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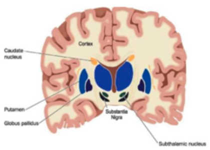
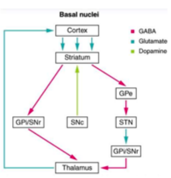
Basal nuclei

Basal nuclei

- **Used** to be **called basal ganglion** but that's a **misnomer** because the **ganglion** is **supposed** to be a **collection of cell bodies in the peripheral** , but **here** its in the **CNS**



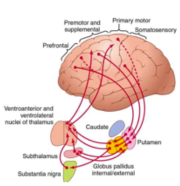
- **Important structures** in the **basal nuclei** :**putamen**, the **globus pallidus**, **caudate**, **substantia nigra (**in the **midbrain**) and the **subthalamus**
  - The **caudate with the putamen** can be **called striatum**
- Keep in mind that the **signal in the basal nuclei** is **inhibitory** and so the **main neurotransmitter** is **GABA except** for **one pathway** , which is the **pathway from** the **subthalamus** to the **globus pallidus**, this **pathway is an excitatory pathway**, the **neurotransmitter is glutamate**.



  - For the **substantia nigra** the **neurotransmitter** of this **pathway is dopamine**
- The **basal nuclei helps plan** and **control complex patterns** of **muscle movement**.
- They **control relative intensities** of the **separate movements**, **directions of movements**, and **sequencing of multiple successive** and **parallel movements** to **achieve specific complicated motor goals**
- the **basal nuclei receive most** of their **input signals** from the **cerebral cortex** and also **return almost all their output** signals **back to the cortex**.
  - So the **circuit will start** from the **cortex** then it **will go to different structures** in the **basal nuclei** and then **it will go to the thalamus** (which **contains ventroanterior** and **ventrolateral nuclei**) so that it **can go back to the cortex**
- Almost **all motor** and **sensory nerve fibers connecting** the **cerebral cortex** and **spinal cord pass through the space** that **lies between the caudate nucleus** and the **putamen**: the **internal capsule of the brain**. An **intimate association between** the **basal nuclei** and the **corticospinal system** for **motor control**.

Puta**m**en circuit

- One of the **principal roles** of the **basal ganglia** in **motor control** is to **function in association** with the **corticospinal system** to **control complex patterns** of **motor activity**.



- the **putamen circuit** has its **inputs mainly** from the **parts of the brain adjacent** to the **primary motor cortex** but **not much** from the **primary motor cortex itself**.
  - We **don't have input from** the **primary motor cortex itself because** the primary motor **cortex is for execution**
- Then **its outputs do go mainly back** to the **primary motor cortex** or **closely associated premotor** and **supplementary cortex**.

- **Pathway**: So **basically information** from **the areas adjacent to the primary motor area** (**like** the **premotor areas** and **supplemental** areas) the will get **integrated in the putamen** and get **processed which** will **then send it to the globus pallidus** and **from there it will go** to the **ventroanterior and ventrolateral nuclei** of the **thalamus** and then **back to the cortex more specifically the primary motor cortex** (since I finished planning and I know what I am going to do so now I need to execute the plan)
  - Cortex→Putamen→Globus Pallidus Interna→Ventroanterior and Venetrolateral nuclei of the thalamus→primary motor area of the cortex
- The **putamen circuit** can be **divided into 2 pathways**, the **direct** and **indirect pathway**

Direct vs indirect pathway

- There are **two distinct pathways** that **process signals through** the **basal ganglia**: the **direct pathway** and the **indirect pathway**.
- These **two pathways** have **opposite net effects** on **thalamic target structures**.
  - **Excitation** of the **direct pathway** has **the net effect** of **exciting thalamic neurons** (which in turn **make excitatory connections onto cortical neurons**).
    - **Pathwaty: Information from** the **cortex to** the **putamen** and the **putamen** will **send a signal** to the **globus pallidus internal** and then it will **send a signal to the ventroanterior** and **ventrolateral nuclei** of the **thalamus** and form there it will **go to the cortex**
    - Cortex→putamen→globus pallidus interna→ventroanterior and ventrolateral nuclei of the thalamus→primary motor cortex
    - The **net effect** of this **pathway** is **excitation because** we said in the **basal nuclei** the **effect is inhibitory** but **since** its **entering 2 basal nuclei** and **both have an inhibitory effect**, the **first inhibitory pathway** will **inhibit** the **second causing a net excitatory** (which means **glutamate is released**)
      - From the **putamen basal nuclei** to the **globus pallidus** → **inhibitory**
      - From the **globus pallidus** to the **thalamus** →**inhibitory**
        - So the **putamen to globus pallidus pathway** will **inhibit the already inhibitory globus pallidus** to **subthalamus pathway making it excitatory**
          - Negative x Negative = Positive
  - **Excitation** of the **indirect pathway** has the **net effect** of **inhibiting thalamic neurons** (**rendering them unable** to **excite motor cortex neurons**).
    - **Pathway**: The **indirect pathway starts** from the **cortex**, **to** the **putamen** (in the putamen itself it will decide if it will continue in the direct or indirect pathway by entering different areas within it)

        - **Then from** the **putamen** it will **go to the globus pallidus external** and **from there** it will **go** to the **subthalamus** to **then go back to the globus pallidus internal** which will **then go to the thalamus then to the primary motor cortex**
        - Cortex→Putamen→Globus Pallidus Externa→Subthalamus→Globus Pallidus Interna→Ventroanterior and Ventrolateral nuclei of the Thalamus→ Primary Motor Cortex
        - The **net effect** here is **inhibitory** because
            - From the **putamen to** the **globus pallidus externa→ inhibitory**
            - Form the **globus pallidus externa to** the **subthalamus→inhibitory**
                - Inhibitory x inhibitory = excitatory
            - From the **subthalamus to** the **globus pallidus interna→excitatory**
                - Excitatory x excitatory= excitatory
            - From the **globus pallidus interna to** the **thalamus→inhibitory**
                - Excitatory x inhibitory = inhibitory
- The **normal functioning** of the **basal ganglia apparently involves** a **proper balance between** the **activity of these two pathways**.

Nigrostriatal projection

- An **important pathway** in the **modulation of the direct** and **indirect pathways** is the **dopaminergic**, **nigrostriatal projection** from the **substantia nigra pars compacta to** the **striatum**.
    - The **substantia nigra** will **send direct** and **indirect motor pathways** to the **striatum** (which we said was the globus pallidum + the putamen)
    - The **effect of these motor pathways sent** from the **substantia nigra** to the **direct and indirect pathway** will **affect each pathway differently**
- **Direct pathway striatal neurons** have **D1 dopamine receptors**, which **depolarize** the **cell** in **response to dopamine**.
    - **Causing excitation**
        - So **excitation** to the **already excitatory pathway** will **only increase the excitation**
- In **contrast**, **indirect pathway striatal neurons** have **D2 dopamine receptors**, which **hyperpolarize** the **cell** in **response to dopamine**.
    - **Causing inhibition**
        - While here **inhibition of the already inhibitory pathway** will cause **excitation**
        - So it will **increase the excitatory signal**

- The **nigrostriatal pathway** thus has the **dual effect** of **exciting** the **direct pathway** while **simultaneously inhibiting** the **indirect pathway**.
- Because of this dual effect, **excitation of the nigrostriatal pathway** has the **net effect** of **exciting cortex** by **two routes**, by **exciting the direct pathway** (which itself has a **net excitatory effect on cortex**) and **inhibiting the indirect pathway** (thereby **disinhibiting** the **net inhibitory effect** of the **indirect pathway on cortex**).
- The **loss** of **these dopamine neurons** in **Parkinson's disease** causes the **poverty** of **movement** that **characterizes this disease**, as the **balance between direct pathway excitation** of **cortex** and **indirect pathway inhibition** of **cortex** is **tipped in favor** of the **indirect pathway**, with a **subsequent pathological global inhibition** of **motor cortex areas**.

Lesions:

Globus pallidus

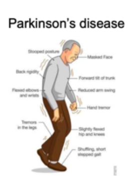
- **lesions** in the **globus pallidus frequently lead** to **spontaneous and often continuous writhing movements** of a **hand, an arm**, the **neck**, or the **face**.
- These **movements** are **called athetosis**.

Subthalamus

- A **lesion** in the **subthalamus** often **leads** to **sudden flailing movements** of an **entire limb**, a **condition called hemiballismus**.

Putamen

- **Multiple small lesions** in the **putamen lead** to **flicking movements** in the **hands, face**, and **other parts of the body**, **called chorea**.

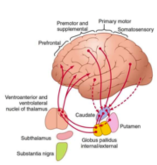


Substantia nigra

- **Lesions** of the **substantia nigra** lead to the **common** and **extremely severe disease** of **rigidity (increase in the tone of the muscle)**, **akinesia**, and **tremors known as Parkinson's disease**
    - **Parkinson's disease** can be **treated by giving L-Dopa**

The caudate circuit

- The **term cognition** means the **thinking processes of the brain**, **using both sensory input** to the **brain plus information already stored** in **memory**.
- **Most** of **our motor actions occur** as a **consequence of thoughts generated** in the **mind**, a **process called cognitive control** of **motor activity**.
- The **caudate nucleus plays** a **major role** in this **cognitive control of motor activity**.
- the **caudate nucleus extends into all lobes** of the **cerebrum**.
- the **caudate nucleus receives large amounts** of its **input** from the **association areas** of the **cerebral cortex overlying** the **caudate nucleus**, **mainly areas** that **also integrate the different types** of **sensory** and **motor information** into **usable thought patterns**.



- **Pathway**: Again here the **circuit starts from the cortex** (almost all the lobes from the cerebral cortex – since I'm doing cognitive control so I need as much information I can gather) to **send input** to the **caudate nuclei** which will **then be sent to the globus pallidus interna** then to the **thalamus** (to the ventroanterior and ventrolateral nuclei) then to the **cerebral cortex** mainly to the **prefrontal cortex** since it's the **only related** to the **cognition** and **decision making** and **planning**
- Cortex→Caudate Nuclei→Globus Pallidus Interna→Ventroanterior and Ventrolateral nuclei of the Thalamus → Prefrontal Cortex

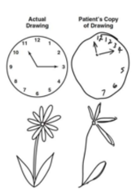
- **Almost none** of the **returning signals passing directly** to the **primary motor cortex**.
- Instead, the **returning signals go** to the **accessory motor regions** in the **premotor** and **supplementary motor** areas that are **concerned with building sequential patterns** of **movement lasting 5 seconds** or **more instead** of **exciting individual muscle movements**.
- **cognitive control** of **motor activity determines subconsciously**, and **within seconds**, which **patterns of movement** will be **used together** to **achieve a complex** goal that might **itself last for many seconds**.

Timing and scaling of movement

- **Two important capabilities** of the **brain** in **controlling movement** are to
  - (1) **determine how rapidly** the **movement is to be performed**
  - (2) **control how large the movement will be**.
- In **patients** with **severe lesions** of the **basal ganglia**, these **timing and scaling functions** are **poor**.

Posterior parietal cortex

- the **basal ganglia do not function alone**; rather, they **function** in **close association** with the **cerebral cortex**.
- **One especially important cortical area** is the **posterior parietal cortex**, which is the **locus** of the **spatial coordinates** for **motor control** of **all parts of the body**, as well as for the **relationship** of the **body** and its **parts to all its surroundings**.



- **Damage** to this **area does not produce simple deficits** of **sensory perception**, such as loss of tactile sensation, blindness, or deafness.
- **Instead**, **lesions** of the **posterior parietal cortex produce** an **inability** to **perceive objects accurately through normally functioning sensory mechanisms**, a **condition called agnosia**.
- Also, **such a person** will **always try to avoid using** his or her **left arm**, **left hand**, or **other portions** of his or her **left body** for the **performance of tasks**; the **person may not even wash** this **side of the body** (**personal neglect syndrome**), almost **not knowing** that **these parts of the body exist**

Huntington's disease

- Huntington disease is an **inherited disorder (autosomal dominant)** in which the **caudate nucleus** and **putamen degenerate**, with **loss of neurons** that **normally release GABA or acetylcholine**.
- A **key sign** of HD is **chorea**, in **which rapid**, **jerky movements occur involuntarily** and **without purpose**.
- **Progressive mental deterioration** also **occurs**.
- **Symptoms** of HD often **do not appear until age 30 or 40**.
- **Death occurs 10 to 20 years after symptoms first appear**.

Tourette syndrome

- characterized by **involuntary body movements** (**motor tics**) and the **use of inappropriate** or **unnecessary sounds or words** (**vocal tics**).
- Although the **cause is unknown**, **research suggests** that this **disorder involves** a **dysfunction** of the **cognitive neural circuits between** the **basal nuclei** and the **prefrontal cortex**.

Psychiatric disorders

- Some psychiatric disorders, such as **schizophrenia** and **obsessive compulsive disorder**, are thought to **involve dysfunction** of the **behavioral neural circuits between** the **basal nuclei** and the **limbic system**.

Initiation of movements

- The **basal nuclei** play a **major role in initiating movements**.
- **Neurons** of the **basal nuclei receive input** from **sensory**, **association**, **and motor areas** of the **cerebral cortex**.
- **Output from** the **basal nuclei** is **sent by way of the thalamus** to the **premotor area**, which **in turn communicates** with **upper motor neurons** in the **primary motor area**, then **activate** the **corticospinal and corticobulbar tracts** to **promote movement**.

Suppression of unwanted movements

- The **basal nuclei suppress unwanted movements** by **tonically inhibiting the neurons** of the **thalamus** that **affect** the **activity of the upper motor neurons** in the **motor cortex.**
- When a **particular movement** is **desired**, the **inhibition of thalamic neurons** by the **basal nuclei** is **removed**, which **allows the thalamic neurons** to **activate** the **appropriate upper motor neurons** in the **motor cortex.**

Regulation of muscle tone

- **Neurons** of the **basal nuclei send action potentials** into the **reticular formation** that **reduce muscle tone via** the **medial and lateral reticulospinal tracts**.
- **Damage** or **destruction** of **some basal nuclei connections causes** a **generalized increase** in **muscle tone.**

Regulation of nonmotor processes

- The **basal nuclei influence several nonmotor aspects** of **cortical function**, **including sensory, limbic, cognitive, and linguistic functions**.
- For example, the **basal nuclei help initiate** and **terminate some cognitive processes**, such as **attention, memory, and planning**.
- In **addition**, the **basal nuclei may act with** the **limbic system** to **regulate emotional behaviors**.