

# PHYSIOLOGY OF BASAL GANGLIA AND REGULATORY MECHANISMS



**Dr Syed Shahid Habib**

*Professor & Consultant Clinical Neurophysiology*

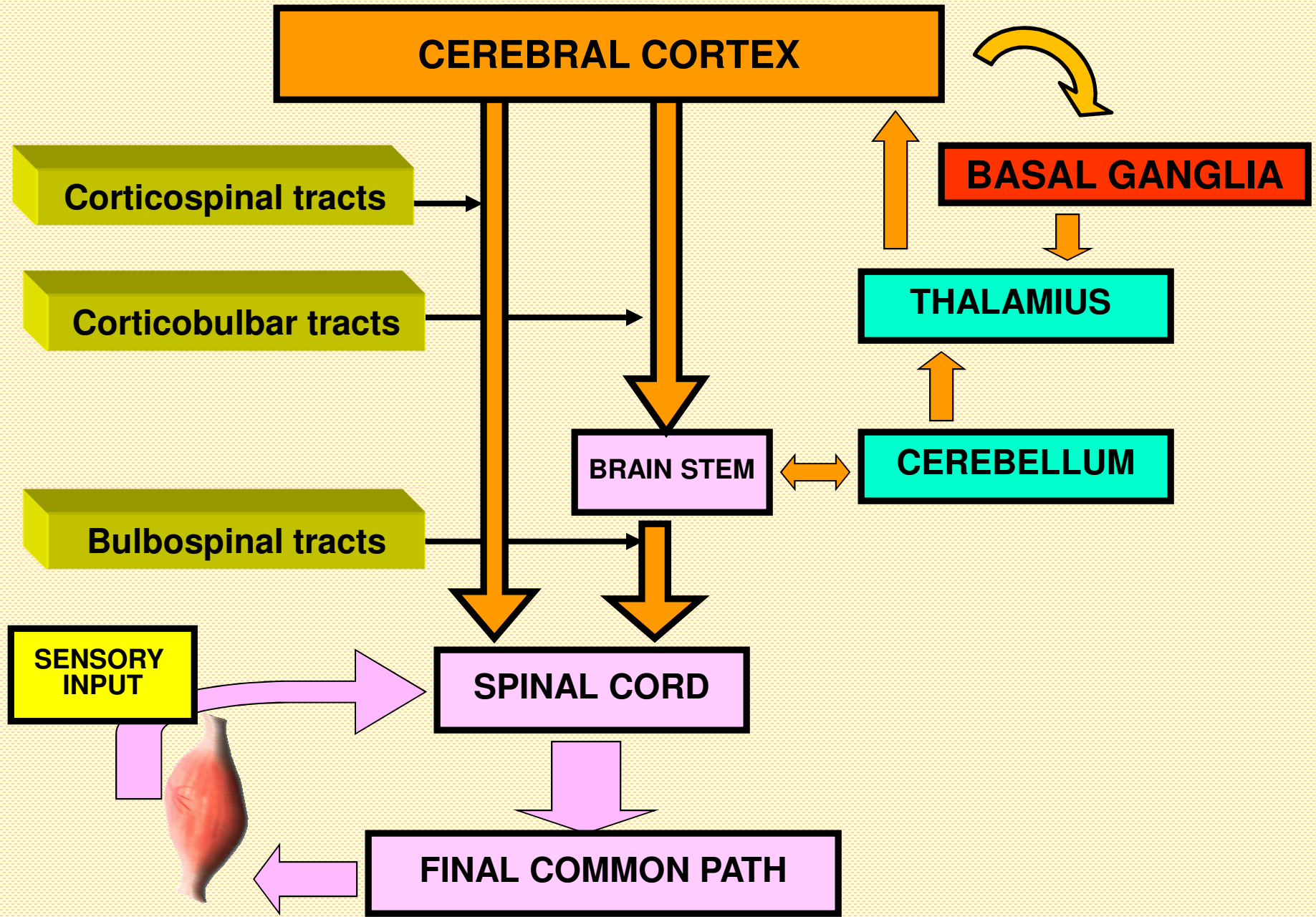
*Dept. of Physiology*

*King Saud University*

# **OBJECTIVES**

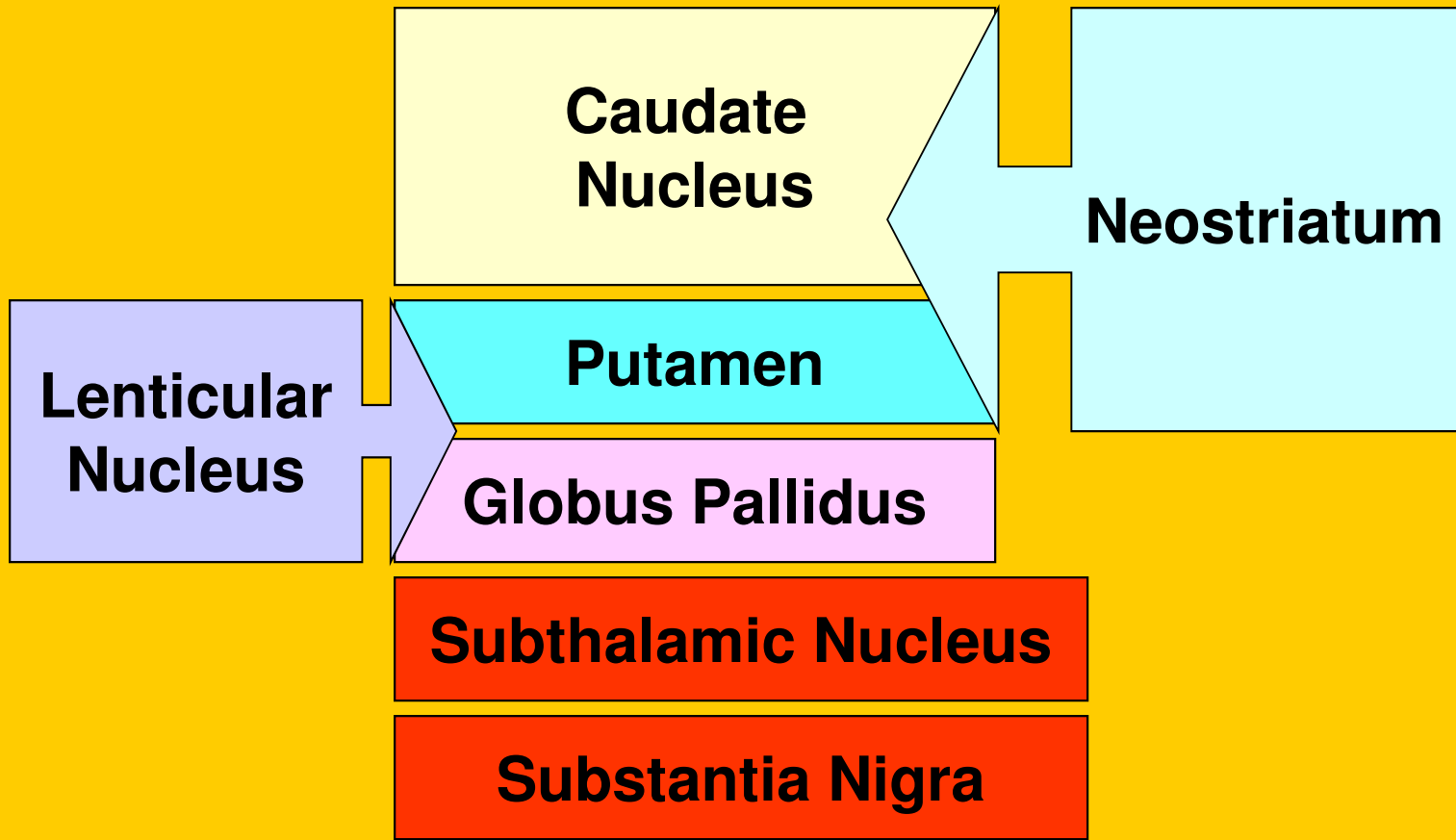
**At the end of this Presentations you should be able to:**

- ❖ Describe the functional divisions of basal ganglia
- ❖ Enumerate basic circuits of movements control
- ❖ Explain Caudate and putamen circuit
- ❖ Explain Direct & Indirect Pathways with Neurotransmitters
- ❖ Appreciate general functions of basal ganglia
- ❖ Diagnose basal ganglial disorders



# Basal Nuclei

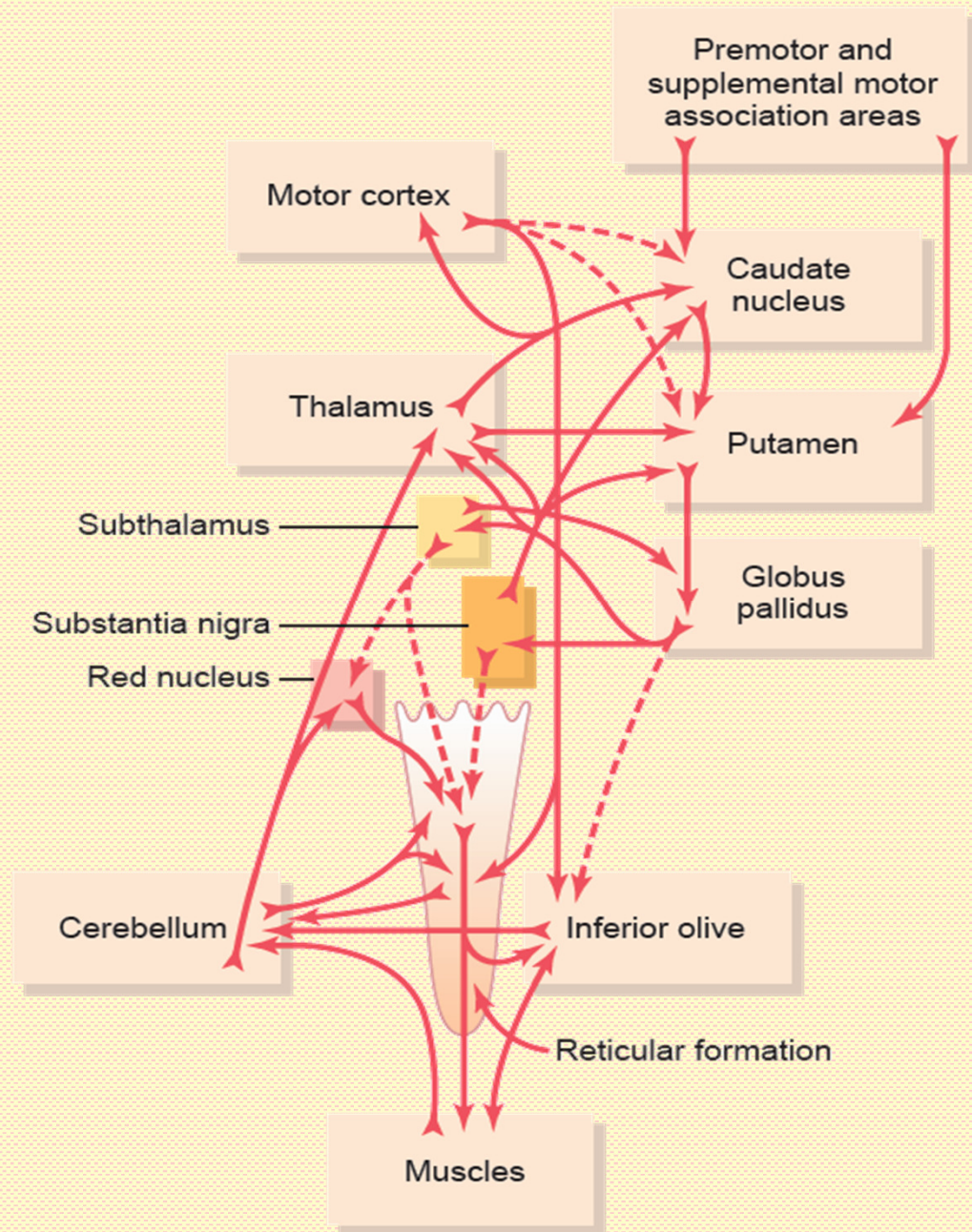
## 5 FUNCTIONAL PARTS



**Corpus striatum = Caudate nucleus plus lentiform nucleus**  
**Neostriatum (striatum) = Caudate nucleus plus putamen**



# Complex Circuitry of Motor Control



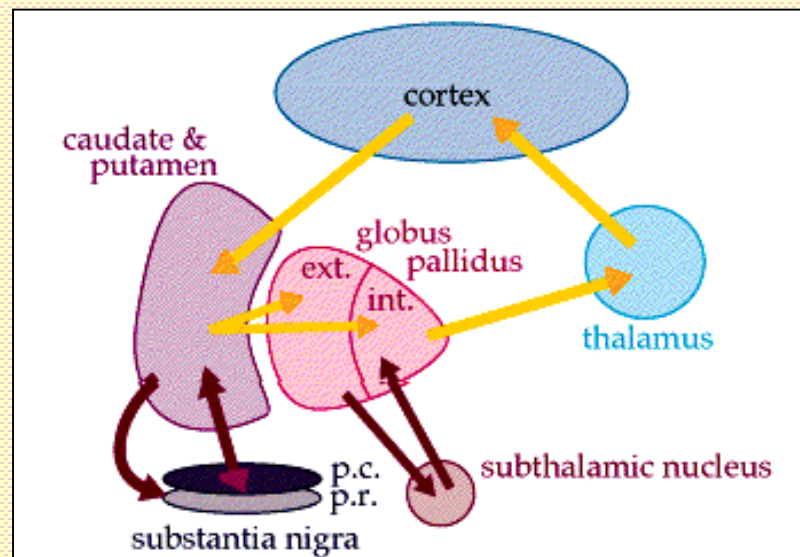
# MAIN INPUT TO THE BASAL GANGLIA

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 MOVEMENTS CONTROL

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.

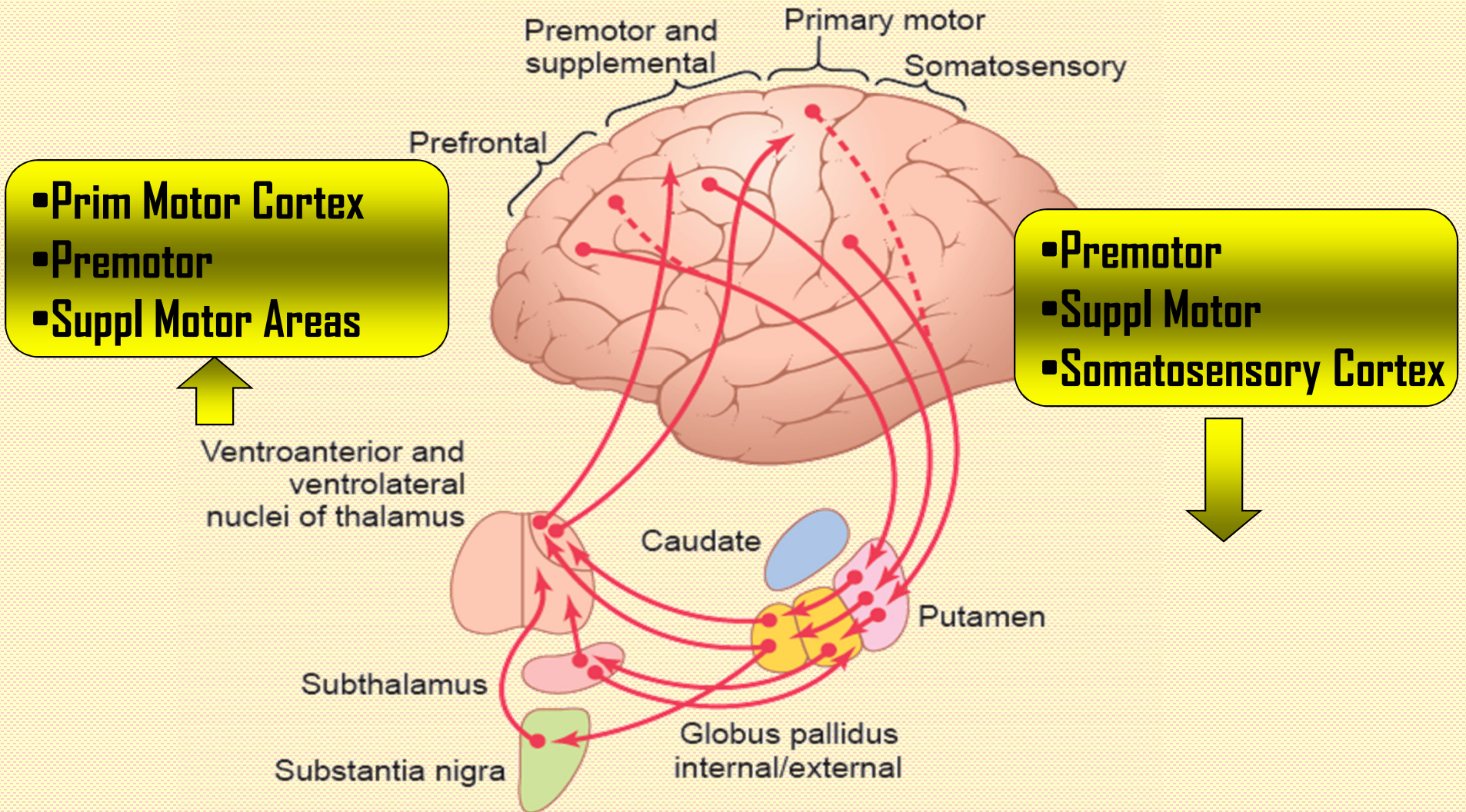
(Note: cognition means thinking process using sensory input with information already stored in memory.)

3. **Limbic loop** involved in giving motor expression to emotions like, smiling, aggressive or submissive posture (**via nucleus accumbens reward circuit**).

4. **Occulomotor loop** concerned with voluntary eye movement [ saccadic movement]

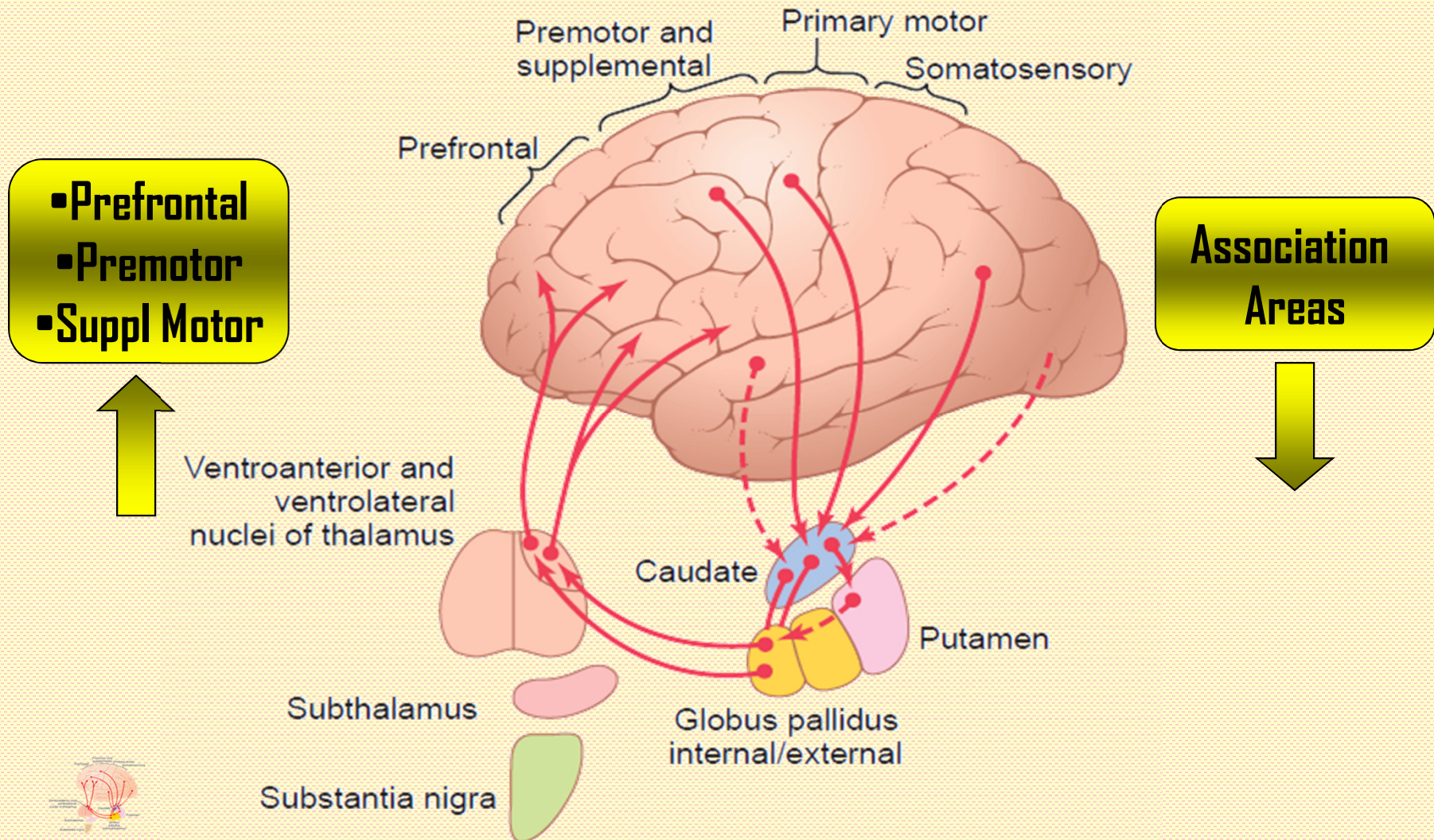


# The Putamen Circuit





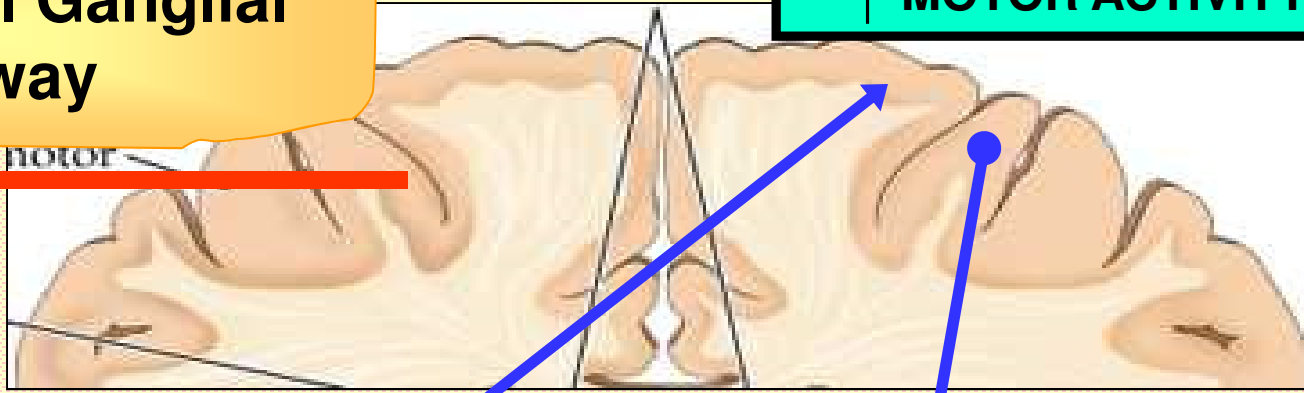
# The Caudate Circuit





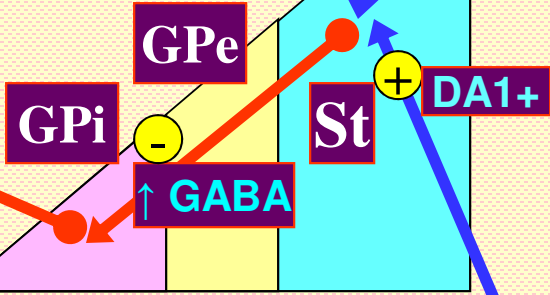
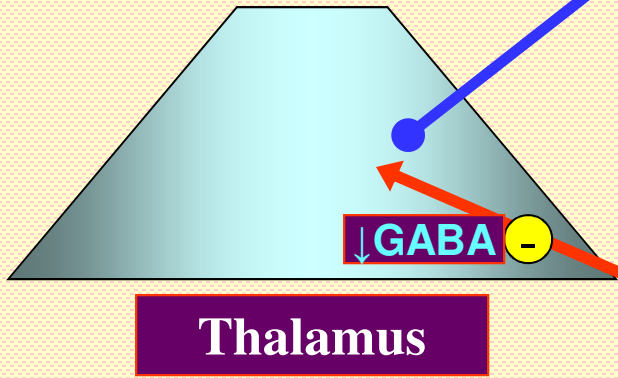
# Direct Basal Ganglial Pathway

↑ MOTOR ACTIVITY

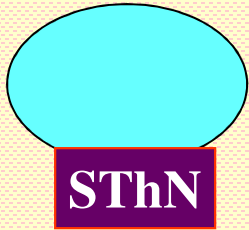


GLU ⊕

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Thalamocortical Neurons are disinhibited



Parkinson's Disease

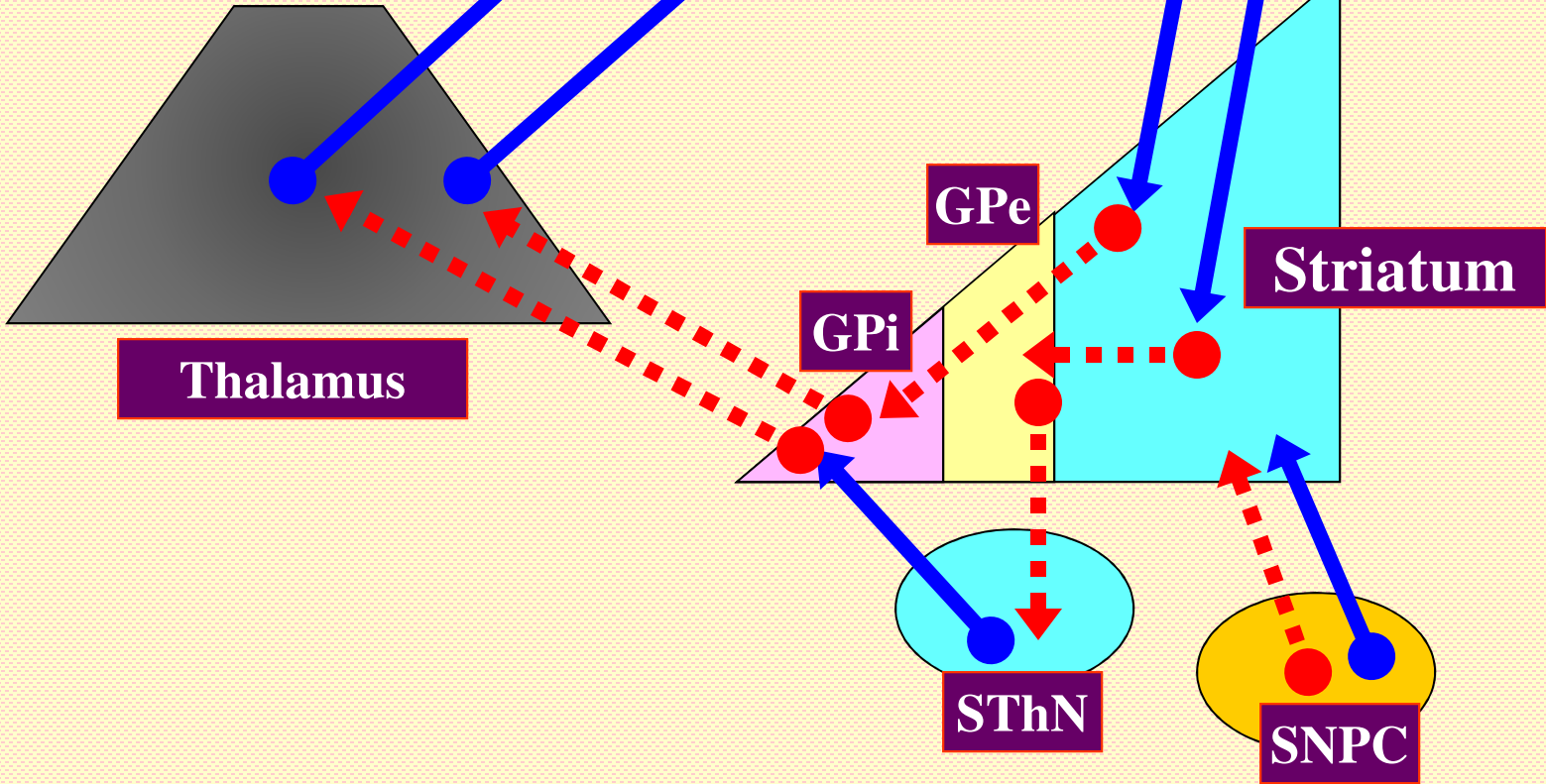
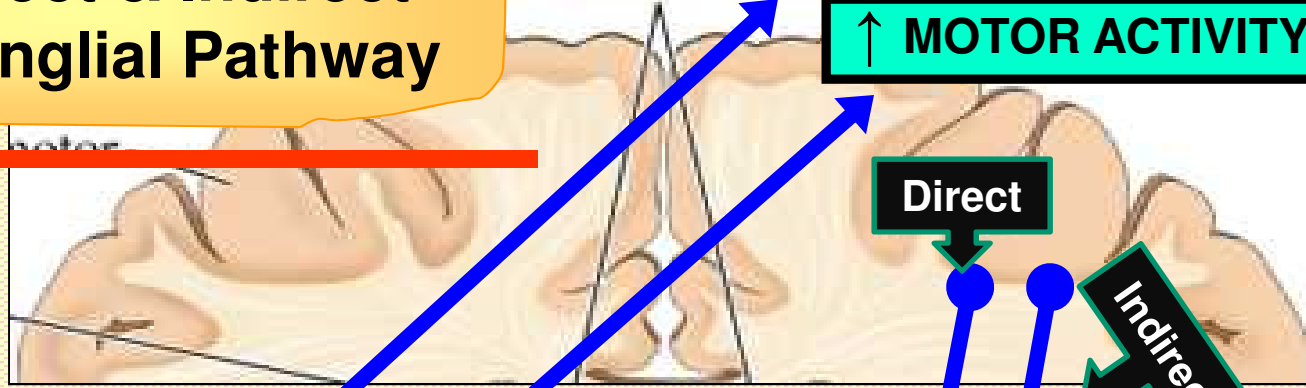




# Both Direct & Indirect Basal Ganglial Pathway

↓ MOTOR ACTIVITY

↑ MOTOR ACTIVITY



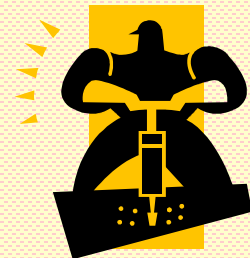
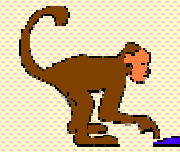
# The Putamen Circuit

## Executes Learned Patterns of Motor Activity

Works in association with the corticospinal system to control complex patterns of **MOTOR ACTIVITY PERFORMED SUBCONSCIOUSLY.**

Examples are:

- Writing of letters of the alphabet
- Cutting paper with scissors
- Hammering nails
- Shooting a basketball through a hoop
- Passing a football
- Most aspects of vocalization



**SUBCONSCIOUSLY WITHOUT A PLAN**



# The Caudate Circuit

## Cognitive Control of Sequences of Motor Patterns

- **THINKING PROCESSES OF THE BRAIN**, using both sensory input to the brain plus information already stored in memory.
- 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.

**WHICH PATTERNS OF MOVEMENT WILL BE USED TOGETHER TO ACHIEVE A COMPLEX GOAL?**

# The Caudate Circuit

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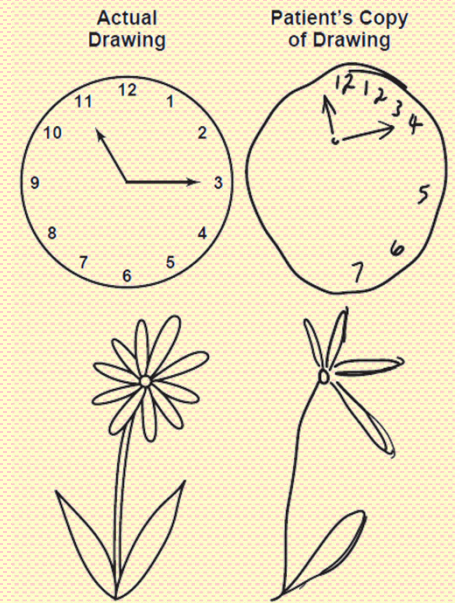
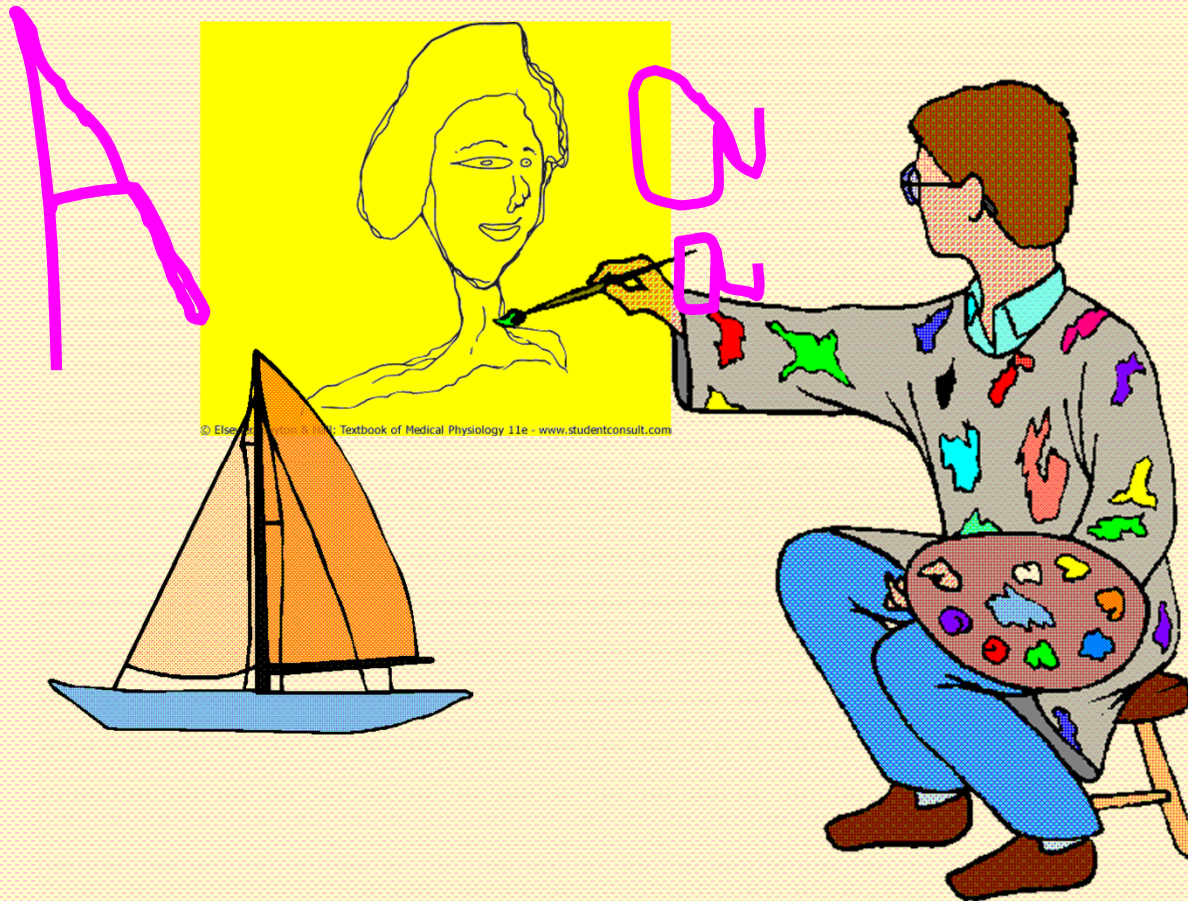


# The Caudate Circuit

## Timing and Scaling 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





## Damage to Caudate Circuit Results in

- Inability to organize pattern of movements to achieve a complex goal.
- Inability to write or draw figures with fixed scale.
- Loss of timing and scaling of movements.

A scroll with a light beige background and a dark brown border. The scroll is unrolled, showing a central yellow banner with the text 'BASAL GANGLIA' in purple. Below the banner, the text 'DISORDERS' is in black, followed by a list of categories: 'MOVEMENTS SPEECH', 'POSTURE', 'GAIT', 'MENTAL ACTIVITY', and 'OTHERS' in black. The scroll is held by four wooden rollers at the corners.

# **BASAL GANGLIA**

## **DISORDERS**

**MOVEMENTS SPEECH**

**POSTURE**

**GAIT**

**MENTAL ACTIVITY**

**OTHERS**

# Movement Disorders

## Hyperkinetic

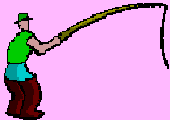
- **Chorea**
  - Huntington's Disease
  - Saint Vitus Dance (Sydenham's Chorea)
- **Athetosis**
- **Dystonia**
- **Hemiballismus/Ballismus**
- **Tardive Dyskinesia**
- **Wilson's Disease**

Lesions affect Indirect  
Pathway Predominantly

## Hypokinetic

- **Parkinson's Disease**
  - Drug Induced eg; MPTP induced
  - Dopamine receptor blockers eg; Neuroleptics & antipsychotic drugs

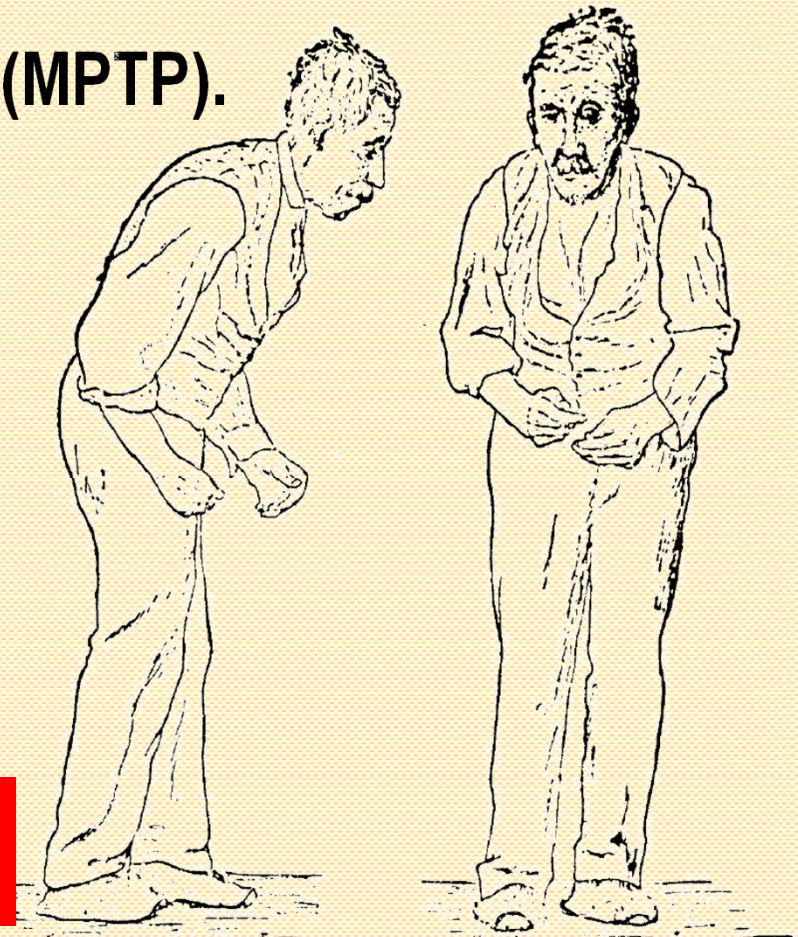
Lesions affect Direct Pathway  
Predominantly

Movement Disorder	Features	Lesion
Chorea	Multiple quick involuntary, random/purposeless movements, usually most prominent in the appendicular muscles	Atrophy of the <b>striatum</b> . Huntington Chorea Saint Vitus Dance (post streptococcal infection)
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>
Tardive Dyskinesia	Either temporary or permanent uncontrolled involuntary movements of the face and tongue and cogwheel rigidity	Neuroleptic drugs blocking dopaminergic transmission



# Parkinson's Disease

- Degeneration of dopaminergic nigrostriatal neurons (60-80 %).
- Methyl-Phenyl-Tetrahydro-Pyridine (MPTP). The oxidant MPP+ is toxic to SN.
- **FIVE CARDINAL FEATURES**
  - Tremor
  - Rigidity
  - Akinesia & Bradykinesia
  - Postural Changes
  - Speech Changes



Loss of DA → Lose excitatory effect on direct & lose inhibition of indirect pathway

# 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 and patient develops choreiform movements and dystonia

