A sketch of the central nervous system and its origins

G. E. Schneider 2014

Part 2: Steps to the central nervous system,

from initial steps to advanced chordates

MIT 9.14 Class 3

Evolution of multicellular organisms

Evolution of multi-cellular organisms: Suggestions based on phylogenetic comparisons

- TOPICS
  - Behaviors most fundamental for survival
  - Intercellular conduction in Ctenophora and Cnidaria*: *suggestions about early stages in the evolution of the nervous system*
  - A generalized conception of the CNS
  - The body plan of primitive chordates illustrated by the Cephalochordate *Amphioxus* (*Branchiostoma*)
  - Elaboration of the neural tube in evolution

**Animals with radial symmetry and stinging tentacles; includes free-swimming medusa forms like jellyfish, and sessile polyp forms like corals and sea anemones.*

Questions, chapter 3

1. Describe some basic, multipurpose actions that every animal, even one-celled animals, must be able to perform.

Basics of behavior enabling survival: critical for evolution

- **The most basic actions** of individual organisms, from amoebae to human, are multipurpose movements:
  - **Locomotion: to approach or to avoid something**
  - **Orienting: towards or away from something**
  - **Exploring/foraging/seeking** (includes the first two, plus instigation by a motivational state)
- Each evolutionary advance had to incorporate these multipurpose actions, needed for various goal-directed activities.
- These take place on a **background of maintenance activity**, including respiration, temperature regulation, postural reflexes.
- In multicellular organisms, these actions require nervous system control and integration.

Questions, chapter 3

✳ 13. Approach and avoidance (or flight) movements are controlled by sensory inputs plus one other important thing. What is that other thing (of great importance in the evolution of the CNS)?

Motivational state,
drive (internal)

✳ Not discussed in order

Questions, chapter 3

12. What are “ongoing background activities”? What type of nervous-system mechanism controls them?

(see slide 4)

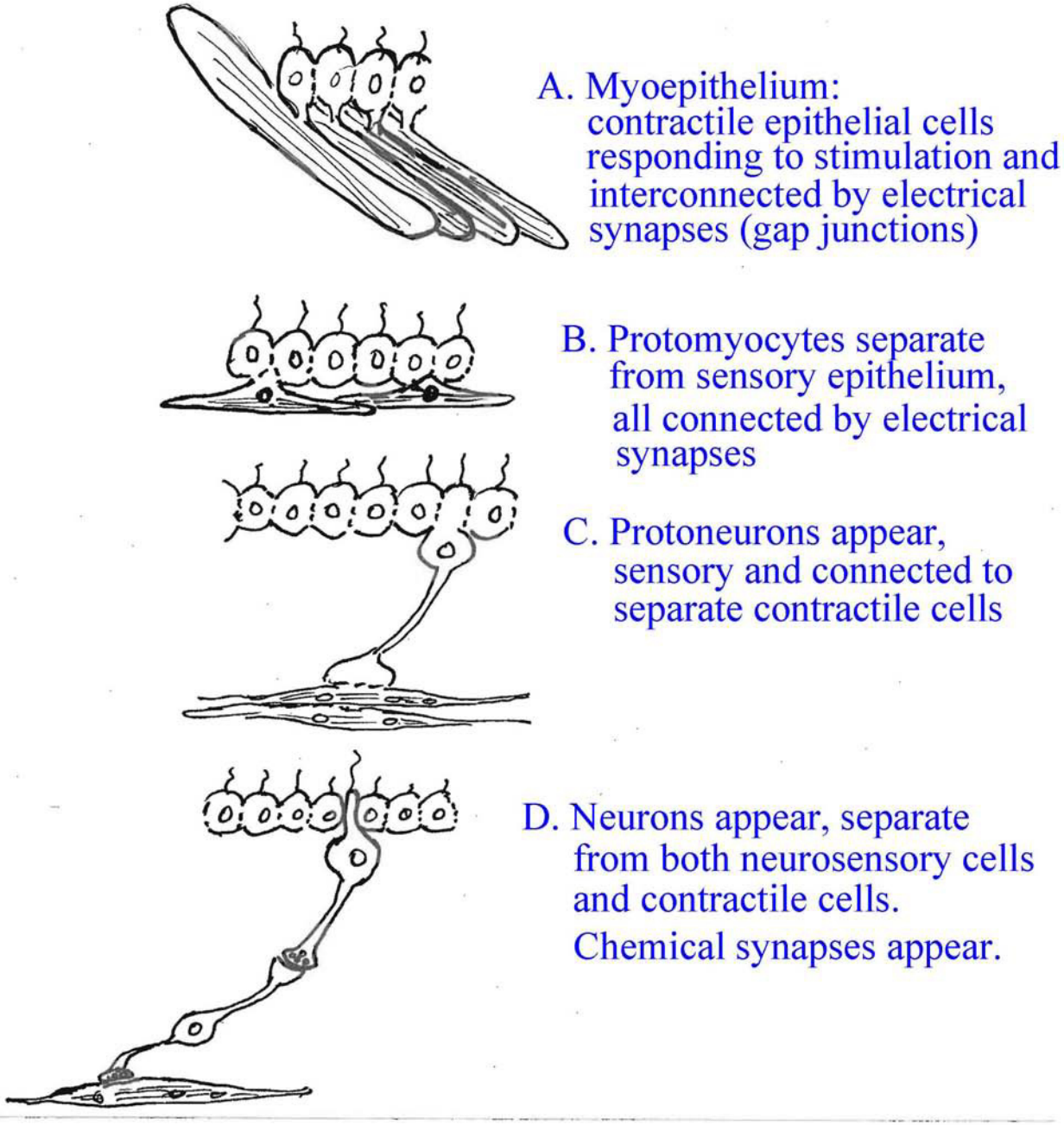
Questions, chapter 3

2. How can conduction between cells occur without synaptic connections? Such conduction is found in sponges and in Cnidarians like Hydra.

All these behaviors depend on the evolution of a nervous system.

Early steps to a nervous system:

- Sponges: responsive contractile cells without neurons, but also “myoid” and “neuroid” conduction (introduced by Nauta & Feirtag, ch. 1)
- Intercellular conduction in Ctenophores and in Cnidarians like jellyfish and hydra: ***The anatomy suggests basic early stages of nervous system evolution***



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. 3-1a

Questions, chapter 3

3. In the very early stages of nervous system evolution envisioned by George Parker and George Mackie, there were only one or two cell-cell connections between the sources of sensation and contractile cells that caused movements. What was the addition emphasized by Nauta?

Nauta's 5th stage: the appearance of intermediate neurons—neither primary sensory or motor: the beginning of the "great intermediate net"

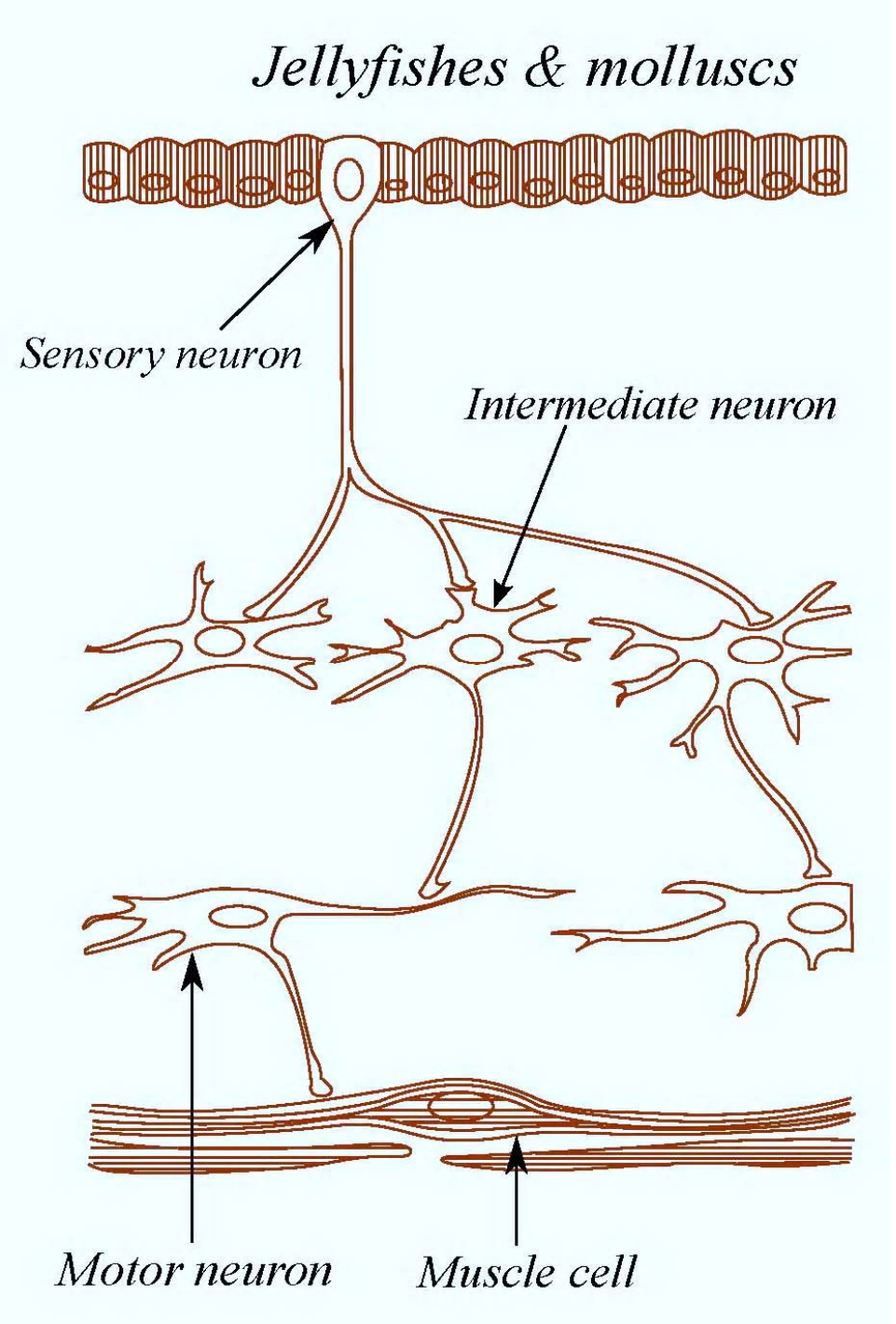


Fig. 3-1b

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Questions, chapter 3

4. Define primary and secondary sensory neurons and motor neurons. What is the intermediate network?

A generalized conception of the nervous system

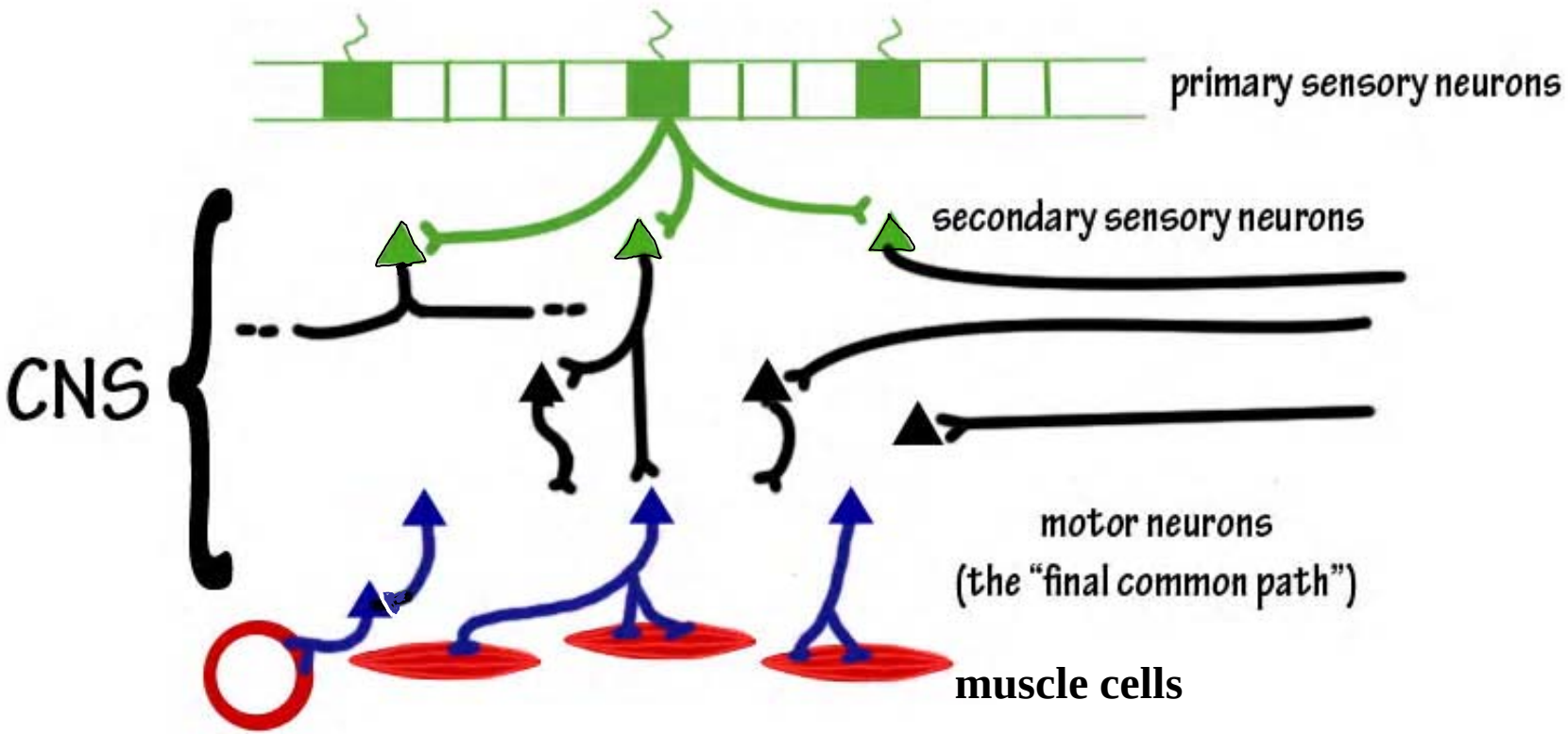

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Fig. 3-2

Questions, chapter 3

5. Where are neuronal cell bodies of the peripheral nervous system located?

in ganglia

6. How are the words “nerve” and “tract” used in the naming of axon bundles?

PNS CNS

Terms

- Primary sensory neuron
- Secondary sensory neuron
- Interneuron (or neuron of the "great intermediate net")
- Motor neuron
- Ganglia (singular: ganglion) in PNS
- Cell groups, “nuclei”, in CNS

- Nerves in PNS
- Tracts in CNS
- Fasciculi (singular: fasciculus) in CNS
- Notochord
- Neural tube

Next slides

See definitions in Schneider ch 3.

Questions, chapter 3

7. What animal is often called “the simplest living chordate”?

Amphioxus (*Branchiostoma*)

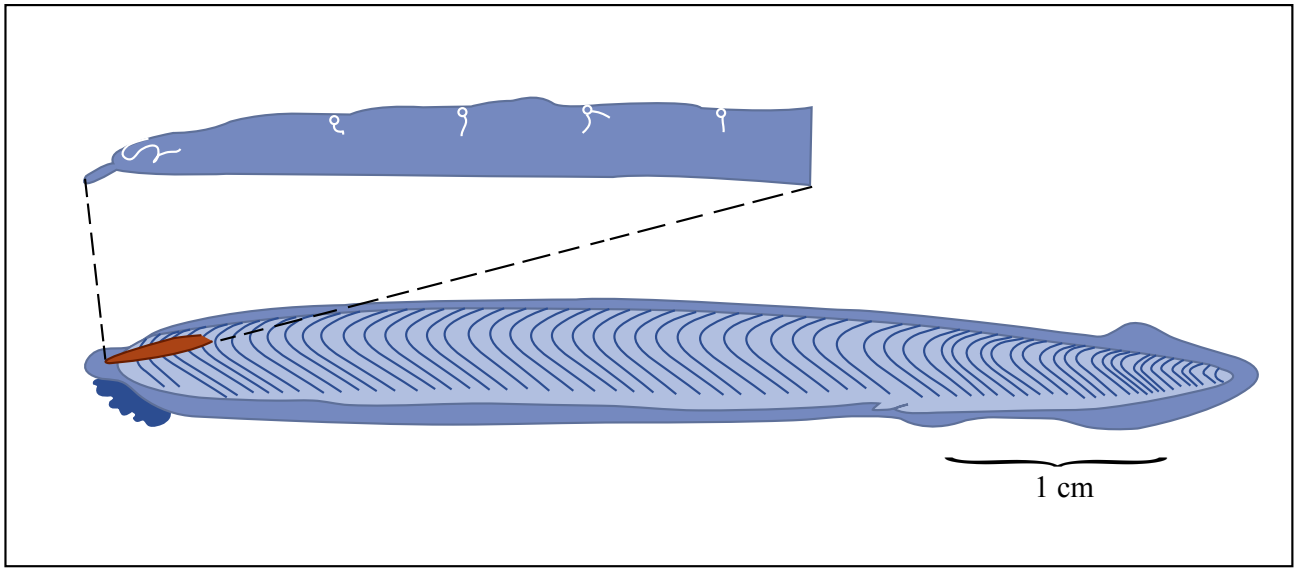


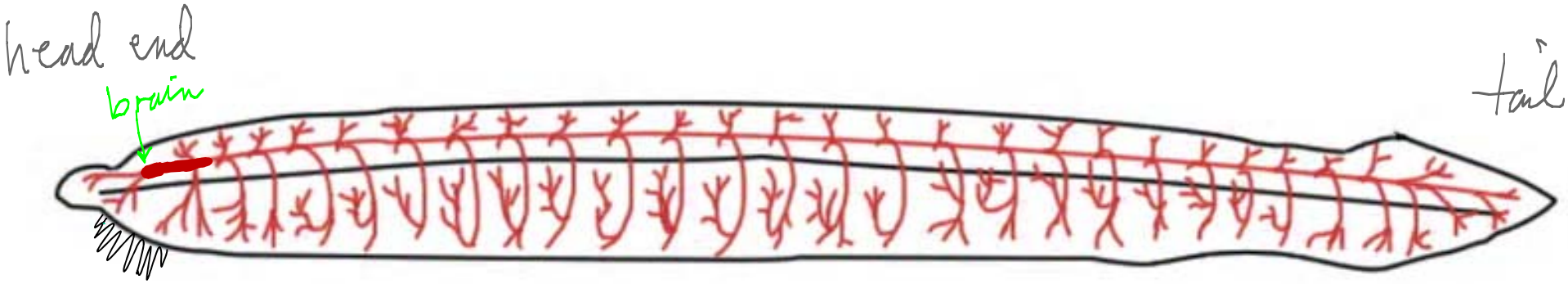
Image by MIT OpenCourseWare.

- -*Amphioxus* is a tiny present-day chordate (an invertebrate *Cephalochordate*), but it has characteristics that suggest similarities to what the earliest chordates must have been like.
- It is sometimes called the simplest living chordate.

What are some major characteristics of its CNS?

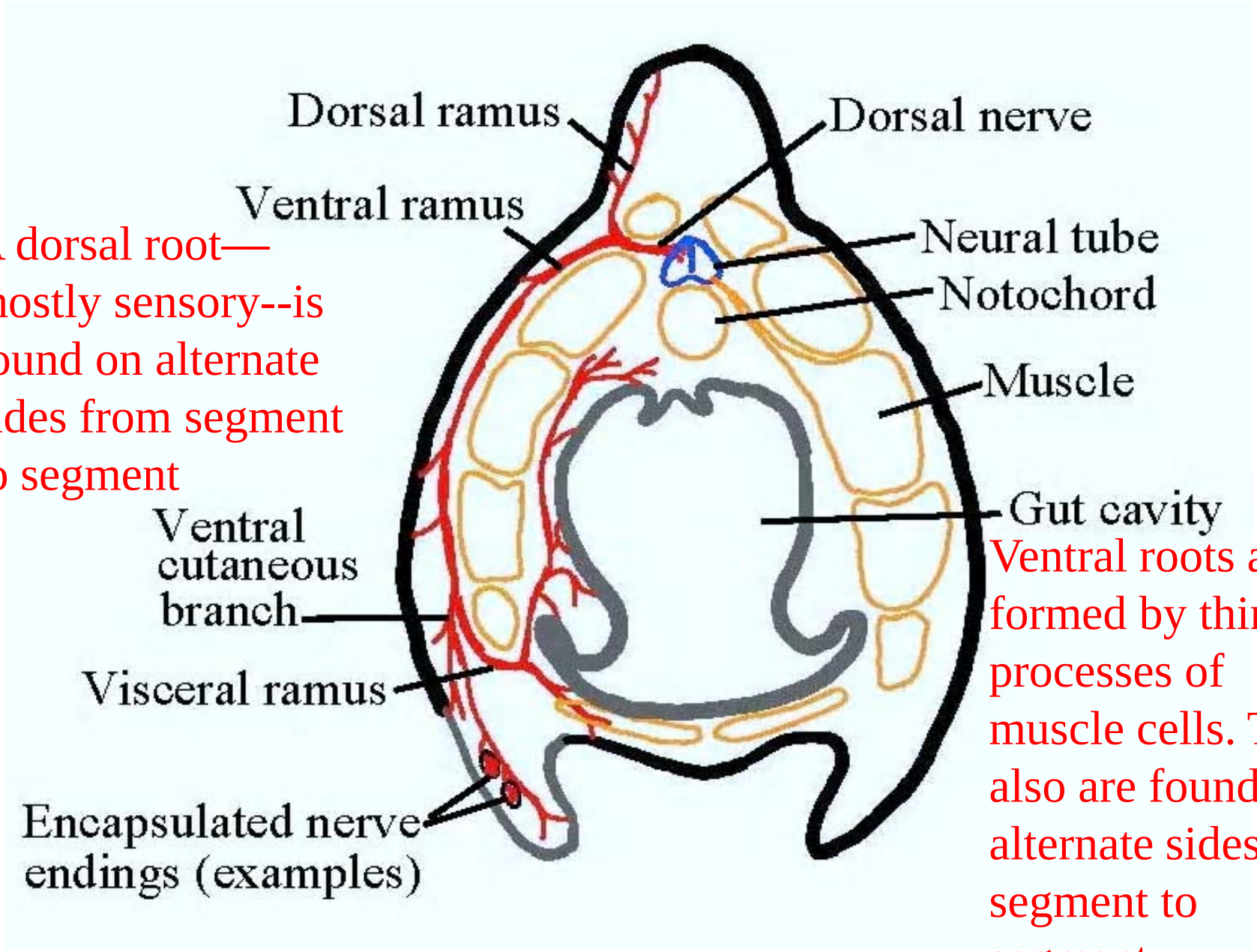
Sketch of the body plan of ***Amphioxus***, the "simplest living chordate":

The name means "sharp at both ends."



A dorsal nerve cord is found **above the notochord**:
It is the central nervous system (CNS), in the form of a neural tube.

Fig. 3-4



A dorsal root—mostly sensory--is found on alternate sides from segment to segment

Ventral roots are formed by thin processes of muscle cells. They also are found on alternate sides segment to segment.

Fig. 3-5 ***Amphioxus*** **in a transverse section**

Questions, chapter 3

1811 1829

8. What is the Bell-Magendie Law? Is it always true?

Laws of roots

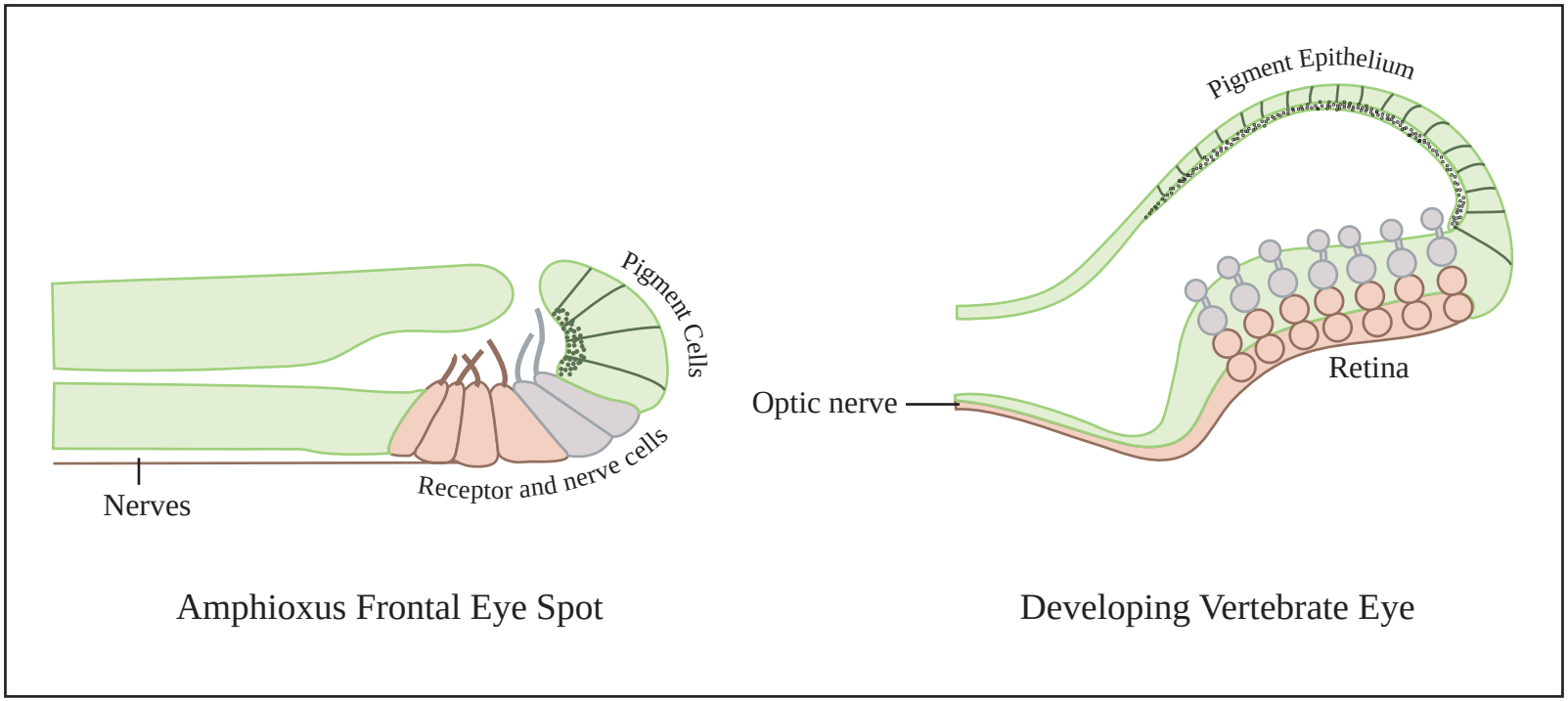
9. What is meant by “primary brain vesicles”?

Hindbrain Midbrain Forebrain

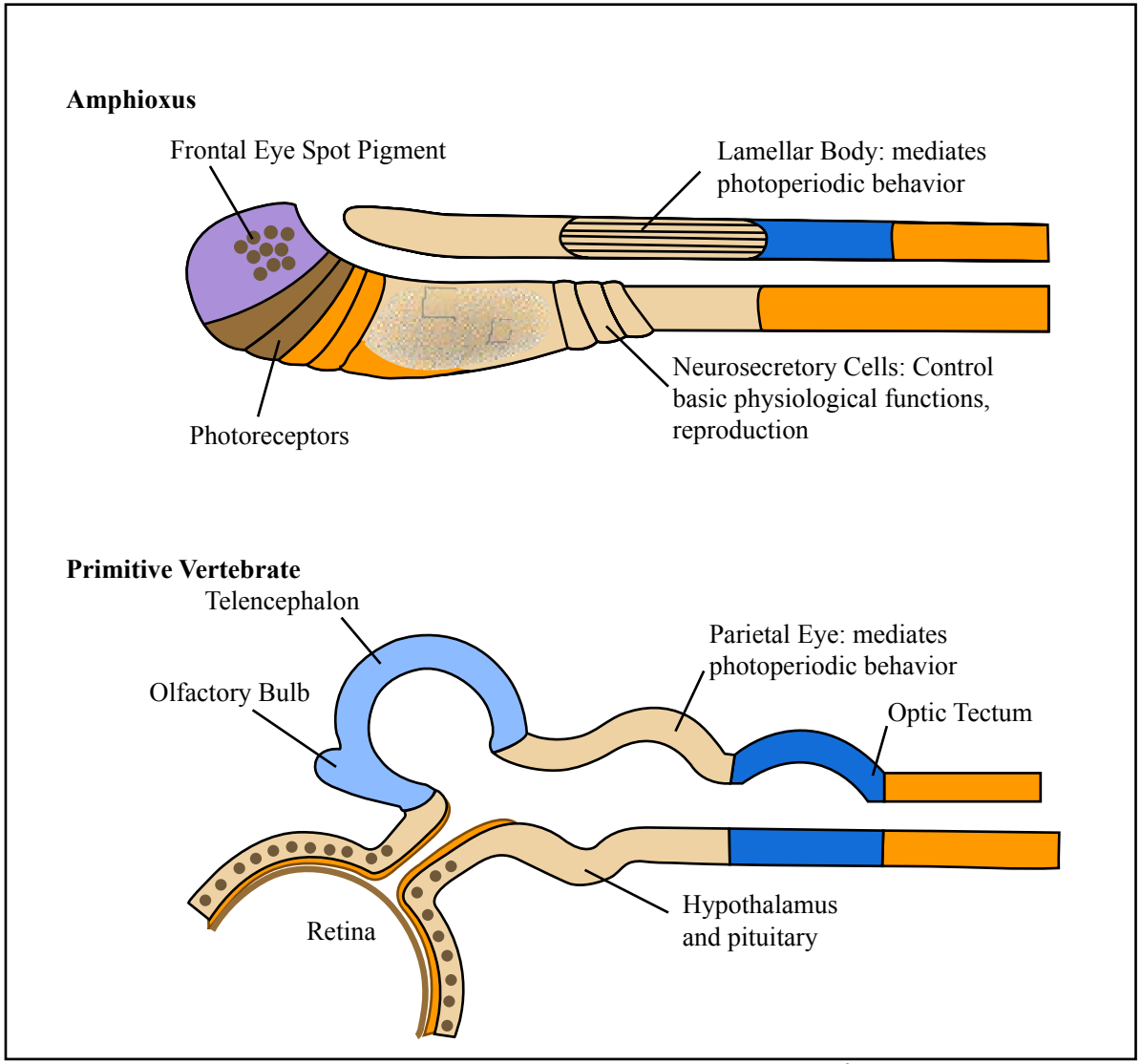
10. In which subdivision of the CNS do visual inputs enter? Describe or name the two visual inputs found in many chordates.

Diencephalon ('tweenbrain),
at caudal end of forebrain

Amphioxus frontal eye spot may correspond to the developing eye in vertebrates:



Amphioxus brain, and the brain of a primitive vertebrate



Questions, chapter 3

11. Summarize the basic rule that governs the process of evolution.

What do I mean by "evolution"?

- I mean the processes of **change -- in a population of animals -- in the way descendants function and behave**, and in the corresponding way their bodies and nervous systems look and function.
- **The changes occur by natural selection**, i.e., because certain genotypes produce more surviving offspring than others, so those genes increase in frequency and others decrease or disappear.
- **The changes are genetic**, and result from a sorting—mostly by natural selection—among genetic variations. Genetic variations are enhanced by sexual reproduction, involving the chance re-sorting of genes and hence the expression of those genes. Evolution works firstly on the current variations in genes among various individuals of a species. Greater variations appear when there are genetic changes resulting from gene mutations.

A consequence of gene sorting in chordates: Elaboration of the neural tube in evolution

- The behavioral demands: What are the highest priorities?
- These demands resulted in progressive evolutionary changes in the neural tube*: "Every brain system grows logically from the tube" (H. Chandler Elliott, 1969).

* because the nervous system controls behavior

The following chapter (Chapter 4) contains much speculation but it is based on comparisons of a wide range of species.

- Questions that led to the speculations:
  - Why did the CNS evolve the way it did?
  - What does it accomplish for an organism?
  - How is this expressed in the basic organization of the CNS?

Brief intro to next class.

Cynodonts: the mammal-like reptiles

9.14 Brain Structure and Its Origins

Spring 2014