Auditory system

- Sensory systems of the dorsolateral placodes and their evolution
- Auditory specializations:
  - For antipredator & defensive behaviors
  - For predator abilities
- Cochlear nuclei and connected structures
  - Transduction and initial coding
  - Channels of conduction into the CNS
- Two functions, with two ascending pathways
  - Sound localization
  - Auditory pattern detection
- **Specializations:**
  - **Echolocation**
  - **Birdsong**
  - **Speech**

Superior and inferior colliculi in various mammals

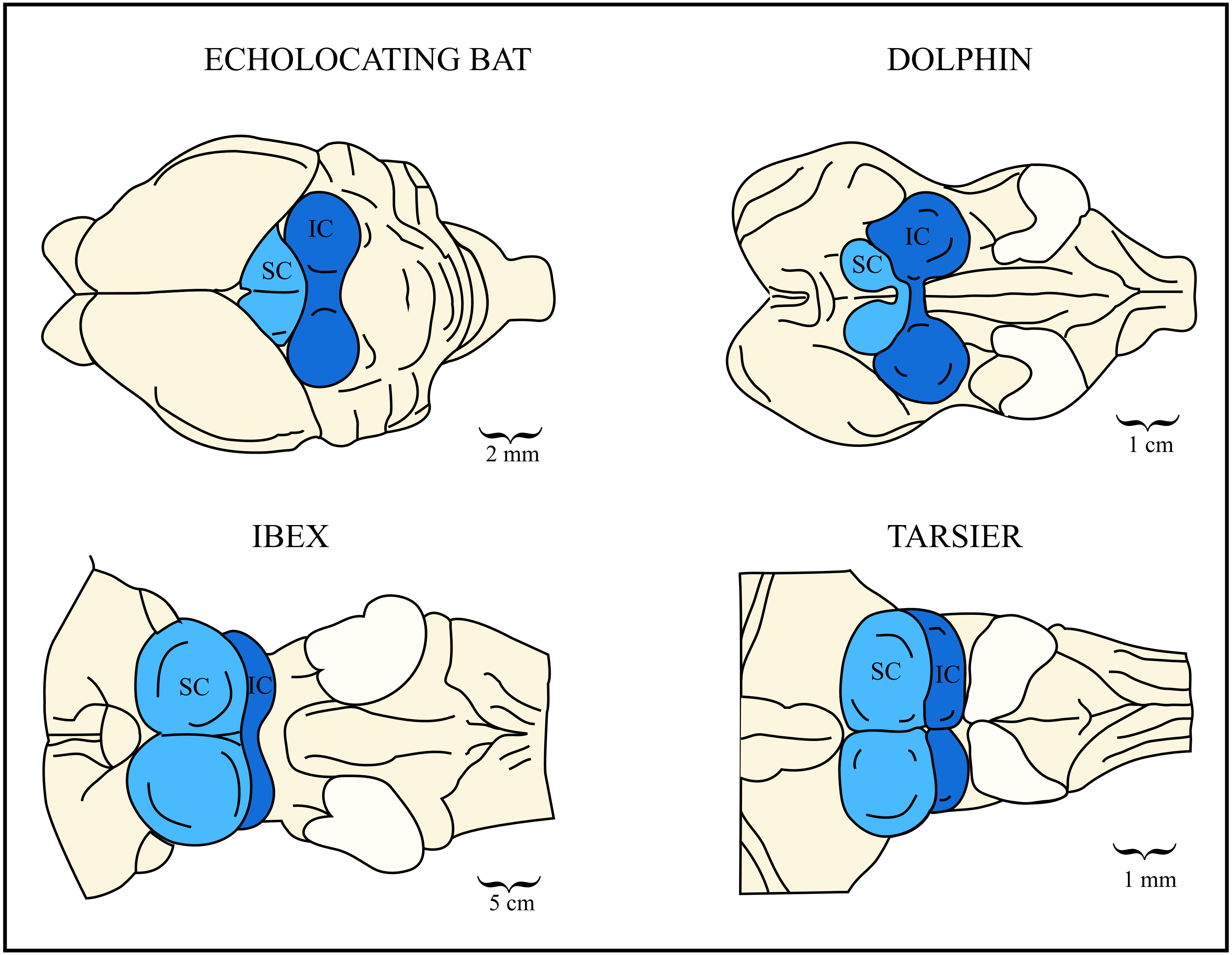


Image by MIT OpenCourseWare.

Auditory cortex of the moustache bat

Butler & Hodos p 414, fig 28-4, from ***N. Suga 1984***

This was a good start, but only a start, in defining neocortical auditory functions in the bat.

Later, units were found that **responded to range and to velocity of prey.**

Figure removed due to copyright restrictions.
Please see Fig 28-4 (page 414) of: Butler, Ann B., and William Hodos. *Comparative Vertebrate Neuroanatomy: Evolution and Adaptation*. Wiley-Liss, 1996.

Questions, chapter 23

12) What is the area in birds that is comparable to the auditory neocortex of a mammal?

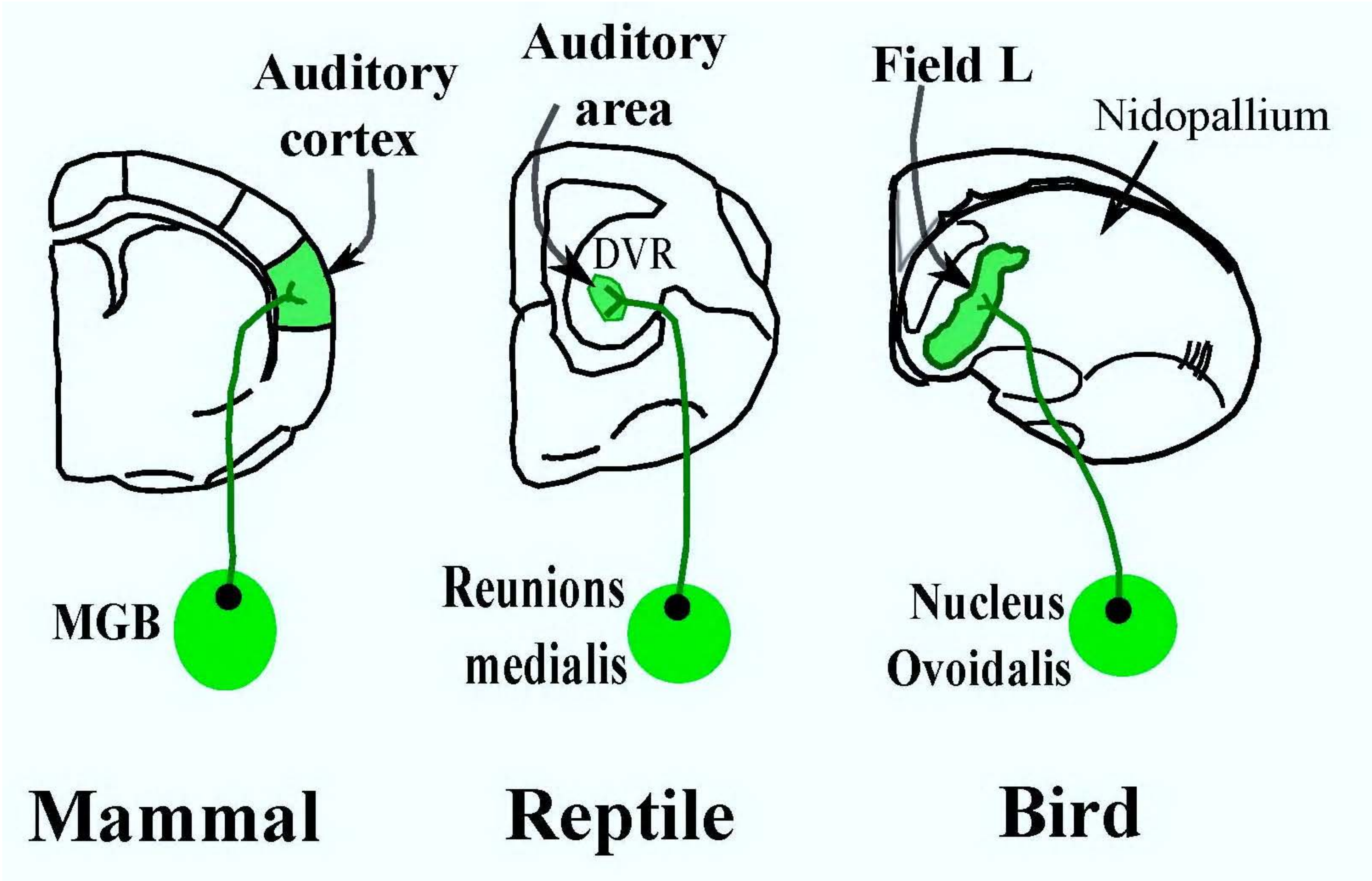


Fig 23-19

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

Auditory fields in pigeon telencephalon's dorsal ventricular ridge

Figure removed due to copyright restrictions.
Please see course textbook or Fig 28-8 (page 416) of: Butler, Ann B., and William Hodos. *Comparative Vertebrate Neuroanatomy: Evolution and Adaptation*. Wiley-Liss, 1996.

* Now referred to as "nidopallium", or nested pallium.

Auditory pathway in a songbird

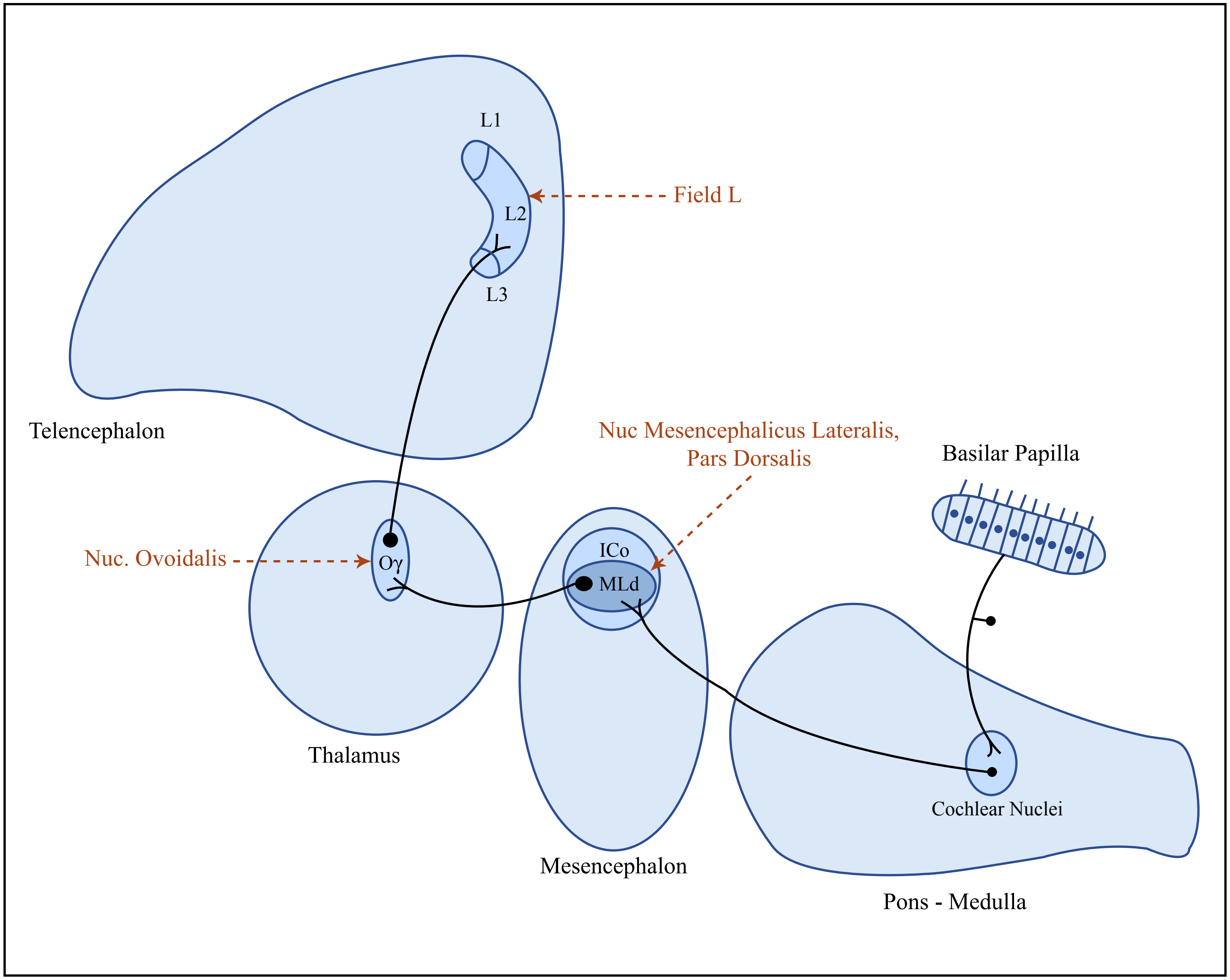


Image by MIT OpenCourseWare.

Direct vocal control pathway in songbird

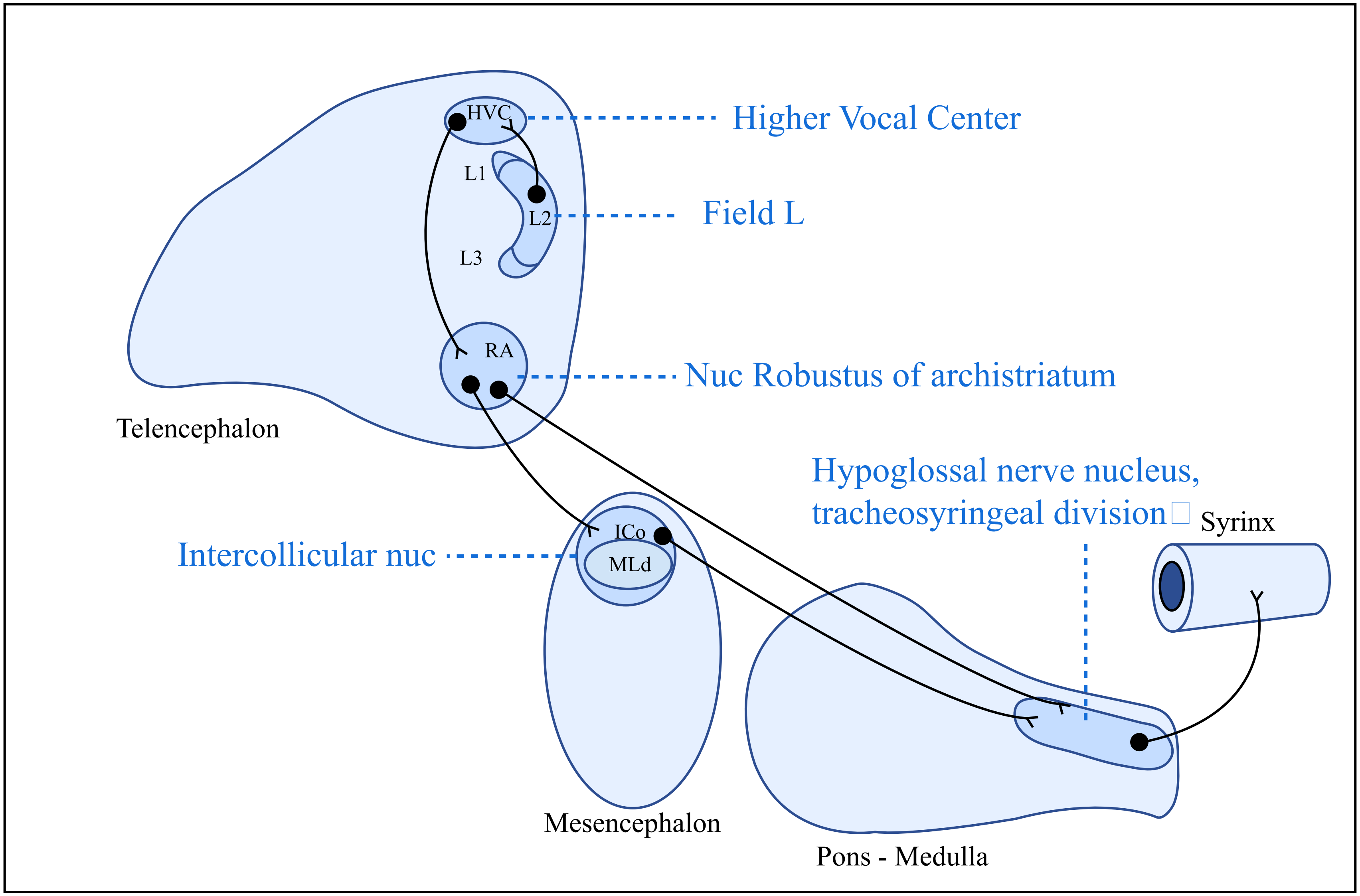


Image by MIT OpenCourseWare.

Indirect vocal control pathway in songbird

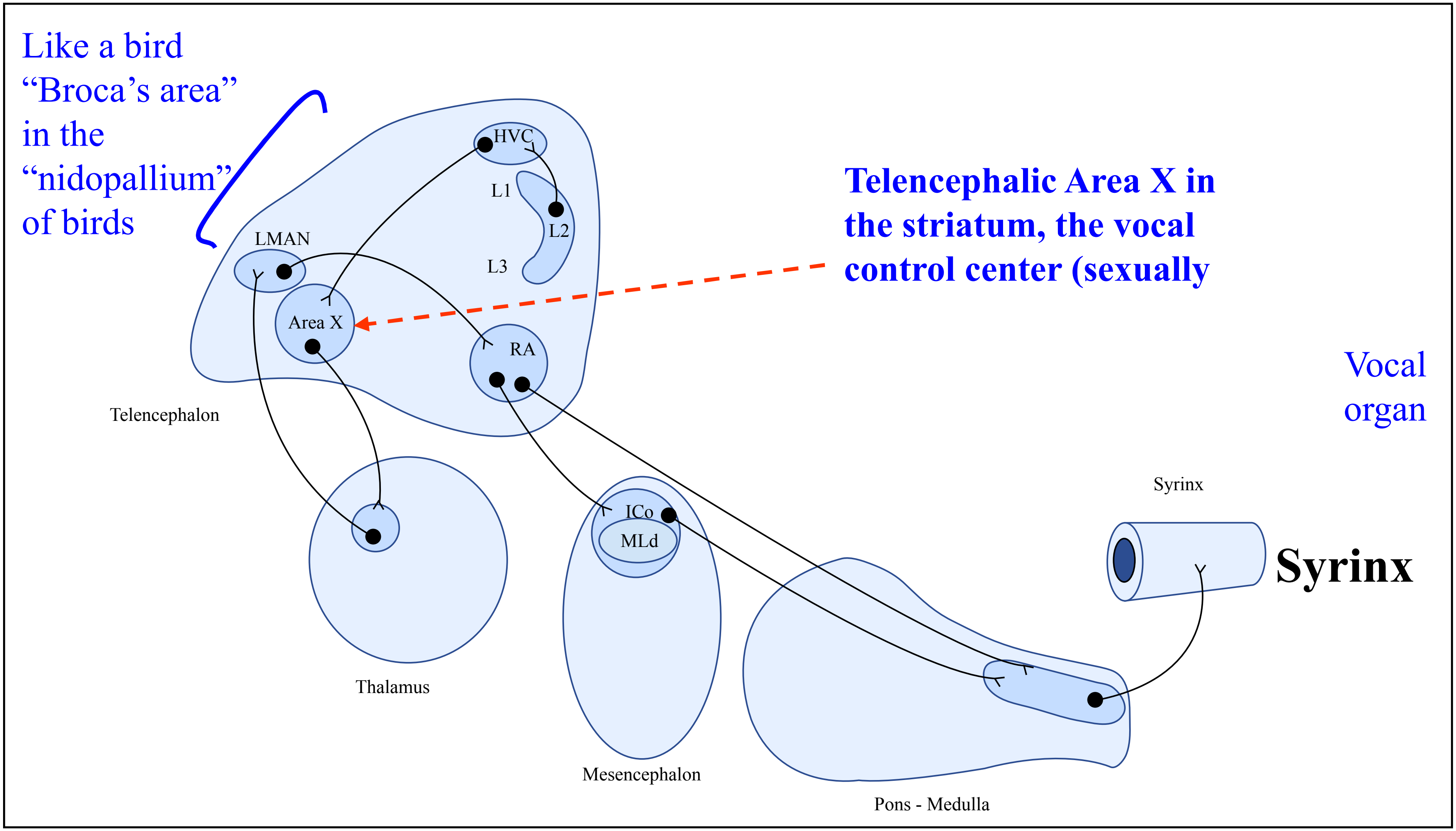


Image by MIT OpenCourseWare.

Songbirds have **left hemisphere dominance** for song that extends to the hindbrain

A sketch of the central nervous system and its origins

G. E. Schneider 2014

Part 8: Forebrain origins

MIT 9.14 Class 26

Introduction to the forebrain and its adaptive prizes

Questions on book chapter 24

9.14
A sketch of the central nervous system and its origins:

Where we are now in the outline

Part 1: Introduction

Part 2: Steps to the central nervous system

- From initial steps to advanced chordates

Part 3: Specializations in the evolving CNS

- With an introduction to connection patterns

Part 4: Development and differentiation

- Spinal cord development and organization
- Autonomic nervous system development and organization

Part 5: Differentiation of the brain vesicles.

- Hindbrain development, elaboration and specializations
- Midbrain and its specializations
- Forebrain of mammals with comparative studies relevant to its evolution
- Differentiation during development: The growth of the long extensions of neurons …

Part 6: A brief look at motor systems

Part 7: Brain states

Part 8: Sensory Systems **[Special sensory]**

- Gustatory and olfactory systems
- Visual systems
- Auditory systems

* **Part 9: Forebrain origins**

Part 10: Hypothalamus & Limbic System

Part 11: Corpus Striatum

Part 12: The crown of the CNS: the neocortex

Questions, chapter 24

1) What was most likely the earliest part of the forebrain? Recall the earlier discussion of the invertebrate chordate Amphioxus (*Branchiostoma*).

   diencephalon

2) What cranial nerves are attached to the forebrain? Two of these are not among the 12 that are usually named for human brain. next →

What can animals do without a forebrain?

- Missing cranial nerves
  - Olfactory (cranial nerve I)
  - Vomeronasal
  - Terminal
  - Optic (cranial nerve II)
  - Epiphysial (pineal)

} closely associated with olfactory

- Also missing central control of pituitary gland by hypothalamus
- A better question: What can animals do without a forebrain if the above structures can be discounted?

Class 7

Questions, chapter 24

3) Long after removal or disconnection of the forebrain, animals are missing major segments of normal behavior, even if an island of hypothalamus remains attached to the pituitary. Describe missing aspects of behavior. (See also chapter 7.)

Forebrain removals in cats, rats and pigeons ("decerebration" with sparing of hypothalamic island)

Class 6 review

- Missing limbic system functions
  - **Lack of normal <u>appetitive</u> behavior**, with no seeking of food or a mate
    - Thus, there is a lack of spontaneous behavior (lack of normal motivation; failure to initiate actions without prodding)
- Missing cortical and corpus striatum functions
  - Poor sensory acuity and lack of fine manipulation
  - Lack of anticipation
  - Failure of spatial memory
  - Failure of learned habits
- What do they retain?

More on forebrain removals in cats, rats and pigeons

Class 6 review

- They **retain much <u>consummatory</u> behavior:**
  - Eating responses such as mouth opening, chewing and swallowing (in response to oral stimulation)
  - Pain-elicited aggressive responses
  - Sexual postures and reflexes
  - Flying in pigeons (if optic nerves are spared) when thrown into the air
  - Righting, walking

Primitive forebrains
(a survey in search of ideas about origins)

- Non-vertebrate chordates
- Non-mammalian vertebrates
  - Proto-mammals: Evidence from bones (paleontology)
  - Evidence from comparative neuroanatomy
- Primitive mammals

Before modern cladistics, a popular view of brain evolution was formulated by Ludwig Edinger (1908):

He illustrated the appearance, in cartilaginous fishes, of a "neencephalon" and its subsequent expansion in tetrapods. *(from Striedter p 32)*

This view was only a suggestion, lacking in adequate knowledge of brain connections and knowledge of evolutionary genetics.

A recent view: from RG Northcutt

Please see: Northcutt, R. Glenn. "Understanding Vertebrate Brain Evolution."
Integrative and comparative biology 42, no. 4 (2002): 743-56.

REVIEW

A cladogram of chordate phylogenetic relationships.

This suggests a close look at groups that appeared before the jawed vertebrates.

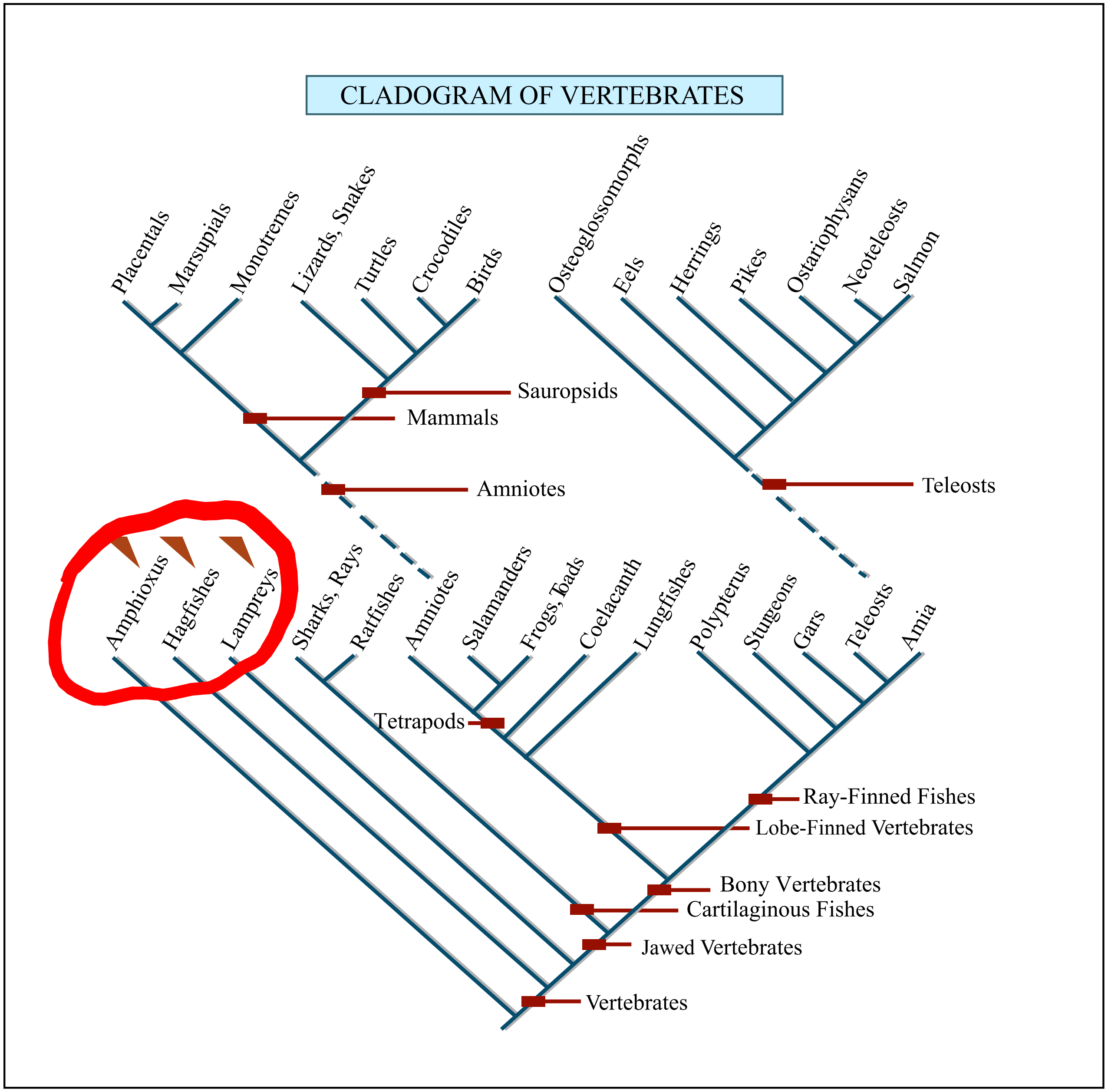


Image by MIT OpenCourseWare.

Bodies and brains of a cephalochordate (Amphioxus) and two jawless vertebrates (Hagfish and Lamprey)

d = diencephalon

m = midbrain

o = olfactory bulb

p = pineal organ

t = telencephalon

t-mp = medial pallium
- **(hippocampal region)**

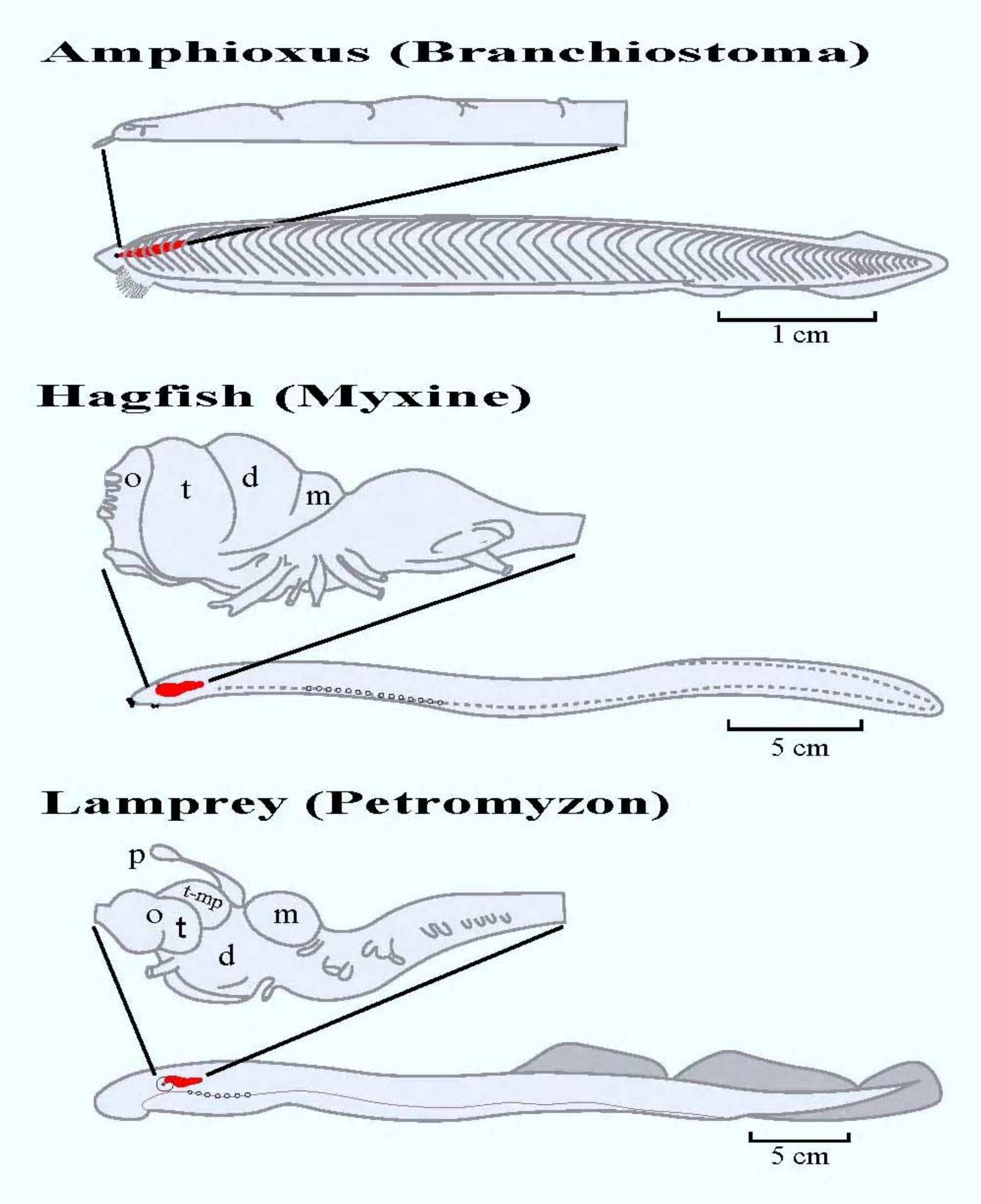


Fig 24-2

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

Bodies and brains of three ray-finned fishes with very different cerebellar development

c, cerebellum

d, diencephalon

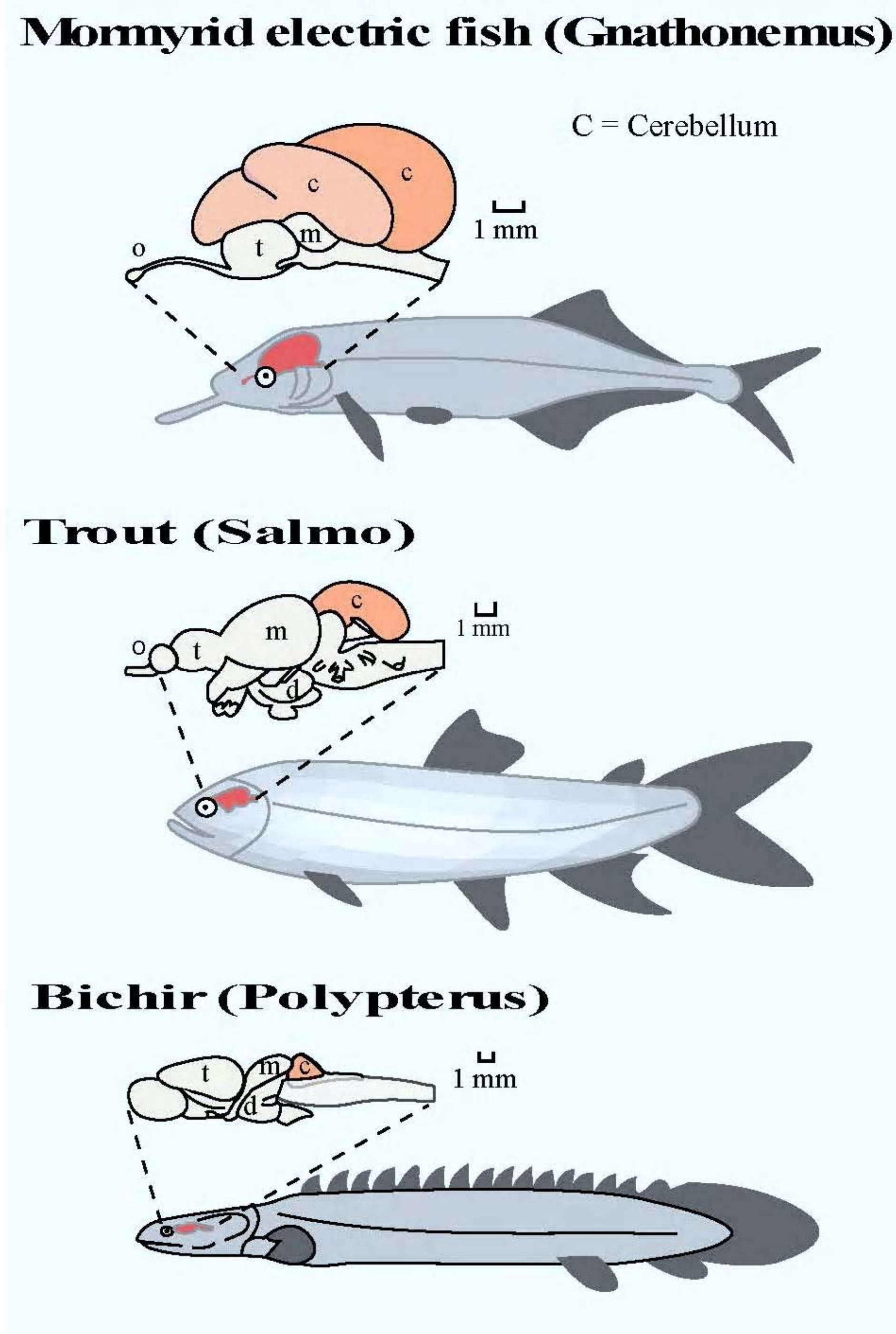
m, midbrain

o, olfactory bulb

t, telencephalon

There are also relative size differences in midbrain and forebrain.

Fig 24-3



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 24

6) In most chordate groups, brain size increases in evolution, but in a few groups, it decreases. Why would it ever decrease? (See also: Striedter readings.)

Energy requirements of brain tissue are very high.

Do brains always increase in size in evolution?

- Answering this requires a very large amount of data on sizes of brains and bodies of different species.
- Much of this was collected by Heinz Stephan and his collaborators (1960s-1980s)
- The data were made available to others for analyses.

Brain *vs* body weights in major animal groups

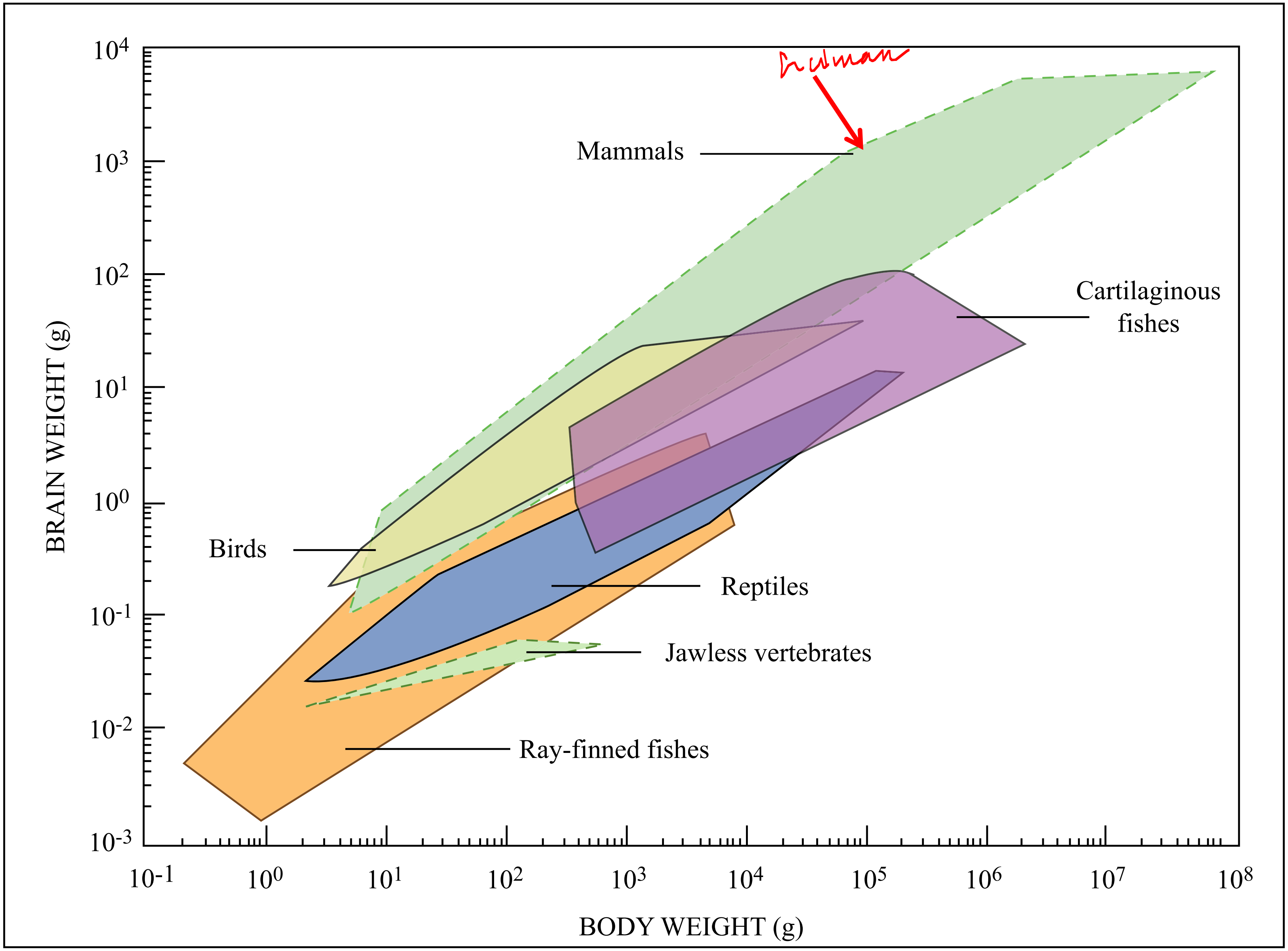


Image by MIT OpenCourseWare.

REVIEW

Increases have been more common than decreases

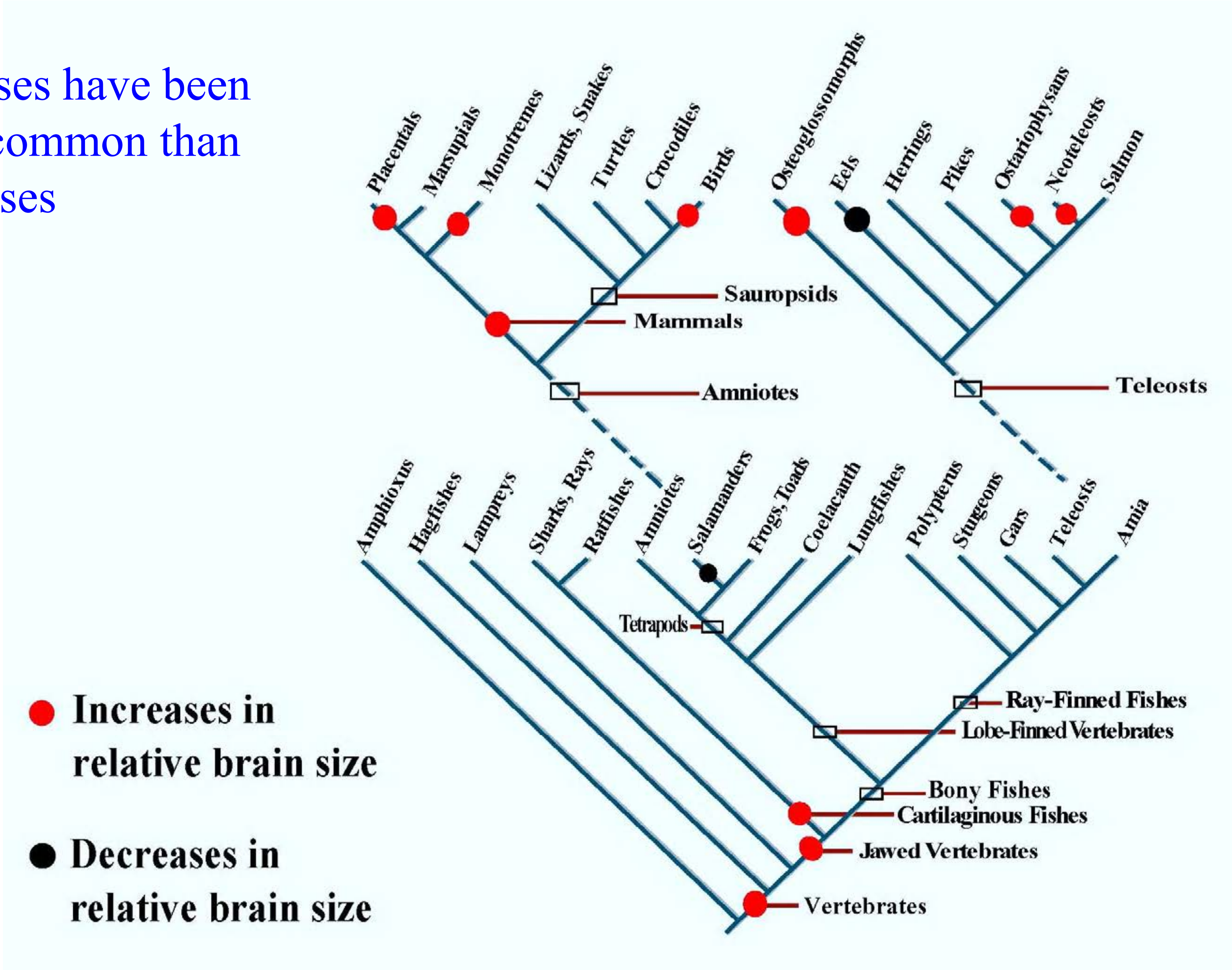


Fig 24-4

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 24

1) (Repeated) What was most likely the earliest part of the forebrain? Recall the earlier discussion of the invertebrate chordate Amphioxus (*Branchiostoma*).

4) What studies in recent years have provided evidence for the old hypothesis that the endbrain in early chordate evolution was dominated by olfaction? (See also chapter 19.)

The very early forebrain

- Diencephalon appeared before there were cerebral hemispheres: See the pictures of Amphioxus and Hagfish.
- Amphioxus has neurosecretory cells in its simple forebrain, an “infundibulum”*, optic inputs (all characteristic of diencephalon) and another forebrain nerve with unclear homologies.
- The tiny forebrain showed considerable expansion in the evolution of the jawless vertebrates (represented by Hagfish and Lamprey).

* Funnel shaped; the pituitary region

Olfaction dominated the primitive endbrain

- It is strongly suggested that olfaction and its links to motor systems caused the earliest endbrain appearance and expansion.
  - Adaptive advantages of olfaction: allowing responses to sources at a distance in space and in time.
  - *Cf*. taste functions; compare with vomeronasal organ
- Remember the studies of olfactory bulb projections in Hagfish and Lamprey. (See class 19 and the following two slides.)

Figure removed due to copyright restrictions.
Please see:
Wicht, Helmut, and R. Glenn Northcutt. "Secondary Olfactory Projections and Pallial Topography in the Pacific Hagfish, Eptatretus Stouti." *Journal of Comparative Neurology* 337, no. 4 (1993): 529-42.

Cladogram of jawless vertebrates and an amphibian showing olfactory bulb projections to forebrain

Please see page 540 of: Wicht, Helmut, and R. Glenn Northcutt. "Secondary Olfactory Projections and Pallial Topography in the Pacific Hagfish, Eptatretus Stouti." *Journal of Comparative Neurology* 337, no. 4 (1993): 529-42.

Questions, chapter 24

5) Contrast the suggested early functional roles of the medial pallium and the corpus striatum.

7) What, in evolution, was the major cause of the differentiation of dorsal and ventral parts of the corpus striatum?