Some notes in the beginning:
#1: there is a slides file contains the sheet info as notes for those who love slides more than word papers.
#2: please go back and see the pictures because I didn’t include them.
#3: doctor said he will not go deep within these slides because we will take them in physiology, so he will explain the anatomical structures, and he will go faster in the functions.

Good luck
Basal Nuclei (Ganglia)

Basal Ganglia

- The basal ganglia include the caudate, putamen, and globus pallidus and number of closely related nuclei. There is other nuclei we will take them.
- They influence motor system primarily through projections to upper motor neurons.
- Motor deficits depend on the specific nucleus damaged.
- Understanding the neurochemistry of basal ganglia drives the development of clinical treatment.

Remember the hierarchy in the last lecture the beginning of motor system was in cerebellum and basal ganglia.

- The basal ganglia act as:
  - Brake against involuntary movement
  - Switch to turn on a fixed action pattern
  - Their major output is to the VA of the thalamus
  - Projects primarily to area 6 ( premotor & supplementary motor areas). There is other functions but we will focus on motor.

Important in smoothness of movement, so if it is disrupted, there will be movement but it will not be smooth and it will be hard.

Basal Ganglia Terminology... they are all close to each other

- Striatum (neostriatum) = caudate + putamen
- Lentiform nucleus = putamen + globus pallidus
- Corpus striatum = caudate + lentiform
- Basal ganglia = corpus striatum + amygdala
- Globus pallidus = pallidum = paleostriatum
- Claustrum is some times included with the basal ganglia
- Basal ganglia is included by the extrapyramidal system

Basal Ganglia: Gross Anatomy

- Caudate nucleus
  - Parts... 1- head of caudate nucleus, largest part, and 2- ends with tail.
  - As you go to tail the caudate will decrease in size.
- Location
- Relations
- Lateral ventricle... part of lateral wall of lateral ventricle.
- Amygdaloid nucleus... found near the end of the caudate nucleus (tail).
• Lentiform nucleus
• Parts
• Putamen
• **Globus pallidus** .. medial to putamen
  • **Internal (GPi)** .. medial to external one
  • **External (GPe)**
• Shape
• Location
• Relations
• **External & internal capsules** .. external capsule is association fibers whereas internal capsule is projection fibers
• **Claustrum** .. found after external capsule, close to Insula
• **Amygdaloid nucleus**
• **Subthalamic nucleus** .. found inferior to thalamus, superior to midbrain, posterior to hypothalamus
• **Substantia nigra**
  • Pars reticulata (SNr)
  • Pars compacta (SNC)
• Claustrum

Caudate with putamen it is stratum, the most anterior part of this stratum called ventral striatum, it is the same "nucleus accumbens"

**Basal Ganglia Circuitry** .. we will take function quickly and more info will be taken in physiology
• Inputs
  • Most inputs enter the striatum
  • From cerebral cortex & thalamus
  • These inputs are excitatory
• Outputs
  • Most leave from Gpi & SNr .. globus pallidus internal & substantia nigra reticulata
  • Most go to VA nucleus of the thalamus, which projects to motor cortex
    • The outputs are GABAergic and inhibitory
      • VA excites motor cortex, leading to movements
        • Increase basal ganglia output will inhibit the VA and reduce overall movements

**Basal Ganglia Circuitry**
**Intrinsic Circuits**
• Large number of connections between components of the basal ganglia
• Can be grouped into
• Direct pathway
• Indirect pathway
• These pathways affect the VA activity and thus the motor cortex Activity

The Direct Pathway
• From striatum to Gpi .. input to striatum is excitatory
  • Uses GABA, which inhibits another GABAergic projection (Gpi to VA)
    • Disinhibition
    • Cortical activity $\rightarrow$ ↑direct pathway $\rightarrow$ ↓Gpi activity $\rightarrow$ ↑VA activity
    • Activity in the direct pathway leads to increased motor cortex activity and increased movements

As we said the output of basal ganglia to Ventral anterior is inhibitory, so, if we inhibit this process (inhibition of inhibition) that’s mean excitation so the ventral anterior nucleus activity will increased.

بالعراقي إذا ما وصلت الفكرة , طبيعة المسار العصبي هو تثبيطي , احنا عملنا تثبيط لهذا المسار ( يعني تثبيط للمسار الي اصلا هو تثبيطي) بالتالي بشكل عام يكون تحيزي

The Indirect Pathway
• Goes from striatum to GPe (GABA) to the subthalamic nucleus (GABA)
• Subthalamic nucleus to Gpi (Glu)
  • ↑ activity in the cortex $\rightarrow$ ↑ activity of subthalamic nu. $\rightarrow$ ↑Gpi $\rightarrow$ ↓ VA activity $\rightarrow$ ↓motor cortex activity

Here in indirect the opposite, again we said the output is inhibitory, but here we didn't inhibit the output, here we increase it! so we increase the inhibiton, so the ventral anterior nucleus activity will decrease so the movements will decrease.

so in the end
direct pathway --> increase movements
indirect pathway --> decrease movements
Basal Ganglia Circuitry
- The direct pathway increase movements
- The indirect pathway decrease movements
- Normal behavior requires a balance between the direct and indirect pathways
- All pathways are uncrossed
- Right basal ganglia modulate right cortex and affect movements on the left side of the body
- Acetylcholine is used by the interneurons in the striatum
- It affects the output of the direct and indirect pathways
- It’s a target for drug therapy

Nigrostriatal Pathway
- In the striatum different cell types give rise to the direct and indirect pathways
  - Both cell types receive dopaminergic input from SN pars compacta
  - These cells have different receptors for DA
    - For direct pathway, DA excites the striatal cells
    - For indirect pathway, DA inhibits the striatal cells
    - Thus the nigrostriatal pathway ↑ the activity of the VA and motor cortex
- PD leads to ..
  - ↓ direct pathway activity
  - ↑ indirect pathway activity
  - ↓ activity of VA and motor cortex

Here we are talking about substantia nigra compacta NOT reticulata
this reticulata affect both direct and indirect pathway
Overall this Nigrostriatal pathway INCREASE the VA and movements
How ??
it excites the direct pathway
 وهو اصلا تفعيل يعني رح يزداد نشاطه
it inhibit the indirect pathway
 وهو اصلا تثبيتيه، فانها نبطه (تثبيط التشطيب) فطلع بالنهائيه تثبيتيه
so in the end it will excite VA and the movements
all these processes are on Dopamine receptor

In parkinson disease the opposite occur !!
Cerebellum .. important in movements, mostly close in function to basal ganglia

Cerebellum
- The cerebellum is essential for normal movements
- It affects motor behavior by affecting UMNs
- The cerebellum acts as a comparator
  - Compares intended movements (data from cerebral cortex) to the actual movements (sensory data)
  - Sends corrective signals into the descending motor Pathways
Remember basal ganglia was initiator for movements but cerebellum for modification of movements

Cerebellar Function .. it has close association with vestibular nuclei for balance during movements
- It affects all movements, it is important in:
  - Balance
  - Locomotion
  - Simple & complex movements
  - Eye movements, etc.
- Site of motor learning
  - Important for learning new motor skills and adjusting movements to changing sensory inputs

Cerebellar Anatomy
Gross Anatomy
- Location ....
- Relations ....
doctor said we already know the location and relations in previous lectures.

- The cerebellum consists of two hemispheres
- The hemispheres are connected by vermis

Cerebellum composed of cerebellar cortex on the periphery, inside there is white matter, and within the white matter there is also islands of grey matter.
Similar to cerebrum, but here the fissure between the two hemispheres is narrow ,, what is this fissure ?? the falx cerebelli.
• Three main lobes
  • Anterior lobe
    • Primary fissure .. between anterior and posterior lobe
  • Posterior lobe (middle lobe) .. the largest lobe
  • Cerebellar tonsils
    • Posterolateral fissure (uvulonodular fissure) .. between posterior and flocculonodular lobe
  • Flocculonodular lobe .. folliculus with nodular (nodular is the most inferior anterior part of vermis )

Cerebellum: Internal Structure

• Content
  • Cerebellar cortex (folia) & central nuclei are grey matter
  • Arbor vitae = tree of life = white matter

The white matter also called arbor vitae or tree of life.

Cerebellar Anatomy
• Cerebellum includes a cortex & deep nuclei
• The deep nuclei are the major source of output from the cerebellum
• Four nuclei from medial to lateral
  • Fastigial
  • Globose
  • Emboliform
  • Dentate

These nuclei, mostly the efferent will exit from them.

The white matter contains 4 nuclei, the fastigial which is the most medial one, Globose and Emboliform called interposed nuclei because they have the same function, and the most lateral one which is Dentate nucleus "Not dentate gyrus!!"

Cerebellar Cortex
• Cerebellar cortex includes 5 cell types in 3 layers
• Five cell types
  • Inhibitory cells
    • Purkinje, basket, Golgi, and stellate cells
• **Excitatory cells**  
  • Granule cells  
• Three layers  
  • Molecular layer  
  • Purkinje cell layer  
  • Granule cell layer

Cerebellar cortex efferent is the purkinje, the other layers affect the purkinje. Purkinje cells "which is the output (efferent)" it is inhibitory so if you inhibit it, overall you are exciting.

**Cerebellar Inputs**  
• **Inputs to the cerebellum**  
  • *Climbing fibers* .. climbing fibers directly affect purkinje  
  • From inferior olivary complex (olivocerebellar fibers)  
  • Decussate  
  • *Inferior cerebellar peduncle*. .. climbing fibers enter cerebellum through inferior cerebellar peduncle

• *Mossy fibers*. .. entrance is different from climbing fibers, mossy fibers affect other cells, where these other cells affect purkinje as we said.

• All remaining inputs: spinal cord, vestibular n. & nuclei, & pontine nuclei  
  • Each type of input fibers branches  
  • Branch to deep nuclei  
  • Branch to cerebellar cortex

**Cerebellar Circuit**  
• The basic cerebellar circuit includes  
  • Main excitatory loop  
  • Inhibitory cortical side loop

**The Main Excitatory Loop**  
• Includes the input and the deep cerebellar nuclei  
• Both the inputs & the cells of the deep nuclei are excitatory

**The Inhibitory Cortical Side Loop**  
• Serves to modulate the activity in the deep cerebellar nuclei
• Mossy & climbing fibers are inputs to cerebellar cortex
• Climbing fibers contact Purkinje cells directly
• Mossy fibers contact granule cells
• Granule cells contact Purkinje cells
□ Output of cerebellar cortex (Purkinje fibers) depend on the mossy & climbing fibers

• Remaining cells (Golgi, basket & stellate) are inhibitory interneurons
• Alter granule & Purkinje cells
• Purkinje cells (cerebellar cortex output) are inhibitory
• Purkinje cells targets
• deep cerebellar nuclei & vestibular nuclei
□ Thus cerebellar output is driven by the main excitatory loop and limited by the inhibitory cortical side loop

Cerebellar Functional Divisions
1. Vestibulocerebellum
   • Flocculonodular lobe & fastigial nu.
   • Balance, eye movements from vestibular nuclei to cerebellum composed of flocculonodular lobe & fastifial nuclei main function is balance and eye movements.

2. Spinocerebellum
   • Vermis & paravermal parts of hemispheres & interposed nuclei (emboliform & globose)
   • Motor execution from spine, composed of vermis and paravermal parts of hemispheres and interposed nuclei function is motor execution.

3. Cerebrocerebellum.. from two hemispheres
   • Lateral hemispheres & dentate
• Motor planning

Vestibulocerebellum
Function
• Balance & eye movements
Inputs
• Vestibular n. fibers
• Vestibular nuclei
• Inferior olive
Deep nucleus
• Fastigial nucleus
Outputs (From fastigial nu. & Purkinje cells) .. this is the only exception in the 3 functional divisions that the purkinje fibers are present here, as we they are efferents.

• Vestibular nuclei
• Reticular formation
• VL of thalamus
Part of motor system targeted
• UMN of medial pathway
Major signs of damage
• Staggering or falling, nystagmus

Spinocerebellum
Function
• Execution of movement
• Compensates for changes in load, regulates muscle tone, guides limb movement, helps maintain posture
• Organized somatotopically
• Head & trunk – vermis
• Limbs – paravermal areas
Inputs
• Spinal & trigeminal inputs
• Inferior olive
Deep nucleus
• Fastigial & interposed nuclei
Outputs
• Vermis
• Reticular formation & Vestibular nu.
• Paravermal
• Red nucleus, VL of thalamus & Inferior olive
Part of motor system targeted
• UMN of medial & lateral pathways
Major signs of damage
• Staggering gait, intention tremor

Cerebrocerebellum
Function
• Coordination, planning of voluntary movements

Inputs
• Pontine nuclei (relaying information from sensory & motor cerebral cortex)
• Inferior olive
• Dentate nucleus

Outputs
• Red nucleus (to inferior olive, back to cerebellum)
• VL of thalamus

Part of motor system targeted
• Motor cortex (via VL)

Major signs of damage
• Decomposition of movements

as we know there are 3 cerebellar peduncles, every one has it's own contents "inputs and outputs"

Cerebellar Peduncles

<table>
<thead>
<tr>
<th>Peduncle</th>
<th>Major inputs to cerebellum</th>
<th>Major outputs from cerebellum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fibers from:</td>
<td>Fibers to:</td>
</tr>
<tr>
<td>Inferior</td>
<td>Inferior olive (climbing fibers)</td>
<td>Vestibular nuclei</td>
</tr>
<tr>
<td>- Restiform body</td>
<td>Dorsal spinocerebellar tract</td>
<td></td>
</tr>
<tr>
<td>- Juxtarestiform body</td>
<td>Cuneocerebellar tract</td>
<td></td>
</tr>
<tr>
<td>- Juxtarestiform body</td>
<td>Vestibular nerve</td>
<td></td>
</tr>
<tr>
<td>- Juxtarestiform body</td>
<td>Vestibular nuclei</td>
<td></td>
</tr>
<tr>
<td>Middle (brachium pontis)</td>
<td>Pontine nuclei (relay inputs from cerebral cortex)</td>
<td>None</td>
</tr>
<tr>
<td>Superior (brachium conjunctivum)</td>
<td>Ventral spinocerebellar</td>
<td>Red nucleus</td>
</tr>
<tr>
<td></td>
<td>Rostral spinocerebellar</td>
<td>VL thalamus</td>
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<tr>
<td></td>
<td></td>
<td>Reticular formation</td>
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<tr>
<td></td>
<td></td>
<td>Inferior olive</td>
</tr>
</tbody>
</table>
Blood Supply of Cerebellum

- SCA
- Superior cerebellar hemispheres
- Superior vermis
- Dentate nucleus
- Most of white matter
- Superior cerebellar peduncle
- AICA
- Middle cerebellar peduncle
- Flocculus
- Anteroinferior surface of the cerebellum
- PICA
- Posteroinferior cerebellar hemispheres
- Inferior portion of the vermis
- Inferior cerebellar peduncle