Visual system invades the endbrain: pathways to striatum and cortex (continued)

Why this happened in evolution

- **What were the adaptive advantages?**
  - ➢ Visual information reaching the **striatum** directly: Advantages for plasticity (habit learning)
  - ➢ Visual information reaching the **neocortex**:
    - Provided other routes to the striatum & to the pretectum, tectum and subthalamus. (Each of these had outputs to the motor system.)
    - Enabled **better acuity** for orienting and for learned approach-avoidance choices
- **Cognitive functions**
  - ➢ Provided a visual route to the amygdala carrying **object** information useful for learning of avoidance and approach responses
  - ➢ Provided a visual route to the hippocampus for learning and remembering **place** information

Visual system invades the endbrain: pathways to striatum and cortex (continued)

- **Binocular vision: Further adaptive advantages** **(**Especially important for predators with frontal eyes): predominantly a neocortical function
  - Improved **depth** vision with better acuity for accurate approach and grasping
  - Cortex became dominant as acuity improved.

Expansions and specializations in the visual system

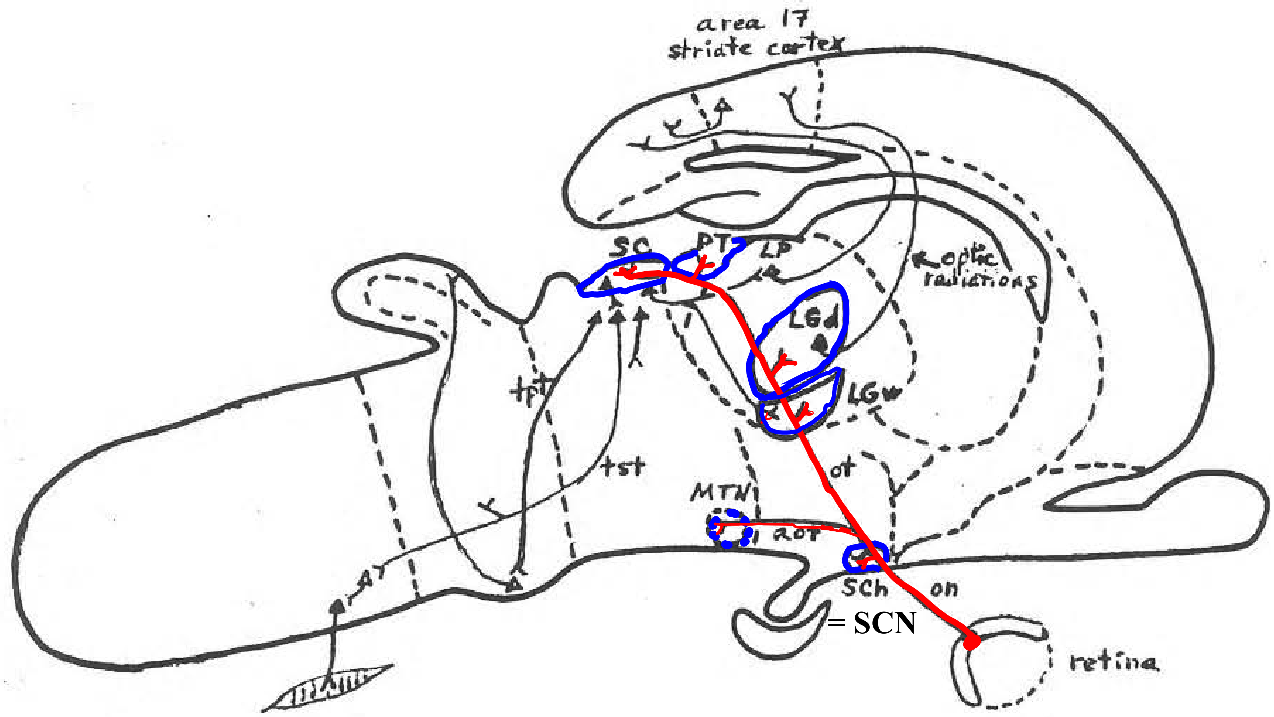
- **Midbrain tectum** (superior colliculus of mammals)
  - Evolution of tectal cortex (lamination at brain surface), varying greatly among different species
  - Evolution of great size differences, e.g., relatively large in teleosts, birds, and some mammals
- **Dorsal thalamus and neocortical projection areas**
  - All mammals have visual cortex, including V1
  - Primate specializations resulted in great expansions of this part of the visual system
    - Transcortical pathways from visual cortex [discussed later] to multiple representations of the visual field
- **Retina**: Evolution of a great range of sensitivity, acuity, color detection
  - *See Striedter p. 261 for discussion of mammals.*
- **Other components** of the subcortical visual system: Expansions were much less marked, as they played roles that made smaller demands on size.

Retinal projections:
the pattern found in all mammals

A very similar pattern is found in other vertebrates as well

Mammalian brain schematic:

Retinal projections, and some further connections in the visual system



on = optic nerve
ot = optic tract
aot = accessory optic tract
tst = tectospinal tract (crossed)
tpt = tectopontine tract
SCh = suprachiasmatic nucleus (hypothalamus)
MTN = medial terminal nucleus of aot (2 others omitted)
LGv = ventral nuc. of lateral geniculate body (subthalamus)
LGd = dorsal nuc. of lateral geniculate body (thalamus)
PT = pretectal area
SC = superior colliculus
LP = nuc. lateralis posterior (thalamus)

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 basic layout of the pathway from retina to midbrain in vertebrates?

1) The course of the axons
2) Their topographic organization

This is our topic for the class

A sketch of the central nervous system and its origins

G. E. Schneider 2014

Part 8: Sensory systems

MIT 9.14 Classes 21-22-23

Sensory systems 2: Visual systems

Topics

- Last time:
  - 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
  - Retinal projections in vertebrates, introduction
- **Today:**
  - Retinal projections in vertebrates, and the layout of the optic tract
  - Species differences in relative size of structures
  - Lamination of midbrain tectum and lateral geniculate body
  - Topography of tract and termination patterns

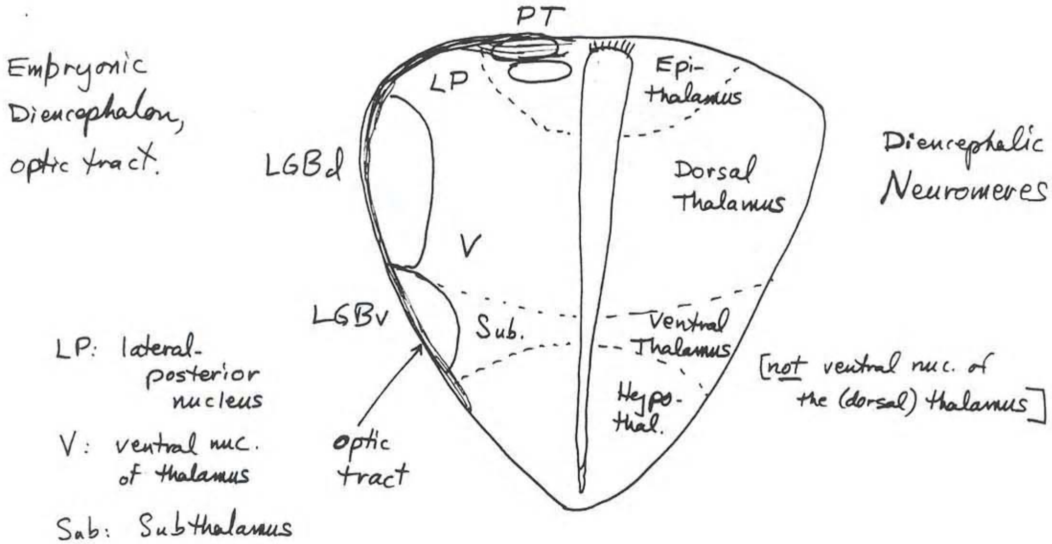
Questions, chapter 21

1) What is the first structure reached by axons from retinal ganglion cells? Name the forebrain subdivision and the major retinal terminal nucleus in that subdivision. See illustrations

2) What is the major difference in the nature of the projections of the dorsal thalamus on the one hand and the ventral thalamus (subthalamus) or the epithalamus on the other? [Answered in class]

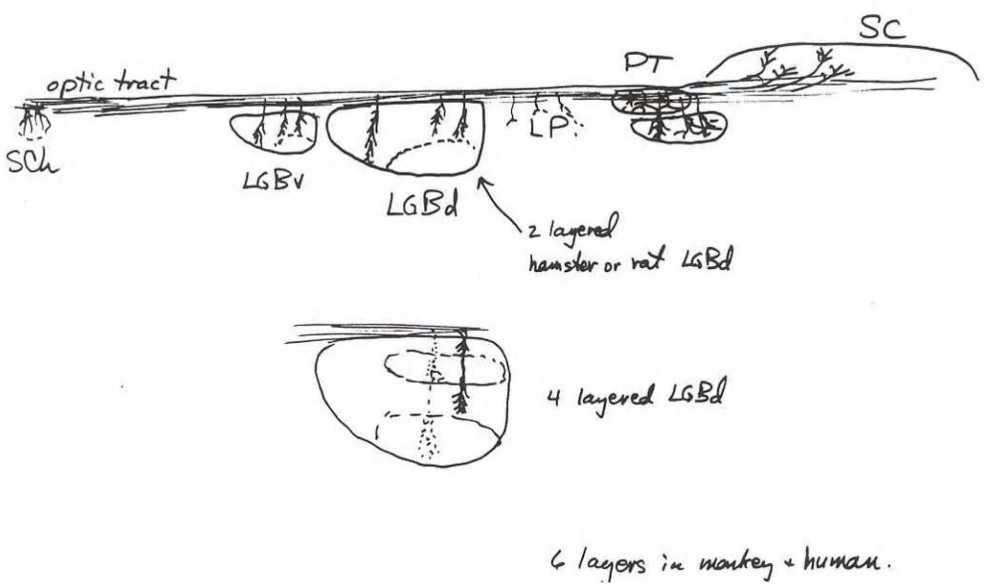
Questions, chapter 21

3) In this chapter, the epithalamus is described as a caudalmost diencephalic neuromere that includes cell groups where the optic tract has dense terminations. What is this terminal area called?



Two ways of looking at the optic tract:

Coronal section of 'tweenbrain



Stretched section through optic tract from chiasm to superior colliculus

Enlarged in later slides

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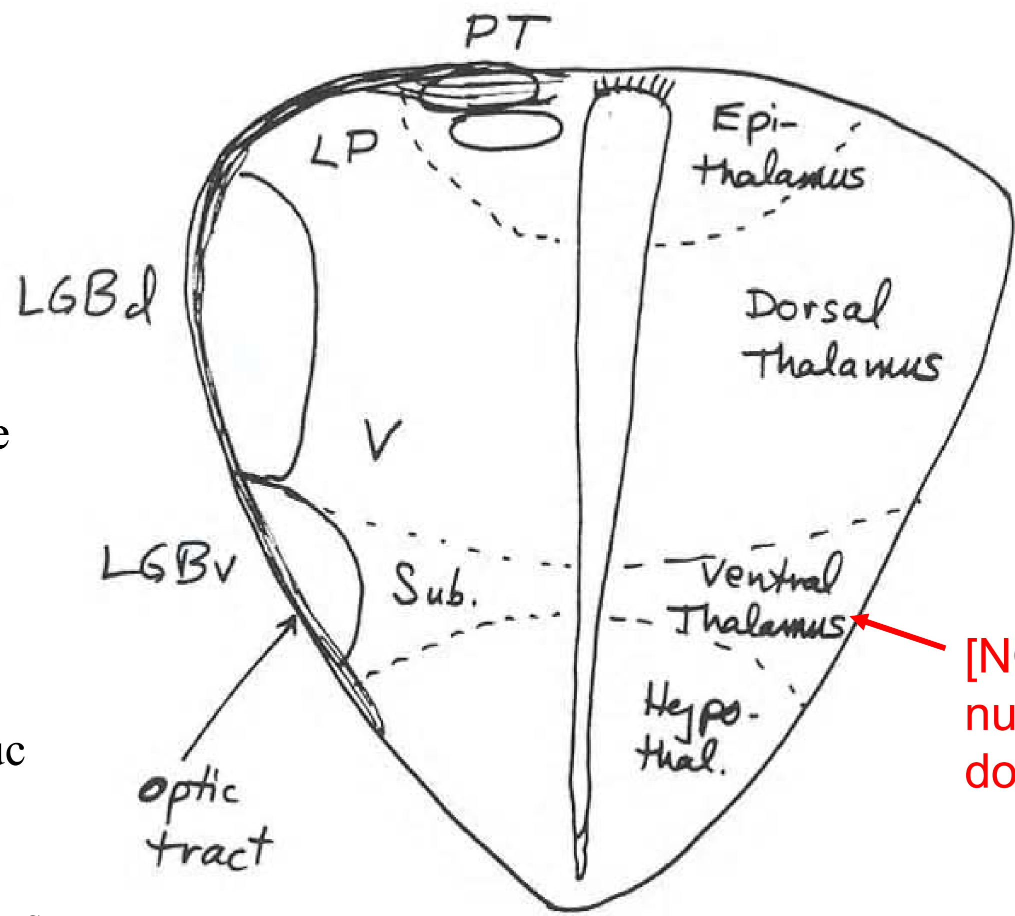
Embryonic Human Diencephalon with Optic Tract



Diencephalic Neuromeres

[NOT the ventral nucleus of the dorsal thalamus]

LGB: Lateral Geniculate Body

d: dorsal part

v: ventral part

LP: Lateral Posterior Nuc

PT: Pretectal area

V: Ventral nuc of thalamus

Sub: Subthalamus

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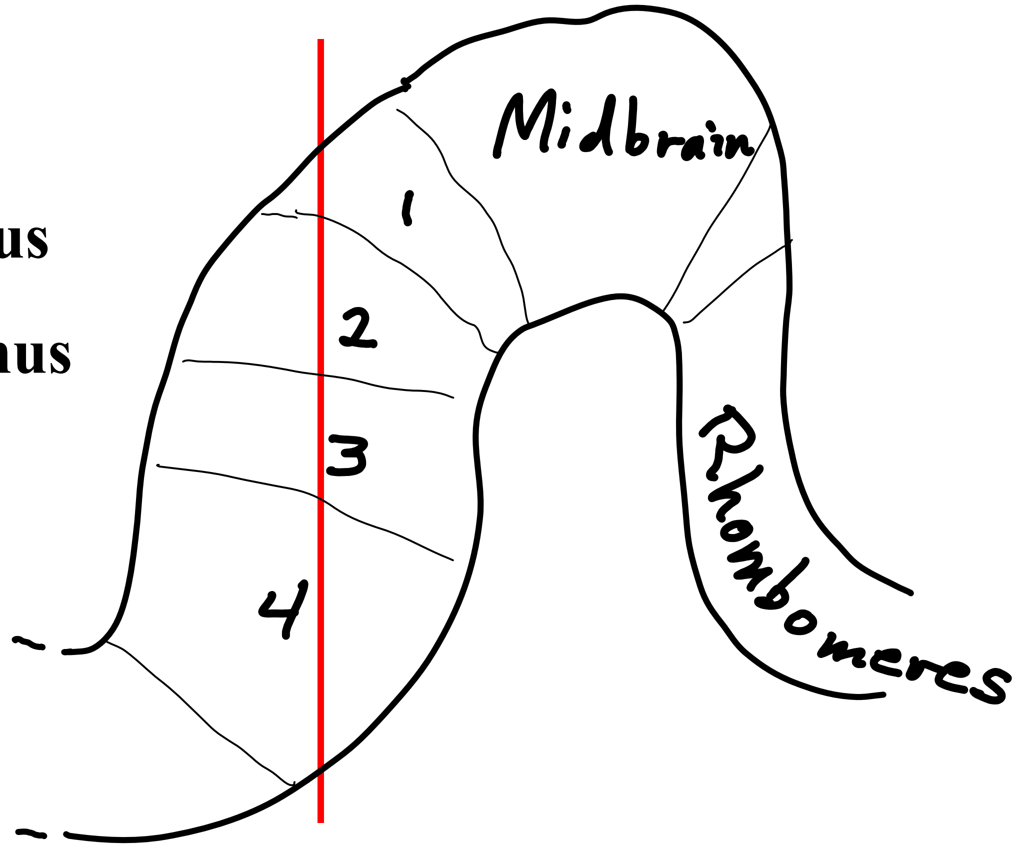
This is very similar to the adult diencephalon of a rat, mouse, or hamster.

Figure removed due to copyright restrictions.
Please see course textbook or:
Clark, WE Le Gros. "A Morphological Study of the Lateral Geniculate Body." *The British Journal of Ophthalmology* 16, no. 5 (1932): 264.

Diencephalic Neuromeres of the embryonic neural tube
Review

1. **Epithalamus**
2. **Dorsal Thalamus**
3. **Ventral Thalamus**
4. **Hypothalamus**
   (actually 2–3 neuromeres)



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

[*Note: In some recent interpretations, there are 5 or 6 diencephalic neuromeres.*]

Questions, chapter 21

4) Name the five main optic-tract termination areas in the order they are reached by the optic tract. What additional areas receive sparse retinal projections from the main optic tract?

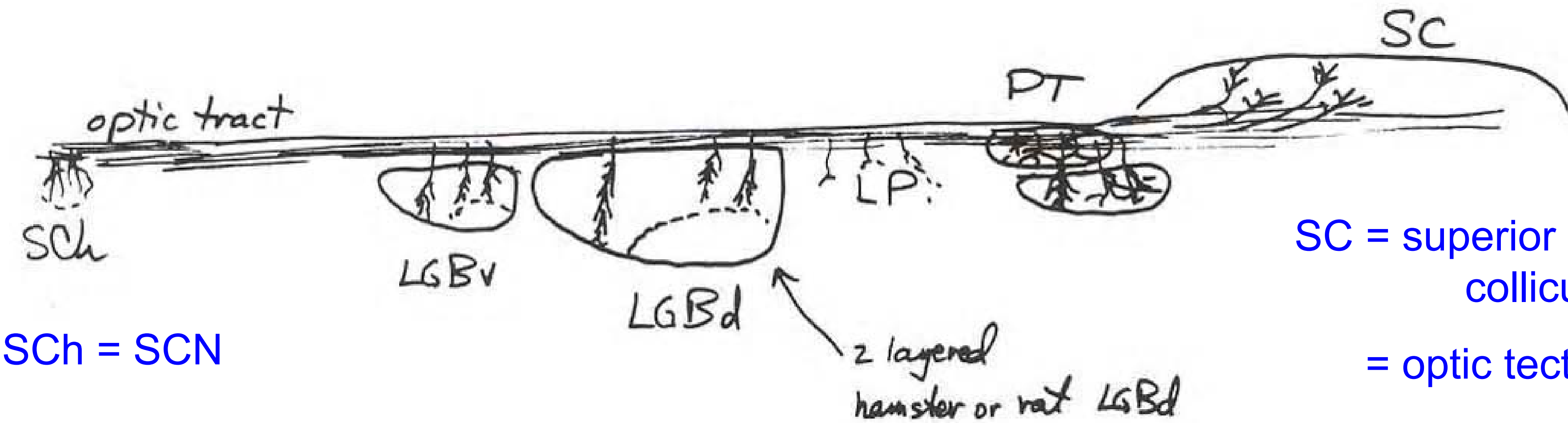
next slide

{ cell groups next to SCN.
{ LP.

5) Inputs from the right and left eyes terminate in distinct areas, a separation that is especially important for creating binocular disparity cues to depth of visually perceived objects. Describe the appearance of the distinct areas in the diencephalon of a small rodent and of a monkey.

geniculate layers

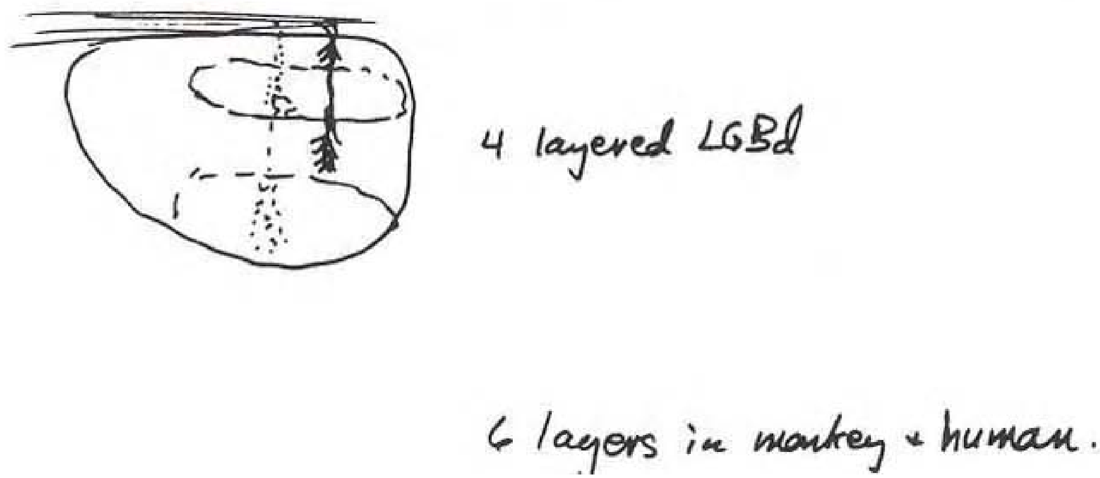
Stretched section through optic tract from optic chiasm to superior colliculus



SCh = SCN

SC = superior colliculus

= optic tectum



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LGN (LGd) of macaque monkey, left side in frontal section. To the left and above it is the Pulvinar nucleus – the expanded Lateral Posterior Nucleus.

(from Zigmond et al, p 836, originally from Hubel and Wiesel.)

Figure removed due to copyright restrictions.

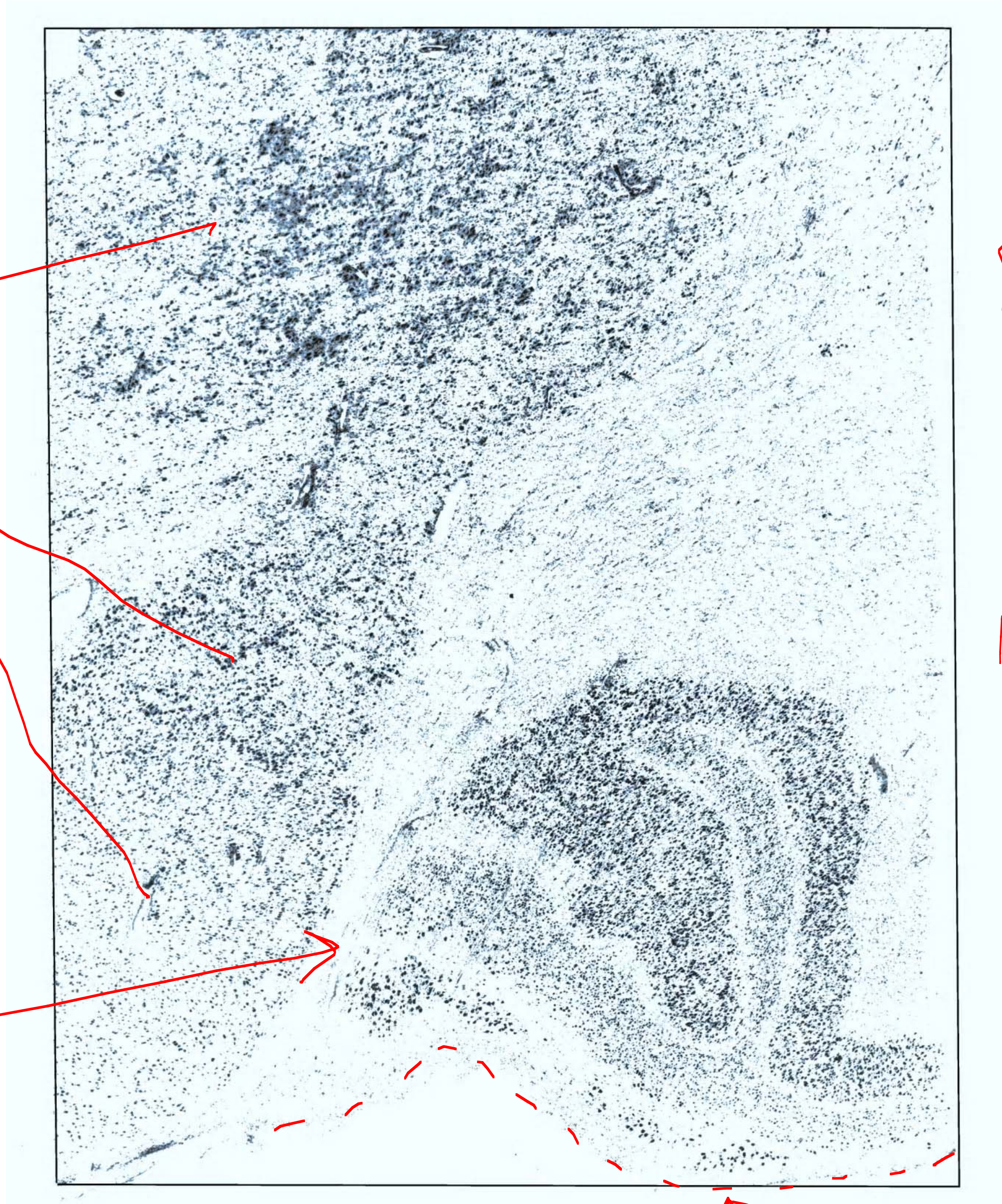

Pulvinar nucleus
Human LGBd
Patient had pathology of one eye:
Note reduction in cells in ipsilateral layers
optic tract surface

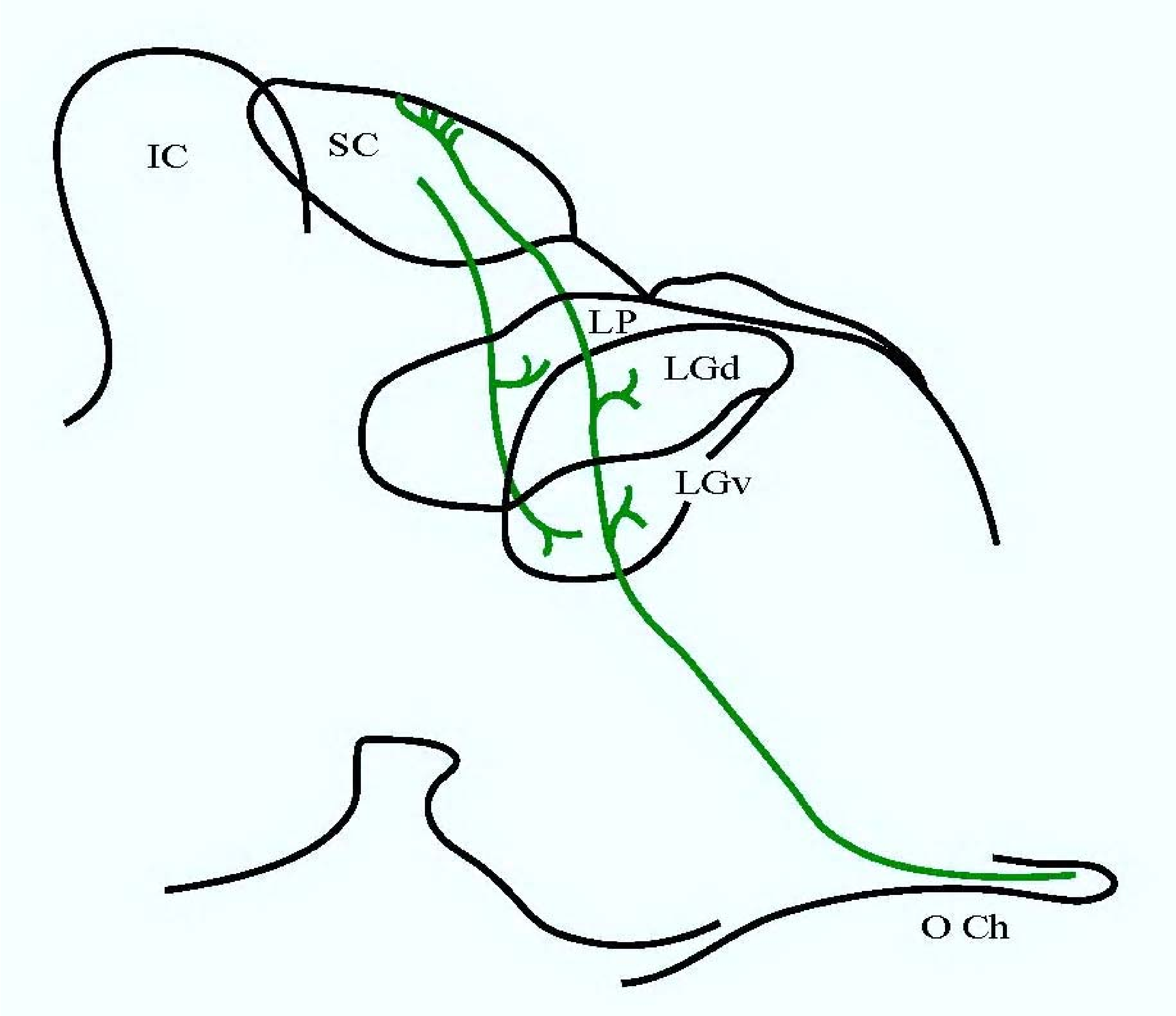
Fig 21-4b

Varieties of laminar patterns in LGBd of primates and tree shrew:

Figure removed due to copyright restrictions.
Please see course textbook or:
Clark, WE Le Gros. "A Morphological Study of the Lateral Geniculate Body." *The British Journal of Ophthalmology* 16, no. 5 (1932): 264.

Fig 21-4c

Next: Side views of a rodent diencephalon showing the optic-tract axons.



Two small bundles of axons are depicted, one coming from the retina and one from the superficial layers of the superior colliculus.

Omitted: Retinal projections to SCN, Pretectal area, nuclei of the accessory optic tract.

Adult optic tract of hamster, side view

Fig 21-5

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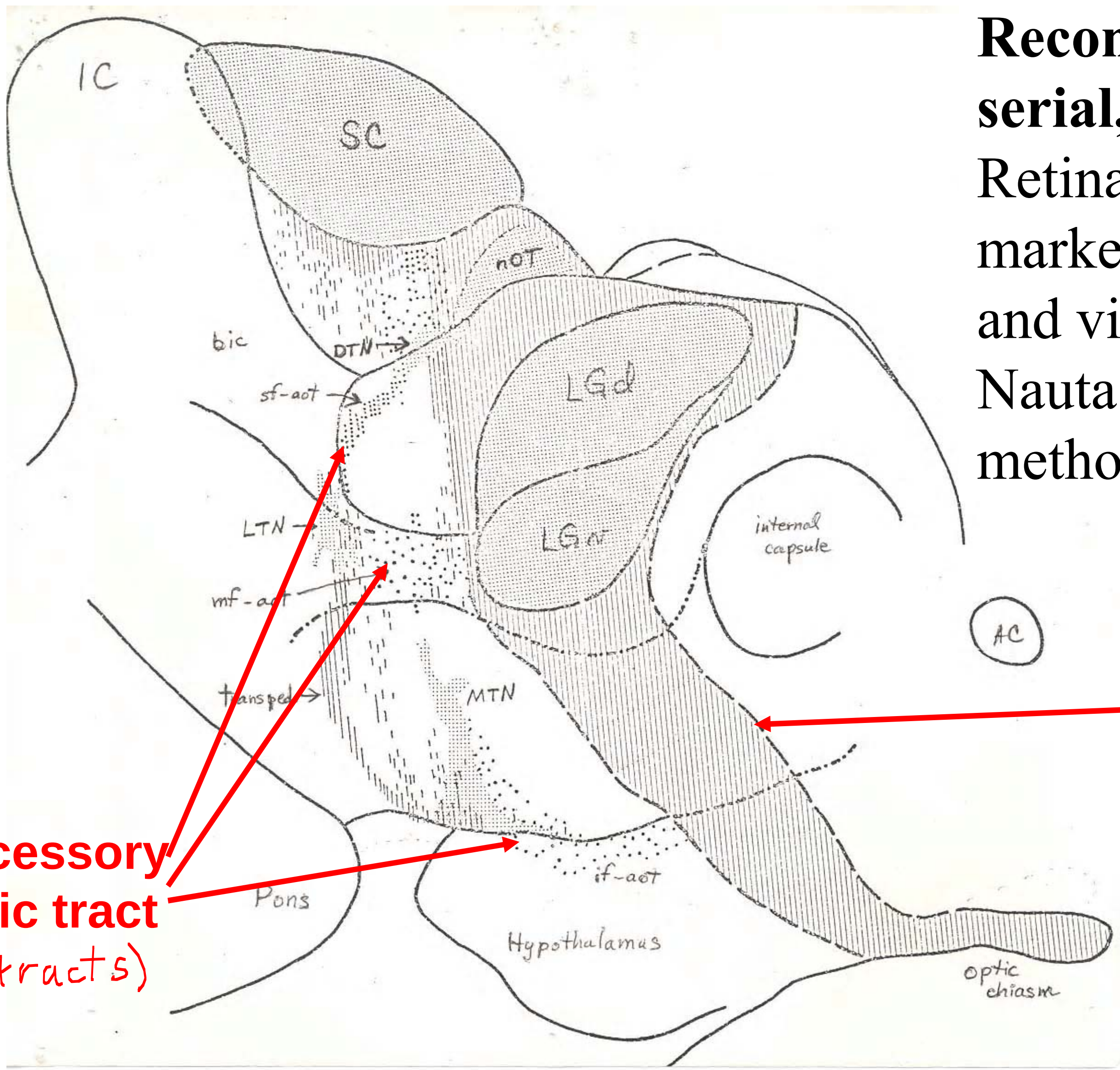
Questions, chapter 21

4) Axons that leave the main optic tract and terminate in small cell groups (up to 3 of them) are described as the ______________________________ optic tract axons.

See next slide

Adult optic tract (Hamster)

Reconstruction from serial, frontal sections. Retinal projections were marked by degeneration and visualized with a Nauta silver-staining method.



NEXT: **Photos** of brains

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

Hamster brain with hemispheres & Cb removed, seen from right side

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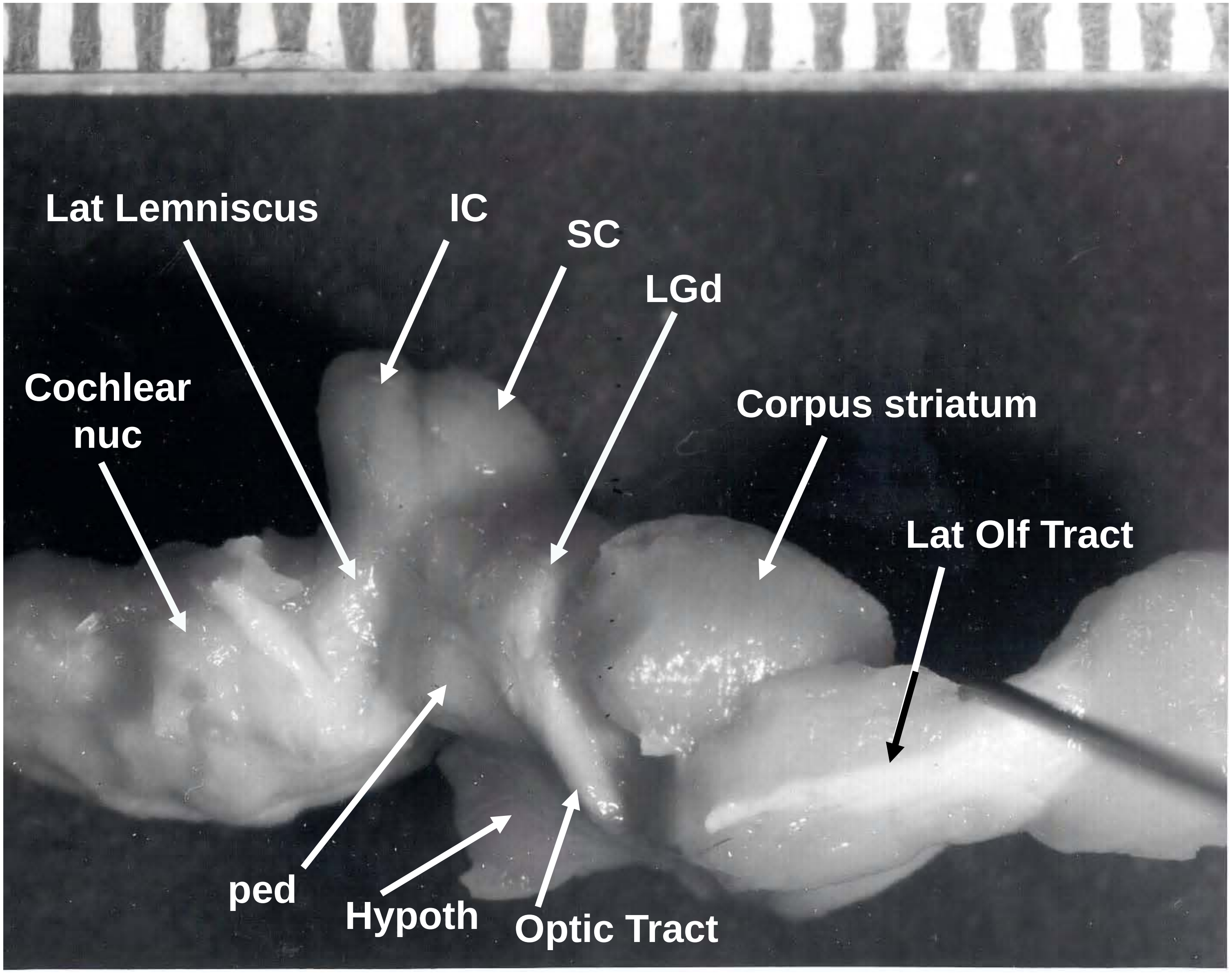
Hamster brain with hemispheres & Cb removed, seen from right side



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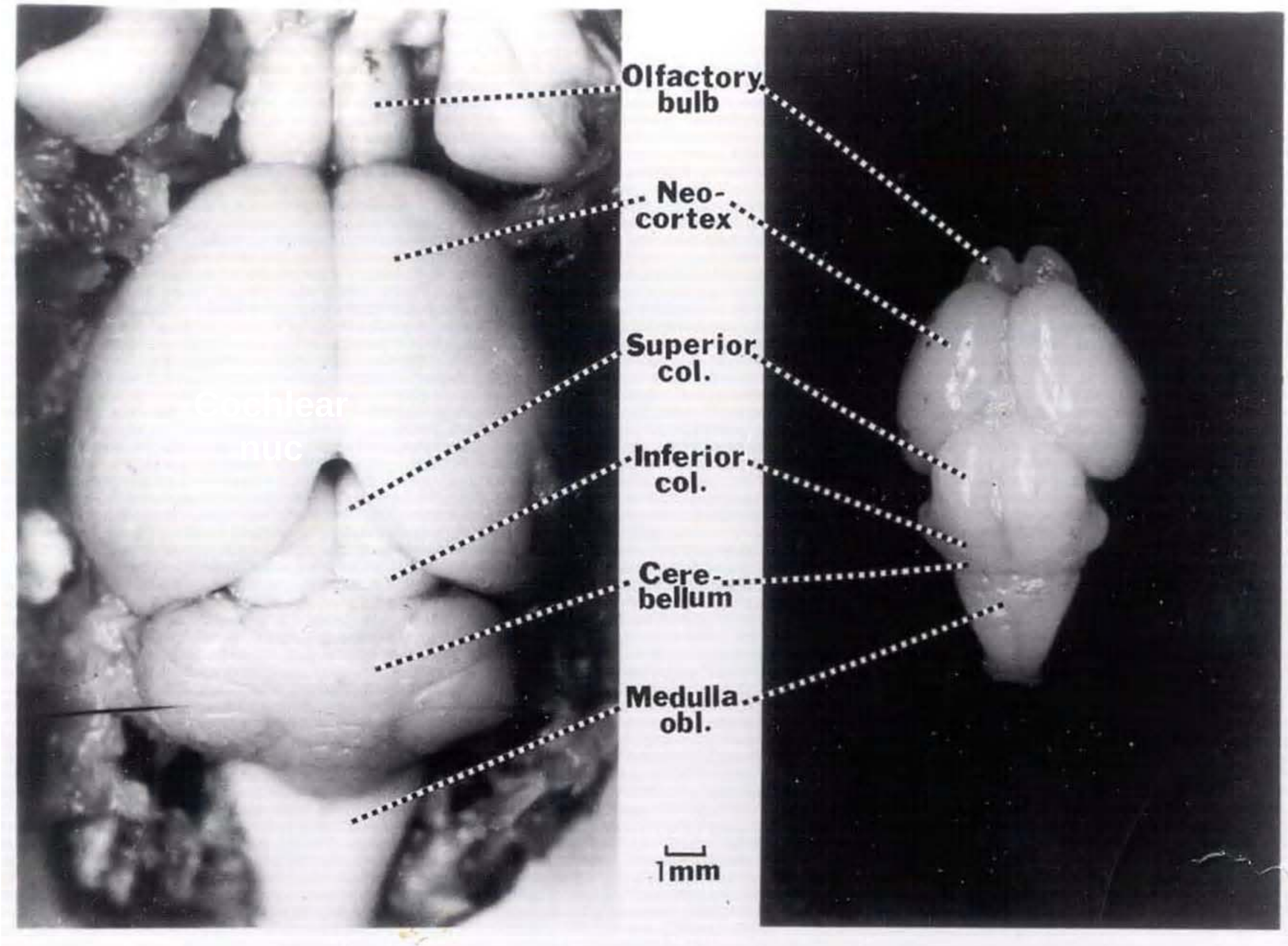
Hamster brain, adult and newborn



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Questions, chapter 21

7) Study figures 21.5, 21.6 and 21.7. Next, cover the labels written above and below the photo of figure 21.7, and see if you can remember the names of structures to which the blue lines are pointed.

8) Do the same for figure 21.8, covering up the names between the two photographs.

Hamster brain with hemispheres & Cb removed, seen from right side

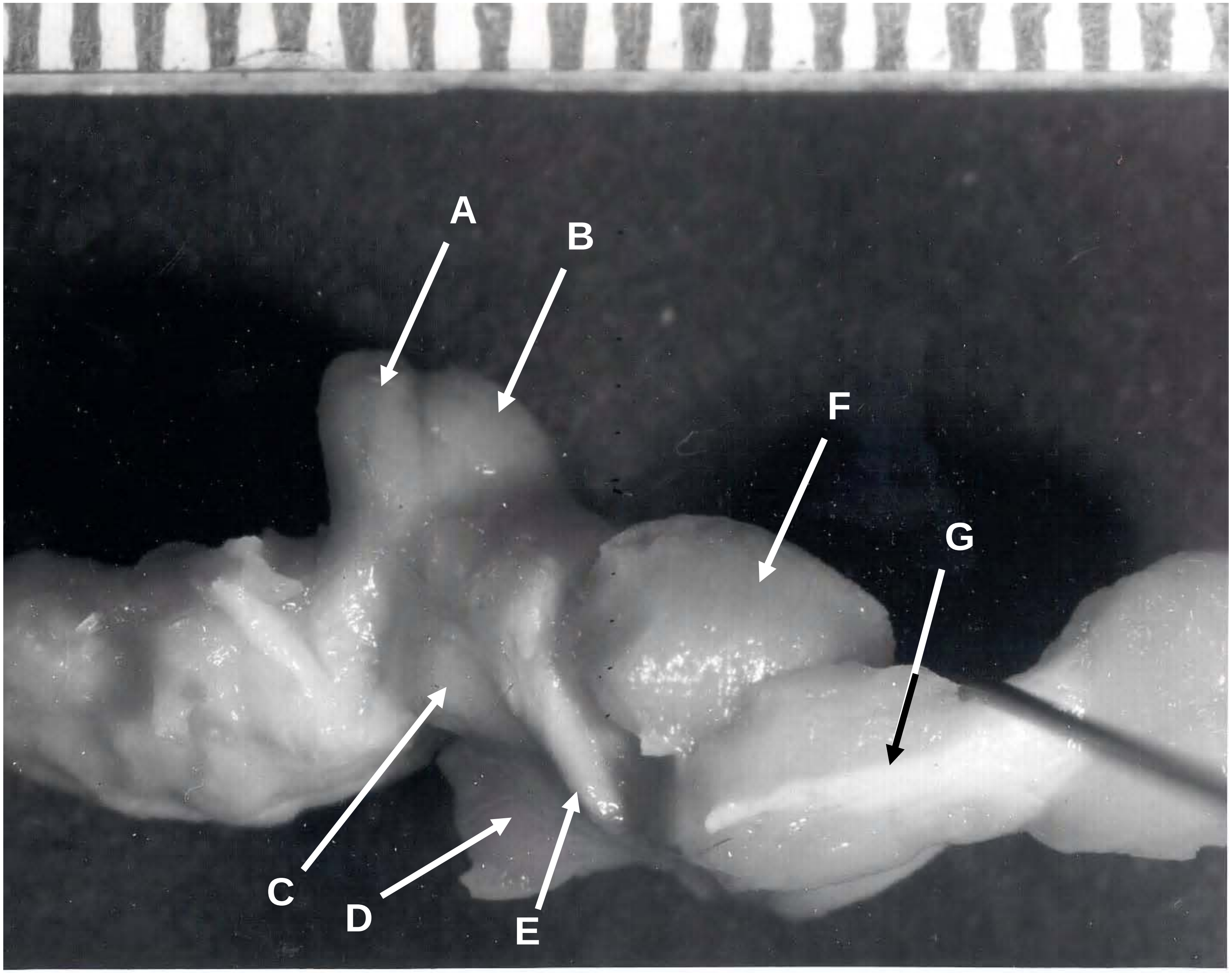

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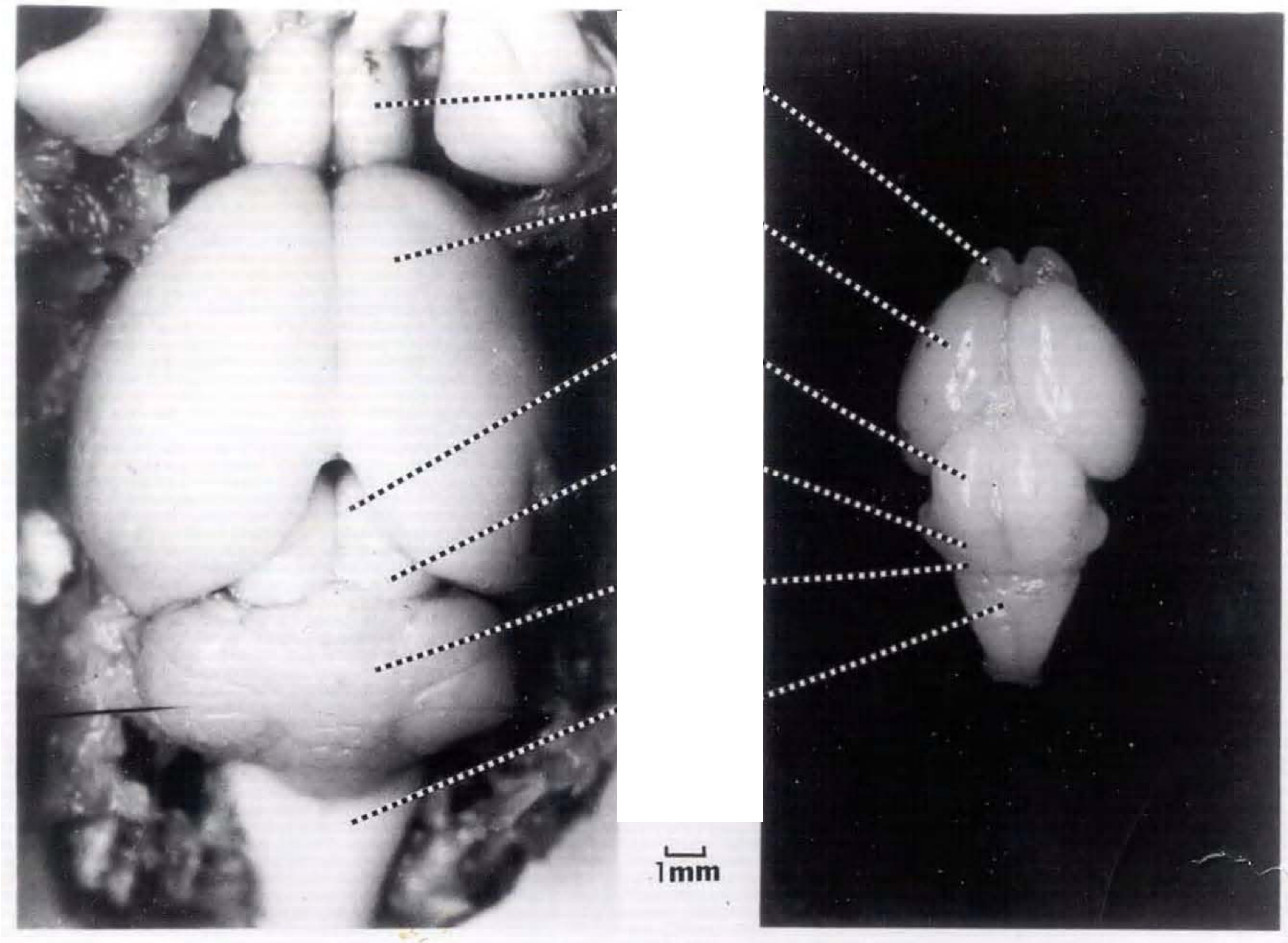
Fig 21.8

Hamster brain, adult and newborn



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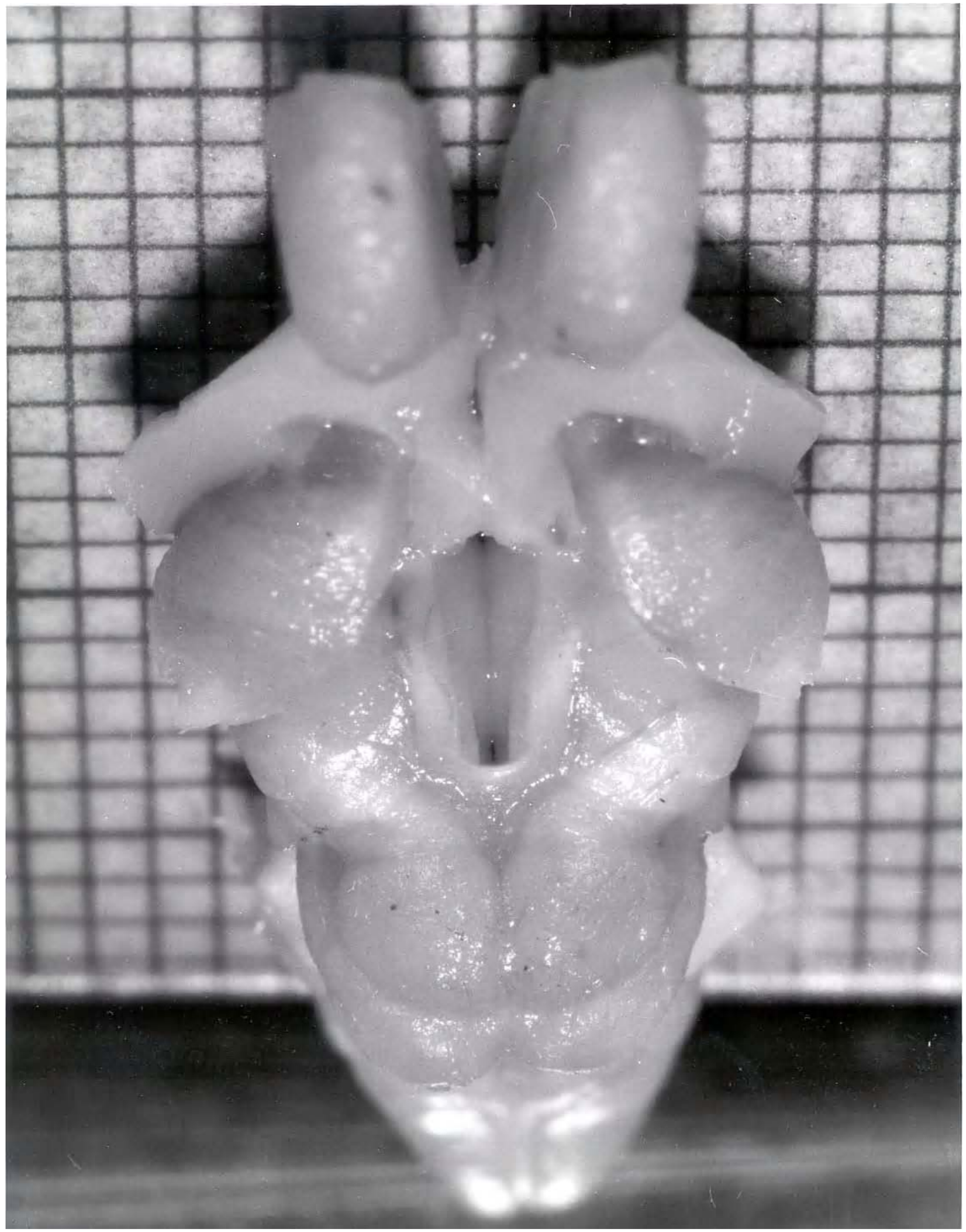
Questions, chapter 21

9) Which structures can you recognize in figures 21.9 and 21.10? What would make this more difficult during a neurosurgical procedure?

Hamster brain with hemispheres & Cb removed, adult, top view



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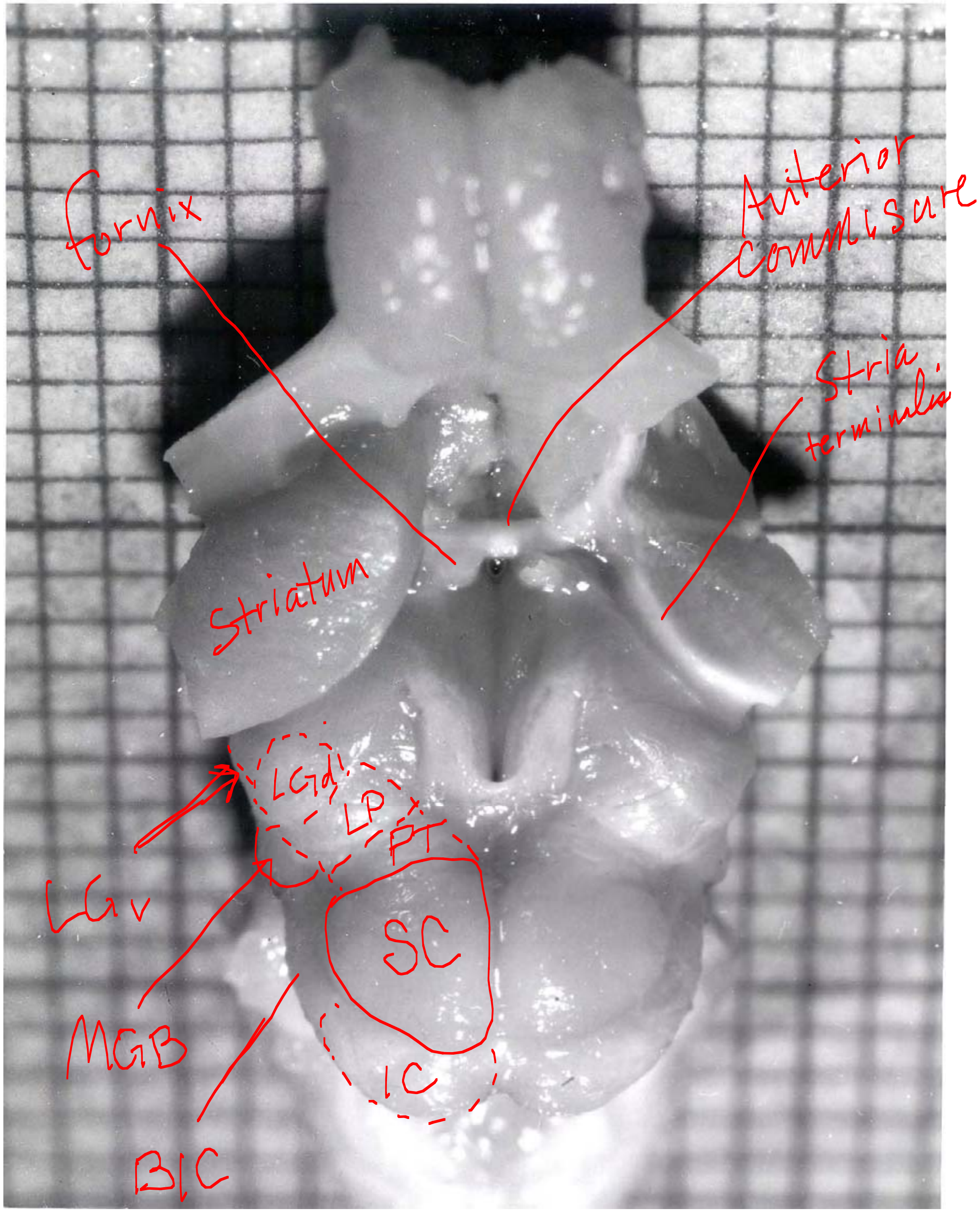

Hamster brain, adult: additional removal of right corpus striatum and exposure of anterior commissure

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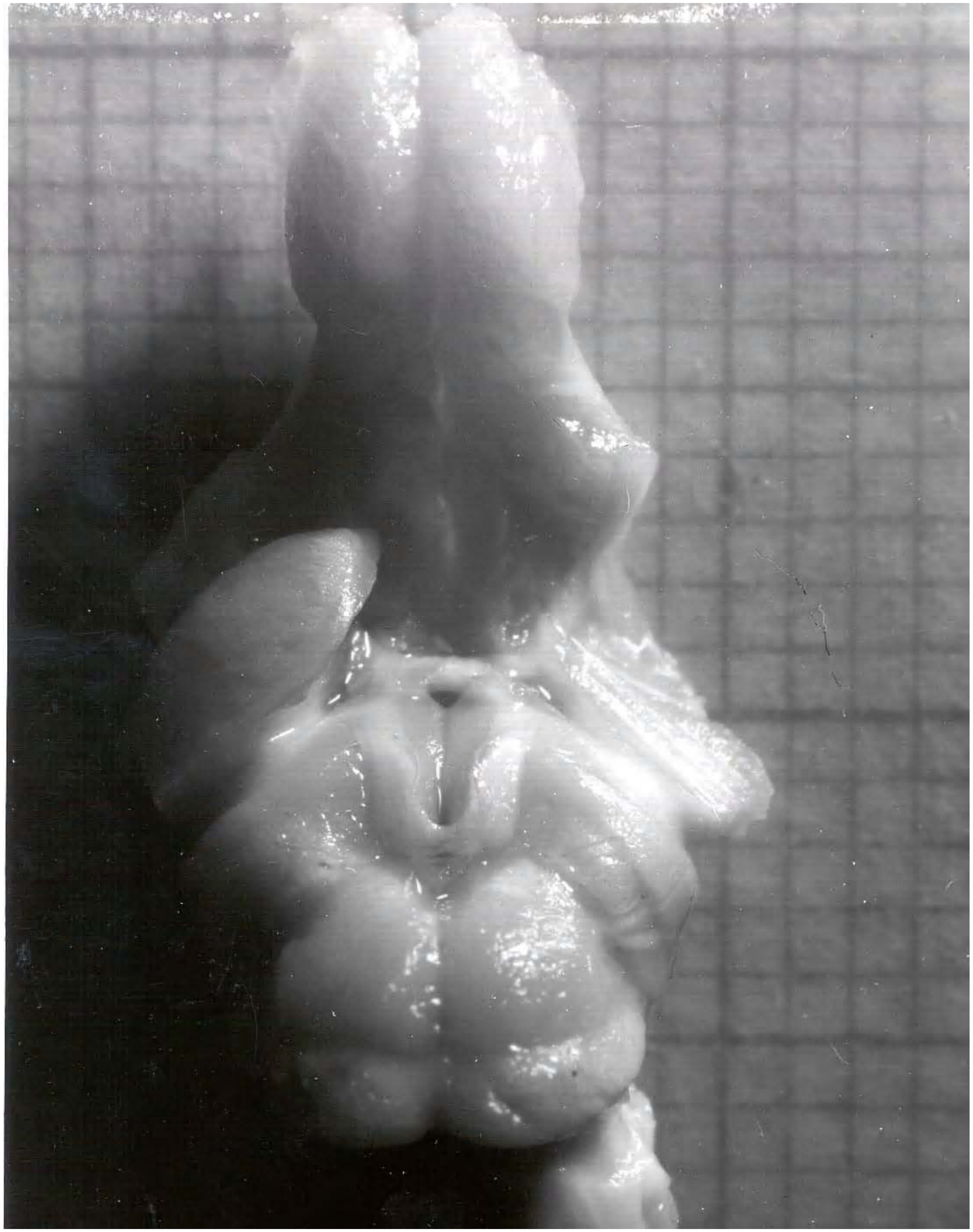

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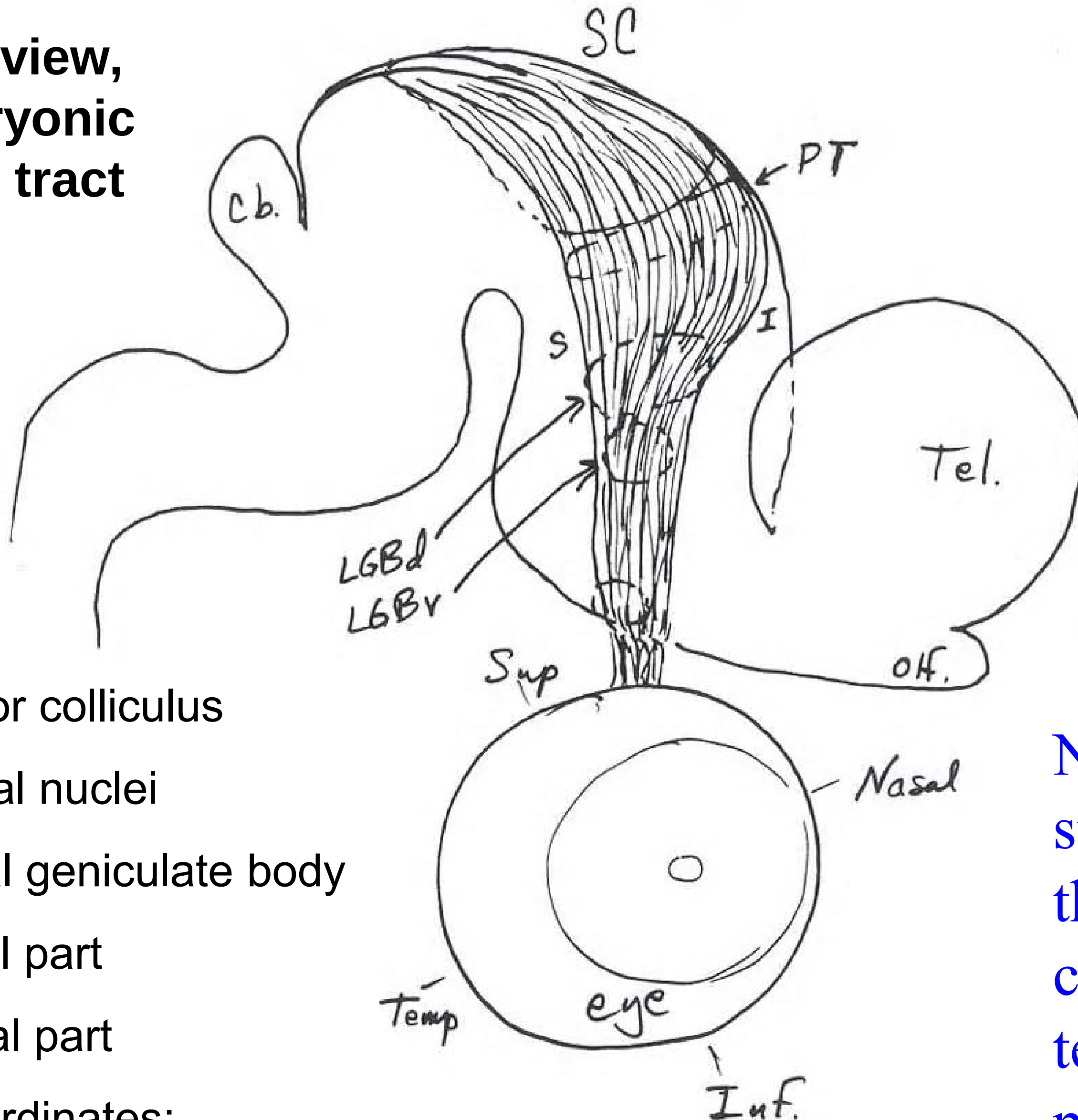
Same after altered tilt and lighting

How is this basic layout in the adult brain different in the embryo when the axons are growing?

Side view, embryonic optic tract



SC: superior colliculus

PT: pretectal nuclei

LGB: lateral geniculate body

- d: dorsal part
- v: ventral part

Retinal coordinates:

- N, T, S, I

Note the relatively straight course of the optic tract from chiasm to midbrain tectum in the prenatal hamster brain (E13).

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Next:

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

9.14 Brain Structure and Its Origins
Spring 2014