Common organizational principles

Basic Circuits or Loops:
- **Motor loop** – concerned with learned movements (scaling the strength of muscle contractions that with the SMA, organizing the requisite sequence of excitation of motor cortex cell columns.)
  - Direct pathway (A) – “five” neuron pathway
  - Indirect pathway (B) – “seven” neuron pathway
- **Cognitive loop** – concerned with motor intention, motor learning or “planning ahead”. When the task is no longer novel and becomes automatic, the motor loop “takes over”).
- **Limbic loop** – concerned with emotional or motor expression of emotions
- **Oculomotor loop** – concerned with voluntary saccades (fast eye-movements)

General principles
- Substantia nigra has two parts (dorsal and ventral striatal system)
  - Compact part (SNc) – provides widespread modulatory dopaminergic projections to the other basal ganglia
  - Reticular part (SNr) - one of the basal ganglia output nuclei (“equivalent role” as the GPe)
- Limbic inputs reach not only the nucleus accumbens, but adjoining parts of the putamen and caudate nucleus so, these limbic-recipient regions are recognized as a separate striatal division – ventral striatum
- **Striatum** and **pallidum** are somatotopically organized; permits selective inhibition of “unwanted” movements
  - Striatum major cell types include:
    - Medium spiny neurons (MSN) – comprise 95% of the neuronal population, use GABA as their primary neurotransmitter and are the only projection neurons out of the striatum. These neurons are distributed into 2 compartments, striosome (these MSNs project to the Substantia nigra compacta and control dopaminergic input to the whole striatum) and matrix (contains most of the direct and indirect MSNs).
    - Striatal interneurons - comprise the 5% of this neuronal population, include cholinergic and GABAergic neurons and play a major role in control of striatal outputs.
- **Subthalamic nucleus** receives input from the cortex (“rapid access” to the basal ganglia or “hyperdirect pathway”) and GPe; Output is excitatory to the GPI and SNr neurons. It is important for inhibiting unwanted movements
- **Globus pallidus externa** or **GPe** (receives inhibitory input from the striatum and excitatory input from the subthalamic nucleus) distributes widespread inhibitory (GABA) outputs to most parts of the basal ganglia.
- **Globus pallidus interna** (GPI) and **Substantia nigra reticularis** (SNr) receives inhibitory input from the striatum and GPe, but excitatory input from the subthalamic nucleus > thalamus (fibers for motor control end in VA/VL; fibers for the caudate and prefrontal end in the DM and VA; some end in the intralaminar nuclei) > cortical areas
Basal Ganglia
- Principal inputs from the cortex ➔ putamen, caudate nucleus, nucleus accumbens, subthalamic nucleus
- Principal outputs from the GPi + SNr ➔ thalamus ➔ cortex
- Nigrostriatal pathway - normally tonically active (SNc and ventral tegmental area project to all of the striatum)
- **Direct pathway**: striatum ➔ GPi is inhibited ➔ Thalamus is disinhibited ➔ cortex is excited
- **Indirect pathway**: striatum (when striatal neurons with D2 receptors are activated by dopamine) ➔ GPe is inhibited ➔ STN (disinhibited) ➔ GPi is facilitated ➔ thalamus is inhibited ➔ cortex is suppressed

Schematic of the classic model of the motor circuit.
Red arrows indicate inhibitory GABA-ergic projections, green arrows represent excitatory glutamatergic projections, and black arrows indicate dopaminergic innervation.

In the normal state (A), the striatum receives cortical excitatory input and projects to output neurons in the GPi through a direct pathway, and by a polysynaptic indirect pathway via the GPe and the STN. Dopamine is thought to inhibit neuronal activity in the indirect pathway and to excite neurons in the direct pathway.

In the parkinsonian state (B), when neuronal degeneration in the SNc and dopamine striatal depletion fall below 50% and 80%, respectively, striatal physiology is disrupted. Dopamine D1 receptor-expressing striatal neurons in the direct pathway become hypoactive, whereas dopamine D2 receptor-bearing striatal neurons in the indirect pathway are hyperactive. The latter response leads to increased inhibition of the GPe, and disinhibition of the STN. Over activity in STN neurons and reduced inhibition in the direct pathway provokes excessive excitation of neurons in the GPi and over inhibition of thalamocortical and brainstem motor centers, resulting in parkinsonism.

The thickness of the arrows indicates the degree of activation of each projection. GPe=globus pallidus externa. GPi=globus pallidus interna. STN=subthalamic nucleus. SNc=substantia nigra pars compacta.

# TEACH-SHEET Cerebellum

## Primary Afferents to the Cerebellum

<table>
<thead>
<tr>
<th>Tract</th>
<th>Origin</th>
<th>Termination</th>
<th>Peduncle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vestibulocerebellar</td>
<td>Vestibular ganglia</td>
<td>Nodulus and uvula - Ipsilateral</td>
<td>Inferior</td>
</tr>
<tr>
<td>Vestibulocerebellar</td>
<td>Vestibular nuclei</td>
<td>Flocculus, nodulus and vermis - Bilateral</td>
<td>Inferior</td>
</tr>
<tr>
<td>Anterior spinocerebellar</td>
<td>Ascends in contralateral spinal cord (T12-L3)</td>
<td>Vermis and intermediate zone - Ipsilateral</td>
<td>Superior</td>
</tr>
<tr>
<td>Posterior spinocerebellar</td>
<td>Clarke’s nucleus (T1-L2/3)</td>
<td>Vermis and intermediate zone - Ipsilateral</td>
<td>Inferior</td>
</tr>
<tr>
<td>Cuneocerebellar</td>
<td>Lateral cuneate nucleus (medulla)</td>
<td>Vermis and intermediate zone - Ipsilateral</td>
<td>Inferior</td>
</tr>
<tr>
<td>Rostral spinocerebellar</td>
<td>Ipsilateral spinal cord (cervical)</td>
<td>Vermis and intermediate zone? - Ipsilateral</td>
<td>Inferior Superior</td>
</tr>
<tr>
<td>Reticulocerebellar</td>
<td>Lateral, paramedian, reticular</td>
<td>Vermis and intermediate zone - Ipsilateral</td>
<td>Inferior (Middle - reticular segmental nucleus)</td>
</tr>
<tr>
<td>Trigeminocerebellar</td>
<td>Spinal and main sensory nucleus of V</td>
<td>Vermis and intermediate zone - Ipsilateral</td>
<td>Inferior</td>
</tr>
<tr>
<td>Olivocerebellar</td>
<td>Inferior olivary, accessory olivary nuclei</td>
<td>All contralateral areas</td>
<td>Inferior</td>
</tr>
<tr>
<td>Pontocerebellar</td>
<td>Pontine nuclei</td>
<td>Anterior and posterior lobes – Contralateral</td>
<td>Middle</td>
</tr>
</tbody>
</table>

![Diagram of Purkinje cell, climbing fibre, and mossy fibre connections](image-url)
Cerebellar hemisphere & dentate nucleus projections

Flocculonodular lobe & fastigial nucleus projections

Vermis & interposed (globose + emboliform) nucleus projections

Cerebellar hemisphere & dentate nucleus projections