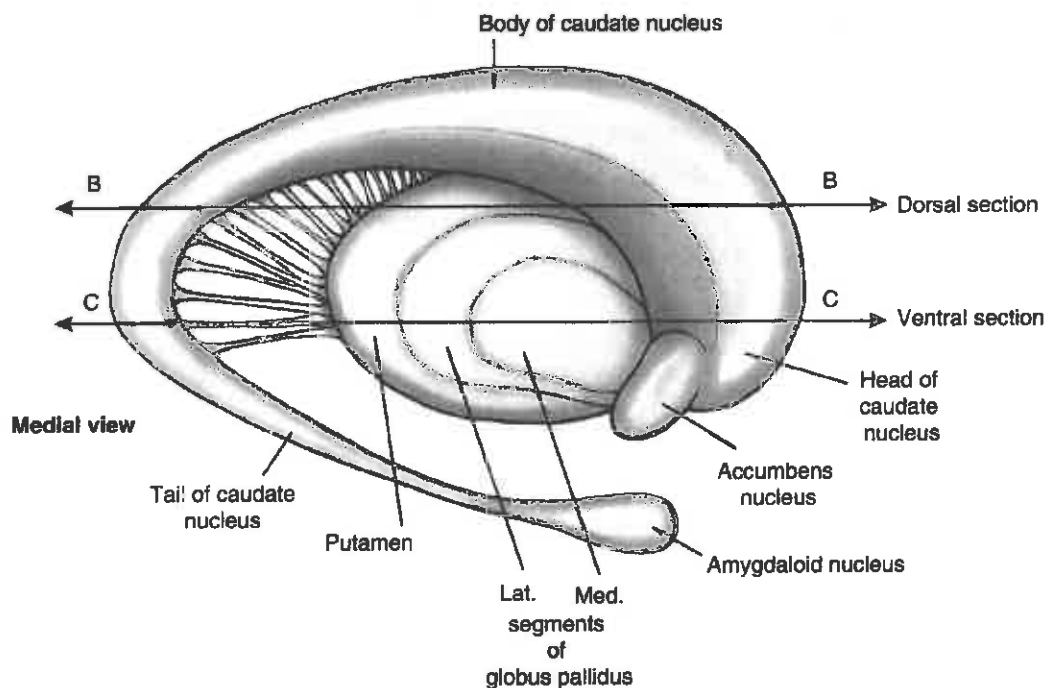


## Globus Pallidus Tracing Guidelines

### Introduction:

Derived from the diencephalon, the globus pallidus, or “pale globe”, lies between the putamen and the internal capsule. Also known as the dorsal pallidum, the globus pallidus consists of an inner and an outer segment, separated by a thin layer of axons. Indirect cortical input from the caudate, putamen, and subthalamic nucleus converge in the striatopallidal fibers of the globus pallidus, with its internal segment serving as the major output component for the entire basal ganglia (Parent 831).



This schematic taken from Young's *Basic Clinical Neuroanatomy*, demonstrates the 3-D relationship between the globus pallidus and the corpus striatum as seen from a medial view (Young 85).

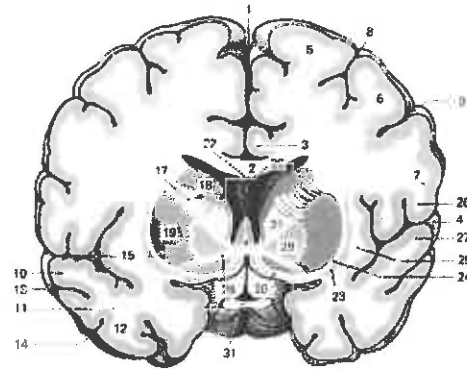
In his discussion on neuroembryology, Carpenter provides an interesting description of the migration of the globus pallidus:

During early development anlage of the corpus subiculum and both segments of the pallidum are arranged in a linear fashion with the anlage of the lateral pallidal segment most rostral, that of the subthalamic nucleus most caudal, and that of the medial pallidal segment (entopeduncular nucleus) in an intermediate position. In the third month of fetal life the lateral pallidal segment migrates rostromedially to contact the medial surface of the putamen. The entopeduncular nucleus (medial pallidal segment) follows the lateral pallidal segment and assumes an adjacent medial position, where it is called the medial pallidal segment (Carpenter 584).

Diagrams A-C, taken from Kahle's *Color Atlas of Human Anatomy*, illustrate the changing shape of the dorsal pallidum as seen on frontal section as one moves from anterior to posterior.

**Diagram A** is an example of a frontal section at the level of the anterior commissure (A28) and the optic chiasm (A31).

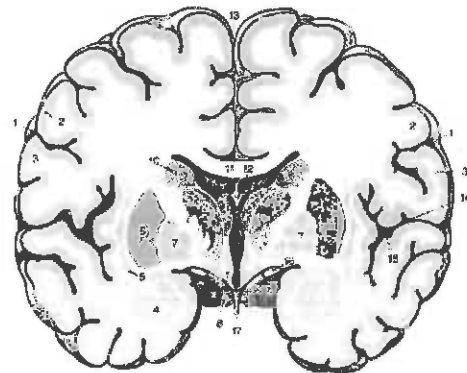
Note the relationship of the anterior commissure (A28), the internal capsule (A17), and the putamen (A19), as they define the borders of the globus pallidus (A29) (Kahle 201).



**Diagram A**

**Diagram B** demonstrates a frontal section at the level of the amygdaloid nucleus (B4) and the optic tract (B16) (Kahle 203).

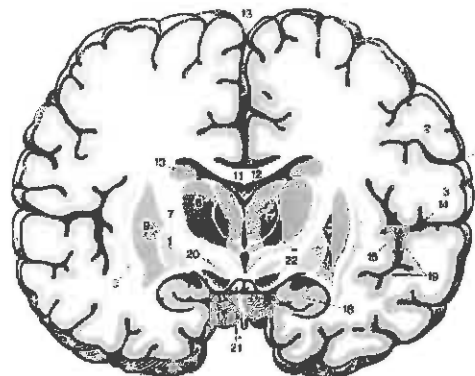
Note the emergence of the distinction between the outer segment (pars lateralis) and the inner segment (pars medialis) of the dorsal pallidum (B7) on diagram B as compared to diagram A.



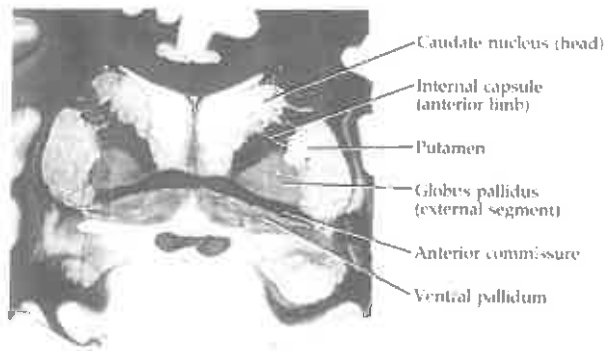
**Diagram B**

**Diagram C** illustrates a frontal section at the level of the hippocampus (C18) and the mammillary bodies (C21) (Kahle 203).

Note the decrease in size of the dorsal pallidum (C7) as the thalamus (C6) becomes more prominent. Also note the asymmetry of the globus pallidus (C7) as one side shows a clear distinction between the pars lateralis and the pars medialis and the opposing side does not.



**Diagram C**



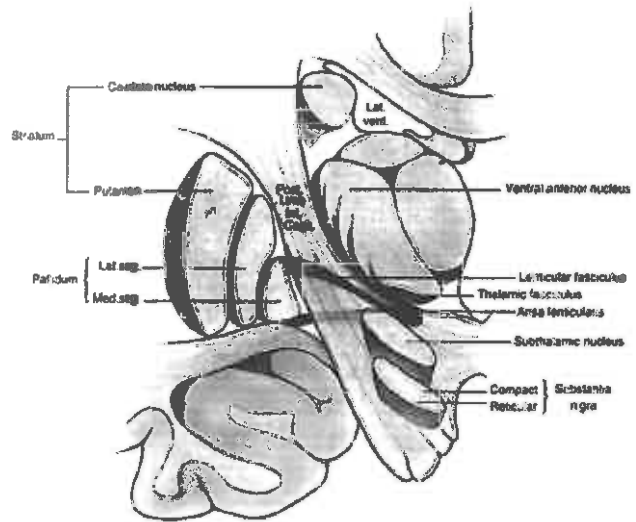
**Diagram D**

**Diagram D**, taken from Martin's *Neuroanatomy: Text and Atlas*, is an example of a myelin-stained frontal section through the external segment of the globus pallidus (Martin 281).

Note the separation of the external segment of the globus pallidus and the ventral pallidum by the anterior commissure, illustrating the usefulness of the anterior commissure in defining the inferior border of the dorsal pallidum.

**Diagram E** is taken from Young's *Basic Clinical Neuroanatomy*. This schematic illustrates the relationship of the globus pallidus to the putamen and the internal capsule as seen on frontal section. These relationships define the lateral and medial borders of the dorsal pallidum, respectively.

Note the triangular shape of the dorsal pallidum as it wedges between the putamen and the fibers of the internal capsule.



**Diagram E**

*It has been noted that bilateral destruction of the dorsal pallidum produces psychiatric disturbances such as impaired cerebral function, irritability, rapid tiredness and reduced concentration (Kahle 180).*

### **Boundaries:**

- i. Using the anterior commissure as a point of reference, tracing of the globus pallidus begins 5 slices anterior to the clearest coronal view of the temporal limb of the anterior commissure (Figures 3-4). The anterior portion of the globus pallidus nestles between the internal capsule, the putamen, and the nucleus accumbens (Figures 5-6) gradually increasing in size as one moves posteriorly from the temporal limb of the anterior commissure (TLAC).

ii. Tracing continues posteriorly until the globus pallidus can no longer be adequately visualized in the coronal plane. Tracing ends 17 slices posterior to the TLAC or when the area of the dorsal pallidum is less than 2x2 voxels in size (Figures 9-10). At this level, both the thalamus and the red nucleus can be visualized.

iii. As one moves posterior from the TLAC, the width of the dorsal pallidum narrows, corresponding to the internal capsule's expansion in width. This decrease in width becomes apparent approximately 7 slices posterior to the clearest view of the TLAC (Figures 7-8) and continues to decrease by one column of voxels per slice until the globus pallidus can no longer be visualized on the trimodal image (Figures 9-10).

iv. The putamen serves as the lateral border of the globus pallidus throughout its course, changing in shape as the shape of the dorsal pallidum changes (Figures 1-10).

v. In the anterior most slices, the internal capsule serves as the superior border of the dorsal pallidum (Figures 5-6). As one moves posteriorly, the putamen and the internal capsule together serve as the superior border (Figures 3-4 & 7-10).

vi. When the globus pallidus first appears in coronal section, it is bound inferiorly by the nucleus accumbens (Figure 5-6). As one moves posteriorly, the nucleus accumbens retreats and the anterior commissure separates the globus pallidus from the ventral pallidum, serving as the inferior boundary of the dorsal pallidum and the superior border of the ventral pallidum (Figures 3-4). When the TLAC is seen most clearly in the coronal plane, the crosshairs are placed on it. This serves as the inferior border when the anterior commissure can no longer be visualized (Figures 3-4).

### **Imaging Modalities:**

In tracing the globus pallidus, the "trimodal" or "superimage" was employed, allowing the user the option of displaying the image in the RGB (red, green and blue) mode. Using the RGB mode, the images are displayed using red to depict information from the T1 image, while green and blue are used to represent information from the T2 and PD images, respectively.

In RGB mode, all three modalities are displayed simultaneously by assigning a different color gun of the computer monitor to each of the image sets. This brings a substantial amount of information to the user in two ways. Through the use of color, the visual system is able to expand its perceptive range from shades of grey to include hue, saturation and intensity. Secondly, more information is provided to the user because information from all three image modalities is displayed simultaneously.

This simultaneous display of information from the T1, T2 and PD imaging modalities allows for the distinction of neuroanatomical structures that may have not otherwise been apparent using any single image modality.

## Figures:

The figures that follow appear in groups of two. The first figure represents a slice as seen on the trimodal image, illustrating the boundaries of the globus pallidus. The second figure represents a frontal section taken from Duvernoy's *The Human Brain Surface, Three-Dimensional Sectional Anatomy and MRI*, representing examples of important anatomical landmarks.

It should be noted that while the Duvernoy atlas does not provide frontal sections in perfect correspondence to the coronal slices seen on the trimodal image, it does serve as a useful tool in delineating neighboring neuroanatomical structures. In his methods section, Duvernoy notes:

Horizontal (or axial) serial sections are obtained according to Talairach's bicommissural plane (CA-CP plane); coronal sections are at a right angle with this plane, while sagittal sections follow the interhemispheric sagittal plane. The sections are 2 mm thick (Duvernoy 2).

It is this use of 2 mm frontal sections, as compared to the 1 mm slice resolution of the trimodal images that may account for slight differences observed in compared sections.

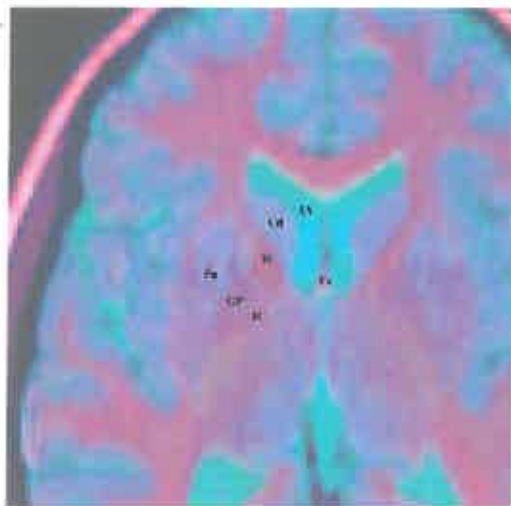


Figure 1

**Figure 1** illustrates the globus pallidus as seen on axial section using the trimodal image. Note the relationship of the internal capsule (IC) as illustrated by the pink hue, the globus pallidus (GP) shown in purple and the putamen (Pu) seen in blue.



Figure 2

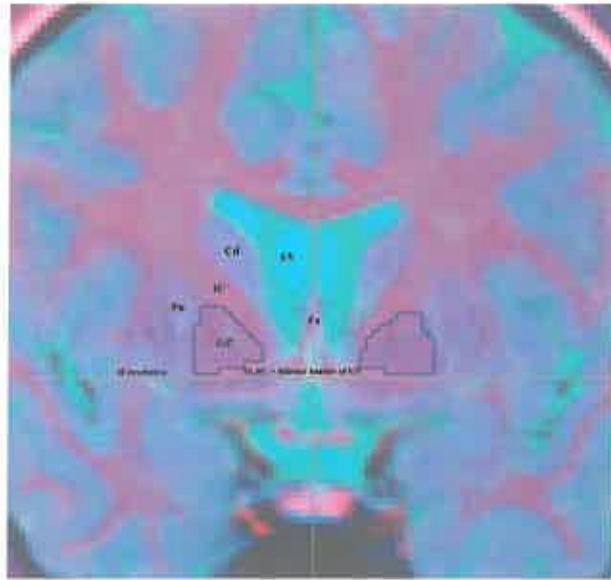
**Figure 2** illustrates a similar view as seen on horizontal section (Duvernoy 301).

ia & ip	internal capsule
hc	caudate nucleus
p	putamen
pl & pm	globus pallidus

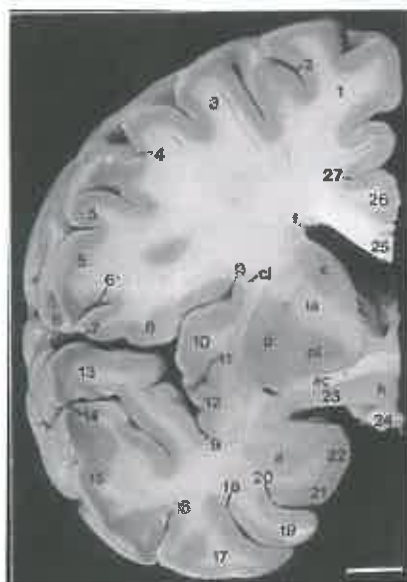
**Figure 3** illustrates the clearest view of the temporal limb of the anterior commissure (TLAC) as seen on the trimodal image.

If the TLAC appears symmetrical (as shown in Figure 3), the crosshairs should be placed one row of voxels superior to the most inferior row of voxels comprised of TLAC tissue. This indicates the inferior border of the dorsal pallidum (GP).

If the TLAC is asymmetrical, the lowest row of voxels on the TLAC's higher of the two sides is used to demarcate the inferior border. This approximates the inferior border for the dorsal pallidum (GP).



**Figure 3**



**Figure 4**

**Figure 4** is a frontal section created at a similar level taken from Duvernoy's *The Human Brain Surface, Three-Dimensional Sectional Anatomy and MRI*.

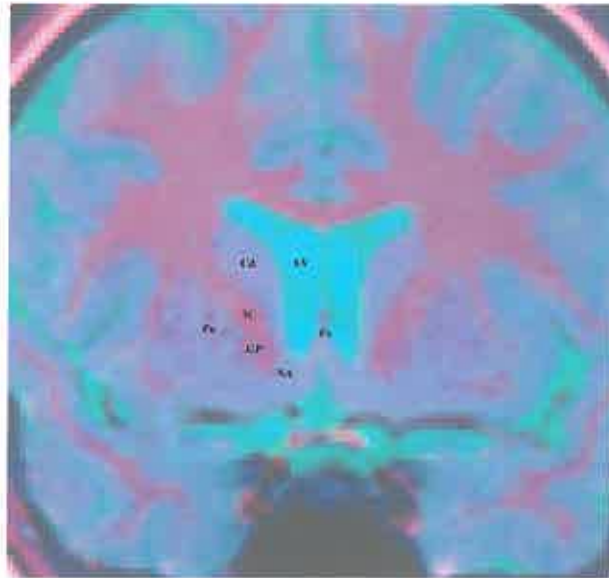
Note the relative location of the caudate nucleus (**c**), the putamen (**p**), and the internal capsule (**ia**) in relation to the globus pallidus (**pl**) on coronal section (Duvernoy 109).

Notice how the anterior commissure (**ac**) provides for a clear separation of the globus pallidus (**pl**) and its underlying structures.

**Figure 5** represents a coronal slice taken 5 slices anterior to the TLAC. This is the slice on which tracing is to begin.

At its most anterior aspect, the globus pallidus (**GP**) can be seen as an irregularly shaped structure nestling between the putamen (**Pu**) and the internal capsule (**IC**).

Moving back and forth from anterior to posterior often aids in developing an appreciation for the shape of the globus pallidus (**GP**) as it changes. One may even choose to begin tracing at the TLAC to make use of this method.



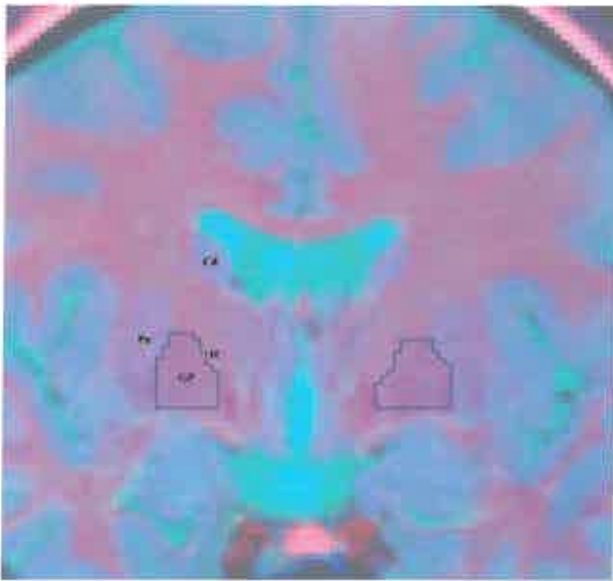
**Figure 5**

**Figure 6**, taken from the Duvernoy atlas, represents a frontal section corresponding to that illustrated in Figure 5.

Note the emergence of the globus pallidus (**pl**), decreasing the apparent width of the anterior limb of the internal capsule (**ia**) as seen on coronal section (Duvernoy 105).



**Figure 6**



**Figure 7**

**Figure 7** illustrates a coronal section 7 slices posterior to the TLAC. This represents the point at which the dorsal pallidum (GP) begins to recede medially. In order to account for this reduction in size, the width of the structure is systematically reduced.

Using the slice with the clearest view of the TLAC and the 6 slices posterior to it, the widest base of the globus pallidus (GP) among these 7 slices is measured.

Reduction of the width of the base of the dorsal pallidum (GP) begins on the 7th slice posterior to the TLAC and can never be greater than 75% of the base at its greatest width.

*For example, if the base of the dorsal pallidum (GP) was 16 voxels wide at its fullest extent, then its width is decreased to 12 voxels on the 7<sup>th</sup> slice posterior to the TLAC.*

**Figure 8** is a similar frontal section taken from the Duvernoy atlas. It illustrates the globus pallidus (pl & pm) at the level of the amygdala (a).

Note how the diagonal medial boundary formed by the internal capsule (i) and the horizontal inferior boundary meet medially. As previously stated, the third side of this triangle was completed as the dorsal pallidum (pl & pm) migrated and contacted the putamen (p) during fetal development (Carpenter 584).



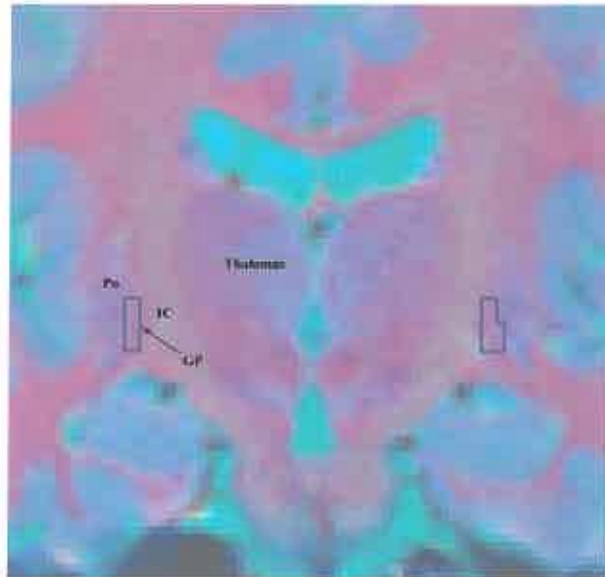
**Figure 8**



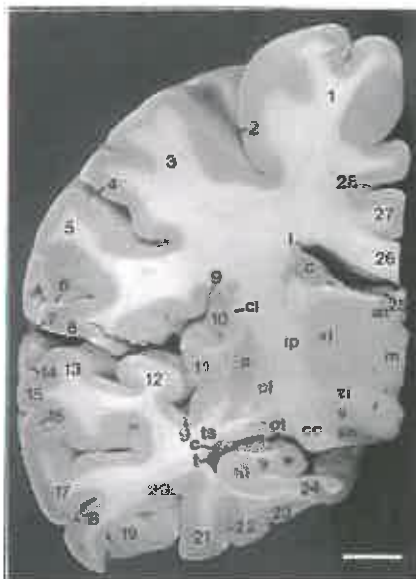
**Figure 9** illustrates the most posterior slice on which the globus pallidus (GP) is traced, approximately 17 slices posterior to the TLAC.

Posterior to the point where the globus pallidus (GP) begins to retreat medially (as described above in Figure 7) one must reduce the width of the base by 1 column of voxels on each subsequent slice.

*For example, if the base of the globus pallidus (GP) is 12 voxels wide on the 7<sup>th</sup> slice posterior to the TLAC, the 8<sup>th</sup> slice posterior to the TLAC will have a base of 11 voxels in width. The following slice will have a base of 10 voxels in width, and so on until the final slice on which the globus pallidus (GP) can be visualized (i.e., the 17<sup>th</sup> slice posterior to the TLAC)*



**Figure 9**



**Figure 10**

**Figure 10** represents a frontal section taken from the Duvernoy atlas corresponding to that of Figure 9. Note the presence of the hippocampus (hi) and the red nucleus (r).

When compared to Figures 7 & 8, this frontal section demonstrates how the width of the globus pallidus (pl) decreases as one moves posteriorly through the brain.

Note the continuity of the posterior limb of the internal capsule (ip) with the crus cerebri (cc) at this level.

## Surface Figures:

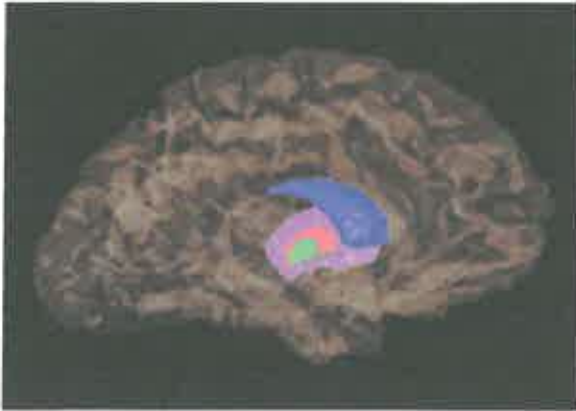


Figure 11

**Figure 11** represents a 3-D reconstruction of the basal ganglia within the brain as seen from an anteromedial view.

Note the close approximation of the pars medialis to the pars lateralis and that of the pars lateralis to the putamen.

**Figure 12** represents a 3-D reconstruction of the basal ganglia within the brain as seen from a medial view.

This view illustrates how the head of the caudate (seen in blue) wraps around the lentiform nucleus (i.e., putamen & globus pallidus) anteriorly and superiorly.

**Figures 11 & 12** illustrate surfaces of the whole brain, the caudate, the putamen and the inner and outer portions of the globus pallidus generated using coronal traces.

whole brains	bronze
caudate nucleus	blue
putamen	purple
GP <sub>e</sub> (pars lateralis)	red
GP <sub>i</sub> (pars medialis)	green

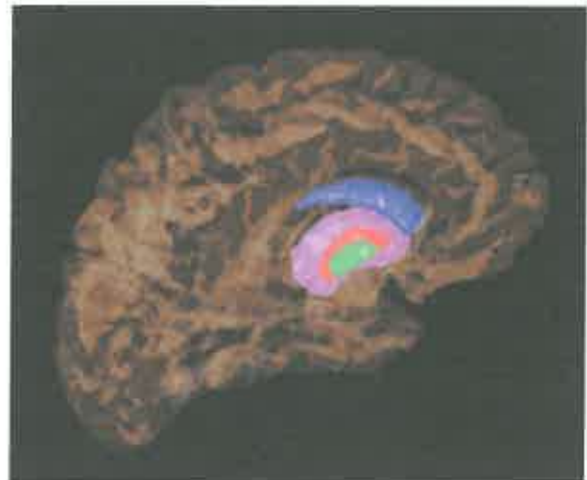


Figure 12

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