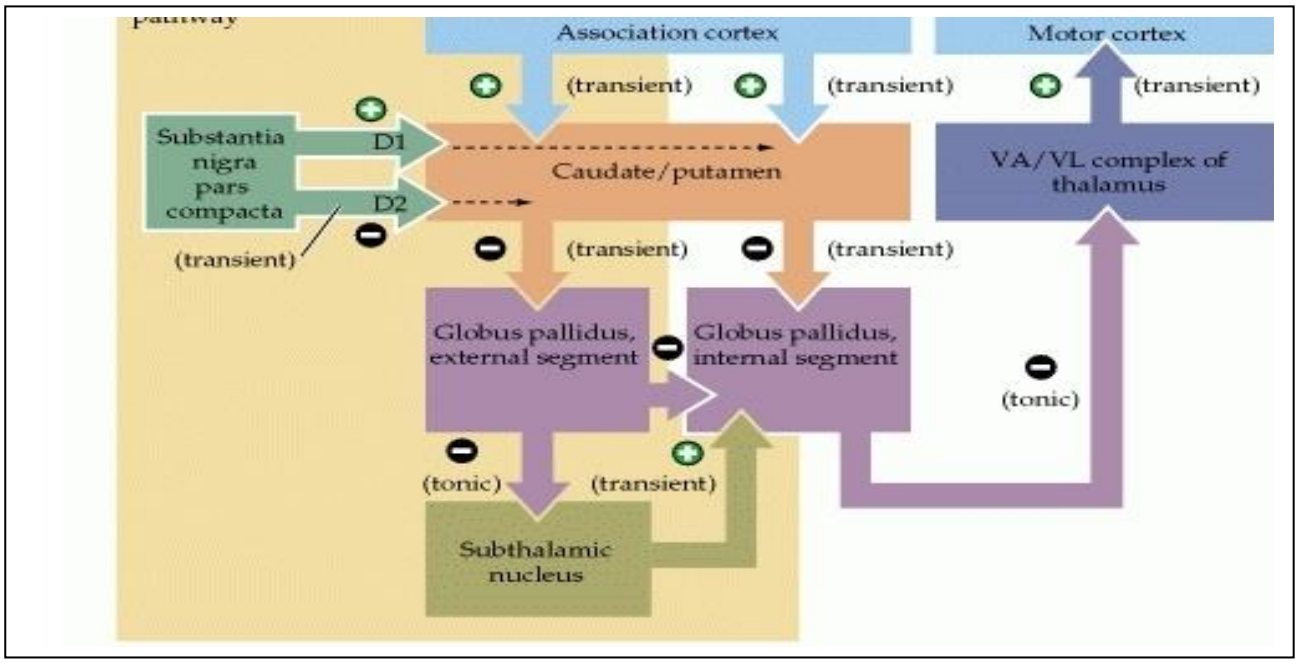
Teach-SHEET Basal Ganglia



Purves D, et al. Neuroscience, 5th Ed., Sinauer Associates, 2012

Common organizational principles

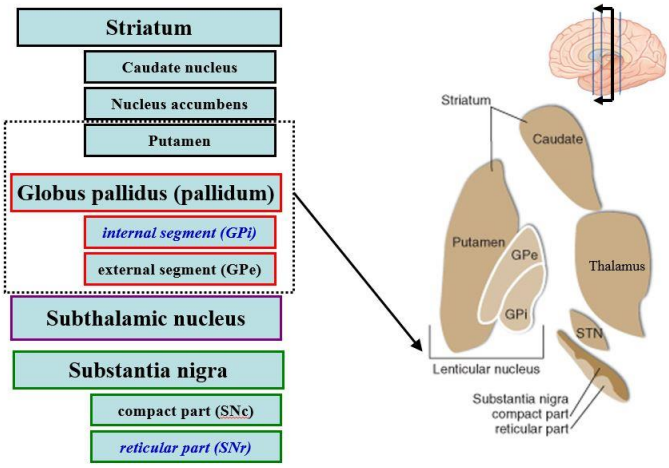
Basic Circuits or Loops:

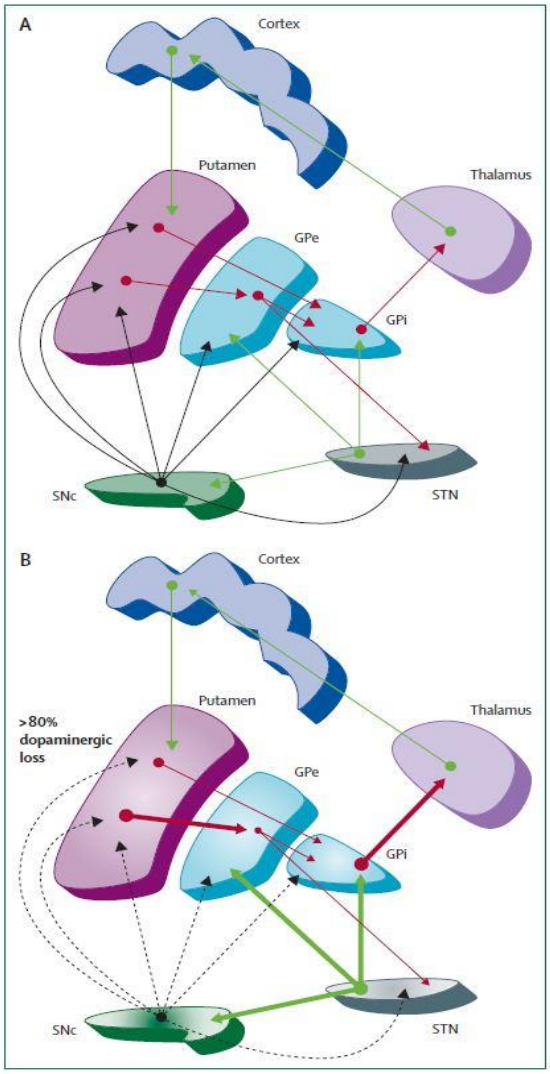
- **Motor loop** – concerned with learned movements (scaling the strength of muscle contractions that with the SMA, organizing the requisite sequence of excitation of motor cortex cell columns.)
  - **Direct pathway (A) – "five" neuron pathway**
  - **Indirect pathway (B) – "seven" neuron pathway**
- **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.

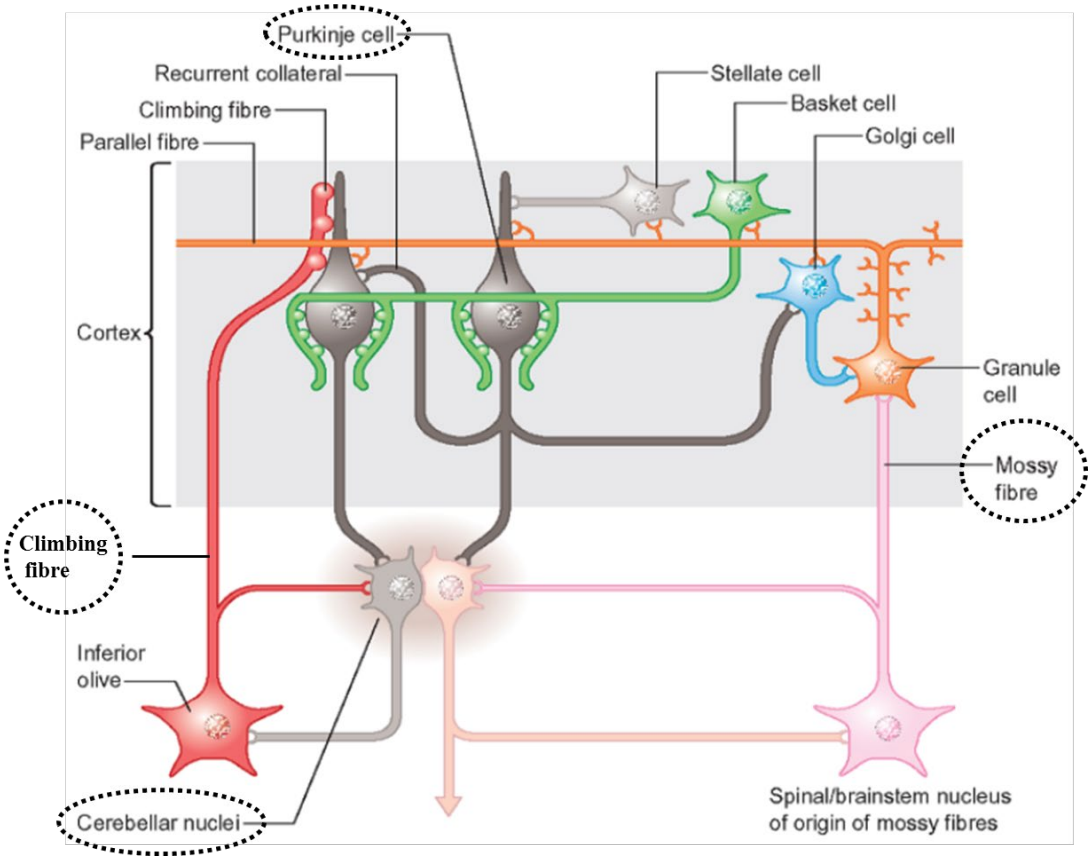
The thickness of the arrows indicates the degree of activation of each projection. GPe=globus pallidus externa. GPi=globus pallidus interna. STN=subthalamic nucleus. SNc=substantia nigra pars compacta.

Obeso JA, Rodriguez-Oroz MC, tamelou M, et al. ***The expanding universe of disorders of the basal ganglia.*** *Lancet 2014; 384: 523–31*

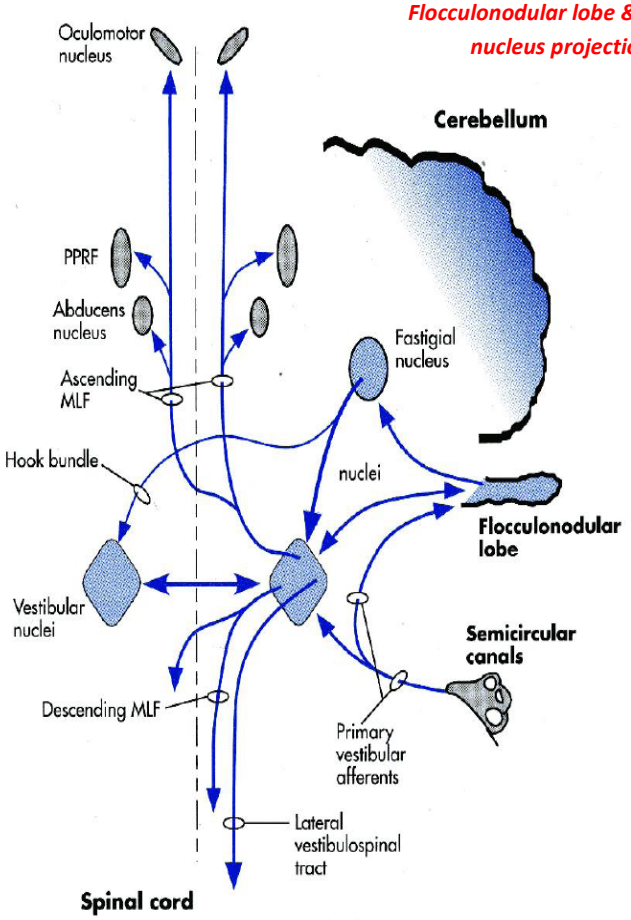
TEACH-SHEET Cerebellum

Primary Afferents to the Cerebellum

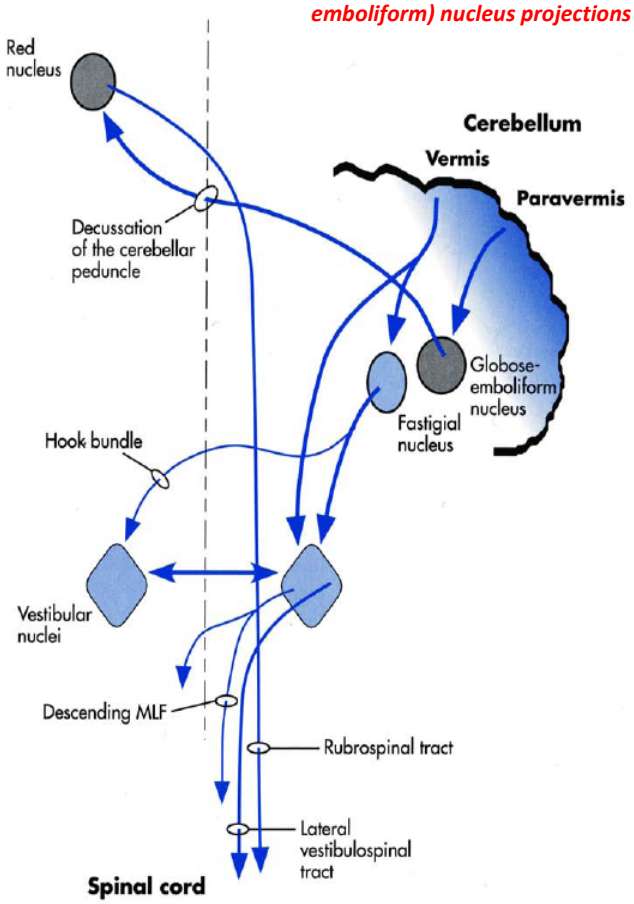
Tract	Origin	Termination	Peduncle
Vestibulocerebellar	Vestibular ganglia	Nodulus and uvula - Ipsilateral	Inferior
Vestibulocerebellar	Vestibular nuclei	Flocculus, nodulus and vermis - Bilateral	Inferior
Anterior spinocerebellar	Ascends in contralateral spinal cord (T12-L5)	Vermis and intermediate zone - Ipsilateral	Superior
Posterior spinocerebellar	Clarke's nucleus (T1-L2/3)	Vermis and intermediate zone - Ipsilateral	Inferior
Cuneocerebellar	Lateral cuneate nucleus (medulla)	Vermis and intermediate zone - Ipsilateral	Inferior
Rostral spinocerebellar	*Ipsilateral spinal cord (cervical)*	*Vermis and intermediate zone? - Ipsilateral*	*Inferior Superior*
Reticulocerebellar	Lateral, paramedian, reticular tegmental nuclei	Vermis and intermediate zone - Ipsilateral	Inferior (Middle - reticular tegmental nucleus)
Trigeminocerebellar	Spinal and main sensory nucleus of V	Vermis and intermediate zone - Ipsilateral	Inferior
Olivocerebellar	Inferior olivary, accessory olivary nuclei	All contralateral areas	Inferior
Pontocerebellar	Pontine nuclei	Anterior and posterior lobes – Contralateral Vermis – Ipsilateral	Middle



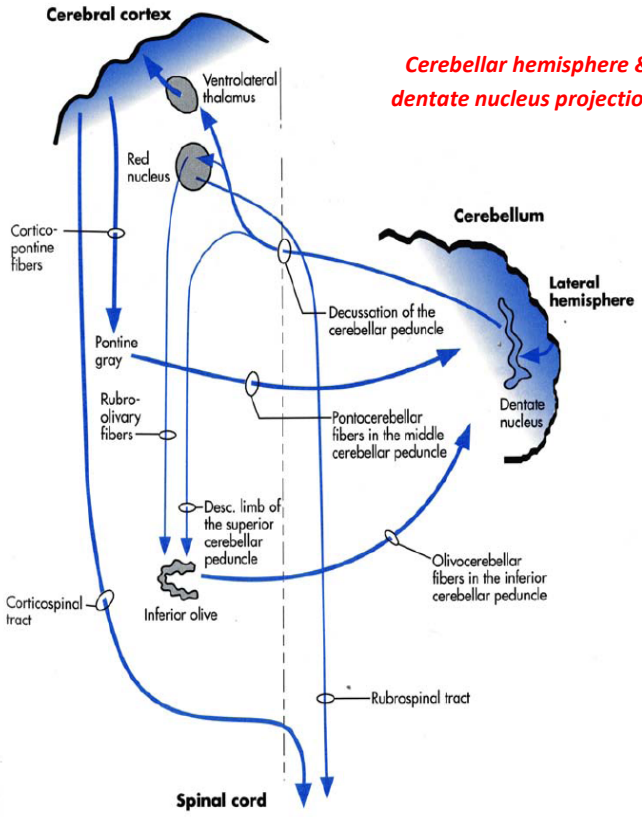
Flocculonodular lobe & fastigial nucleus projections

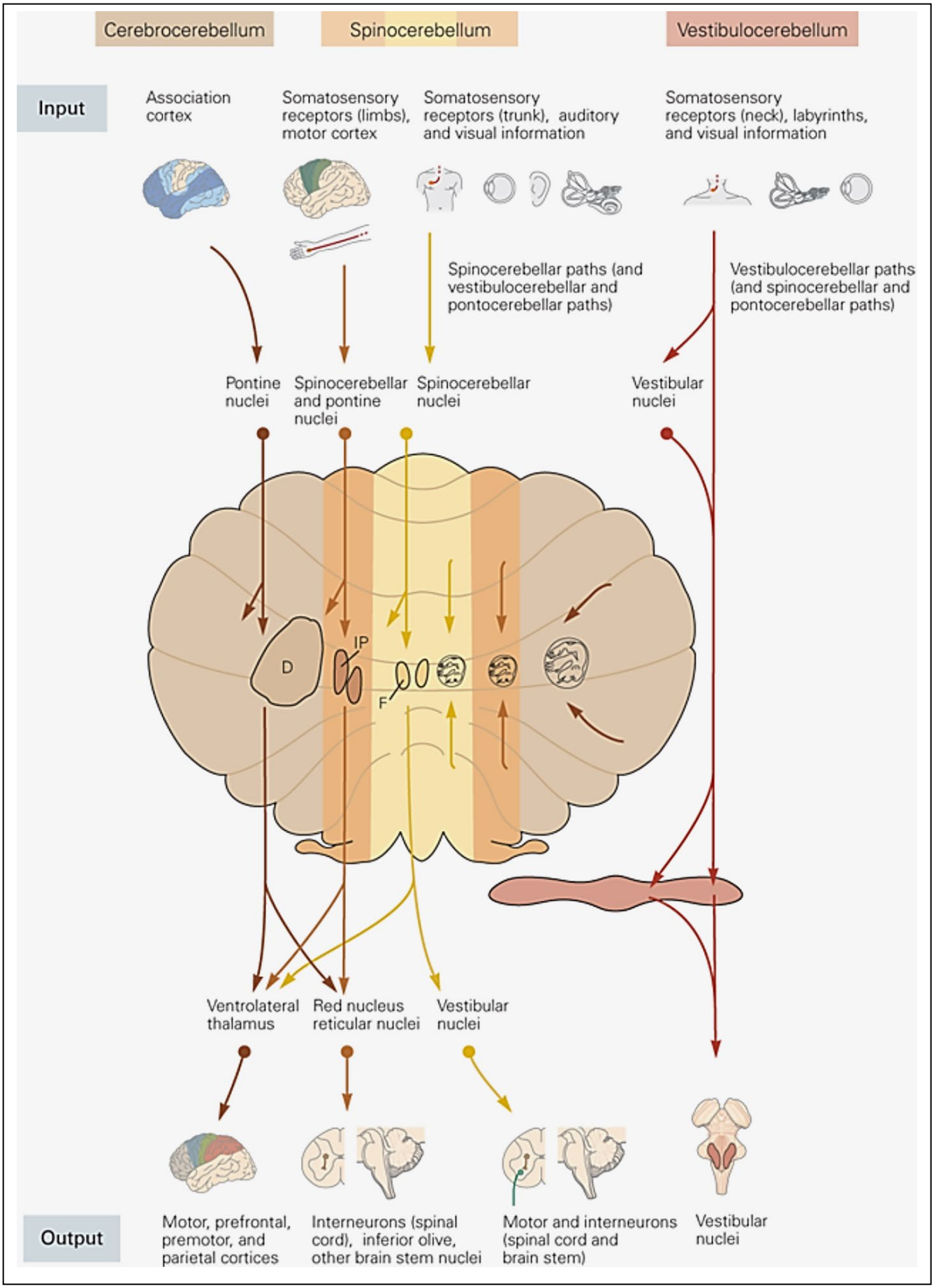


Vermis & interposed (globose + emboliform) nucleus projections



Cerebellar hemisphere & dentate nucleus projections





Kandel ER, Schwartz JH, Jessell TM, Siegelbaum SA, Hudspeth AJ, Mack S. Principles of Neural Science, Fifth Editon; 2012