The Sensory-Motor System

Functional Neuroanatomy

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Dr. Brozowski --- 1978

Lab. #1 - Functional Neuroanatomy
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Advanced Neuropsychology
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The Sensory-Motor System of the Mammalian Brain

It is supposed that the basic function of the nervous system is motor. Essential to life is irritation and locomotion. If touched, the primoridal cell will withdraw its pseudopod. It will show spontaneous movement. At the most primitive level, sensory input and motor output are operative; whereas, other senses are non-existent, or poorly developed (with the possible exception of vision present in the form of photosensitive pigments in the multicellular organism.) Theories compete to explain the evolution of the nervous system; but, that the sensory-motor system holds a major place in the mediation of the stimulus-response behavior of animals, and is extremely complex in mammals, is indisputable.

The overall organization of the mammalian sensory-motor system is presented in a schematic, derived from the metaphor of a cybernetic system, and from the metaphor of evolution. The schematic may be read clockwise. Spinal reflex arcs, and simple feedback systems, including the autonomic, kinesthetic, cutaneous-sensory, and gamma-motorneuron systems, are presented at the bottom of the diagram. The ascending sensory system is indicated on the left side of the schematic. Sensory-motor cortex and its connections are at top. The upper portion of the schematic is devoted to the complex pathways of the descending motor system. Constant reference will be made as to how the input is processed at the various anatomical centers of the brain.

Lab... all figures so they can be specifically referred to in the text and used more effectively

? (i) Sensory information arrives from three basic sources. First, pressure differentials, mechanical skin deformations, light, deep and diffuse touch, and 'pain' are effective stimuli for cutaneous and other superficial receptors (vibrissae, antennae, hooves, nails, horns, etc...).

It is supposed that pressure receptors, Meissener Corpuscles, and free nerve endings are touch receptors. 'Nociceptors' are purported 'pain' receptors. Krause end bulbs, and Ruffini cylinders are proposed as specific temperature receptors, but this theory contends with the neurovascular theory of temperature sensation. Second, joint receptors register changes in the positions of bones via Pacinian Corpuscles, changes in tension by Golgi Tendon Organs, and degree, direction, and rate of change by Spindle fibers. Intrafusal spindal fibers are connected in parallel to extrafusal muscles, hence, when the latter contract, tension of the former is reduced and activity diminishes; conversely, when extrafusal fibers stretch (relaxed extrafusal fibers stretch when contralateral fibers contract), tension of the spindle fibers is also increased, and receptors buried in these spindal fibers maintain an excited neuronal firing rate. Tendon organs are in series with the extrafusal fibers, and stretch when the muscle stretches or relaxes. (Bioelectrically, the tendon organ shows a brief burst of neuronal firing at each tension change.) Pacinian corpuscles are embedded between the bones in the joints, and consequently, are adequate indicators of bone position. These ~~The~~ three (levels of ?) receptors work in unison to provide haptic information. Third, receptors located on internal organs register information about their movements, ?

What is the purpose of such a negative feed-back loop?

ii. Spinal reflex arcs and simple feedback systems

Sacral and thoracico- thoracolumbar input has a simple motor reflex arc. Sensory input is relayed via the sensory nerve, through the mixed nerve, and doraal root ganglion, where it enters the spinal chord. Here the nerves synapse on an efferent motor nerve which exits via the ventral root ganglion and mixed nerve. ~~The~~ some of these nerves then bifurcate according to whether they are part of the sympathetic or parasympathetic division of the autonomic system. Sympathetic nerves synapse in the sympathetic ganglion (parallel and exterior to the spinal column) ~~on~~

Don't imply that the entire peripheral control system is autonomic

Specifically might want distinguish somatic from autonomic control on post-sympathetic nerves which, in turn, synapse on the smooth or cardiac muscles of the target organ. Parasympathetic nerves exit the mixed nerve, and activate organ muscles via parasympathetic nerve and interneurons.

This somewhat redundant with the paragraph before preceding one; Perhaps both could be condensed into one?

Kinesthetic input follows a reflex arc modified by a simple feedback system: the gamma motor system. Pacinian corpuscles transmit bone angle information via afferent nerves through the spinal chord, and via alpha motoneurons to muscle endplates. Likewise, the Golgi tendon organ transmits tension change information via nerve fibers, the spinal chord, and alpha motoneurons to muscle effectors. However, the spindal organ has modifiable pathways. Tension information is sent via the spindle afferent to the spinal chord. Here pathways bifurcate. The message either synapses on an alpha motoneuron, or is fedback by synapsing on a gamma motoneuron, which in turn, synapses on the spindal organ. The gamma motoneuron is mediated by several higher brain regions including the medulla, and reticular formation (see the basic vestibular postural system, and Reticular gamma motor system). Several gamma loops may occur before the message is transmitted to the muscle effector via the alpha motor neuron.

Sensory input from cutaneous tissue ramnifies in the cord. Either messages continue down an alpha motoneuron or synapse on gamma motor neurons, and hence send information to the intrfusal spindal organ.

iii. Ascending Sensory Pathways

Cutaneous and Kinesthetic information also ascends to higher brain regions, and to somatosensory cortex by three pathways: spinothalamic tract, dorsal column, and spinocervical tract. It is proposed that the information processing at the spinal funiculi where the paths originate is selection for epicritic versus protopathic aspects of ~~sensory input.~~

Grammer needs some work.

sensory input. Hence, the lemniscal tract and dorsal column transfer specific (epicritic) stimuli: touch and pressure. The spina~~l~~othalamic tract, on the other hand, transfers vague (protopathic) stimuli: pain, temperature, diffuse and vague touch.

The spinalcervical and dorsal tracts ascend in parallel. Each synapses on a nucleus in the medulla (later cervical nucleus for the former, gracile cuneate nucleus for the latter). Some information is relayed, at this point, to the paleocerebellum to aid in postural behavior, and to the superior colliculus to combine with visual and auditory informatin to aid in visual-auditory-postural adjustment. The spin~~al~~ocervical synapses in the reticular formation; whereas, the dorsal column continues through the formation. Both tracts synapse on thalamic relay nuclei, ventroposterialis lateralis and ventroposterialis medialis. This primary projection zone projects via thalamocortical radiations to discrete areas of the somatosensory anamunculus posterior to the ansate (central) sulcus, and to parietal and temporal cortex association areas.

The spin~~al~~othalamic tract ascends from the large (processing) cells of the posterior spinal funiculi, and first synapse on interneurons in the brain stem reticular formation. Nerves then ascend to the thalamic nuclei, ventroposterialis lateralis and medialis. Messages then relay to somatosensory cortex.

Cutaneous facial receptors synapse directly on thalamic nuclei via the trigeminal nerve.

iv. Sensory-Motor Cortex

There is a high degree of correlation between the area of sensory cortex devoted to a specific body area, and the distribution of corporal receptors. Furthermore, the anamunculus' somatopic bias reflects the animal's behavioral emphasis. In homo sapiens, for example, most of the

A pretty easy sidestep of the fairly awesome subject!

homunculus is dedicated to hand and speech organ reception and locomotion. Motor cortex is a virtual mirror image of somatosensory cortex. Understanding information processing at this locus comprises the study of Perception.

B. i. Descending Motor System

In comparison to the somatosensory system, the motor system is complex and poorly understood. From cortex signals descend directly to thalamus, midbrain tectum (basal ganglia), and pyrimdal systems. Other major areas, affected indirectly are the extrapyramidal, reticular formation, vestibular nuclei, and medulla systems.

A major division of the descending motor system is the pyramidal tract. It has both monosynaptic pathways and lateral projections. Monosynaptic pathways of the pyramidal tract extend directly from motor cortex to effector muscles. Pyramidal cells have dendrites and soma in cortex, and extend their asons (two to three feet, the longest in the body) through the medulla, where tracts cross eighty to one hundred per cent at the medullary decussation, and descend down the spinal chord to muscles. The pyramidal tract is a late evolutionary development. Monosynaptic pathways are expecially prominent in primate extremities, where they afford much agility. Subcortical nuclei are also affected by lateral rammifications of the pyramidal tract. Collectively, these nuclei constitute the extrapyramidal system.

x

80 100

use numerals for large numbers

allow?

The interconnections of the extrapyramidal tract (area three on the schematic) are complex. (Many authorities dispute whether such a system exists.) Input to the extrapyramidal system is from cortex via the basal ganglia, or indirectly from the pyramidal tract via the read nucleus or reticular formation. Interconnections of the basal ganglia,

3 in

Figure 5

red

A controversial view to say the least... but interesting

red nucleus, and reticular formation constitute an 'innate' behavioral program. Extrapyramidal components of fleeing, fighting, running, mating, and sleeping are pre-wired. Functionally, the, pyramidal and cortical commands are mixed with innate behavioral programs, to produce the net effect of modifiable (in summation of influences) innate behavior. Extrapyramidal output is via the reticular formation. The reticular formation gamma motoneuron system allows for additional modification. (This system is one of the descending influences on the spindal gamma motor system mentioned above).

The vestibular postural system (area two on the schematic) is the area concerned with processing extapyramidal and cerebellar output for postural adjustment. Reticular formation, red nucleus, and substantia nigra information enter the inferior olive. From the word? point, information is transmitted to the fastigial nucleus, and either feedsback directly to the vestibular nucleus and spinal chord, or enters the paleocerebellum, which, in turn, feeds/back to the fastigial nucleus, and hence, vestibular nuclei and spinal chord.

Looks like 4 to me

The fine-tuning center of sensory and vestibulomotor input, cortical and pyramidal commands, and extrapyramidal innate programs is the cerebellum (area six on the schematic). Pyramidal cells from cortex arrive at the neocerebellum (the evolutionarily newer region) via the pontine nucleus. Commands are temporally patterned, and returned to cortex via the brachium conjunctivum. Extrapyramidal programs are also modified. Input is from the inferior olive (receiving its input from the red nucleus and reticular formation), and directly from the reticular formation. Impulses are then transmitted from the inferior olive to cerebellum. Information is fine-tuned for smoothness and continuity, by temporally patterning the impulses, and then returns by the dentate (subthalamic) nucleus. Sensory and vestibulomotor inform-

grammar

6 in Figure 5

Through

[↳ hippocampus]

ation enters the paleocerebellum (the evolutionarily older region) through the vestibular nuclei. Output from these sources is fine-tuned and returned along the axon process of a Purkinje cell to the dentate nucleus, or to the fastigial nucleus, and thus either to the vestibular nuclei or the reticular formation. (It is found that cerebellar Purkinje cells, with soma and dendrites in cerebellar cortex, and only axons projecting exterior, are exclusively inhibitory. They exhibit IPSP's, and their probable neurotransmitter is GABA. Of course, the net effect of inhibitory influences allows messages to be excitatory as well as inhibitory.)

ii. The Medullary Pyramidal-Cranial Nerve System

It should be noted that cranial nerves of the autonomic system are under direct influence of descending pyramidal cells. Such a direct line allows for easy control of cranial functions such as eye and masticatory movements. The trochlear (eye), oculomotor (eye), trigeminal (masticatory movements), abducens (eye), hypoglossal (tongue), glosspharyngeal (tongue and pharynx), spinal accessory (neck and visceral movements), vagus (heart), and facial (face) nerves are all a part of this system.

C - again, this is not just autonomic but also has a large somatic component

Best to put figs on separate page

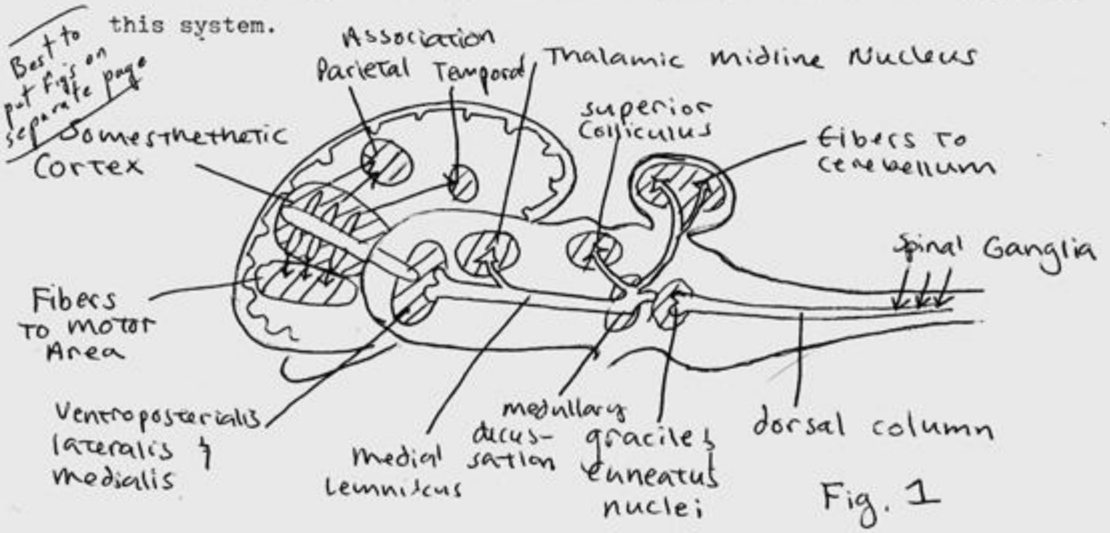


Fig. 1

Figure ~~one~~ 1. is a mid-saggital view of a mammalian brain. The figure gives a truer perspective of the relative positions of nuclei involved in the transmission of sensory and motor information.

iii. Final Motor Effectors

Every motor system must ultimately synapse on a muscle via an alpha motoneuron. The final result of the sensory-motor system is muscle contraction, neurovascular contraction, or gland activation. Furthermore, one motoneuron may activate from one to several thousand muscle~~s~~ units. Each motonueron and the muscles i~~n~~t exclusively activates are collectively termed the motor unit. The fewer muscles a motoneuron activates, the more control the animal has over that region of his body.

The neuromuscular synapse itself is an interesting structure? phenomenon, and has several distinct features. (See inset on the right-hand corner of ~~the~~ Figure 5. schematic.) Nerve impulses travel down the mylenated axon to the motor endplate (region of elevated sarcoplasm). Here the impulse travels bidirectionally, setting up the muscle contraction by concentrating impulses at either end of the muscle endplate, and thus the corresponding muscle fibre regions, (in skeletal muscle) The neurotransmitter has proven to be acetylcholine. Electrochemical transmission allows the small electrical impulse of the motoneuron to amplify more than one hundred times its EPSP or IPSP effect on the muscle by opening ionic gates.

C. Conclusion

One may marvel at how the evolution of the sensory-motor system has proceeded from simple irritation in the unicellular organism, to the complex fine-motor control exhibited by a concert pianist. But, the observable portion of animal behavior is incommesurate with the unobservable component. Motor pathways can be modified in so many ways in the higher mammal, that it is possible for the mammal to exercise subtle control over behavioral response probability so that he may meet each situation with several unexternalized motor states of varying emphasis, each awaiting the final command to be executed. Only one, or portions of each motor state is externalized at any moment. If studying the sensory-motor system allows us to appreciate the complexity of observable behavior, it should prompt us, far more, to recognize the complexity of unexternalized behavior. Indeed, evolution has, in part, been behavioral involution.

An energetic and
scholarly attempt at
describing a very large
functional system. In some
cases there was redundancy
that could have been reduced.
Also your figures should have all
been labelled clearly and
integrated more effectively into
the body of the text, i.e.,
use them to illustrate all your
major points.

3.25

Sensory-Motor System

Eric Wasiolek

Fig. 3.

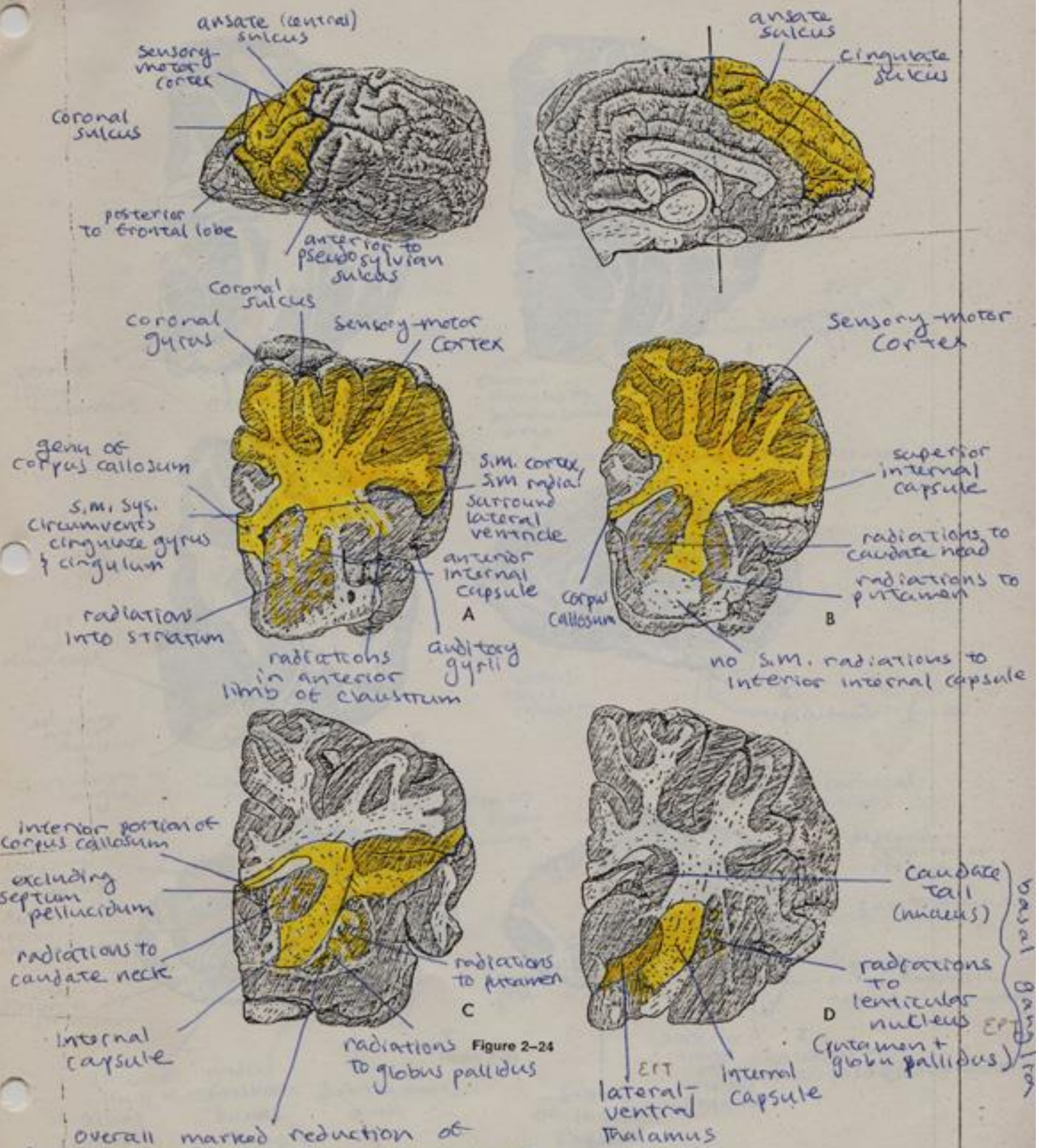
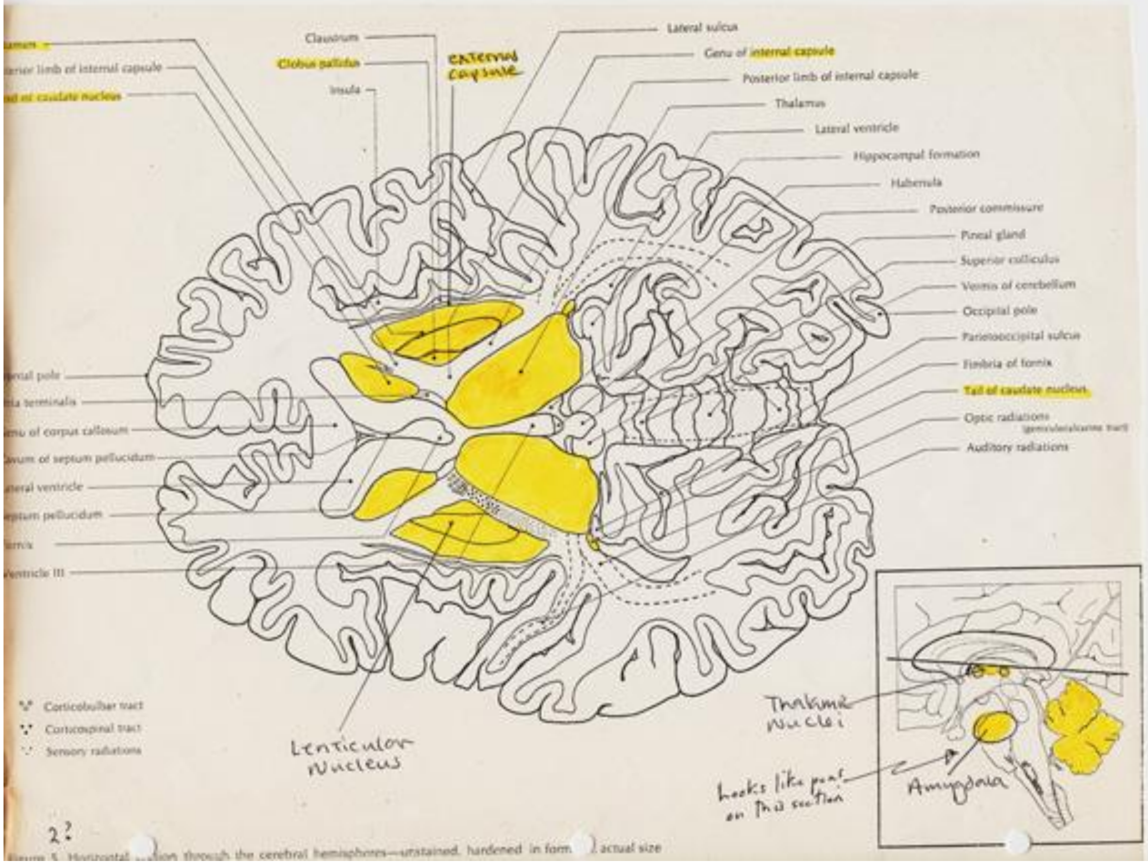


Figure 2–24

overall marked reduction of sensory-motor cortex just posterior to ansate sulcus (coronal section runs through the anterior comissure and the posterior optic chiasma)



2?

igure 5. Horizontal [illegible]tion through the cerebral hemispheres—unstained, hardened in form[illegible] actual size

Sensory - motor System

Fig 4

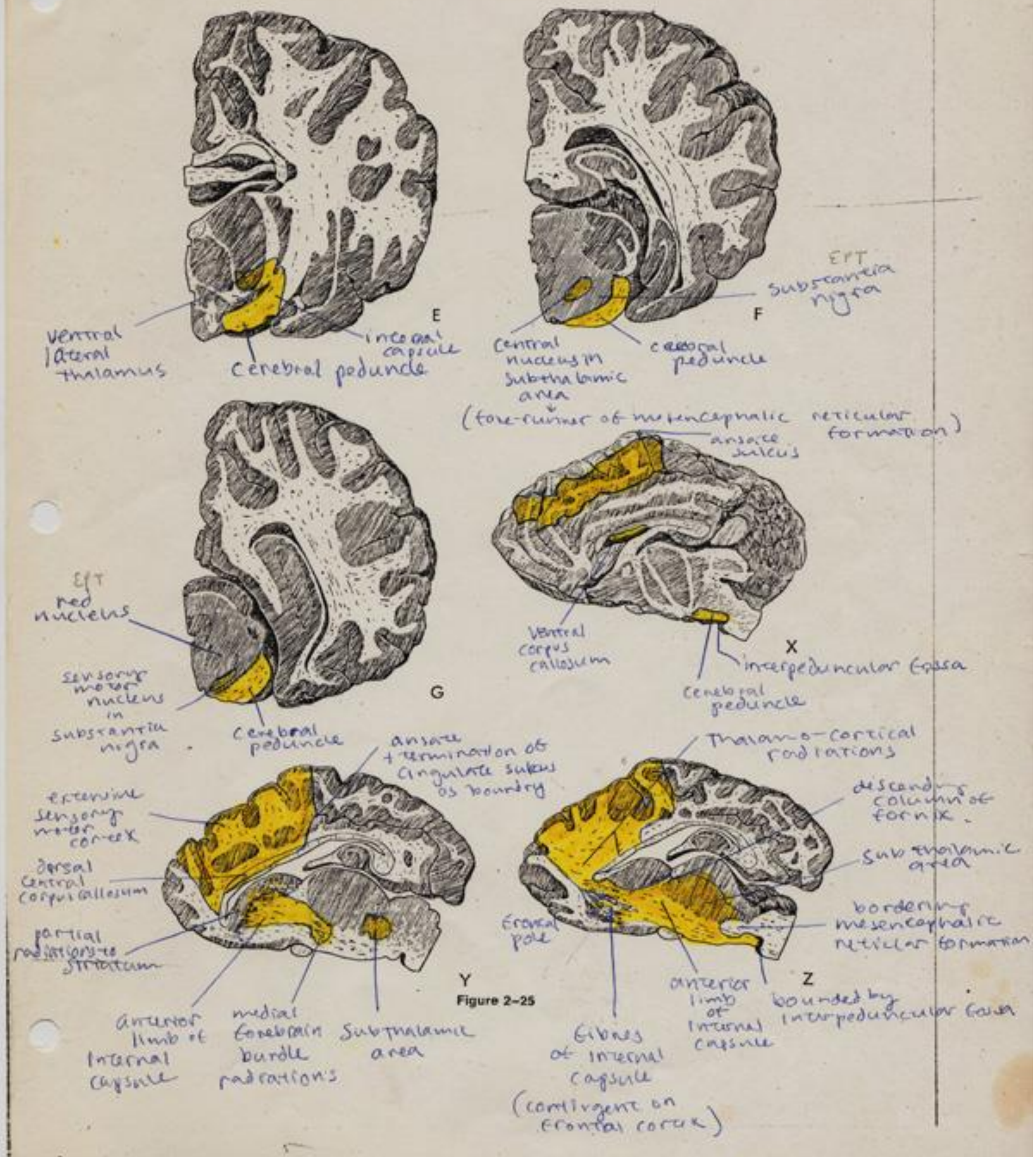


Figure 2–25

Bibliography:

Neuroscience: A Laboratory Manual, James E. Skinner
W.B. Saunders Company 1971

The Metaphorical Brain, Michael A. Arbib
John Wiley & Sons, Inc. 1972

Introduction to Physiological Psychology, Richard F. Thompson
Harper & Row, Publishers 1975

Sensation and Perception, Harvey Richard Schiffman
John Wiley & Sons, Inc. 1976

Understanding the Brain, John C. Eccles
"Peripheral Synaptic Transmission" (Chapter 2)

Atlas of the Human Brain

"Development of the Vertebrate Motor System"
Alfred J. Coulombre
The Neurosciences: A Study Program
Rockefeller University Press 1967