Lecture IX. Brain Pathways: Sensation

Bio 3411

Wednesday

September 23, 2009

What the last lecture was about

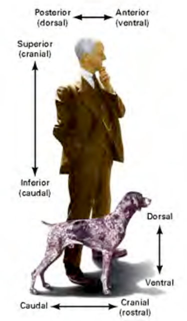
Spinal Cord

Peripheral Nerves

Spinal Nerves

Spinal Reflexes

Introduction to Pathways



"**Readings**" (background only)

Neuroscience 4th ed

Page(s)	Feature
207	Touch
231	Pain
253	Eye
289	Central Visual Pathways
313	Auditory Function
343	Vestibular Function
363	Olfactory receptors
381	Taste buds & receptors

The Brain Atlas 3rd ed

Page(s)	*Feature*
182-183	*Dorsal Column/Medial Leminscus – Touch & Position*
186-187	*Spinothalamic Tract – Crude touch, Pain & Temperature*
41, 45	*Brain stem showing optic pathway*
192-193	*Visual Pathways*
196-197	*Auditory Pathways*
198-199	*Vestibular Pathways*
194-195	*Olfactory Pathways*
190-191	*Taste Pathways*

References

†Cox, J. J., Reimann, F., Nicholas, A. K., Thornton, G., Roberts, E., Springell, K., Karbani, G., Jafri, H., Mannan, J., Raashid, Y., Al-Gazali, L., Hamamy, H., Valente, E. M., Gorman, S., Williams, R., McHale, D. P., Wood, J. N., Gribble, F. M., & Woods, C. G. (2006). An SCN9A channelopathy causes congenital inability to experience pain. *Nature, 444*(7121), 894-898.

†Goodwin, G. M., McCloskey, D. I., & Matthews, P. B. (1972). Proprioceptive illusions induced by muscle vibration: contribution by muscle spindles to perception? *Science, 175*(28), 1382-1384.

†Mogil, J. S., Yu, L., & Basbaum, A. I. (2000). Pain genes?: natural variation and transgenic mutants. Annu Rev Neurosci, 23, 777-811.

† Posted on class web site.

What the last lecture was about:

Spinal Cord - Segmental organization

Peripheral Nerves - Compound action potential *(Erlanger & Gasser Prix Nobel 1944)*

Spinal Nerves - Dermatomes, motor neuron pools (nuclei) and motor units

Spinal reflexes - stretch (knee jerk); withdrawal/ crossed extensor

Introduction to Pathways - 1 sensory (DC-ML); 1 motor (CST)

Overview

Sensation

- Sensory Transduction
- Receptive Fields
- Adaptation
- Feature Detection
- Maps

Charles Scott Sherrington
1857 – 1957
(Prix Nobel 1932)

Edgar Douglas Adrian
1889 – 1977
(Prix Nobel 1932)

The Five Senses

- **Touch:** e.g., fine, muscle/position, pain
- **Smell:** e.g., odorants, "taste", opposite sex
- **Taste:** bitter, sweet, sour, salt, ?(glutamate/ umami)
- **Hearing/Balance:** e.g., frequency & amplitude; linear & angular acceleration
- **Sight:** light/dark, color (chromatic)

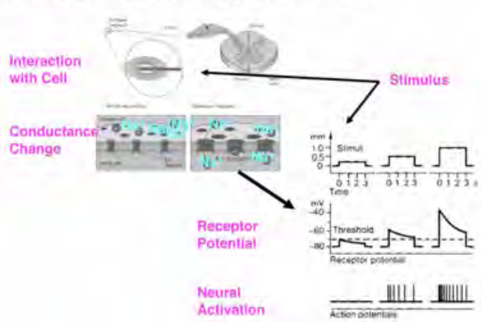
Domains

- Exteroception vs Interoception
- Distance vs Direct

Sensory Transduction

- Single fiber recording (E. Adrian, *Prix Nobel 1932*)
- Transduction is the conversion of a relevant physical stimulus into altered membrane potential, the currency of the nervous system.
- Stimuli:
  - *radiant* – light and thermal
  - *mechanical* – pressure and sound
  - *chemical* – molecules and ions

General Scheme for Sensory Transduction

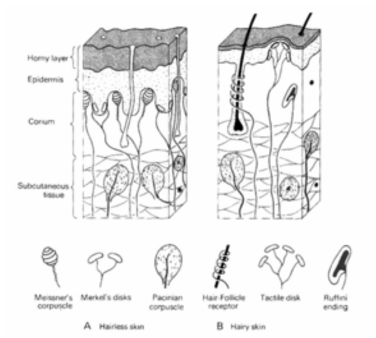


Transducers

- **Direct:** by neurons
- **Mediated:** by extensions, cell filters, receptor cells, complex organs
- **Code:** onset, duration, intensity, change

Touch “Receptors” in Skin

There are many different kinds of sensory endings in the skin. They are relatively more sensitive to movement (amplified by the lever of a hair (B)), vibration, light pressure, pain, temperature etc.



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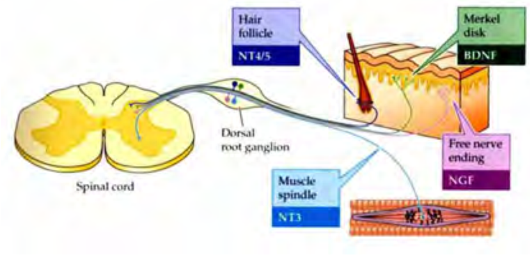

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Photoreceptors in Eye - Sight

The sensors in the eye contain “visual pigments” that change chemically when exposed to light of different colors and intensities. Photoreceptors sensitive to red, blue and green are called cones (C) while those sensitive to low light levels are rod like (R).

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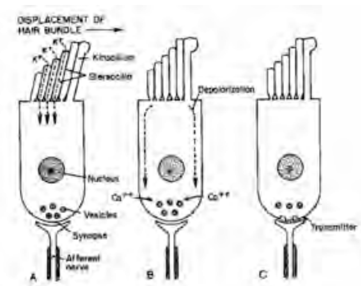
Hair Cells in Ear

The sensors in the ear are modified “touch” receptors. Sound causes the membrane on which these “hair cells” (because they have cell protrusions that look like hairs) rest to move and this causes the hairs to bend. When the hairs bend the hair cells depolarize and release transmitter to activate the sensory nerve endings.



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With respect to neurons:

- **Threshold** (the magnitude of a stimulus sufficient to depolarize the sensory neuron)
- **Adequate Stimulus** (the form of energy to which a particular sensory cell is ***most*** sensitive - light, touch, sound, etc.)
- **Law of specific nerve energies** (depolarization of neurons in a pathway is interpreted as a particular form of stimulation - pressure to the eyes or direct electrical activation of the visual cortex are both interpreted as a change in light)

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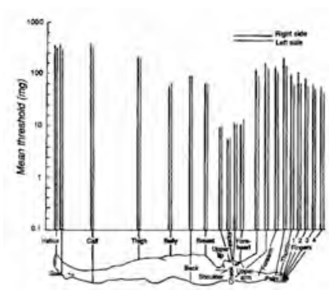
Thresholds by Location

The threshold to pressure differs over the body. The lips and the ends of the fingers are most sensitive. In part, this reflects different innervation densities (higher in the fingers and lips). Similar differences innervation density associated with high acuity vision and speech sounds are found in the eye and the ear respectively.



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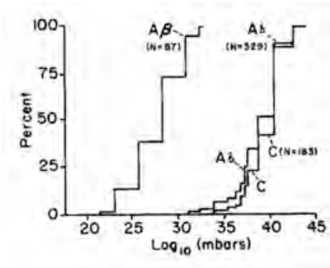
Thresholds by Fiber Type

The thresholds to mechanical force (mbars) differ for endings associated with different fiber sizes. Smaller forces activate myelinated faster conducting fibers (A - β) while greater forces are required to activate unmyelinated C and thin myelinated slower conducting fibers (A -δ).

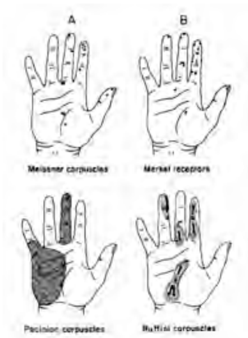


Receptive Fields

- Mainly about change
- Tuning and fidelity
- Organization - orientation, direction

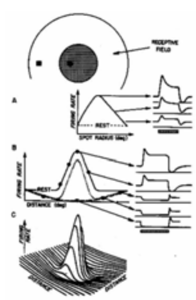
Receptive Fields - Endings

Single sensory neurons innervating the hand have different receptive fields depending on the kind of ending they are associated with. These different endings (here named for famous guys in Italy or Germany) respond to very localized stimulation (Meissner & Merkel) or to more widely placed stimuli (Pacini and Ruffini).



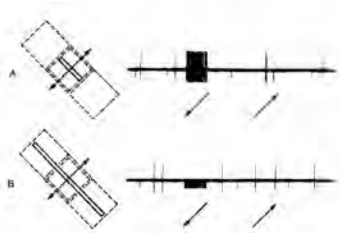
Receptive Fields - Retina (Center/Surround)

The neurons projecting from the eye to the rest of the brain (ganglion cells) respond stimuli in the center of their receptive fields by increasing depolarization (which will increase firing) while stimuli in the periphery of the receptive field will hyperpolarize them (which will make the cell less likely to fire). The cell fires best when the stimulus covers only the central excitatory part of the receptive field as shown in the histogram at the bottom.

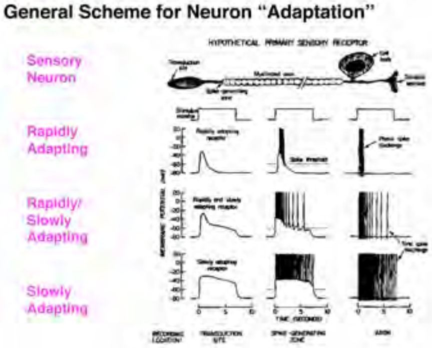


Receptive Fields - Visual Cortex (Orientation & Length)

A neuron in the visual cortex that responds best to stimuli of a particular lengths, in a particular orientation, moving in a particular direction at a prefered speed. (The bar in A is the right length. The one in B is too long and the cell fires less.)



General Scheme for Neuron "Adaptation"



Sensation

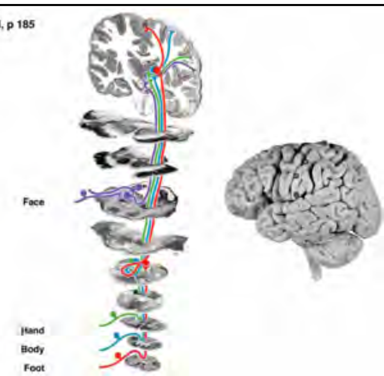
Maps

- Somatotopic, Visuotopic, Tonotopic, etc.
- All Levels
- Distortions ≈ innervation density

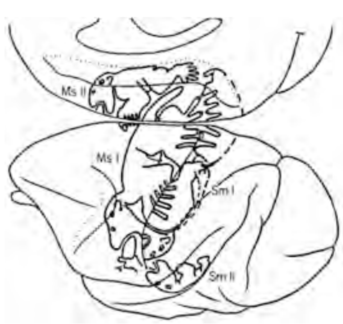
Dorsal Column – Medial Lemniscus Pathway

This pathway carries fine discriminative and active touch, body and joint position, and vibration sense.

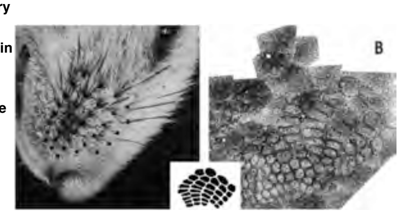
THE BRAIN ATLAS, 3rd ed, p 185



This is a sketch of the left cerebral hemisphere of a monkey brain. The body parts to which neurons in the cerebral cortex of the monkey best respond are organized in 2 systematic maps (Sm I and Sm II) in the parietal lobe.



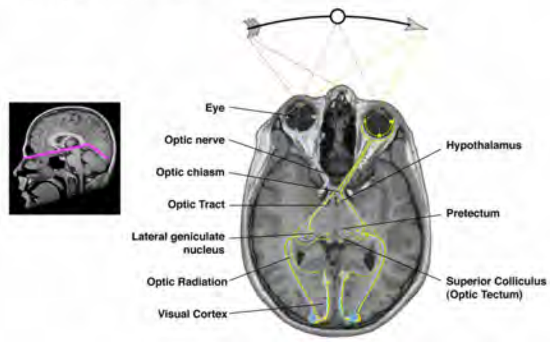
The whiskers on the mouse's face are innervated by sensory neurons that project to a pathway ending in the somatosensory cortex. In sections parallel to the surface of the cortex, simple stains show a "visible" map of the whiskers and easily identify groups of cells which fire when the homologous whisker is moved.



Visual Pathways

These pathways convey visual information for recognizing scenes and objects, directing gaze, controlling light levels on the retina, and modulating body function with changes in the length of the day.

THE BRAIN ATLAS, 3rd ed, pp. 192-193



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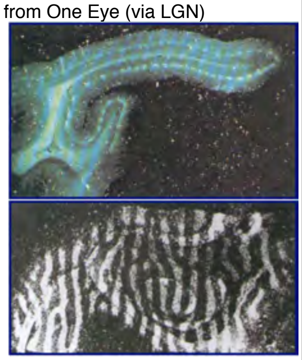
Innervation of Visual Cortex from One Eye (via LGN)

The axons to the visual cortex of monkeys that represent one eye are separate from those from the other eye. A technique was used that labeled axons from one eye. The image above cuts through the thickness of the visual cortex showing patches; the one below was reconstructed from sections cut in the plane of the cortex showing that the patches above are actually stripes (ocular dominance stripes).



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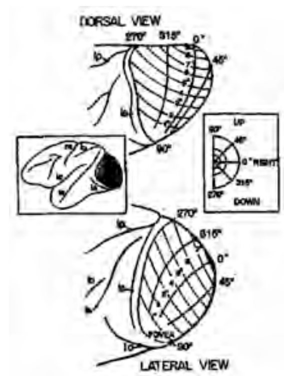
The map of the visual world (right) onto the visual cortex of the monkey (dark area in the box to the left).



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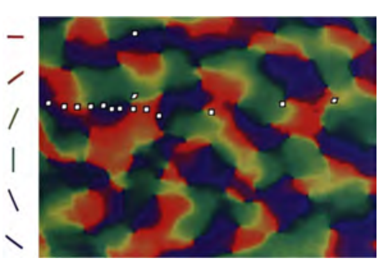
Orientation Map in the Monkey Visual Cortex (Optical Imaging)

The different colors represent areas responding to bars of light in different parts of the visual field in different orientations as indicated in the key on the left of the figure.



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The 6th Sense

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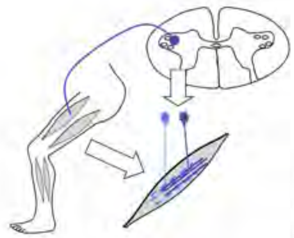
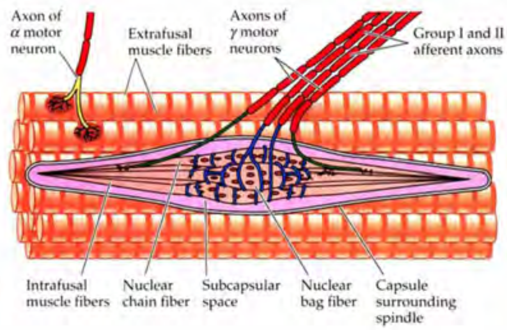


Motor Unit - A motor neuron and the muscle fibers it innervates.



Demonstration

Loss of myelin in dorsal columns in late stage Syphilis – *Tabes Dorsalis*

Two Clinical Findings in *Tabes Dorsalis*:

1) Difficulty walking over uneven surfaces in the dark.

2) Reduced or absent knee jerk reflexes.

What this Lecture was About

- Sensory Transduction
- Receptive Fields
- Adaptation
- Feature Detection
- Maps
- Sensory Integration

END