PHYSIOLOGY OF BASAL GANGLIA AND REGULATORY MECHANISMS




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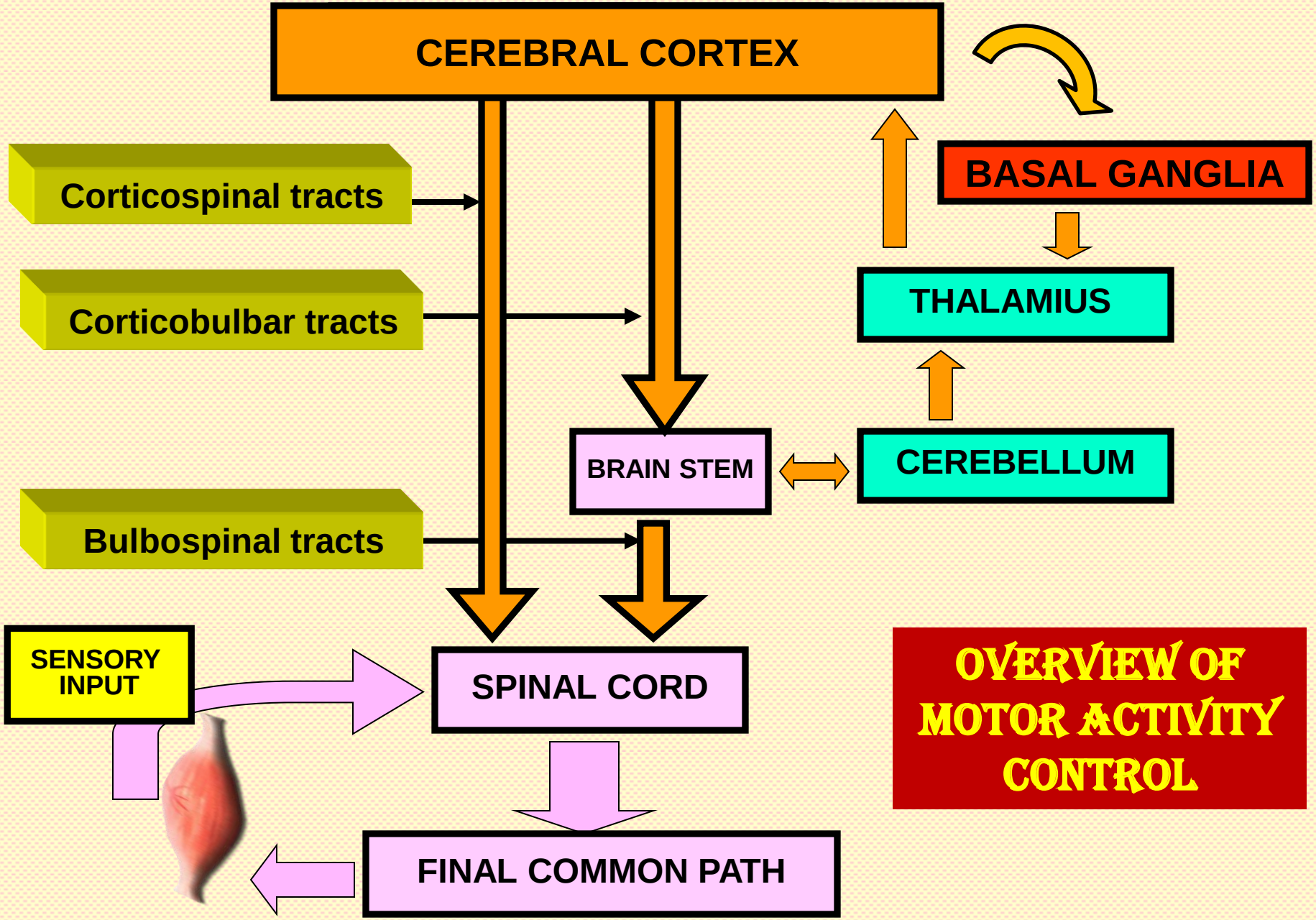
OBJECTIVES

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

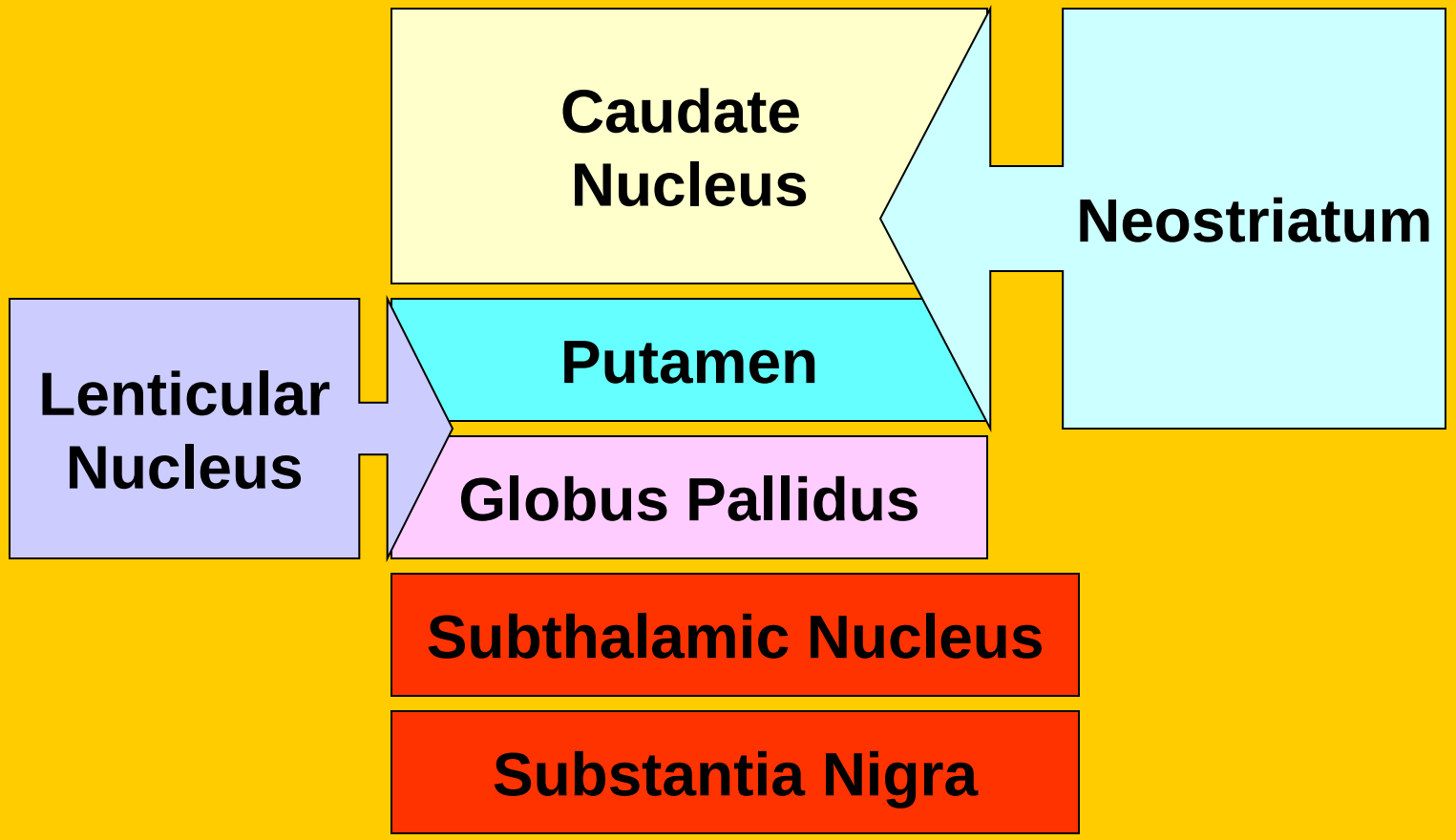

CEREBRAL CORTEX
BASAL GANGLIA
THALAMIUS
Corticospinal tracts
Corticobulbar tracts
BRAIN STEM
CEREBELLUM
Bulbospinal tracts
SENSORY INPUT
SPINAL CORD
FINAL COMMON PATH
OVERVIEW OF MOTOR ACTIVITY CONTROL

BASAL GANGLIA

COMPONENTS
FUNCTIONAL ANATOMY

Basal Nuclei

5 FUNCTIONAL PARTS

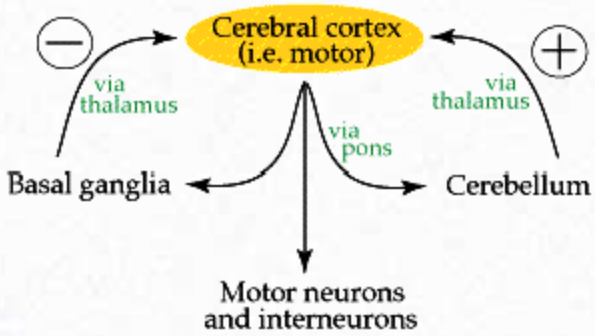


Corpus striatum = Caudate nucleus plus lentiform nucleus

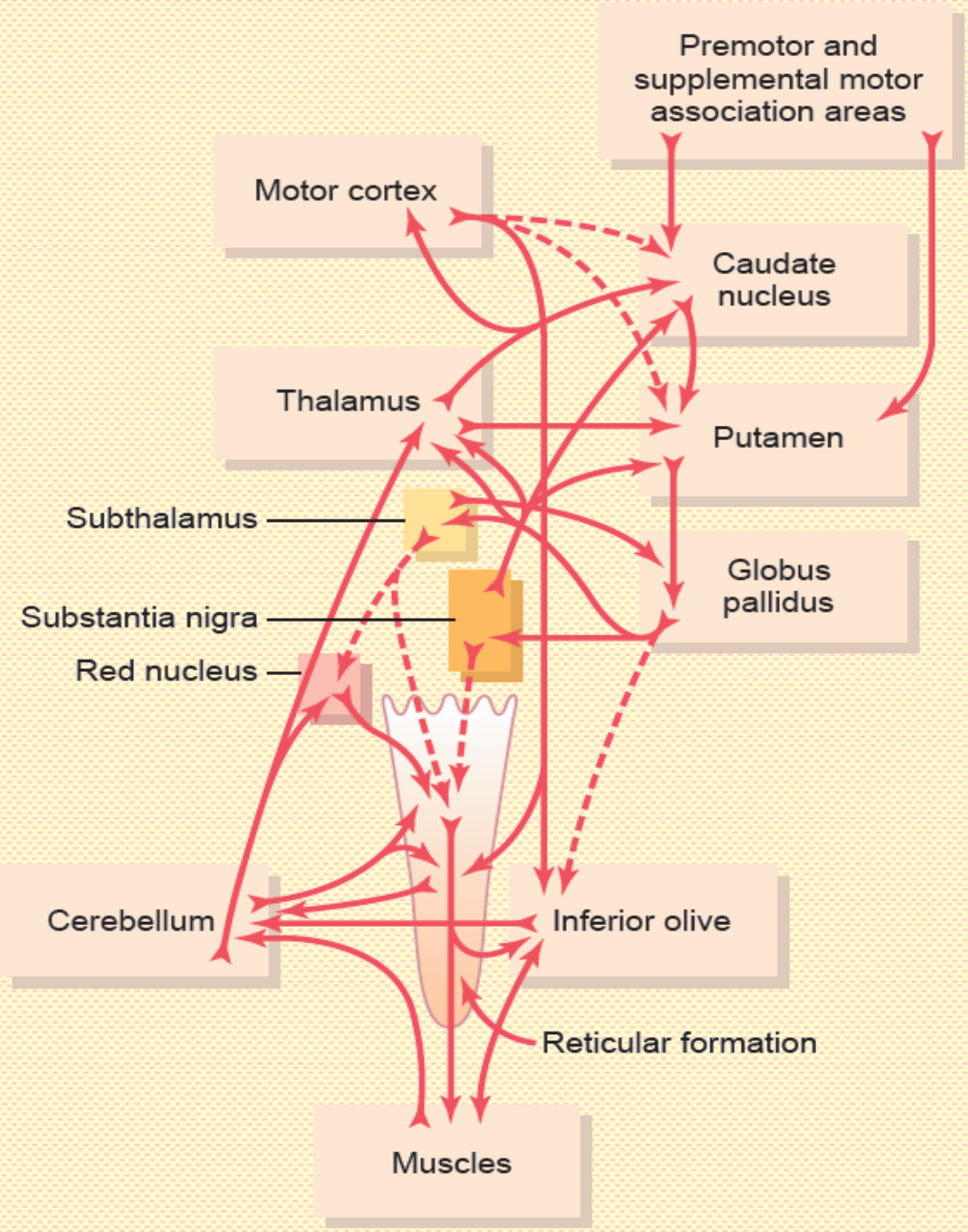
Neostriatum (striatum) = Caudate nucleus plus putamen

BASAL GANGLIA

CONNECTIONS



Complex Circuitry of Motor Control



MAIN INPUT TO THE BASAL GANGLIA

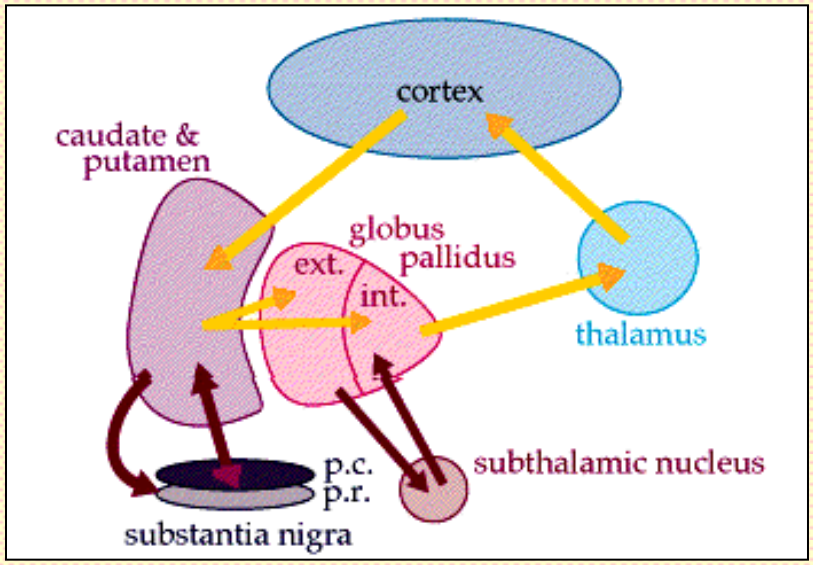
The comes from the cerebral cortex (motor area) and projects to the NEOSTRIATUM

(a term for the caudate nucleus and putamen)

THE MAIN OUTPUT

Is via the thalamus to the cerebral cortex

(motor area)

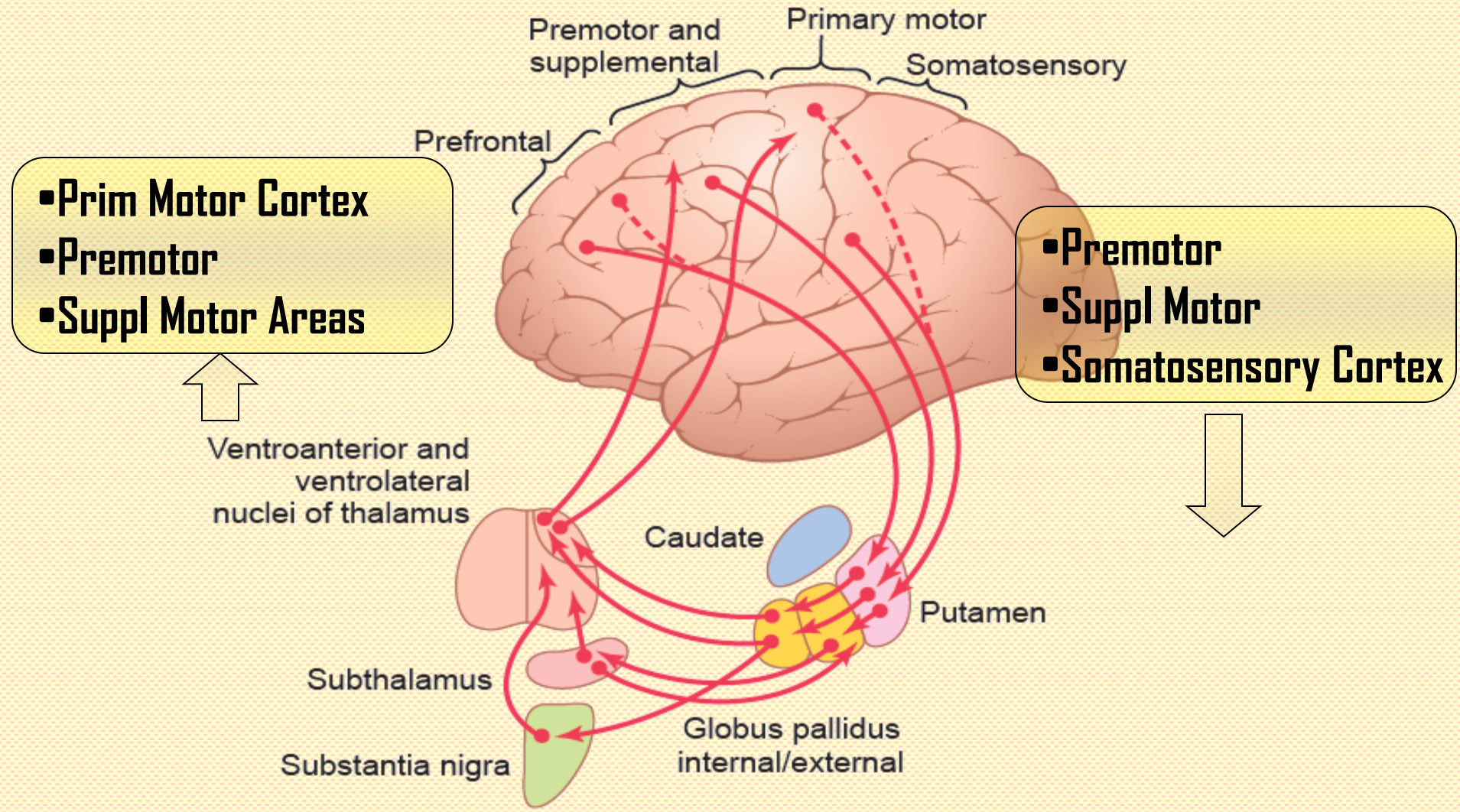


BASIC CIRCUITS OF MOVEMENTS CONTROL

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

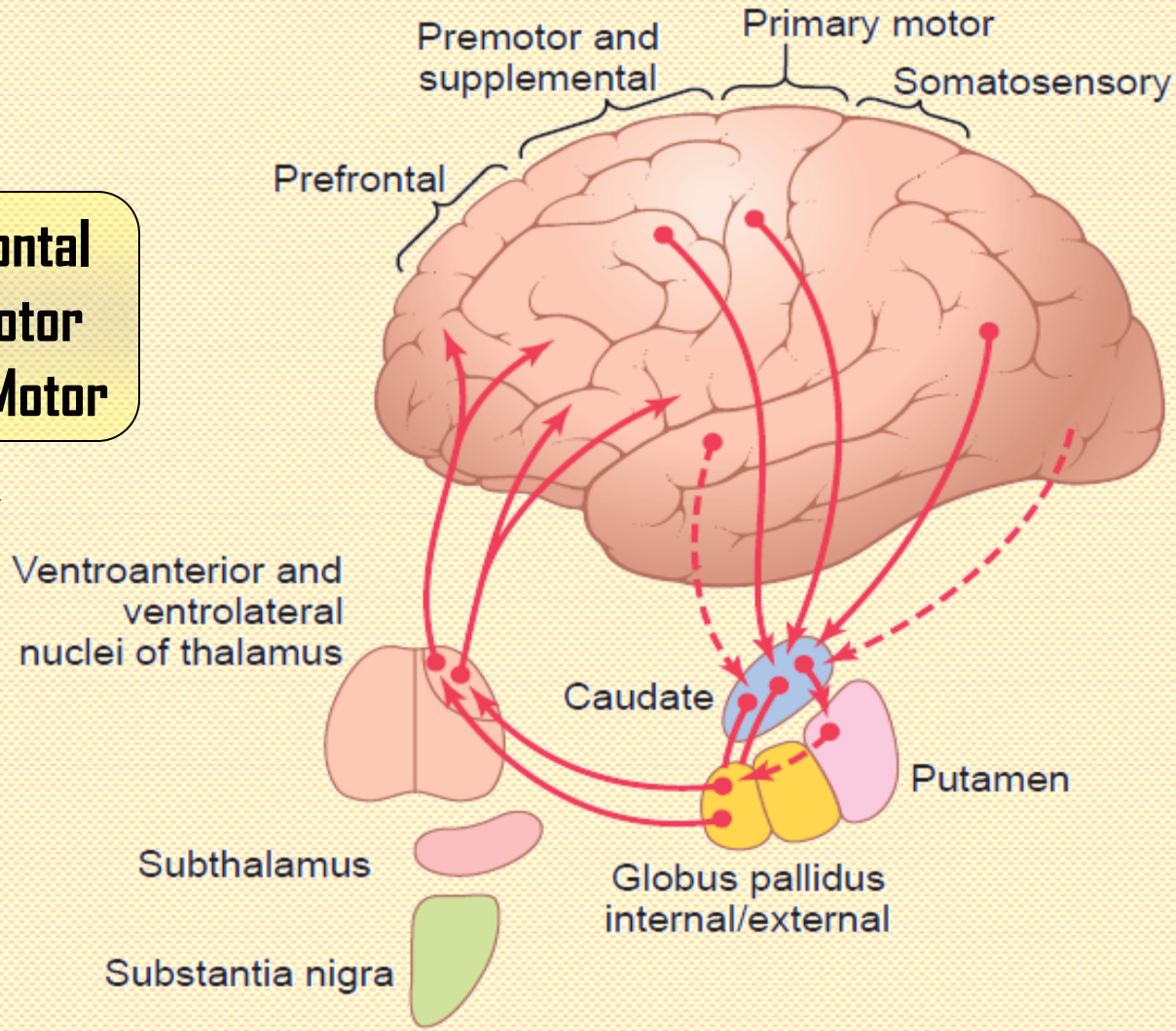
   (Note: cognition means thinking process using sensory input with information already stored in memory.)
3. **Limbic loop involved in giving motor expression to emotions like, smiling, aggressive or submissive posture (via nucleus accumbens reward circuit).**
4. **Occulomotor loop concerned with voluntary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

The Putamen Circuit



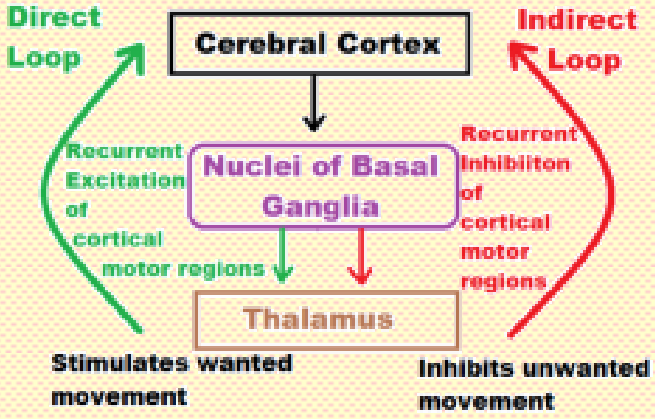
The Caudate Circuit

- Prefrontal
- Premotor
- Suppl Motor

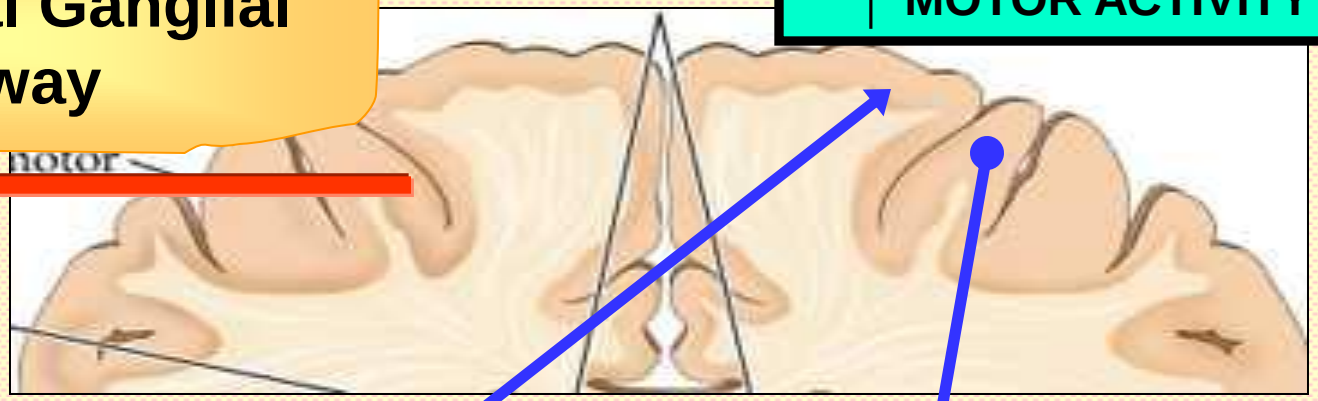


Association Areas

Basal Ganglial Neurotransmitters & Pathways (Direct and Indirect)



Direct Basal Ganglial Pathway



↑ MOTOR ACTIVITY

GLU +

GLU

+

↓GABA -

Thalamus

GPe

GPi

St

-

+ DA1+

↑ GABA

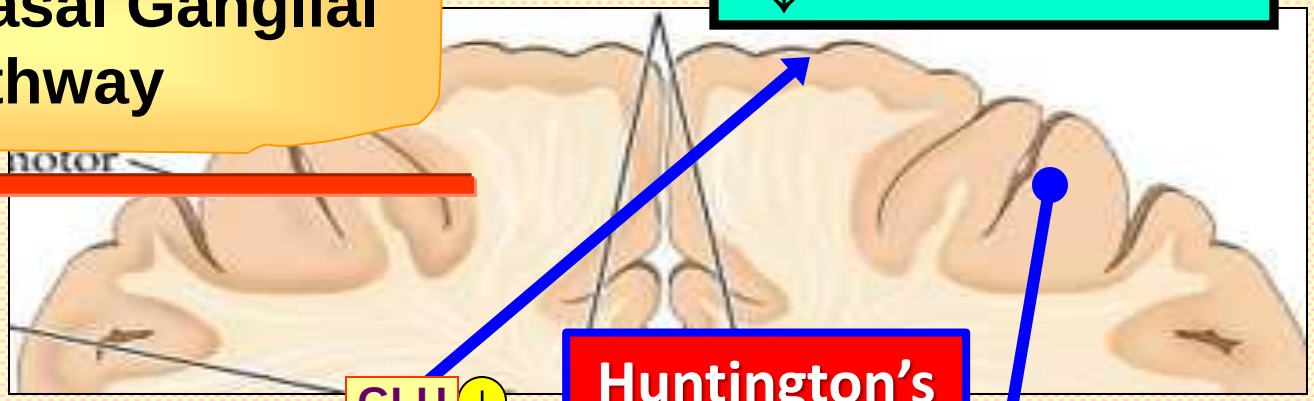
Parkinson's Disease

Thalamocortical Neurons are disinhibited

SThN

SNPC

Indirect Basal Ganglial Pathway



↓ MOTOR ACTIVITY

GLU +

Huntington's Disease

+ GLU

↑GABA -

GPe

St

GPi

- ↑ GABA

Thalamus

- DA2 -

GLU +

- ↓GABA

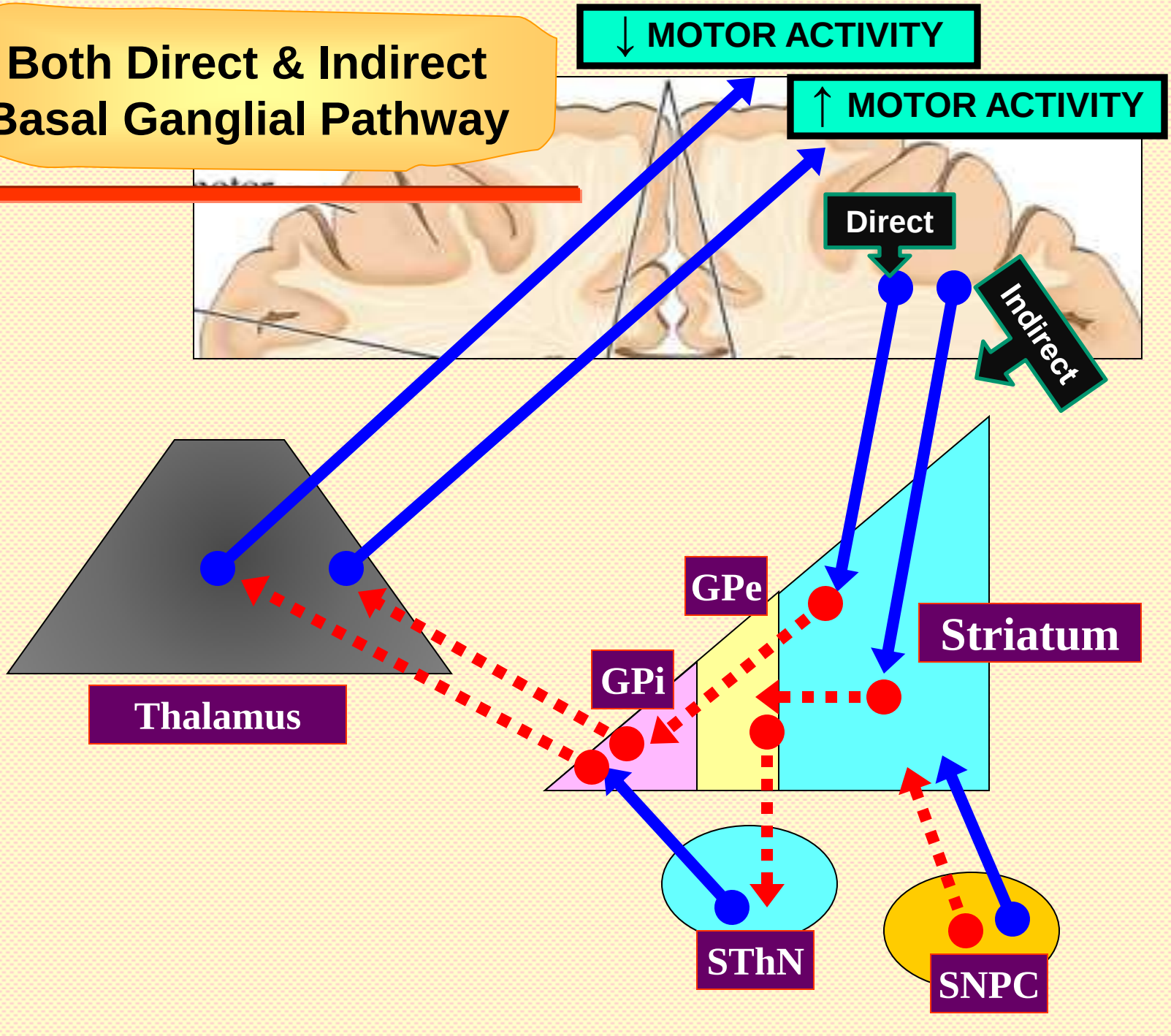
STh N

SNPC

Subthalamic Neurons are disinhibited

Hemiballism Athetosis

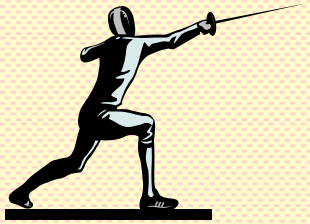
Both Direct & Indirect Basal Ganglial Pathway



The Putamen Circuit

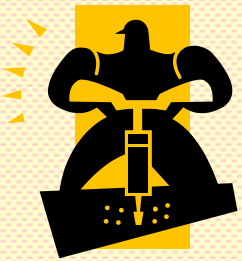
Executes Learned Patterns of Motor Activity

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**



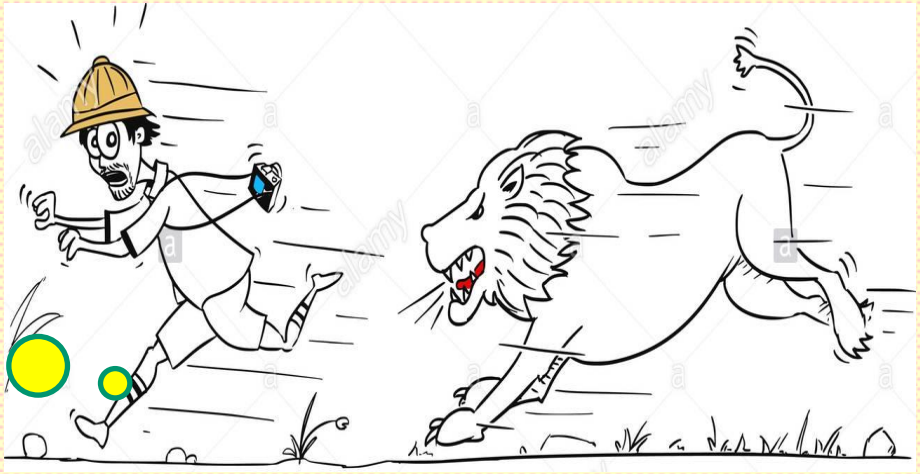
SUBCONSCIOUSLY WITHOUT A PLAN

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?

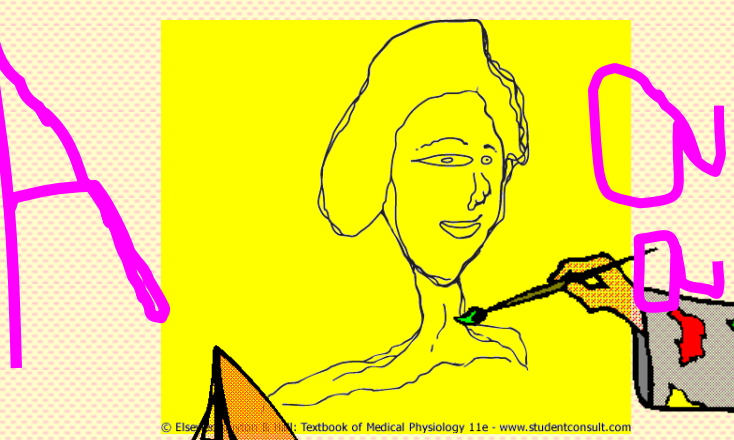


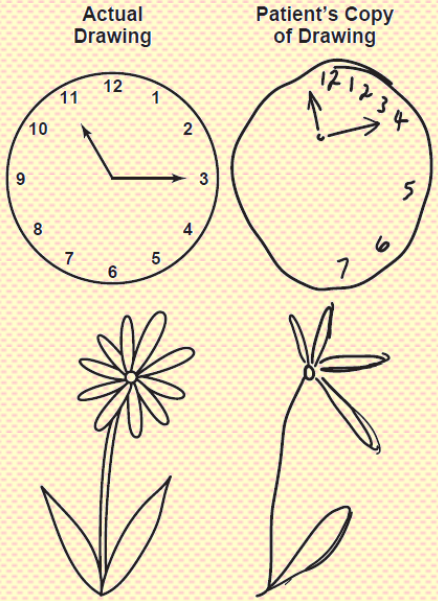
The Caudate Circuit

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.

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

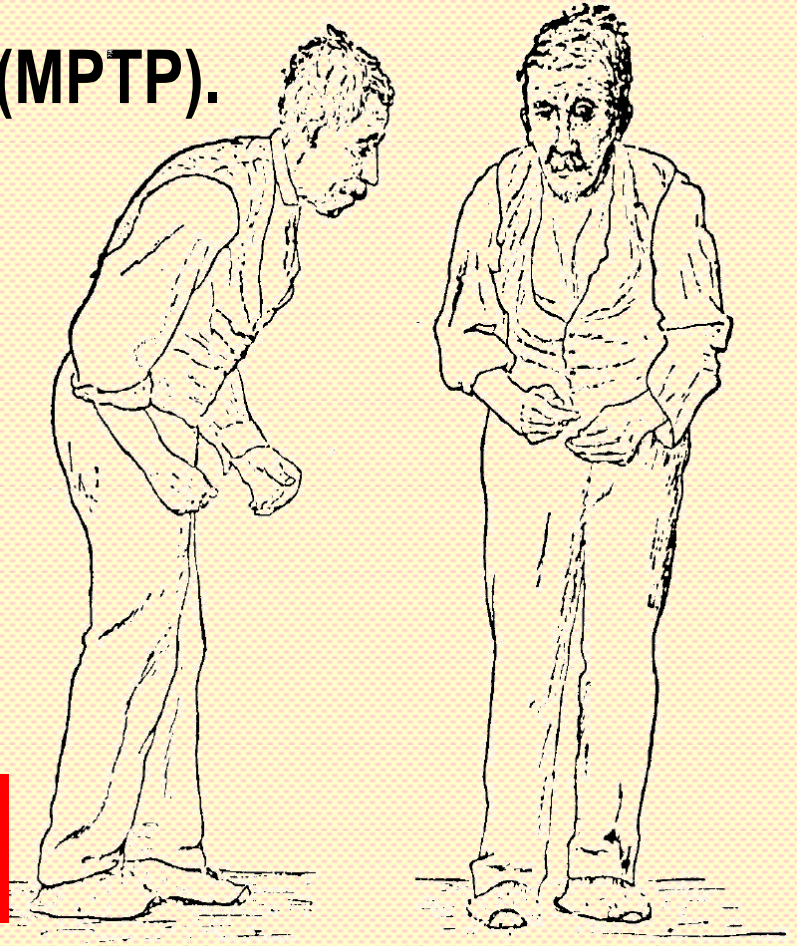
Lesions affect Direct Pathway Predominantly

Movement Disorder	Features	Lesion
Chorea	Multiple quick involuntary, random/purposeless movements, usually most prominent in the appendicular muscles	Atrophy of the striatum. Huntington Chorea Saint Vitus Dance (post streptococcal infection)
Athetosis	Slow writhing ovements,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
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



Sir William Richard Gowers Parkinson Disease sketch 1886

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 and patient develops choreiform movements and dystonia