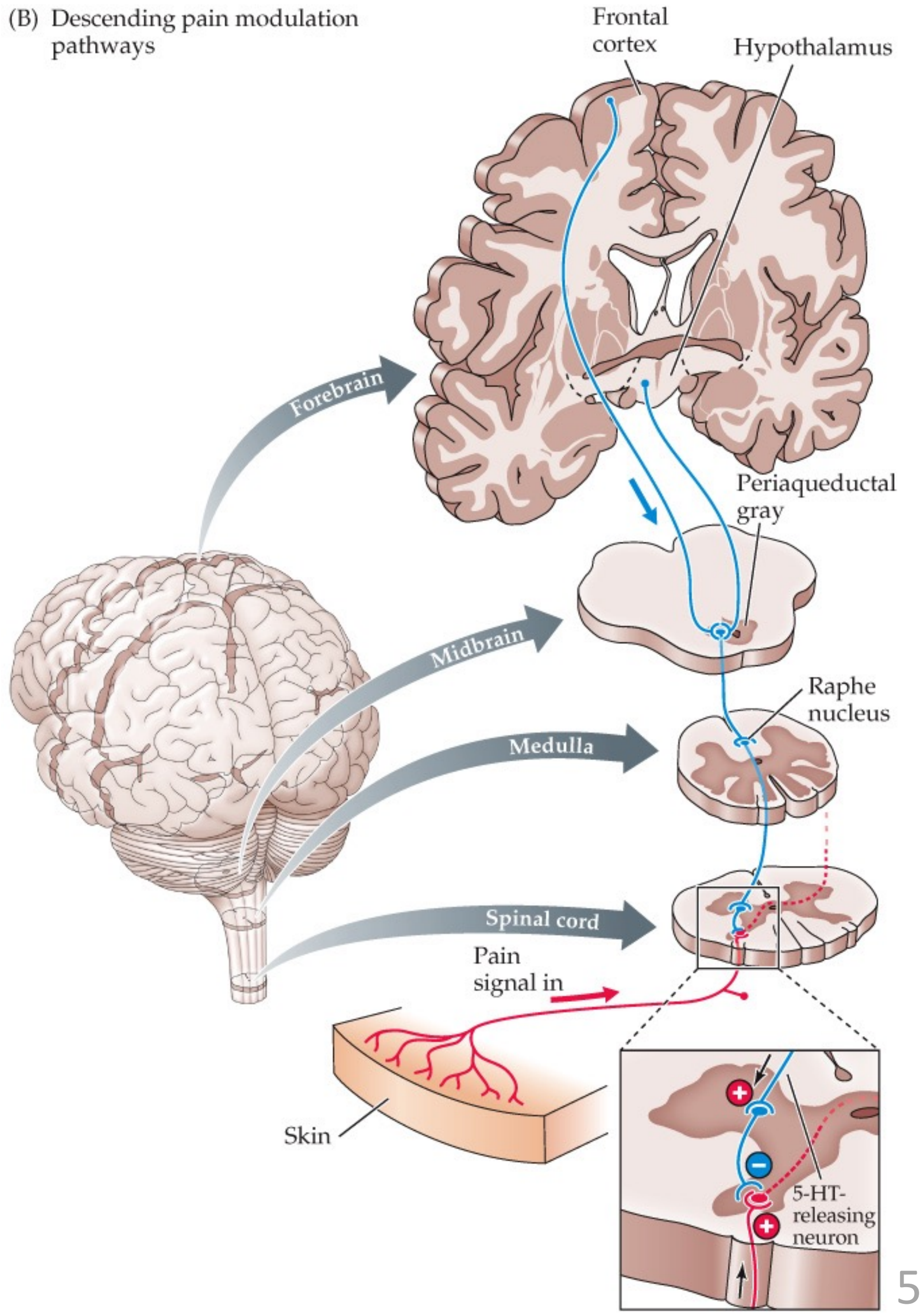
i.e. The **periaqueductal gray** (**PAG**)

Also in the tegmentum (midbrain)

Endogenous analgesic effects

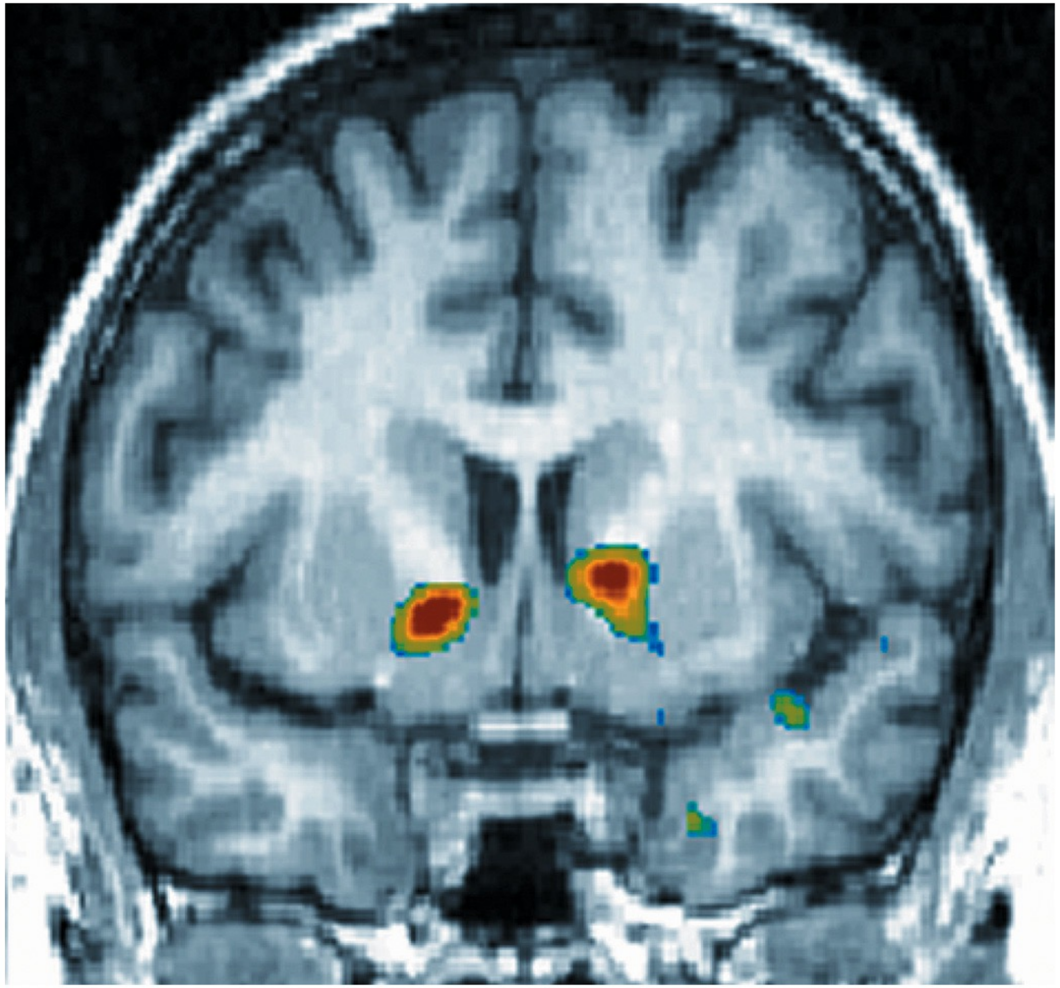
Artificial stimulation

Acts by blocking incoming pain signals



Pain management: placebo

- Strong effects in pain
- Weak/no effects in other modalities
- Vary according to our expectations
  - e.g. small intervention (pill) vs. large (injection)
- Likely mediated by endogenous opioids



BEHAVIORAL NEUROSCIENCE 8e, Figure 8.28