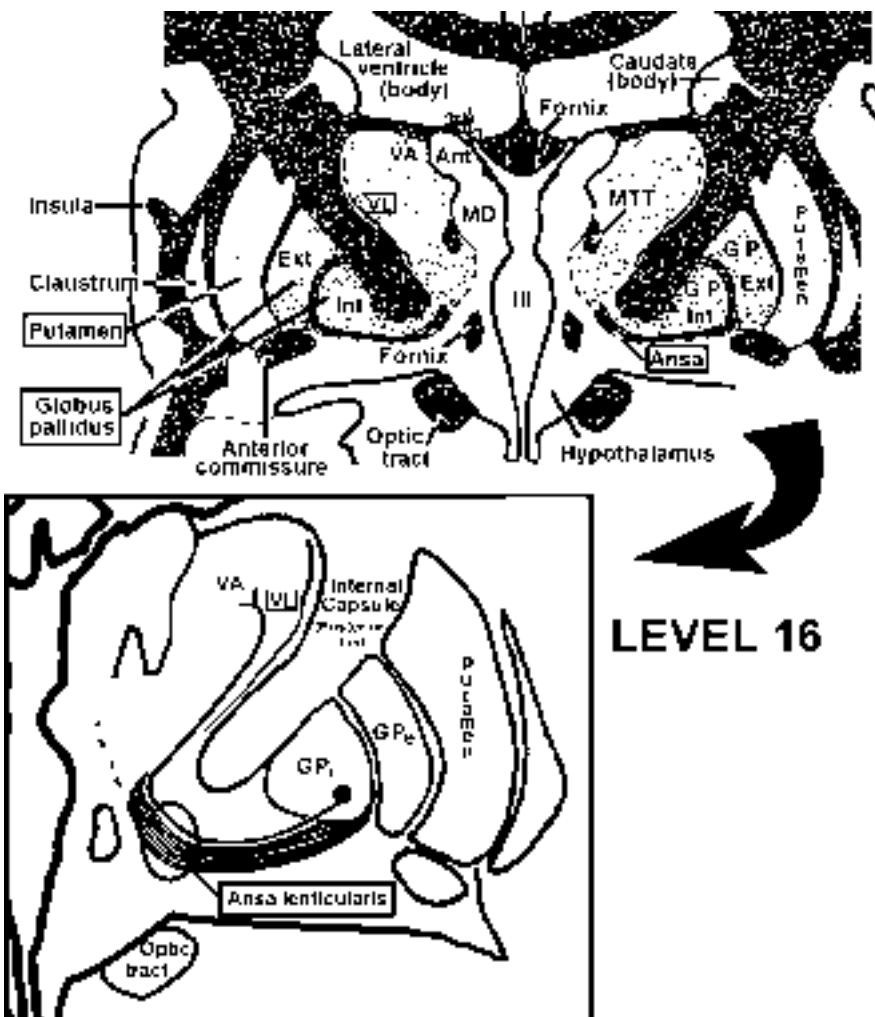


Basal Ganglia

You have just read about the different motor-related cortical areas. Premotor areas are involved in planning, while MI is involved in execution; corticospinal fibers from MI target LMNs. What you don't know is that the cortical areas involved in movement control need some "help" from the basal ganglia in order to smoothly orchestrate motor behaviors. Without the information from the basal ganglia, the cortex is unable to properly direct motor control, and the deficits seen in Parkinson's and Huntington's disease and other movement disorders become apparent.

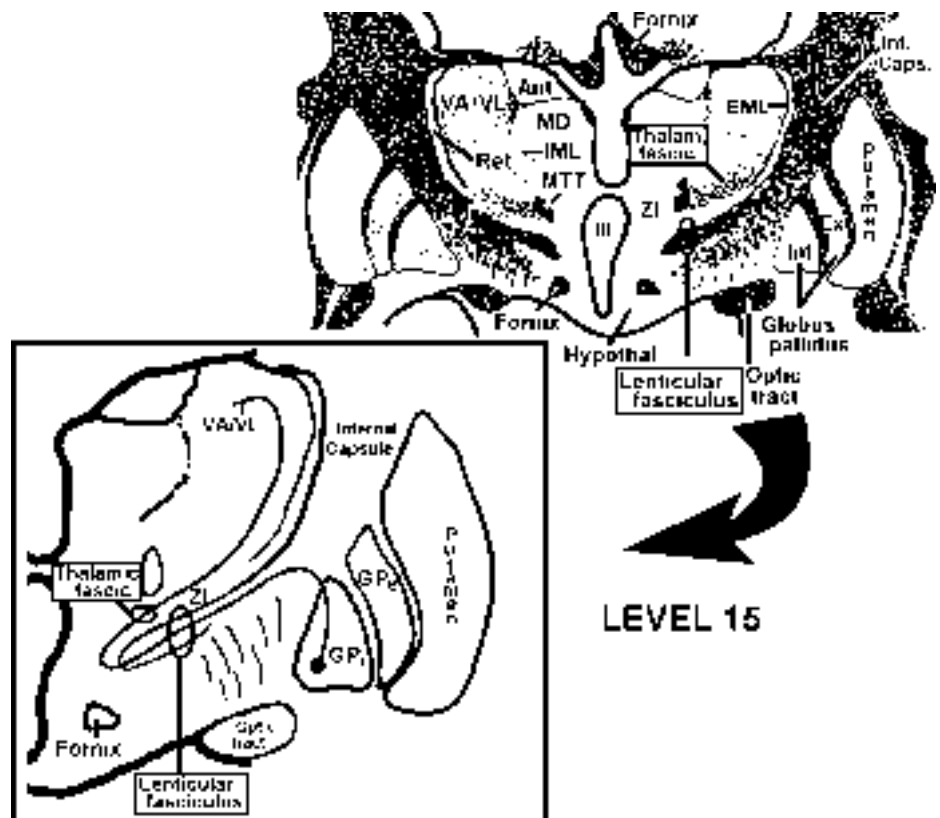
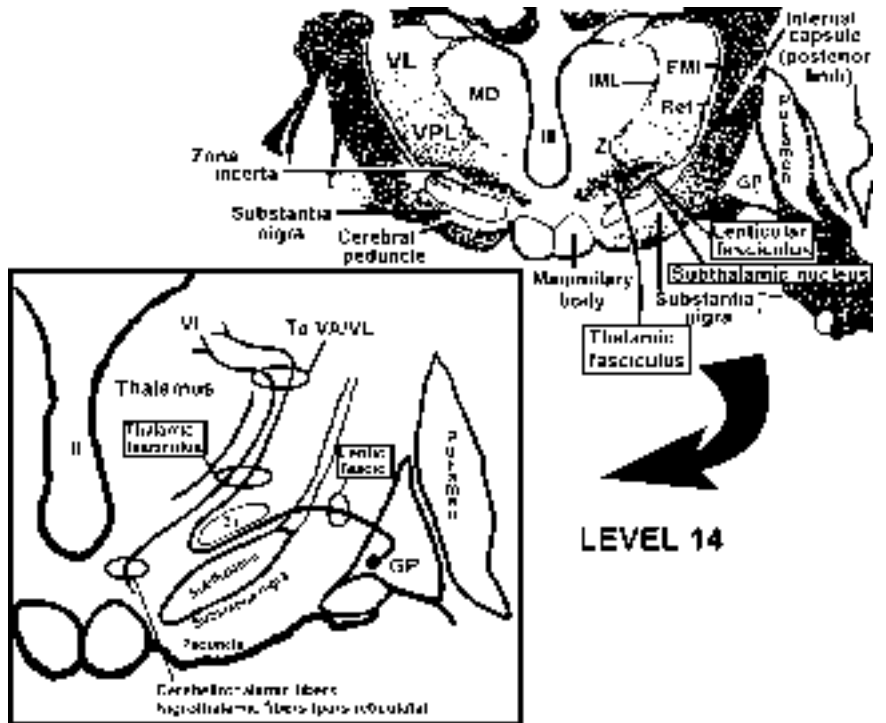
The adjacent drawings show level 16 of our series of brain sections. Some of the important "players" can be seen. They are the **caudate** nucleus and the **putamen** nucleus. Together they are called the **neostriatum** or simply **striatum**. Next to the putamen is the globus pallidus, and it can be seen to have two parts, a lateral (external or outer) segment and a medial (internal or inner) segment. The **putamen** and **globus pallidus**, which lie adjacent to each other, are called the **lenticular** nucleus. Finally, the **striatum** and the **globus pallidus** are called the **corpus striatum**.

You can also see a nice thick fiber bundle associated with the globus pallidus called the **ansa lenticularis**. This fasciculus passes **under** (ventral) the posterior limb of the internal capsule. While not apparent in this section, the **ansa lenticularis** then heads dorsally to reach the motor thalamic nuclei (VA/VL). The ansa arises from cells of the inner segment of the **globus pallidus** and terminates in the **ipsilateral VA/VL**.



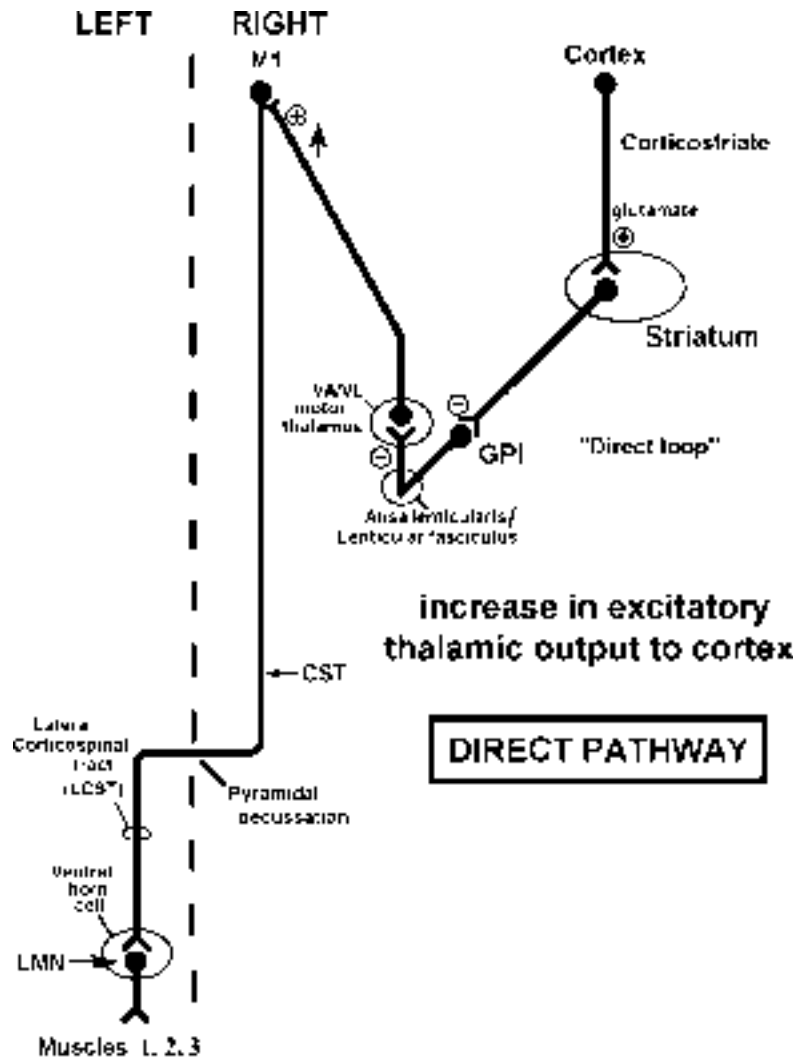
In addition to the **ansa lenticularis**, information from the globus pallidus can also reach the VA/VL via the **lenticular fasciculus**. This is not as simple as the ansa (called the jug handle). Globus pallidus fibers that pass into the lenticular fasciculus pass **through** (rather than under or ventral) the posterior limb of the internal capsule. We can see the lenticular fasciculus (levels 14 and 15) caudal to where we see the ansa (level 16). The fibers in the lenticular fasciculus then pass a little caudally where they lie right on top of the **subthalamic nucleus** (level 14). The fibers in the lenticular fasciculus then suddenly loop dorsally and then pass rostrally towards the VA/VL (I told you it is not as simple as the jug handle). As the fibers comprising the lenticular fasciculus pass rostrally toward the VA/VL they join the cerebellothalamic (interpositus and dentate) fibers that are also headed for the VA/VL. This combined bundle (and another to be mentioned soon) is called the **thalamic fasciculus**.

Cortical inputs from all of the areas involved in the planning and execution of movements project to the striatum (caudate and putamen). Striatal neurons receiving these cortical inputs then project to the globus pallidus, which in turn projects to the VA/VL. VA/VL in turn projects to MI. So, the caudate, putamen and globus pallidus act on the motor thalamus, which acts on the motor cortex. **There are no descending pathways that go directly to the spinal cord.**

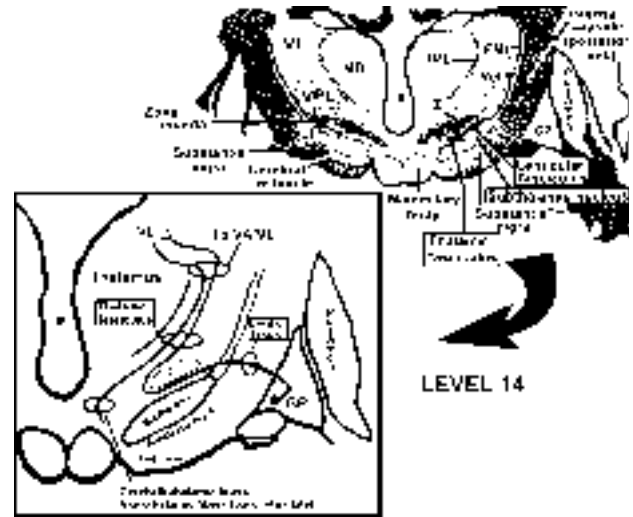


Let's take a more detailed look at the circuitry we have just described. The cortical projections to the striatum use the **excitatory** transmitter **glutamate**. When they are activated, these cortical projections **excite** striatal

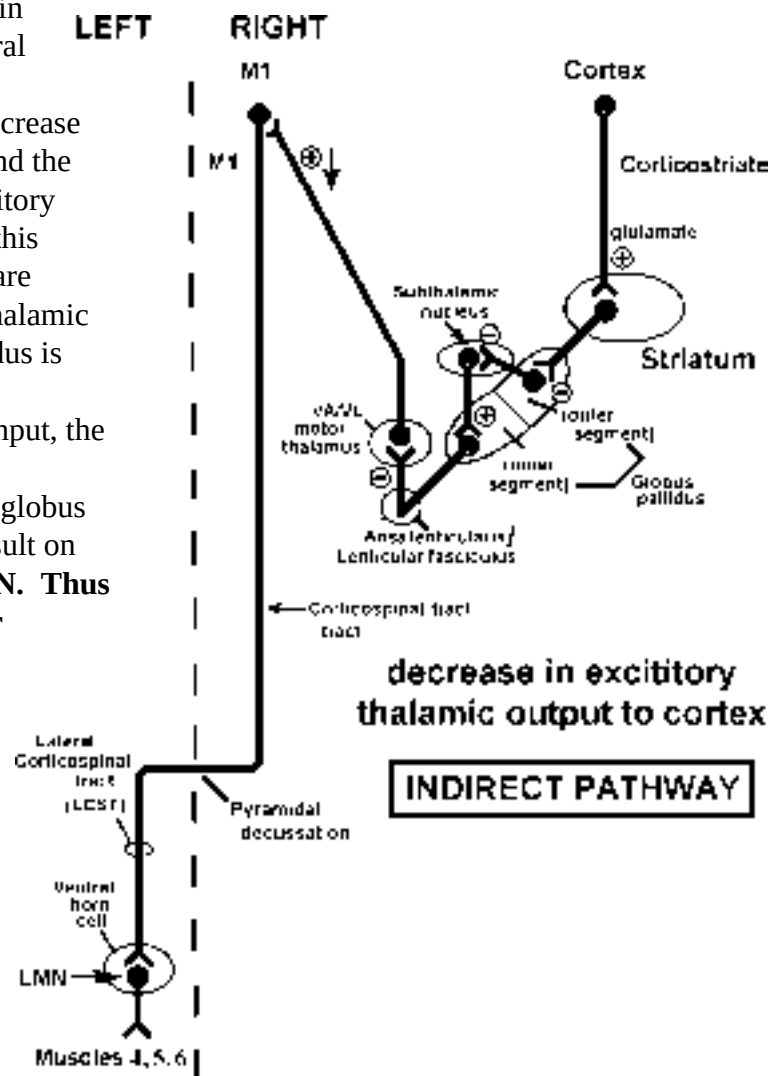
REMEMBER, THE DIRECT PATHWAY TURNS UP MOTOR ACTIVITY. Increased inhibition of the inhibitory input to the motor thalamus = increased firing of the motor thalamus and MI neurons.



Now let's turn to the **Indirect Pathway**. To do this we need to add another nucleus. This is the **subthalamic nucleus**. This nucleus lies just above the rostral portion of the substantia nigra. As shown here, it is bordered dorsally by the lenticular fasciculus. In addition to projecting to the VA/VL, the globus pallidus also projects to the subthalamic nucleus. In particular, cells in the **outer** or **lateral** part of the globus pallidus project to the subthalamic nucleus (cells in the **inner** or **medial** part project to VA/VL). Cells in the subthalamic nucleus project back upon the **inner** or **medial** segment of the globus pallidus, which in turn has an effect on the thalamus.



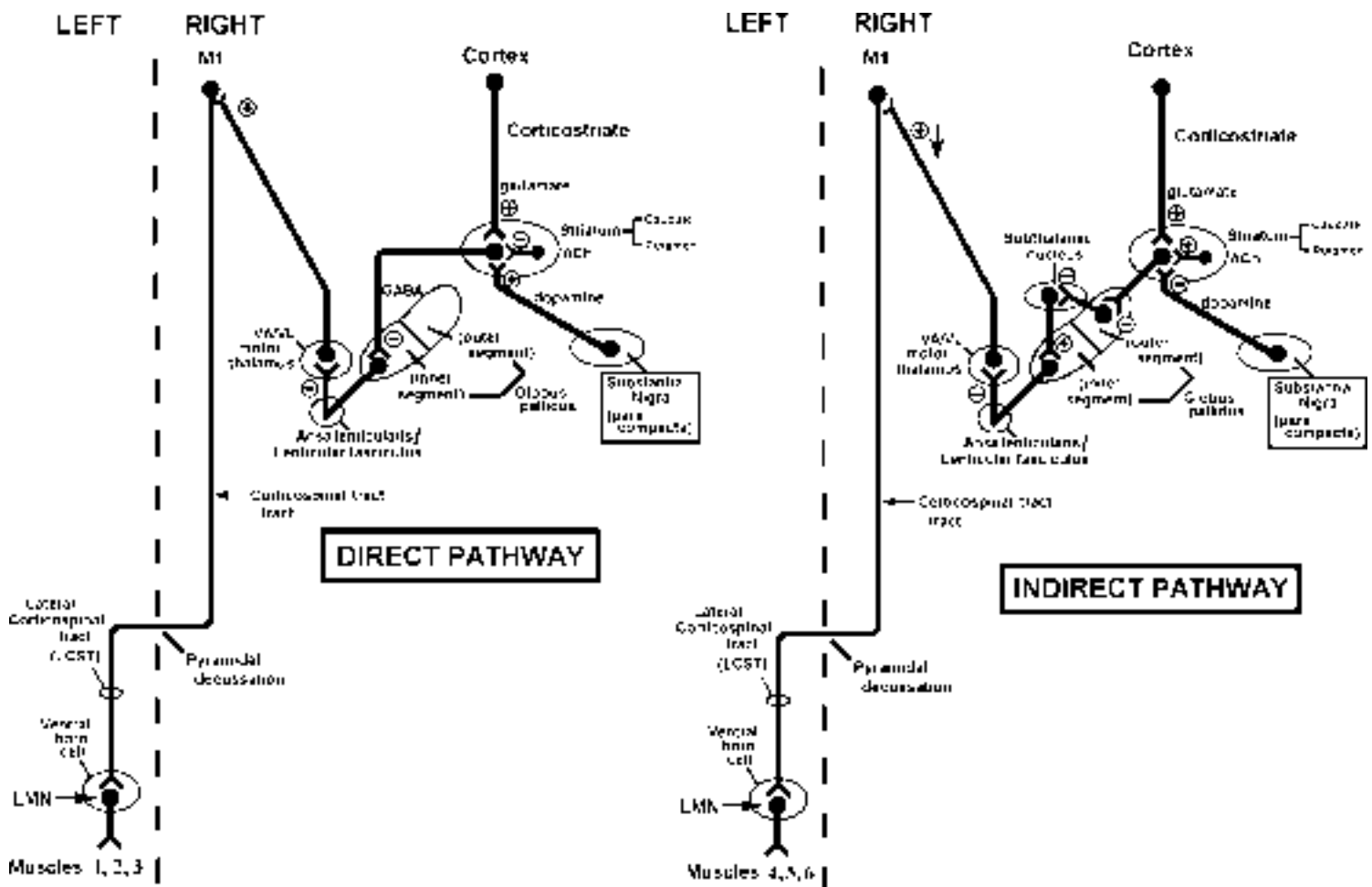
Now let's take a signal through the **Indirect Pathway**. The cortical fibers excite striatal neurons. The cells that are excited project to the **lateral segment** of the globus pallidus. This cortical input increases the firing of the striatal neuron, which in turn increases the inhibition of cells in the lateral segment of the globus pallidus. Cells in the lateral segment of the globus pallidus are inhibitory (they're GABAergic) upon cells in the subthalamic nucleus. Since there is an increase in inhibition flowing out of the striatum to the lateral segment of the globus pallidus, cells in the subthalamic will have less inhibition and thus increase their firing. Think of the subthalamic nucleus and the VA/VL as similar in that they both receive inhibitory projections from the globus pallidus, and when this inhibition is reduced, they increase their firing (are excited). The “return” projection from the subthalamic nucleus to the inner segment of the globus pallidus is excitatory. Thus, when the pallidal input to the subthalamic nucleus is inhibited by the striatal input, the end result is more excitation flowing out of the subthalamic nucleus to the inner segment of the globus pallidus. You can take it from here—the end result on the thalamus is an **INCREASE** in **INHIBITION**. Thus **the Indirect Pathway turns DOWN the motor thalamus and in turn the motor cortex. In contrast, the Direct Pathway turns UP the firing of VA/VL neurons and in turn the motor cortex.**



REMEMBER, THE INDIRECT PATHWAY TURNS DOWN MOTOR ACTIVITY. By inserting an excitatory neuron between the inhibitory striatal neuron and the inhibitory globus pallidus input to the thalamus, the effect of the pallidal input on the VA/VL has been changed from decrease in inhibition (relative excitation) to increase in inhibition.

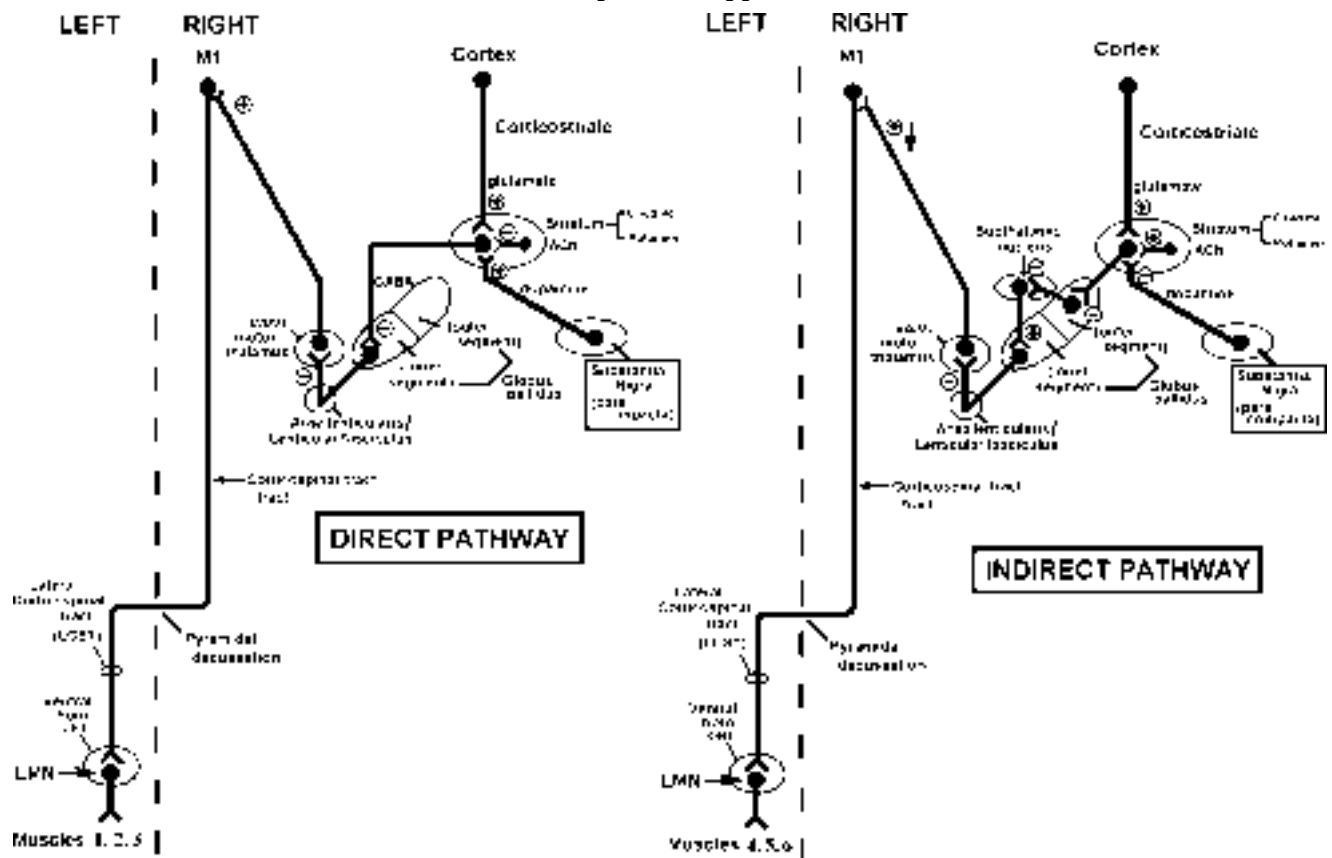
Now let's add the **substantia nigra** to the system. We will look at the direct pathway first. As you now know from the brain stem lectures, dopamine is produced by cells in the pars compacta of the substantia nigra (SNc). Nigrostriatal axon terminals release the dopamine into the striatum. Dopamine has an **EXCITATORY** effect upon cells in the striatum that are part of the **Direct Pathway**. This is via **D1** receptors. This results in an increase in firing of thalamic neurons and an increase in motor activity.

While dopamine excites striatal neurons of the Direct Pathway, dopamine has an **INHIBITORY** effect upon striatal cells associated with the **Indirect Pathway**. This is via **D2** receptors. It is easy to see in the figure below, that the inhibitory drive of the substantia nigra on these striatal neurons will ultimately cause the thalamus to increase firing which will increase movement.



Cholinergic and Dopaminergic Modulation of Direct and Indirect Basal Ganglia Loops

Now we need to add a couple of more cells to the circuitry of the basal ganglia. There is a population of **cholinergic** (ACh) neurons in the striatum whose axons **do not** leave the striatum (called **interneurons** or local circuit neurons). These interneurons synapse on the GABAergic striatal neurons that project to the GPi or GPe (called **projection neurons**). These ACh cells **INHIBIT** striatal cells of the **Direct pathway** and **EXCITE** striatal cells of the **Indirect pathway**. (ACh=INHIBIT DIRECT; ACh=EXCITE INDIRECT; they are more “planner” than “doer”) You should also recall from the brain stem module that terminals of cells in the substantia nigra pars compacta (SNpc) release dopamine (DA) into the striatum. There are different DA receptors on the striatal neurons associated with the Direct (project to GPi) and Indirect pathways (project to GPe). Thus, there are **D1** receptors on striatal cells that project to GPi (Direct pathway) and **D2** receptors on striatal cells that project to the GPe (Indirect pathway). Most importantly, DA **EXCITES** striatal cells in the **Direct Pathway** and **INHIBITS** striatal cells in the **Indirect pathway**. This DA effect on striatal cells associated with the two loops is the opposite of the effects of ACh.



REMEMBER:

ACh=INHIBITS STRIATAL CELLS IN DIRECT LOOP

ACh=EXCITES STRIATAL CELLS IN THE INDIRECT LOOP

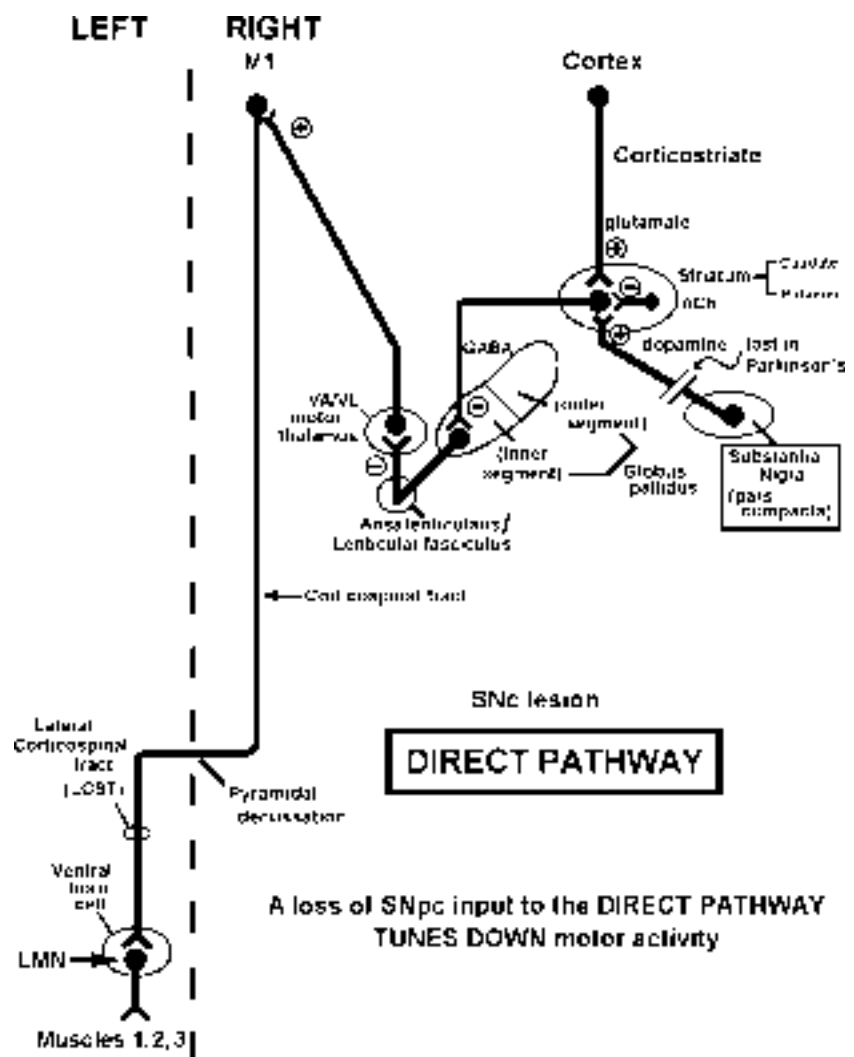
DA=EXCITES STRIATAL CELLS IN THE DIRECT LOOP VIA D₁

DA=INHIBITS STRIATAL CELLS IN THE INDIRECT LOOP VIA D₂

Now that we know the major circuits involved in the basal ganglia, let's take a look at some basic disorders and why they occur. Damage to the basal ganglia causes two different classes of syndromes, one characterized by an increase in movement (hyperkinetic) and the other characterized by decreased movement (hypokinetic). The most well known hypokinetic syndrome is Parkinson's disease, and it generally affects the elderly population. You will hear more about Parkinson's in a subsequent clinical lecture, so for now let's just talk about a few of the classic signs. While hypokinesia (reduced movement) is the hallmark, three other signs, (rigidity, tremor and loss of postural reflexes), accompany this decrease in movement.

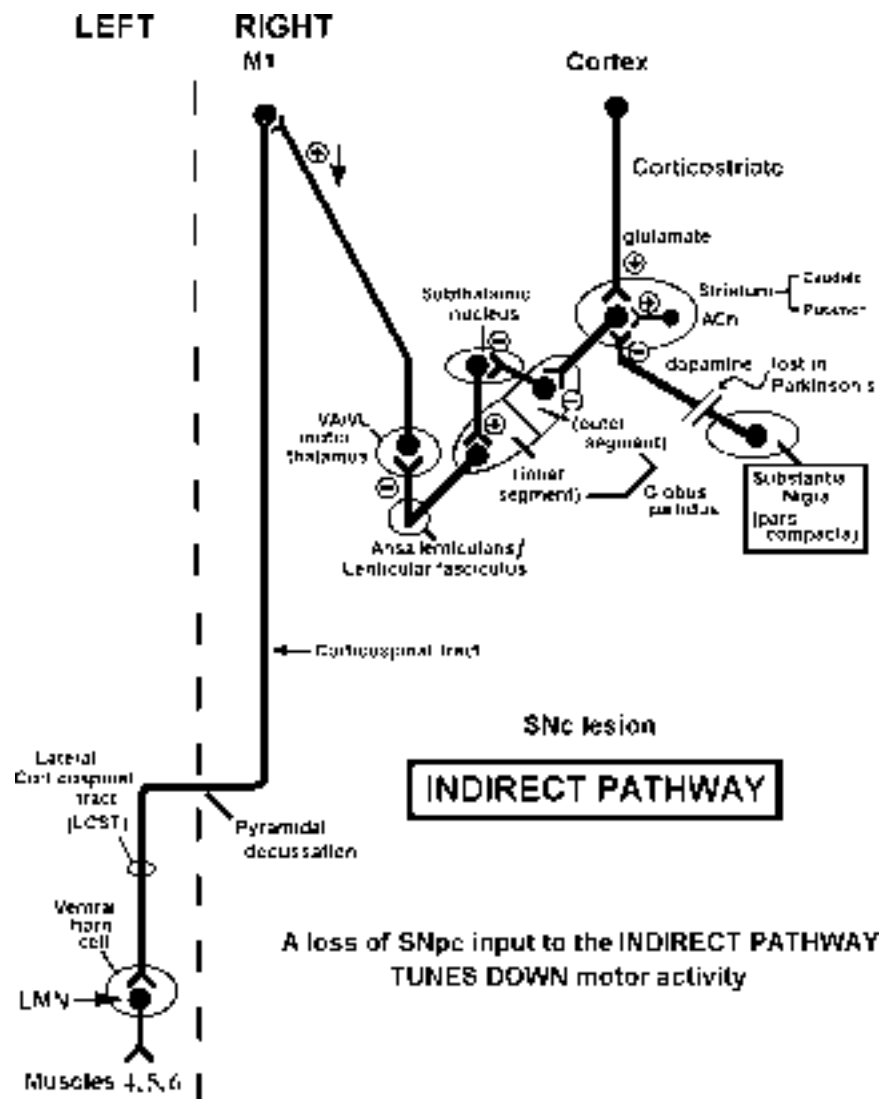
The rigidity is present in all muscle groups, both flexor and extensor, so that the resistance to passive movement is intense and consistent through the entire range of motion, so-called **lead-pipe rigidity**. Unlike the spasticity linked to upper motor neuron lesions, there is no change in the tendon reflexes and all muscles are affected although there is a tendency for the patients to maintain a flexed posture in both arms and legs. The tremor of Parkinson's patients is a **static or resting tremor**, which refers to the fact that there are involuntary 4-5 Hz movements when the limb is held at rest but disappears during a voluntary movement. In this way it contrasts sharply with the intention tremor of cerebellar signs. It is difficult to explain all of these symptoms with the knowledge that we currently have, but we can certainly account for the hypokinesia.

Let's consider a **lesion in the SN pars compacta** as it relates to the direct pathway (see following figure). Loss of this excitation of striatal neurons means that there is **LESS** inhibition of inner segment pallidal neurons by striatal neurons and **MORE** inhibition of the VA/VL. Also, compounding this reduction in inhibition flowing out of the striatum to the medial pallidal segment, is the fact that ACh interneurons are inhibiting these same striatal cells. So there is a double whammy, loss of the excitation from the dopamine and the remaining acetylcholine inhibitory input. Again, the end result is **LESS** inhibition headed to the medial pallidal segment from the striatum and **MORE** inhibition reaching the VA/VL. That is, the motor thalamus and cortex are **slowed down**!



Now let's walk through a lesion of the SNc as it relates to the Indirect Pathway (see following figure). The loss of the dopamine **inhibition** on striatal neurons means that there is **MORE** inhibition going to the lateral segment of the globus pallidus. This in turn means that there is **LESS** inhibition going to the cells in the subthalamic nucleus that **excite** the cells in the inner segment of the globus pallidus. The result is that the subthalamic nucleus will **INCREASE** its excitation of the cells in the inner segment that project to, and inhibit, the VA/VL. This results in more inhibition of cells in the VA/VL. The results of losing dopamine on both the Direct and Indirect Pathways is a reduction in the activity of VA/VL and in turn motor cortical neurons. This results in hypokinetic symptoms such as akinesia (no movement) or bradykinesia (slow movement). Think of it this way; **the tuning up system (direct pathway) is tuned DOWN, and the tuning down system (indirect pathway) is tuned UP.** The result is **tuning down** of motor activity or hypokinesia.

Since the hypokinetic (Parkinson's) patients have decreased levels of dopamine in the striatum and substantia nigra pars compacta, they can be treated symptomatically with **dopaminergic** drugs, such as L-dopa. This is a precursor of dopamine that crosses the blood brain barrier. Parkinson's patients can also be treated with drugs that **decrease** the level of acetyl choline in the striatum. Remember, the ACh cells inhibit striatal cells that project into the Direct Pathway. If a drug reduces this inhibition, then there will be more inhibition flowing from the striatum to the medial segment of the globus pallidus and in turn inhibition of the pallidal projection to the VA/VL. Also remember that ACh cells are excitatory on striatal cells projecting into the Indirect Pathway. If this excitation is blocked by anticholinergic drugs then the "tuning down" system will not be as active.



TO SUMMARIZE-PARKINSON'S PATIENTS CAN BE HELPED BY RAISING THE DOPAMINE LEVELS OR LOWERING THE ACh LEVELS IN THE STRIATUM. BOTH TREATMENTS **INCREASE** THE ACTIVITY IN THE **TUNING UP SYSTEM (DIRECT PATHWAY)** AND **DECREASE** THE ACTIVITY IN THE **TUNING DOWN SYSTEM.**

In the last few years there has been considerable interest generated by the discovery that a “synthetic heroin” drug of abuse contains a substance (**MPTP** or N-methyl, 4-phenyl, 1,2,5,6-tetrahydropyridine) that causes neurological symptoms virtually indistinguishable from Parkinson’s disease. Perhaps the natural disease is caused by chronic exposure to environmental chemicals similar to MPTP in structure. MPTP itself seems to be harmless, but it is converted to a toxic derivative MPP⁺ by monoamine oxidase B enzymes in the brain. Studies indicate that monoamine oxidase B inhibitors may help slow the course of the disease. There has also been considerable interest in the possibility of using transplants of dopaminergic cells into the striatum of patients suffering from Parkinson’s disease as a means of alleviating its symptoms. Success in a very limited number of patients has been reported from implants from either the adrenal medulla or fetal dopamine-secreting cells.

Recently, it has been demonstrated that some of the symptoms of Parkinson’s disease can be reduced or alleviated by **stimulating implants** placed in the **thalamus, subthalamic nucleus or pallidum**. The improvement gained from these electrical stimulating techniques depends on the location of the stimulator. Thalamic stimulators seem to be effective in reducing tremor, but do little for akinesia. Pallidal stimulation seems to have a more all-encompassing therapeutic effect. It is not immediately apparent when you look at the loop circuits, why stimulation in these areas would actually improve the situation until you understand that the stimulation that is used is actually high frequency blocking stimulation, which stops neuronal firing for a short period of time.

While these stimulators, transplants and various drug therapies have come a long way in improving the lives of people with basal ganglia disorders, there is a great deal that we don’t understand about the disease.

While the loss of dopamine from the substantia nigra results in hypokinetic symptoms seen in Parkinson’s disease, hyperkinetic problems are caused by pathologies in other nuclei of the basal ganglia. Two classic hyperkinetic disorders are hemiballism and Huntington’s chorea. Hemiballism is characterized by wild, flinging movements of the body and it results from lesions in the subthalamic nucleus. The excitatory input to the inner segment of the globus pallidus is lost following such lesions. The result is **LESS** inhibition reaching the VA/VL (the subthalamic nucleus normally increases the inhibition in the pallidal-VA/VL projection). Thus, the VA/VL is turned up, as is the motor cortex, and there is uncontrollable **hyperactivity** of the motor system.

Huntington’s chorea is characterized by involuntary **choreiform** movements which show up as rapid, involuntary and purposeless jerks of irregular and variable location on the body. They are spontaneous and cannot be inhibited, controlled, or directed by the patient. Huntington’s chorea is an inherited disease, which usually shows up in the fourth decade. The onset is slow and hard to diagnose, but usually a general irritableness and explosive behavior precede any real symptoms. Later, there is memory loss and attention deficit, followed by restless or fidgety hands. Finally, the disease progresses with facial movements and constant jerky movements of all parts of the body. Despite the continual movements, there may be hypotonia. The cause of these uncontrollable movements is the loss of GABAergic cells in the striatum that project only to the lateral segment of the globus pallidus. This loss shows up on MRI as degeneration in the caudate nucleus. The loss of this inhibition on the pallidal cells means that there is more inhibition reaching the subthalamic nucleus. This means that there is less excitation of the inhibitory projection from the globus pallidus projection to the VA/VL. The end result is that the VA/VL is turned up, as is the motor cortex, and

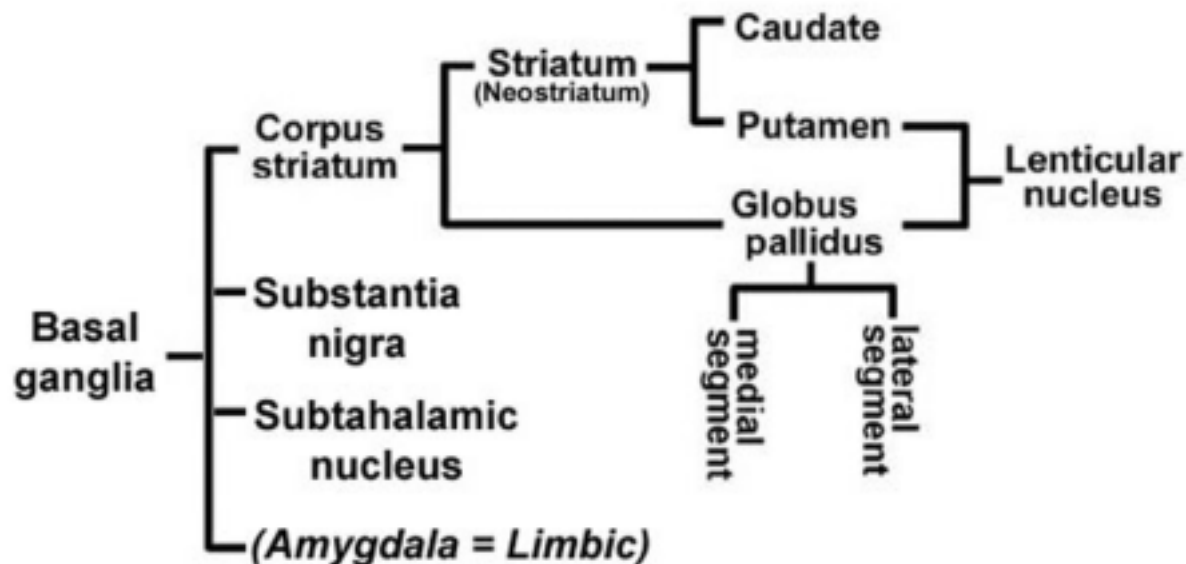
there is uncontrollable hyperactivity of the motor system. In addition to the loss of GABAergic cells, the cholinergic cells of the striatum also begin to die. The loss of both types of cell causes less inhibition at the level of the thalamus and consequently more motor output.

How can these hyperkinetic problems be treated? Well, remember that the indirect pathway is tuned **down** due to interruption of GABA cells from the external palladium and the direct pathway is **dominating**. Since there is a depletion of ACh cells of the striatum and ACh is inhibitory on striatal cells in the direct pathway (see figure below), it makes sense that increasing ACh will increase the amount of inhibition on the striatal cells that project to the inner segment of the pallidum. This will mean that there is more inhibition reaching the cells in the VA/VL and the hyperkinetic activity will be corrected. ACh is excitatory on the indirect pathway and will result in more inhibition flowing out of the striatum. The net effect would be more inhibition of the motor thalamus and lessening of the hyperactivity.

The same cholinergic agonists will help hemiballism. Again, there is hyperactivity of the motor thalamus because the pallidal inhibition upon the VA/VL is **decreased** due to the loss of the excitation from the subthalamic nucleus. Think about what you could do to decrease the direct pathway (which normally tunes things up). You could slow the direct pathway down by increasing the amount of ACh reaching those striatal neurons that project into the direct pathway. This means there is less inhibition flowing out of the striatum to the medial pallidal segment, and more inhibition flowing from the lateral pallidal segment to the VA/VL. The end result is less movement, i.e., reduction of the hyperkinesia.

IN SUMMARY

HYPERKINETIC PROBLEMS RESULT WHEN THE INHIBITORY GLOBUS PALLIDAL PROJECTION TO THE VA/VL IS REDUCED. THIS RESULTS IN INCREASED ACTIVITY OF THE VA/VL AND OF THE MOTOR CORTEX. IN CONTRAST HYPOKINETIC DISEASES RESULT WHEN THE PALLIDAL INPUT TO THE VA/VL IS INCREASED. THIS RESULTS IN A REDUCTION OF VA/VL FIRING AND A DECREASE IN MOTOR CORTICAL ACTIVITY



Now for some National Board stuff. The term “basal ganglia” usually includes the caudate, putamen, globus pallidus, and amygdala. We will use the term more loosely to refer to a group of nuclei that are anatomically interconnected and have important motor functions. These are the **caudate, putamen, globus pallidus, substantia nigra, and subthalamic** nuclei. The amygdala is technically part of the basal ganglia (due to its developmental origin), but functionally is part of the limbic system (emotions and visceral stuff!) so it will be discussed as part of that system later in the course. The striatum and the globus pallidus are collectively known as the **corpus striatum**. Finally because of their close proximity, the globus pallidus and putamen are often called the **lenticular** (lens shaped) nuclei, although the two structures are quite distinct anatomically and physiologically.

Although we have emphasized the motor function of the basal ganglia via a loop from motor cortex to the BG and back again, I would like you to note that many other behaviors can be modified and updated by way of other loops through the BG. Some other loops are the oculomotor loop, limbic loop and the prefrontal loop. As our understanding of these other loops increases, we may be able to alter the course of many different diseases by enhancing specific neurotransmitter pathways.

As a review, let’s look at the results of lesions involving the different motor systems.

Lower Motor Neuron	Upper Motor Neuron	Basal Ganglia
Paralysis	Paresis (weakness)	No paralysis
Muscle atrophy	No atrophy	No atrophy
Areflexia & atonia	Hyperreflexia, hypertonia, spasticity	Parkinson's: rigidity, resting tremor, bradykinesia Huntington's: chorea, hyperkinesia
Ipsi deficit in spinal cord	Contra deficit above decussation Ipsi deficit below decussation	Contra

Problem solving-Basal Ganglia

1. Which of the following statements is **TRUE** regarding cells in the lateral (outer) segment of the globus pallidus?
 - A. receive excitatory input from the striatum
 - B. project directly to the VA/VL
 - C. are part of the indirect pathway
 - D. send inhibitory projections to the subthalamic nucleus
 - E. two of the above statements are true
2. Which of the following statements is **TRUE** regarding the striatum?
 - A. receives inhibitory input from the cortex
 - B. consists of the lenticular nucleus and the putamen
 - C. receives dopaminergic input from the substantia nigra pars compacta
 - D. contains cells that use acetylcholine as their transmitter
 - E. two of the above statements are true
3. Which of the following statements is **FALSE** regarding cells in the VA/VL?
 - A. activity over a normal direct pathway will increase their firing rate
 - B. activity over a normal indirect pathway will decrease their firing rate
 - C. in Huntington's chorea, there is an increase in their firing rate
 - D. in hemiballism there is an increase in their firing rate
 - E. in Parkinson's there is an increase in their firing rate
4. Which of the following statements is **FALSE** regarding cells in the inner segment of the globus pallidus?
 - A. receive excitatory input from the subthalamic nucleus
 - B. receive excitatory (glutamate) input from the cerebral cortex
 - C. contain GABA
 - D. project to the ipsi. VA/VL
 - E. axons run in the ansa lenticularis and lenticular fasciculus
5. Which of the following statements is **TRUE** regarding dopamine input to the striatum?
 - A. excites striatal cells associated with the indirect pathway
 - B. inhibits striatal cells associated with the direct pathway
 - C. reduction in striatum increases motor activity
 - D. reduction can be off-set by giving patient acetylcholine antagonists
 - E. reduction can be off-set by giving patient acetylcholine agonists

6. Which of the following statements is **TRUE** regarding acetylcholine?
- A. excites cells in the direct pathway
 - B. inhibits cells in the indirect pathway
 - C. present in cortico-striatal terminals
 - D. present in the terminals of striatopallidal neurons
 - E. has opposite effects to dopamine on striatal neurons
7. Which of the following statements is **TRUE** regarding Parkinson's disease?
- A. increase in firing of striatal neurons that project to the medial segment of the globus pallidus
 - B. decrease in firing of cells in the medial segment of the globus pallidus
 - C. increase in firing of cells in the subthalamic nucleus
 - D. decrease in firing of cells in the subthalamic nucleus
 - E. increase in firing of VA/VL neurons
8. Which of the following statements is **TRUE** regarding Parkinson's disease?
- A. spasticity
 - B. atrophy
 - C. hypotonia
 - D. movement (intention) tremor
 - E. decreased movement/hypokinesia/bradykinesia
9. Which of the following statements is **TRUE** regarding Huntington's chorea?
- A. Babinski sign
 - B. akinesia
 - C. rigidity
 - D. uncontrollable involuntary movement
 - E. spasticity
10. Which of the following statements is **TRUE** regarding a Babinski sign?
- A. seen in Parkinson's disease
 - B. seen in Huntington's disease
 - C. seen in radiculopathy
 - D. seen in myopathies
 - E. seen in UMN syndrome
11. Which of the following statements is **FALSE** regarding hemiballism?
- A. there is uncontrollable involuntary movement
 - B. there is intention tremor
 - C. can result from a lesion in the subthalamic nucleus
 - D. results in an increase in the firing of VA/VL neurons
 - E. is a result of a lesion somewhere in the indirect pathway

12. Which of the following statements is **TRUE** regarding substantia nigra pars compacta?
- A. cells project to the lateral globus pallidus
 - B. lesion results in hyperkinetic problems
 - C. projects to the VA/VL
 - D. transmitter associated with cells is excitatory on direct pathway
 - E. loss of these neurons result in Huntington's chorea
13. Which of the following statements is **FALSE** regarding the medial segment of the globus pallidus?
- A. receives inhibitory input from the striatum
 - B. lesion will increase thalamic output
 - C. sends axons into the ansa lenticularis
 - D. sends axons into the lenticular fasciculus
 - E. receives GABA input from the SUB
14. Which of the following statements is **FALSE** regarding the striatum?
- A. contains cells that project to the medial segment of the globus pallidus
 - B. contains cells that project to the lateral segment of the globus pallidus
 - C. contains cells that receive inputs from all areas of cortex
 - D. contains cells that contain ACh
 - E. contains cells that project to the subthalamic nucleus
15. Which of the following statements is **FALSE** regarding the lateral segment of the globus pallidus?
- A. projects to the VA/VL
 - B. cells contain GABA
 - C. receives inhibitory input from the striatum
 - D. projects to the subthalamic nucleus
 - E. is involved in the indirect pathway
16. Which of the following statements is **FALSE** regarding the corticospinal tract?
- A. has decreased activity following a loss of cells in the pars compacta of the substantia nigra
 - B. has increased activity following a lesion of the subthalamic nucleus
 - C. has increased activity following a loss of ACh cells in the striatum
 - D. has decreased activity following a loss of cells in the lateral segment of the globus pallidus
 - E. has decreased activity following a lesion of the medial segment of the globus pallidus
17. Which if the following statement is **TRUE**?
- A. cells in the striatum that project to GPi are excitatory
 - B. stimulation of a cell in the striatum that projects to the GPi results an increase in the amount of inhibition reaching the thalamus
 - C. stimulation of the GPi results in an increase in excitation of VA/VL
 - D. a decrease in firing of GPi cells results in an increase in firing of VA/VL cells
 - E. none of the above are **TRUE**

18. Which of the following statement is **TRUE**?

- A. the direct pathway increases movement
- B. activity in the direct pathway through the basal ganglia results in reduced firing of thalamic neurons (VA/VL)
- C. the striatum is defined as the globus pallidus and the putamen
- D. cells in the striatum project directly to the VA/VL
- E. GPi excites the thalamus

19. Which of the following are excitatory?

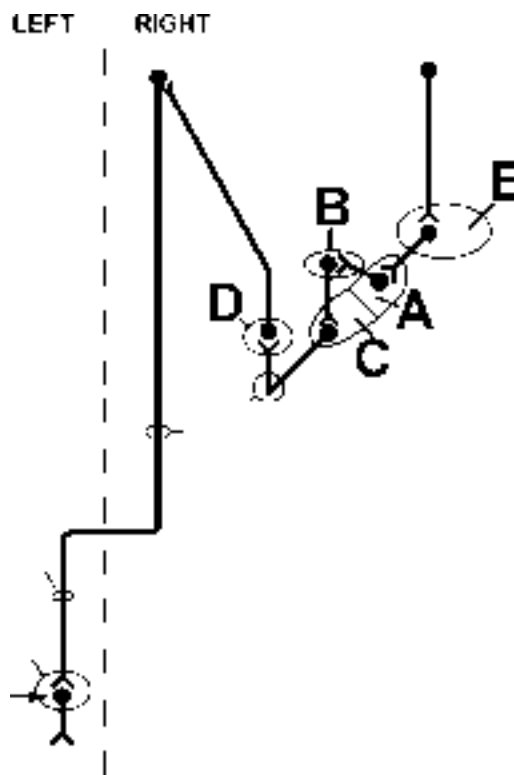
- A. striatal cells that project to the GPi
- B. GPi cells
- C. VA/VL cells
- D. corticostriate cells
- E. two of the above are excitatory

20. Which of the following statements is **TRUE** regarding the lettered structures below and to the right? Consider only the circuitry illustrated. **A=GPi; B=SUB; C=GPi; D=VA/VL; E=striatum**

- A. cells in **E** inhibit **A**
- B. a lesion of **B** results in **increased** firing of **C**
- C. cells in **D** **increase** their firing following a lesion of **A**
- D. cells in **C** **increase** their firing with a lesion of **E**
- E. **A** is part of the Direct Pathway through the basal ganglia

21. **Stimulation** of which of the lettered structures to the right will result in **increased** firing of **D**? Consider only the circuitry illustrated. **A=GPi; B=SUB; C=GPi; D=VA/VL; E=striatum**

- A. **E**
- B. **C**
- C. **B**
- D. **A**
- E. **B** and **C** are **TRUE**



22. Which of the following statements is **TRUE**?

- A. striatal cells with D1 receptors project to GPi
- B. ACh inhibits the Indirect pathway
- C. striatal cells with D2 receptors project to GPe
- D. ACh excites the Direct pathway
- E. two of the statements above are **TRUE**

23. Which of the following statements is **TRUE**?

- A. the loss of dopamine (DA) results in hyperkinesia
- B. ACh antagonists **decrease** the firing of striatal cells associated with the Direct pathway
- C. DA agonists **increase** the firing of striatal cells associated with the Indirect pathway
- D. cholinergic (ACh) agonists **increase** the firing of striatal cells associated with the Direct pathway
- E. there is too much movement in Huntington's chorea and too little movement in Parkinson's Disease

24. Which of the following statements is **TRUE**?

- A. **hemiballism** occurs **ipsilateral** to the lesion in the subthalamic nucleus (SUB)
- B. a lesion of the **subthalamic** nucleus (SUB) **increases** the firing of **GPi** cells associated with the **Indirect** pathway
- C. a person with **hemiballism** could be helped by administration of a **cholinergic agonist**
- D. a person with **hemiballism** could be helped by administration of a **cholinergic antagonist**
- E. a person with **hemiballism** could be helped by administration of a DA **agonist**

25. Louise Bermel is a 60 year old female who presents to the office with difficulty using her right arm. Ms. Bermel states that the difficulty in using her right arm has occurred over the past 2 months. She is right-handed. The clumsiness and intermittent tremor have become progressively worse. No other symptoms are present. To direct questioning she says the right shoulder aches, "it may be bursitis", and that she has noted saliva on her pillow in the mornings. Her children feel she is slower and looks depressed. She denies any visual disturbances, vertigo, palpitations, sensory symptoms or unconsciousness. She denies headaches and there is no history of trauma. Her lab results are normal, her physical exam demonstrates some hypertonia, and a paucity of movements. She is slow to start, but has no retropulsion when pulled from behind. Select the **correct** statement concerning this patient.

- A. she probably has degeneration in her striatum.
- B. her decrease in movements can be improved by the administration of ACh
- C. she is in the early stages of Huntington's disease.
- D. her condition could be improved by the administration of L-Dopa
- E. all are correct

26. A 45 y.o. male is brought in to the doctor by his wife. She says that he has been irritable for the past three months and is acting strange. She also claims and he supports that in the past two weeks he has been fidgety with his hands and now he is demonstrating some strange facial tics. The historical exam yields little information as this patient was an orphan and has no parental or family history. The physical exam showed normal reflexes and sensation, normal strength and no ataxia. There appeared to be mild hypotonia, but this was subjective. The one constant finding was an apparent restlessness during the exam and constant movements of the face. He was given a simple test of memory and attention where he performed below average, and according to his wife way below what she knew he could do. During the test he was irritable and had one outburst over a seemingly trivial event. Select the **true** statement concerning this patient.

- A. he is in the early stages of Parkinson's disease and his restless hands are the early signs of a resting tremor
- B. in the advanced stage of this disease he will have degeneration in the caudate nucleus
- C. he probably has a loss of dopamine producing cells in the substantia nigra
- D. his condition will improve with the administration of L-Dopa
- E. all are true

ANSWERS TO BASAL GANGLIA REVIEW QUESTIONS

- | | |
|-------------------------|--------------------------|
| 1. E (C and D are true) | 15. A |
| 2. E (C and D are true) | 16. E |
| 3. E | 17. D |
| 4. B | 18. A |
| 5. D | 19. E (C and D are true) |
| 6. E | 20. A |
| 7. C | 21. D |
| 8. E | 22. E (A and C are true) |
| 9. D | 23. E |
| 10. E | 24. C |
| 11. B | 25. D |
| 12. D | 26. B |
| 13. E | |
| 14. E | |

SELF LEARNING Tuesday, March 2, 11AM-12

You should finish the practice questions regarding the Basal Ganglia. Watch the review CD-ROM on basal ganglia connections.

DON'T GET BEHIND THIS WEEK!!!!

Review the self-learning www sites for **Parkinson's, Tourette Syndrome** and **Deep Brain Stimulation**. Moreover, look over "old stuff" cases: 1) muscular dystrophy, 2) myasthenia gravis, 3) Guillain-Barre, 4) S1 radiculopathy, 5) amyotrophic lateral sclerosis (ALS), 6) Brown Sequard syndrome (spinal cord hemisection), 7) facial colliculus-vestibulo-cochlear, 8) lateral medullary (Wallenberg's) syndrome, 9) acoustic neuroma, 10) Weber Syndrome, 11) syringomyelia and 12) subacute combined systems disease. Finally, look over the "Motor Systems power point for quiz #6."

YOU SHOULD ALSO GO UP TO THE LABS AND LOOK AT THE BRAIN IN ORDER TO VISUALIZE THE BASAL GANGLIA. THIS WILL HELP YOU A LOT!!! WE WILL BE UP THERE WAITING FOR YOU!!!!!!

IT IS TUESDAY AND THE QUIZ IS NOT FAR AWAY!! BE A FRIDAY "NOONER!"