ANATOMOPHYSIOLOGY OF THE BASAL GANGLIA

Dr J. Yelnik

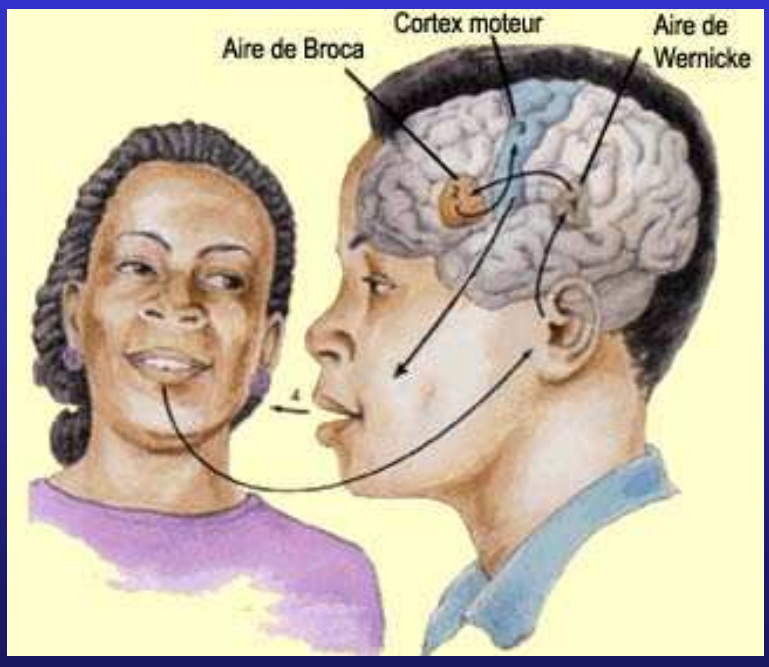
Basal Ganglia Speech Disorders and DBS

Aix-en-Provence, June 29 – July 1st

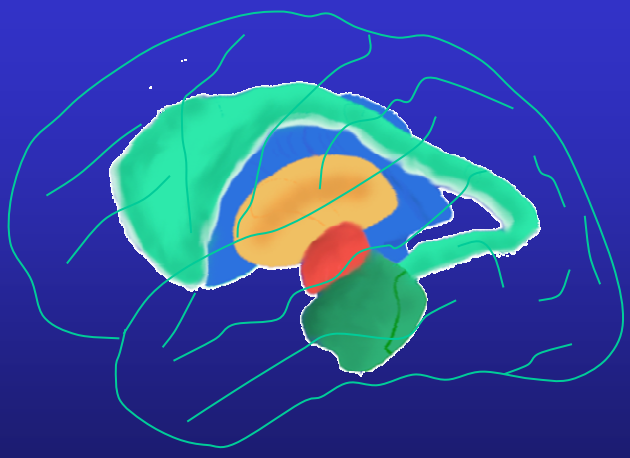
CRICM – BEBG Team

UPMC/INSERM UMRS_975/CNRS UMR 7225

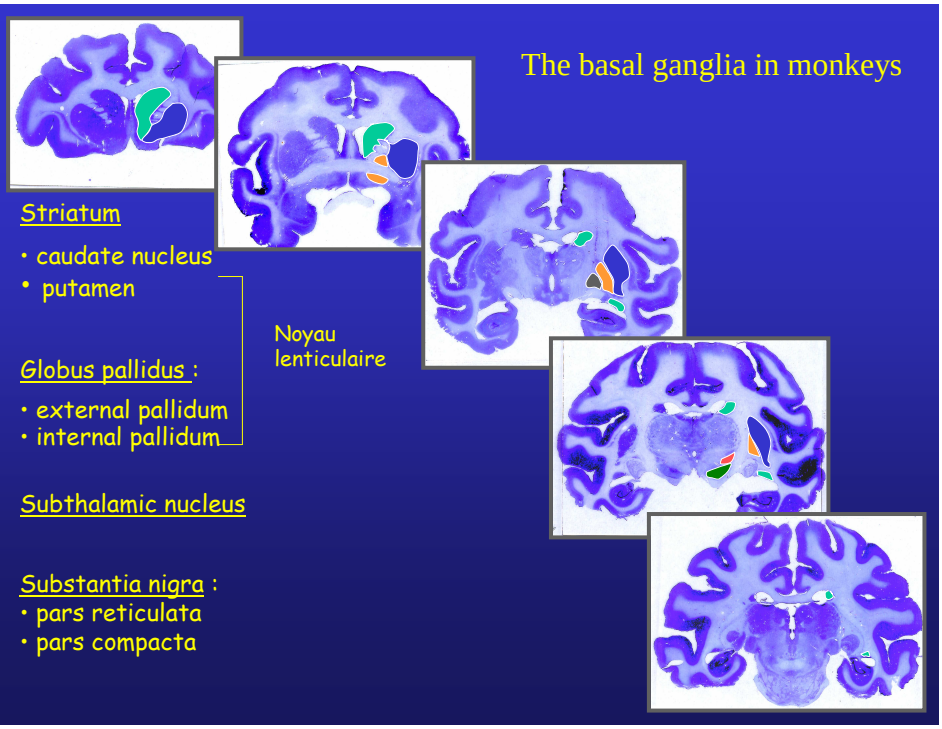
Groupe hospitalier Pitié-Salpêtrière, Paris



THE BASAL GANGLIA SYSTEM



The basal ganglia in monkeys



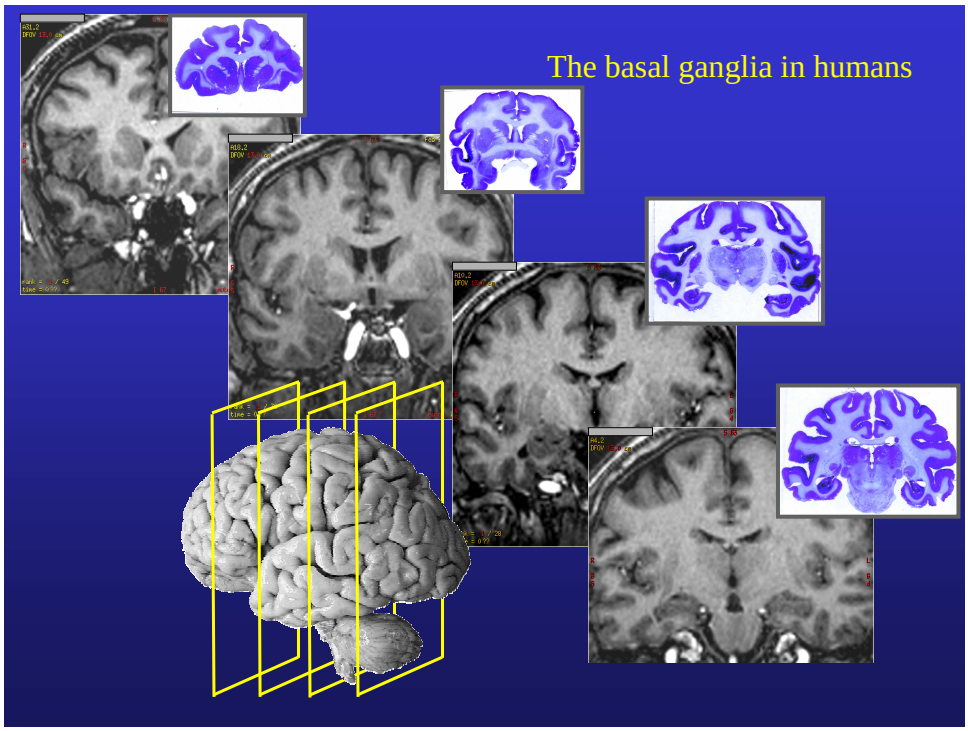
Striatum
- caudate nucleus
- putamen

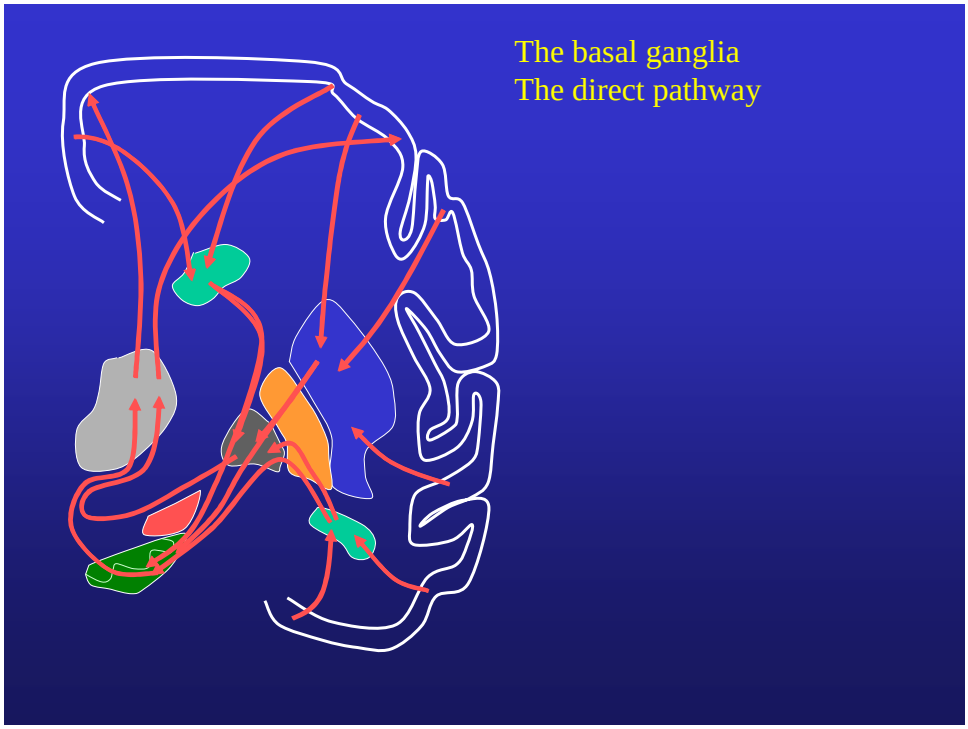
Noyau lenticulaire

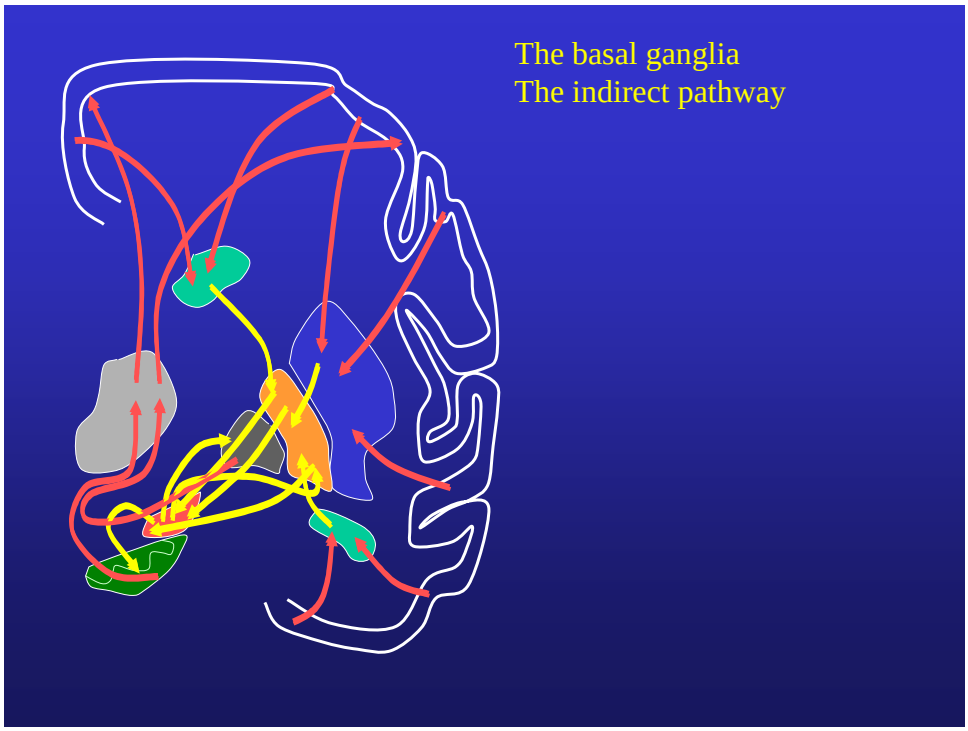
Globus pallidus :
- external pallidum
- internal pallidum

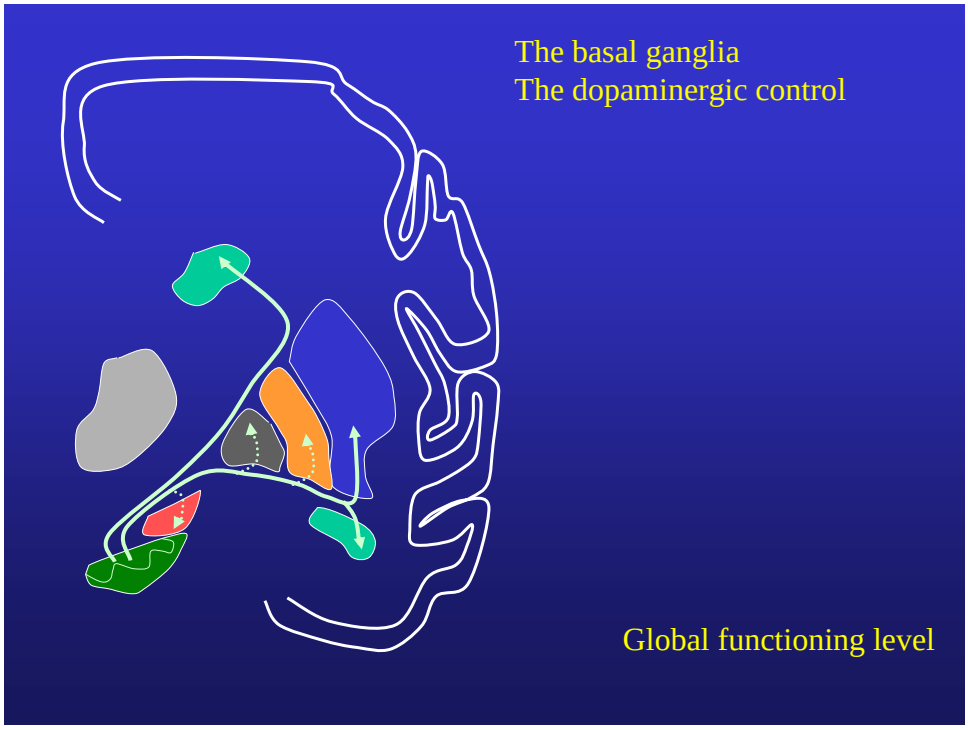
Subthalamic nucleus

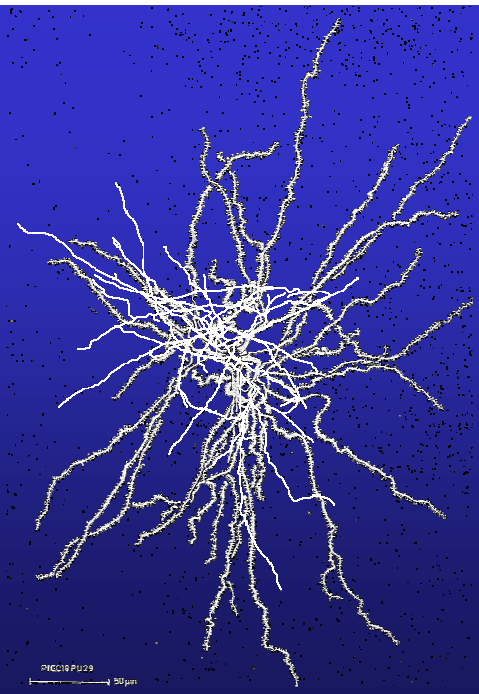
Substantia nigra :
- pars reticulata
- pars compacta

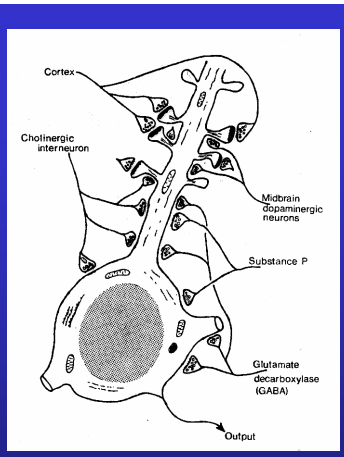

The basal ganglia in humans


The basal ganglia
The direct pathway


The basal ganglia
The indirect pathway


The basal ganglia
The dopaminergic control
Global functioning level





Smith et Bolam 1990

Reinforced learning

THE BASAL GANGLIA SYSTEM
(Yelnik, Rev. Neurol., 2008)

1 – THE BOX AND ARROWS MODELS

1 – The dual-circuit model

2 – The triple-circuits model

2 – THE INSIDE OF THE BOXES

1 – The three functional territories

2 – The integrative properties of the basal ganglia

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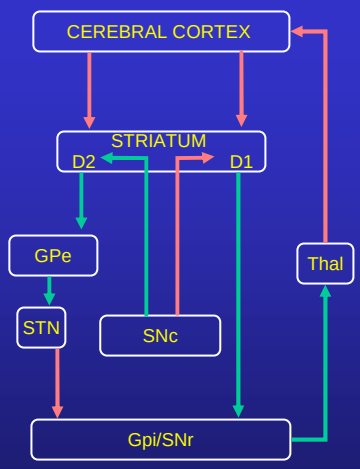
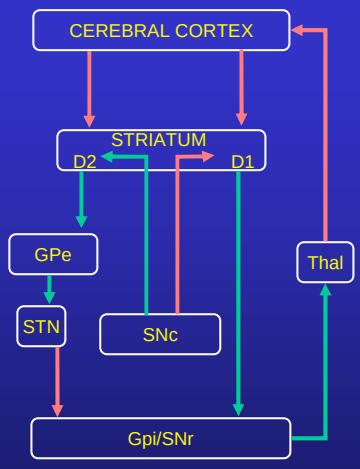
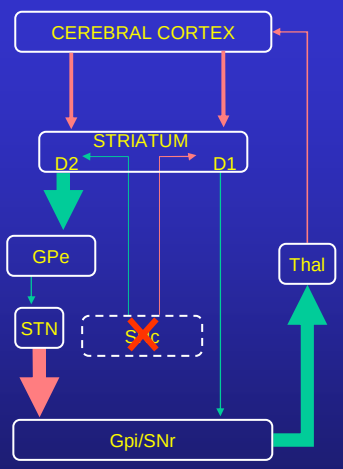


Functioning in the normal state
Albin et al., 1990



Functioning in the normal state
Albin et al., 1990



Functioning in the
Parkinsonian state

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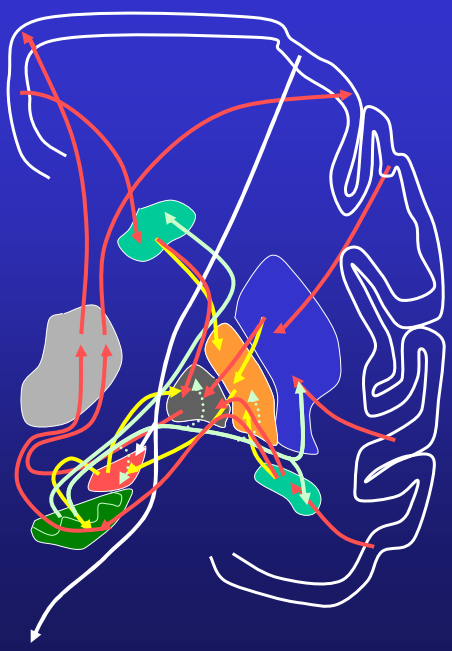


The hyperdirect pathway

The triple circuit : a spatial model (Mink, 1996)
Focused selection of action and inhibition of competing programs

Pergamon

Progress in Neurobiology, Vol. 50, pp. 381 to 425, 1996

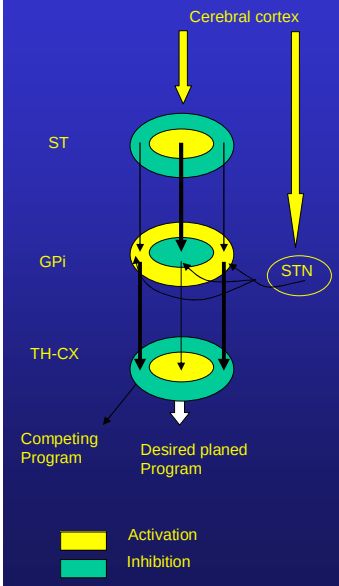
Printed in Great Britain
0301-0082/96/$32.00

PII: S0301-0082(96)00042-1

THE BASAL GANGLIA: FOCUSED SELECTION AND INHIBITION OF COMPETING MOTOR PROGRAMS

JONATHAN W. MINK
Department of Neurology, Box 8111, Washington University School of Medicine, 660 S. Euclid Ave., St. Louis, MO 63110, U.S.A.

(*Received* 17 *January* 1996; *Accepted* 23 *June* 1996)



CX-ST	**CX-STN**
All CX	Frontal CX
Inhibitory	Excitatory
Slow (powerful)	Rapid
Focal	Divergent
=	=
Slow focalised inhibition	Rapid divergent excitation

In the GPi : Focal Inhibition and lateral activation

In the TH-CX : focal facilitation and lateral inhibition

The triple circuit : a sequential temporal model (Nambu 2002)

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Neuroscience Research

Neuroscience Research 43 (2002) 111–117

www.elsevier.com/locate/neures

Update article

Functional significance of the cortico–subthalamo–pallidal 'hyperdirect' pathway

Atsushi Nambu [a,*], Hironobu Tokuno [b], Masahiko Takada [a]

[a] *Department of System Neuroscience, Tokyo Metropolitan Institute for Neuroscience, Tokyo Metropolitan Organization for Medical Research, 2-6 Musashidai, Fuchu, Tokyo 183-8526, Japan*

[b] *Department of Brain Structure, Tokyo Metropolitan Institute for Neuroscience, Tokyo Metropolitan Organization for Medical Research, 2-6 Musashidai, Fuchu, Tokyo 183-8526, Japan*

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Hyperdirect pathway = Inhibition of competing programs
Direct pathway = Execution of desired program
Indirect pathway = End of execution

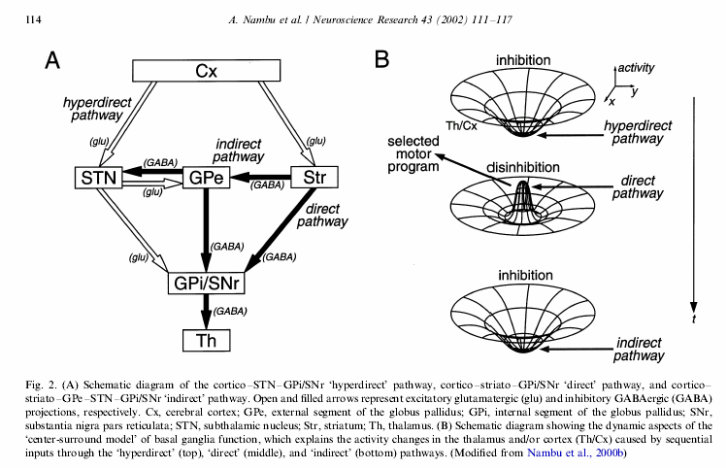


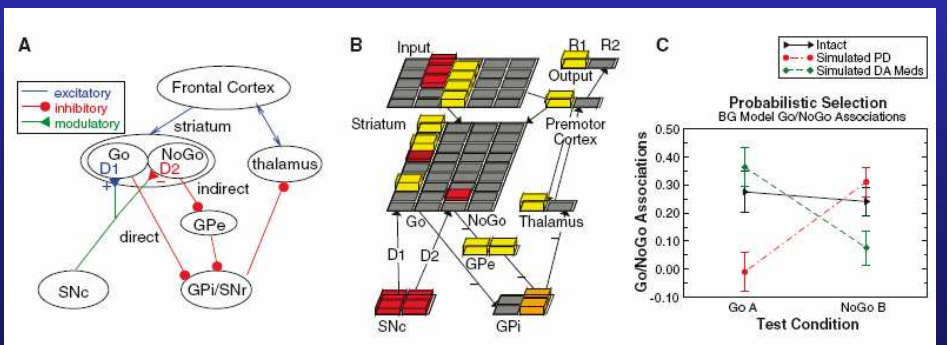
Fig. 2. (A) Schematic diagram of the cortico–STN–GPi/SNr 'hyperdirect' pathway, cortico–striato–GPi/SNr 'direct' pathway, and cortico–striato–GPe–STN–GPi/SNr 'indirect' pathway. Open and filled arrows represent excitatory glutamatergic (glu) and inhibitory GABAergic (GABA) projections, respectively. Cx, cerebral cortex; GPe, external segment of the globus pallidus; GPi, internal segment of the globus pallidus; SNr, substantia nigra pars reticulata; STN, subthalamic nucleus; Str, striatum; Th, thalamus. (B) Schematic diagram showing the dynamic aspects of the 'center-surround model' of basal ganglia function, which explains the activity changes in the thalamus and/or cortex (Th/Cx) caused by sequential inputs through the 'hyperdirect' (top), 'direct' (middle), and 'indirect' (bottom) pathways. (Modified from Nambu et al., 2000b)

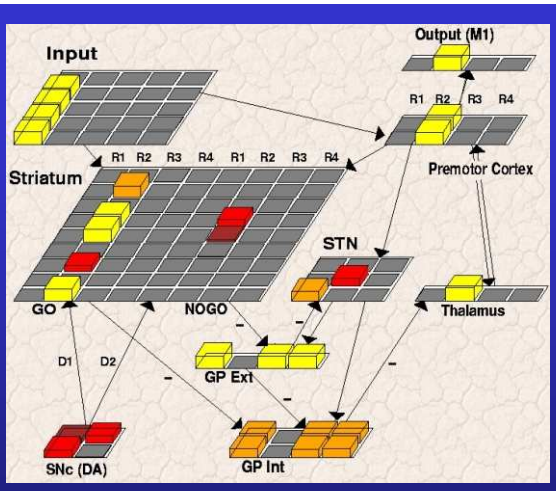
The Go NoGo model
Michael Frank

By Carrot or by Stick: Cognitive Reinforcement Learning in Parkinsonism

Michael J. Frank,[1*] Lauren C. Seeberger,[2] Randall C. O'Reilly[1*]

10 DECEMBER 2004 VOL 306 SCIENCE





Hyperdirect pathway = initial NoGo 'Hold your horses' preventing impulsive response

Direct pathway = Go unit = selection of selected action

Hold Your Horses: Impulsivity, Deep Brain Stimulation, and Medication in Parkinsonism

Michael J. Frank,[1*] Johan Samanta,[2,3] Ahmed A. Moustafa,[1] Scott J. Sherman[3]

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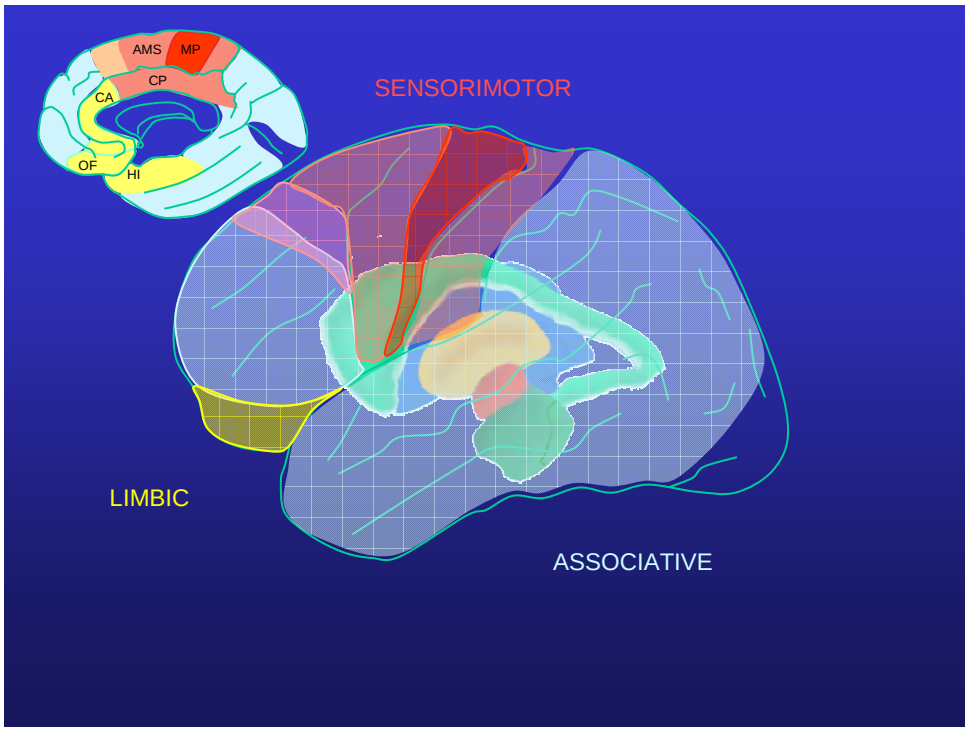
AMS
MP
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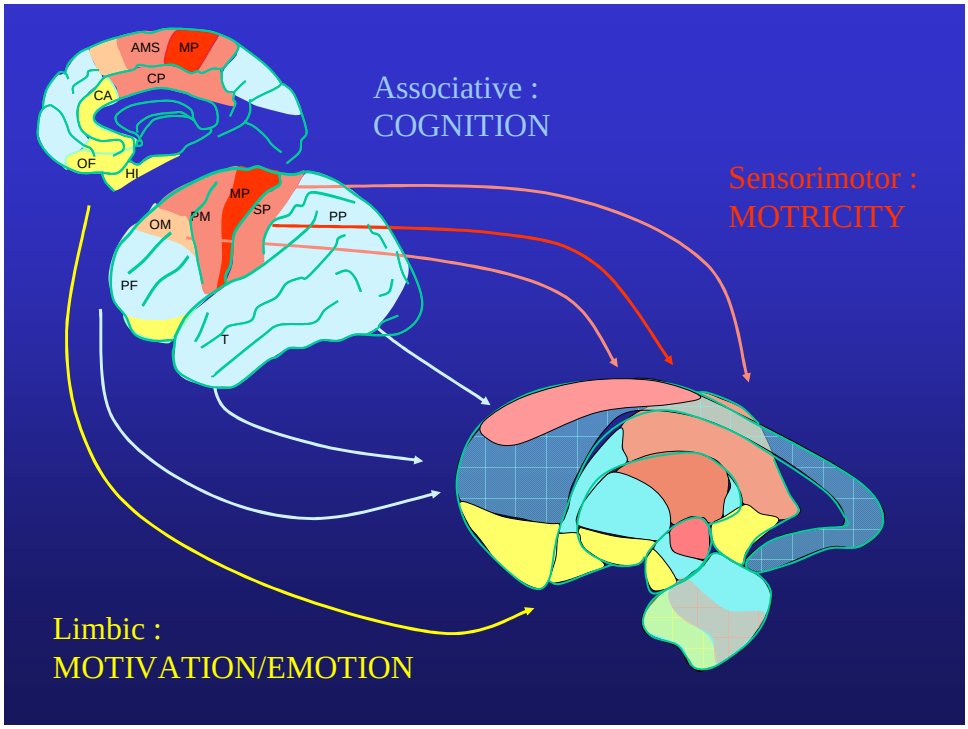
LIMBIC
ASSOCIATIVE


AMS
MP
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OF
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Associative :
COGNITION
Sensorimotor :
MOTRICITY
MP
SP
PM
OM
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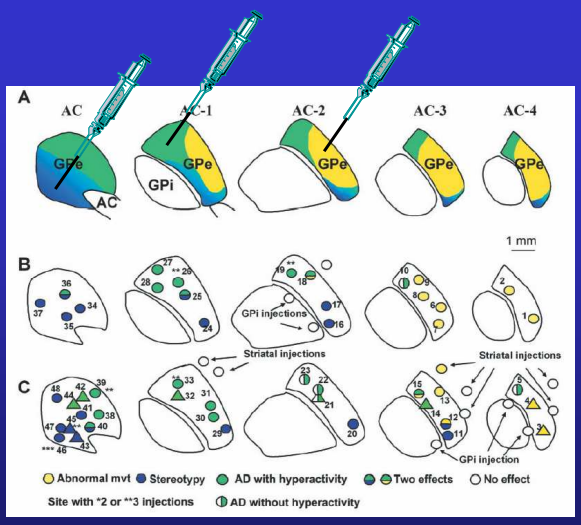
PF
T
Limbic :
MOTIVATION/EMOTION



Grabli et al., Brain, 2004

Abnormal Movements

Hyperactivity

Stereotypies

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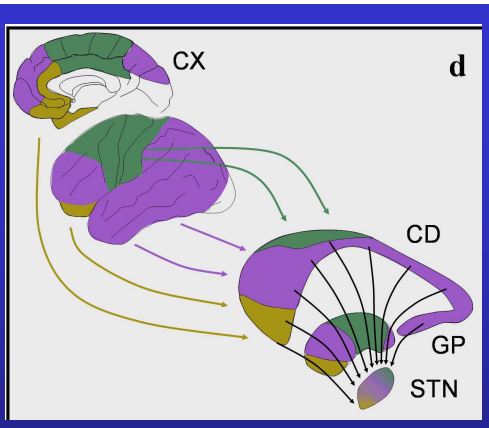
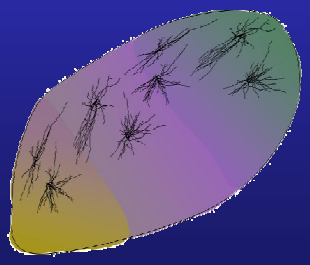


Integrative role of the STN



Mallet et al., PNAS, 2007

3 – THE BASAL GANGLIA SYSTEM AND SPEECH CONTROL

Then ?….

What the basal ganglia have to do with speech ?

What do the basal ganglia do ?

- Dopamine reinforced learning of behavioral sequences
- Automatic execution of learnt sequences
- Action selection

Which is typically what occurs in speech production

Speech production is a behavioral activity that includes:

- A motor content = motricity of the larynx, tongue, facial muscles etc…leading to articulation, phonation, verbal expression
- A cognitive content = the semantic significance of speech
- An emotional content = positive or negative emotions that are associated and can be expressed with speech

The BG system is specifically involved in the automatic processing of these three components

Stuttering

The Go NoGo processing could explain the pathophysiology of stuttering by a deficiency of the Go signal (Per Alm, The Stuttering foundation)

But also:
Exaggerated impulsivity and emotion… A role for the STN ?....