

The Sensory Modalities

Lecture 11

Learning as Cognition

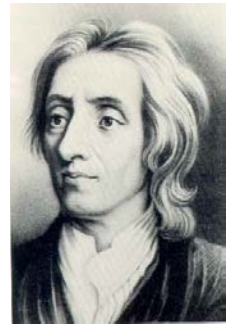
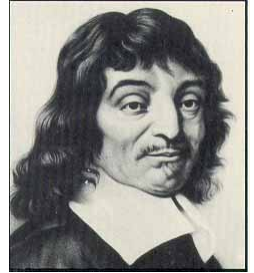
- Not Just a Change in Behavior
- Change in *Knowledge* About the World
 - Predict Events
 - Control Events

Cognition

- Basis of Intelligent Behavior
 - Beyond Reflex, Taxis, and Instinct
 - Beyond Conditioned Response
- Acquire Knowledge About World
 - Integrate with Prior Knowledge
 - Store Knowledge in Memory
- Use Knowledge in Action
 - Cope, Achieve
- Language as a Tool
 - Thought, Communication

How Do We Know the World?

- Nativism (Descartes)
 - Innate Knowledge
 - Independent of Sensory Experience
- Empiricism (Locke)
 - Knowledge Acquired Through Experience
 - Reflections on Experience
- Synthesis (Kant)
 - Knowledge Acquired Through Experience
 - Presumes Categories of Thought

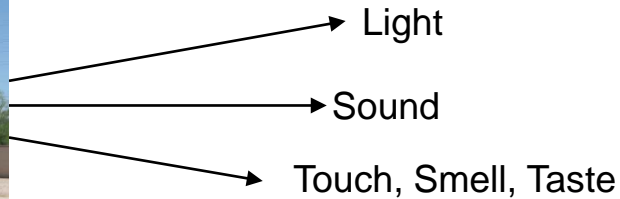


Acquiring Knowledge Through Experience

- Sensation
 - Is There Something Out There?
 - How Intense Is It?
- Perception
 - Where Is It?
 - What Is It Doing?
 - What Is It?
 - What Can I Do With It?
 - What Can *It* Do to *Me*?

Relations Between Sensation, Perception

- Distal Stimulus
- Proximal Stimulus



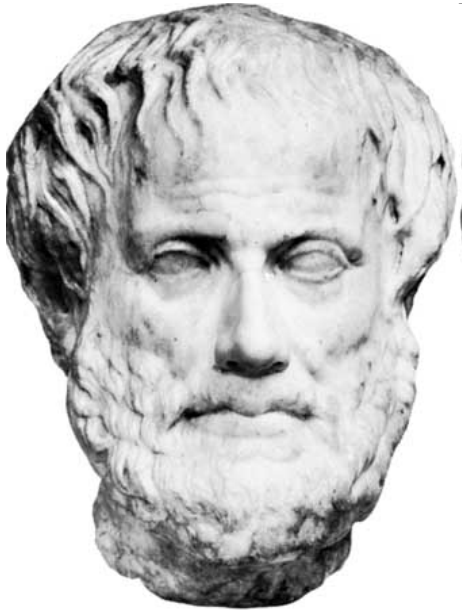
- Transduction
- Neural Impulse
- Mental Representation
 - of Distal Stimulus

- Object, Event
- Stimulus Energy
 - Radiated
 - Reflected
- Sensory Receptor
- Transmitted to Cortex
- Object, Event
 - Physical Features
 - Meaning, Implications

How Do We Get
From the Stimulus to the Percept?

Aristotle's Five Senses

De Anima (4th c. BCE)



Vision
Audition
Olfaction
Gustation
Touch



The Sensory Modalities

Sherrington (1906)

Exteroception

- Distance Senses
 - Vision
 - Audition
- Chemical Senses
 - Gustation
 - Olfaction
- Skin (Cutaneous) Senses
 - Touch (Tactile)
 - Temperature (Thermal)
 - Pain (Nociception)

Proprioception

- Kinesthesia
- Equilibrium (Vestibular)
- (Skin Senses)
 - Touch
 - Temperature
 - Pain

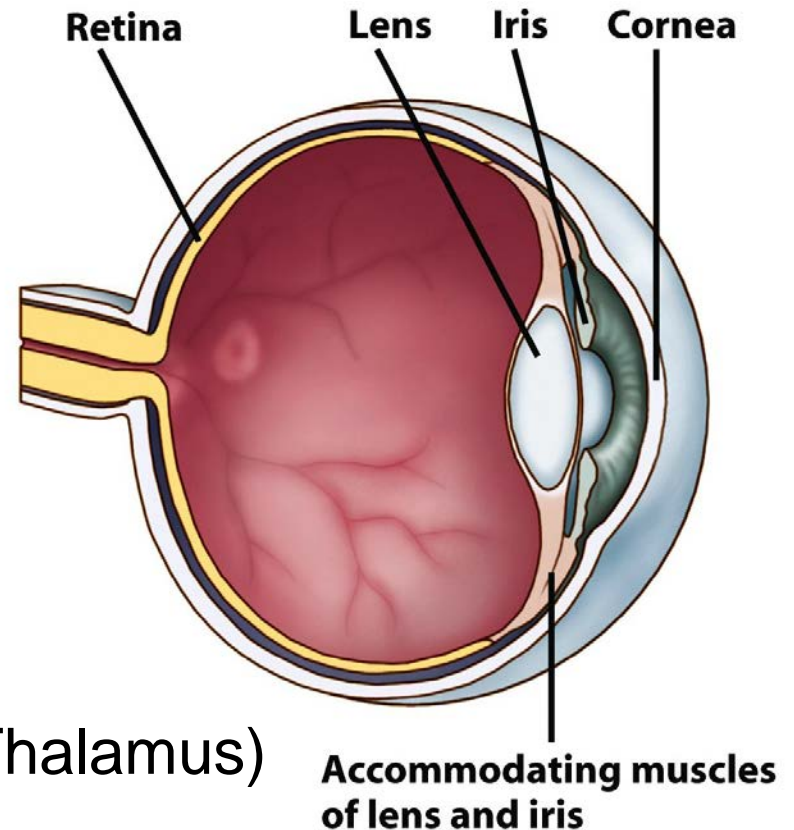
Interoception

Defining the Sensory Modalities

- Proximal Stimulus
- Receptor Organ
- Sensory Tract
- Projection Area

Vision

- Proximal Stimulus
 - Electromagnetic Radiation
 - 380-780 Nanometers
 - Retinal Image
- Receptor Organ
 - Rods and Cones in Retina
- Sensory Tract
 - Optic Nerve (II)
 - Lateral Geniculate Nucleus (Thalamus)
- Primary Visual Cortex (V1)
 - Brodmann's Area 17 (Occipital Lobe)



Details of the Visual System

VISUAL SYSTEM: THE EYE.

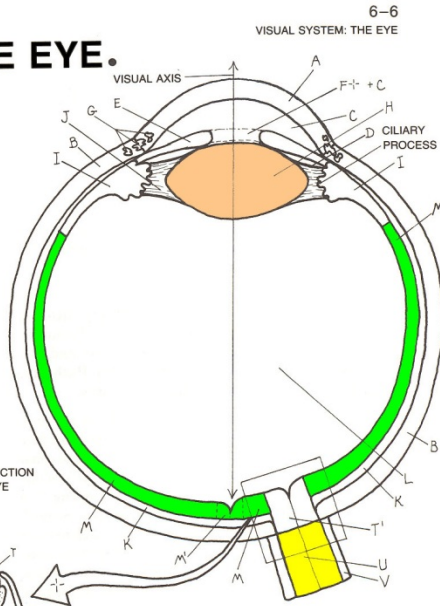
EYEBALL*

CORNEA_A
 SCLERA_B
 ANT./POST. CHAMBER.
 IRIS_E
 PUPIL_F + C

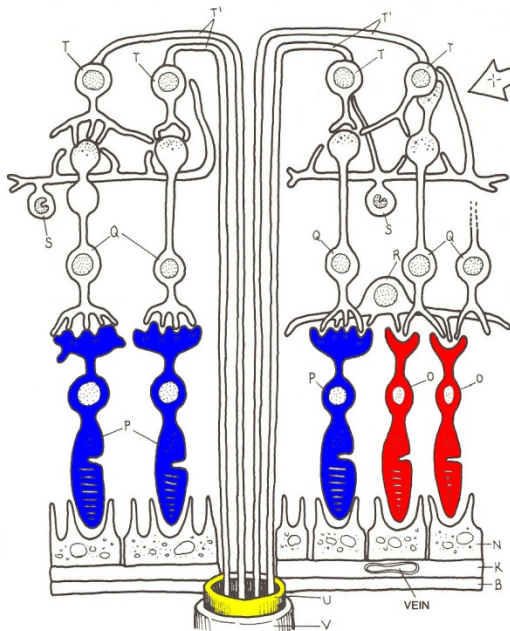
CANALS OF SCHLEMM_G

LENS_H
 CILIARY BODY,
 SUSPENSORY LIGAMENTS,
 CHOROID_K
 VITREOUS BODY_L

RETINA_M
 MACULA LUTEA_{M'}



HORIZONTAL SECTION OF THE LEFT EYE

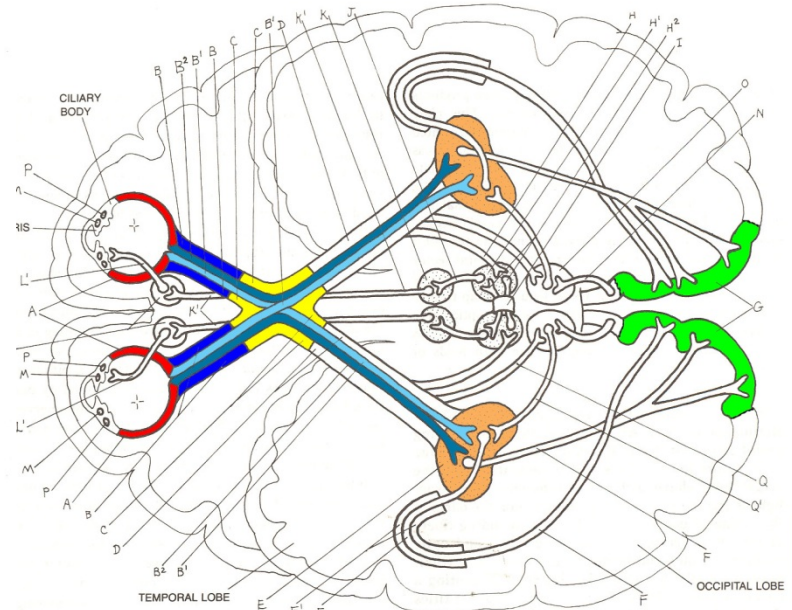


SCHEMATIC OF RETINAL CELLULAR ORGANIZATION

RETINA*

PIGMENT LAYER_N
 ROD CELL_O
 CONE CELL_P
 BIPOLAR CELL_Q
 HORIZONTAL CELL_R
 AMACRINE CELL_S
 GANGLION CELL/Axon_T
 OPTIC NERVE_U
 SHEATH OF OPTIC N._V

VISUAL SYSTEM: VISUAL PATHWAYS.



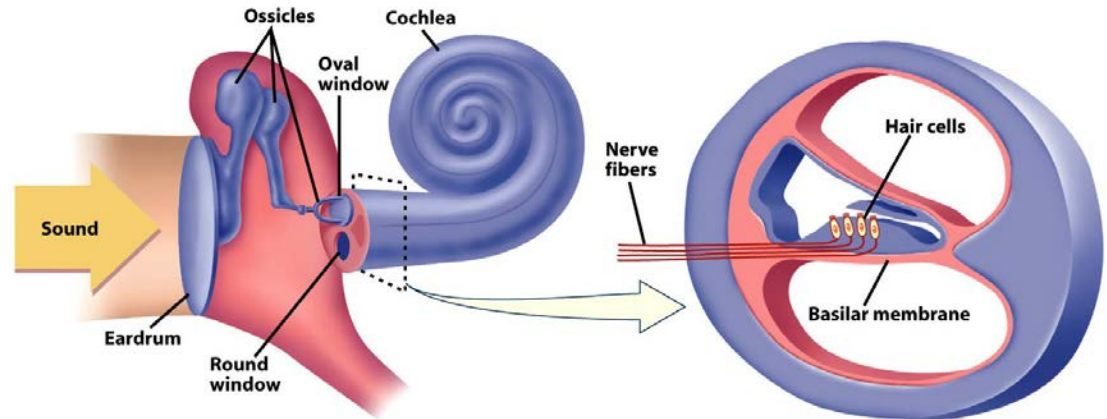
PRIMARY VISUAL PATHWAY*

RETINA_A
 OPTIC NERVE_B
 NASAL FIBER_{B'}
 TEMP. FIBER_{B''}
 OPTIC CHIASM_C/TRACT.
 LAT. GENIC. BODY_E
 OPTIC RADIATION_F
 MEYER'S LOOP_{F'}
 VIS. CORTEX/AREA 17_G
 PUPILLARY LIGHT REFLEX PATHWAY*
 RETECT. AFF._H/NUC._{H'}/EFF._{H''}
 POST. COMMISSURE,
 INTERNEURON.

NUC. EDINGER WESTPHAL_K
 PREGANGLIONIC FIBER_{K'}
 CILIARY GANGLION,
 POSTGANGLIONIC FIBER_L
 CONSTRICTOR PUPILLAE_M
 ACCOMMODATION REFLEX PATHWAY*
 CORT.-COLLIC. FIBER_N
 SUPERIOR COLLICULUS,
 CILIARY MUSCLE,
 VISUAL STARTLE/TRACKING REFLEX PATHWAY*
 OPTIC TR.-COLLIC. FIBER_O
 COLLIC-GENICULATE FIBER_{O'}

Audition

- Proximal Stimulus
 - Mechanical Vibration
 - 20-20,000 cycles per second
- Receptor Organ
 - Cochlea
 - Basilar Membrane
 - Hair Cells
- Sensory Tract
 - Vestibulo-Cochlear Nerve (VIII)
 - Auditory Component
 - Medial Geniculate Nucleus (Thalamus)
- Primary Auditory Cortex A1
 - Brodmann's Area 41 (Temporal Lobe)



Details of the Auditory System

6-17
AUDITORY SYSTEM:
THE EAR

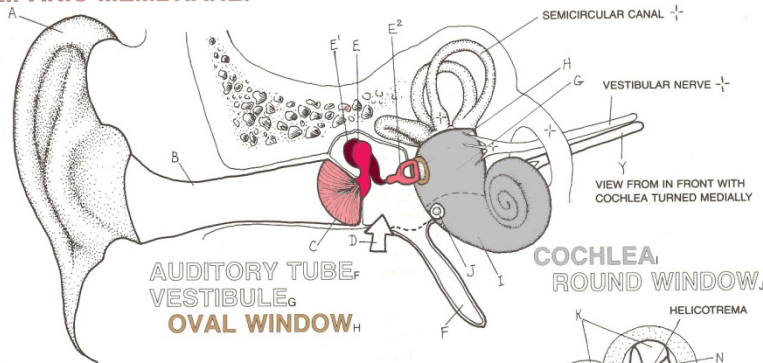
AUDITORY SYSTEM: THE EAR.

EXTERNAL EAR.

AURICLE_A
EXT. AUD. MEATUS_B
TYMPANIC MEMBRANE_C

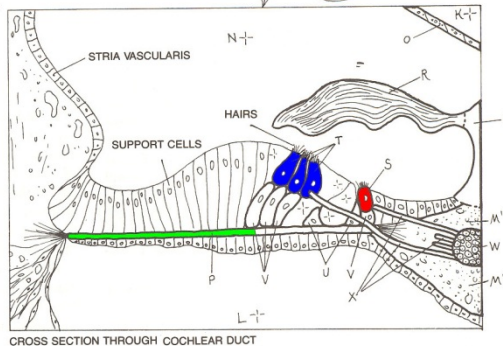
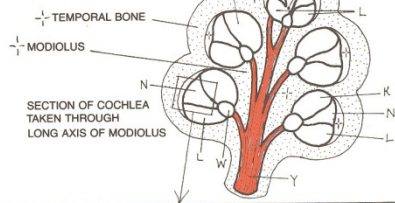
MIDDLE EAR.

MIDDLE EAR CAVITY.
MALLEUS_E/INCUS_E/STAPES_E



COCHLEA OF THE INNER EAR.

SCALA VESTIBULI_K
SCALA TYMPANI_L
MODIOLUS_M
OSSEOUS SPIRAL LAM._{M'}
COCHLEAR DUCT_N
REISSNER'S MEMBRANE_O
BASILAR MEMBRANE_P
LIMBUS_Q
TECTORIAL MEMBRANE_R
ORGAN OF CORTI *
INNER HAIR CELL_S
OUTER HAIR CELL_T
PILLAR CELL_U
PHALANGEAL CELL_V
SPIRAL GANGLION_W
PERIPH. PROCESS_X
COCHLEAR NERVE FIBERS_Y



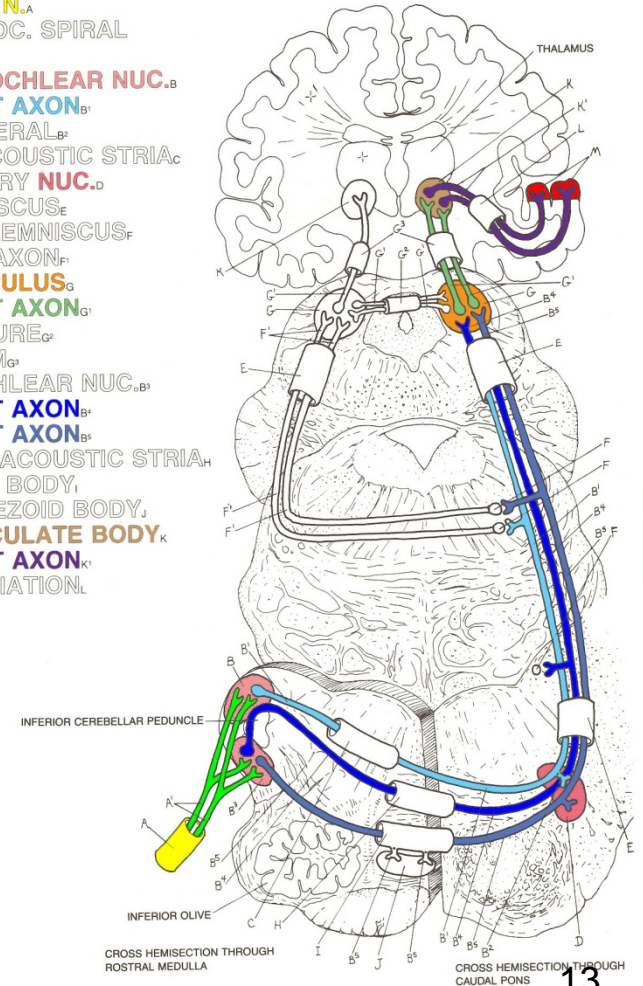
CROSS SECTION THROUGH COCHLEAR DUCT

6-18
AUDITORY SYSTEM: COCHLEAR (VIII)
NERVE PATHWAYS

AUDITORY SYSTEM: COCHLEAR (VIII) NERVE AND PATHWAYS.

COCHLEAR N._A

CENT. PROC. SPIRAL GANGL._{A'}
DORSAL COCHLEAR NUC._B
EFFERENT AXON_{B'}
COLLATERAL_{B''}
DORSAL ACOUSTIC STRIA_C
SUP. OLIVARY NUC._D
LAT. LEMNISCUS_E
NUC. LAT. LEMNISCUS_F
DECUSS. AXON_{F'}
INF. COLLICULUS_G
EFFERENT AXON_{G'}
COMMISSURE_{G''}
BRACHIUM_{G'''}
VENT. COCHLEAR NUC._{B''}
EFFERENT AXON_{B'''}
EFFERENT AXON_{B''''}
INTERMED. ACOUSTIC STRIA_H
TRAPEZOID BODY_I
NUC. TRAPEZOID BODY_J
MED. GENICULATE BODY_K
EFFERENT AXON_{K'}
AUDIT. RADIATION_L
AREA 41_M



CROSS HEMISECTION THROUGH ROSTRAL MEDULLA

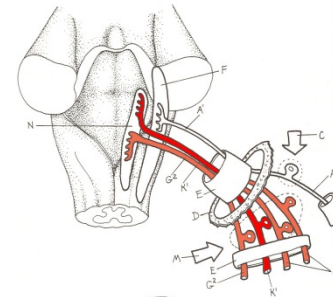
CROSS HEMISECTION THROUGH CAUDAL PONS

Gustation

- Proximal Stimulus
 - Chemical Molecules in Food, Drink
 - Dissolved in Saliva
- Receptor Organ
 - Papillae (Taste Buds)
- Sensory Tract
 - Glossopharyngeal Nerve (IX)
 - Facial Nerve (VII), Vagus Nerve (X)
- Primary Gustatory Cortex
 - Frontal Lobe
 - Anterior Insula, Frontal Operculum
 - Somatosensory Cortex

GLOSSOPHARYNGEAL (IX) NERVE: SENSORY COMPONENT.

6-21
GLOSSOPHARYNGEAL (IX) NERVE:
SENSORY COMPONENT

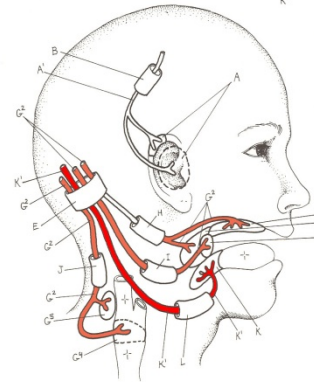


SKIN OF EXT. EAR,
GEN. SOM. AFF. NEURON,
AURIC. BR. VAGUS N.,
SUP. GANGLION,
JUGULAR FORAMEN,
GLOSSOPHARYNGEAL N.,
SPINAL TRIGEM. NUC.

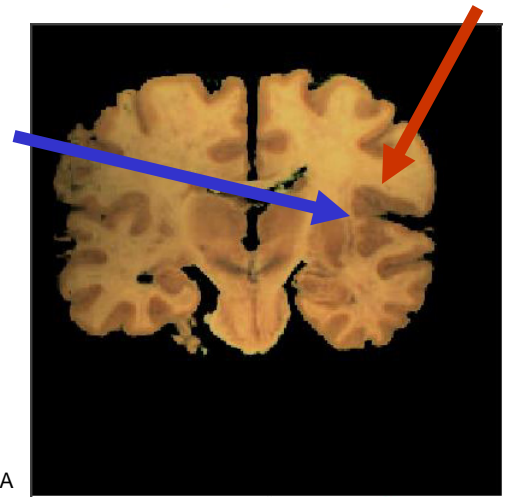
PALATE/PHARYNX,
GEN. VISC. AFF. NEUR.,
PHARYNGEAL BR.

TONSIL,
TONSILLAR BR.

CAROTID SINUS,
CAROTID BODY,
SINUS N.



POSTSULCAL
TASTE REGION,
SPEC. VISC. AFF.
NEURON,
LINGUAL BR.,
INF. GANGLION,
NUC. SOLITARIUS.



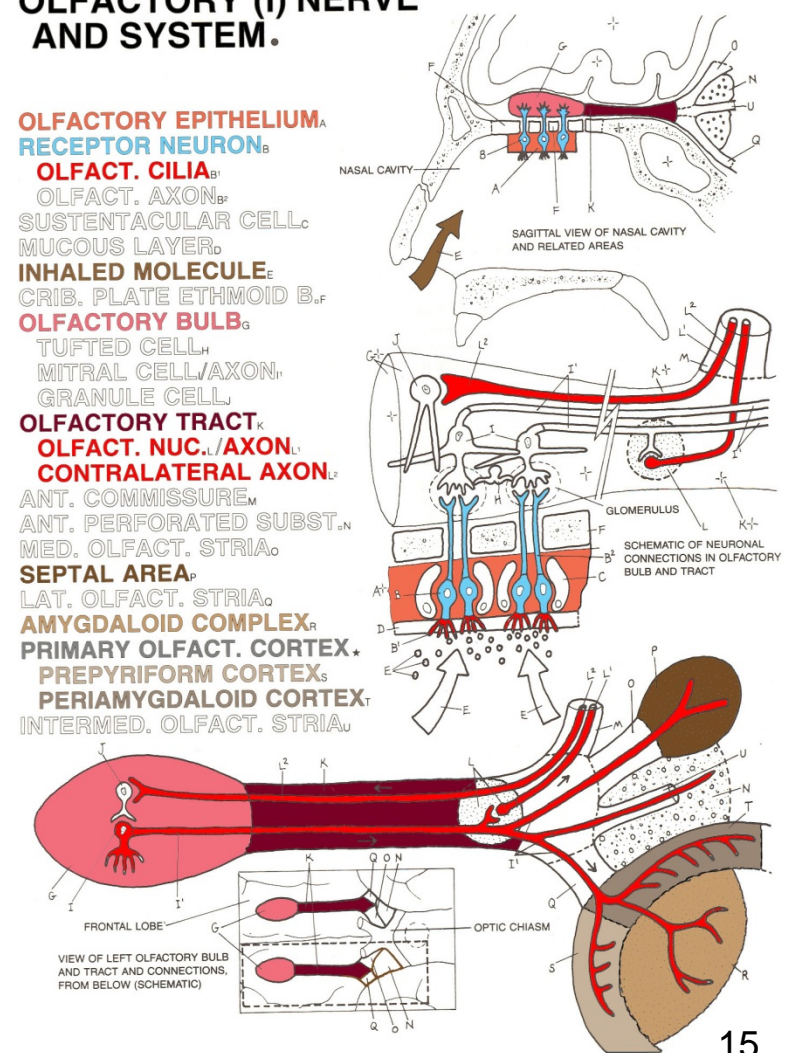
Olfaction

- Proximal Stimulus
 - Chemical Molecules in Air
 - Dissolved in Mucous
- Receptor Organ
 - Olfactory Epithelium
- Sensory Tract
 - Olfactory Bulb
 - Olfactory Nerve (I)
- Primary Olfactory Cortex
 - Prepyriform Cortex
 - Periamygdaloid Complex

OLFACTORY (I) NERVE AND SYSTEM.

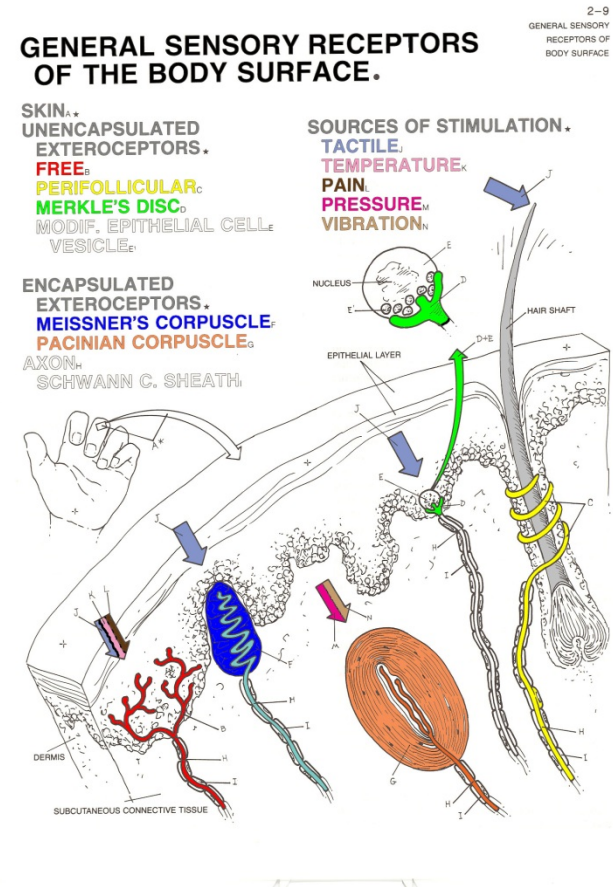
6-5
OLFACTORY (I) NERVE AND SYSTEM

- OLFACTORY EPITHELIUM_A
- RECEPTOR NEURON_B
- OLFACT. CILIA_{B1}
- OLFACT. AXON_{B2}
- SUSTENTACULAR CELL_C
- MUCOUS LAYER_D
- INHALED MOLECULE_E
- CRIB. PLATE ETHMOID_{B,F}
- OLFACTORY BULB_G
- TUFTED CELL_H
- MITRAL CELL/AXON_I
- GRANULE CELL_J
- OLFACTORY TRACT_K
- OLFACT. NUC._{L1}/AXON_{L2}
- CONTRALATERAL AXON_{L3}
- ANT. COMMISSURE_M
- ANT. PERFORATED SUBST._N
- MED. OLFAC. STRIA_O
- SEPTAL AREA_P
- LAT. OLFAC. STRIA_Q
- AMYGDALOID COMPLEX_R
- PRIMARY OLFAC. CORTEX_S
- PREPYRIFORM CORTEX_T
- PERIAMYGDALOID CORTEX_U
- INTERMED. OLFAC. STRIA_V



Touch (the Tactile Sense)

- Proximal Stimulus
 - Mechanical Pressure on Skin
- Mechanoreceptors
 - Free Nerve Endings
 - “Basket” Endings, Merkel’s Disks
 - Meissner’s / Pacinian Corpuscles
- Sensory Tract
 - Afferent Tract
 - Spinal, Cranial Nerves
 - Spinal Cord
- Primary Somatosensory Cortex
 - Brodmann’s Areas 1, 2, 3

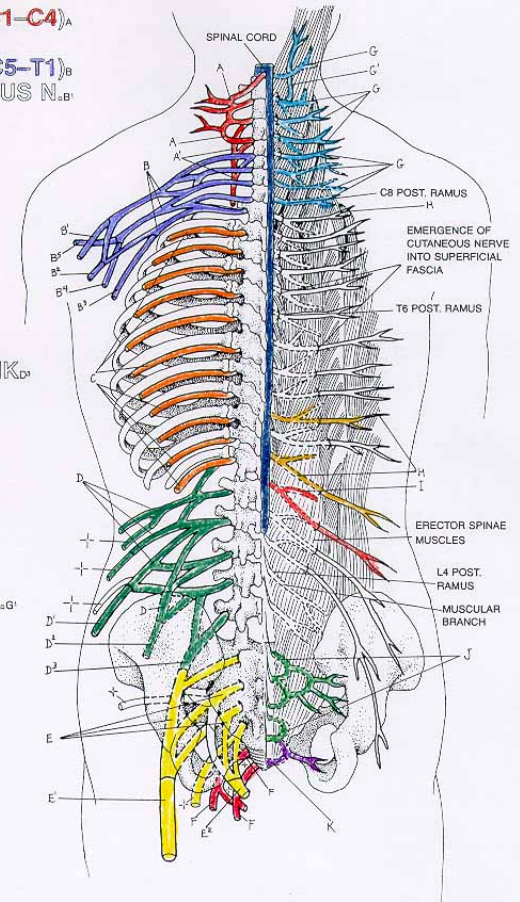


Temperature (The Thermal Sense)

- Proximal Stimulus
 - Temperature Differential
- Receptor Organ
 - Krause End-Bulbs
 - Ruffini End-Organs
- Sensory Tract
 - Spinal Nerves
 - (Afferent) Cranial Nerves
- Primary Somatosensory Cortex
 - Brodmann's Areas 1, 2, 3

SPINAL NERVES AND PLEXUSES.

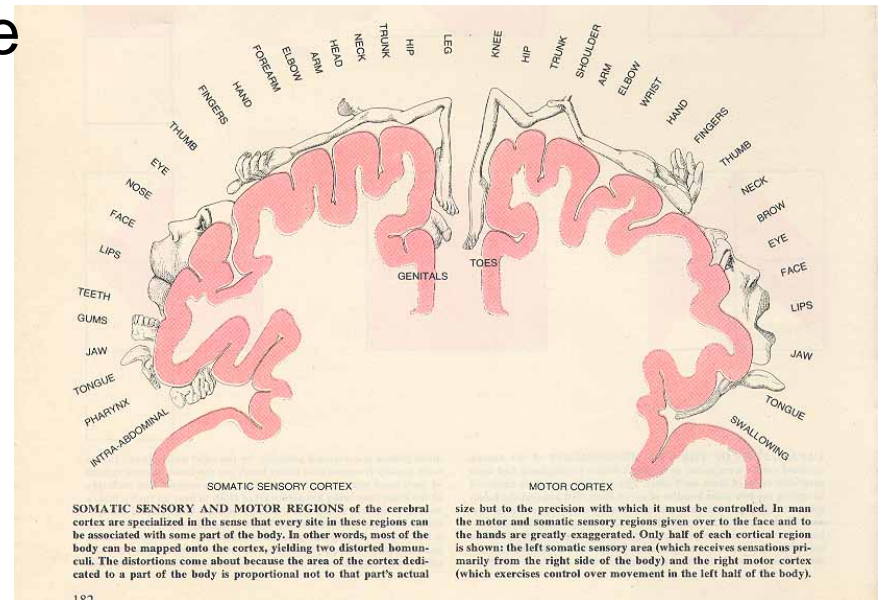
ANTERIOR RAMI.
CERVICAL PLEXUS (C1-C4)_A
 PHRENIC N._{A1}
BRACHIAL PLEXUS (C5-T1)_B
 MUSCULOCUTANEOUS N._{B1}
 MEDIAN N._{B2}
 ULNAR N._{B3}
 RADIAL N._{B4}
 AXILLARY N._{B5}
INTERCOSTAL N.
 (T1-T12)_C
LUMBAR PLEXUS
 (L1-L4)_D
 FEMORAL N._{D1}
 OBTURATOR N._{D2}
 LUMBOSACRAL TRUNK._{D3}
SACRAL PLEXUS
 (S1-S3)_E
 SCIATIC N._{E1}
 PUDENDAL N._{E2}
COCCYGEAL PLEXUS
 (S4-Co1)_F
 POSTERIOR RAMI.
CERVICAL BR._G
 GR. OCCIPITAL N._{G1}
THORACIC BR._H
LUMBAR BR._I
SACRAL BR._J
COCCYGEAL BR._K



7-4
 SPINAL NERVES
 AND PLEXUSES

Cutaneous Pain (Nociception)

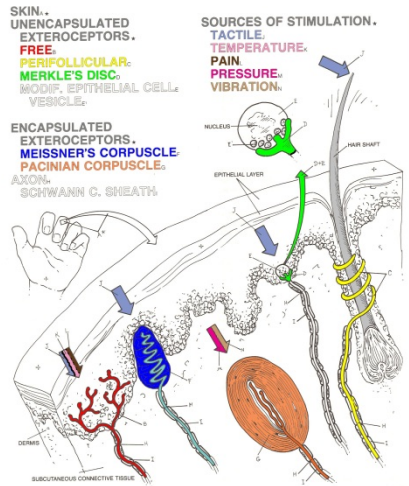
- Proximal Stimulus
 - Injury/Destruction of Tissue
 - Inflammation
- Receptor Organs
 - Free Nerve Endings
 - A-delta fibers, C fibers
- Sensory Tract
 - Neospinothalamic Tract
 - Paleospinothalamic Tract
- Primary Somatosensory Cortex
 - Brodmann's Areas 1, 2, 3



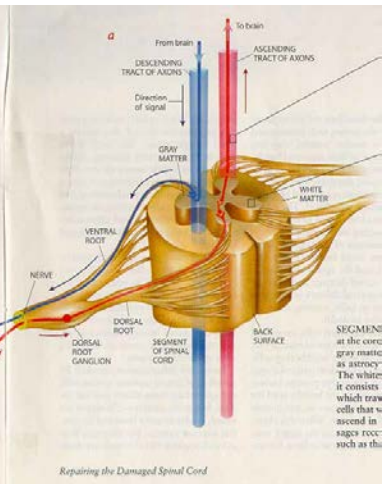
The Skin Senses Reviewed

GENERAL SENSORY RECEPTORS OF THE BODY SURFACE.

2-9
GENERAL SENSORY RECEPTORS OF BODY SURFACE



...rd reside in a gray, butterfly-shaped re that spans the length of the spinal rd. The ascending and descending onal fibers travel in a surrounding is known as the white matter, so led because the axons are wrapped in elin, a white insulating material. Both ions also house glial cells, which help axons to survive and work properly. e glia include star-shaped astrocytes, roglia (small cells that resemble mponents of the immune system) oligodendrocytes, the myelin pro- cess. Each oligodendrocyte myelin- ses as many as 40 different axons ultaneously.



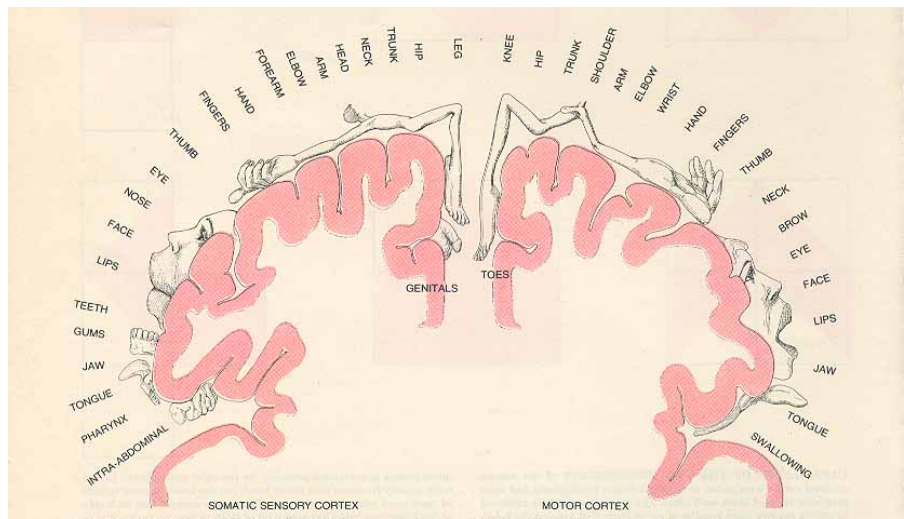
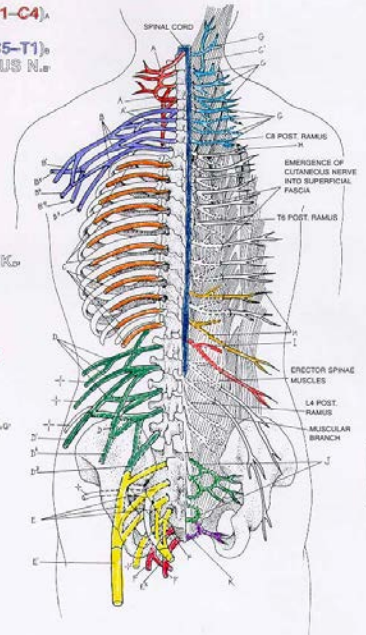
Repairing the Damaged Spinal Cord

Repairing the Damaged Spinal Cord

SPINAL NERVES AND PLEXUSES.

7-4
SPINAL NERVES AND PLEXUSES

- ANTERIOR RAMI.
- CERVICAL PLEXUS (C1-C4).
- PHRENIC N.
- BRACHIAL PLEXUS (C5-T1).
- MUSCULOCUTANEOUS N.
- MEDIAN N.
- ULNAR N.
- RADIAL N.
- AXILLARY N.
- INTERCOSTAL N. (T1-T12).
- LUMBAR PLEXUS (L1-L4).
- FEMORAL N.
- OBTURATOR N.
- LUMBOSACRAL TRUNK.
- SACRAL PLEXUS (S1-S3).
- SCIATIC N.
- PUDENDAL N.
- COCCYGEAL PLEXUS (S4-Co1).
- POSTERIOR RAMI.
- CERVICAL BR.
- GR. OCCIPITAL N.
- THORACIC BR.
- LUMBAR BR.
- SACRAL BR.
- COCCYGEAL BR.

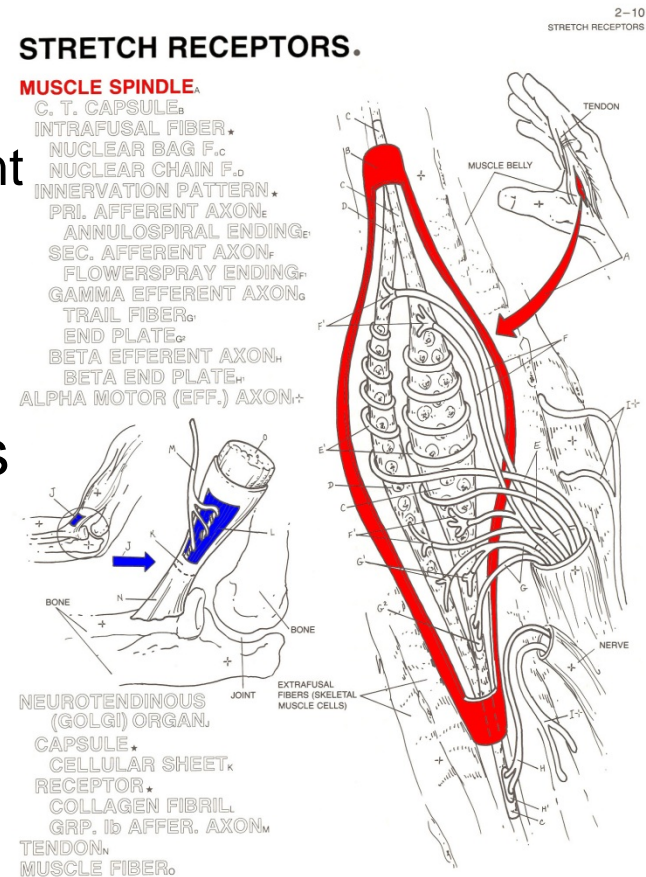


SOMATIC SENSORY AND MOTOR REGIONS of the cerebral cortex are specialized in the sense that every site in these regions can be associated with some part of the body. In other words, most of the body can be mapped onto the cortex, yielding two distorted homunculi. The distortions come about because the area of the cortex dedicated to a part of the body is proportional not to that part's actual

size but to the precision with which it must be controlled. In man the motor and somatic sensory regions given over to the face and to the hands are greatly exaggerated. Only half of each cortical region is shown: the left somatic sensory area (which receives sensations primarily from the right side of the body) and the right motor cortex (which exercises control over movement in the left half of the body).

Kinesthesia (Movement, Position)

- Proximal Stimulus
 - Activity in Skeletal Musculature
 - Stretching, Contraction, Movement
- Receptor Organ
 - Neuromuscular Spindles
 - Neurotendinous (Golgi) Organs
 - Nerve Endings in Joints
- Sensory Tract
 - Spinal Nerves
 - (Afferent) Cranial Nerves
- Primary Somatosensory Cortex
 - Brodmann's Areas 1, 2, 3



The Vestibular Sense (Equilibrium)

- Proximal Stimulus
 - Gravitational Force on Otoliths
- Receptor Organ
 - Hair Cells
 - Vestibular Sac
 - Semicircular Canals
- Sensory Tract
 - Vestibulo-Cochlear Nerve (VIII)
 - Vestibular Component Projection Area
- Cerebellum

VESTIBULAR SYSTEM: INNER EAR.

6-19
VESTIBULAR SYSTEM:
INNER EAR

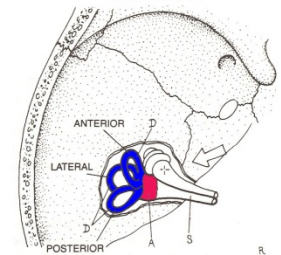
VESTIBULE_A

UTRICLE_a
SACCULE_b

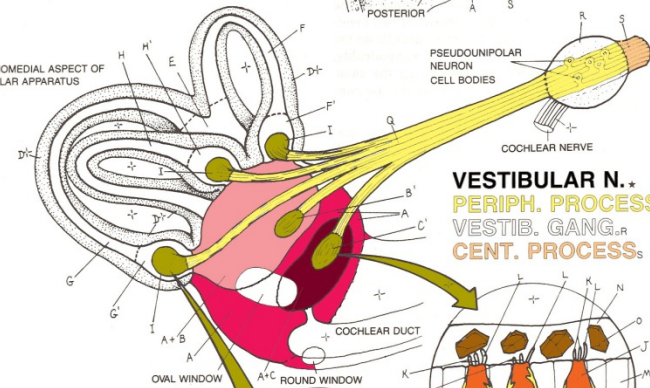
SEMICIRC. CANAL_D

COMMON DUCT_F
ANT. S. C. DUCT/AMPULLA_F
POST. S. C. DUCT/
AMPULLA_G
LAT. S. C. DUCT/AMPULLA_H

DIRECTION OF VIEW OF VESTIBULAR
APPARATUS IN MIDDLE ILLUSTRATION



POSTERIO-MEDIAL ASPECT OF
VESTIBULAR APPARATUS



VESTIBULAR N._I
PERIPH. PROCESS_o
VESTIB. GANG._R
CENT. PROCESS_s

UTRIC. MACULA_B
SACC. MACULA_C
CRISTA AMPULLARIS
HAIR CELL_J
STEREOCIL_K
KINOCILIUM_L
SUPPORT. CELL_M
GELATIN. MASS_N
OTOLITH_O
CUPULA_P



SECTION THROUGH MACULA

How Do We Know the World?

- Distance Senses
 - Vision
 - Audition
- Chemical Senses
 - Gustation
 - Olfaction
- Skin Senses
 - Touch (Tactile)
 - Temperature (Thermal)
 - Pain (Nociception)
- Proprioception
 - Kinesthesia
 - Equilibrium (Vestibular)



Jan Brueghel the Younger,
An Allegory of the Five Senses (1625)