

Medical Neuroscience | Tutorial Notes

Modulation of Movement by the Basal Ganglia

MAP TO NEUROSCIENCE CORE CONCEPTS¹

- NCC1. The brain is the body's most complex organ.
- NCC3. Genetically determined circuits are the foundation of the nervous system.
- NCC4. Life experiences change the nervous system.

LEARNING OBJECTIVES

After study of the assigned learning materials, the student will:

1. Identify the major components of the basal ganglia, including the parts of the dorsal motor stream and ventral limbic stream.
2. Discuss the role of the basal ganglia in the initiation and suppression of behavior.
3. Describe the principle of “disinhibition” and explain how it applies to the circuitry and functions of the basal ganglia.
4. Discuss the critical role of dopamine in facilitating the function of basal ganglia circuitry.

TUTORIAL OUTLINE

- I. Introduction
 - A. **basal ganglia**
 1. collection of nuclei located deep in the anterior telencephalon that are intimately related to the functions of the cerebral cortex
 - a. receive widespread inputs from the cerebral cortex
 - b. after several steps of processing, basal ganglia output is directed to the thalamus, which in turn projects back to the cerebral cortex
 - c. thus, the overall function of the basal ganglia is *to modulate thalamo-cortical activity*
 2. there are multiple parallel processing “streams” through the basal ganglia (see **Box 18D²**); three important streams are:
 - a. dorsal motor stream (motor loop)
 - b. dorsal cognitive (“executive”) stream (prefrontal loop)

¹ Visit [BrainFacts.org](https://www.brainfacts.org) for Neuroscience Core Concepts (©2012 Society for Neuroscience) that offer fundamental principles about the brain and nervous system, the most complex living structure known in the universe.

² Figure references to Purves et al., *Neuroscience*, 5th Ed., Sinauer Assoc., Inc., 2012. [[click here](#)]

- c. ventral limbic (“emotional”) stream (limbic loop)
- B. general sense of basal ganglia function:
 1. processes executive commands for the **initiation** of appropriate behavior and the **suppression** of inappropriate behavior
 2. diseases associated with the basal ganglia
 - a. *hypokinetic* movement disorders (e.g., Parkinsonism)
 - b. *hyperkinetic* movement disorders (e.g., Huntington’s disease, hemiballism)
 - c. possibly, certain affective and cognitive disorders (e.g., depression, schizophrenia, Tourette’s syndrome)
- II. The circuitry
 - A. basic components of basal ganglia system (see [Figure 18.1](#))

Table 1. Major components of the basal ganglia.

	Dorsal Motor Stream (volitional movement)	Ventral Limbic Stream (emotional behavior)
Cortical input	Sensory and motor cortex	Prefrontal cortex, amygdala, hippocampal formation
Striatum	Caudate nucleus Putamen	Nucleus accumbens Ventral striatum (several small subdivisions)
Pallidum	Globus pallidus, internal segment Globus pallidus, external segment Substantia nigra, pars reticulata	Ventral pallidum Substantia nigra, pars reticulata
Modulatory inputs	Substantia nigra, pars compacta (dopamine) Subthalamic nucleus (glutamate)	Ventral tegmental area (dopamine)
Thalamic target of output	Ventral anterior/ventral lateral nuclei	Mediodorsal nucleus

- B. inputs to basal ganglia (striatum)
 1. input “commands” are relayed from widespread parts of cerebral cortex
 - a. dorsal motor stream (see [Figure 18.2](#))
 - (i) receives “uni-modal” information from frontal motor areas, parietal somatic sensory and visual areas, and temporal auditory and visual areas
 - (ii) receives “multi-modal” (associational) information from areas in frontal, parietal and temporal lobes

- (iii) receives modulatory (dopamine) inputs from substantia nigra, pars compacta
 - b. ventral limbic stream (see **Box 18D** & **Figure 29.10**)
 - (i) receives sensory information from prefrontal cortical areas that process olfaction, gustation and visceral-sensory inputs
 - (ii) receives associational information from additional sectors of the prefrontal cortex, amygdala and hippocampal formation
 - (iii) receives modulatory (dopamine) inputs from the ventral tegmental area (medial to the substantia nigra, pars compacta)
- C. circuitry within the basal ganglia and outputs to thalamo-cortical circuits
 - 1. dorsal motor stream (see **Figure 18.7**)
 - a. 'direct' pathway (from basal ganglia to thalamus)
 - (i) cerebral cortex → caudate/putamen
 - (ii) caudate/putamen → internal segment of the globus pallidus (and substantia nigra, pars reticulata)
 - (iii) internal segment of globus pallidus (and substantia nigra, pars reticulata) → ventral anterior/ventral lateral complex of the thalamus
 - (iv) ventral anterior/ventral lateral complex → motor cortical areas in frontal lobe
 - b. 'indirect' pathway (from basal ganglia to thalamus)
 - (i) cerebral cortex → caudate/putamen
 - (ii) caudate/putamen → external segment of the globus pallidus
 - (iii) external segment of globus pallidus → subthalamic nucleus
 - (iv) subthalamic nucleus → internal segment of the globus pallidus
 - (v) internal segment of globus pallidus → ventral anterior/ventral lateral complex of the thalamus
 - (vi) ventral anterior/ventral lateral complex → motor cortical areas in frontal lobe
 - 2. ventral limbic stream
 - a. orbital-medial prefrontal cerebral cortex, amygdala and hippocampal formation → ventral striatum (caudal-medial parts of caudate nucleus, nucleus accumbens, other ventral striatal divisions)
 - b. ventral striatum → ventral pallidum (and substantia nigra, pars reticulata)
 - c. ventral pallidum (and substantia nigra, pars reticulata) → mediodorsal nucleus of the thalamus

- d. mediodorsal nucleus → prefrontal cortex
- 3. consideration of circuit function
 - a. **disinhibition** (study [Figure 18.5](#))
 - b. direct and indirect pathways of the dorsal motor stream
 - (i) transient activation of caudate/putamen projection neurons transiently **inhibits** projection neurons of the internal and external segments of the globus pallidus
 - (ii) direct pathway (see [Figure 18.7A](#)):
 - transient inhibition of projection neurons of the globus pallidus internal segment **removes** tonic inhibition of ventral anterior/ventral lateral complex
 - ventral anterior/ventral lateral complex neurons are transiently **“released”** activate motor cortex
 - (iii) indirect pathway (see [Figure 18.7B](#))
 - transient inhibition of the external segment of the globus pallidus **disinhibits** the subthalamic nucleus
 - subthalamic nucleus is then **“released”** to transiently activate the internal segment of the globus pallidus
 - activation of internal segment of globus pallidus increases tonic inhibition of the ventral anterior/ventral lateral complex
 - ventral anterior/ventral lateral complex neurons are **inhibited** from activating the motor cortex
 - (iv) both direct and indirect pathways are modulated by dopamine in the striatum
 - (v) notice that the direct and indirect pathways have **opposing effects** on the thalamo-cortical projection
 - (vi) the output of the basal ganglia (via the internal segment of the globus pallidus) depends upon the balance of activity in the direct and indirect pathways
 - c. ventral limbic stream (analogous to direct pathway)
 - (i) transient activation of ventral striatum projection neurons transiently **inhibits** projection neurons in the ventral pallidum and substantia nigra, pars reticulata
 - (ii) transient inhibition of pallidal projection neurons **removes** tonic inhibition of neurons in the mediodorsal nucleus
 - (iii) neurons of the mediodorsal nucleus are transiently **“released”** to activate prefrontal cortex

STUDY QUESTIONS

Q1. Which of the following structures is a component of the “**striatum**”?

- A. putamen
- B. globus pallidus
- C. substantia nigra pars compacta
- D. substantia nigra pars reticulata
- E. subthalamic nucleus

Q2. Which of the following structures is a component of the “**pallidum**”?

- A. putamen
- B. caudate nucleus
- C. nucleus accumbens
- D. substantia nigra pars compacta
- E. substantia nigra pars reticulata
- F. subthalamic nucleus