

# **BASAL GANGLIA**

## **Physiology of basal ganglia and regulatory mechanisms**

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# OBJECTIVES

*At the end of this lecture the students should be able to:-*

- *Appreciate different nuclei of basal ganglia*
- *Know different neurotransmitters that have a role in basal ganglia functions*
- *Appreciate general functions of basal ganglia*
- *Diagnose basal ganglia disorders*

# **OVERVIEW OF MOTOR ACTIVITY CONTROL**

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**CEREBRAL CORTEX**

**Corticospinal tracts**

**Corticobulbar tracts**

**BASAL GANGLIA**

**THALAMIUS**

**BRAIN STEM**

**CEREBELLUM**

**Bulbospinal tracts**

**SENSORY INPUT**

**SPINAL CORD**

**FINAL COMMON PATH**



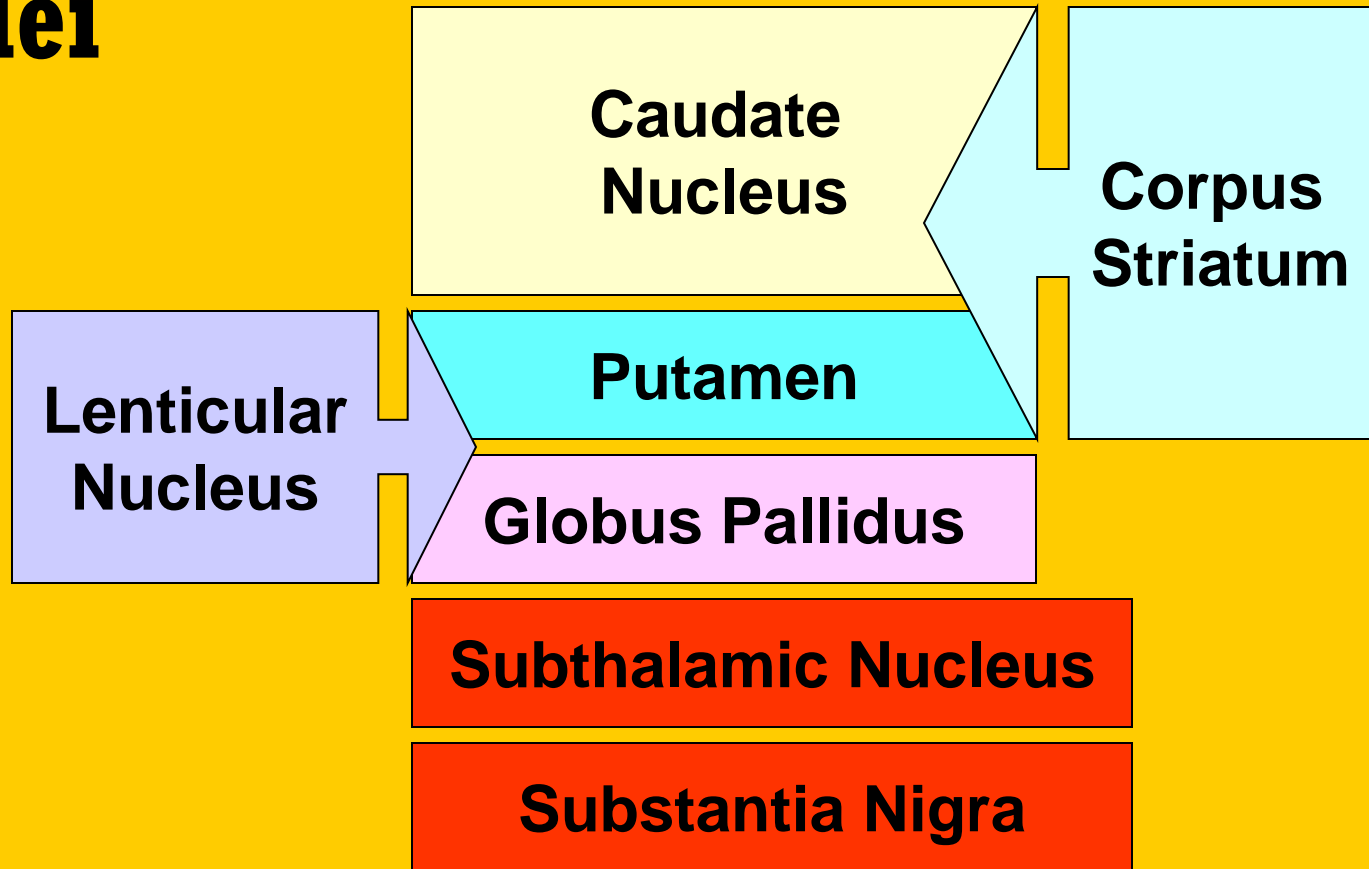
**FINAL COMMON PATH**

A scroll with a yellow banner containing the text 'BASAL GANGLIA'. The scroll is unrolled and has four wooden rollers at the corners. The banner is a bright yellow color with a slight gradient and a drop shadow.

# **BASAL GANGLIA**

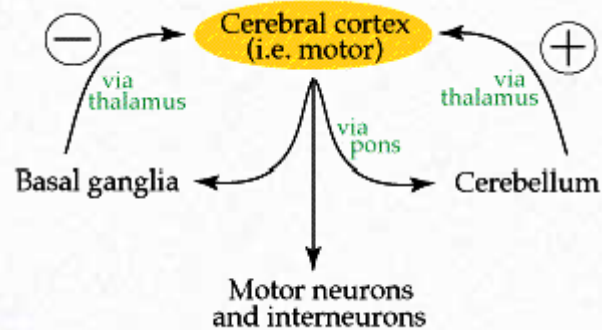
**COMPONENTS  
FUNCTIONAL ANATOMY**

# Basal Nuclei

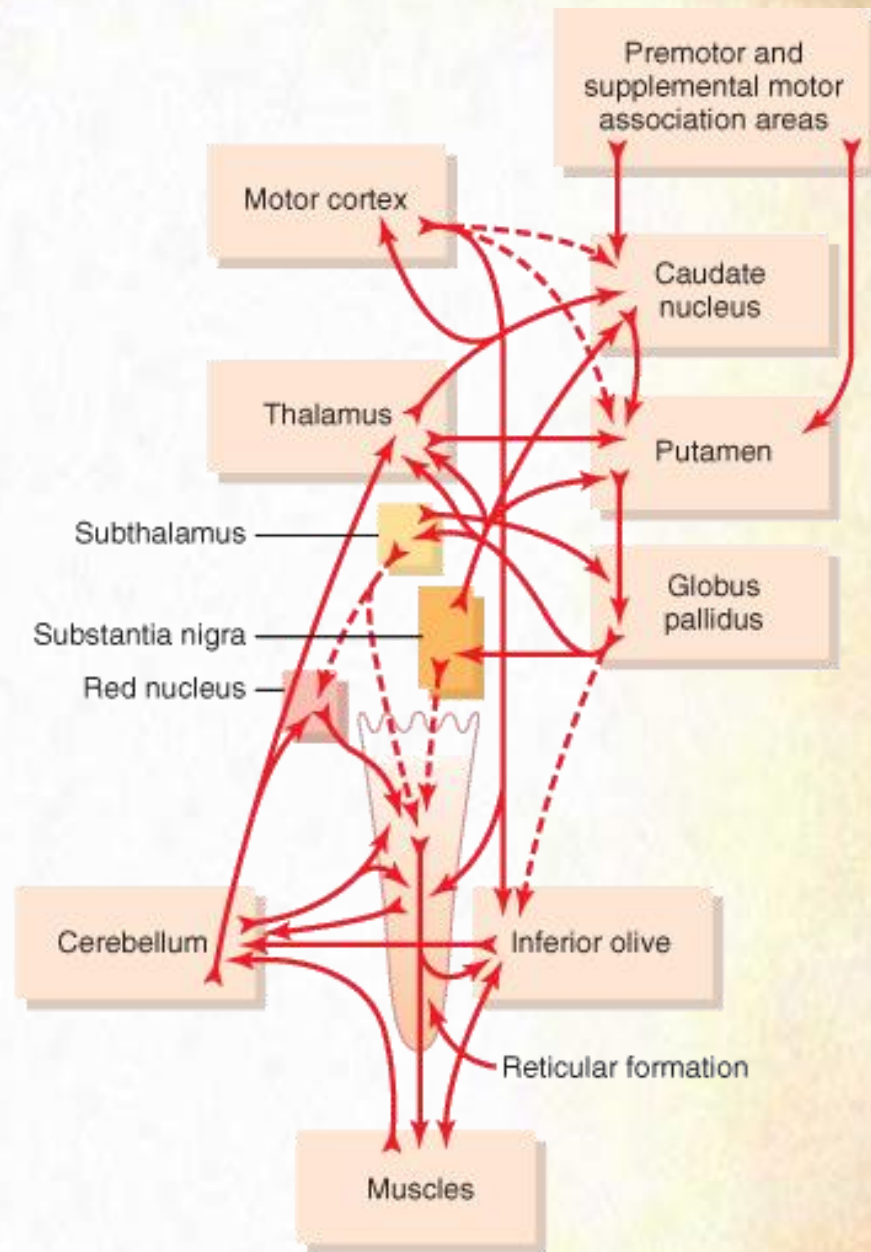


# BASAL GANGLIA

## CONNECTIONS



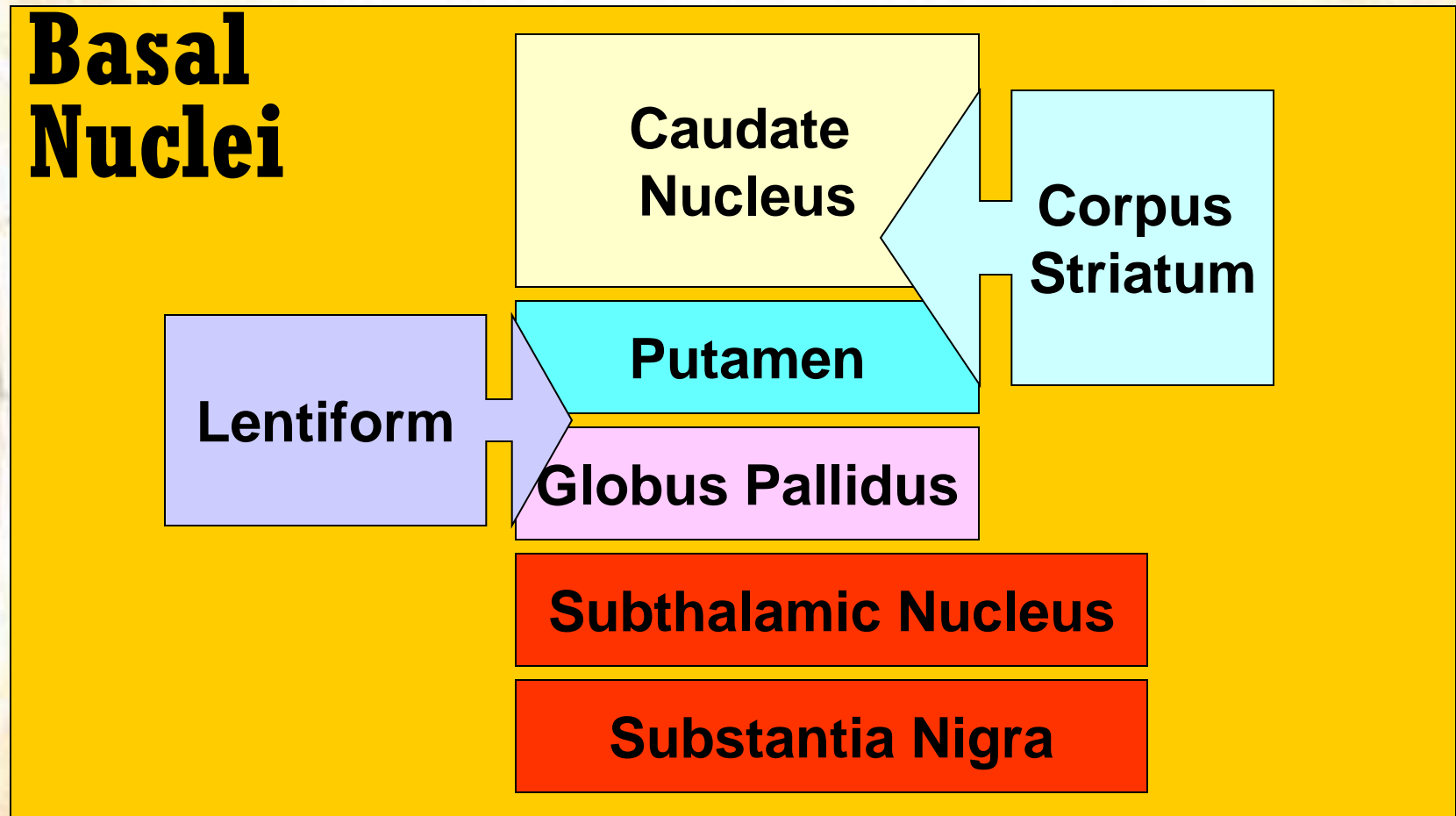
# Connections for Motor Control





# 3 Connections to remember

1. Main input to the basal ganglia
2. Main output from the basal ganglia
3. Connections between parts of basal ganglia

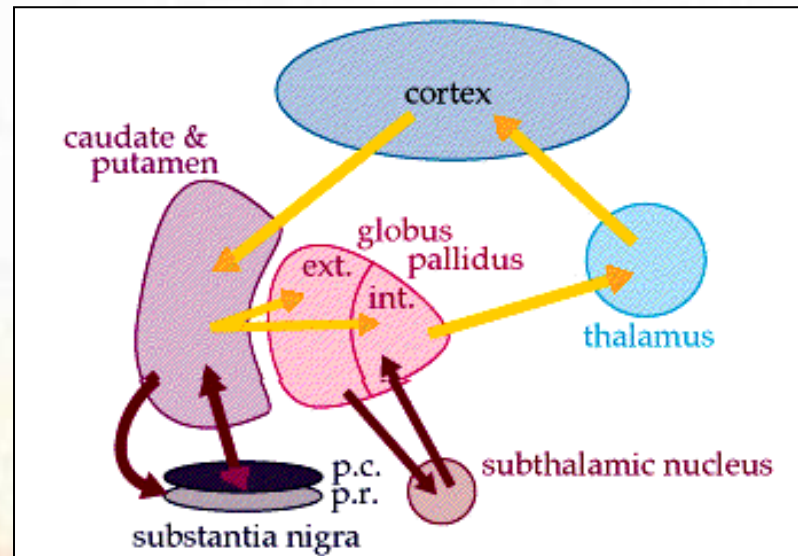


# MAIN INPUT TO THE BASAL GANGLIA

The comes from the cerebral cortex (motor area) and projects to the **NEOSTRIATUM** (a term for the caudate nucleus and putamen)

## THE MAIN OUTPUT

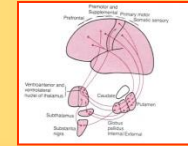
Is via the thalamus to the cerebral cortex (motor area)



# BASIC CIRCUITS OF BASAL GANGLIA

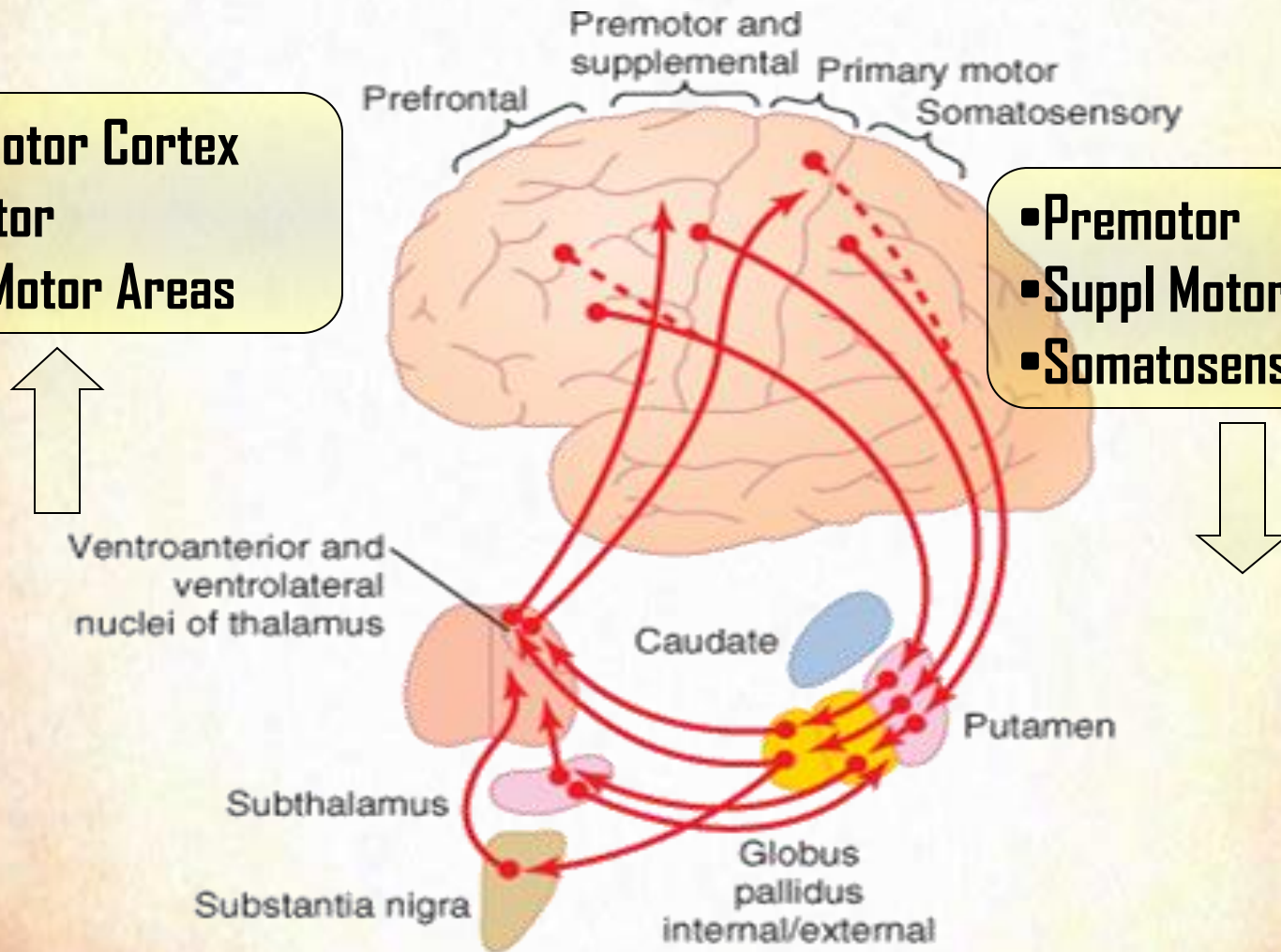
1. **Motor loop (putamen circuit)** concerned with learned movement.
2. **Cognitive loop (Caudate circuit)** concerned with cognitive control of sequences of motor pattern. Basically it is concerned with motor intentions.  
(Note: cognition means thinking process using sensory input with information already stored in memory.)
3. **Limbic loop** involved in giving motor expression to emotions like, smiling, aggressive or submissive posture.
4. **Occulomotor loop** concerned with voluntary eye movement [ saccadic movement]

# The Putamen Circuit



- Prim Motor Cortex
- Premotor
- Suppl Motor Areas

- Premotor
- Suppl Motor
- Somatosensory Cortex



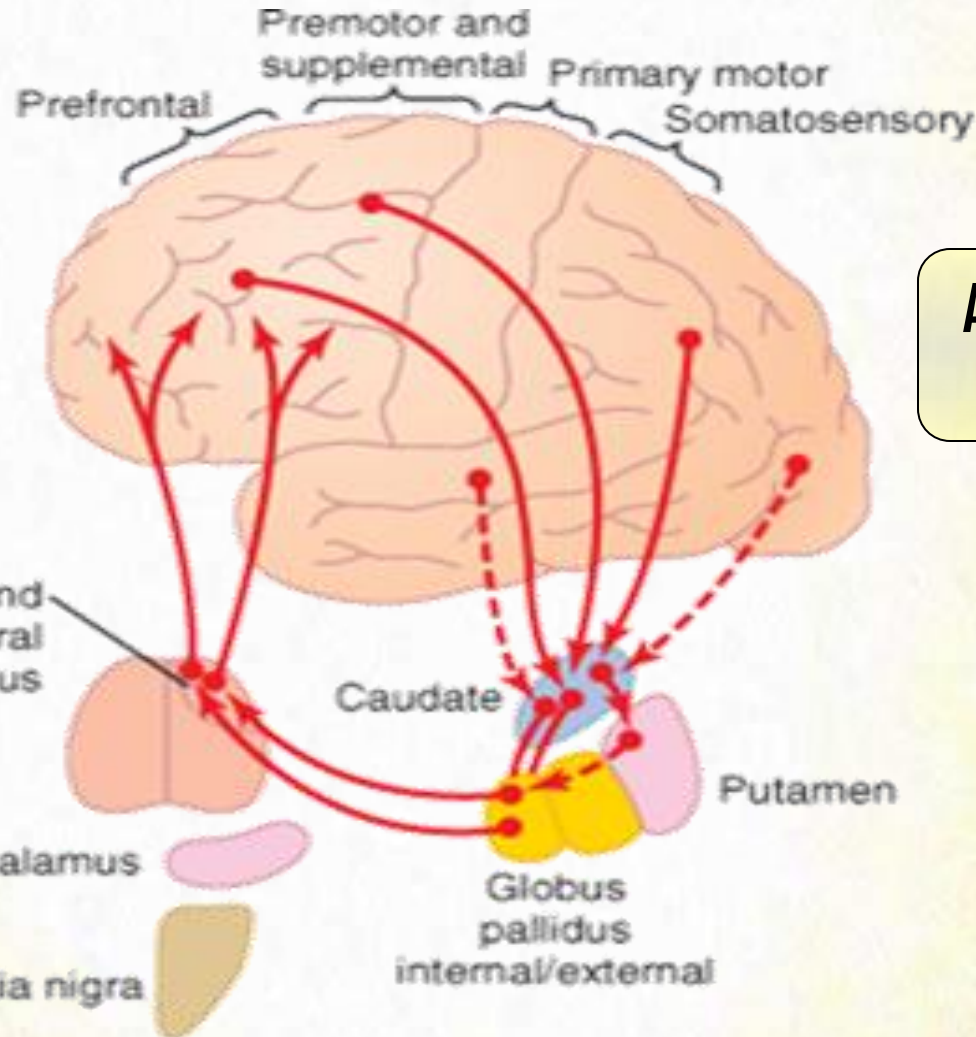
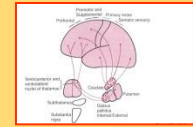
# The Putamen Circuit

## Executes Learned Patterns of Motor Activity

- Basal ganglia function in association with the corticospinal system to control *complex patterns of motor activity*.
- Examples are:
  - writing of letters of the alphabet.
  - cutting paper with scissors,
  - hammering nails,
  - shooting a basketball through a hoop,
  - passing a football,
  - throwing a baseball,
  - the movements of shoveling dirt,
  - most aspects of vocalization,
  - controlled movements of the eyes
  - virtually any other of our skilled movements, most of them performed subconsciously.



# The Caudate Circuit



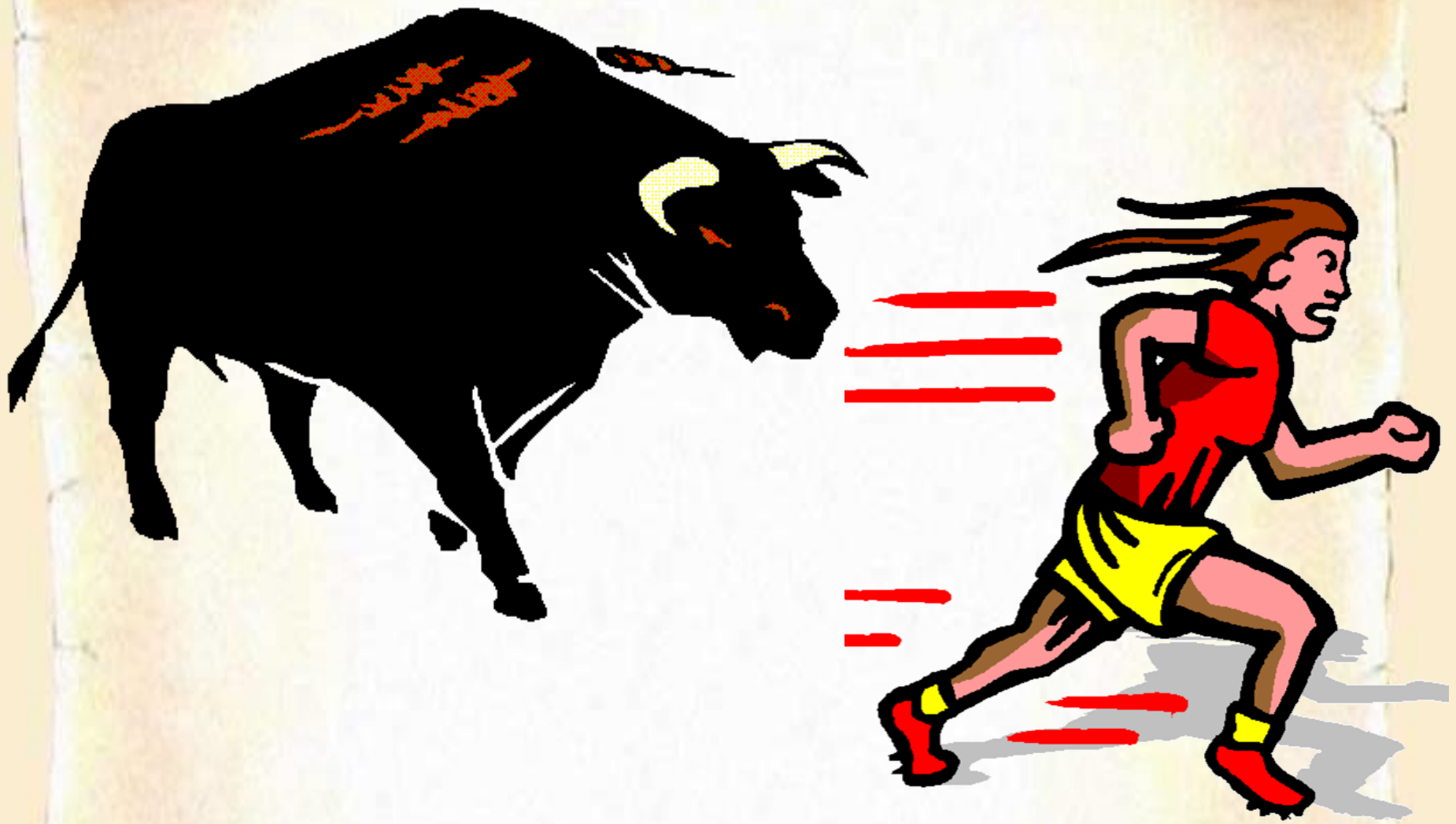
- Prefrontal
- Premotor
- Suppl Motor

Association  
Areas

# The Caudate Circuit

## Cognitive Control of Sequences of Motor Patterns

- **Cognition means the thinking processes of the brain, using both sensory input to the brain plus information already stored in memory. Thoughts are generated in the mind by a process called cognitive control of motor activity.**
- **Example: A person seeing a lion approach and then responding instantaneously and automatically by (1) turning away from the lion, (2) beginning to run, and (3) even attempting to climb a tree.**
- **Thus, cognitive control of motor activity determines subconsciously, and within seconds, which patterns of movement will be used together to achieve a complex goal**





# The Caudate Circuit

## Change the Timing and to Scale the Intensity of Movements

- **Two important capabilities of the brain in controlling movement are**
  - **(1) to determine how rapidly the movement is to be performed and**
  - **(2) to control how large the movement will be.**
- **For instance, a person may write the letter "a" slowly or rapidly. Also, he or she may write a small "a" on a piece of paper or a large "a" on a chalkboard. Regardless of the choice, the proportional characteristics of the letter remain nearly the same**

# **Basal Ganglial Pathways**

## **Direct and Indirect**

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Basal ganglia

Nuclei: Striatum, globus pallidus, subthalamic nucleus, substantia nigra

Function: movement modulation

Direct pathway

Type: Excitatory

Pathway: cortex -> striatum -> globus pallidus, pars externa -> thalamus -> motor cortex -> spinal cord / brainstem

Function: movement initiation

Indirect pathway

Type: Inhibitory

Pathway: cortex -> striatum -> globus pallidus,  
pars interna -> subthalamic nucleus -> globus  
pallidus, pars externa -> thalamus -> motor  
cortex -> spinal cord / brainstem

Function: movement termination

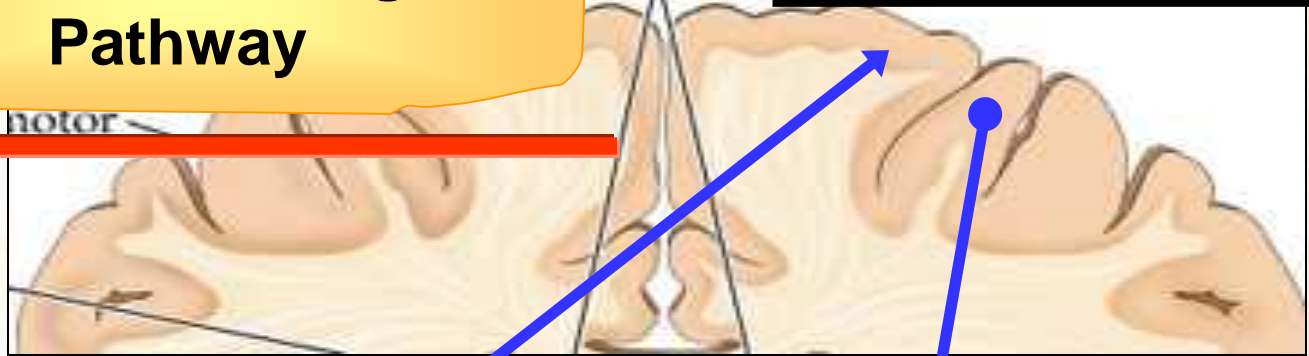
Main circuits of the basal ganglia The + and – signs at the point of the arrows indicate whether the pathway is excitatory or inhibitory, respectively, in effect. blue arrows refer to excitatory glutamatergic pathways, red arrows refer to inhibitory GABAergic pathways and dopaminergic pathways that are excitatory on the direct pathway and inhibitory on the indirect pathway.

blue arrows refer to excitatory glutamatergic pathways, red arrows refer to inhibitory GABAergic pathways, dopaminergic pathways that are excitatory on the direct pathway and inhibitory on the indirect pathway.

# Direct Basal Ganglial Pathway

↑ MOTOR ACTIVITY

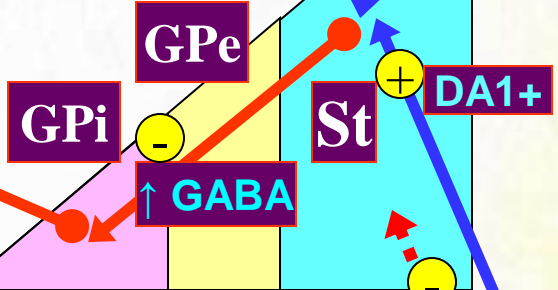
motor



GLU ⊕

GLU ⊕

↓ GABA ⊖



Thalamus

Thalamocortical Neurons are disinhibited

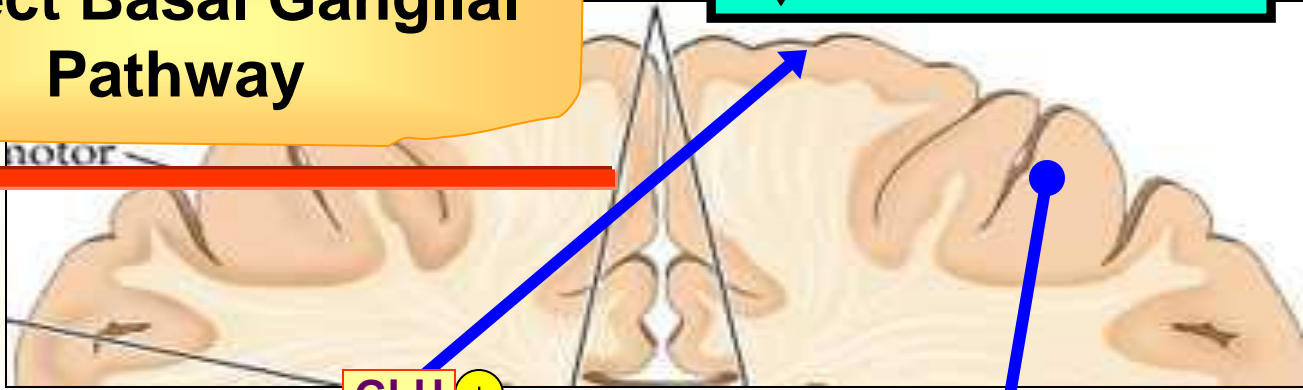
SThN

SNPC

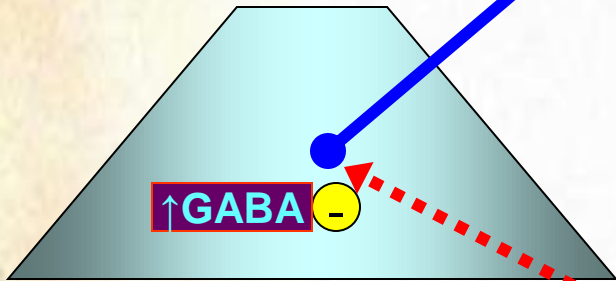
# Indirect Basal Ganglial Pathway

↓ MOTOR ACTIVITY

motor

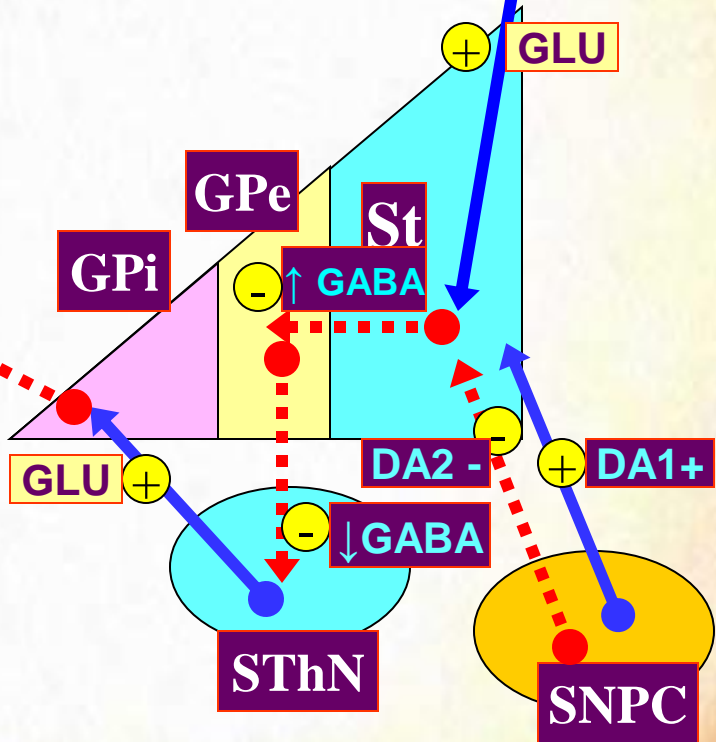


GLU ⊕



Thalamus

Subthalamic Neurons are disinhibited



# Direct and indirect pathways together facilitate action selection

- Activation of direct pathway facilitates movement
- Activation of indirect pathway suppresses movement
- Direct output makes focal inhibitory contact on GPi/SNr
- Indirect output makes diffuse, widespread excitatory contact on GPi/SNr
- Co-activation of these pathways facilitates action selection through center-surround mechanism



# Dopamine effects on direct and indirect pathways

- Dopamine signaling through D2 receptors in the indirect pathway suppresses striatal activity
- Dopamine signaling through D1 receptors in the direct pathway:
  - Facilitates strong, phasic inputs
  - Suppresses weak inputs

# Metabolic characteristics

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- High Oxygen consumption .
- High Copper content in **Wilson's disease** (Copper intoxication):
- Autosomal Recessive
- Copper binding protein **Ceruloplasmin** is low
- Lenticular degeneration occurs

# **BASAL GANGLIA**

## **FUNCTIONS**

- **Control of movements**
- **Planning and programming of movements**
- **Cognition**

# **BASAL GANGLIA**

## **DISORDERS**

**MOVEMENTS (ATAXIA *Rate, Range, Force, Direction*)**

**SPEECH**

**POSTURE**

**GAIT**

**MENTAL ACTIVITY**

**OTHERS**

# Movement Disorders

## Hyperkinetic

- Hemiballismus
- Huntington's Disease
- Athetosis



## Hypokinetic

- Parkinson's Disease
- Drug Induced (Neuroleptics, MPTP)

Movement Disorder	Features	Lesion
Chorea	Multiple quick, random movements, usually most prominent in the appendicular muscles	Atrophy of the <b>striatum</b> . Huntington Chorea
Athetosis	Slow writhing movements, which are usually more severe in the appendicular muscles	Diffuse hypermyelination of <b>corpus striatum and thalamus</b>
Hemiballismus	Wild flinging movements of half of the body	Hemorrhagic destruction of contralateral <b>subthalamic n.</b> Hypertensive patients
Parkinsonism	Pill rolling tremor of the fingers at rest, lead pipe rigidity and akinesia	Degeneration of <b>Substantia Nigra</b>



# Parkinson disease



Decreased  
amount  
of dopamine

Normal  
amount of  
acetylcholine

# Parkinson's Disease

- Described by James Parkinson
- Degeneration of dopaminergic nigrostriatal neurons (60-80 %).
- Phenthiazines (tranquilizers drugs) .
- Methyl-Phenyl-Tetrahydro-Pyridine (MPTP). The oxidant MPP<sup>+</sup> is toxic to SN.
- Five cardinal features
  - Tremor
  - Rigidity
  - Akinesia & Bradykinesia
  - Postural Changes
  - Speech Changes







# Parkinson's disease

- Parkinson's disease is characterized by resting tremor, rigidity, akinesia (difficulty in initiation of movement) and bradykinesia (slowness in the execution of movement).
- These symptoms are due to loss of function of the basal ganglia which is involved in the coordination of body movement.

## Levodopa

- L-dopa or Dihydroxyphenylalanine
- Biosynthetic precursor of dopamine
- Increase dopamine in the brain
- Main treatment used to decrease motor dysfunction
- Absorbed from proximal duodenum
- Protein-restricted diet
- Vit B6 should not be co-administrated with L-dopa
- L-dopa exhibits a large first-pass effect
- Only about 1% reaches brain tissue

# Surgery -

- **Deep Brain Stimulation**

- Brain pacemaker, sends electrical impulses to brain to stimulate the subthalamic nucleus.
- Improves motor functions and reduce motor complications.
- Complications include: brain hemorrhage, seizures, death.

