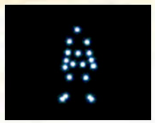


PHYSIOLOGY OF BASAL GANGLIA AND REGULATORY MECHANISMS





Dr Syed Shahid Habib

MBBS DSDM FCPS

Professor & Consultant Clinical Neurphysiology

Dept. of Physiology

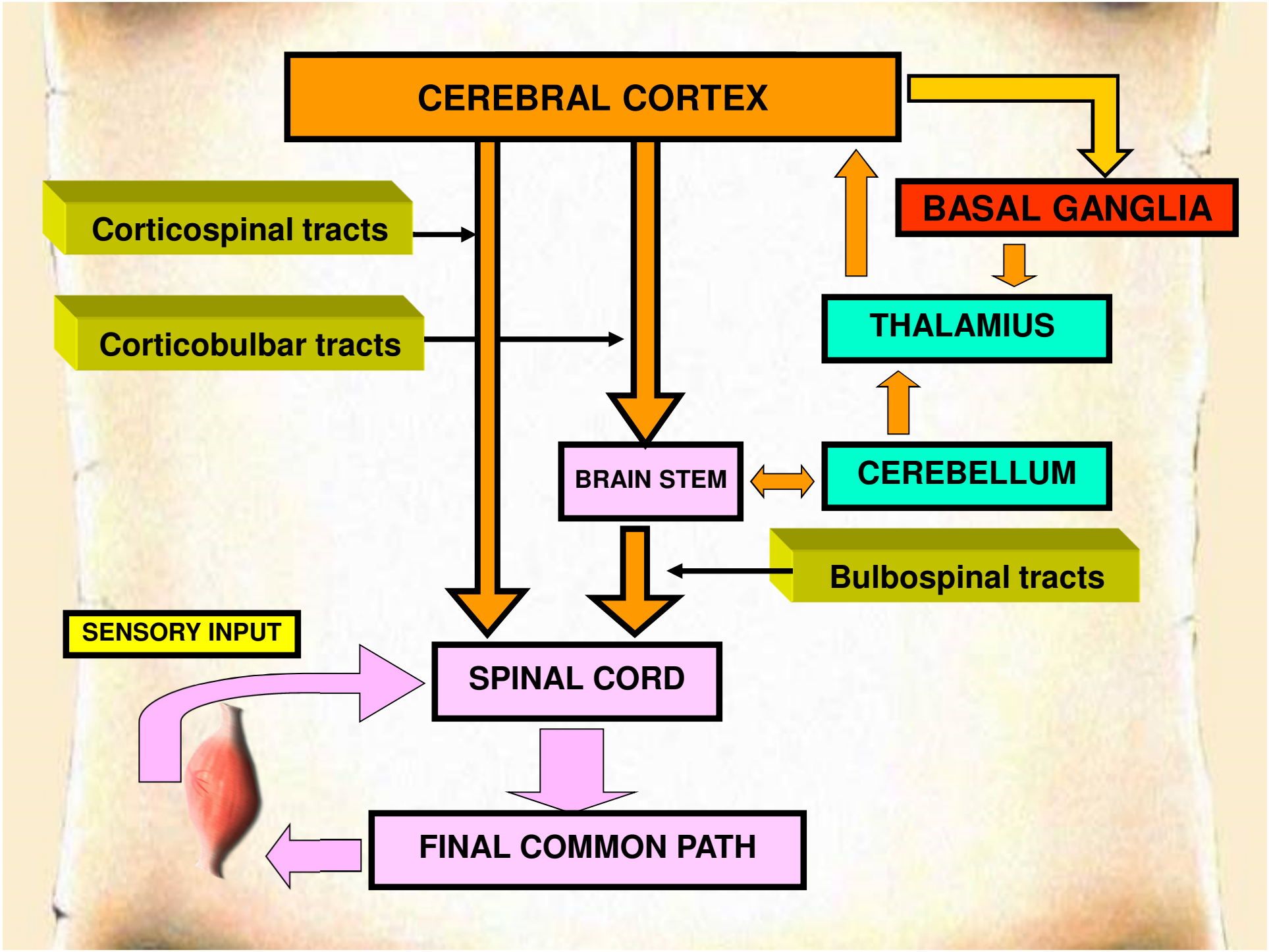
King Saud University

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***

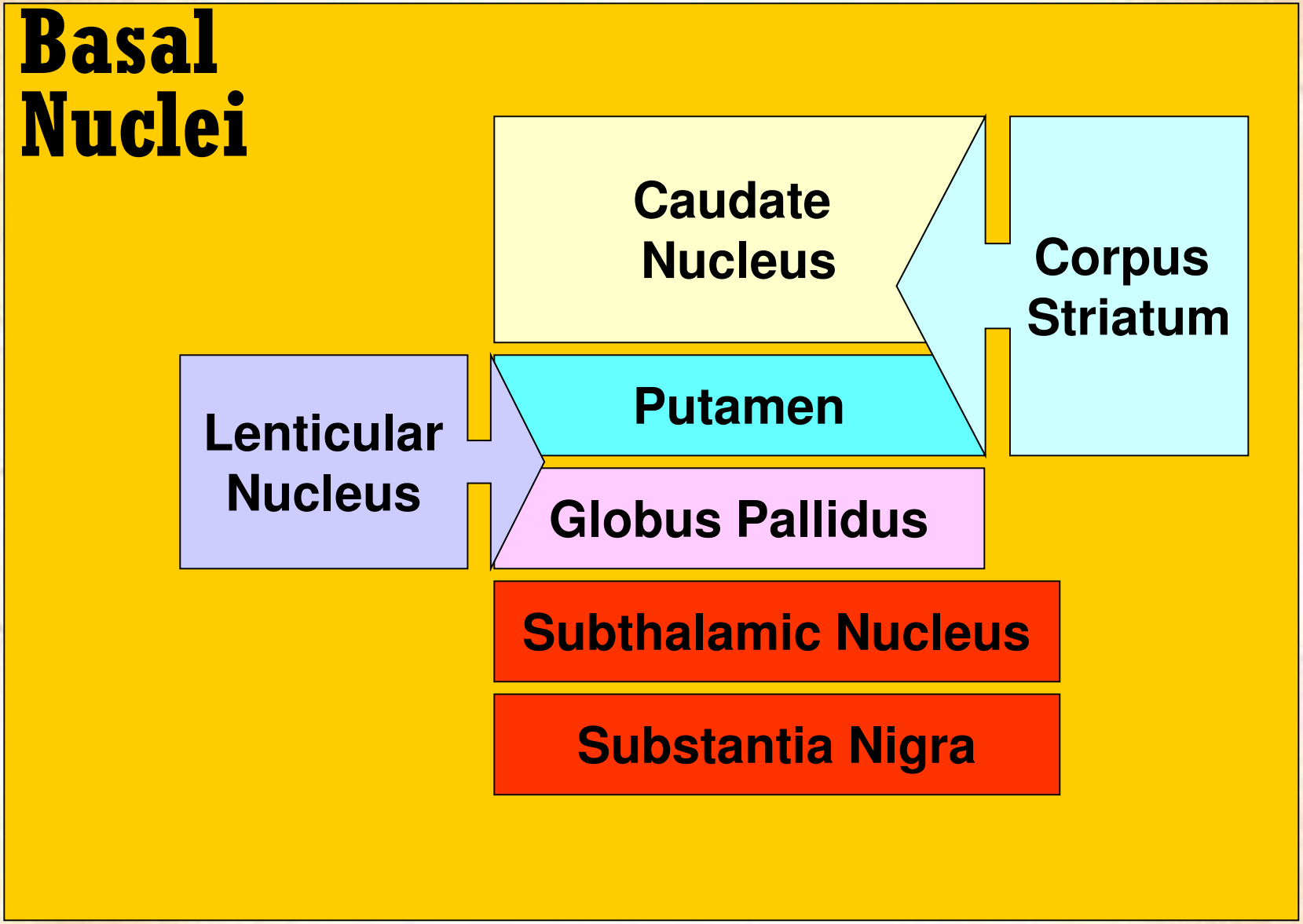
OVERVIEW OF MOTOR ACTIVITY CONTROL


CEREBRAL CORTEX
BASAL GANGLIA
Corticospinal tracts
Corticobulbar tracts
THALAMIUS
BRAIN STEM
CEREBELLUM
Bulbospinal tracts
SENSORY INPUT
SPINAL CORD
FINAL COMMON PATH

BASAL GANGLIA

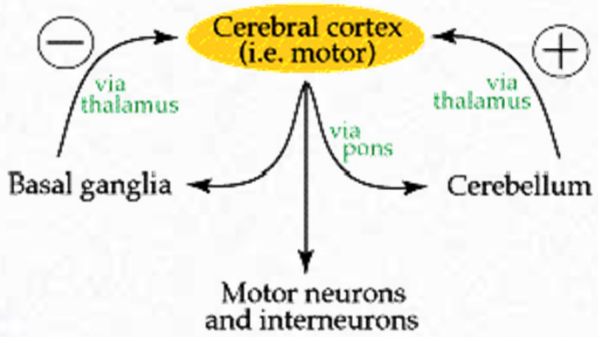
COMPONENTS
FUNCTIONAL ANATOMY

Basal Nuclei

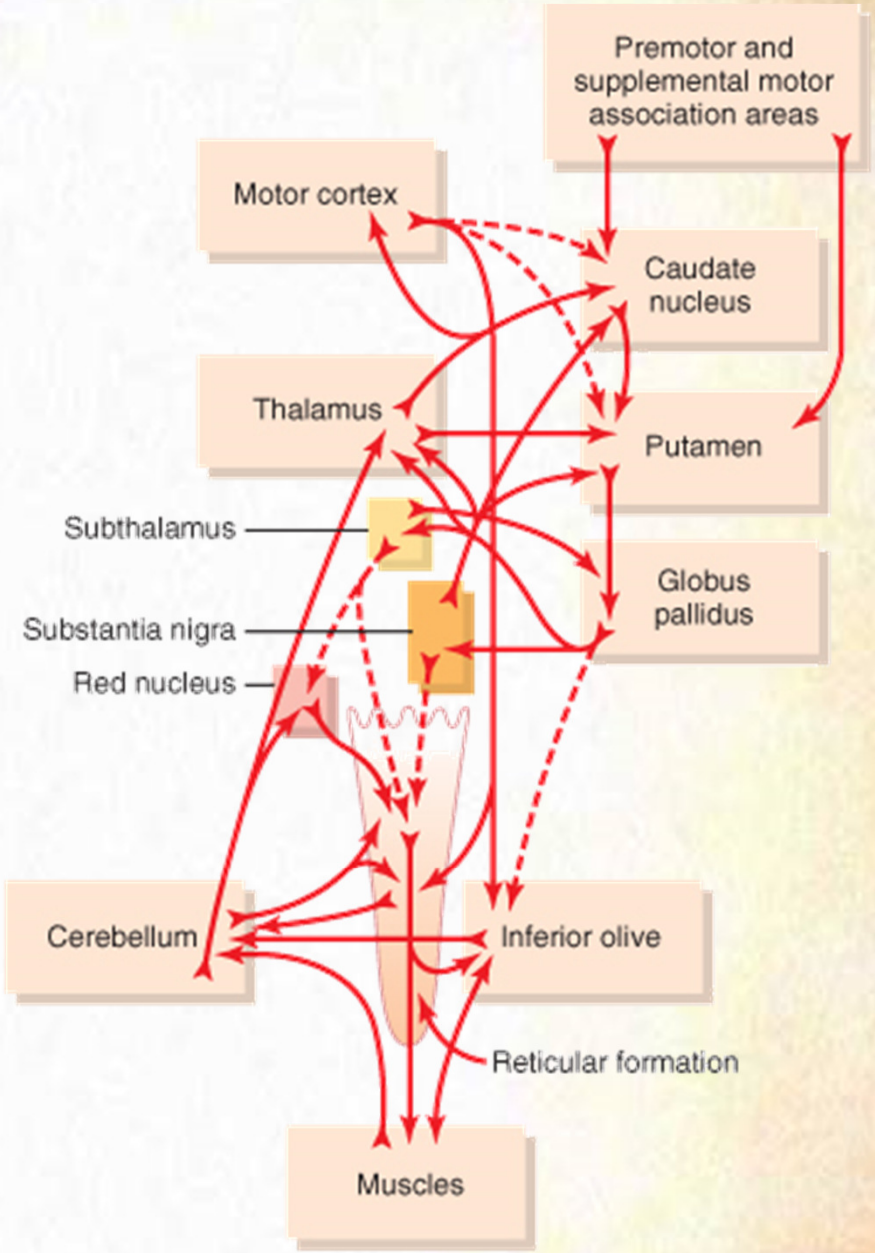


BASAL GANGLIA

CONNECTIONS

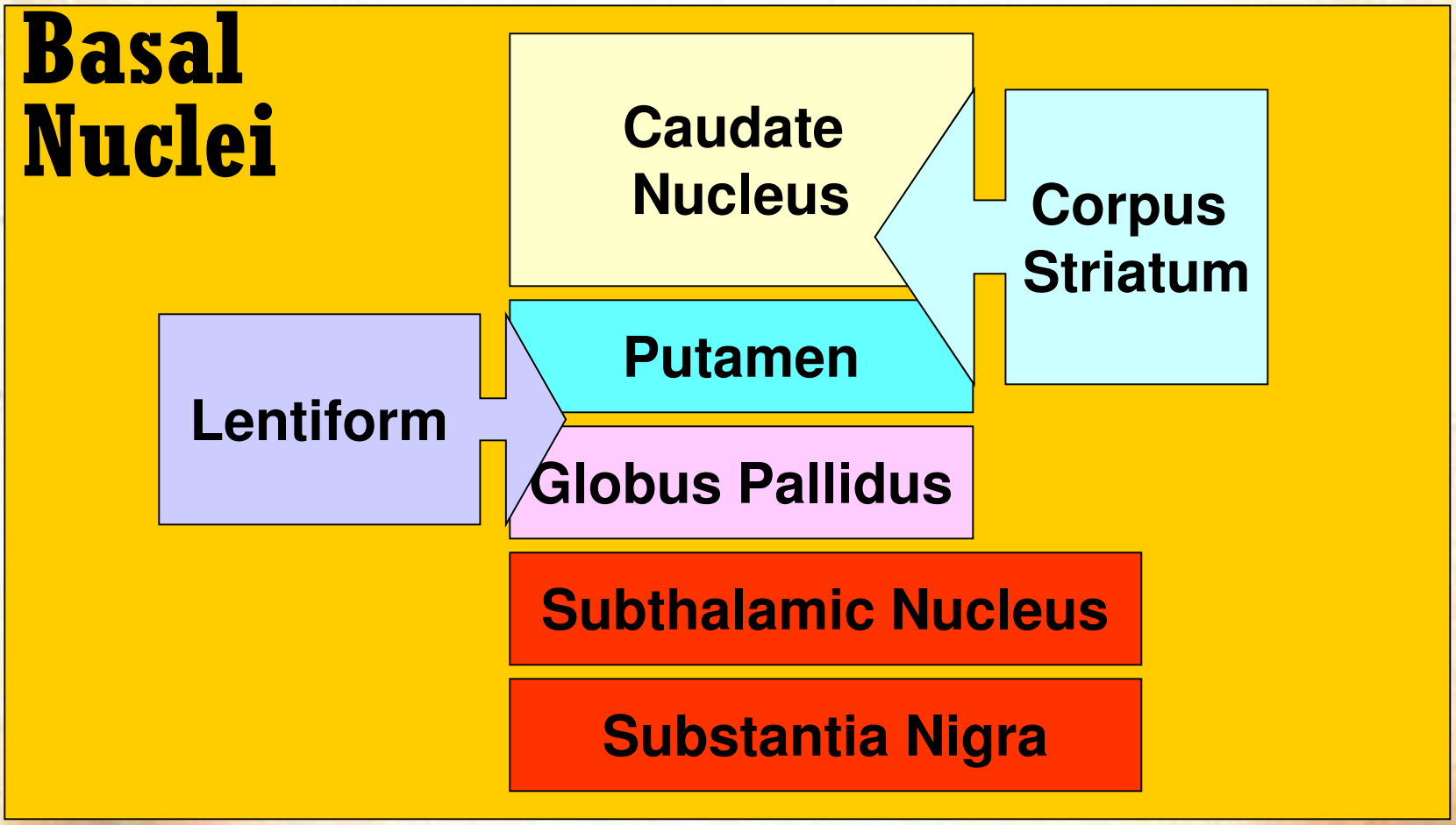


Connections for Motor Control



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

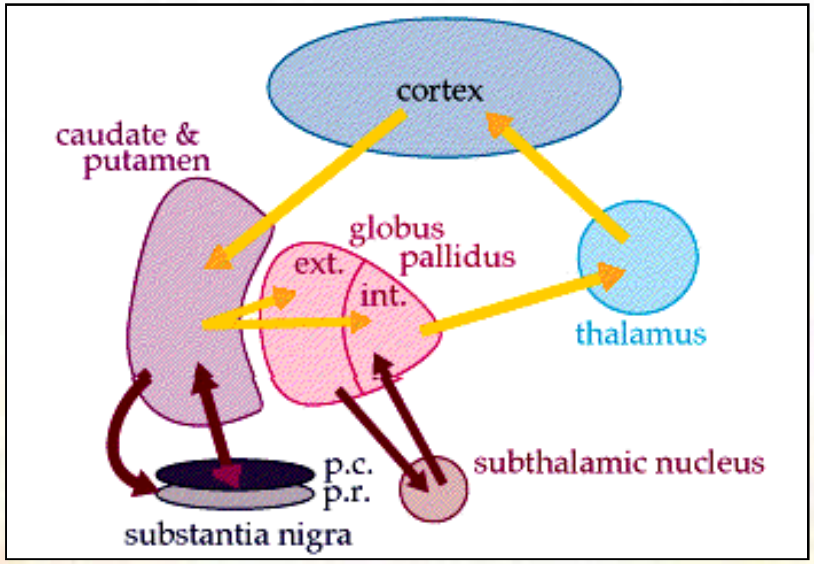
The comes from the cerebral cortex (motor area) and projects to the NEOSTRIATUM

(a term for the caudate nucleus and putamen)

THE MAIN OUTPUT

Is via the thalamus to the cerebral cortex

(motor area)

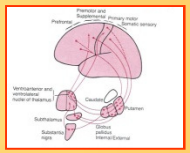


BASIC CIRCUITS FOR CONTROL OF MOVEMENTS

1. **Motor loop (putamen circuit)** concerned with learned movment.
2. **Cognitive loop (Caudate circuit)** concerned with cognitive control of sequences of motor pattern. Basically it is concerned with motor intentions.

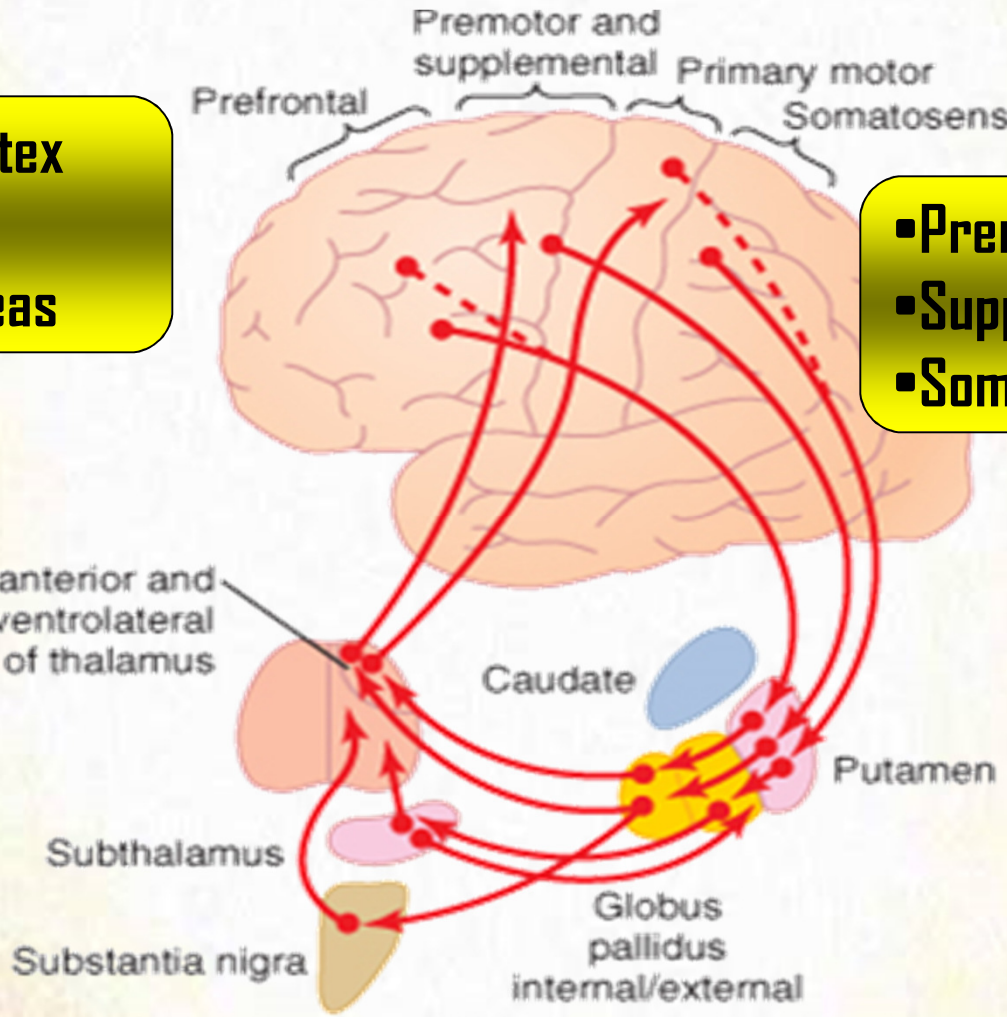
   (Note: cognition means thinking process using sensory input with information already stored in memory.)
3. **Limbic loop** involved in giving motor expression to emotions like, smiling, aggressive or submissive posture.
4. **Occulomotor loop** concerned with voluntary eye movement [saccadic movement]

The Putamen Circuit

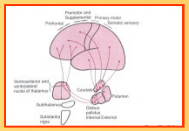


- Prim Motor Cortex
- Premotor
- Suppl Motor Areas

- Premotor
- Suppl Motor
- Somatosensory Cortex

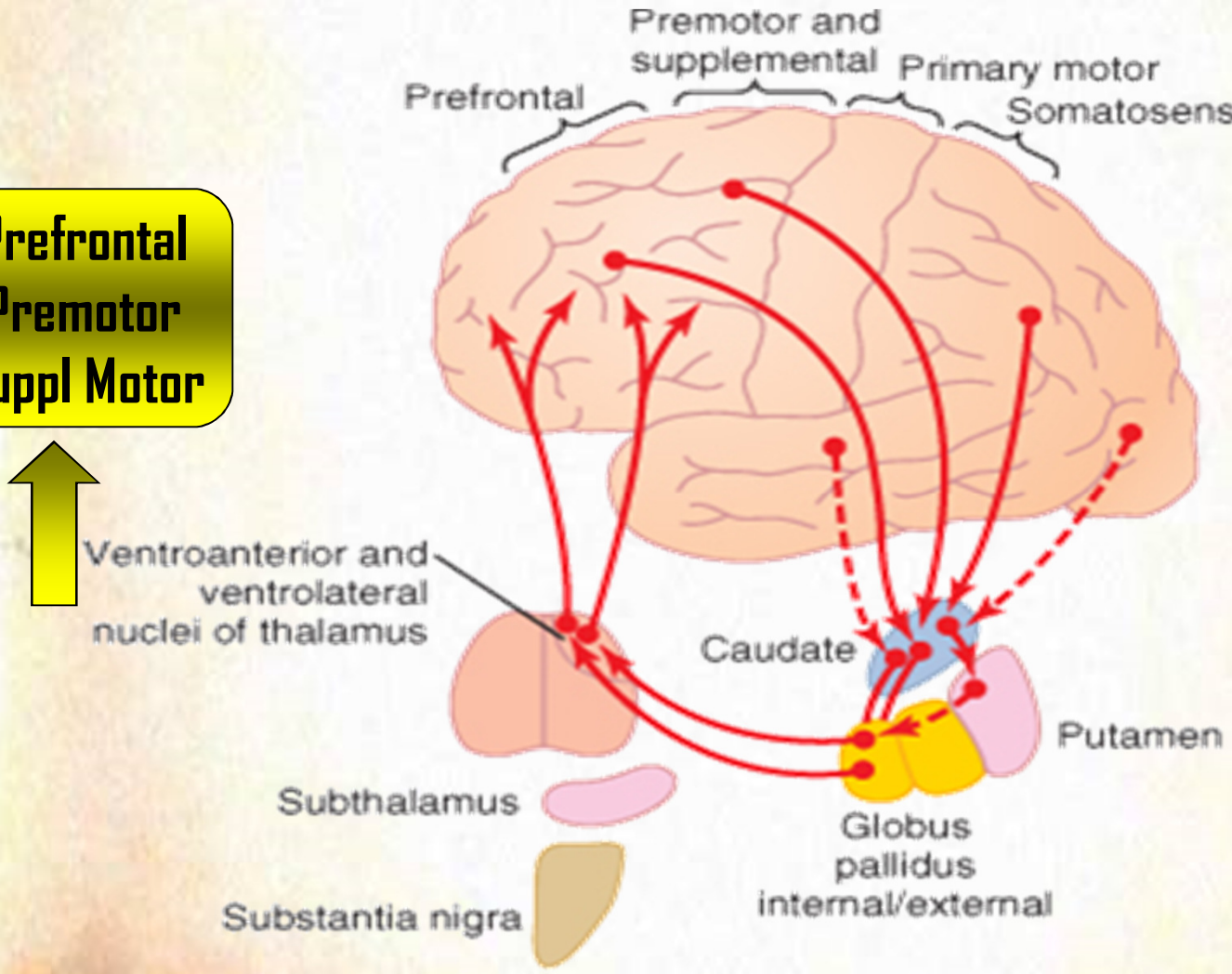


The Caudate Circuit

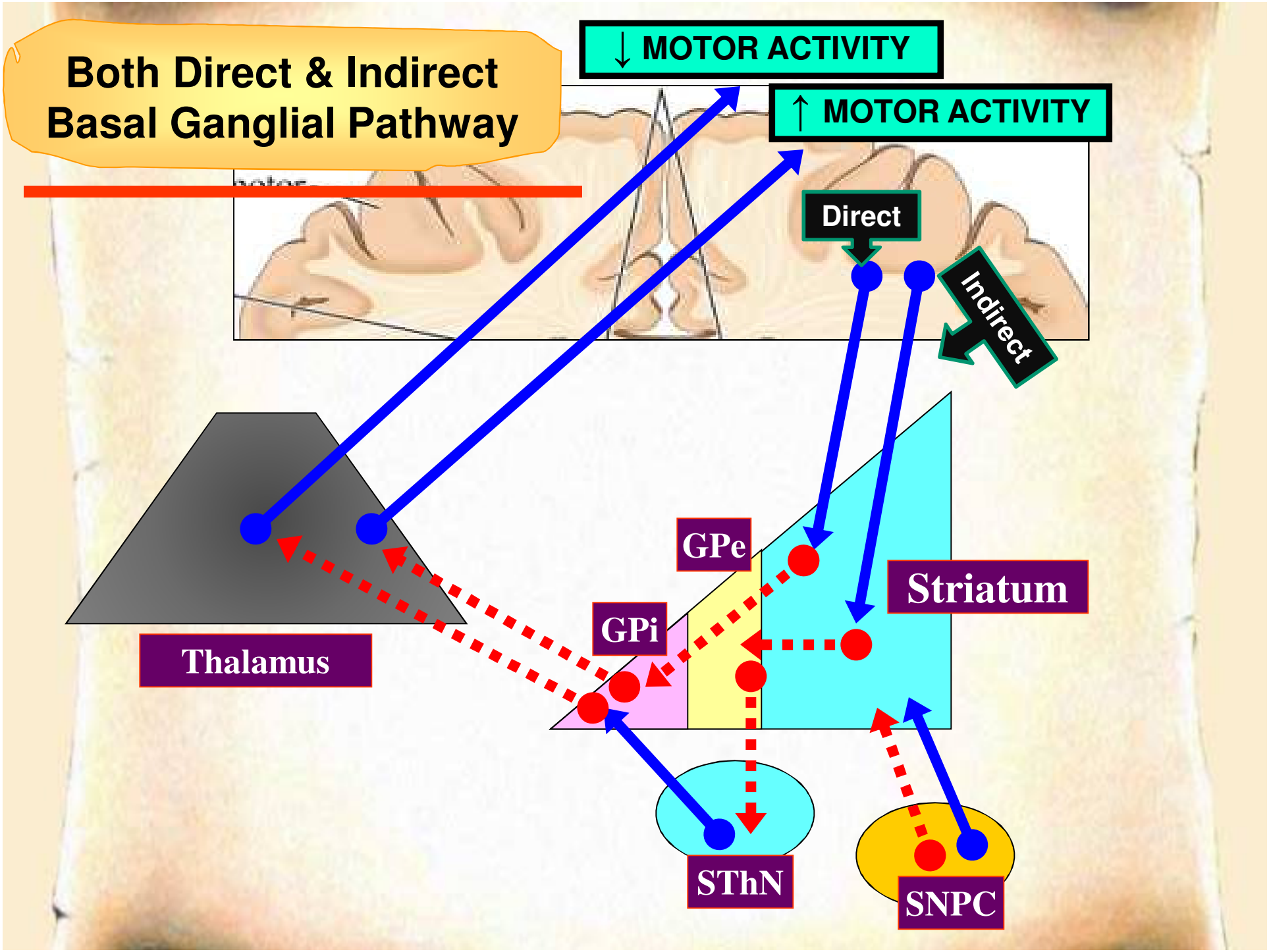


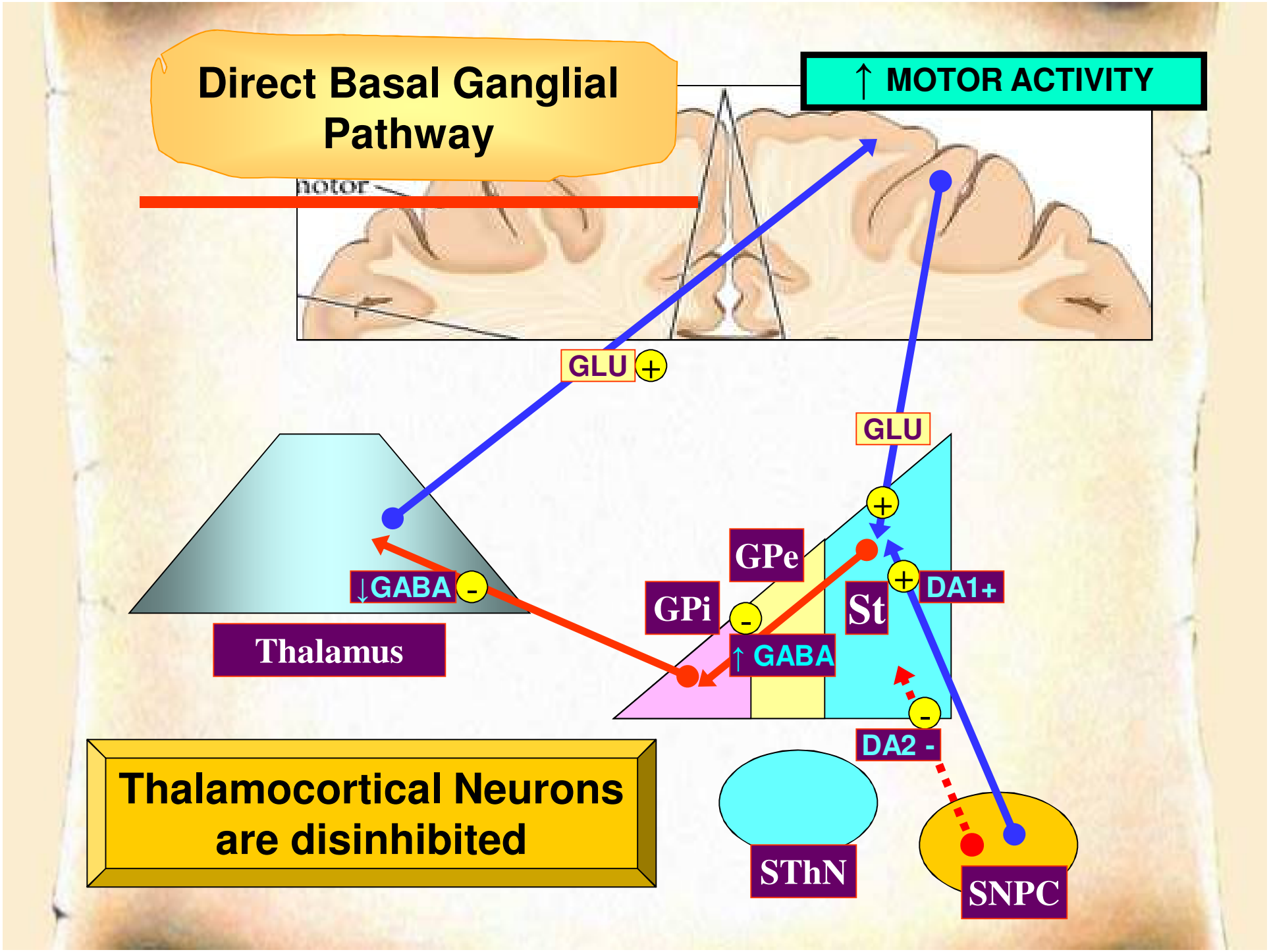
- Prefrontal
- Premotor
- Suppl Motor

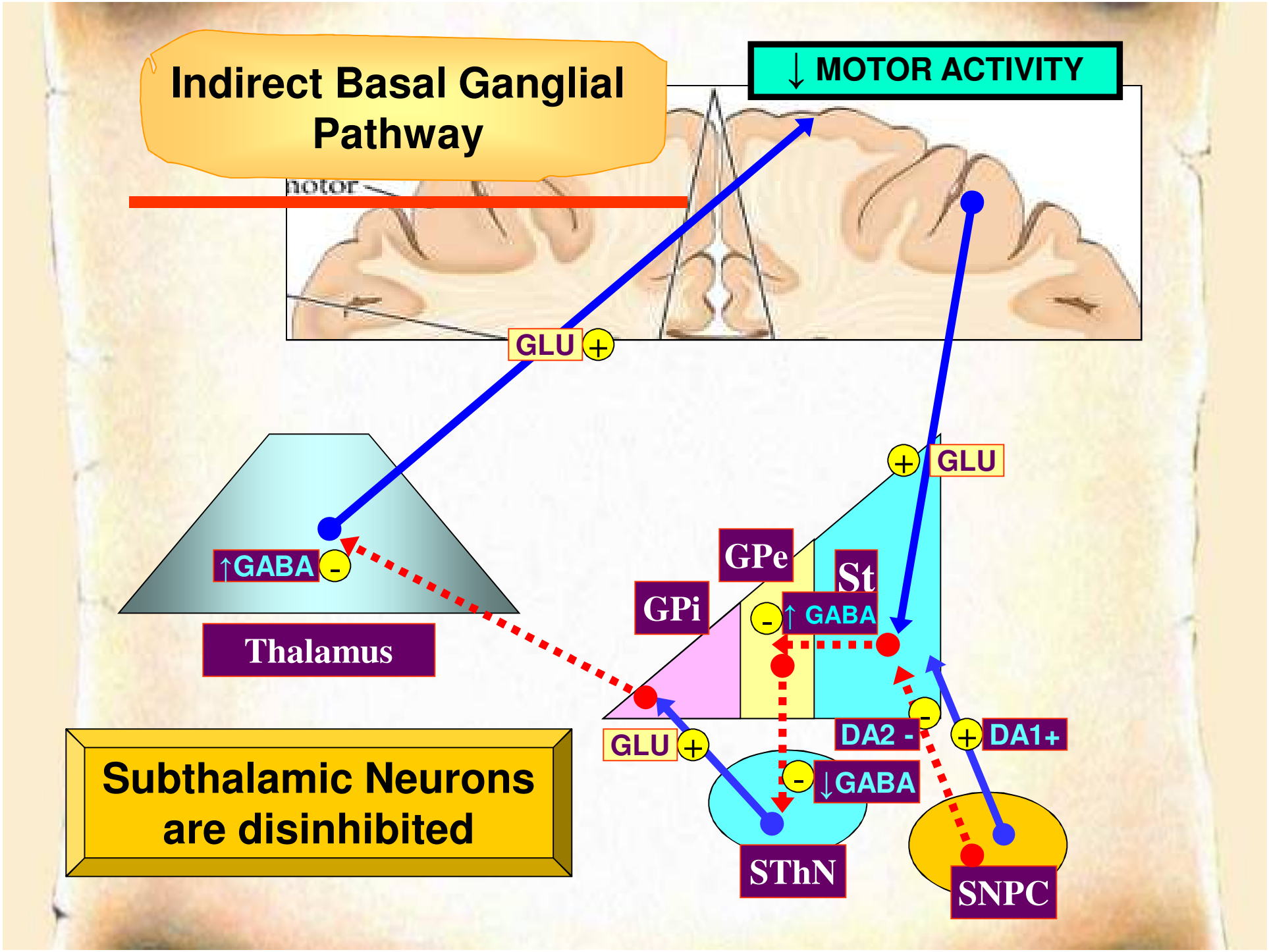
Association Areas

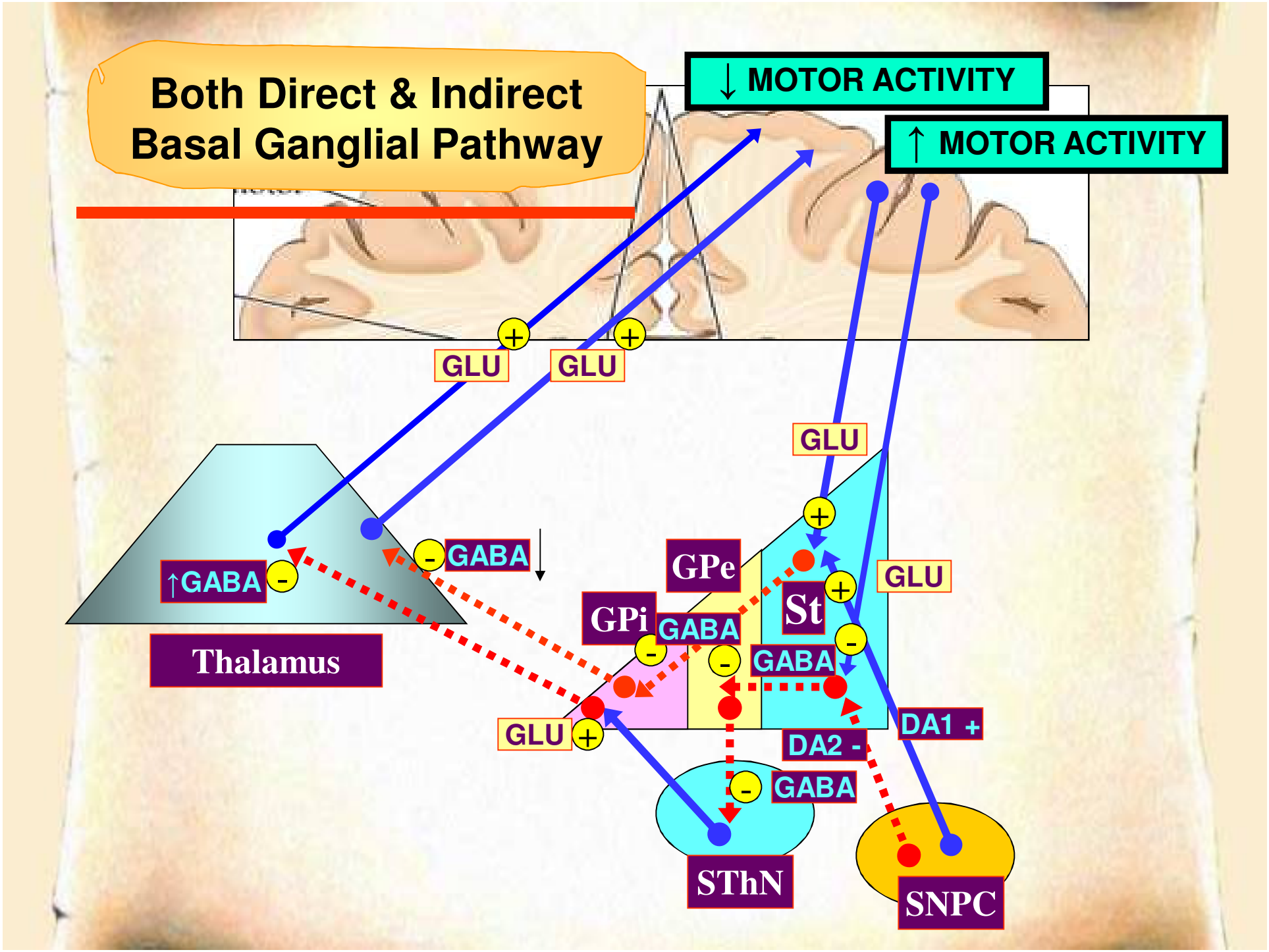


Basal Ganglial Pathways
Direct and Indirect


Both Direct & Indirect
Basal Ganglial Pathway
↓ MOTOR ACTIVITY
↑ MOTOR ACTIVITY
Direct
Indirect
Thalamus
GPe
GPi
Striatum
SThN
SNPC


Direct Basal Ganglial Pathway
↑ MOTOR ACTIVITY
GLU +
GLU
+
↓GABA -
Thalamus
GPe
GPi
-
St
+
DA1+
↑ GABA
-
DA2 -
Thalamocortical Neurons are disinhibited
SThN
SNPC


Indirect Basal Ganglial Pathway
↓ MOTOR ACTIVITY
GLU +
↑GABA -
Thalamus
+ GLU
GPe
St
GPi
- ↑ GABA
GLU +
DA2 -
+ DA1+
- ↓GABA
SThN
SNPC
Subthalamic Neurons are disinhibited


Both Direct & Indirect
Basal Ganglial Pathway
↓ MOTOR ACTIVITY
↑ MOTOR ACTIVITY
GLU
GLU
GLU
GLU
↑GABA
GABA
Thalamus
GPe
GPi
GABA
St
GABA
GLU
GLU
DA1 +
DA2 -
GABA
SThN
SNPC

Metabolic characteristics

- 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

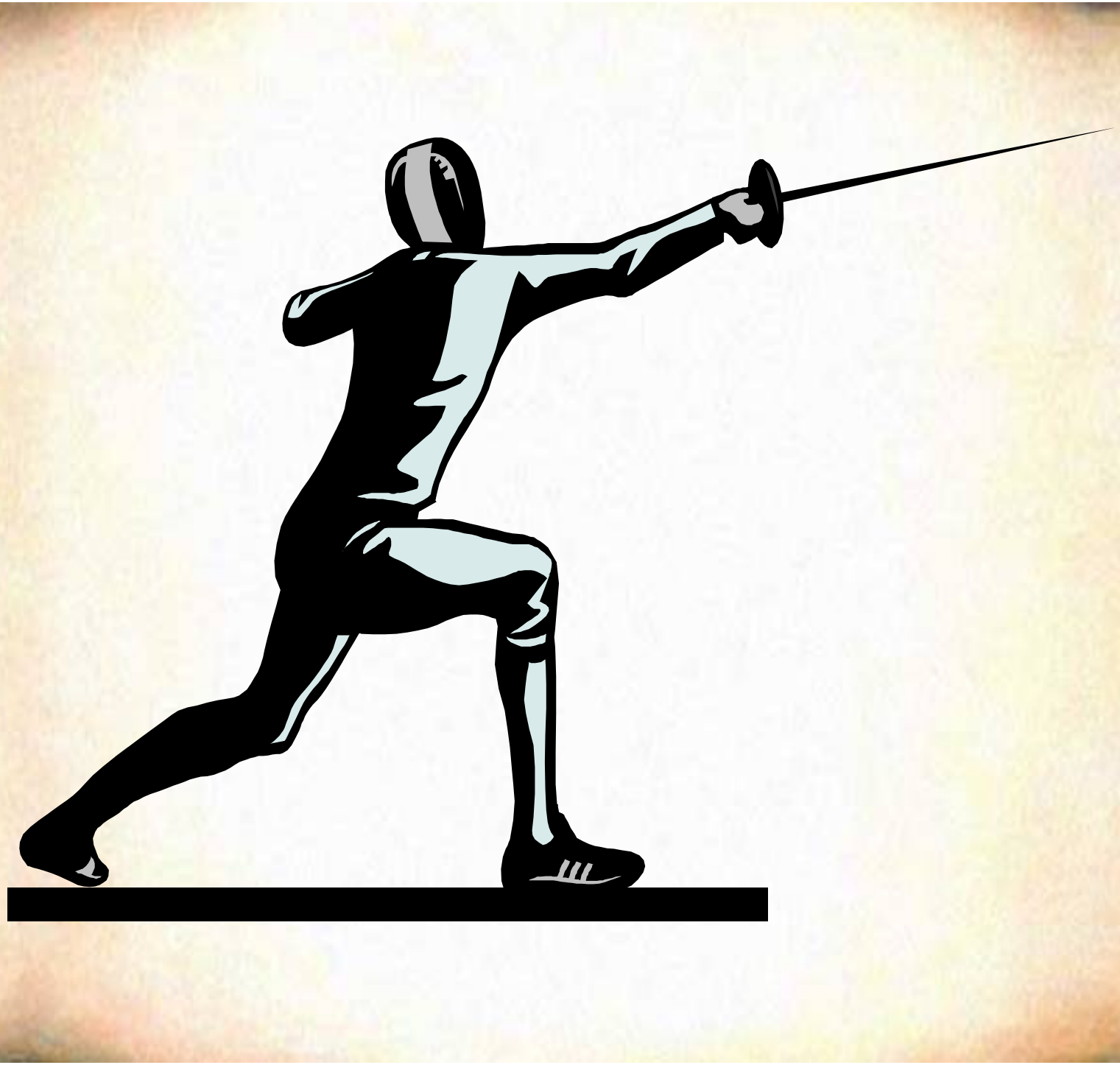
FUNCTIONS

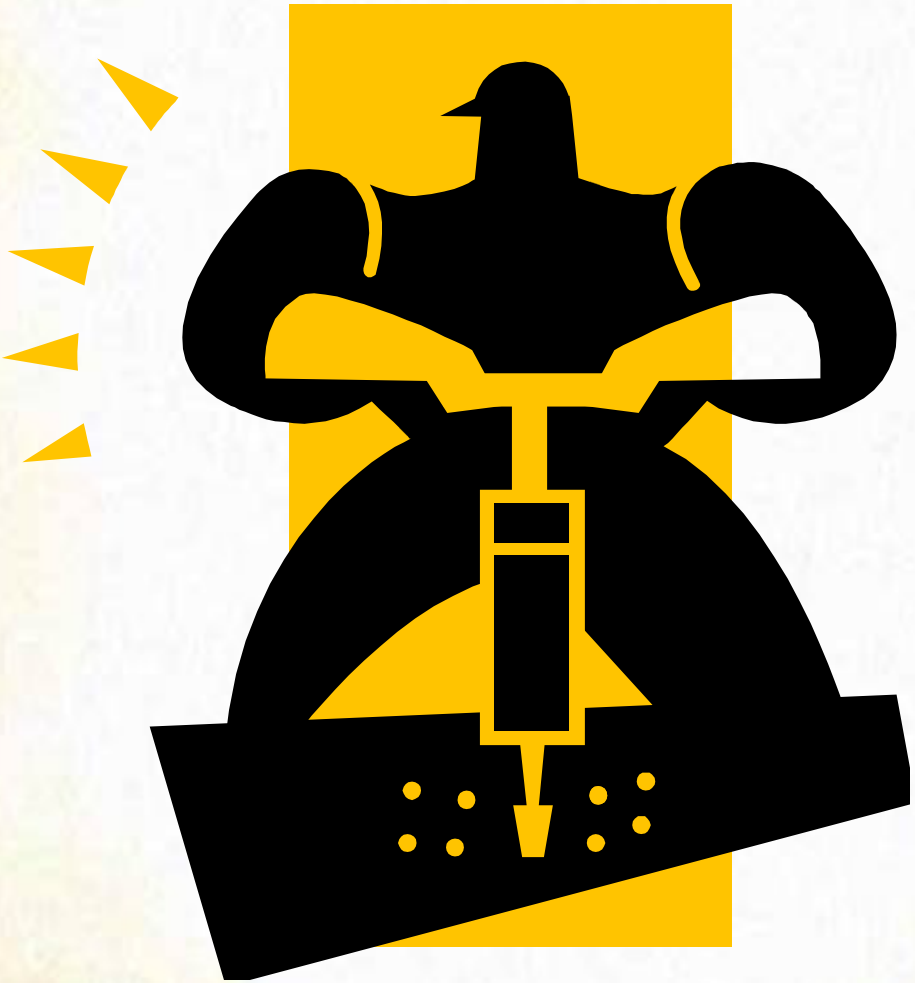
- Control of movements
- Planning and programming of movements
- Cognition

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, which are **performed subconsciously**.





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 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)

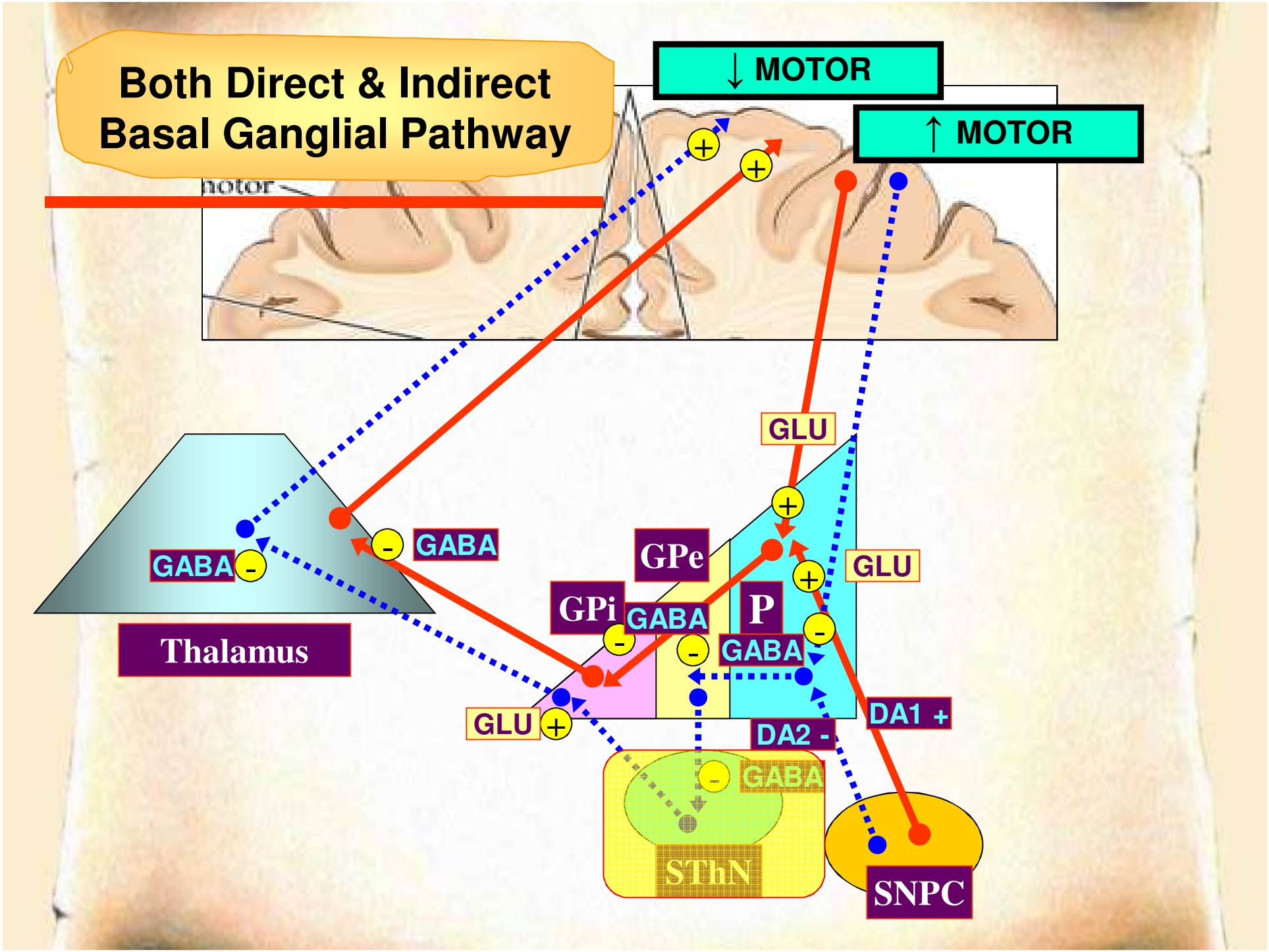
Movement Disorder	Features	Lesion
Chorea	Multiole quick, random movements, usually most prominent in the appendicular muscles	Atrophy of the striatum. Huntington Chorea
Athetosis	Slow writhing movements,which are usually more severe in the appendicular muscles	Diffuse hypermyelination of corpus striatum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

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+ is toxic to SN.
- Five cardinal features
  - Tremor
  - Rigidity
  - Akinesia & Bradykinesia
  - Postural Changes
  - Speech Changes

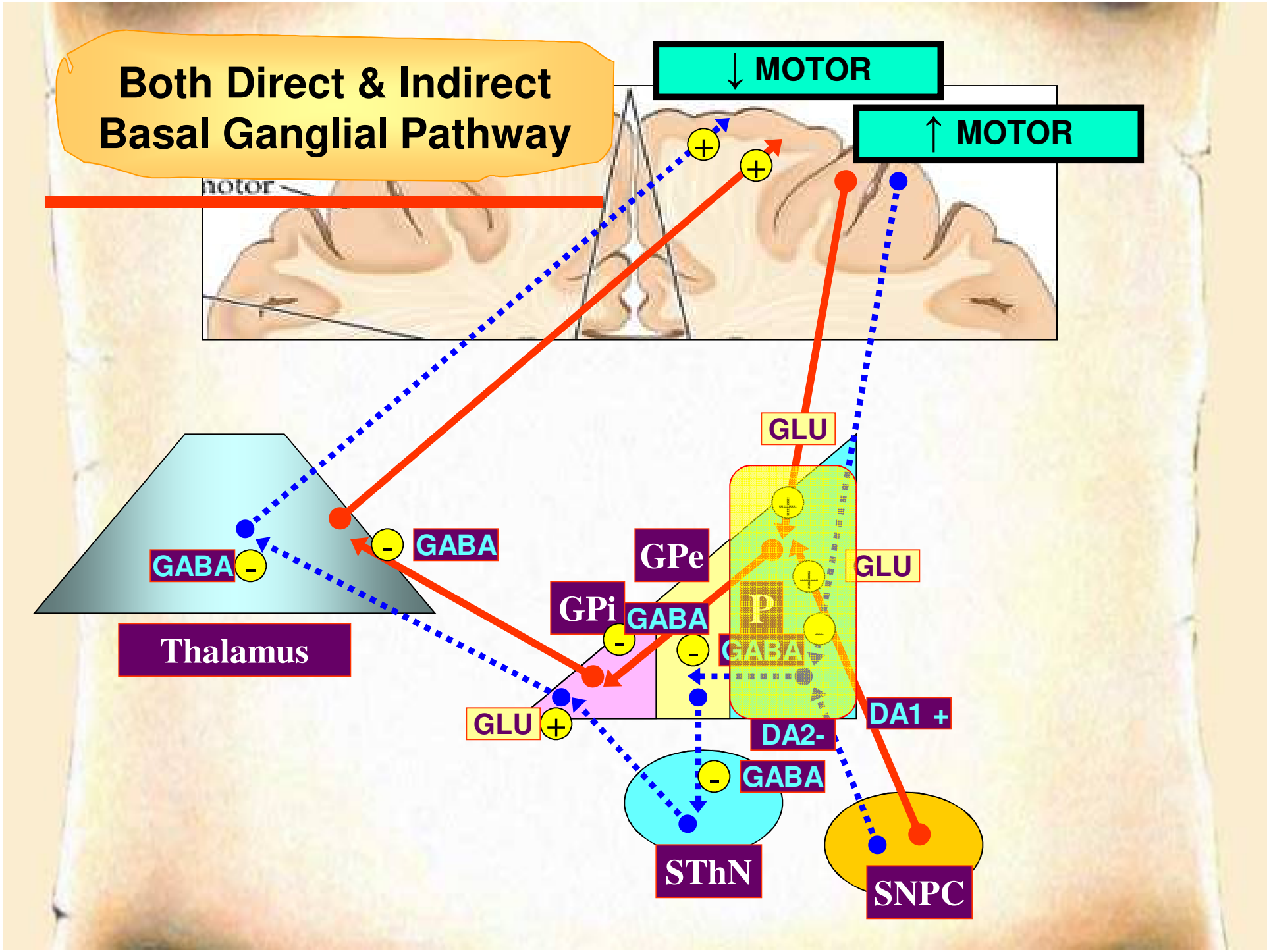
Hemiballismus

- Injury usually to STN
- Decreased inhibition (Indirect Pathway)
- Characterized by uncontrolled flinging
- TX: Dopamine Antagonist


Both Direct & Indirect
Basal Ganglial Pathway
↓ MOTOR
↑ MOTOR
motor
GLU
GABA
GABA
GPe
GPi
GABA
P
GLU
GABA
Thalamus
GLU
DA2 -
DA1 +
GABA
STN
SNPC

Huntington's Disease

- Hereditory , autosomal dominant
- Rare onset at 30-40s as early as 20s
- Disease of caudate & putamen.
- Early, Jerky movement of hands toward end of reaching an object
- Later, hyperkinetic choreiform movements appear and gradually increase until they incapacitate the patient
- Slurred speech and incomprehensive
- Progressive Dementia
- Loss of GABA nergic neurons


Both Direct & Indirect
Basal Ganglial Pathway
↓ MOTOR
↑ MOTOR
GLU
GABA
GABA
GPe
GPi
GABA
GLU
P
GABA
Thalamus
GLU
DA1 +
DA2-
GABA
SThN
SNPC