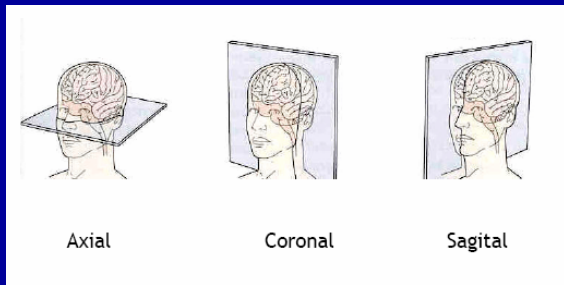
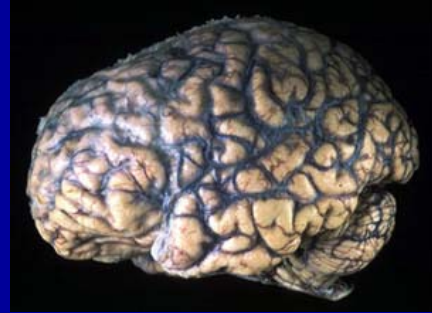


## Introduction to the Brain

- Anatomic Structure
- Blood Vessels
- Functional Organization

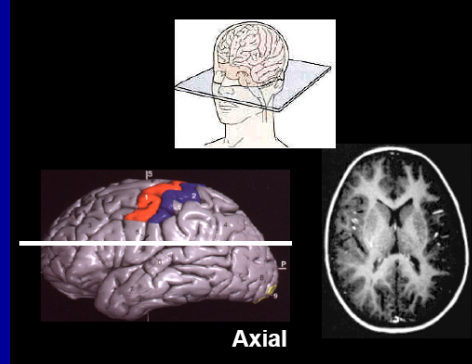
A Neuroanatomy primer.



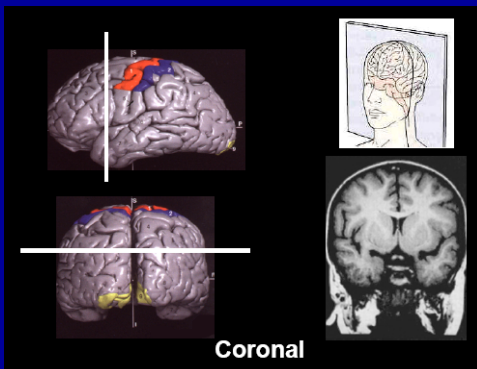
Axial

Coronal

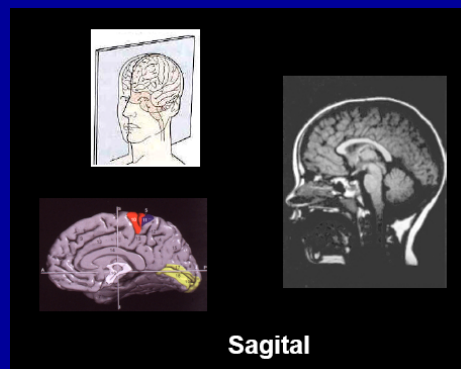
Sagittal



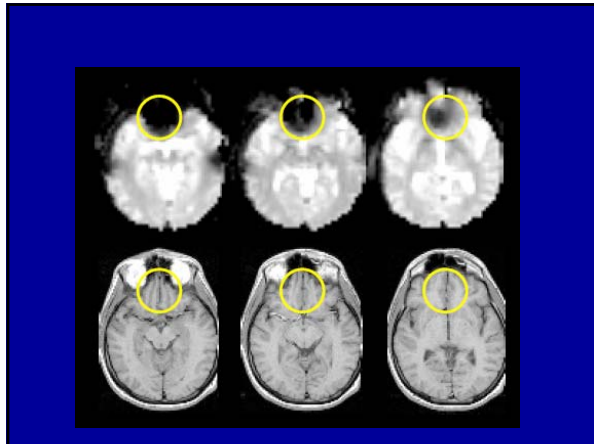
Axial



Coronal



Sagittal



### Gross surface anatomy of the human brain.

References:

Duvernoy, H. The Human Brain: Surface, Blood Supply, and Three-Dimensional Sectional Anatomy, 3<sup>rd</sup> Edition, 1999: Absolutely the best atlas of the human brain and blood supply.

Nolte, J. The Human Brain 3<sup>rd</sup> Edition, Mosby Year Book, 1993:  
 Good coronal slices and great in depth text on whole brain anatomy and motor pathways

Damasio, H. Human Brain Anatomy in Computerized Images, Oxford University Press, 1995: Old but purely visual book that's worth looking through

A myriad of web sites – surf to your heart's content!  
<http://www.neuropat.dote.hu/anastru/anastru.htm> - this site has great coronal images  
<http://www.neuropat.dote.hu/atlas.html> - same as the above site but with fantastic pathology pictures for those interested  
<http://www.med.harvard.edu/AANLIB/home.html> - nice neuropathology and movies of angiograms  
[http://www.neuroguide.com/neuroimg\\_1.html#human\\_neuroanatomy](http://www.neuroguide.com/neuroimg_1.html#human_neuroanatomy) – couldn't get this one to work at time of writing this – but it looks interesting!

### Defining the lobes

frontal lobe

central (rolandic) sulcus

parietal lobe

occipital lobe

temporal lobe

sylvian (lateral) sulcus

### 14 Major Sulci

Main sulci are formed early in development  
 Fissures are really deep sulci

Typically continuous sulci

- Interhemispheric fissure
- Sylvian fissure
- Parieto-occipital fissure
- Collateral sulcus
- Central sulcus
- Calcarine Sulcus

Typically discontinuous sulci

- Superior frontal sulcus
- Inferior frontal sulcus
- Postcentral sulcus
- Intraparietal sulcus
- Superior temporal sulcus
- Inferior temporal sulcus
- Cingulate sulcus
- Precentral sulcus

Other minor sulci are much less reliable

Source: Ono, 1990

### Interhemispheric Fissure

-hugely deep (down to corpus callosum)  
 -divides brain into 2 hemispheres

### Sylvian Fissure (or lateral sulcus)

-deep, mostly horizontal  
 -insula (purple) is buried within it  
 -separates temporal lobe from parietal and frontal lobes

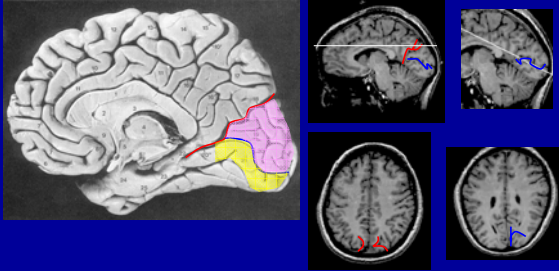
## Parieto-occipital Fissure and Calcarine Sulcus

**Parieto-occipital fissure (red)**  
 -very deep  
 -often Y-shaped from sagittal view, X-shaped in horizontal and coronal views

**Calcarine sulcus (blue)**  
 -contains V1

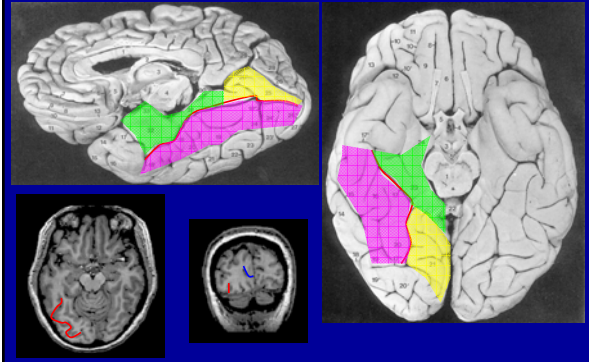
**Cuneus (pink)**  
 -visual areas on medial side above calcarine (lower visual field)

**Lingual gyrus (yellow)**  
 -visual areas on medial side below calcarine and above collateral sulcus (upper visual field)



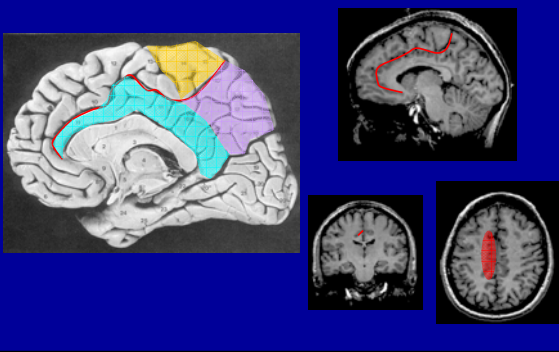
## Collateral Sulcus

-divides lingual (yellow) and parahippocampal (green) gyri from fusiform gyrus (pink)



## Cingulate Sulcus

-divides cingulate gyrus (turquoise) from precuneus (purple) and paracentral lobule (gold)

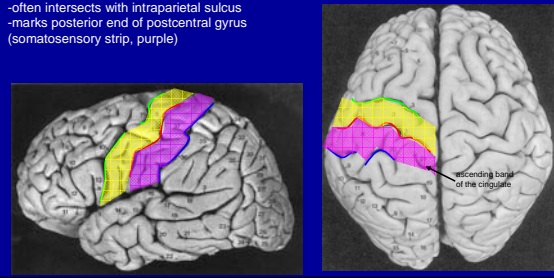


## Central, Postcentral and Precentral Sulci

**Central Sulcus (red)**  
 -usually freestanding (no intersections)  
 -just anterior to ascending cingulate

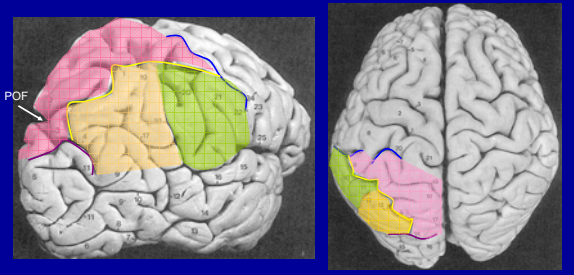
**Postcentral Sulcus (red)**  
 -often in two parts (superior and inferior)  
 -often intersects with intraparietal sulcus  
 -marks posterior end of postcentral gyrus (somatosensory strip, purple)

**Precentral Sulcus (red)**  
 -often in two parts (superior and inferior)  
 -intersects with superior frontal sulcus (T-junction)  
 -marks anterior end of precentral gyrus (motor strip, yellow)

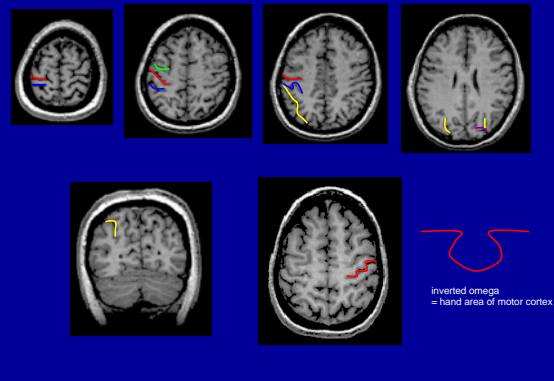


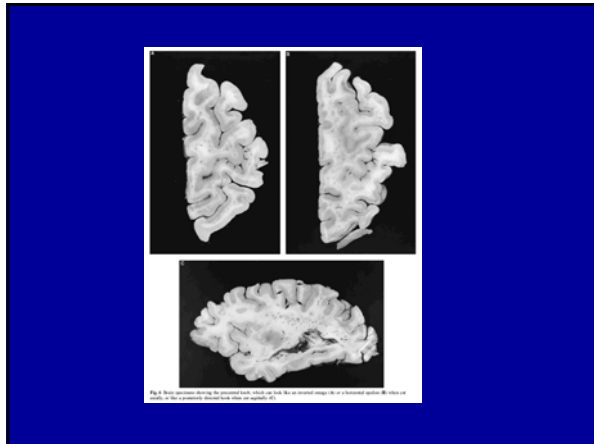
## Intraparietal Sulcus

-anterior end usually intersects with inferior postcentral (some texts call inferior postcentral the ascending intraparietal sulcus)  
 -posterior end usually forms a T-junction with the transverse occipital sulcus (just posterior to the parieto-occipital fissure)  
 -IPS divides the superior parietal lobule from the inferior parietal lobule (angular gyrus, gold, and supramarginal gyrus, lime)



## Slice Views





### Superior and Inferior Temporal Sulci

**Superior Temporal Sulcus (red)**  
 -divides superior temporal gyrus (peach) from middle temporal gyrus (lime)

**Inferior Temporal Sulcus (blue)**  
 -not usually very continuous  
 -divides middle temporal gyrus from inferior temporal gyrus (lavender)

### Superior and Inferior Frontal Sulci

**Superior Frontal Sulcus (red)**  
 -divides superior frontal gyrus (mocha) from middle frontal gyrus (pink)

**Inferior Frontal Sulcus (blue)**  
 -divides middle frontal gyrus from inferior frontal gyrus (gold)

orbital gyrus (green) and frontal pole (gray) also shown

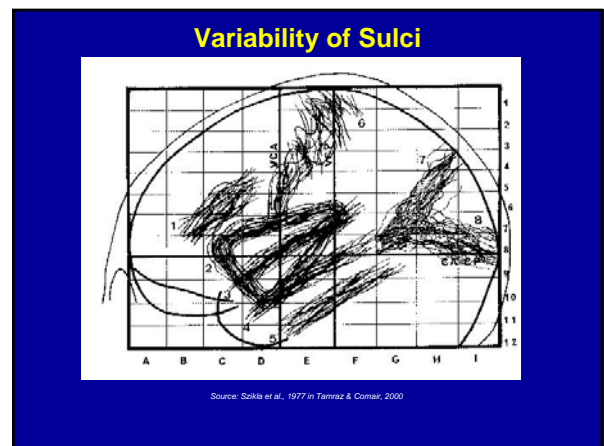
Frontal Eye fields lie at this junction

### Medial Frontal

-superior frontal gyrus continues on medial side  
 -frontal pole (gray) and orbital gyrus (green) also shown

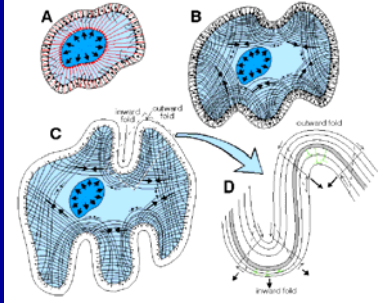
### Anatomical Localization Sulci and Gyri

Source: Ludwig & Klingler, 1956 in Tamraz & Comair, 2000



## Sulcal Formation

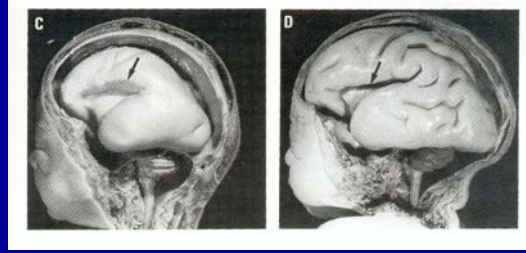
Although sulci vary considerably from person to person (even in identical twins), there is considerable regularity in where the folds occur... Why?



David Van Essen proposes that as the brain develops, areas that are richly interconnected will be pulled together to form a gyrus (and those that are weakly interconnected form sulci).

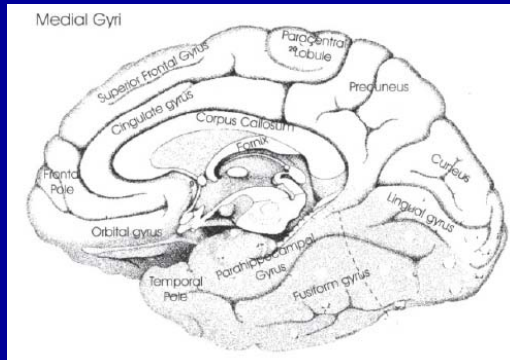
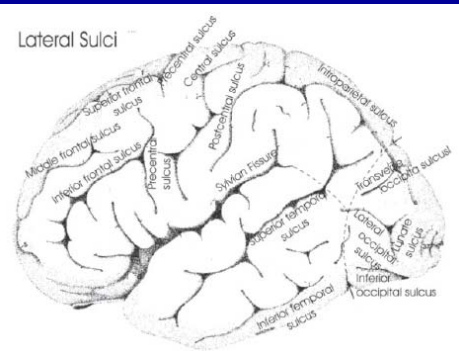
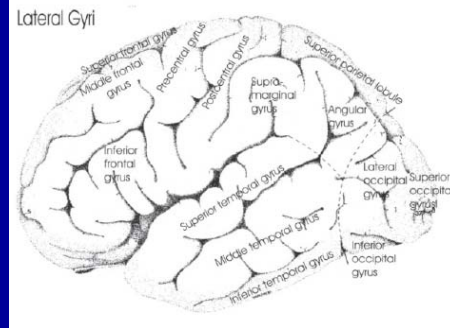
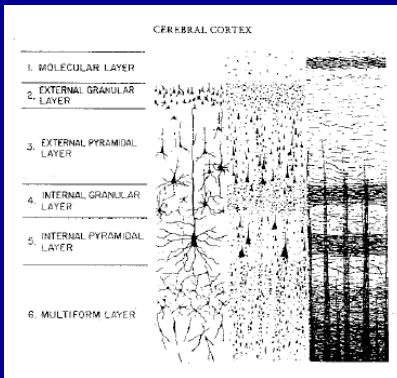
Source: Van Essen, 1997

## Development of Sulci

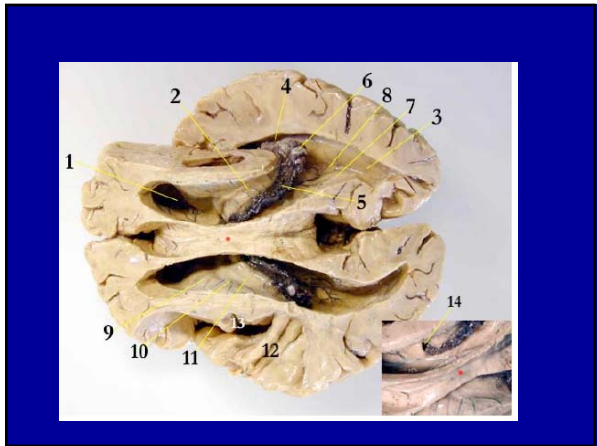
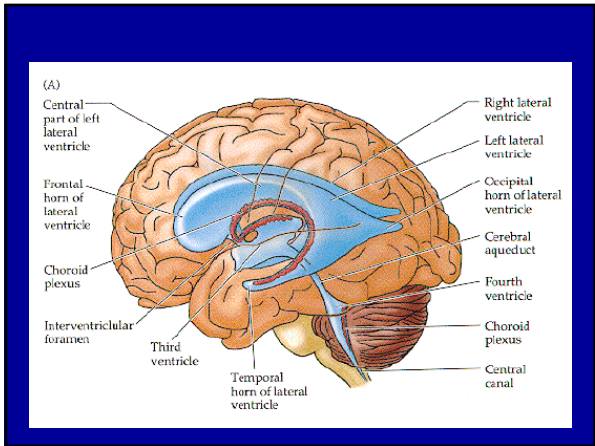
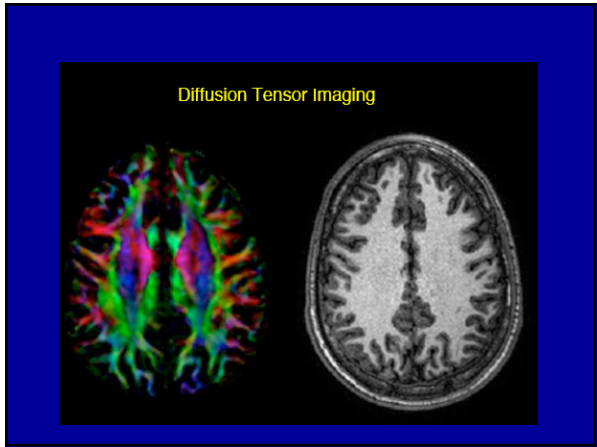
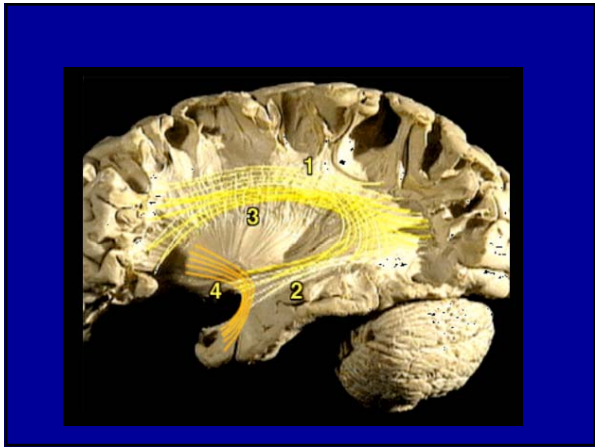
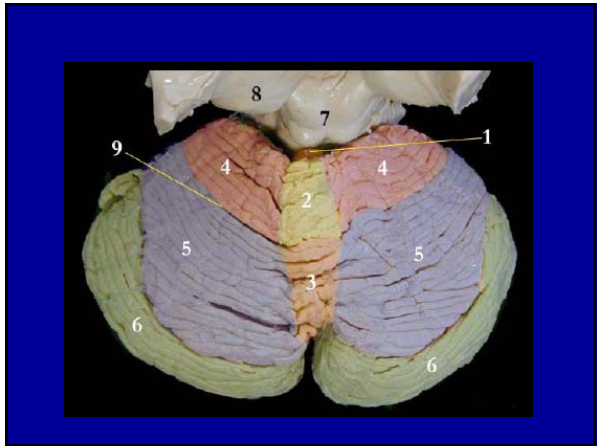
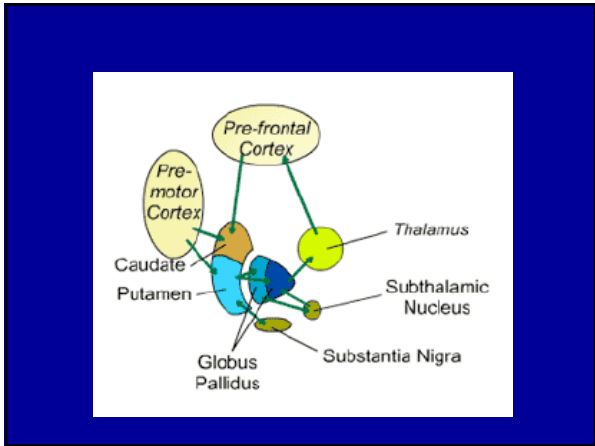


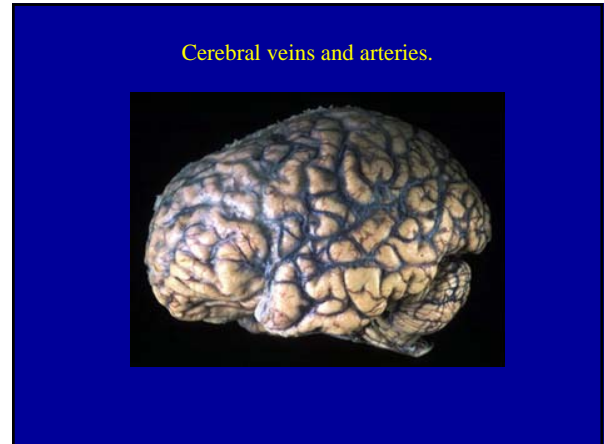
Sulci appear at predictable points in fetal development with the most prominent sulci (e.g., Sylvian fissure) appearing first.

Source: Ono, 1990









### Arterial Blood Supply

- Internal carotids supply hemispheres:
  - middle, anterior cerebral arteries, ophthalmic artery
- vertebrals supply hemispheres, brainstem, spinal cord, cerebellum via numerous vessels.

Labels in diagram include: Medial leptocephalic artery, Anterior communicating artery, Anterior cerebral artery, Recurrent artery (of Heubner), Internal carotid artery, Medial and lateral leptocephalic arteries, Middle cerebral artery, Lateral leptocephalic artery, Ascending frontal (candyliform) artery, Anterior choroidal artery, Posterior communicating artery, Posterior cerebral artery, Superior cerebellar artery, Basilar artery, Posterior artery, Internal acoustic (labyrinthine) artery, Anterior inferior cerebellar artery, Vertebral artery, Anterior spinal artery, Posterior inferior cerebellar artery (PICA), Posterior spinal artery.

<http://pathology.mc.duke.edu/neuropath/hawr/blood-supply.html#arteries>  
great animation of blood supply

### Circle of Willis

- Internal carotid and vertebrals anastomose in the Circle of Willis

Labels in diagram include: Anterior communicating artery, Anterior cerebral artery, Cylindrical artery, Internal carotid artery, Middle cerebral artery, Posterior communicating artery, Superior cerebellar artery, Basilar artery, Long and short posterior arteries, Anterior inferior cerebellar artery, Vertebral artery, Perforating arteries, Hypothalamic artery, Recurrent artery, Lenticular artery, Superior cerebellar artery, Inferior cerebellar artery, Anterior thalamus, Posterior thalamus, Perforating artery, Perforating artery, Internal acoustic (IAC).

### Anterior / Posterior Cerebrals

Labels in diagram include: Medial frontal branches, Posterior, Middle, Anterior, Callosomarginal artery, Frontopolar artery, Right anterior cerebral artery, Medial orbitofrontal artery, Anterior communicating artery (x2), Recurrent artery (of Heubner), Right internal carotid artery, Pericallosal artery, Pericallosal artery, Cingulate branches, Right posterior cerebral artery, Precuneal artery, Posterior pericallosal artery, Preoccipital artery, Calcarine artery, Posterior temporal artery, Anterior temporal artery, Posterior communicating artery.

### Middle Cerebral

Labels in diagram include: Anterior parietal (supercerebral) artery, Central (Rolando's) artery, Precuneal (post-Rolando's) artery, Ascending frontal (candyliform) artery, Terminal branches of anterior cerebral artery, Lateral leptocephalic artery, Left middle cerebral artery, Left anterior cerebral artery, Anterior communicating artery, Right anterior cerebral artery, Left internal carotid artery, Anterior parietal (supercerebral) artery, Posterior parietal artery, Angular artery, Temporal (of paracentral), Middle temporal artery, Anterior temporal artery, Posterior temporal artery.



### Blood supply – lateral surface

Middle cerebral artery – red  
 Anterior cerebral artery – green  
 Posterior cerebral artery – blue  
 Veins - black

frontoparietal  
 parietal  
 frontopolar  
 superficial middle

### Blood supply – medial surface

- Anterior cerebral artery – green
- Posterior cerebral artery – blue
- Veins - black

### Blood supply – inferior surface

- Anterior cerebral artery – green
- Posterior cerebral artery – blue
- Veins - black

### Aneurysms

Angiogram - Aneurysm of ICA  
 Blood vessels dissected - ACA aneurysm  
 Aneurysm displaces hemisphere

### Cerebral Vessel Infarcts

Infarct of MCA  
 Watershed infarct - fragile area at boundary of 2 vessels

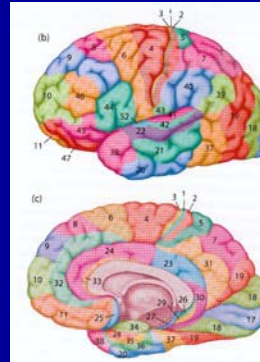
### Large draining veins.

- Cerebral veins drain into venous sinuses and into internal jugular
- Superficial veins lie on surface of cortex and drain into superior sagittal sinus
- Deep veins drain internal structures and empty into the straight sinus
- Large draining veins can lead to artefacts in fMRI

See Nolte, J. The Human Brain

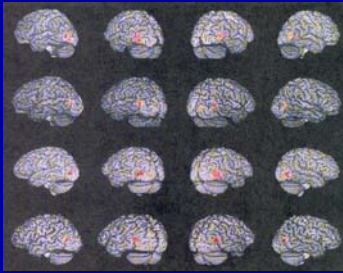
## Brodmann Areas

## Brodmann's Areas



**Brodmann (1905):**  
 Based on cytoarchitectonics: study of differences in cortical layers between areas  
 Most common delineation of cortical areas  
 More recent schemes subdivide Brodmann's areas into many smaller regions  
 Monkey and human Brodmann's areas not necessarily homologous

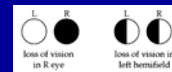
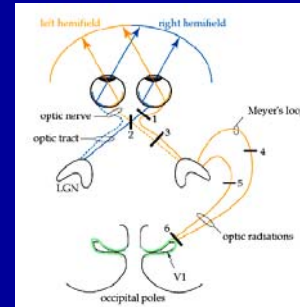
## Variability of Functional Areas



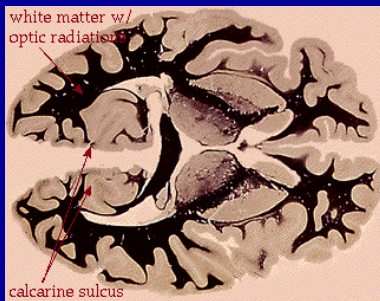
Watson et al., 1995  
 -functional areas (e.g., MT) vary between subjects in their Talairach locations  
 -the location relative to sulci is more consistent

Source: Watson et al. 1995

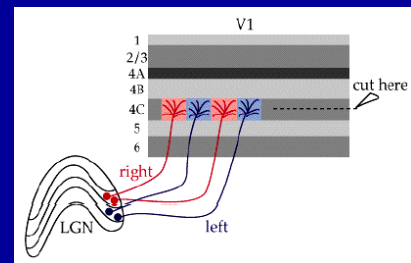
## Visual Pathways



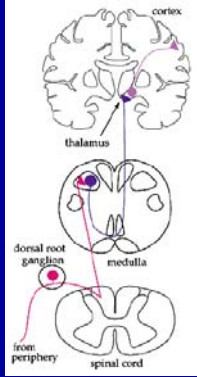
## Visual Pathways



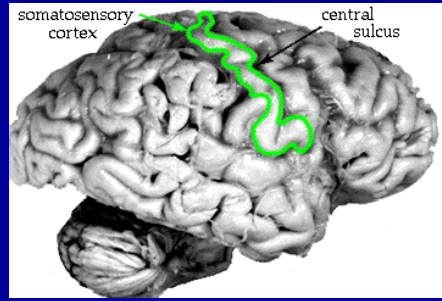
## Ocular Dominance Columns



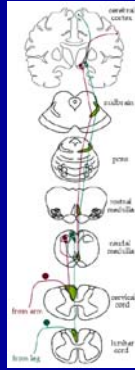
### Somatosensory Pathway



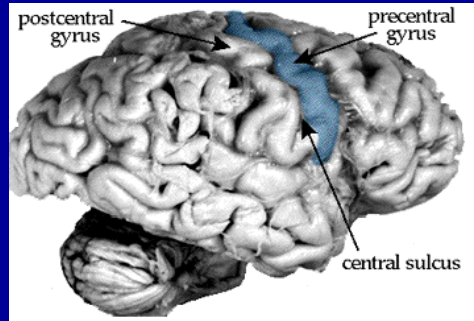
### Somatosensory Cortex



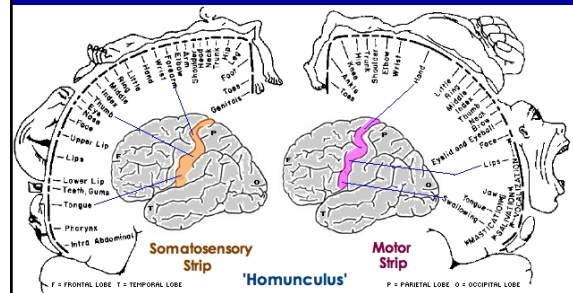
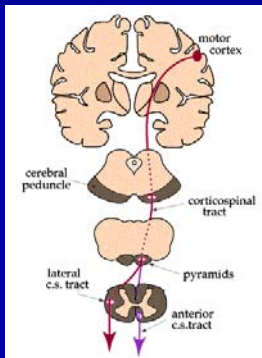
### Somatosensory Pathway



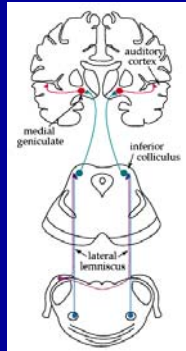
### Motor Cortex



### Motor Pathway



## Auditory

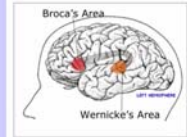


## Language



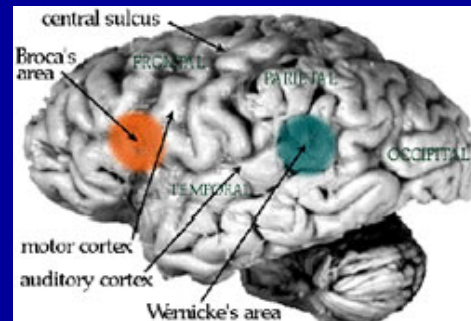
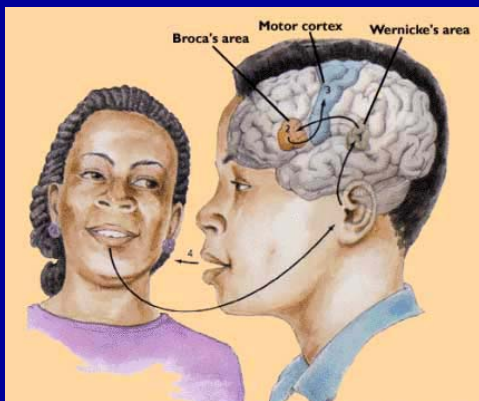
### Paul Pierre Broca (1824-1880)

- Patient could only say, "Tan, tan" after stroke.
- Autopsy of brain (see left) found damage to lateral posterior (side, rear area) of frontal lobe.
- Broca's or expressive aphasia: inability or difficulty speaking clear language.



### Carl Wernicke (1848-1904)

- Damage to superior (top) posterior area of temporal lobe
- Receptive or Wernicke's aphasia (unable either to understand or to express spoken language)



## Learning More Anatomy

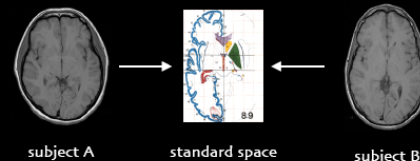
Duvernoy, 1999, *The Human Brain: Surface, Blood Supply, and Three-Dimensional Sectional Anatomy*  
 • beautiful pictures  
 • clear anatomy  
 • slices of real brain

Damasio, 1995, *Human Brain Anatomy in Computerized Images*  
 • good for showing sulci across wide range of slice planes  
 • really crappy reconstructions

Ono, 1990, *Atlas of the Cerebral Sulci*  
 • great for showing intersubject variability  
 • gives probabilities of configurations and stats on sulci

Tamraz & Comair, 2000, *Atlas of Regional Anatomy of the Brain Using MRI with Functional Correlations*  
 • good overview

## dealing with different heads: spatial normalization



### Caveats:

normalize via affine transformation and non-linear deformation

- inter-subject variability in anatomy (e.g. sulcal variation)
- variability in structure: function relationships