Basal Ganglia

General Info

Neural clusters in peripheral nervous system are ganglia. In the central nervous system, they are called nuclei. Should be called Basal Nuclei but usually called Basal Ganglia.
Works on disinhibition principle
  It's the brain brake
If no input = steady fire at high rates
Neurotransmitters
  Inputs use glutamate
  Outputs use GABA
  Internal connections use dopamine or ACh

Group of nuclei
Distinct masses of gray matter
  Left-right sides mirror each other
Work together as functional unit
Interact with cortex, thalamus, etc

FOUR PARTS
Striatum
  Dorsal
    caudate & putamen
  Ventral
    nucleus accumbens & olfactory
Pallidum
  globus pallidus (dorsal)
  ventral pallidum
Substantia nigra (pons)
Subthalamic nucleus (below thalamus)

Two large parts
  Striatum & Pallidum
Two smaller parts (& farther back)
  Substantia Nigra & Subthalamic

Disorders
  Huntington's disease
    Major loss of medium spiny neurons in striatum
    Inability to prevent parts of the body from moving unintentionally

1. Striatum
Largest

Looks striped
Looks like two blobs of gray separated by large white stripe
input from many brain areas
only outputs to other parts of basal ganglia
Complex internal organization
  Direct pathway (D1)
  Indirect (D2)
Organized in 3D
  Cortex is layered; organized 2D
Coordinates multiple aspects of cognition
action planning
decision making
motivation
reinforcement
reward

Interneurons
  Release acetylcholine
  Many types of interneurons
    include fast-spiking interneurons
Continuously produce new neurons in striatum

Striatum is activated by stimuli associated with reward
aversive
novel & unexpected
intense stimuli

Ventral striatum composed of olfactory tubercle & nucleus accumbens
As a whole, major role in cognitive processing of
  aversion & pleasure
  motivation
  reward & reinforcement
  addiction
As a whole, minor role
  cognitive processing of:
  fear (type of aversion)
  impulsivity
  placebo effect
Also involved in
  encoding of new motor skills

Nucleus accumbens
  Two, one in each hemisphere
  Each has two structures:

- Nucleus accumbens core
  - Increased density of dendritic spines
  - Increased branch segments
  - Increased terminal segments
  - Processes
    - motor function related to reward
    - encodes new motor programs that help get future rewards
- Nucleus accumbens shell
  - Lower density of dendritic spines
  - Less terminal segments
  - Less branch segments
  - Processes
    - want (motivational salience)
    - reward perception
    - positive reinforcement
    - drugs & naturally rewarding stimuli
    - addictive drugs affect dopamine in shell more than core

Function

- Reward
  - Subset of VTA neurons
    - Dopamine (D1) medium spiny neurons in shell
- Drugs
  - Increase dopamine in shell & core; more pronounced in shell
    - morphine
    - cocaine
    - amphetamines
      - at high levels, increase dopamine level to similar levels in both shell & core
  - Drug rewards
    - has abnormal strengthening effect on stimulus
    - drug associations
    - increases drug-reward stimuli's resistance to extinction
    - effect was more pronounced in shell than core
- Addiction
  - Links to addictions to
    - alcohol, cannabinoids, cocaine
    - nicotine, opioids & amphetamines

Links to

- Depression
- OCD
- Placebo effect

2. Pallidum
  Input from striatum
  Sends inhibitory output to a number of motor-related areas
  Globus Pallidus
    Latin for "pale globe“
      AKA, paleostriatum or dorsal pallidum
    Output to substantia nigra
    Very large neurons
    Very large dendritic arbors
      3-dimensional shape of flat discs
    Involved in plan & inhibit move
      regulation of voluntary movement
      regulate subconscious movements
      If damaged, can cause movement disorders
    Balances excitatory action of cerebellum
      allow people to move smoothly
      even & controlled movements

3. Substantia Nigra
  Located in pons
  Important role in reward, addiction & movement
  Latin for black substance
    due to high levels of neuromelanin found in dopaminergic neurons
  Discovered in 1784
  Largest nucleus in midbrain
  Two substantiae nigrae; one on each side
Function
  eye movement
  motor planning
  reward-seeking
  learning
  addiction
Mediated thru striatum
  Co-dependence between striatum & substantia nigra
Looks like a continuous band
  Two parts with very different connections and functions:
    1. Pars Compacta
      Supplies striatum with dopamine
      Heavily involved in learned responses to stimuli
      Activity increases when new $ is presented
      Partial dopamine deficits do not affect motor control
        Can lead to disturbances in the sleep-wake cycle
        Especially in hippocampus
      Parkinson’s

Neurodegenerative disease
tremor, stiffness, akinesia
bradykinesia, fatigue, depression
Death of dopaminergic neurons in pars compacta
Impacts motivation
Hunger fails to initiate movements
"Paralysis of will"
kinesia paradoxica
Moves easily in emergency
Immobile after issue passed
Animal with severe basal ganglia damage won't move toward food
Even if placed within inches
Chew & swallow if put in mouth
Why neurons die is unknown
unique susceptibility?
abnormalities in mitochondrial?
result in abnormal protein handling and neuron death
Dopaminergic neurons in pars compacta contain less calbindin
protein involved in calcium ion transport within cells
excess calcium in cells is toxic
Plasticity of pars compacta is robust
no symptoms until 50-80% of pars compacta dopaminergic neurons have died

2. Pars Reticulata
output to rest of brain
spontaneously fire action potentials
inhibits targets of basal ganglia
decreases in inhibition are associated with movement
Parkinson's and epilepsy
Altered patterns of firing
single-spike
burst firing

Schizophrenia
Patients have increased levels of dopamine
dopamine antagonists remain a standard and successful treatment for schizophrenia
Substantia nigra's pars compacta
reduction in synaptic terminal size
more active NMDA receptors
reduced dysbindin expression

Wooden Chest Syndrome
aka, fentanyl chest wall rigidity syndrome
rare side effect of synthetic opioids (ie Fentanyl)

generalized increase in skeletal muscle tone
increased dopamine release and decreased GABA release in substatia nigra/striatum
most pronounced on chest wall muscles
leads to impaired ventilation
most common in anesthesia where rapid and high doses given intravenously

Cocaine
inhibition of dopamine reuptake
cocaine is more active in VTA than substantia nigra
increases metabolism in substantia nigra
altered motor function
also inhibits spontaneous firing by the pars compacta
inactivation of substantia nigra as treatment for cocaine addiction?

4. Subthalamic nucleus (also called Luys' Body)
Input from striatum & cerebral cortex
Output to the globus pallidus
Small lens-shaped nucleus; major part of subthalamus
Functionally part of basal ganglia
Location
ventral to thalamus
dorsal to substantia nigra
medial to internal capsule
Discovered 1865, by Jules Luys
Structure
long sparsely-spiny dendrites
elliptical dendritic arbors
Spontaneously firing cells
Pace-maker of the brain?
Oscillatory and synchronous activity
Stimulated to treat Parkinson's
causes nearby astrocytes to release ATP
precursor to adenosine
catabolic process
Damage
small vessel stroke in patients with diabetes, hypertension, or a history of smoking
produces hemibaliismus
uncontrollable flinging movements of arms and legs
Functions
impulse control
OCD cause?
action selection?

Basal ganglia all work together

Impacts
- Eye movements
- Action selection
- Voluntary motor control
- Inhibits motor systems
- Procedural learning
- Eye movements
- Habits

Lots of brain regions work

Basal ganglia impacts implicit learning
- Action selection?
- Which behavior to do when?

Parkinson's

Cerebral palsy
- Damage to basal ganglia during 2nd and 3rd trimester

Foreign accent syndrome
- Some combination of problems in cerebellum, Broca's area & basal ganglion
- Caused by stroke or injury
- Mispronunciation of words
- Listener's hear it as accent
- Not new vocabulary
- Sufferer's may imitate other aspects to normalize syndrome