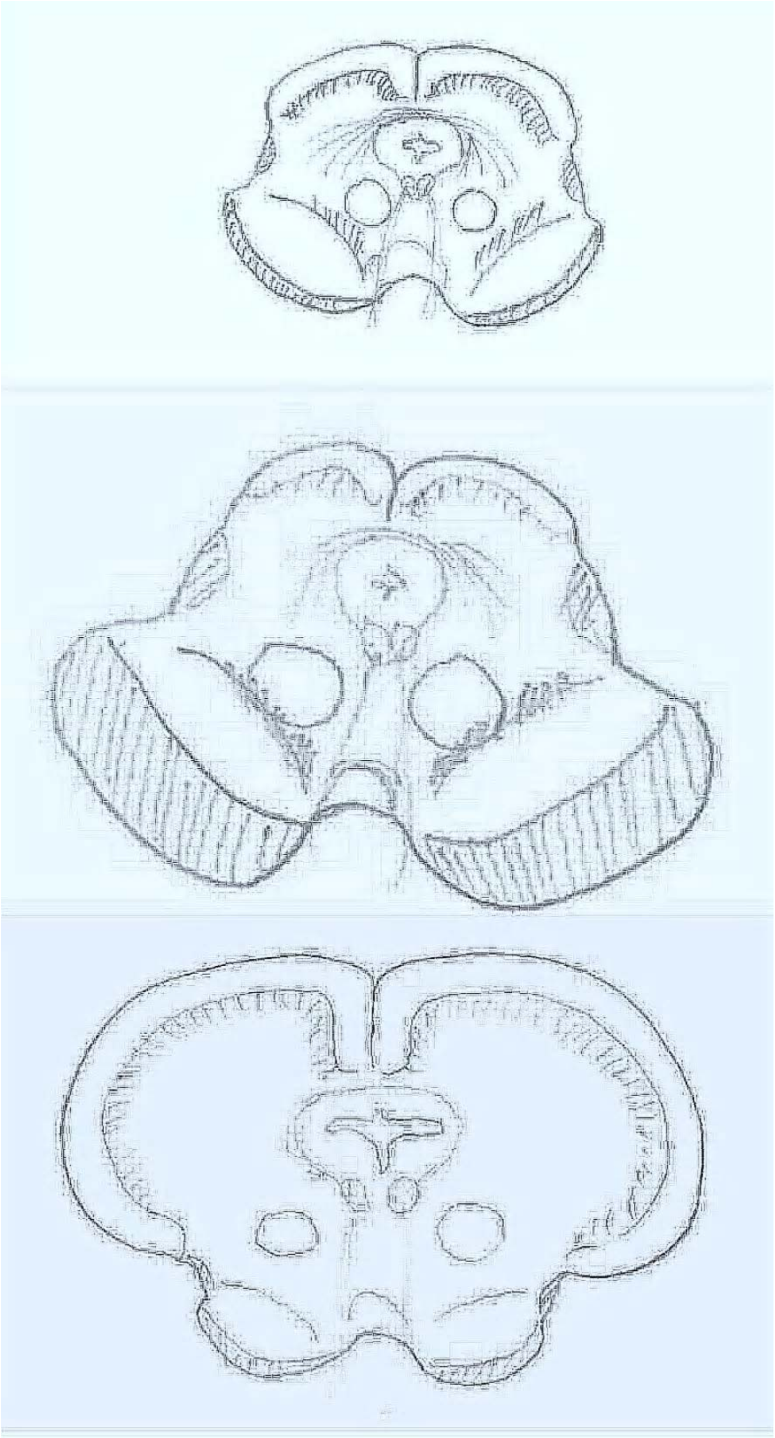
Next:

- **Before we talk about topographic organization**, we will review some species differences, and take a look at lamination in the midbrain tectum.

Midbrain:
Species comparisons

- An exercise in topology: size distortions (REVIEW)
  - The huge optic tectum in tree shrews and squirrels – cf. optic lobes of birds and many fishes
  - The smaller optic tectum in rats and humans
- Lamination patterns
  - Fishes
  - Lizard
  - Mammal



Rodent

Human

Tree Shrew

(Squirrel is similar)

(Sections are not drawn to the same scale)

Fig 11-3

Schneider, G. E. *Brain Structure and its Origins: In the Development and in Evolution of Behavior and the Mind*. MIT Press, 2014. ISBN: 9780262026734.

Questions, chapter 21

10) Describe at least four different anatomical methods that can be used to uncover distinct layers within the optic tectum or superior colliculus. (See also ch. 2, ch 11.)

11) Name three animals or groups of animals that have a very large optic tectum? (See also chapters 6 and 11.)

12) Why is the term "optic tectum" misleading about this structure? It also receives strong auditory and somatosensory inputs

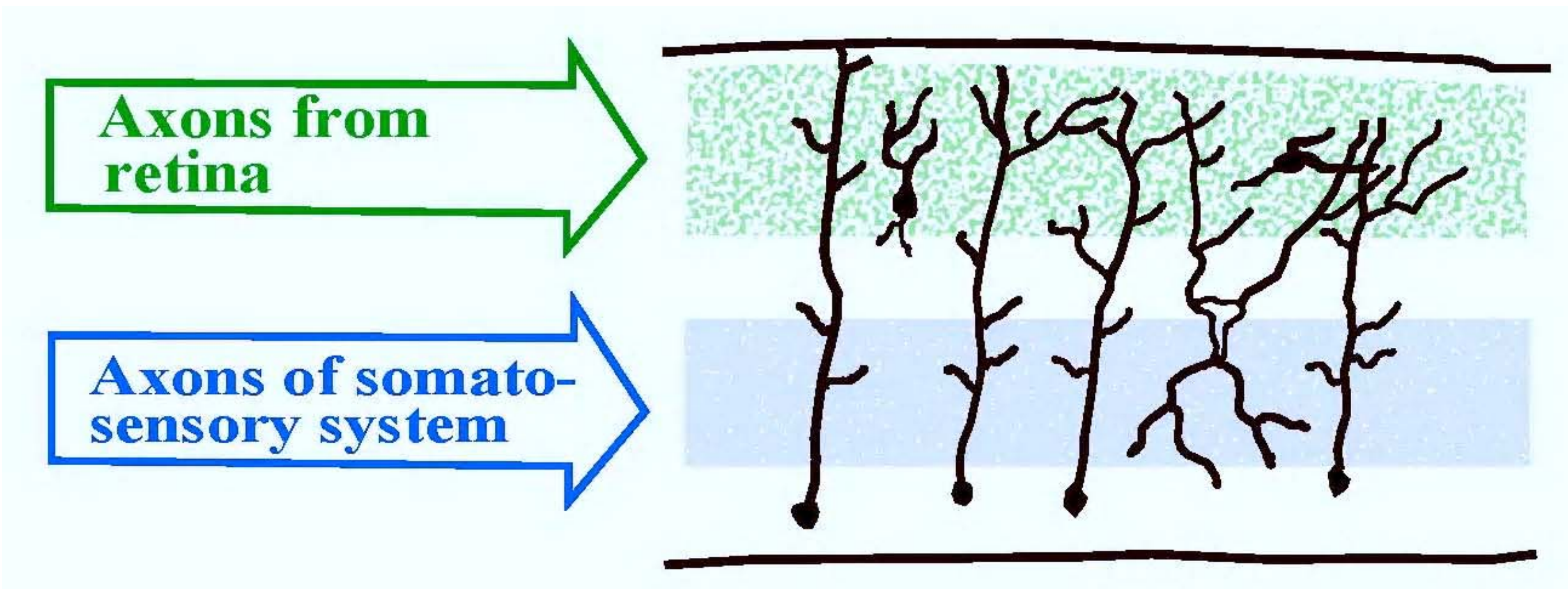
Midbrain of a ray-finned fish (a bowfin)

S, C, G:

Superficial, Central, Periventricular Gray zones of optic tectum

In red: axons from the left eye

Figure removed due to copyright restrictions. Please see course textbook or:
Butler, A. B., and R. G. Northcutt. "Retinal Projections in the Bowfin, Amia Calva: Cytoarchitectonic and Experimental Analysis." *Brain, Behavior and Evolution* 39, no. 3 (1992): 169-94.



Schneider, G. E. *Brain Structure and its Origins: In the Development and in Evolution of Behavior and the Mind*. MIT Press, 2014. ISBN: 9780262026734.

Fig 21-13

Figure removed due to copyright restrictions. Please see course textbook or:
Parent, A., L. Dube, et al. "The Organization of Monoamine Containing Neurons in the Brain of the Sunfish (Lepomis gibbosus) as Revealed by Fluorescence Microscopy." *Journal of Comparative Neurology* 182, no. 3 (1978): 495-516.

Midbrain of a teleost fish showing large optic tectum

Neurons in optic tectum of a teleost

Midbrain section from brain of a frog (*Rana temporaria)*

Figure removed due to copyright restrictions.

Axons from retina terminating in frog optic tectum

Note fiber and cell layers at left, Golgi-stained neurons at right

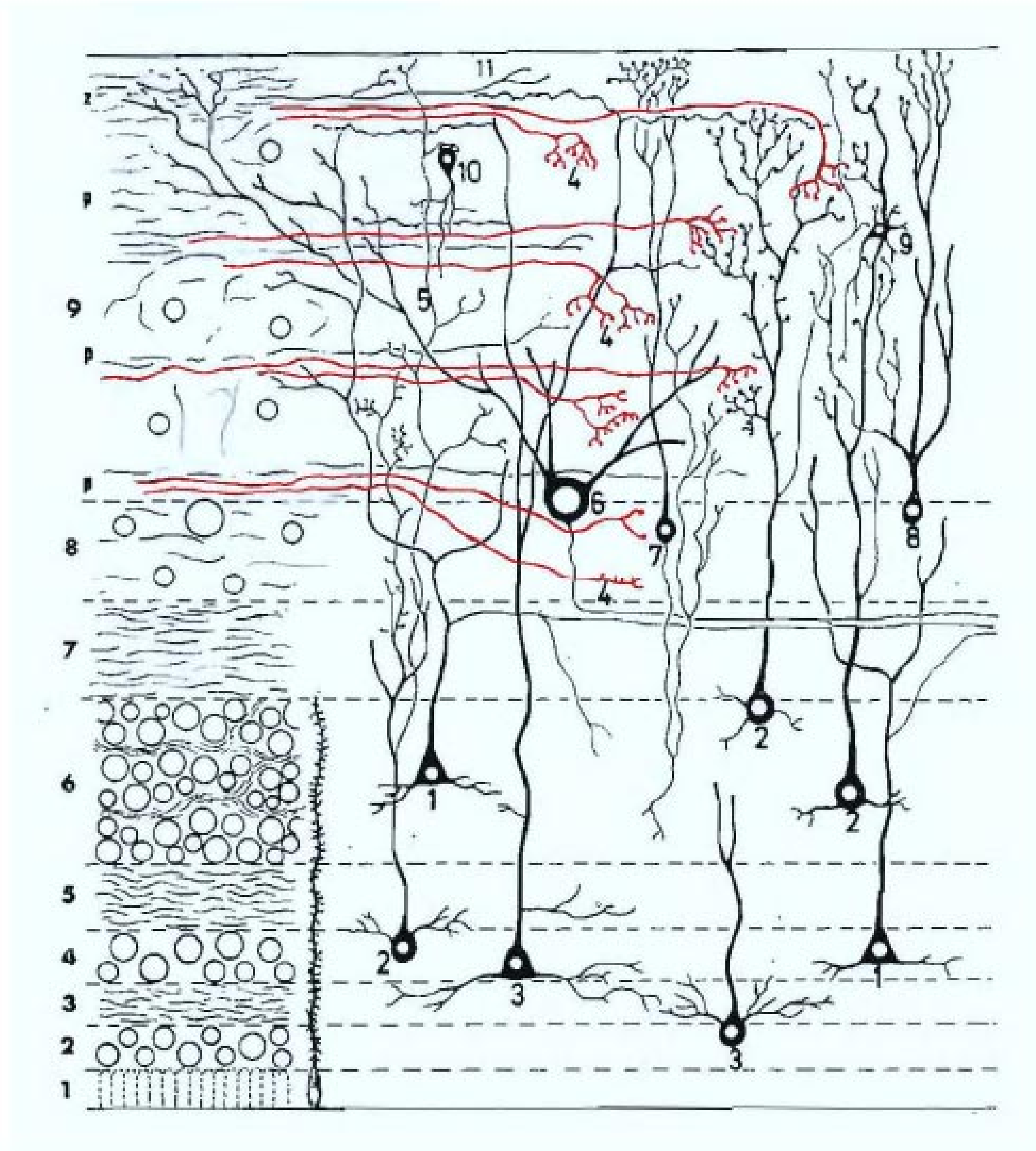
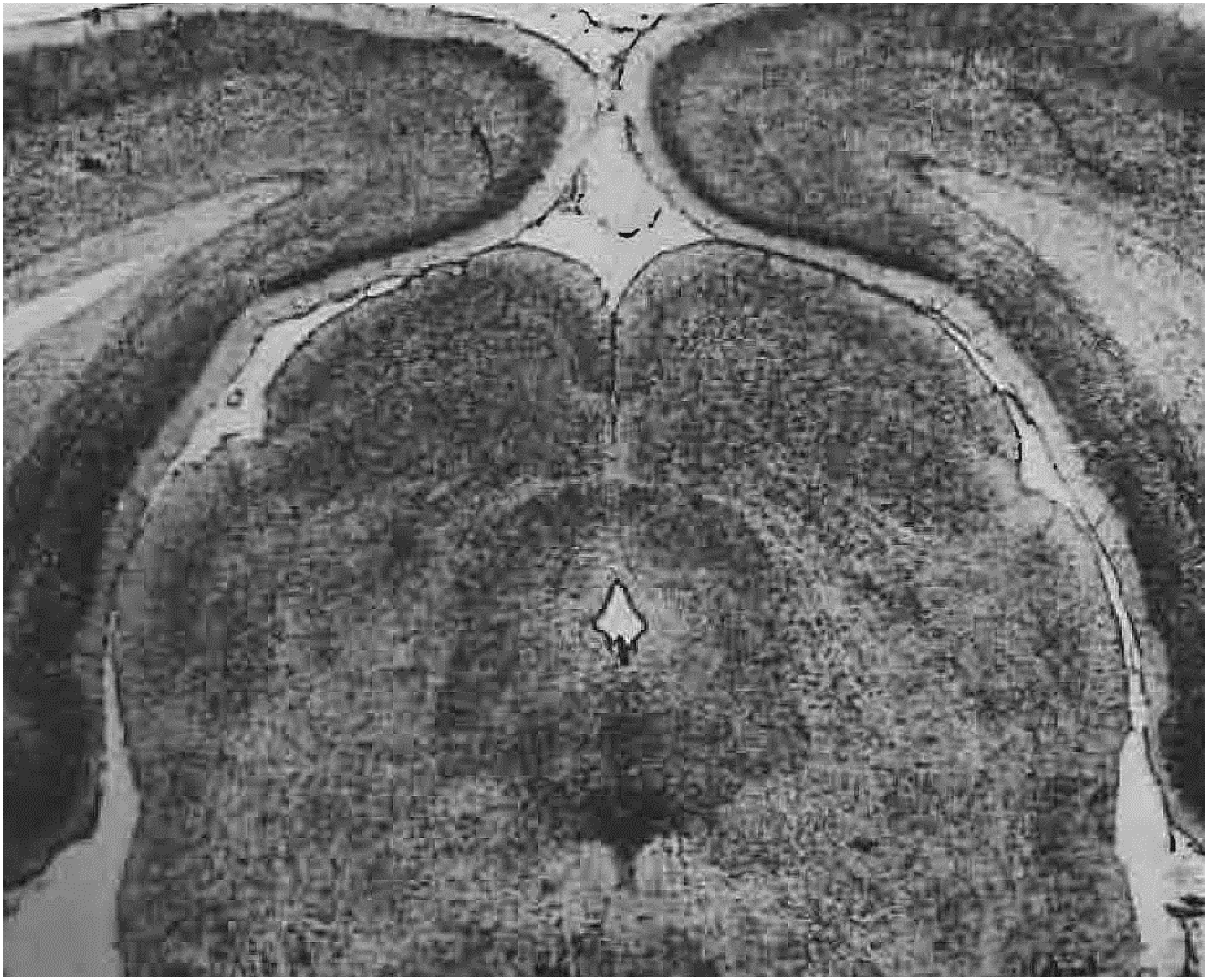


Fig 21-16b

Figure removed due to copyright restrictions. Please see:
Foster, Robert E., and William C. Hall. "The Connections and Laminar Organization of the Optic Tectum in a Reptile (Iguana Iguana)." *Journal of Comparative Neurology* 163, no. 4 (1975): 397-425.



Nissl stain of Syrian hamster midbrain section

Figure removed due to copyright restrictions. Please see:
Schneider, G. E. "Early Lesions of Superior Colliculus: Factors Affecting the Formation of Abnormal Retinal Projections." *Brain, Behavior and Evolution* 8, no. 1-2 (1973): 91-109.

Mammalian superior colliculus in frontal section: myelin stain, Syrian hamster

Fig 21-17

Nissl stain of rat midbrain section

Figure removed due to copyright restrictions. Please see:
Butler, Ann B., and William Hodos. *Comparative Vertebrate Neuroanatomy: Evolution and Adaptation*. Wiley-Liss, 1996. ISBN: 9780471888895.

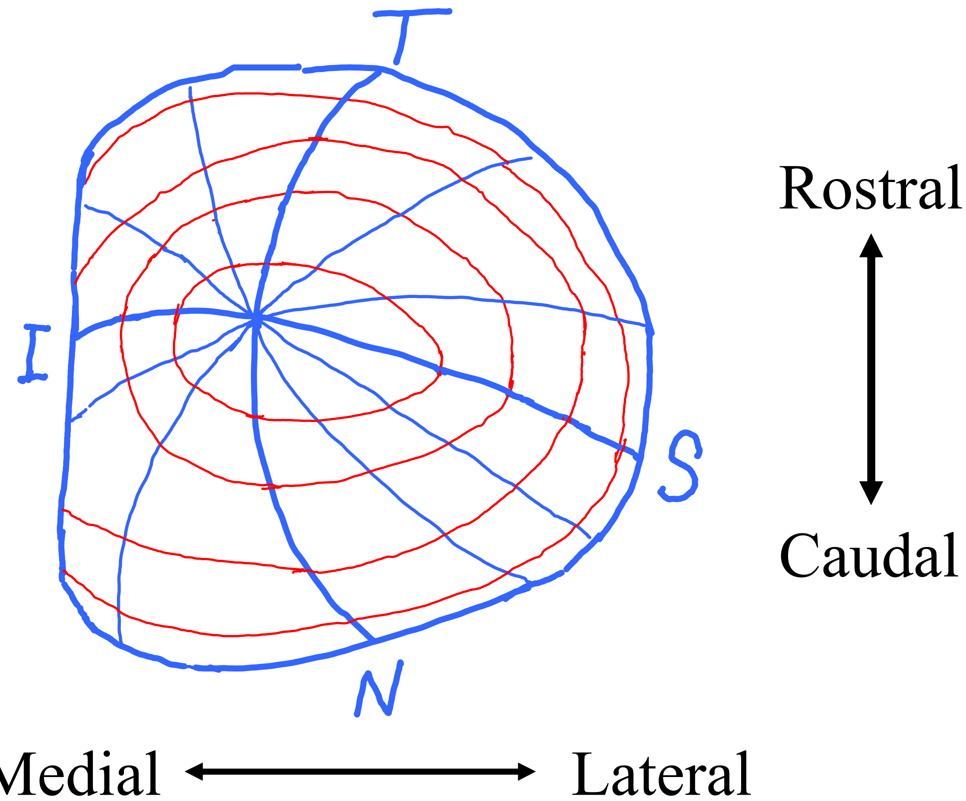
Topographic organization of the main optic tract

- Goldfish optic tectum
- Hamster optic tract and termination patterns

Topography of retinal projections to goldfish optic tectum:

Analysis by electrophysiological recordings

(Purves & Lichtman)



Schneider, G. E. *Brain Structure and its Origins: In the Development and in Evolution of Behavior and the Mind*. MIT Press, 2014. ISBN: 9780262026734.

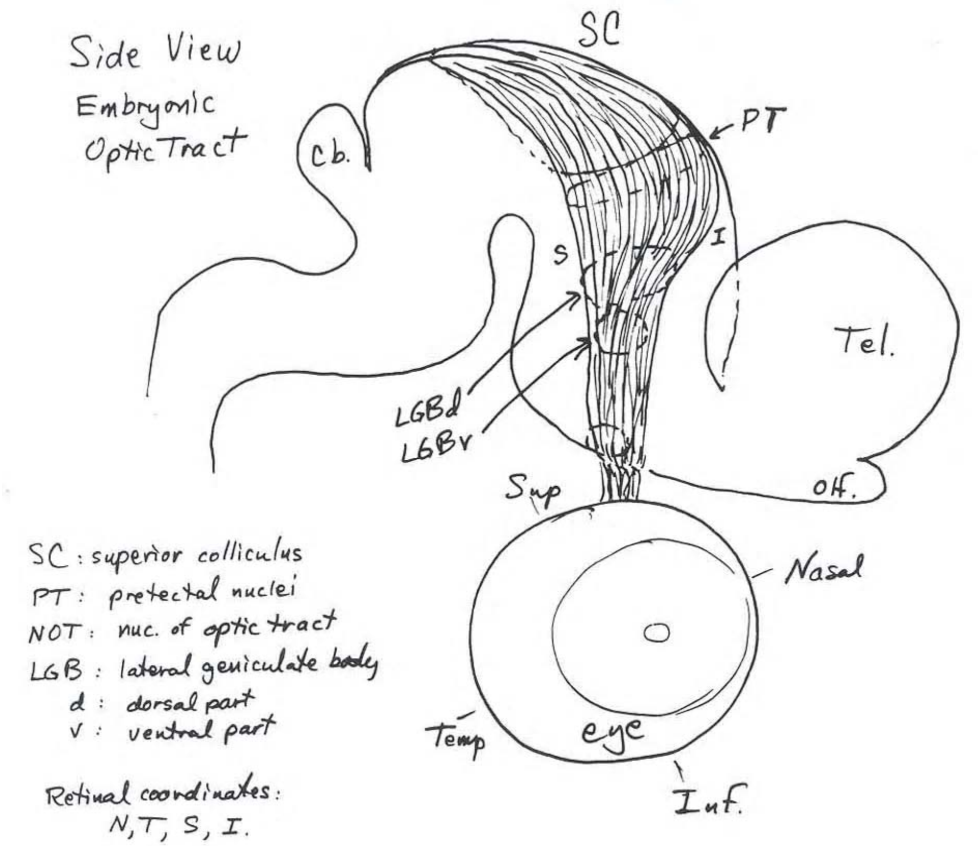
Fig 20-5 Map of the contralateral retina on the surface of the right superior colliculus of an adult Syrian hamster. Coordinates aligned with centers of extrinsic eye muscle attachments

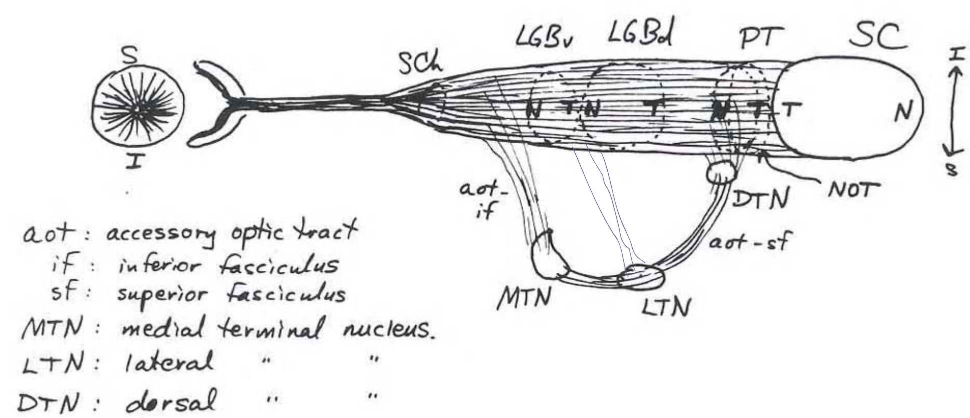
Map determined by neuroanatomical methods of tract tracing from small retinal areas

(top) side view, optic nerve & tract of prenatal hamster brain

(bottom) flattened view of optic tract

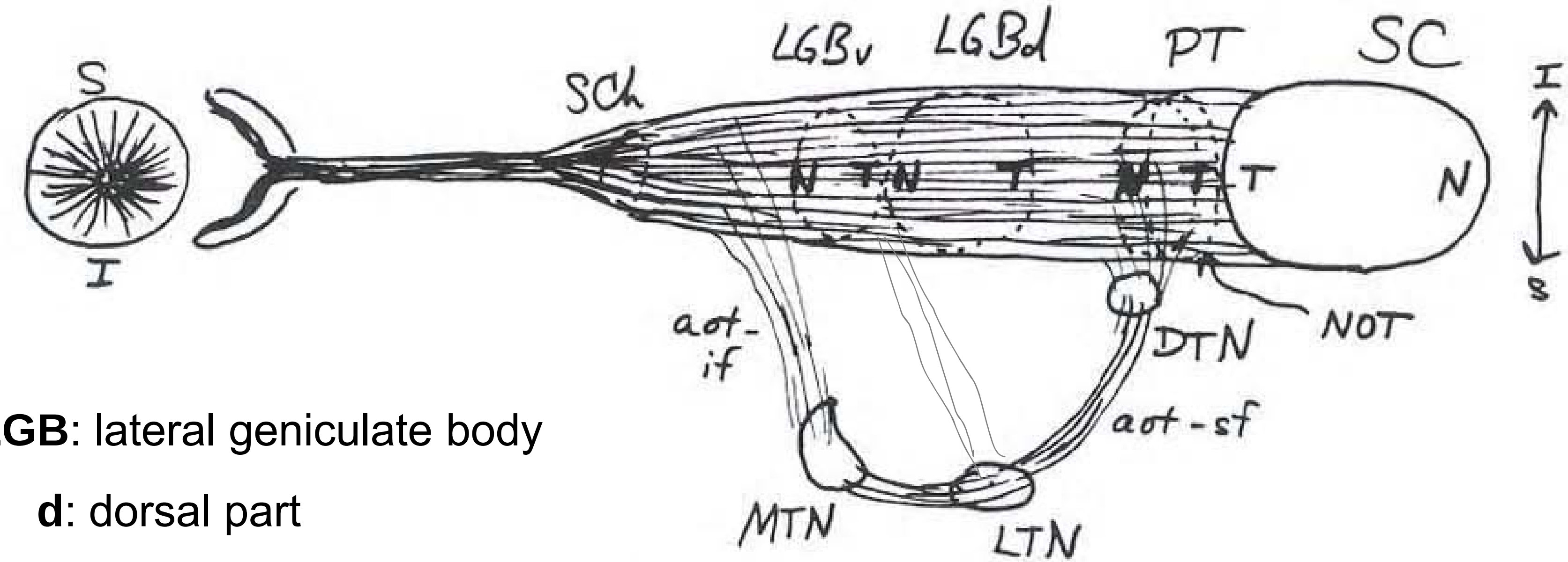
From experimental neuroanatomical studies





Schneider, G. E. *Brain Structure and its Origins: In the Development and in Evolution of Behavior and the Mind*. MIT Press, 2014. ISBN: 9780262026734.

Flattened view of optic tract and its terminal areas



Schneider, G. E. *Brain Structure and its Origins: In the Development and in Evolution of Behavior and the Mind*. MIT Press, 2014. ISBN: 9780262026734.

LGB: lateral geniculate body

d: dorsal part

v: ventral part

N, T, S, I: retinal coordinates

NOT: nucleus of the optic tract (in pretectal area)

PT: pretectal nuclei

SC: superior colliculus

SCh: suprachiasmatic nucleus

aot: accessory optic tract

if: inferior fasciculus

sf: superior fasciculus

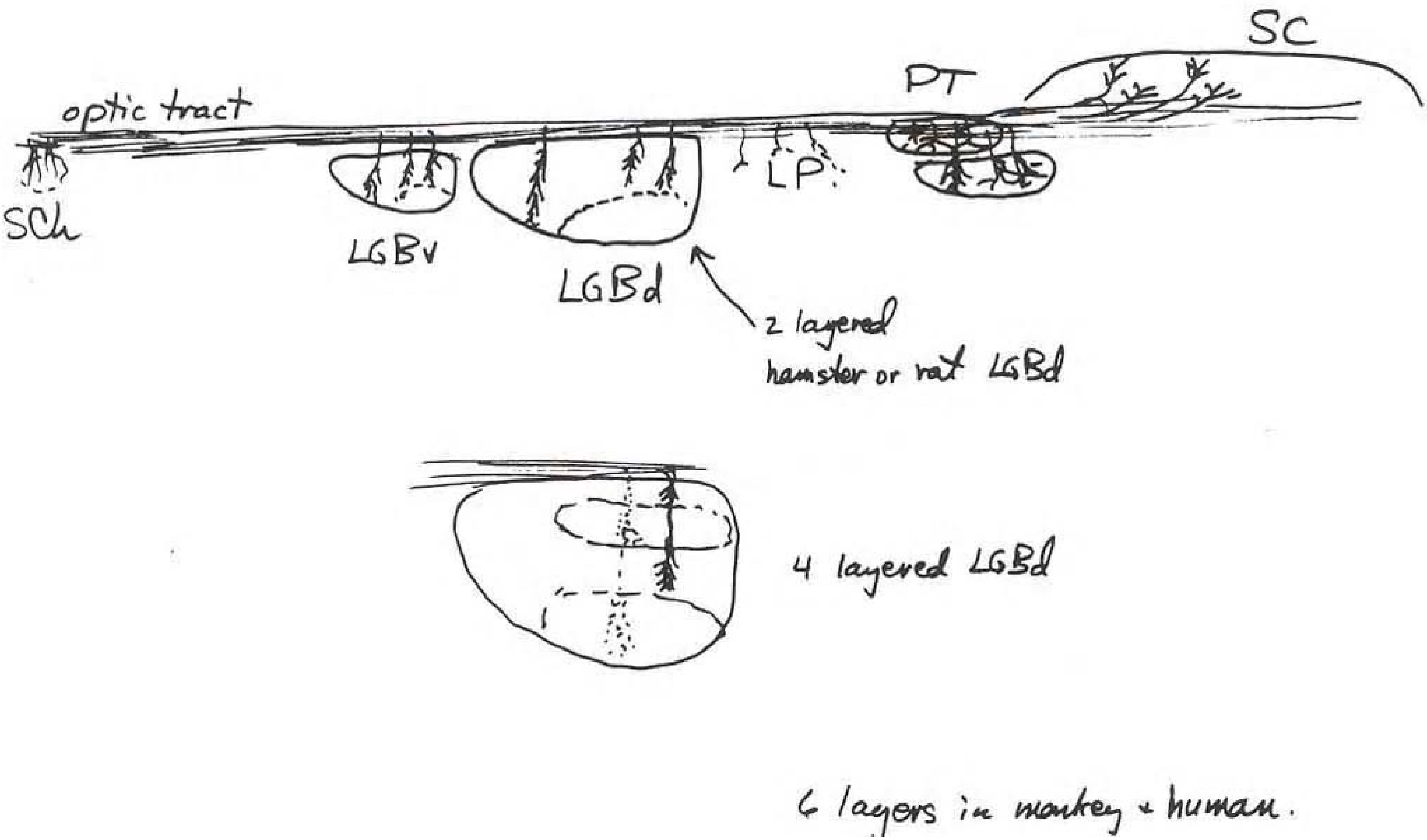
MTN: medial terminal nucleus of aot

LTN: lateral terminal nucleus of aot

DTN: dorsal terminal nucleus of aot

REVIEW:

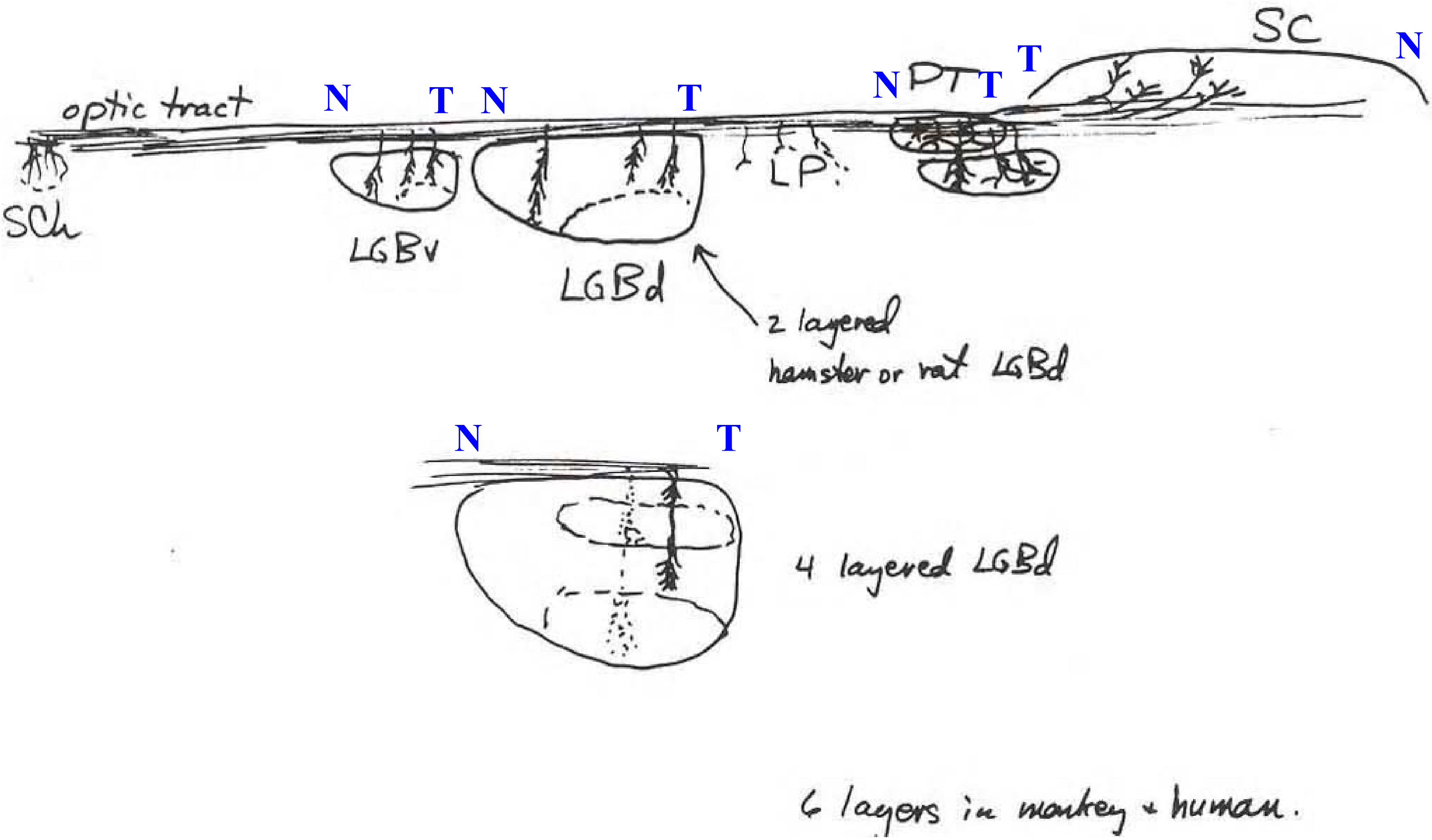
Stretched section through optic tract from chiasm to superior colliculus



Schneider, G. E. *Brain Structure and its Origins: In the Development and in Evolution of Behavior and the Mind*. MIT Press, 2014. ISBN: 9780262026734.

Stretched section through optic tract from chiasm to superior colliculus:

with addition of retinotopic organization



Schneider, G. E. *Brain Structure and its Origins: In the Development and in Evolution of Behavior and the Mind*. MIT Press, 2014. ISBN: 9780262026734.

A sketch of the central nervous system and its origins

G. E. Schneider 2014

Part 7: Sensory systems

MIT 9.14 Classes 21-22-23

Sensory systems 2: Visual systems

Book chapter 22: *The Visual Endbrain Structures*

Topics

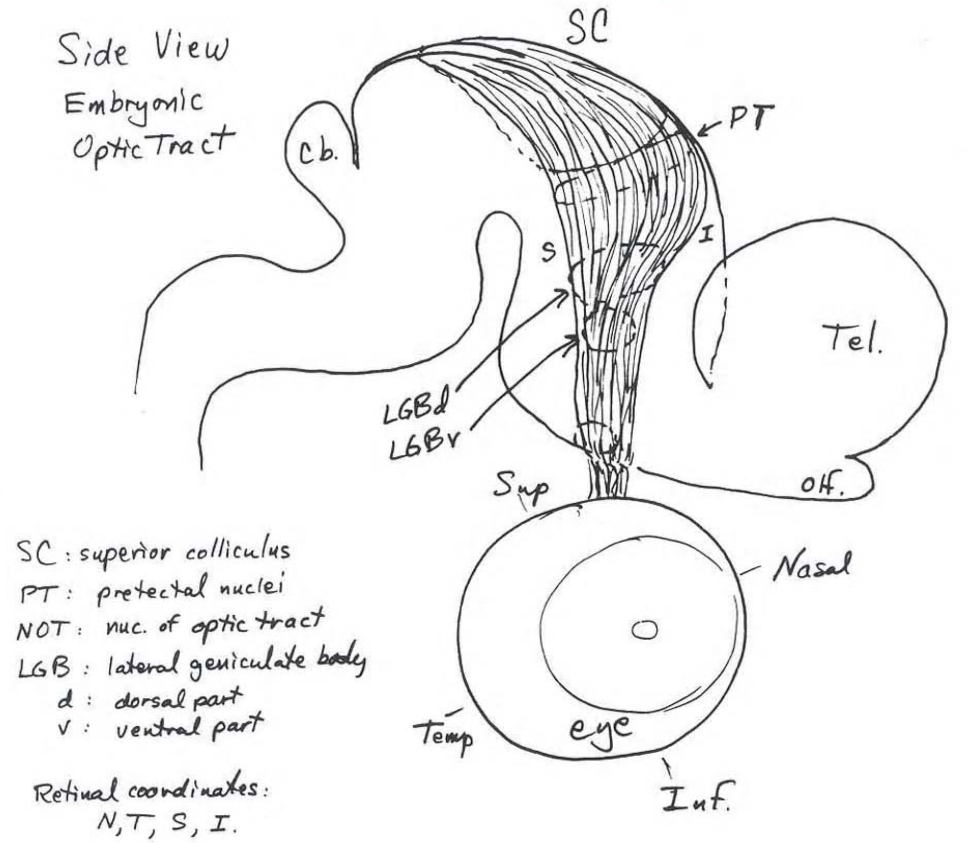
- Visual systems 1:
  - Origins of vision, 1: Light detection
  - Origins of vision, 2: Image formation
    - Structures serving three major functions: predator escape, orienting towards objects, identifying patterns and objects
- Visual systems 2:
  - Retinal projections in vertebrates, and the layout of the optic tract
  - Species differences in relative size
  - Lamination of midbrain tectum
  - Topography of optic tract and its termination patterns (introduction)
- **Today:**
  - ✓ Topography of optic tract and its termination patterns
  - Accessory optic tract
  - Multiple routes from retina to the endbrain; optic radiations
  - Old and new neocortical areas; evolutionary multiplications of visual areas; temporalization with neocortex expansion
  - The nature of connectivity between cortical areas
  - Major transcortical pathways beginning at the striate area

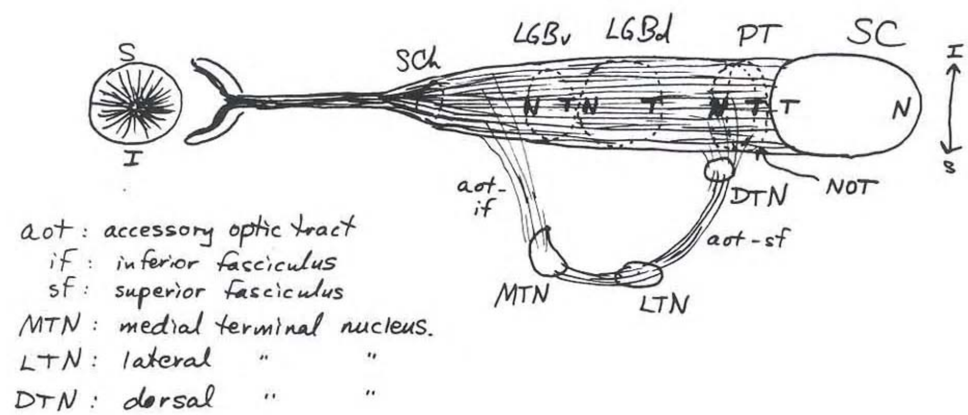
(top) side view, optic nerve & tract of prenatal hamster brain

(bottom) flattened view of optic tract

From experimental neuroanatomical studies

You should be able to relate these two figures!

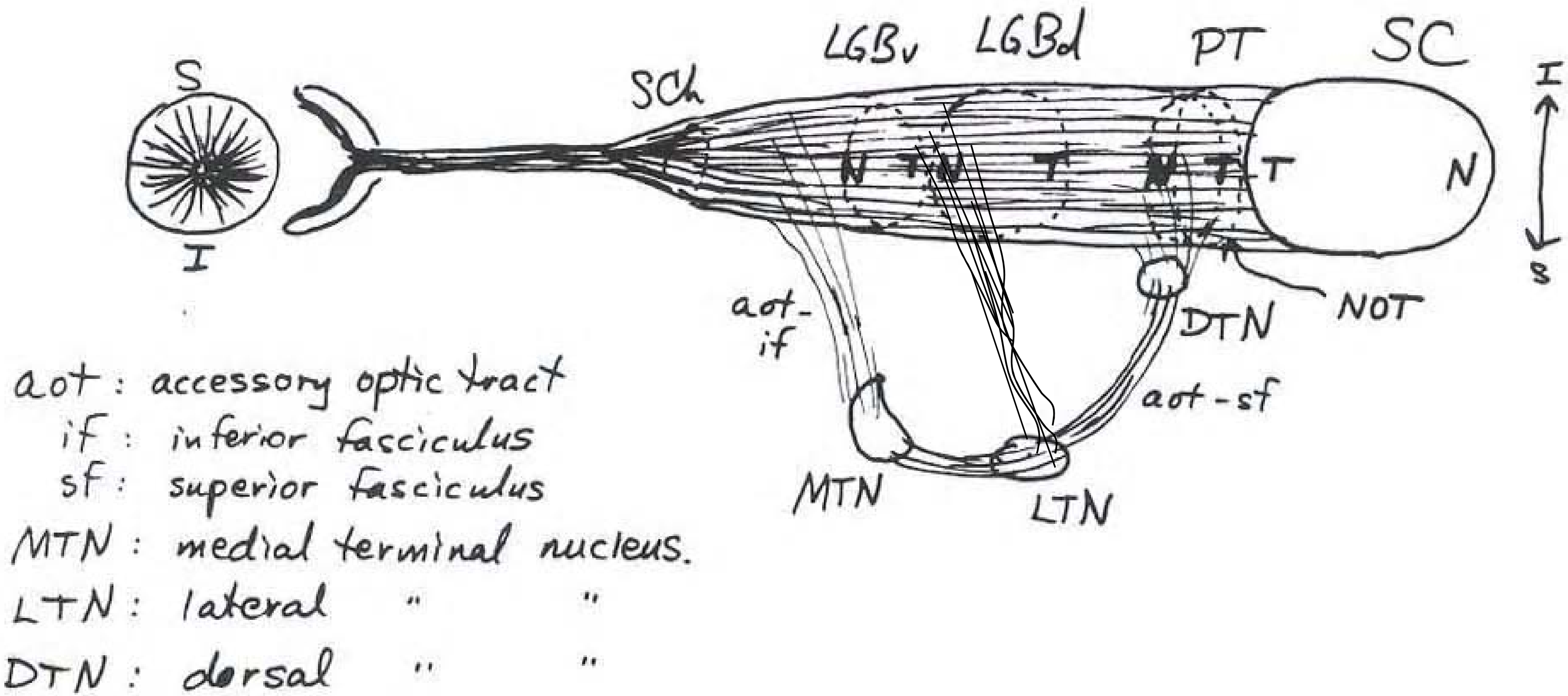




Courtesy of MIT Press. Used with permission.
Schneider, G. E. *Brain Structure and its Origins: In the Development and in Evolution of Behavior and the Mind*. MIT Press, 2014. ISBN: 9780262026734.

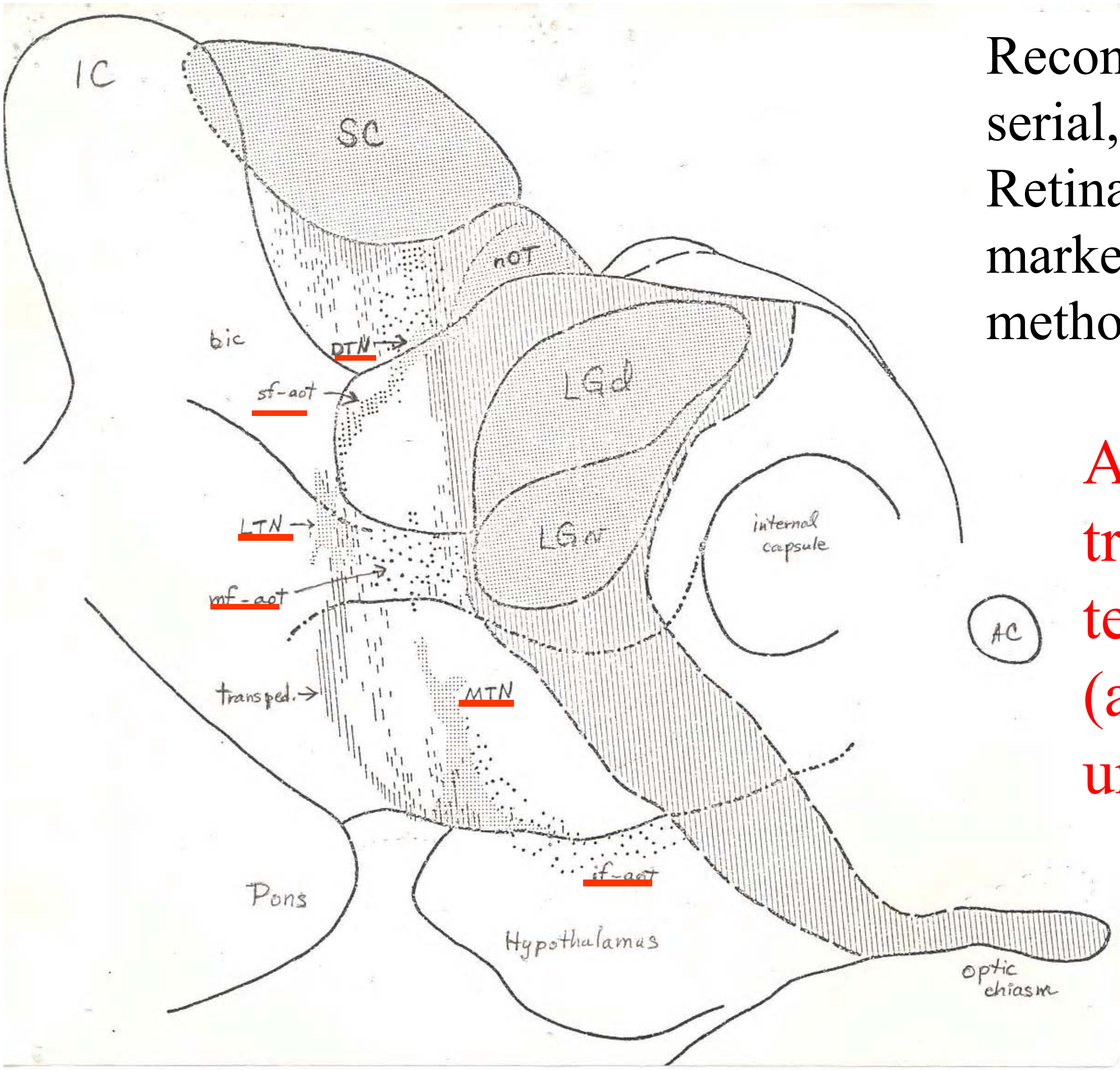
What is the accessory optic tract?

Flattened view of optic tract, showing caudal offshoots called the accessory optic tracts



Schneider, G. E. *Brain Structure and its Origins: In the Development and in Evolution of Behavior and the Mind*. MIT Press, 2014. ISBN: 9780262026734.

Adult optic tract (Hamster)

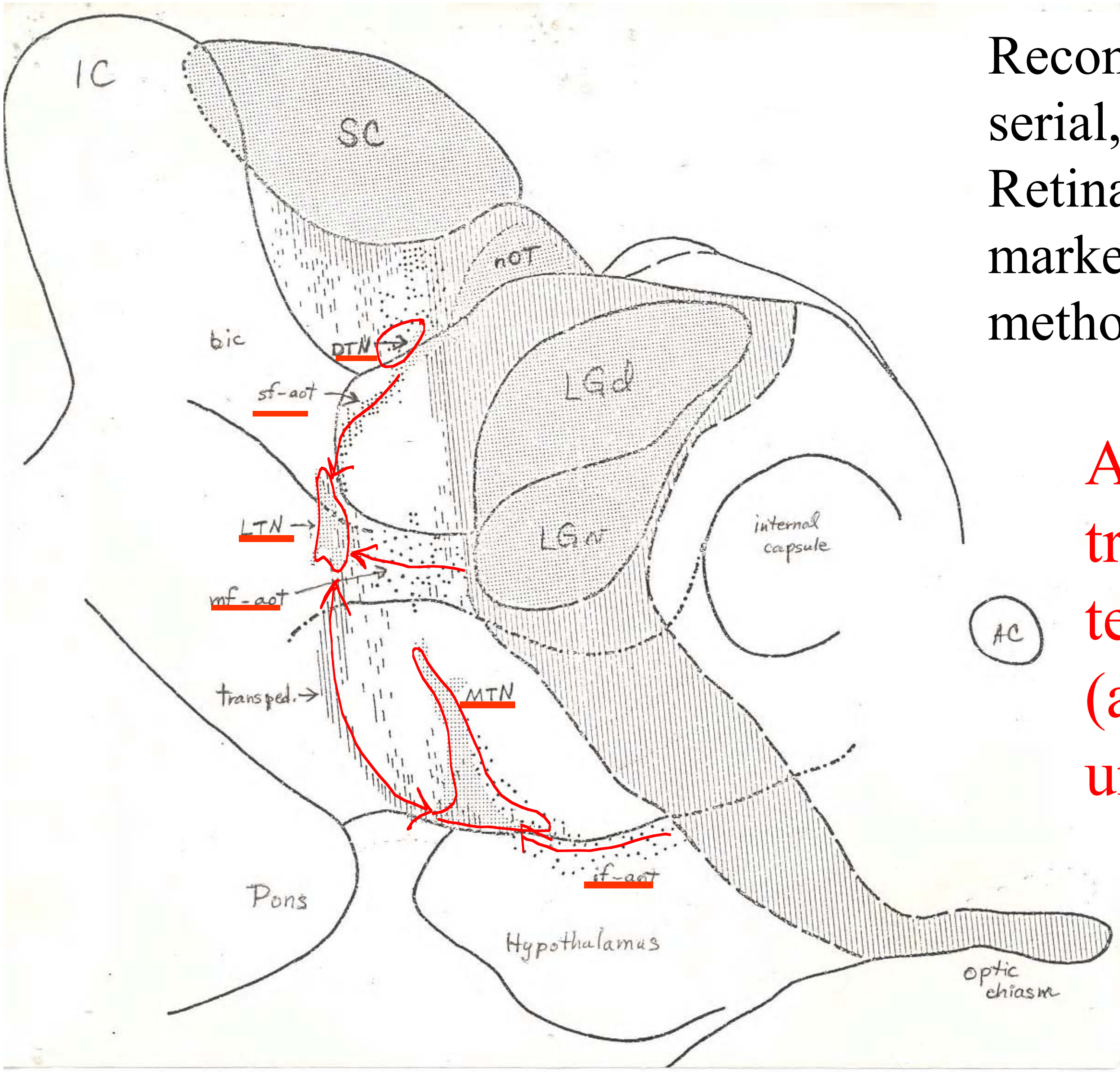


Reconstruction from serial, frontal sections. Retinal projections marked by Nauta method.

Accessory optic tracts and terminal nuclei (abbreviations underlined)

Schneider, G. E. *Brain Structure and its Origins: In the Development and in Evolution of Behavior and the Mind*. MIT Press, 2014. ISBN: 9780262026734.

Adult optic tract (Hamster)



Reconstruction from serial, frontal sections. Retinal projections marked by Nauta method.

Accessory optic tracts and terminal nuclei (abbreviations underlined)

Schneider, G. E. *Brain Structure and its Origins: In the Development and in Evolution of Behavior and the Mind*. MIT Press, 2014. ISBN: 9780262026734.

What is the function of the accessory optic tract and its terminal nuclei?

Neurons respond to movement that occurs simultaneously across the entire retina, as during locomotion or head movement, or during a loss of balance.

Next topic: pathways to endbrain areas

Multiple routes from retina to the endbrain: the "optic radiations"

- Two of these are usually cited, but there is evidence for four others.

five

Questions, chapter 22

1) Deacon's rule ("large equals well-connected") is an important rule of thumb in brain evolution. What does this rule suggest in the discussion of multiple routes to the forebrain for visual information?

The largest structure – the midbrain tectum – should have greater connections to the forebrain.

Questions, chapter 22

2) What are the two routes to the endbrain taken by visual information that are usually considered the major ones in present-day mammals, reptiles and birds?

3) What is the most rapid route from retina to endbrain, the route that has become the most dominant of the multiple visual pathways to the endbrain in the primates?

4) Describe one other unimodal pathway taken by visual information to the endbrain that is also probably of major importance in modern mammals although it is less discussed.

From retina to the endbrain:
multiple routes in mammals

(All but the first were mentioned in class 21.)

- *Via* 1) Subthalamus (LGBv)
  - Via Zona Incerta (located medial to LGv in the subthalamus) to Striatum and to midline and intralaminar nuclei of thalamus (thence widely to endbrain)
- *Via* 2) optic tectum and 3) pretectum (deeper layers of both structures)
  - To intralaminar nuclei of thalamus ("paleothalamus"): hence to striatum and to neocortex
- *Via* 4) pretectum (superficial layers)
  - To lateral thalamus (LD): hence to posterior neocortex
- ***Via* 5) optic tectum** (superficial layers)
  - **To lateral thalamus (LP/Pulvinar): hence to posterior neocortex**
  - **6)** A lesser projection from LP to the lateral nucleus of the amygdala (ch 20)
- ***Via* 7) LGBd directly**
  - **Hence to occipital neocortex** (the "geniculostriate" pathway)

About the seven routes

(six in chapter 22; the seventh was mentioned in ch 20)

- The **first** is almost always ignored. I think it may be important in evolution.
- The **second**, **third** and **fourth** are also seldom mentioned; they have attracted few researchers.
- The **fifth** and **seventh** are the ones always discussed. They are the largest pathways in the mammals commonly studied.

The following slides show illustrations of these pathways and some of the structures involved.

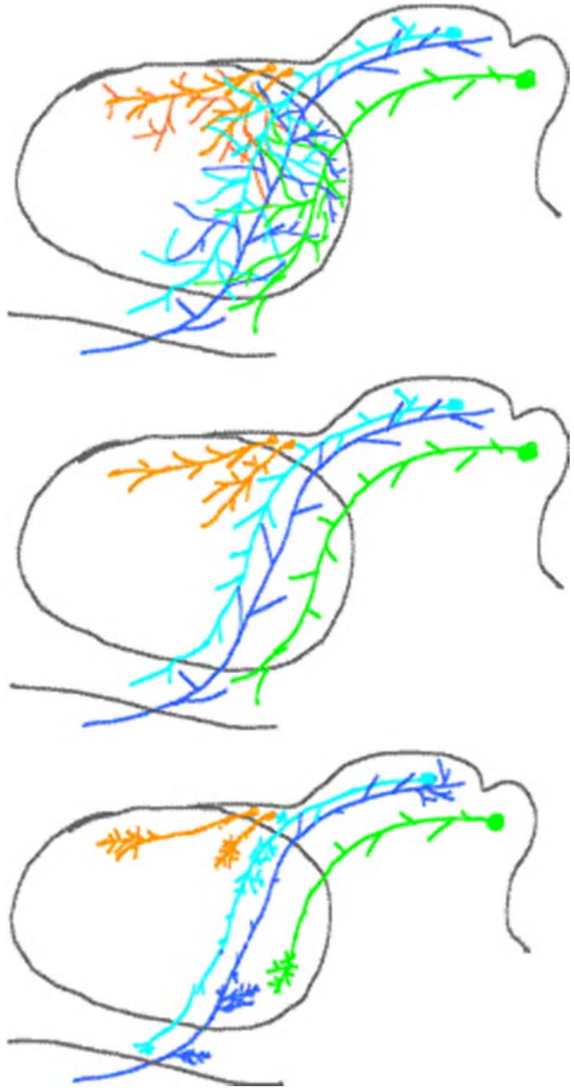
Origin of the pathways in thalamic evolution:

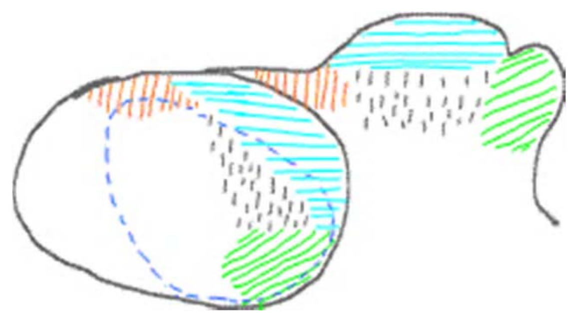
“Parcellation by competition” indicated in studies of projection areas and axonal pathways in hamster

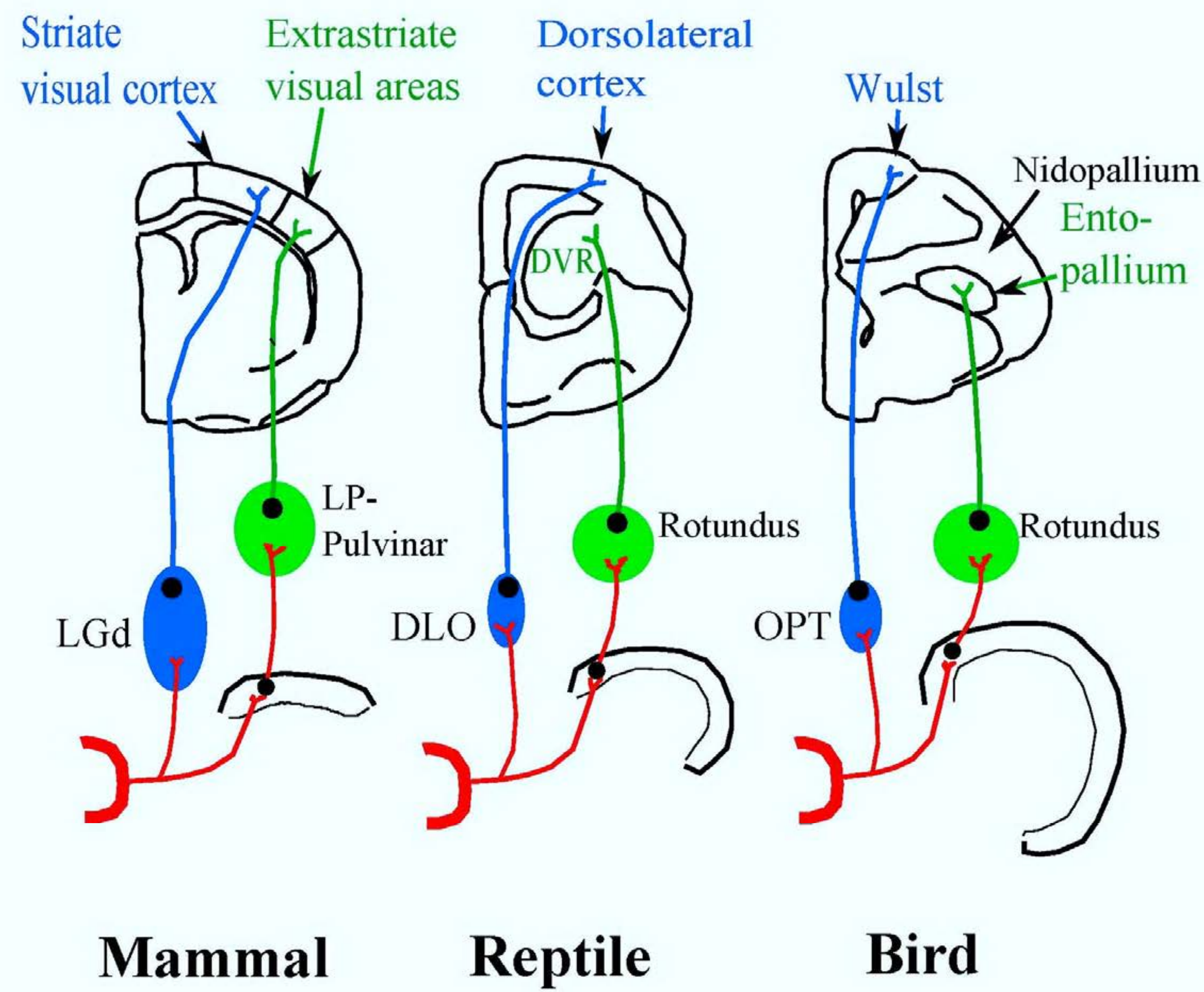
Stage 1

Stage 2

Stage 3







Two major routes from retina to endbrain in phylogeny

Schneider, G. E. *Brain Structure and its Origins: In the Development and in Evolution of Behavior and the Mind*. MIT Press, 2014. ISBN: 9780262026734.

Fig 22-2

Figure removed due to copyright restrictions. Please see course textbook or:
Balaban, Carey D., and Philip S. Ulinski. "Organization of Thalamic Afferents to Anterior Dorsal Ventricular Ridge in Turtles. I. Projections of Thalamic Nuclei." *Journal of Comparative Neurology* 200, no. 1 (1981): 95-129.

Transverse section and drawing through telencephalon of a turtle

Occipital lobe of a raccoon in Nissl section, showing striate area

(Butler & Hodos)

Figure removed due to copyright restrictions. Please see:
Butler, Ann B., and William Hodos. *Comparative Vertebrate Neuroanatomy: Evolution and Adaptation*. Wiley-Liss, 1996. ISBN: 9780471888895.

Figure removed due to copyright restrictions. Please see:
Hubel, David H. *Eye, Brain, and Vision*. Scientific American Library/Scientific American Books, 1995.

Occipital lobe, rhesus monkey showing striate area in Nissl-stained section

Note the sharp borders between area 17 (V1) and area 18 (V2)

Questions, chapter 22

5) What visual areas of the neocortex are believed to be the most primitive?

6) What causes the "temporalization" of the cerebral hemispheres? In development and in evolution it is correlated with the expansion of one group of thalamic nuclei. Which nuclei?

7) What are the optic radiations, and what happens to them in animals with relatively large temporal lobes?

Visual system pathways to the endbrain,
beginning with the route through the lateral geniculate body

Questions:

- What are the **optic radiations**? Describe their course from the thalamus to the neocortex.
- What fibers travel in these radiations in the opposite direction ("secondary optic radiations") ?
- What are the **"old" and "new" visual areas**?

Corticotectal and corticothalamic axons

Myelinating Pathways, postnatal 7-wk human
(from Paul Flechzig)

Geniculo-
striate
pathway

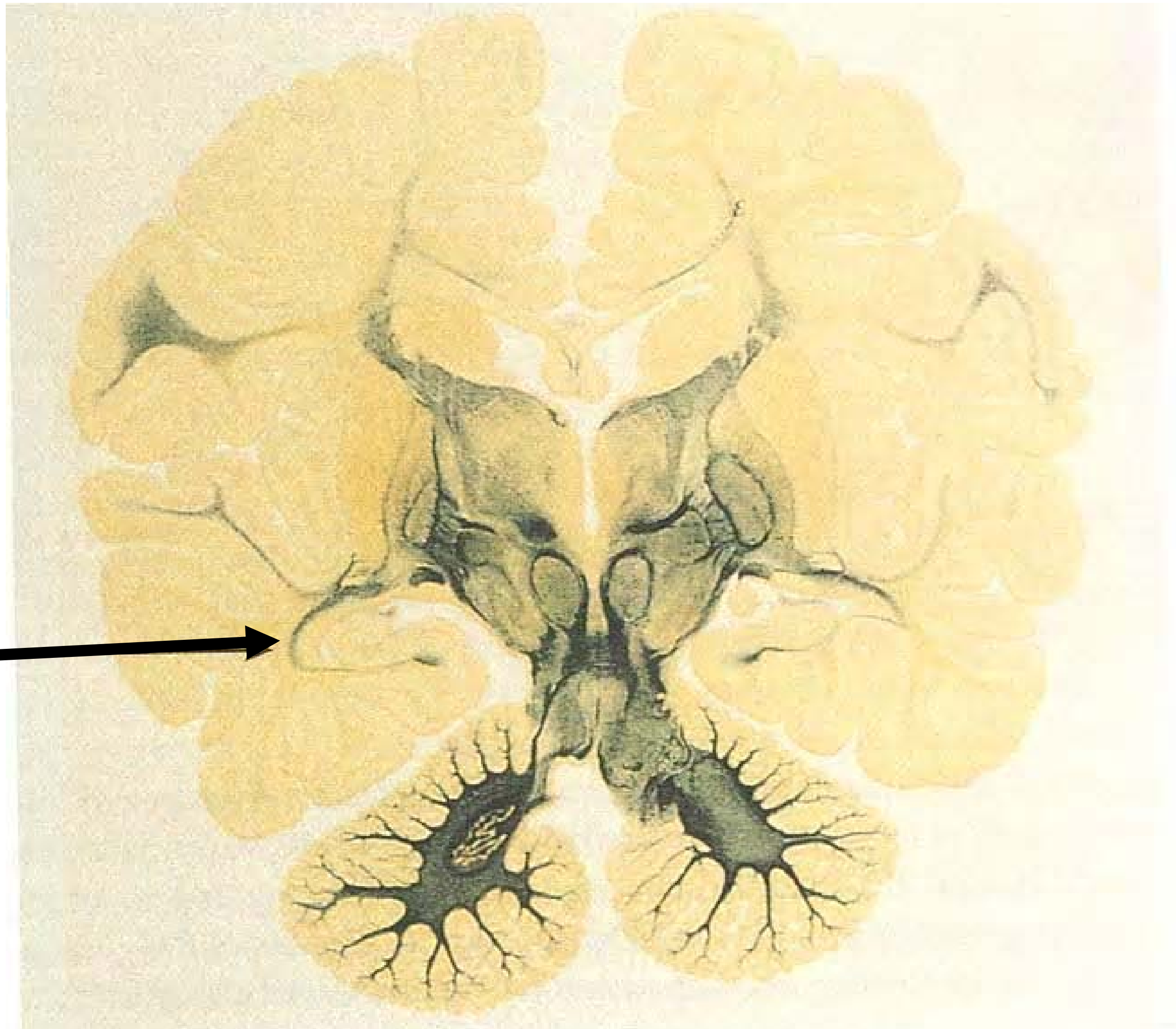


Fig 22.5

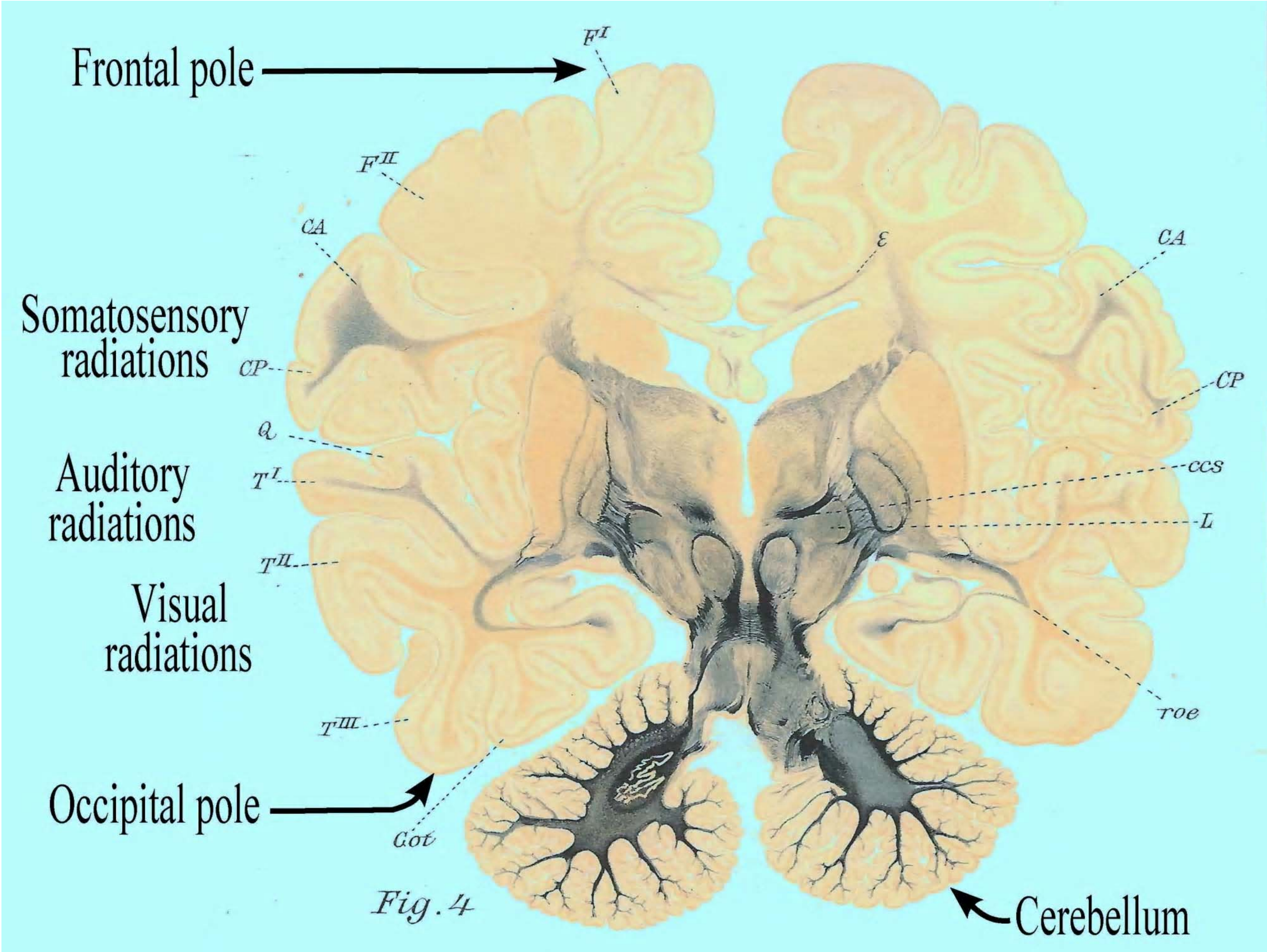


Image is in public domain. Flechsig, Paul. 1920. Anatomie des menschlichen Gehirns und Rückenmarks auf myelogenetischer Grundlage. Leipzig: G. Thieme.

Flechsig's figure with the original German labels undeleted.

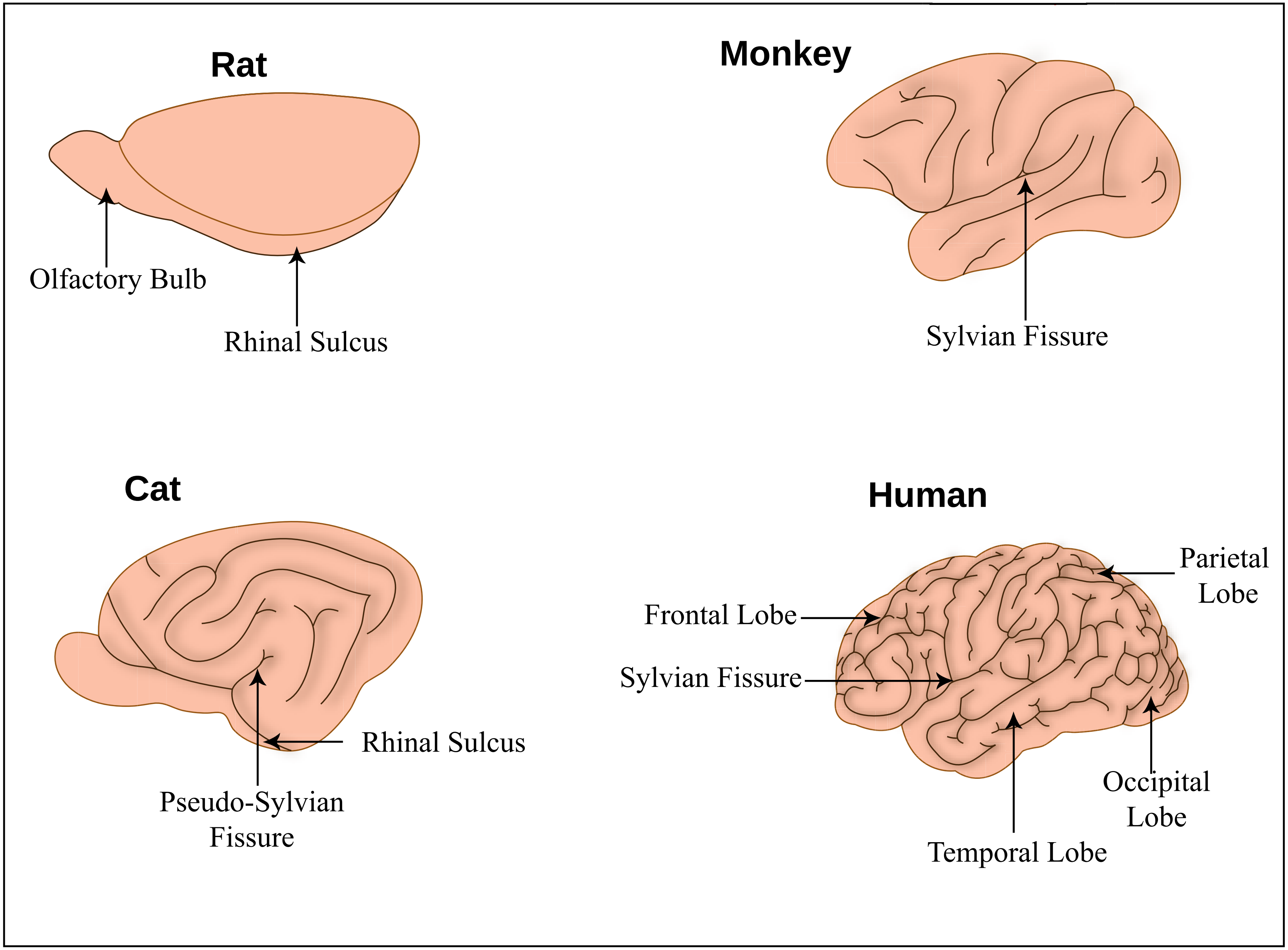
Growth of human brain: prenatal week 10 - 41

Note the growth of the temporal lobe

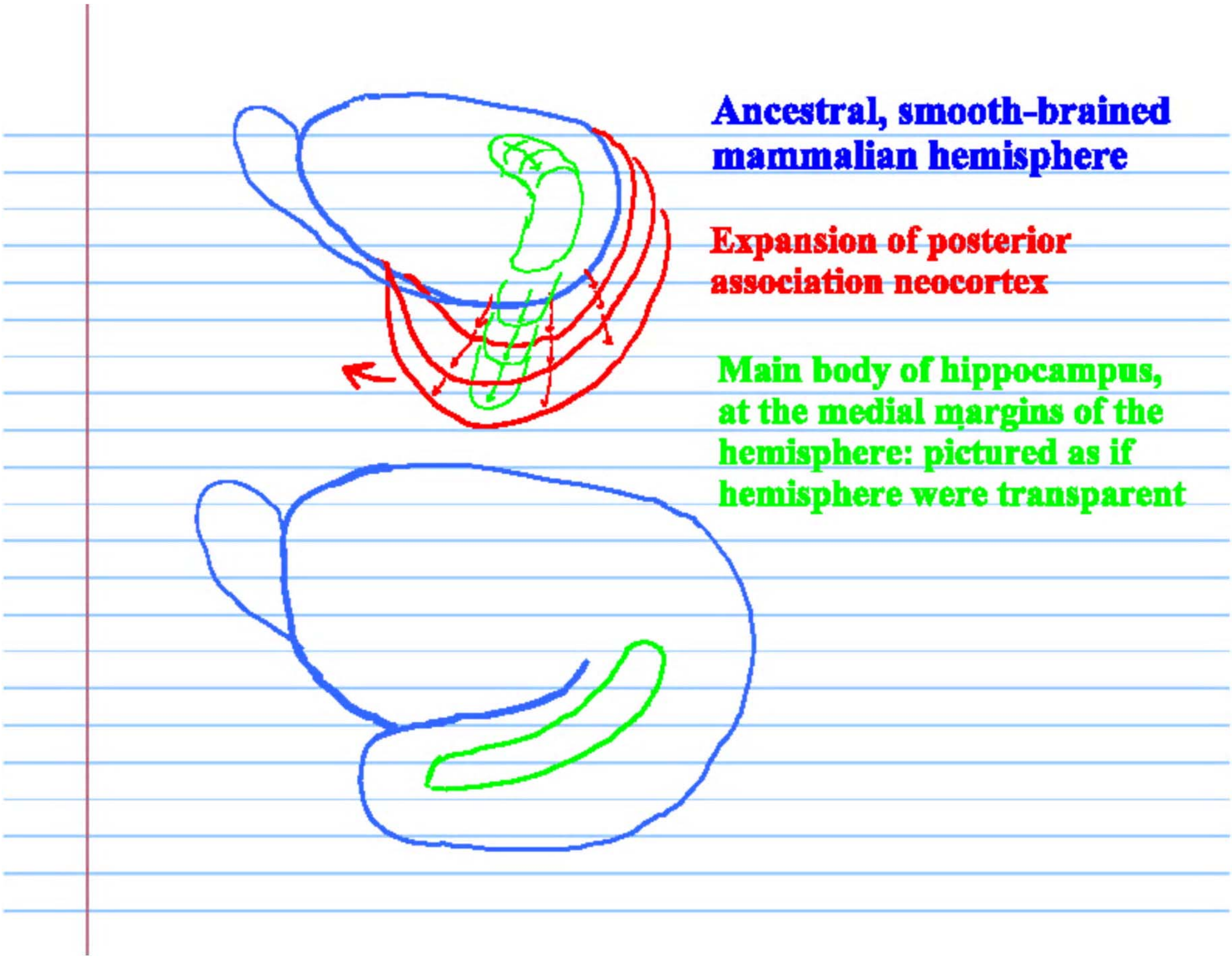
Figure removed due to copyright restrictions. Please see:
Larroche, J. Cl. "The Development of the Central Nervous System During Intrauterine Life." *Human Development. Saunders* (1966): 257-76.

Medial views, human brain, prenatal week 19–41

Figure removed due to copyright restrictions. Please see:
Larroche, J. Cl. "The Development of the Central Nervous System During Intrauterine Life." *Human Development. Saunders* (1966): 257-76.



Temporalization of the cerebral hemisphere as neocortex expands in phylogeny



Schneider, G. E. *Brain Structure and its Origins: In the Development and in Evolution of Behavior and the Mind*. MIT Press, 2014. ISBN: 9780262026734.

Progressive temporalization of neocortex in evolution

From Nauta & Feirtag:

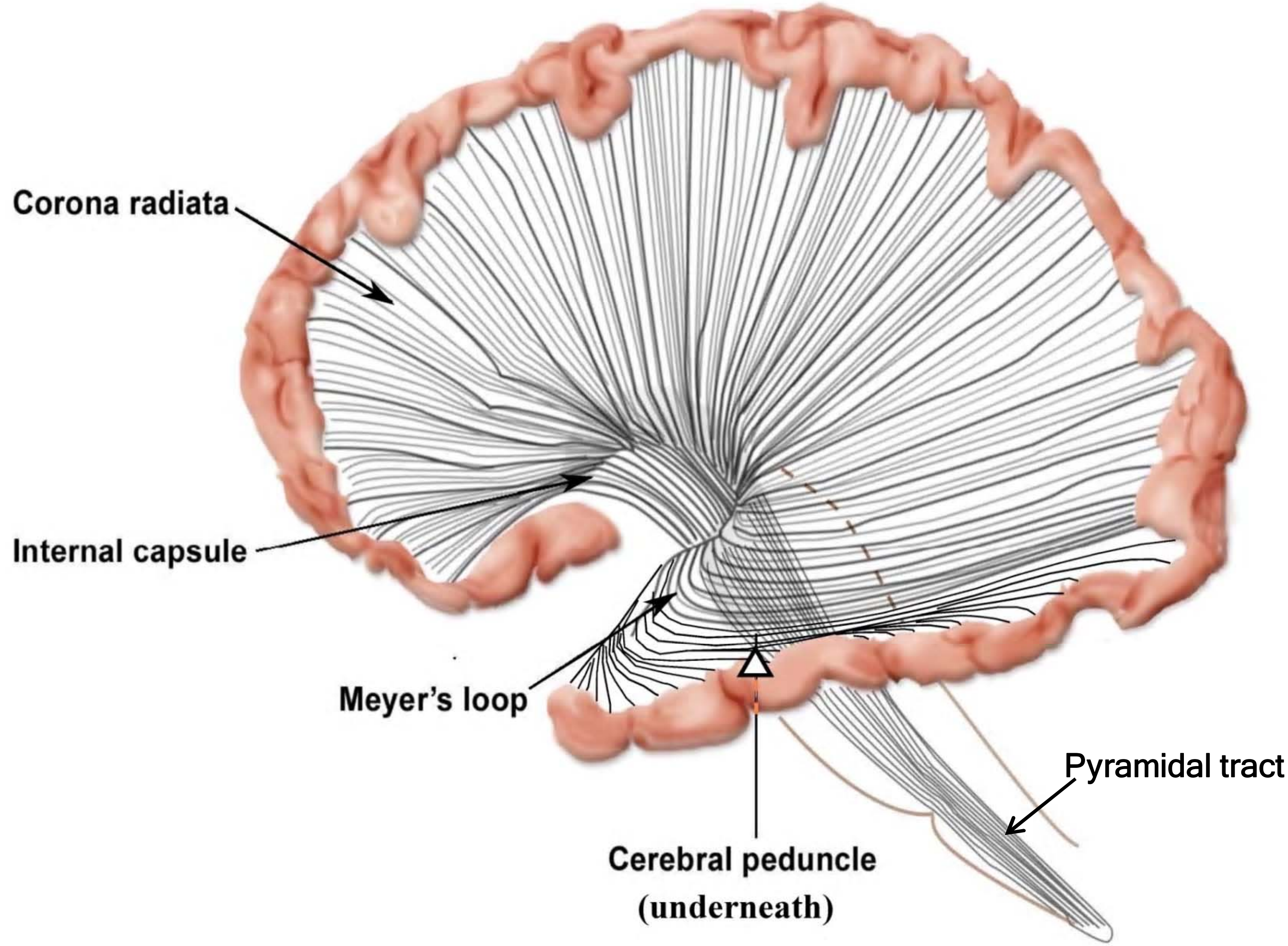
What is Meyer's loop?

It is part of the so-called optic radiations in human brain, coming from lateral geniculate body.

It also contains fibers coming from visual cortex destined for the brainstem. These are part of the "secondary optic radiations."

Distortion of the internal capsule by the formation of a temporal lobe in development

"Meyer's Loop" refers to the portion of the optic radiations pulled into the temporal lobe: **see also next slide**



Schneider, G. E. *Brain Structure and its Origins: In the Development and in Evolution of Behavior and the Mind*. MIT Press, 2014. ISBN: 9780262026734.

Fig 22-8

Part of the optic radiations are pulled into the temporal lobe as neocortex expands. This part, Meyer's loop, represents the upper visual field.

Questions, chapter 22

8) What are two methods used by neuroscientists to map multiple visual areas in the neocortex?

   Why is it believed that the human brain contains more visual areas than the 32 described for the rhesus monkey? see graphs, slide 53.

9) Why might there be so many visual areas in mammals with large brains? (a discussion question)

Evolutionary multiplications of cortical representations of the retina, especially in primates

(Left) Microelectrode mapping of visual area M of the owl monkey.

(Right) All visual areas thus mapped seen from the lateral side, including areas in the posterior parietal, temporoparietal, and inferotemporal neocortex.

Neocortical size *vs.* number of visual cortical areas

(Striedter fig. 6.16)

Many of the numbers on the ordinate are too small. See next slide for mouse.

Figure removed due to copyright restrictions. Please see:
Striedter, Georg F. *Principles of Brain Evolution*. Sinauer Associates, 2004. ISBN: 9780878938209.

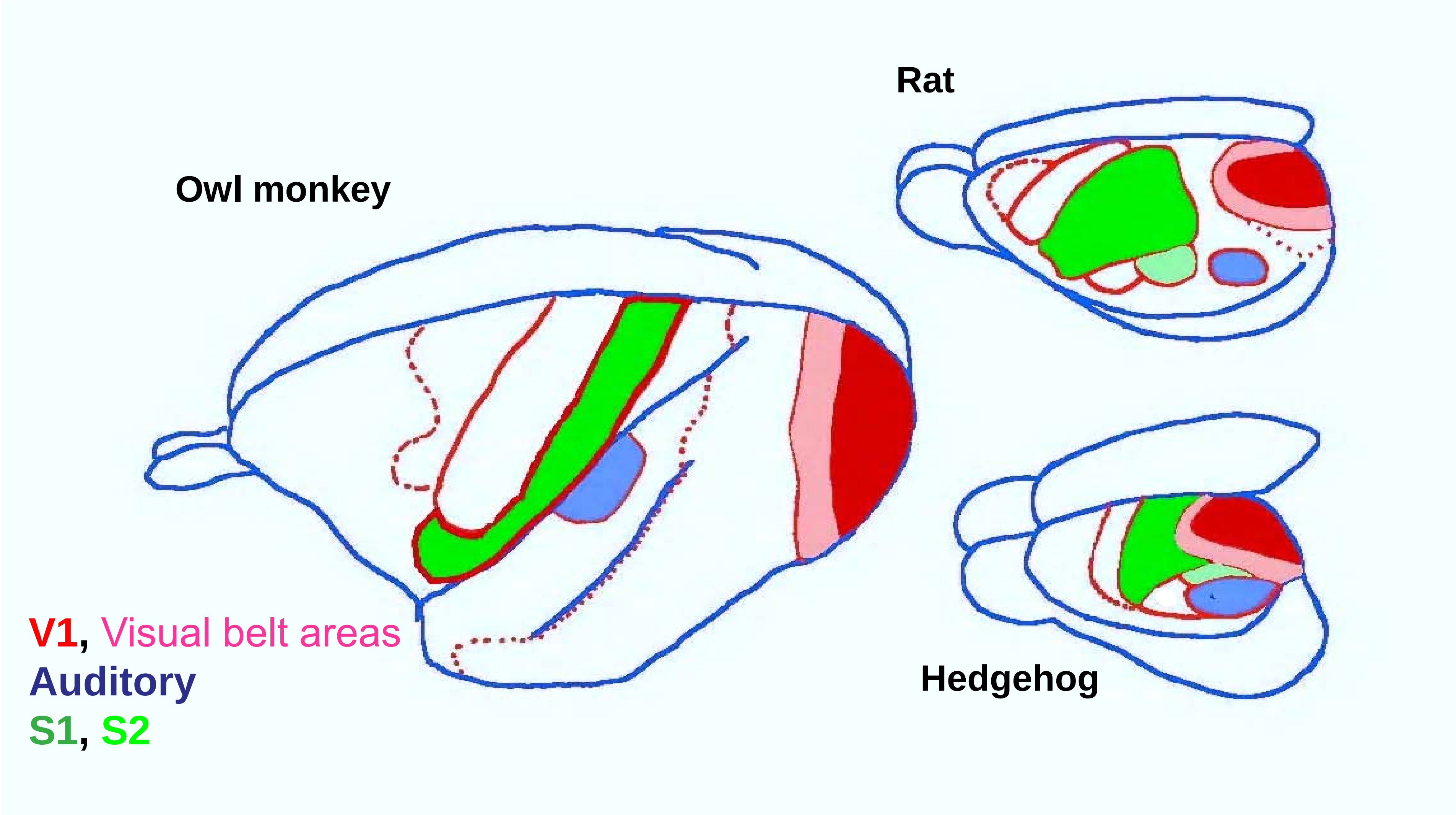
Figure removed due to copyright restrictions. Please see course textbook or:
Wang, Quanxin, and Andreas Burkhalter. "Area Map of Mouse Visual Cortex." *Journal of Comparative Neurology* 502, no. 3 (2007): 339-57.

Three diff. tracers
injected in striate area

A phylogenetic tree of visual cortical areas

Marcello G.P. Rosa and Leah A. Krubitzer (1999)

A phylogenetic tree of visual cortical areas.
According to Rosa (1999), all placental mammals have an anterior visual cortical area that is homologous across species, as well as homologous areas V1 and V2.



Schneider, G. E. *Brain Structure and its Origins: In the Development and in Evolution of Behavior and the Mind*. MIT Press, 2014. ISBN: 9780262026734.

Oldest sensory areas of neocortex, illustrated in three species

3 diff. modalities

Fig 22-12

Questions, chapter 22

10) Visual inputs to most, probably all, visual areas in neocortex come via two types of pathways. What are the two types?

Thalamocortical

Transcortical

End session 24

Transcortical connections

- As neocortical area and neuron number increase in evolution, the amount of white matter increases also, at a slightly greater rate.
- Specific long transcortical connections have received special emphasis in neuropsychology because of their importance in understanding functions of the neocortex in humans.

9.14 Brain Structure and Its Origins
Spring 2014