Notes from [KAND1]

"The central tenet of modern neural science is that all behavior is a reflection of brain activity. According to this view, ... what we commonly call mind is a range of functions carried out by the brain." [:5]

- Cell types: nerve cells (neurons) and glial cells
- "even highly complex behaviors can be localized to specific regions of the brain" [:5]
- Experimental traditions in neural science [:6]
  1) anatomy; 2) embryology; 3) physiology; 4) pharmacology; 5) psychology

- Central nervous system has 6 main divisions [:7]
  1) Spinal cord; 2) medulla oblongata; 3) pons (and cerebellum);
  4) midbrain; 5) diencephalon; 6) cerebral hemispheres
  The brain stem consists of (2), (3), and (4) except for the cerebellum

Wernicke (in 1876) was the first to propose a distributed processing model of brain function. In this model [:10-11]

1) Only the most basic mental functions, those concerned with simple perceptual and motor activities, are localized to single cortical areas
2) Interconnections between these functional sites make more complex intellectual functions possible

Although processing is distributed, current studies "lead us to believe that regional specialization is a key principle of of cortical organization" and that the brain is divided into a large number (>52) of functional regions. There is some evidence also that emotional aspects of behavior are also localized [:12-13]. However, "the functions localized to discrete regions in the brain are not complex faculties of mind, but <u>elementary operations</u>. More elaborate faculties are constituted from the serial and parallel (distributed) interconnections of several brain regions" [:15]. "All mental functions are divisible into subfunctions" [:15]

Notes from [KELLI] Anatomical Organization of The Nervous System

Components of the nervous system [KELLI: 273-274]

1) Peripheral nervous system
   - composed of ganglia and peripheral nerves that lie outside The brain and spinal cord
   - has 2 divisions
     a) somatic division: sensory neurons that provide info to The central nervous system about muscle and limb positions and The outside environment
     b) autonomic division: The motor system for The viscera (The smooth muscles of The body and exocrine glands); it consists of The sympathetic system, The parasympathetic system, and The enteric nervous system
        i) sympathetic system: participates in body response to stress
        ii) parasympathetic: acts to conserve body's resources and restore homeostasis
        iii) enteric: controls The smooth muscles of The gut

2) Central nervous system
   - composed of The brain and spinal cord
   - interconnects w/ The peripheral nervous system
   - organized along 2 major axes
     a) longitudinal rostral-to-caudal axis
     b) dorsal-to-ventral axis

Terminology for The major axes [:274-275]

1) In The spinal cord
   rostral means "toward The head"
   caudal means "toward The coccyx (L. cauda = "tail")
   ventral means "toward The belly"
   dorsal means "toward The back"

2) In the brain

rostral = "toward the nose"

caudal = "toward the back of the head"

ventral = "toward the jaw" (aka "inferior")

dorsal = "toward the top of the head" (aka "superior")

Regions of the Central Nervous System

1) <u>Spinal cord</u> [:275]

a) receives sensory info from skin, joints, and muscles of the trunk and limbs

b) contains motor neurons responsible for both voluntary and reflex movements

c) receives sensory info from the internal organs

d) has clusters of neurons that control many visceral functions

e) organization

i) has 31 pairs of spinal nerves (peripheral nerves formed by the joining of the dorsal and ventral roots)

ii) dorsal roots carry sensory info into the spinal cord from the muscles, skin, and viscera

iii) ventral roots carry outgoing motor axons that innervate muscles and preganglionic sympathetic and parasympathetic axons

iv) within the spinal cord "there is an orderly arrangement of sensory cell groups that receive input from the periphery and motor cell groups that control specific muscle groups" [:27

v) spinal cord contains ascending pathways and descending pathways for sensory input to and motor commands from the brain

2) <u>Medulla</u> [:276]

a) is direct rostral extension of the spinal cord

b) with the pons, it participates in regulating blood pressure & respiration

c) it is part of the brain stem

d) it resembles the spinal cord in organization and function

[KELL]

3a) Pons [:276]

a) lies rostral to the medulla

b) contains a large number of neurons that relay info from the cerebral hemispheres to the cerebellum; this info is info about movement

c) it is part of the brain stem

3b) Cerebellum [:276]

a) is not part of the ~~cort~~ brain stem but many of its motor functions are related to those of the pons

b) lies dorsal to the pons and medulla and wraps around the brain stem

c) is divided into several functionally independent lobes separated by distinctive fissures

d) receives • somatosensory input from the spinal cord
• motor info from the cerebral cortex
• input about balance from the vestibular organs of the inner ear

e) the cerebellum integrates this info for coordinating the planning, timing, and patterning of skelatal muscle contractions during movement

f) plays a role in maintaining pasture and in coordination of head and eye movements

4) Midbrain [:276]

a) lies rostral to the pons and is smallest component of the brain stem

b) plays a dominant role in the direct control of eye movement

c) contains essential relay nuclei of the auditory and visual systems

5) Diencephalon (or "between-brain")

A. Thalamus

a) processes and distributes almost all sensory and motor info going to the cerebral cortex

b) is thought to regulate levels of awareness and emotional aspects of sensory experiences through a wide variety of effects on the cortex

B. Hypothalamus

a) lies ventral to the Thalamus

b) regulates the autonomic nervous system

c) regulates hormonal secretion by the pituitary gland

d) has extensive afferent and efferent connections with the Thalamus, the midbrain, and some cortical areas that receive info from the autonomic nervous system

6) <u>Cerebral hemispheres</u>

A) Consists of

a) The cerebral cortex

b) The underlying white matter

c) The basal ganglia

d) The hippocampal formation

e) The amygdala

B) is concerned w/

a) perceptual, cognitive, and higher motor functions

b) emotion

c) memory

<u>The Cerebral Cortex</u> [: 276-277]

The cerebral cortex is the "highly convoluted" surface of the cerebral hemispheres. The surface convolutions consist of sulci (grooves) that separate elevated regions (gyri). Certain sulci are distinctive enough to use as "landmarks" to divide the cortex into 4 lobes.

These are the frontal, parietal, occipital, and temporal lobes.

There are 2 other areas of the cortex that are "comparable" to lobes. These are the insular cortex and the limbic lobe.

The limbic lobe is aka the limbic system.

Below these main divisions, we have a number of definable "regions" (see fig. 19-4, pg 278 of [KELLI]). These include

Primary motor cortex : lies within the precentral syrus in the frontal lobe; contains neurons that project directly to the spinal cord; mediates voluntary movements of the limbs and trunk

Primary sensory areas (visual, auditory, somatic sensory, and gustatory areas) receive info from peripheral receptors w/ only a few synapses interposed.

- Primary visual cortex : located @ the caudal pole of the occipital lobe
- Primary auditory cortex : lies in the temporal lobe and makes up a portion of the lateral sulcus
- Primary somatic sensory cortex : lies on the postcentral gyrus (in the parietal lobe)

Higher-order (secondary and tertiary) sensory and motor areas surround the primary areas; these process complex aspects of a single sensory modality or info related to motor function;

Higher-order sensory areas integrate info coming from their primary sensory cortex

Higher-order motor areas send complex info required for a motor act to the primary motor cortex

The higher-order areas also include a portion of the posterior parietal lobe called the posterior parietal cortex which coordinates somatic sensation and vision, and integrates aspects of these sensory perceptions with movement

There are three association areas lying outside the primary, secondary, and tertiary areas. These areas primarily "integrate diverse information for purposeful action, and they are involved to different degrees in the control of the three major brain functions: perception, movement, and motivation" [KELLI:277]

- Parietal-temporal-occipital association cortex:
  a) occupies the interface between those three lobes
  b) is concerned w/ higher perceptual functions related to somatic sensation, hearing, and vision (which are the primary sensory inputs to these lobes)
  c) info from these different sensory modalities is combined in the association cortex to form complex perceptions

see also chap 5) of [KAND]

- Prefrontal association cortex
  a) occupies most of the rostral part of the frontal lobe
  b) plans voluntary movements

- Limbic association cortex
  a) located on the medial and inferior surfaces of the cerebral hemispheres in portions of the parietal, frontal, and temporal lobes
  b) is primarily devoted to motivation, emotion, and memory

~~The higher order areas connect to the association areas; these, in turn,~~

Schematically, we have the following arrangement [:277]

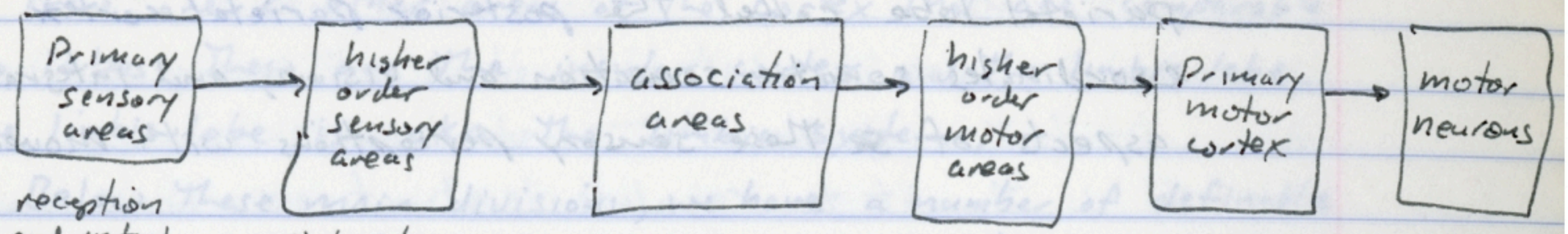

Table 53-1 of [KUPFER 3 : 824] summarizes the anatomical organization as follows

Functional Designation	Lobe	Location in lobe
Primary sensory cortex		
Somatic sensory	Parietal	Postcentral syrus
Visual	occipital	Calcarine fissure
Auditory	Temporal	Heschl's gyrus
Higher-order sensory cortex		
Somatic sensory II	Parietal	Dorsal bank of Silvan fissure
Visual II	occipital	occipital syri
Visual III, IIIa, IV, V	occipital, parietal	Occip. gyri & superior temporal sulcus
Visual Inferotemporal area	Temporal	Anterior and inferior ~~Anter~~ temporal cortex
Posterior parietal cortex	Parietal	Superior parietal lobule
Auditory	Temporal	Superior temporal gyrus
Association cortex		
Parietal-temporal-occipital (Polymodal, sensory, language)	P, T, & O	junction between lobes
Prefrontal (cogn. behavior & motor Planning)	Frontal	rostral portion of dorsal & lateral surface
Limbic (emotion & memory)	T, P, and F	Cingulate and parahippocampal syri, temporal pole, & orbital surface of frontal lobe
Higher-order motor cortex		
Premotor	Frontal	rostral to postcentral syrus
Primary motor cortex	Frontal	precentral syrus

~~Deep Structures~~

Deep-lying Structures of the Cerebral Hemispheres [: 277-279]

A. The basal ganglia
   1) major components are the caudate nucleus, ~~and~~ the putamen (together aka the corpus striatum), and the globus pallidus
   2) The basal ganglia play a role in regulating movement and contribute to cognition
   3) They receive input from all four ~~lobes~~ lobes of the cerebral cortex
   4) Their efferent projections go only to the frontal ~~lobe~~ cortex by way of the thalamus

B. Hippocampus
   1) is part of the limbic system
   2) is involved in memory storage

C. Amygdala
   1) is part of the limbic system
   2) coordinates the actions of the autonomic and endocrine systems
   3) is involved in emotions

D. The limbic system has a direct connection to the hypothalamus, by means of which it modulates the activity of the autonomic nervous system, and coordinates visceral responses (such as blood pressure, heart rate, and pupillary size) with ~~emotional states~~ the motivational state. It also regulates the release of hypothalamic hormones (which lets it exercise a major control over the endocrine system)

The limbic system consists of the hippocampus, amygdala, and the medial portions of the frontal, parietal, and temporal lobes. (note: the medial and inferior surfaces of the cerebral hemispheres, i.e., these portions of the F, P, and T lobes, is called the limbic association cortex)

The limbic lobe (limbic association cortex) forms a continuous band of cortex overlying the rostral brain stem and the diencephalon.

Summarizing,

D. Limbic System

a) consists of
   1) hippocampus (memory storage)
   2) amygdala (emotions; coordination of autonomic nervous system and endocrine system)
   3) limbic association cortex (aka limbic lobe)
      made up of p/o frontal, parietal, & temporal lobes

b) topology
   1) limbic lobe forms a band of cortex overlying the rostral brain stem and the diencephalon
   2) connects directly to the hypothalamus

c) functions
   1) modulates activity of autonomic nervous system
   2) coordinates visceral responses w/ motivational state
   3) regulates release of hypothalamic hormones which control the endocrine system
   4) memory storage
   5) is involved with emotions

Even simple behaviors involve the activity of the sensory, motor and motivational system. The frontal lobe appears to be involved in motivation, as is a portion of the limbic system

Notes from [GHEZI] "The Control of Movements"

The motor control system is likened to a state-variable control system having both feedback and feedforward control. The system is hierarchal w/ 3 levels

1) Spinal cord : automatic and stereotyped reflexes that are independent of the brain as well as descending pathways for voluntary movements; spinal interneurons are responsible for these reflexes and also can produce complex effects in response to descending commands

2) Brain stem : contains 3 neuronal systems that project to and regulate the segmental networks of the spinal cord. The brainstem integrates visual and vestibular info with somatosensory inputs for the control of posture. The brain stem also controls eye and head movements

3) ~~Motor cor~~ Primary motor cortex, premotor cortex, and supplementary motor area (all in the cerebral cortex): Projects directly to the spinal cord and also to the brain stem. The premotor cortex and the supplementary motor area are important in coordinating and planning complex movement sequences; both of these receive input from the posterior parietal and the prefrontal association areas

The motor system is <u>regulated</u> by the cerebellum and the basal ganglia. The cerebellum improves the accuracy of movements (it's a compensator). The basal ganglia receive input from <u>all</u> cortical areas and projects principally to motor planning areas of the frontal cortex. It appears to be involved with voluntary spontaneous movement.

The motor control system is described by Figure 35-3 [GHEZI:539]

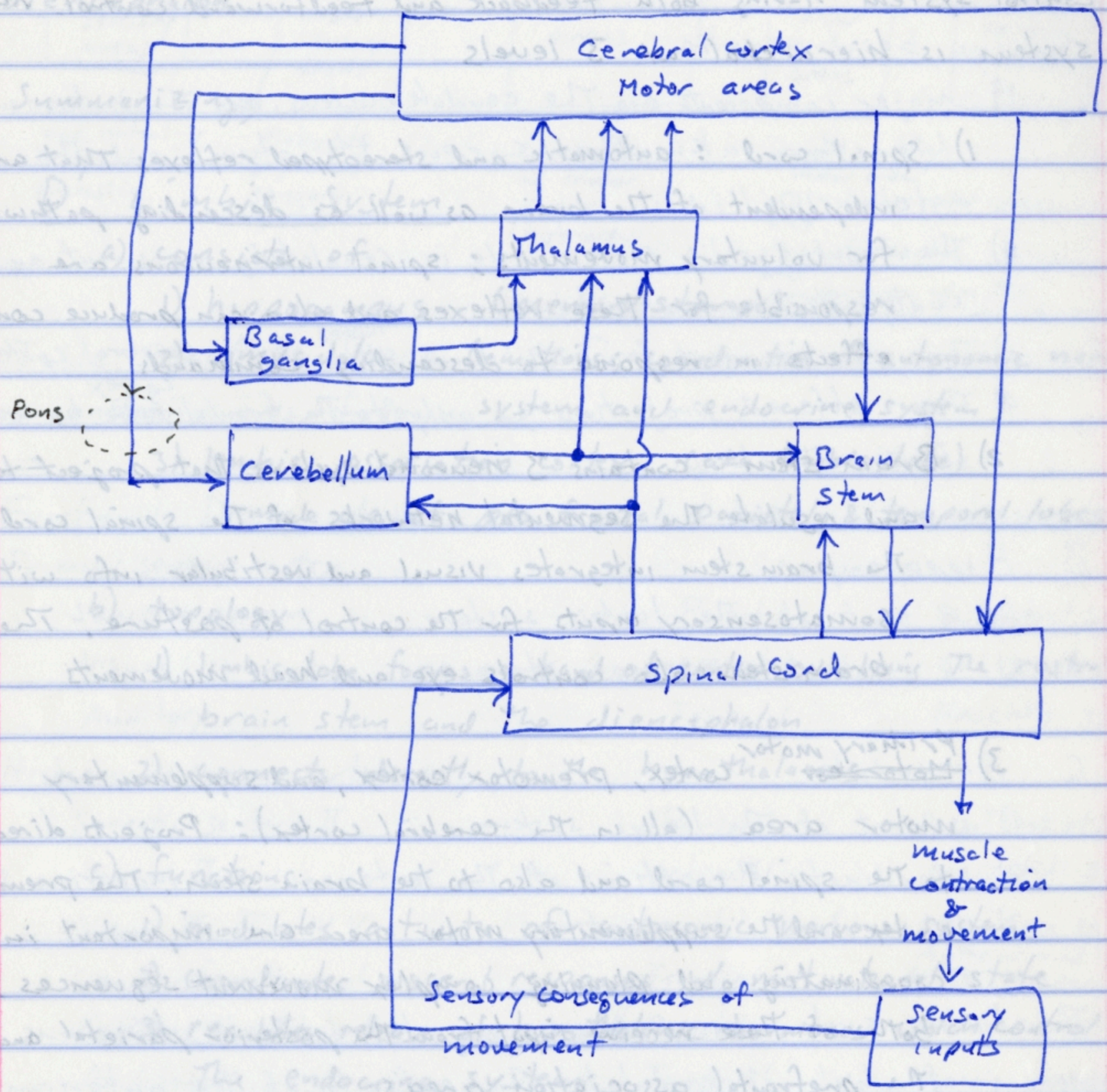

Fig 35-3

One interesting fact is that muscle weakness may result from disturbances (lesions, diseases) in the descending motor pathways or in the spinal motor neurons rather than in the muscles themselves [GHEZI:545]

Notes from [GHEZZ] "Voluntary Movement" :609-625

Ghez's description in this chapter calls upon the anatomical terminology of the 6 layers of the neocortex given in [KELL2 : 292-293]. The 6 layers of the neocortex are :

1) mostly axons running laterally thru the layer and glial cells ; these axons "presumably" interconnect large cortical areas

2) contains mostly small pyramidal cells

3) contains mostly large pyramidal cells
layers 2 and 3 "provide much of the output to other cortical regions"

4) contains ~~mostly~~ a great many nonpyramidal cells and receives most of the afferent input from the thalamus

5) contains the largest pyramidal cells ; these cells have long axons ~~and~~ that leave the cortex and descend to the basal ganglia, brain stem, and the spinal cord

6) contains pyramidal cells that project back to the thalamus

Below layer 6 is the "white matter" which carries axons to and from the cortex. Layer 1 is the "outermost" layer and layer 6 is the "innermost" layer of the cerebral cortex.

Pyramidal cells are projection interneurons that carry output from a cortical area (primarily). Non-pyramidal cells are primarily involved in receiving input to the cortex and in local processing of info. ~~All of the info~~.

All of the above is taken from [KELL2 : 292-293].

The following major points give an overview of the motor system and voluntary movement [GHEZZ : 624]

1) The motor areas are not simply distribution centers for signaling. ~~The fo~~

2) The motor areas have a modular organization. The distribution, interneuronal connections, and the organization of "arrays" of neurons "provides the elements of a fundamental motor vocabulary."

3) The firing of individual cortical neurons encodes movement parameters such as the amount of force or range of force that needs to be developed. This coding is continuously modulated by feedback from the periphery

4) Intention is translated into action in the premotor and parietal association areas. Neurons in these areas ~~are~~ do not encode "fine detail" of movement; rather, they are concerned with "global" actions such as coordination of posture and movements.

At a lower level of detail,

1) The posterior parietal areas integrate the "state" of the animal with that of potential "targets" of movement and are thought to "create a context or ~~framework for~~ frame of reference for directing movements" [:624]

2) lesions in the posterior parietal cortex (in monkeys) produce "severe attentional disturbances, referred to as neglect, of tactile or visual stimuli" [:623]

3) lesions in the primary motor cortex cause weakness [:619]

4) lesions in the premotor area impair the ability to develop an appropriate strategy for movement. For example, the affected strategies described are similar to Stage 4 sensori-motor schemata described by Piaget [:619, but GHEZ doesn't mention Piaget]

5) The supplementary motor area plays an important role in "programming" complex sequences of movements [:619]

6) Cortical activity related to emotion or to different sensori-motor schemata (such as grasping w thumb and finger vs. grasping with all fingers at once) modifies the activation (firing) patterns of neurons in the primary motor cortex [:616]

7) The primary motor cortex participates in the initiation or triggering of movements. The discharge frequency of corticospinal tract neurons encodes the amount of force used to move the limb [:614]

8) The premotor area located within the cingulate gyrus (a part of the limbic system) is important in allowing motivation to directly influence motor planning [:611]

9) Ghez gives a few more details about the "block diagram level" organization of the motor control system [:611-613]. Fig. 40-4 illustrates this (see below)