Contents

1 The Brain and Behavior

1.1 The Brain Has Distinct Functional Regions

The Central Nervous System Has Seven Main Parts

- **Spinal cord**: most caudal part of the central nervous system. It is subdivided into cervical, thoracic, lumbar, and sacral regions.
- **Brain stem**: consists of the medulla oblongata, pons, and midrain. Relays input from the spinal cord and back, and controls input to and from the head.
- **Medulla oblongata**: rostral to spinal cord and includes several centers responsible for vital autonomic functions.
- **Pons**: rostral to medulla and conveys information about movement.
- **Cerebellum**: lies behind pons, modulates force and range of movement, and involved in learning motor skills.
- **Diencephalon**: lies rostral to midrain and contains two structures, thalamus (processes information reaching cerebral cortex) and hypthalamus (regulates autonomic, endocrine, and visceral functions).
- **Cerebrum**: comprises two cerebral hemispheres, each consisting of wrinkled outer layer (the cerebral cortex), and three deep lying structures (basal ganglia, the hippocampus, and the amygdaloid nuclei).
- **Cerebral cortex**: divided into four distinct lobes— frontal, parietal, occipital, and temporal. The frontal lobe is largely concerned with short-term memory and planning, as well as movement; the parietal lobe with somatic sensation, forming a body image, and relating it to extrapersonal space; the occipital lobe with vision; and the temporal lobe with hearing—combined with deeper structures—with learing, memory, and emotion.

2 Nerve Cells, Neural Circuitry, and Behavior

2.1 The Nervous System Has Two Classes of Cells

- There are two main classes of cells in the nervous system: nerve cells, or neurons, and glial cells, or glia.
- A neuron has four defined regions:
  - **Cell body**: or *soma*, is the metabolic center of the cell, containing normal cell organelles.
  - **Dendrites**: branch out in tree-like fashion and are main apparatue for receiving signals.
  - **Axon**: extends some distance from a cell and carries signals to other neurons.
  - **Presynaptic terminals**: specialized enlarged regions of it's axon's branches and is responsible for tranfer of signals.
- **Principle of dynamic polarization**: electrical signals only forlow in one direction in neurons.
- **Connectional specificity**: nerve cells do not connect randomly with one another in these formation of networks.
- Neurons are classified into three groups:
  - **Unipolar**: simpiliest due to single primary process, which gives rise to many branches. One branch as axon and others as receiving structures. These cells predominate invertebrates; they orccur in the autonomic nervous system in vertebrates.
  - **Bipolar**: oval soma that gives rise to two processes: a dendritic structure that receives signals and an axon that carries information towards the central nervous system. Many sensory cells are bipolar, and pain receptors are pseudo-unipolar.
  - **Multipolar**: predominate nervous system of vertebrates and vary greatly in shape; typically containing a single neuron and many dendritic points emerging from various points around the cell body.

- Glial cells support nerve cells and greatly outnumber neurons.
- Glial cells surround the cell bodies, axons, and neurons and can be divided into two major classes:
  - **Microglia**: immune system cells that become phagocytes during injury, infection, or degenerative diseases.
  - There are three main types of **macroglia**: oligodendrocytes, Schwann cells, and astrocytes. About 80% of all brain cells are macrogalia.

3 Genes and Behavior

This chapter has been intentionally left blank, see genetic notes for more information.

4 The Cells of the Nervous System

This chapter was intentionally left blank, see cell biology notes for more information.

5 Ion Channels

5.1 Rapid Signaling in the Nervous System Depends on Ion Channels

- Up to 100 million ions can pass through a single channel each second, comaprable to the turnover rate of the fastest enzymes, catalase and carbonic anhydrase.
- Each channel allows only one or a few types on ions to pass.
- Many open and close, however, some remain open resulting in significant contribution to resting potential.
- Ions pumps maintained gradients and are 100 to 100,000 times slower than channels.
- Questions for this chapter:
    - Why do nerve cells have channels?
    - How can channels conduct ions at such high rates adn still be selective?
    - How are channels gated?
    - How are properties of theses channels modified by various intrinsic and extrinsic conditions?

5.2 Ion Channels are Proteins That Span the Cell Membrane

- Cells have channels in order the transport ions across lipid bilayer easily and eliminate the need to be stripped of waters of hydration.
- The smaller the ion, the greater attraction to water, and the lower its mobility. This partially explains selection, but does how does the inverse selection, that selecting of lower mobility, occur?
- Some ions bind to proteins that can transport them, but this is far to slow for some cases.

- An extension of pore theory says that channels have narrow regions that act as molecular sieves, where the ion sheds most of it's water and only is let through by a binding to a specifically charged selectivity filter.

5.3 Ion Channels in ALl Cells Share Several Characteristics

- The opening and closing of a channel invole conformational changes.
- *Gating*: the transition of a channel between theses stable functional states.
- Three major gating mechanisms:
    - Ligand: binding of chemical ligands known as agonists at either cellular site; transmitters on the extracelluar; others that activate signaling cascades; and more.
    - Voltage-gated: changes in electrochemical changes as often as temperature sensors.
    - Mechanical stretch or physical changes in the membrane.

6 Electrical Properties of the Neuron

This chapter was intentionally left blank. No alternatvie notes, but may need to review chemistry and physics if this chapter is needed.

7 Propagated Signaling

7.1 Personal Notes

- The variety of voltage-sensitive ion channels and the influence of cytoplasmic factors may be analogous to bias/weights or other hyperperamters in neural networks.
- Genetic changes thus change change these networks and may be how transfer learning takes place instead of starting from complete scratch for every organism.
- Innate abilities could represent earlier layers in the network and heavily genetically promgrammed, while later layers are given more time to develop based on environment.
- Can epigenetics have a relatively fast acting change on inherited intelligence?

The rest of this chapter has been left blank, as it is more of an extension of molecular gentics, which I may need to return to later to answer questions like those listed above.

8 Overview of Synaptic Transmission

8.1 Synapses Are Either Electrical or Chemical

- ▷ Average neuron forms and receive several thousand synaptic connections each, with the Purkinje cell of the cerebellum receiving up to 100,000.
- ▷ Both forms of transmission can be enhanced or diminished by cellular activity.
- ▷ Electrial synapses are used to send rapid stereotyped depolarizing signals.
- ▷ Chemical synapses are capable of more complex behaviors due to vairable signaling.
- ▷ Most synapses are chemical.

8.2 Electrical Synapses Provide Instantaneous Signal Transmission

- ▷ Presynaptic terminals must be big enough for its membrane to contain many ion channels to trigger initial depolarization.
- ▷ Postsynaptic terminals must be relatively to small in due to Ohm’s law.
- ▷ Even weak subthreshold depolarizing currents can be carried to the postsynaptic neuron and depolarize it.
- ▷ Electrical synapses have a specialized region of contact called the gap junction, with seperation of only 4 nm, bridged by gap-junction channels specialized to conduct ionic current.
- ▷ Electrical transmission can be used to orchestrate actions or large groups of neurons.
- ▷ Groups of electrically coupled cells allows for explosive reactions.
- ▷ Gap junctions are formed between glial cells as well as neurons.

8.3 Chemical Synapses Can Amplify Signals

- Chemical synapses are used to amplify or inhibit signals.
- The synaptic cleft is 20-40 nm wide and depend on the diffusion of neurotransmitters to carry out signaling.
- Neurotransmitters are clustered at speclizied regions called *active zones*, which allow for selective activate of nearby postsynaptic receptors, which lead to the opening or closing of ion channels.
- Chemical synapses can be as short as 0.3 ms but often last several ms.
- Weak activations of chemical synapses can activate larger electrial synapses.
- The action of a transmitter depends on the properties of the postsynaptic receptor, not the chemical properties of itself.
- Neurotransmitters control the opening of ion channels in the postsynaptic cell either directly or indirectly.
- Indirect effects tend to last seconds to minutes and often modulate behavior due to alterations in the excitability of neurons and their synaptic connections.

9 Directly Gated Transmission

This chapter has been intentionally left blank. Unlikely to return to this chatper.

10 Synaptic Integration in CNS

10.1 Central Neurons Receive Excitatory and Inhibitory Inputs

- Generation of an action potential often requires the near-synchronous firing of a number of sensor neurons.
- Small inhibitory postsynaptic potential (ISPS), if strong enough, can counteract the sum of the excitatory actions and prevent membrane potential from reaching threshold potential.
- **Sculpting** function of synaptic inhibition that exerts control over action potentials in neurons that are spontaneously active due to intrinsic pacemaker channels, often completely shaping the firing patterns of cells.
- Most transmitters usually are inhibitory or excitatory despite being able to be either type.

10.2 Inhibitory Synaptic Action

- Inhibitory synapses play an essential role in the nervous system both by preventing too much excitation and by helping coordinate activity among networks of neurons.
- Inhibitory inputs that hyperpolarize the cell perform subtraction on the excitatory inputs, where those that *shunt* perform division.
- Adding or removing nonshunting inhibitory inputs results in summation, while the combination or excitatory with the removal of inhibitory shunt produces a multiplication.

11 Second Messengers

This chapter has been intentionally left blank. Molecular focused chapters may be reviewed later when a more narrow question needs to be ansewered.

12 Transmitter Release

This chapter has been intentionally left blank. More on the chemistry and molecular function of transmission. Such information May answer questions in the future, but it's not the focus of inquiry at the moment.

13 Neurotransmitters

13.1 Four Criteria of a Neurotransmitter

- ▷ Four steps of synaptic transmission:
  1. Synthesis and storage of a transmitter.
  2. Release of the transmitter.
  3. Interaction of the transmitter with receptors and postsynaptic membrane.
  4. removal of the tranmitter from the synaptic cleft.
- ▷ First approximation of a neurotransmitter can be defined as a substance released by a neuron that affects a specific target in a specific manner.
- ▷ Neurotransmitters typically act on targets other thanthe releasing neuron itself, unlike autacoids.
- ▷ Neurotransmitter interaction with receptors is typically transient, lasting from milliseconds to minutes.
- ▷ General criteria for neurotransmitters:
  - It is synthesized in the presynaptic neuron.
  - It is present in the presynaptic terminal and is released in amounts sufficient to exert a defined action on the postsynaptic neuron or effector organ.
  - When administered exogenously in a reasonable concentrations it mimics the action of the endogenous transmitter.
  - A specific mechanism usually exists for removing the substance from the synaptic cleft.

13.2 Only a Few Small-Molecule Substances Act as Transmitters

- ▷ **Acetylcholine (ACh)**:

- Only low weight amine transmitter substance that is not an amino acid or derived directly from one.
- Nervous tissue cannot synthesize choline, which limits ACh biosynthesis due to choline acetyltransferase being the only enzymatic reaction.
- ACh is released by spinal motor neurons.
- In the autacoids nervous system it is the transmitter for all preganglionic neurons and for parasympathetic postganglionic neurons as well.
- ACh is the principle neurotransmitter of the reticular activating system, which modulates arousal, sleep, wakefulness, and other critical aspects of human consciousness.

▷ **Biogenic Amines**:

- **Catecholamine Transmitters**:
  - **Dopamine** — Tyrosine
  - **Norepinephrine** — Tyrosine
  - **Epinephrine** — Tyrosine
  - Tyrosine hydroxylase is the rate-limiting for synthesis of bothdopamine and norepinephrine.
  - β-hydroxylase converts dopamine to norepinephrine and is membrane-associated.
  - Norepinephrine is the only transmitter synthesized within vesicles.
  - In order for epinephrine to be formed, then its immediate precursor, norepinephrine, must exit from vesicles into the cytoplasm.
  - In order to be released, epinephrine must be taken up into vesicles.
  - Three of four dopaminergic nerve tracts arise in the midrain, with the last arising in the arcuate nucleus of the hypothalamus.

    - Synthesis of biogenic amines is highly regulated and ca be rapidly increased.
  - **Serotonin** — Tryptophan
  - **Melatonin** — Serotonin
    - Typtophan hydroxylase is the limiting reaction and the first enzyme in the pathway.
    - Cell bodies with serotonergic neurons are found around the midline raphe nuclei of the brain stem and are involved in regulating attention.
    - Productions of serotonergic cells are widely distrubted throughout the brain and spinal cord.
    - Antidepressant mediacation inhibit the uptake of serotonin, norepinephrine, and dopamine.
  - **Histamine** — Histidine
    - Long been recognized as a autacoid, active when released from mast calls in the inflammatory reaction.
    - Concentrated in the hypothalamus.
- **Amino Acid Transmitters**:
  - **Apartate** — Oxaloacetate
  - **γ-Aminobutyric acid (GABA)** — Glutamine:
    - Presnet at high concentrations thoughout the central nervous system and detectable in other tissues.
  - **Glutamate** — Glutamine:
    - Most frequently used at excitatory synapses throughout the central nervous system.
  - **Glycine** — Serine:
    - Major transmitter used by inhibitory interneurons of the spinal cord.
- **ATP and Adenosine**

- Can act as transmitters at some synapses.
- Adenosine has an inhibitory effect in the central nervous system.
- Caffeine's stimulatory effect depends on inhibition of adenosine binding to its receptors.
- ATP released by tissue damage acts to transmit pain sensation in some cases.

13.3 Small-Molecule Transmitters Are Actively Taken up into Vesicles

- *Tranmitter* glutamate must be kept separate from *metabolic* glutamate; this is done through compartmentalization in synaptic vesicles.
- Drugs that are sufficiently similar to the normal transmitter substance can act as false transmitters, tho they often bind weakly decreasing efficacy of of transmission.

13.4 Removal of Transmitter from the Synaptic Cleft Terminates Synaptic Transimission

- If transmitter molecules released in one synaptic action were allowed to remain in the cleft after release, then they would prevent ner signlas from getting through, the synapse would become refractory due to desensitization.
- Transmitters are removed by three mechanisms: diffusion, enzymatic degradation, and reuptake.
- Degradation is only used by cholinergic synapses.
- Degradation allows for single use signaling and for the lingering choline to be reused.

14 Diseases of the Nerve and Motor Unit

This chapter has been intentionally left blank. Might revisit, reading comprehension was low.

15 Organization of the Central Nervous System

15.1 The Central Nervous System Consists of the Spinal Cord and the Brain

- The spinal cord is divided into a core of central gray matter and surrounding white matter.
- The gray matter is divied into *dorsal* and *ventral* horns.
- *Dorsal horn*: contains orderly sensory relay neurons that receive input from periphery.
- *Ventral horn*: contains group of motor neurons and interneurons that regulate motor neural firing patterns.
- The brain stem(*Medulla, pons, and midbrain*) has five distinct functions:
  1. Spinal cord mediate sensation and motor control of trunk and limbs, but the brain stem control the head, neck and face.
  2. Site of entry for information from several specialized sites such as hearing, balance, and taste.
  3. Mediation of parasympathetic reflexes, such out cardiac output, pupil constriction, and more.
  4. Contains ascending and descending pathways that carry sensory and motor information to other parts of the CNS.
  5. Contains the *reticular formation*, which receives a summary of incoming sensory information and regulates alertness and arousal.

15.2 The Major Functional Systems Are Similarly Organized

- The central nervous system consists of several functional systems that are relatively autonomous and much work together using numerous interconnected anatomical sites throughout the brain.
- Information is transformed at each synaptic relay, with the output rarely being the same as the input.

- ▷ Neurons at each synaptic relay are organized into a neural map of the body.
- ▷ Most sensory systems inputs are arranged topographically through out successive stages of processing.
- ▷ Each functional system is hierarchically organized.
- ▷ *Decussations*: crossing of second order fiber from the brain stem and the spinal cord.

15.3 The Cerebral Cortex is Concerned with Cognition

- ▷ Increasing the surface area due to sulci and gyri allow for greater number of cortical neurons which provide a greater capacity for information processing.
- ▷ Neurons in the cerebral cortex are organized in layers and columns which helps computational efficiency.
- ▷ The neocortex receives inputs from the thalamus, other cortical regions on both sides of the brain, and other structures then output to other various regions.
- ▷ The input-output relation is organized into orderly layering of cortical neurons, with most containing six layers.
    - ○ Layer I: the *molecular layer*, is occupied by dendrites of cells located in deeper layers and axons that make connections to other areas of the cortex.
    - ○ Layer II: the *external granule cell layer*, one of two layers that contain small spherical neurons.
    - ○ Layer III: the *external pyramidal cell layer*, second layer of small spherical neurons, typically larger that layer II.
    - ○ Layer IV: the *internal granule cell layer*, contains much larger number of spherical neurons and is main recipient of sensory input from the thalamus.
    - ○ Layer V: the *internal pyramidal cell layer*, contains pyramidal neurons

that are also larger than it's external layer. Theses neurons give rise to major output pathways of the cortex.

- Layer VI: the *multiform layer*, a blend neurons into white matter that forms the deep limit of the cortex and carries axons to and from areas of the cortex.

- Thickness of the layers vary throughout the cortex.
- The cerebral cortex has a large variety of neurons, more than 40 different types based only on the distribution of their dentrites and axons.
- Most neurons are either principal (projection) neurons or local interneurons.

15.4 Subcortical Regions of the Brain are Functionally Organized into Nuclei

- Three major structures lie deep within the cerebral hemisphere: the basal ganglia, the hippocampal foramtion, the amygdala, and the basal ganglia. These subcortical structures act to regulate the cortical activity.
- Basal ganglia regulates movement and certain cognitive functions such as learning of motor skills.
- THe basal ganglia has five major functional subcomponents: the caudate nucleus, putamen, globus pallidus, subthalamic nucleus, and substantia nigra.
- The hippocampal formation includes the hippocampus, dentate gyrus, and subiculum. Together theses structures are responsible for the formation of long-term memories episodic memories, but not responsible for storage.
- The amygdala is involved in analying the emotional significance of sensory stimuli.

15.5 Modulatory Systems in the Brain Influence Motivation, Emotion, and Memory

- Some brain areas are neither sensory nor motor, but instead modify specific functions.
- Distinct modulatory systems within the brain stem modulate attention and arousal.

15.6 The Peripheral Nervous System is Anatomically Distinct from the Central Nervous System

- The peripheral nervous system supplies the central nervous system with a continuous stream of information about both externala and internal environments. It is split into two divisions.
- The *somotic division* includes the sensory neurons that receive information from skin, muscles, and joints and provide information about position and pressure.
- The *autonomic division* mediates visceral sensation as well as motor control of the viscera, vascular, and exocrine glands. It consists of sympathetic (response to stress), parasympathetic (restores homeostasis), and enteric (controls smooth muscle of the gut) systems.

16 Organization of Perception and Movement

16.1 Sensory Information Processing is Illustrated in the Somatosensory System

- ▷ Complex behaviors require the integrated action of several nuclei and cortical regions, processed in a hierarchical fashion, and becomes increasingly complex.
- ▷ Complex processing results in a light touch or painful prick in the skin being mediated by often very different pathways.
- ▷ Somatosensory information from the trunk and limbs is conveyed to the spinal cord.
- ▷ The spinal cord is divied into four major regions: cervical, thoracic, lumbar, and sacral.
- ▷ Spinal nevres at the cervical level are involved with sensory perceptions and motor function of the back of the head, neck, and arms.
- ▷ Thoracic nerves innervate the upper trunk.
- ▷ Lumbar and sacral nevres innervate the lower trunk, back, and legs.
- ▷ Each of the four regions of the spinal cord contains several segments, depsite the lack of appearance of segmentation of mature spinal cords.
- ▷ The spinal cord varies in size and shape due to two organizational features.
- ▷ First, the relatively few sensory axons enter the cord at the sacral level, with number of entering axons increasing progressively at higher levels.
- ▷ Most descending axons from the brain terminate at cervical levels.
- ▷ Second, the variation in the size of the ventral and dorsal hons.
- ▷ The number of ventral motor neurons dedicated to the body region roughly parallels the dexterity of movements of that region.
- ▷ *lumbosaral* and *cervical enlargements*: regions of the spinal cord where fibers enter the cord due demends of sensory neurons for finer tactile discrimination in limbs.

- The primary sensory neurons of the trunk and limbs are clustered in the dorsal root ganglia. These neurons are pseudo-unipolar in shape and have bifurcated axon with central and peripheral branches.
- Local branches activate local reflex circuits while ascending branches carrying information to the brian that give rise the perception.
- The central axons of dorsal root ganglion neurons are arranged to produce a map of the body surface.
- Each somatic submodality if processed in a distinct subsystem from the periphery to the brain.

16.2 The Thalamus is an Essential Link Between Sensory Receptors and the Cerebral Cortex for All Modalities Except Olfaction

- The thalamus conveys sensory input to the primary sensory areas of the cerebral cortex and additionally acts as a gatekeeper depending of behavioral state of the animal.
- The thalamus is a good example of a brain region made up of several well-defined nuclei.
- Some nuclei receive information specific to a sensory modality and projet to a specific area of the neocortex.
- The nuclei of the thalamus are most commonly classified into four groups:
  - *anterior group*: recvies most input form the mammillary nuclei of the hypothalamus and presubiculum of the hippocampal formation. The role of this region is uncertain, but thought to be related to memory and emotion.
  - *Medial group*: consists mostly of the mediodorsal nucleus. It receives input from the basal ganglia, amygdala, and midrain and is been implicated in memory.
  - *ventral group*: important for motor control and carry information from basal ganglia and cerebellum to the motor cortex.

- *posterior group*: includes the medial and lateral geniculate nucleus (component of auditory system), lateral posterior nucleus (componenet of the retina and visual cortex in the occipital lobe), and the pulmonary(involved in the parietal-occipital-temporal cortex).

▷ *Reticular nucleus*: a unique sheet-like structure covering the thalamus.

▷ Neurons ot the reticular nucleus are not interconnected with the neocortex, instead the axons terminate on the other nuclei of the thalamus.

▷ Thus, the reticular nucleus modulates activity in other thalamic nuclei based on its moitoring of the entirety of the thalamocortical stream.

▷ The thalamus not only relays information but is a crucial step and adds substantial degree of information processing.

16.3 Sensory Information Processing Culminates in the Cerebral Cortex

▷ Parts of the body are represented in the cortex somatotopically, but the area of the cortex is not proportional to it mass. Instad, it proportional t the density of innervation.

▷ The cortical areas involved in the early stages of sensory processing are concerned primarily with a single modality.

▷ Unimodal association areas converge on multimodal association areas of the cortex concerned with combining sensory modalities.

▷ Multimodal associational areas are heavily interconnected with the hippocampus and appear to be important for unified percept and representation of the percept in memory.

▷ There is a close linkage between the somatosensory and motor functions of the cortex.

16.4 Voluntary Movement is Mediated by Direct Connections Between the Cortex and Spinal Cord

- ▷ The human corticospinal tract consists of approximately one million axons, with 40% originating from the motor cortex.
- ▷ Most of the corticospinal fibers cross the midline in the medulla at a location known as the pyramidal decussation.
- ▷ 10% of those fibers do not cross until they reach the local where they terminate.
- ▷ THe motor information carried in the corticospinal tract is significantly modulated by the sensory information and information from other motor regions.
- ▷ The cerebellum is thought to be part of an error-correcting mechanism for movements because it can compare movement commands from the cortex with somatic sensory information about what actually happened.

17 Representation of Space and Action

17.1 The Brain has an Orderly Representation of Personal Space

- ▷ Internal representation can be thought of as a certain pattern of neural activity that has at least two aspects:
  - The pattern of activation within a particular population of neurons.
  - the pattern of firing in individual cells.
- ▷ The cortex has a map of the sensory receptive surface for each sensory modality.
- ▷ Cortical maps of the body are the basis of accurate clinical neurological examinations.
- ▷ The is a direct relationship between the anatomical organization of the functionalpathwaysin the brain and specific perceptual and motor behaviors.

17.2 The Internal Representation of Personal Space can be Modified by Experience

- ▷ Details of sensory maps vary considerably from one individual to another.
- ▷ Lost connections can be taken over by existing nearby connections.

17.3 Is Consciousness Accessible to Neurobiological Analysis?

- ▷ John Searle and Thomas Nagel have defined three essential features of self-awareness:
  - Subjectivity, or the awareness of a self that is the center of experience.
  - Unity, or the fact that our experience of the world at any given moment is felt as a single unified experience.

  - Intentionality, or the the experience that connets successive moments and the sense that the successive moments are directed to some goal.

- Crick and Koch argue that our efforts should be focused on visual perceptionand in particular on two phenomena: binocular rivalry and selective attention.

- Sensory input alone does not give rise to consciousness; higher-level interpretation of that input is needed.

18 Organization of Cognition

18.1 Functionally Related Areas of Cortex Lie Close Together

- ▷ The cortex of each cerebral hemisphere is a continuous sheet of gray matter.
- ▷ At the coarsest level, it consists of five lobes, with each lobe further subdivided.
- ▷ Functional areas are distinguished by cellular structure, connectivity, and the physiological response properties of neurons.
- ▷ Precepts that govern the organization of functional areas in the macaque (old world monkey) cerebral cortex:
    1. All areas fall into a few major functional groups.
    2. Areas in a given category occupy a discrete, continuous portion of the cortical sheet.
    3. Functionally related areas occupy neighboring sites.

18.2 Sensory Information is Processed in the Cortex in Serial Pathways

- ▷ Cortical areas communicate with each other through bundles of axons traveling together in identifiable tracts.
- ▷ *Primary sensory areas* posses four properties characteristic of their role in the early stages of information processing:
    - Inputs from thalamic sensory relay nuclei.
    - Neurons in a primary sensory area have small receptive fields adn are arranged to form a precise somatotopic map of the sensory receptor surface.
    - Injury to a part of the map causes a simple sensory loss confined to the corresponding part of the contralateral sensory receptor surface.

    - Connections to other cortical areas are limited, mostly to nearby areas that process information in the same modality.

- Higher-order sensory areas have a different set of properties important to their role in the later stages of information processing:
    - Inputs arise from other thalamic nuclei and lower-order areas of sensory cortex instead of sensory relay nuclei.
    - Large receptive fields and imprecise maps of the array of receptors in the periphery.
    - Injury results in abnormalities of perception, but does not impair ability to detect sensory stimuli.
    - Connected to distant areas in the frontal and limbid nodes as well as nearby unimodal areas.
- Sensory information is processed serially, but not exclusively; higher-order areas project back to lower-order areas which can modulate the activity of neurons in lower-order areas.
- **Association cortex**: regions of the cortex where injury causes cognitive deficits that cannot be explained by impairment of sensory or motor function alone.
- Large regions of association cortex are contained within each of the four lobes:
    - *parietal*: critical for sensory guidance of motor behavior and spatial awareness.
    - *temporal*: recognition of sensory stimuli and for storage of semantic (factual) knowledge.
    - *frontal*: key role in organizing behavior in working memory.
    - *limbic*: complex functions related to emotion and episodic (autobiographical) memory.
- Association areas have much more extensive input and output connections than do lower-order sensory and motor areas.

- All association lobes are densley interconnected network of pathways.

18.3 Goal-Directed Motor Behavior Is Controlled in the Frontal Lobe

- All areas of th frontal lobe participate in the control of motor behavior and are connected in a series of functional hierarchy.
- Neuronal activity in the premotor cortex, adjacent to the primary motor cortex, reflect global aspects of motor behavior.
- Dorsolateral prefrontal cortex contributes to cognitive control of behavior.
- The orbital-ventromedial prefrontal corftex, connected to the dorsolateral prefrontal cortex (then premotor), is involved with emotional processes associated with executive control of behavior.
- Information flows from higher-order areas in the frontal lobe to primary order cortex, contrasting sensory's periphery first flow.
- Prefrontal cortex is important for the executive control of behavior.
- The orbital-ventromedial prefrontal cortex is linked strongly to the hypothalamus and amygdala, receives input from every sensory system, and projects to the dorsolateral prefrontal cortex.
- Thus, the above pathway allows for response to emotional and sensory inputs and allows the trigger of appropriate behavior.

18.4 Limbic Association Cortex is a Gateway to the Hippocampal Memory System

- The limbic (limbus—edge) association cortex forms a ring that is visible in the medial view of the hemispher.
- Previously it was thought to make up an entire system in combinations with other areas, but some divisions of the limbic lobe have other functions, with some not yet well understood.