Once upon a time, psychiatric conditions were divided into “organic” and “functional,” based on whether there was an observable structural or chemical deviation. This categorization is no longer meaningful. Scientific research continues to find more and more anatomical structures that have a tangible connection to the neuronal functions with which most psychiatrists are concerned: mood, thought, cognition, behavior, and also movement and sensation. Changes in these structures, often at microscopic scale, may have significant impact on mental function. Knowledge of these anatomical structures is essential in understanding the biological aspect of psychiatry.

The general organization of the central nervous system is presented in Figure 1–1. Anatomy of the spinal cord is not reviewed here because of its relatively limited application in common psychiatric disorders. Selected topics on spinal cord anatomy are reviewed in Chapter 43, in combination with spinal cord diseases.

![General organization of the central nervous system](image-url)

Figure 1–1 General organization of the central nervous system. Only the major structural components are labeled. Structures described in this chapter are listed in italic font.
Part I. Intellectual Foundation of Psychiatry

Amygdala: anatomy (Figure 1–2)

From Greek, “almond.”

- Groups of neurons deep within the medial temporal lobes
- An essential part of the limbic system
- Involved in memory, emotional reactions, and appetite conditioning
- Output to:
  - Hypothalamus: activation of the sympathetic nervous system
  - Nuclei of the trigeminal nerve (CN V) and facial nerve (CN VII): facial expressions
  - Ventral tegmental area (VTA): activation of dopamine
  - Locus coeruleus: activation of norepinephrine

Amygdala: roles in anxiety and fear

- Mediates learned fear responses
- Directs the expression of certain emotions
- Exerts influence on the cortex
- Damage to the amygdala may ablate the ability to distinguish fear and anger
- Positron emission tomography (PET) shows that harm avoidance is associated with increased activity in the right amygdala and other structures

Auditory system

- Peripheral system:
  - Changes of air pressure form sounds
  - Vibration of tympanic membrane
Vibration is transmitted through ossicles to the endolymph of the cochlear spiral. Vibrations of the endolymph move cilia on hair cells. Hair cells generate neural impulses.

**Central system:**
- Neural impulses travel through cochlear nerves to cochlear nuclei (brainstem)
- Then the impulses travel to the medial geniculate nucleus (MGN, at thalamus)
- MGN projects to the primary auditory cortex (Heschl's gyri)

**Basal ganglia (Figure 1–3)**

- **Anatomical components:**
  - Putamen
  - Caudate nucleus
  - Nucleus accumbens
  - Globus pallidus
  - Subthalamic nucleus
  - Substantia nigra

- **Function (consists of a series of circuits that are associated with a variety of functions):**
  - Motor control
  - Cognition
  - Emotions
  - Learning

**Caudate nucleus**

- **Anatomy:**
  - Part of basal ganglia
  - Together with putamen, forms the dorsal striatum
  - Separated from the lenticular nucleus by the internal capsule
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Function:
- Important part of the learning and memory system

Neurochemistry:
- Highly innervated by dopamine neurons
- These neurons originate mainly from the VTA and the substantia nigra

Cerebellum function
- Activated before a planned – or even imagined – movement
- Modulates the tone of agonistic and antagonistic muscles
- Predicts the relative contraction needed for smooth motion

Cerebrospinal fluid: formation and absorption (Figure 1–4)

Formation:
- Choroid plexuses of lateral, third, and fourth ventricles

Flow:
- Choroid plexuses
- Ventricles
- Median aperture (foramen of Magendie) or lateral apertures (foramina of Luschka)
- Subarachnoid space

Absorption:
- Through arachnoid granulations, also known as arachnoid villi
- To the superior sagittal sinus or venous lacunae

Cingulate

Anatomy:
- A gyrus between the corpus callosum and the cingulate sulcus
- An integral part of the limbic system
Chapter 1. Functional Neuroanatomy

Function:
- Emotion formation and processing
- Learning
- Memory
- Unconscious priming

Glial cells

- Astrocytes:
  - Most common type of glial cells
  - Nutritional support to neurons
  - Deactivation of neurotransmitters
  - Integration with the blood-brain barrier

- Oligodendrocytes:
  - Appear only in the central nervous system
  - Form myelin sheaths

- Schwann cells:
  - Appear only in the peripheral nervous system
  - Form myelin sheaths
  - Remove cellular debris

Globus pallidus (Figure 1–5)

- Anatomy:
  - A subcortical structure
  - A major element of the basal ganglia
  - Forms the dorsal striatum

- Function:
  - Involved in the regulation of voluntary movements at a subconscious level
  - Probably involved in physiological pace-making

Figure 1–5 Coronal cut shows globus pallidus and its surrounding structures.
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Heschl's gyri (Figure 1–6)

Richard Heschl (1824–1881) was an Austrian anatomist.

- Also known as the transverse temporal gyri or Heschl's convolutions
- Located bilaterally in the primary auditory cortex in the superior temporal gyrus
- Receives auditory stimuli from the contralateral ear
- Supplied by the middle cerebral artery

Hippocampus

From Latin, “sea horse.”

- Located in the medial temporal lobe
- Part of the limbic system
- Plays an important role in memory and spatial navigation

Hypothalamus

- Anatomy:
  - Located below the thalamus, just above the brain stem
  - Occupies the major portion of the ventral region of the diencephalon
- Function:
  - Links the nervous system to the endocrine system via the pituitary gland (hypophysis)
  - Synthesizes and secretes hypothalamic-releasing hormones, and these in turn stimulate or inhibit the secretion of pituitary hormones
  - Regulates certain metabolic processes and other autonomic activities – body temperature, hunger, thirst, and circadian cycles
**Important brain fissures (Figure 1–7)**

Luigi Rolando (1773–1831) was an Italian anatomist. Franciscus Sylvius (1614–1672) was a German-Dutch physician and anatomist.

- **Rolandic fissure:**
  - Also known as the central sulcus or fissure of Rolando
  - Separates the parietal lobe from the frontal lobe, and the primary motor cortex from the primary somatosensory cortex

- **Sylvian fissure:**
  - Also known as the lateral sulcus or lateral fissure
  - Divides the frontal and parietal lobes from the temporal lobe

**Limbic system**

- Anatomy (major components as listed):
  - Amygdala
  - Cingulate gyrus
  - Hippocampus
  - Hypothalamus
  - Mammillary body
  - Nucleus accumbens
  - Orbitofrontal cortex
  - Thalamus

- Function:
  - Pleasure
  - Sexual arousal
  - Health consciousness
  - Not completely understood
Part I. Intellectual Foundation of Psychiatry

Nucleus accumbens (Figure 1–3)
- Location: the head of the caudate and the anterior portion of the putamen
- Neurobiological role:
  - Reward
  - Pleasure
  - Addiction
- Neurotransmitter:
  - Mainly gamma-aminobutyric acid (GABA)
  - Some cholinergic interneurons
- Associated with the action of addictive drugs such as cocaine and amphetamine; almost every drug abused by humans has been shown to increase dopamine levels in the nucleus accumbens

Prefrontal cortex
- Anterior part of the frontal lobes, generally involved in executive function (regulating thoughts and actions in accordance with internal goals)
- Orbitofrontal cortex:
  - Decision making
  - Emotion and reward
  - Part of the limbic system
- Medial prefrontal areas
  - Planning complex cognitive behaviors
  - Personality expression
  - Moderating appropriate social behavior

Primary sensory cortex
- Lateral postcentral gyrus in the parietal lobe
- Roughly overlaps with Brodmann areas 3, 1, and 2
- Receives the thalamocortical projection from the sensory input fields

Putamen (Figure 1–3)
From Latin, “shell.”
- Anatomy:
  - Part of basal ganglia
  - Dorsal striatum
  - Outermost part of the lenticular nucleus (the inner part is globus pallidus)
- Function:
  - Not well defined
  - Likely to play a role in reinforcement learning

Reticular formation
- Also known as the reticular activating system
- Anatomy:
  - Centered in the pons, connected to the thalamus, hypothalamus, cortex, and cerebellum
Function:
- Arousal and motivation
- Maintaining the state of consciousness
- Circadian rhythm

Reward system
- Primarily involves the mesolimbic and mesocortical dopamine pathway
- Anatomical structures include VTA, nucleus accumbens, substantia nigra, and prefrontal lobe

Substantia nigra (Figure 1–3)
From Latin, “black substance.”
- A heterogeneous portion of the midbrain
- A component of basal ganglia
- Center of dopamine production
- Plays a central role in the reward system and addiction

Striatum
- A subcortical structure of telencephalon, it consists of:
  - Putamen
  - Caudate nucleus
- Striatum is the major input station of basal ganglia

Ventral tegmental area
- Also known as ventral tegmentum
- Is part of the midbrain
- Consists of dopamine, GABA, and glutamate neurons
- Is part of two major dopamine pathways
  - The mesolimbic pathway, which projects to the nucleus accumbens
  - The mesocortical pathway, which projects to cortical areas in the frontal lobes
- Functions:
  - Part of the reward system
  - Emotion and security motivation
  - Avoidance and fear-conditioning
2 Neurochemistry

The synthesis, metabolism, transportation, interaction, and other behaviors of neurochemicals play important roles in mental activities. Two major categories of neurochemicals are studied in psychiatry: neurotransmitters and neuroactive drugs. This chapter reviews the important neurotransmitters, which include

- Acetylcholine
- Dopamine
- Gamma-aminobutyric acid (GABA)
- Glutamate
- Glycine
- Histamine
- Melatonin
- Norepinephrine
- Serotonin

**Acetylcholine synthesis and metabolism (Figure 2-1)**

Theodor Meynert (1833–1892) was a German-Austrian neuropathologist and anatomist.

- **Location**
  - Basal nucleus of Meynert at basal forebrain
- **Precursors**
  - Acetyl-CoA and choline
- **Metabolism**
  - Breaks down to acetyl-CoA and choline
  - Catalyzed by acetylcholinesterase in the synaptic cleft

**Adrenergic \(\alpha-1\) antagonism: clinical effects**

- Sedation
- Orthostatic hypotension
- Priapism

**Adrenergic \(\alpha-2\) receptor**

- Presynaptic receptors provide negative feedback on the release of serotonin and norepinephrine
- Agonists – decreases serotonin and norepinephrine release
  - Clonidine – sympatholytic action; helpful in opiate withdrawal
- Antagonists – increases serotonin and norepinephrine release