General Design of Nervous System:

**Processing = Integrative System**

- 99% of sensory information discarded
- Synapses determine pathway of signals
- Memory: Highly facilitated synaptic pathways (sensory input not required to excite pathway)

**Output = Motor System**

- Skeletal muscle
- Smooth muscle
- Glandular secretion

**Analogy = Computer**

- Input = Sensory System
- Processing = Integrative System
- Output = Motor System
- Receptors: Tactile, Visual, Auditory, Olfactory
- Memory: Information stored for future use

Organization of Nervous System:

- Nervous system
  - Central nervous system (CNS)
    - Brain
    - Spinal cord
  - Peripheral nervous system (PNS)
    - Motor division (efferent)
    - Sensory division (afferent)

- Autonomic nervous system
  - Sympathetic division
  - Parasympathetic division

- Somatic nervous system
  - Voluntary: skeletal muscle
  - Involuntary: smooth & cardiac muscle

Histology of Nervous System:

A. **Neuroglia** (supporting cells - "nerve glue")

- Astrocytes: Anchor neurons to capillaries; repair damaged neural tissue; maintain "blood / brain barrier"
- Microglia: Macrophages; engulf invaders; line canals / ventricles of brain
- Oligodendrocytes: Insulate neurons (myelin sheath); produce cerebrospinal fluid (CSF)
- Ependymal cells: Function similar to astrocytes
- Schwann cells: Insulate neurons (myelin sheath); produce myelin sheath

B. **Neurons**

- Long-lived (~ 100 years)
- High metabolic rate
- Specialized "excitable" cells
- Allow for communication throughout body (via electrical impulses)

Neuron Anatomy:

1. **Dendrites**: Receive information (environment / other neurons)
2. **Cell body ( soma)**: Integrates information / initiates response
3. **Axon**: Conducts action potential (AP – electrical impulse)
4. **Synaptic terminals**: Transmit signal (other neurons / effector organs)

- Axon hillock (AP generation)
- Cell body

Functional Classification of Neurons:

1. **Sensory (Afferent) neurons**: Carry information from sensory receptors to CNS
2. **Motor (Efferent) neurons**: Carry information from CNS to effector organs
3. **Association neurons (Interneurons)**: Interconnects neurons in brain / spinal cord
### Structural Classification of Neurons (# of processes):

- **Sensory neurons** (e.g., special sense organs)
- **Motor neurons**
- **Interneurons**

#### Multipolar (# ≥ 3 processes)
- Axon
- Dendrites
- Trigger zone

#### Bipolar (2 processes)
- Axon
- Dendrites
- Trigger zone

#### Unipolar (1 process)
- Axon
- Dendrites
- Trigger zone

- Specialized “excitable” cells
- Allow for communication throughout body (via electrical impulses)

### Fundamentals of Nervous System

#### B. Neurons
- Long-lived (~100 years)
- High metabolic rate

### Gross Anatomy:
- Brain: 
  - ~3.5 lbs (35 billion neurons)
  - ♂ brain ~10% larger than ♀ brain
- No correlation exists between brain size and intelligence...

### Organization of Nervous System:

- Nervous system
- Peripheral nervous system (PNS)
- Integration
- Motor division (afferent)
- Sensory division (efferent)

- Autonomic nervous system
  - Somatic nervous system (voluntary; skeletal muscle)
  - Sympathetic division
  - Parasympathetic division

- Brainstem 
- Cerebellum

### Central Nervous System

#### Embryonic Development of Brain:

- 3 week old embryo
  - Neural plate forms from surface ectoderm
- 4 week old embryo
  - Neural tube forms neural groove
- 5 week old embryo
  - Neural tube becomes neural tube; sinks deep

#### Embryonic Development of Brain: (Marieb & Hoehn — Figure 12.1)

#### Organization of Nervous System: (Marieb & Hoehn — Figure 12.2)
Embryonic Development of Brain: Central Nervous System

Space restriction greatly affects brain development

- Flexures develop to fit rapidly growing brain into membranous skull
- Convolutions develop to increase surface area of brain

5 week old embryo

• Cerebrum
• Diencephalon
• Brain stem (midbrain)
• Brain stem (pons)
• Brain stem (medulla)
• Cerebellum

13 week old embryo

• Cerebrum forced to grow posterior and lateral (‘horseshoe’)

26 week old embryo

• Convolutions develop to increase surface area of brain

Newborn

Marieb & Hoehn – Figure 12.3

Basic Layout of Neurons:

White matter: Regions of myelinated axons in CNS
Gray matter: Regions of unmyelinated axons / cell bodies in CNS

Brain Anatomy: Cerebrum (cerebral hemispheres):

- 85% of brain mass

Marieb & Hoehn – Figure 12.6

Brain Anatomy:

A. Ventricles: Hollow chambers enclosed within brain (continuous with each other…)

- Cerebrospinal fluid (CSF)
  - Provide constant, controlled environment for brain cells
  - Protect brain from toxins
  - Prevent escape of local neurotransmitters

- Choroid plexus:
  - Vascular network; produces CSF
  - Similar ion composition to blood plasma
  - ↓ protein content
  - 0.5 L / day produced

- Gasses cross freely
- Lumbar puncture (spinal tap)

Marieb & Hoehn – Figure 12.5

CSF Circulation:

1) CSF produced by choroid plexus in ventricles
2) CSF flows through ventricles and into subarachnoid space via lateral and median apertures
3) CSF exits subarachnoid space via arachnoid villi

Hydrocephalus: (water on the brain)

Marieb & Hoehn – Figure 12.26

Brain Anatomy: Cerebrum (forebrain)

Marieb & Hoehn – Figure 12.9
**Brain Anatomy:**

**B. Cerebrum (cerebral hemispheres):**

1) **Cerebral cortex:**
   - Contains 3 types of functional areas:
     1. Motor areas (send output)
     2. Sensory areas (receive input)
     3. Association areas (interpret data)

2) **Cerebral white matter**

3) **Basal nuclei**

**Corpus callosum:**
White tract connecting cerebral hemispheres

**Basic regions:**
- Cerebral cortex (gray matter)
- Basal nuclei

**Functional MRI scan**
Measure blood flow

**Neural cartography**
Electrostimulation

**Central Nervous System**

**B. Cerebrum (cerebral hemispheres):**

**Brain Anatomy:**

1) **Cerebral cortex:**
   - Motor areas:
     - Primary motor cortex
       - Conscious control of skeletal muscle movements
     - Premotor cortex
       - Controls learned motor skills of repetitive or patterned nature (e.g., typing)
     - Broca's area
       - Controls muscles involved in speech production (often more pronounced in one hemisphere of brain)

2) **Premotor cortex**
   - Communicates directly with primary motor cortex

3) **Sensory areas:**
   - Primary somatosensory cortex
     - Receives information from sensory receptors in skin & proprioceptors in joints
   - gustatory cortex
   - Auditory association area
   - olfactory cortex
   - spatial discrimination
   - somatosensory association cortex
   - visual association area

4) **Olfactory cortex**
   - Receives olfactory information

**Frontal eye field**
- Controls voluntary movement of eyes

**Somatosensory association cortex**
- Integrates / interprets sensory inputs (e.g., visual / auditory)

**Olfactory cortex**
- Receives chemical information

**Primary auditory cortex**
- Receives auditory information (tonotopic mapping)

**Primary visual cortex**
- Receives visual information (retinotopic mapping)

**Auditory Association area**
- Integrates / interprets auditory inputs (e.g., music / speech)

**Visual Association area**
- Integrates / interprets visual inputs (e.g., color / form)

**Marieb & Hoehn – Figure 12.8**

**Note:**
- One-to-one correspondence between cortical neurons and muscles misleading; map really "fuzzy"

**Homunculus ("little man"):**

- Communicates directly with primary motor cortex (often more pronounced in one hemisphere of brain)

**Marieb & Hoehn – Figure 12.9**

**Corpus callosum:**
White tract connecting cerebral hemispheres

**Cerebral cortex:**
- Only 2-4 mm thick but comprises 40% of the brain's mass
- 2.5 ft² of surface area

**Functional MRI scan**
Measure blood flow

**Neural cartography**
Electrostimulation

**Central Nervous System**

**B. Cerebrum (cerebral hemispheres):**

**Brain Anatomy:**

- Motor areas:
  - Homunculus ("little man")

- Sensory areas:
  - Primary somatosensory cortex
    - Receives information from sensory receptors in skin & proprioceptors in joints
  - Gustatory cortex
  - Auditory association area
  - Olfactory cortex
  - spatial discrimination
  - Somatosensory association cortex
  - Visual association area

- Association areas:
  - Premotor cortex
  - Broca's area

- Cortical neurons and muscles misleading; map really "fuzzy"

**Pyramidal cells extend long axons to the spinal cord, forming pyramidal tracts, or corticospinal tracts**

**Somatotopic mapping:**
The entire body is spatially represented in the cerebral cortex

**Marieb & Hoehn – Figure 12.8**

**Primary motor cortex**
- Conscious control of skeletal muscle movements

**Premotor cortex**
- Controls learned motor skills of repetitive or patterned nature (e.g., typing)

**Marieb & Hoehn – Figure 12.9**

**Corpus callosum:**
White tract connecting cerebral hemispheres

**Cerebral cortex:**
- The cerebral cortex is the seat of conscious behavior
- Only 2-4 mm thick but comprises 40% of the brain's mass
- 2.5 ft² of surface area

**Central Nervous System**

**B. Cerebrum (cerebral hemispheres):**

**Brain Anatomy:**

1) **Cerebrum** (cerebral hemispheres)

- **Cerebral cortex**
  - The seat of conscious behavior
  - Only 2-4 mm thick but comprises 40% of the brain's mass
  - 2.5 ft² of surface area

- Contains 3 types of functional areas:
  1. Motor areas (send output)
  2. Sensory areas (receive input)
  3. Association areas (interpret data)

- Functional MRI scan
  - Measure blood flow

- Neural cartography
  - Electrostimulation

**Central Nervous System**

**B. Cerebrum (cerebral hemispheres):**

**Brain Anatomy:**

- Motor areas:
  - Primary motor cortex
    - Conscious control of skeletal muscle movements
  - Premotor cortex
    - Controls learned motor skills of repetitive or patterned nature (e.g., typing)
  - Broca's area
    - Controls muscles involved in speech production

- Sensory areas:
  - Primary somatosensory cortex
    - Receives information from sensory receptors in skin & proprioceptors in joints
  - Gustatory cortex
  - Auditory association area
  - Olfactory cortex
  - spatial discrimination
  - Somatosensory association cortex
  - Visual association area

- Association areas:
  - Premotor cortex
  - Broca's area

- Cortical neurons and muscles misleading; map really "fuzzy"

**Pyramidal cells extend long axons to the spinal cord, forming pyramidal tracts, or corticospinal tracts**

**Somatotopic mapping:**
The entire body is spatially represented in the cerebral cortex

**Marieb & Hoehn – Figure 12.8**

**Primary motor cortex**
- Conscious control of skeletal muscle movements

**Premotor cortex**
- Controls learned motor skills of repetitive or patterned nature (e.g., typing)

**Broca's area**
- Controls muscles involved in speech production

**Primary auditory cortex**
- Receives auditory information (tonotopic mapping)

**Primary visual cortex**
- Receives visual information (retinotopic mapping)

**Auditory Association area**
- Integrates / interprets auditory inputs (e.g., music / speech)

**Olfactory cortex**
- Receives olfactory information

**Primary somatosensory cortex**
- Receives information from sensory receptors in skin & proprioceptors in joints

**Marieb & Hoehn – Figure 12.9**

**Note:**
- One-to-one correspondence between cortical neurons and muscles misleading; map really "fuzzy"
Locations where sensations, thoughts, and emotions become conscious (makes us who we are...)

Anterior association area
- Intelligence
- Complex learning
- Recall
- Personality

Central Nervous System
1) Cerebral cortex:
   B. Cerebrum (cerebral hemispheres):
   - Association areas (multimodal):
     - Pattern recognition
     - Spatial recognition
     - Sensory grouping
     - Language centers (Wernicke's area)

Posterior association area
- Processes emotions related to personal/social interactions

Limbic association area
- Processes emotions related to personal/social interactions

Brain Anatomy:
B. Cerebrum (cerebral hemispheres):
- Association areas (multimodal):

The cerebral cortex is the seat of conscious behavior
- Contains 3 types of functional areas
- Contralateral control (e.g., left hemisphere controls right body)
- Occur at different locations in CNS
- Lateralization (i.e., hemisphere specialization)

The American Crowbar Case
Phineus Gage (1823 – 1860)
Franz Gall (1758 – 1828)
Phrenology:
The brain is the organ of the mind; contains localized, specific modules

Categorical
Representational
Basic regions:
1) Cerebral cortex (gray matter)
2) Cerebral white matter
3) Basal nuclei
Brain Anatomy:

B. Cerebrum (cerebral hemispheres):

2) Cerebral white matter:
   - Fiber tracts responsible for communication between cerebral areas and lower CNS
   - A) Commissural Fibers (form commissures):
     - Interconnect cerebral hemispheres
   - B) Association Fibers:
     - Interconnect areas of neural cortex within a single hemisphere
   - C) Projection Fibers:
     - Interconnect cerebral hemispheres with other regions of the brain

Corresponding diagrams illustrate these fiber tracts.

Brain Anatomy:

B. Cerebrum (cerebral hemispheres):

3) Basal nuclei:
   - Composed of gray matter (neuron cell bodies)
   - Function:
     1) Subconscious control of skeletal muscle tone
     2) Control stereotypical motor movements (e.g., arm swing)
     - Regulate intensity / inhibit unnecessary movements

Corresponding diagrams illustrate the basal nuclei.

Brain Anatomy:

C. Diencephalon:

Thalamus:
- Composes 80% of diencephalon
- Relay station for all information entering/exiting the cerebral cortex

Hypothalamus:
- Autonomic control center
- Center for emotional response
- Body temperature regulation
- Regulation of food/water intake
- Regulation of sleep-wake cycles
- Control of endocrine system

Epithalamus:
- Houses pineal gland (melatonin) and choroid plexus (forms CSF)

Corresponding diagrams illustrate the diencephalon structures.

Brain Anatomy:

Limbic system (functional brain system):

“Emotional brain”
- Thalamus (anterior thalamic nuclei)
- Hypothalamus
- Cingulate gyrus
- Parahippocampal gyrus
- Hippocampus
- Amygdala

Fornix:
- Fiber tract linking regions together

Corresponding diagrams illustrate the limbic system and its components.
Brain Anatomy:

D. Brain stem:
- Deep gray matter; superficial white matter
- Produce rigidly programmed, autonomic behaviors necessary for survival
- Conduction pathways between higher and lower brain centers

Midbrain:
- Visual / auditory reflex centers
- Pons:
- Regulate respiration rate / depth

Medulla oblongata:
- Location where fiber tracts from spinal cord cross over (decussation)
- Autonomic reflex center
- Heart rate / blood pressure
- Respiratory rhythm
- Vomiting / hiccupping / etc.

Brain Anatomy:

E. Cerebellum:
- Gray matter superficial; white matter deep
- Precise timing of muscle coordination (balance, posture, repeated movements)
- All activity subconscious

Cerebellar Processing:
- Cerebellum sends signal to move
- Sensory information from body
- Commands to motor neurons of spinal cord

Protection of the Brain:

Meninges:
- Inflammation of the meninges

A) Dura mater ("tough mother")
- Fibrous outer coating of brain
- Protects CNS

B) Arachnoid mater ("spider mother")
- Delicate middle layer
- Nourishes CNS

C) Pia mater ("gentle mother")
- Thin inner membrane
- Contains blood vessels
**Protection of the Brain:**

1) **Bone** (Skull – cranium portion)
2) **Meninges** (specialized connective tissue membranes)
3) **Blood-brain barrier**: Astrocyte-maintained barrier lining blood capillaries

Three layers of protection:
A. Capillary endothelium
B. Thick basal lamina
C. Bulbous feet of astrocytes

Tightly regulate substances bathing brain:
- **In**: glucose, amino acids, selected electrolytes
- **Out**: metabolic waste (e.g., urea), proteins, toxins, drugs

*Displays differentially permeable (e.g., vomit center → brain stem)*

**Homeostatic Imbalances of the Brain:**

1) **Traumatic brain injury**
   - Concussion: Alteration in brain function following blow to head
   - Subdural hemorrhage: Bleeding into subarachnoid space via ruptured vessels
   - Cerebral edema: Swelling of the brain

2) **Cerebrovascular accident**
   - Ischemic stroke: Blockage of blood supply to brain due to blood clot

3) **Degenerative brain disorders**
   - Alzheimer’s disease
   - Parkinson’s disease
   - Huntington’s disease

**Central Nervous System**

- **Organization of Nervous System**
  - Nervous system
  - Peripheral nervous system (PNS)
  - Motor division (afferent)
  - Sensory division (efferent)

- **Autonomic nervous system**
  - Innervation of limbs
  - Innervation of limbs

- **Somatic nervous system**
  - Motor division
  - Sensory division

- **Sympathetic division**
  - Parasympathetic division

- **Grey matter**
  - White matter

- **Spinal Cord**
  - Cross-sectional Anatomy:
    - Ascending tracts: Carry information to brain
    - Descending tracts: Carry information from brain
    - Transverse tracts: Carry information across cord

**Characteristics:**
1) Decussation present
2) Multi-neuron pathways
3) Somatotopy exhibited
4) Symmetrical arrangement

**Spinal Cord**

- **Cross-sectional Anatomy**
  - Dorsal white column
  - Ventral spinocerebellar tract
  - Ventral spinothalamic tract
  - Ventral spinocerebellar tract
  - Lateral spinothalamic tract

- **Central canal**
  - Posterior median sulcus
  - Posterior funiculus

**Central Nervous System**

- **Organization of Nervous System**
  - Integration
  - Central nervous system (CNS)
  - Peripheral nervous system (PNS)
  - Motor output
  - Sensory input

- **Autonomic nervous system**
  - Innervation of limbs
  - Innervation of limbs

- **Somatic nervous system**
  - Motor division
  - Sensory division

- **Sympathetic division**
  - Parasympathetic division

- **Grey matter**
  - White matter

- **Spinal Cord**
  - Cross-sectional Anatomy:
    - Dorsal white column
    - Ventral spinocerebellar tract
    - Ventral spinothalamic tract
    - Ventral spinocerebellar tract

**Characteristics:**
1) Decussation present
2) Multi-neuron pathways
3) Somatotopy exhibited
4) Symmetrical arrangement
Central Nervous System

Spinal Cord: Cross-sectional Anatomy:

- Central canal
- Posterior median sulcus
- Posterior horn (interneurons)
- Lateral funiculus
- Anterior median fissure
- Anterior horn (somatic motor neurons)
- Posterior funiculus
- Lateral horn (visceral motor neurons)
- Anterior horn (somatic motor neurons)
- White matter
- Gray matter
- Gray commissure

Spinal Cord: Cross-sectional Anatomy:

- Dorsal Root
- Dorsal root ganglion
- Sensory neuron
- Interneuron
- Motor neuron
- Spinal nerve
- Ventral Root

Spinal Cord: Organization of Gray Matter:

- Interneurons receiving input from somatic sensory neurons
- Interneurons receiving input from visceral sensory neurons
- Visceral motor (autonomic) neurons
- Somatic motor neurons

Homeostatic Imbalances of the Spinal Cord:

1) Spinal cord trauma
   - Paralysis / Paresthesias: Damage to spinal cord leading to functional / sensory loss
   - Paraplegia: Transection of spinal cord between T1 and L1
   - Quadriplegia: Transection of spinal cord between C4 and C7

2) Poliomyelitis
   - Destruction of ventral horn motor neurons by poliovirus

3) Amyotrophic lateral sclerosis (ALS)
   - Progressive destruction of ventral horn motor neurons (autoimmune?)