# ANIMAL FORM AND FUNCTION

## Communication I: Nervous and Sensory System

## ❑ INVERTEBRATE NERVOUS SYSTEMS

# In protozoa and sponges

All cells respond to some stimuli and relay information both internally and externally. Thus, even when **no real nervous system** is present, such as in the protozoa and sponges, coordination and reaction to external and internal stimuli do occur.

**For Example:**

- ✓ The regular beating of protozoan cilia or the response of flagellates to varying light intensities requires intracellular coordination.
- ✓ level of organization (e.g., the diploblastic and triploblastic animals) have true nervous systems, however. This clearly excludes the protozoa and sponges.

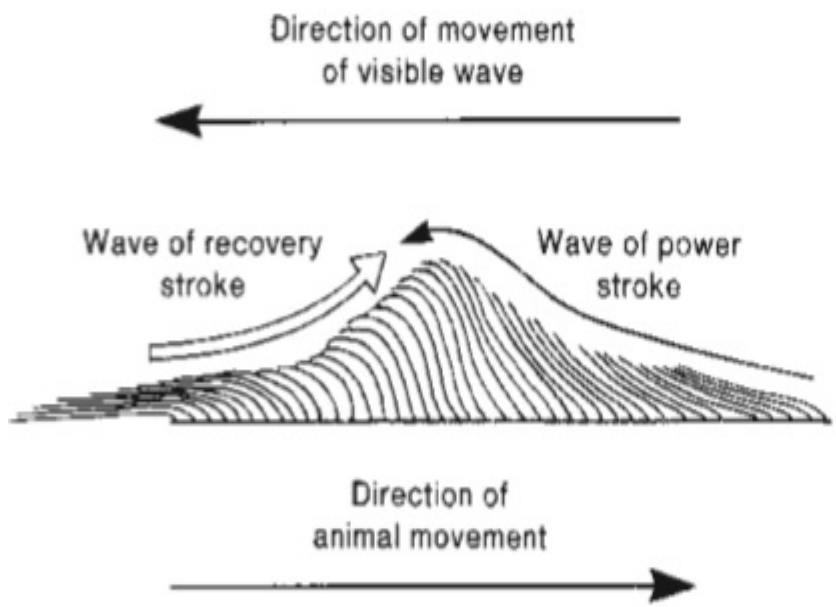



**Fig: Ciliary Movement. A metachronal (coordinated) wave passing along a row of cilia.**

# In Cnidarians

- ✓ Of all animals, the cnidarians (hydras, jellyfishes, and sea anemones) have the simplest form of nervous organization.
- ✓ These animals have a **nerve net**, a latticework that conducts impulses from one area to another.
- ✓ In **jellyfishes**, this type of nervous system is involved in slow swimming movements and in keeping the body right-side up.

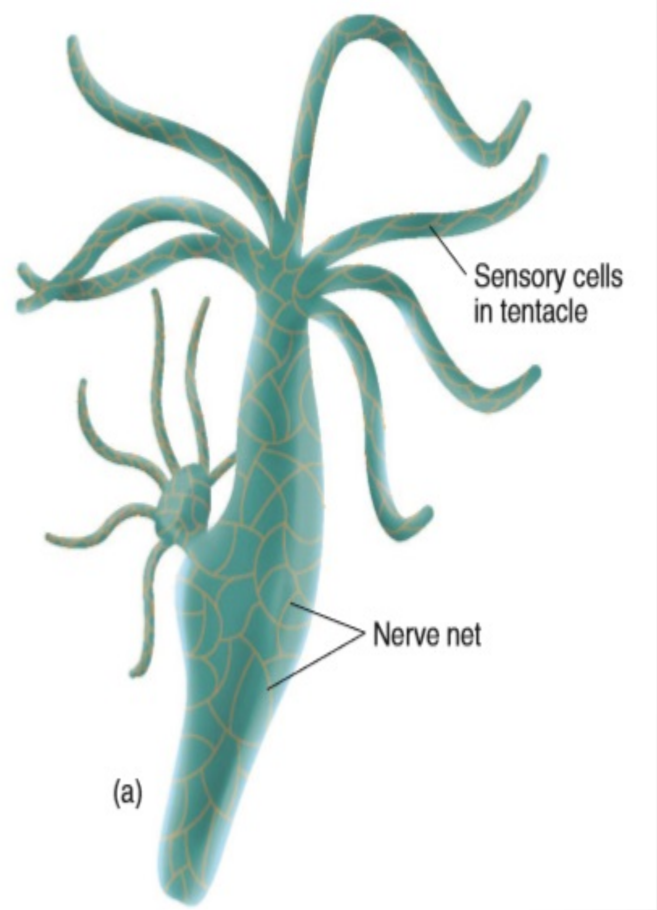



**Fig: Some Invertebrate Nervous Systems. (a) The nerve net of Hydra, a cnidarian, represents the simplest neural organization.**

## ❑ Echinoderms

Echinoderms (e.g., sea stars, sea urchins, sea cucumbers) still have nerve nets, but of increasing complexity

For example

**Nerve nets in Sea stars**

**1** The one that lies just under the skin has: a **circumoral ring** and five sets of nerve cords running out to the animal's arms

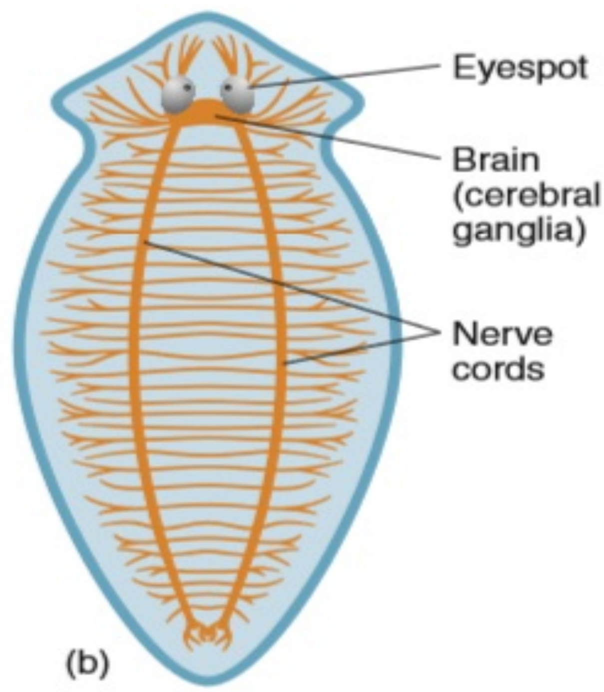
**2** Another net serves the muscles between the skin plates, called **ossicles**

**3** The third net connects to the tube feet.

**Thus, the second trend in nervous system evolution involves cephalization, which is a concentration of receptors and nervous tissue in the animal's anterior end.**

## Flatworm's nervous system:

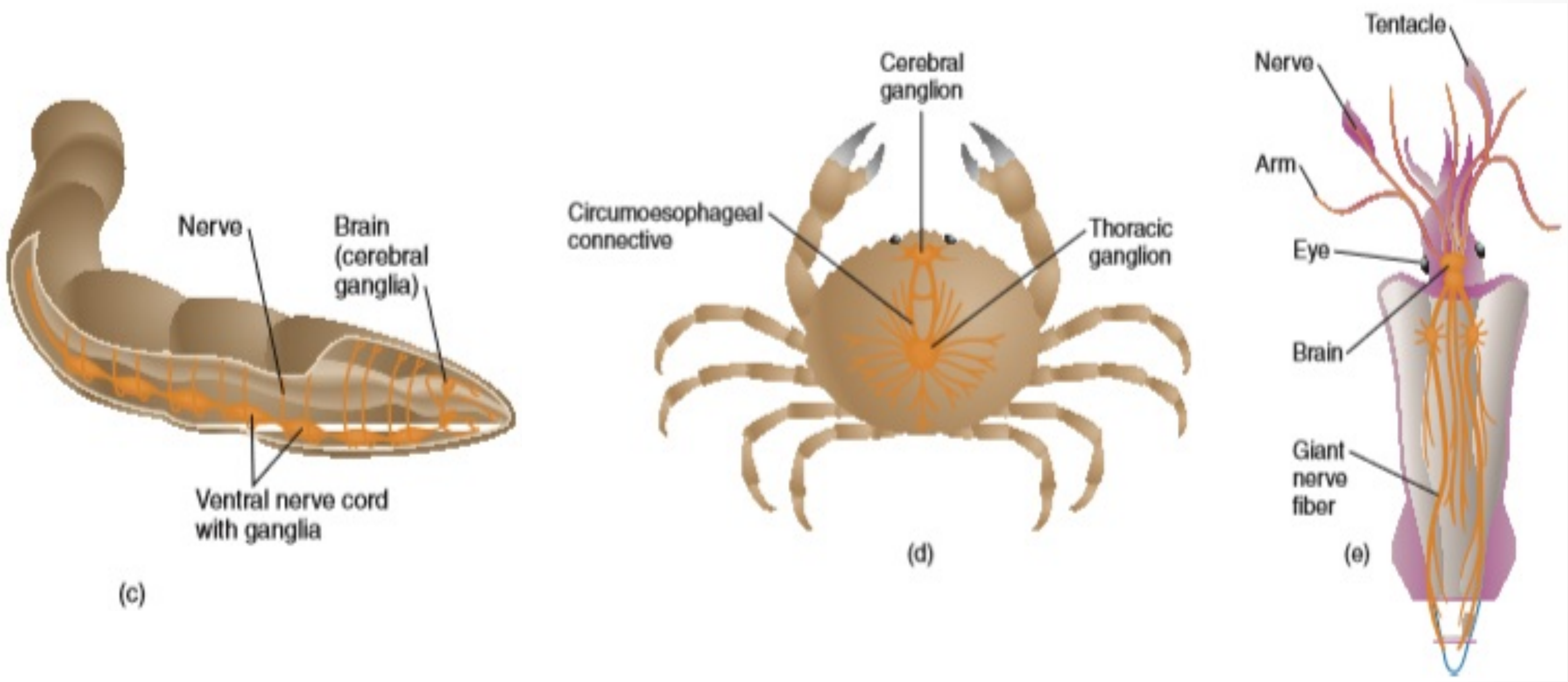
- ✓ It contains **ganglia** which are distinct aggregations of nerve cells in the head region. Ganglia function as a **primitive "brain".**
- ✓ Distinct **lateral nerve cords** on either side of the body carry sensory information from the periphery to the head ganglia and carry motor impulses from the head ganglia back to muscles, allowing the animal to react to environmental stimuli




**(b) Brain and paired nerve cords of a planarian flatworn. This is the first nervous system showing differentiation into a peripheral nervous system and a central nervous system.**

## ❑In other invertebrates, such as crustaceans, segmented worms, and arthropods

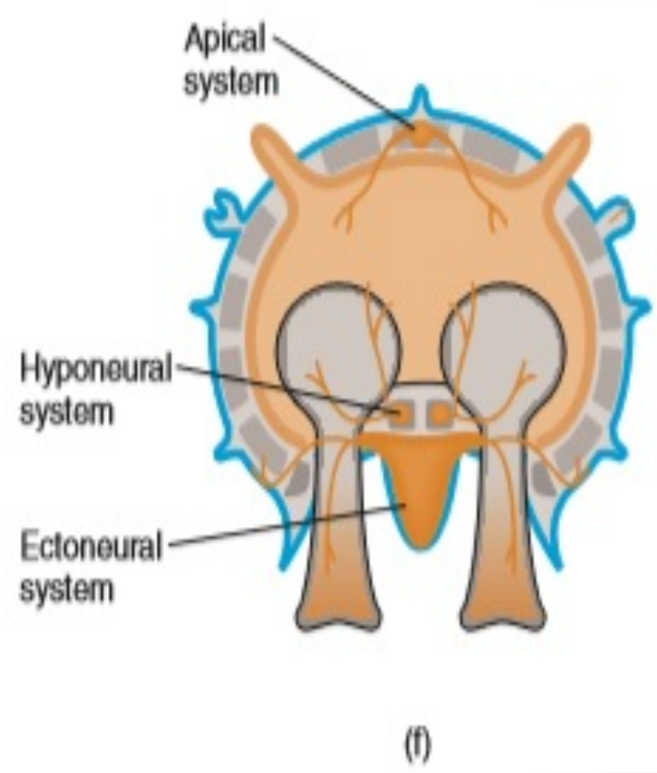
- ✓ axons join into nerve cords, and in addition to a small, centralized brain, smaller peripheral ganglia help coordinate outlying regions of the animal's body.




**(c) Brain, ventral nerve cord, ganglia, and peripheral nerves of the earthworm, an annelid worm. (d) A crustacean, showing the principal ganglia and visceral connective nerves. The most primitive crustaceans have nervous systems similar to those of the Platyhelminthes, whereas (e) some cephalopods (such as the squid) have brains and behavior as complex as those of fishes.**

## In echinoderms:

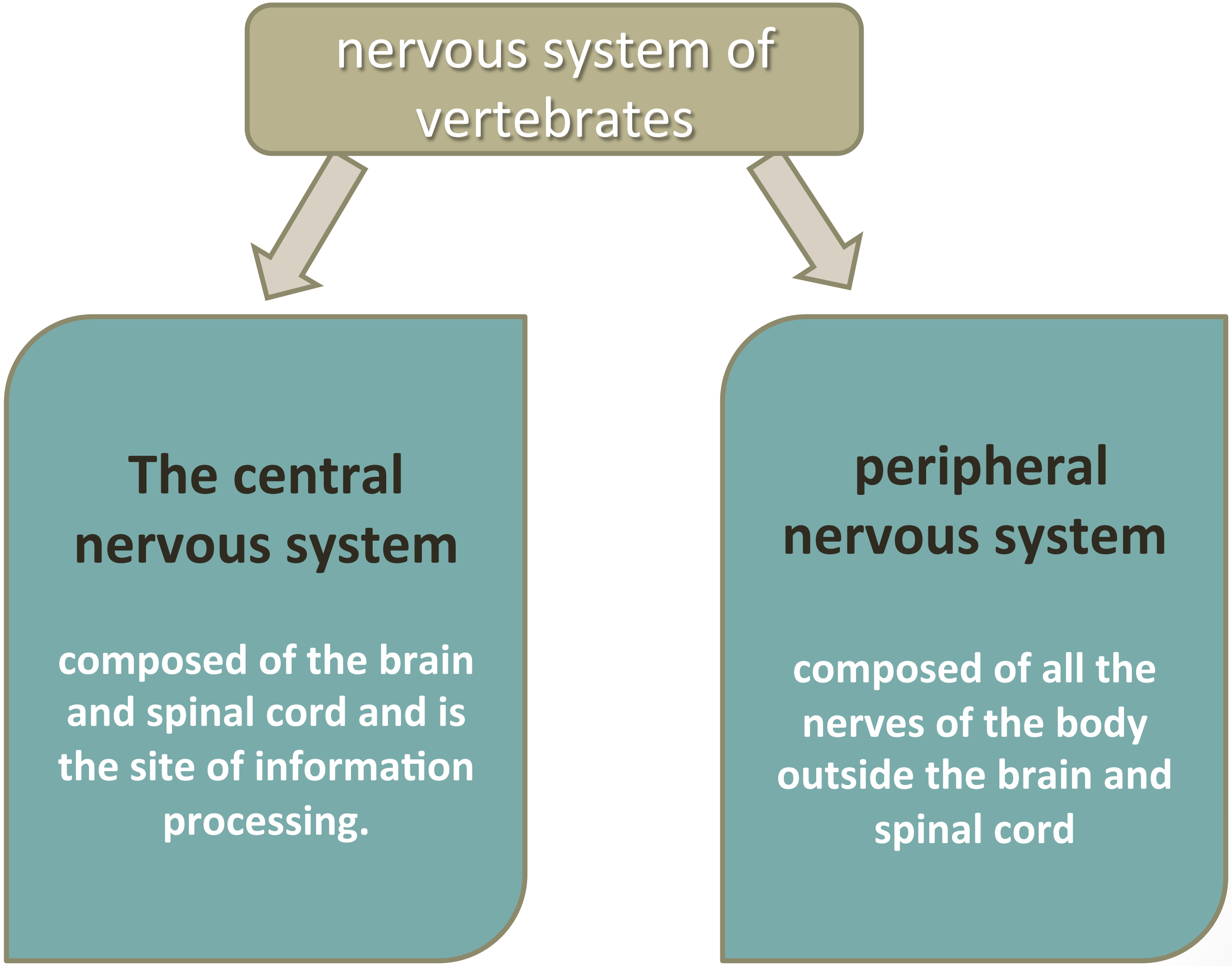
- i.e., in starfishes, The ectoneural system retains a primitive epidermal position and combines sensory and motor functions.
- A radial nerve extends down the lower surface of each arm.
- A deeper hyponeural system has a motor function, and the apical system may have some sensory functions.




**Fig(f): Cross section of a starfish arm. Nerves from the ectoneural system terminate on the surface of the hyponeural system, but the two systems have no contact**

## ❑ VERTEBRATE NERVOUS SYSTEMS

- Bilateral symmetry, a notochord, and a tubular nerve cord characterize the evolution of vertebrate nervous systems.
- The nervous system of vertebrates has two main divisions



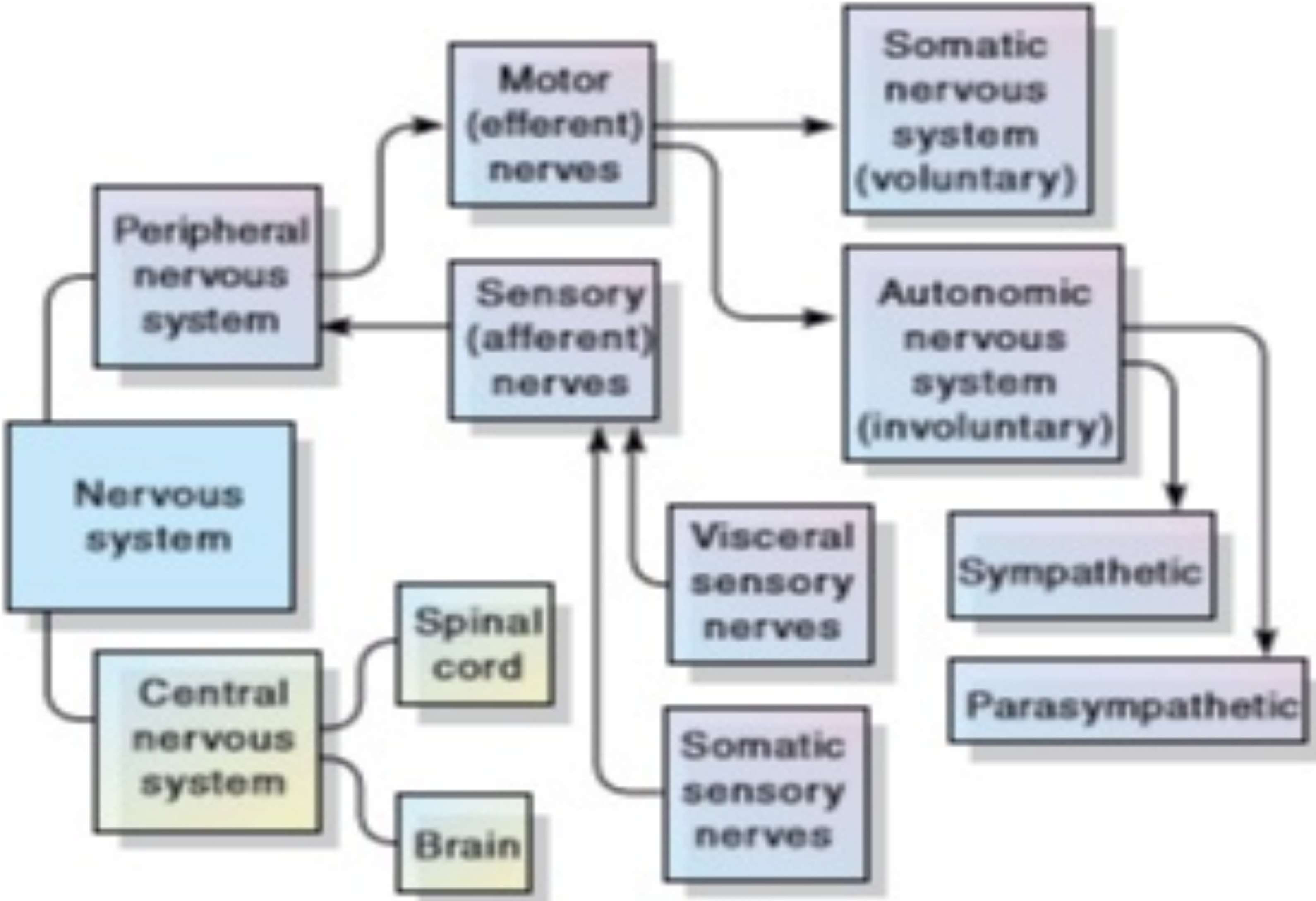



**Fig: The Basic Organization of the Nervous System Is Similar in All Vertebrates. This flowchart shows the divisions and nerves of the vertebrate nervous system. Arrows indicate the directional flow of nerve impulses (information).**

**Nerves are commonly divided into two groups:**

1) sensory (afferent) nerves, which transmit information to the central nervous system;
2) motor (efferent) nerves, which carry commands away from the central nervous system.

The motor nerves divide into:

- the **voluntary (somatic)** nervous system, which relays commands to skeletal muscles, and
- **the involuntary (visceral or autonomic)** nervous system, which stimulates other muscles (smooth and cardiac) and glands of the body.
- The nerves of the autonomic nervous system divide into **sympathetic and parasympathetic systems.**

## ❑ THE SPINAL CORD

The spinal cord is the part of the central nervous system that extends from the brain to near or into the tail.

## ❑ FUNCTION OF SPINAL CORD:

1) It is the connecting link between the brain and most of the body,
2) It is involved in spinal reflex actions.

- Extending from the spinal cord are the ventral and dorsal roots of the spinal nerves containing the main motor and sensory fibers (axons and/or dendrites).
- Three layers of protective membranes called **meninges** surround the spinal cord.
- **The outer layer**, the dura mater, is a tough, fibrous membrane. **The middle layer,** the arachnoid, is delicate and connects to **the innermost layer**, the pia mater. The pia mater contains small blood vessels that nourish the spinal cord.

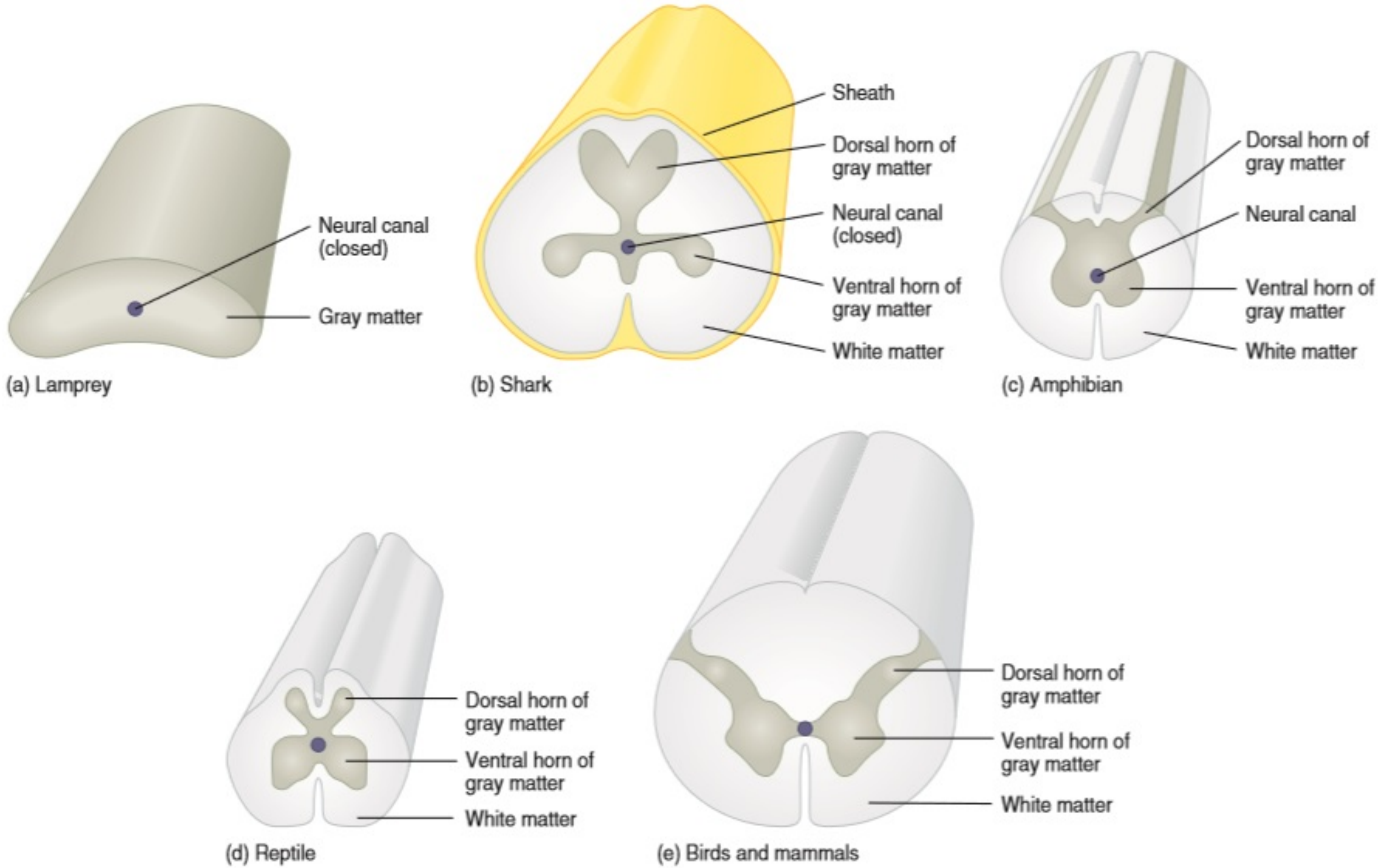



**Fig: Spinal Cords of Vertebrates. (a) The spinal cord of a typical agnathan (lamprey) is flattened and possesses no myelinated axons. Its shape facilitates the diffusion of gases, nutrients, and other products. (b,c) In fishes and amphibians, the spinal cord is larger, well vascularized, and rounded. With more white matter, the spinal cord bulges outward. The gray matter in the spinal cord of (d) a reptile and (e) birds and mammals has a characteristic butterfly shape.**

## ❑SPINAL NERVES

- ❑ Generally, the number of spinal nerves is directly related to the number of segments in the trunk and tail of a vertebrate.
- ❑ For example, a frog has evolved strong hind legs for swimming or jumping, a reduced trunk, and no tail in the adult. It has only 10 pairs of spinal nerves.
- ❑ By contrast, a snake, which moves by lateral undulations of its long trunk and tail, has several hundred pairs of spinal nerves.

## ❑ THE BRAIN

During embryonic development, the brain undergoes regional expansion as a hollow tube of nervous tissue forms and develops into the **hindbrain, midbrain, and forebrain.**

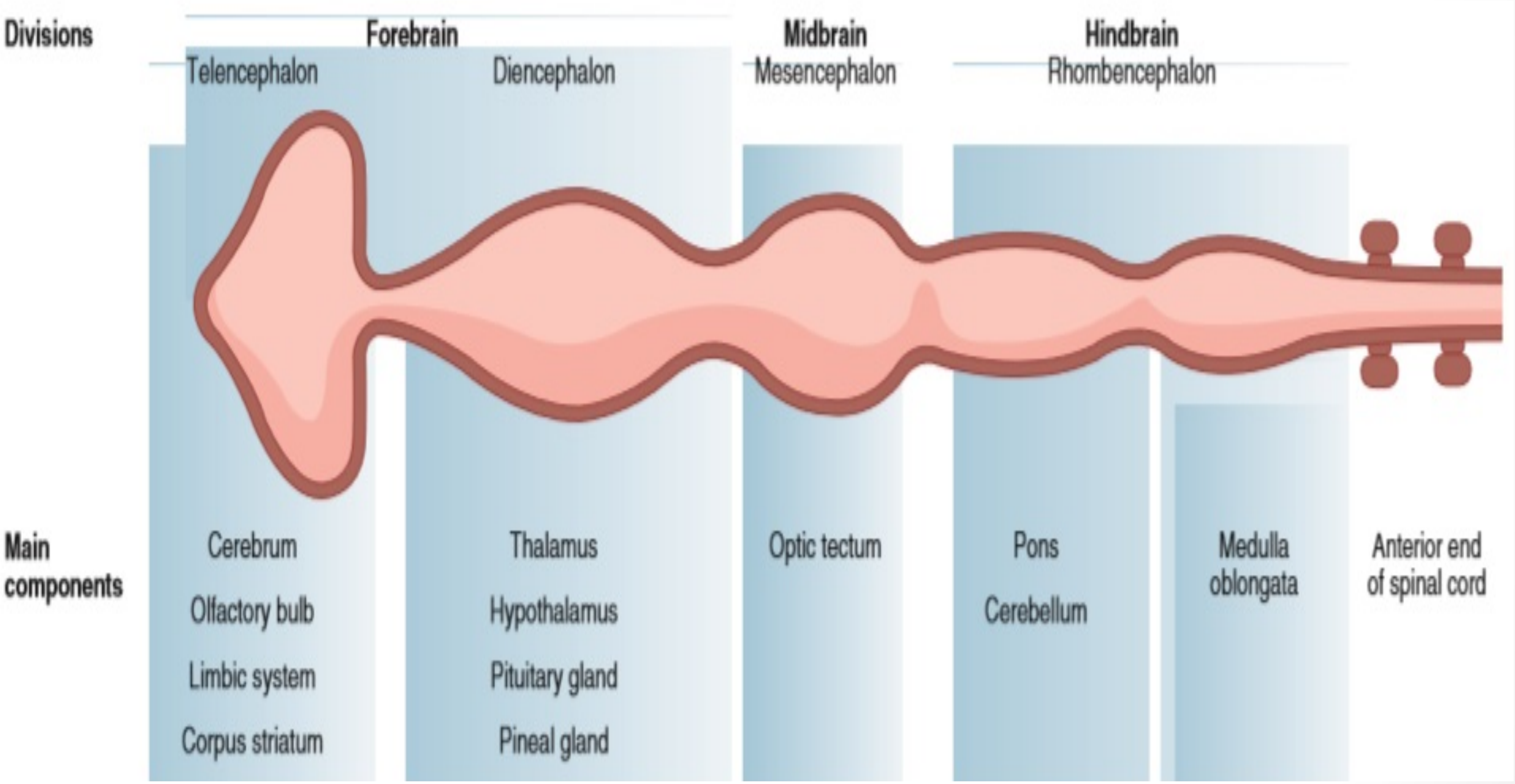



**Fig: Development of the Vertebrate Brain. Summary of the three major subdivisions and some of the structures they contain. This drawing is highly simplified and flattened.**

# ❑ Hindbrain

## medulla oblongata

- ✓ The medulla oblongata is the enlargement where the spinal cord enters the brain
- ✓ It contains reflex centers for breathing, swallowing, cardiovascular function, and gastric secretion.
- ✓ Well developed in all jawed vertebrates

## cerebellum

- ✓ Outgrowth of the medulla oblongata.
- ✓ It coordinates motor activity associated with limb movement, maintaining posture, and spatial orientation.
- ✓ In cartilaginous fishes it has distinct anterior and posterior lobes.
- ✓ In teleosts, it is large in active swimmers and small in relatively inactive fishes.
- ✓ Amphibians often have a rudimentary cerebellum
- ✓ In tetrapods, the cerebellum is laterally expanded.

## pons

- ✓ It is a bridge of transverse nerve tracts from the cerebrum of the forebrain to both sides of the cerebellum.
- ✓ It also contains tracts that connect the forebrain and spinal cord in all vertebrates.

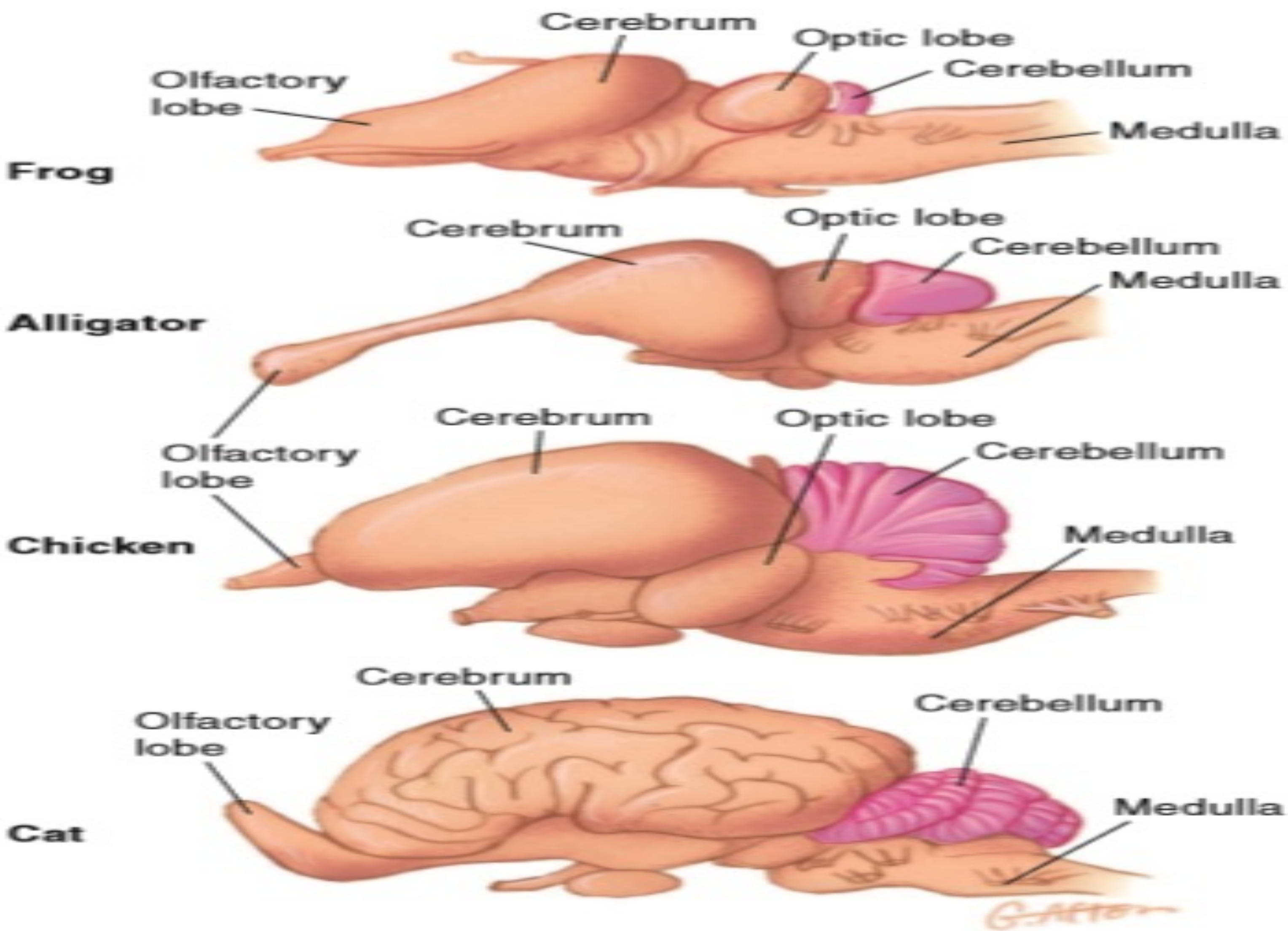



**Fig: Vertebrate Brains. Comparison of several vertebrate brains, as viewed from the side. The drawings are not drawn to the same scale. Notice the increase in relative size of the cerebrum from amphibian (frog) to mammal (cat).**

## ❑ Midbrain

- ✓ The midbrain was originally a center for coordinating reflex responses to visual input.
- ✓ As the brain evolved, it took on added functions relating to tactile (touch) and auditory (hearing) input.
- ✓ The roof of the midbrain, called the **optic tectum**, is a thickened region of gray matter that integrates visual and auditory signals.

## ❑ Forebrain

The forebrain has two main parts: the **diencephalon** and **telencephalon**.

### 1) Diencephalon

The diencephalon lies just in front of the midbrain and contains:

- ✓ pineal gland
- ✓ pituitary gland
- ✓ hypothalamus
- ✓ thalamus

- ❑ The thalamus relays all sensory information to higher brain centers.
- ❑ The hypothalamus lies below the thalamus and regulates many functions, such as body temperature, sexual drive, carbohydrate metabolism, hunger, and thirst.
- ❑ The pineal gland controls some body rhythms.
- ❑ The pituitary is a major endocrine gland,

## 2) Telencephalon

The Telencephalon contains:

- ✓ Cerebrum
- ✓ Olfactory bulb
- ✓ Limbic system
- ✓ Corpus striatum

- ❑ External to the corpus striatum is the **cerebrum**, which a large groove divides into right and left cerebral hemispheres.
- ❑ In mammals, the outermost part of the cerebrum, called the **cerebral cortex**, progressively increased in size and complexity.
- ❑ The cerebral cortex contains primary sensory areas and primary motor areas.
- ❑ Other areas of the cortex are involved in the perception of visual or auditory signals from the environment.
- ❑ In humans, this includes the ability to use language both written and spoken.

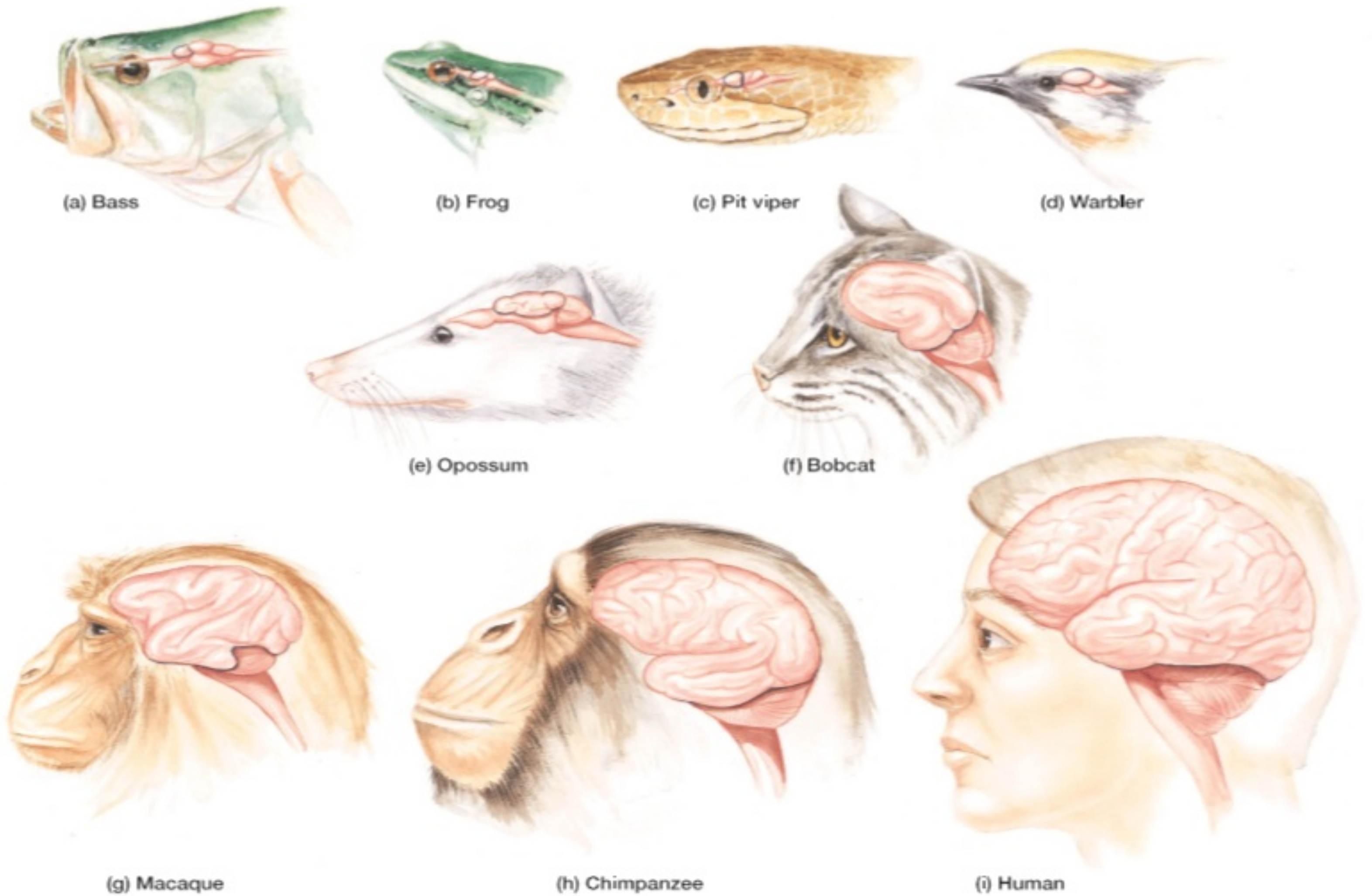



**Fig: Cerebrum in Different Vertebrate Species. The cerebrum increases in both size and complexity of its neural connections in more advanced groups. (a) Fishes and (b) amphibians lack cerebral cortices, whereas (c) reptiles and (d) birds have a small amount of gray matter covering their cerebrums. Most primitive mammals, such as (e) the opossum, have smooth cortices. Carnivores, such as (f) the bobcat, have larger cerebrums, and the cortex has a few convolutions, (g,h) In the primates, the cerebrum is much increased relative to other brain structures, and the cortex is highly convoluted. (i) The human cerebrum dominates in brain evolution and is highly convoluted.**

# CRANIAL NERVES

- ✓ In addition to the paired spinal nerves, the peripheral nervous system of vertebrates includes paired cranial nerves.
- ✓ Reptiles, birds, and mammals have **12 pairs** of cranial nerves.
- ✓ Fishes and amphibians have only the first 10 pairs. Some of the nerves (e.g., optic nerve) contain only sensory axons, which carry signals to the brain.
- ✓ Others contain sensory and motor axons, and are termed mixed nerves.
- ✓ For example, the vagus nerve has sensory axons leading to the brain as well as motor axons leading to the heart and smooth muscles of the visceral organs in the thorax and abdomen.

## FUNCTIONS OF THE CRANIAL NERVES OF REPTILES, BIRDS, AND MAMMALS

| NERVE | | TYPE | INNERVATION AND FUNCTION |
|---|---|---|---|
| I | Olfactory | Sensory | Smell |
| II | Optic | Sensory | Vision |
| III | Oculomotor | Primarily motor | Eyelids, eyes, adjustments of light entering eyes, lens focusing (motor) |
| IV | Trochlear | Primarily motor | Condition of muscles (sensory)<br>Eye muscles (motor) |
| V | Trigeminal | Mixed | Condition of muscles (sensory) |
| | Ophthalmic division | | Eyes, tear glands, scalp, forehead, and upper eyelids (sensory) |
| | Maxillary division | | Upper teeth, upper gum, upper lip, lining of the palate, and skin of the face (sensory) |
| | Mandibular division | | Scalp, skin of the jaw, lower teeth, lower gum, and lower lip (sensory) |
| VI | Abducens | Primarily motor | Jaws, floor of the mouth (motor)<br>Eye muscles (motor) |
| VII | Facial | Mixed | Condition of muscles (sensory)<br>Taste receptors of the anterior tongue (sensory)<br>Facial expression, tear glands, and salivary glands (motor) |
| VIII | Vestibulocochlear | Sensory | |
| | Vestibular branch | | Equilibrium; vestibule |
| | Cochlear branch | | Hearing; cochlea |
| IX | Glossopharyngeal | Mixed | Pharynx, tonsils, posterior tongue, and carotid arteries (sensory)<br>Pharynx and salivary glands (motor) |
| X | Vagus | Mixed | Speech and swallowing, heart, and visceral organs in the thorax and abdomen (motor)<br>Pharynx, larynx, esophagus, and visceral organs of the thorax and abdomen (sensory) |
| XI | Accessory | Motor | |
| | Cranial branch | | Soft palate, pharynx, and larynx |
| | Spinal branch | | Neck and back |
| XII | Hypoglossal | Motor | Tongue muscles |

# THE AUTONOMIC NERVOUS SYSTEM

The vertebrate autonomic nervous system is composed of two divisions that act antagonistically (in opposition to each other) to control the body's involuntary muscles (smooth and cardiac) and glands.

## THE AUTONOMIC NERVOUS SYSTEM

### Parasympathetic nervous system

- ✓ functions during relaxation.
- ✓ It contains nerves that arise from the brain and sacral region of the spinal cord.
- ✓ It consists of a network of long efferent nerve fibers and short efferent neurons that extend from the ganglia to the organs.

### Sympathetic nervous system

- ✓ It is responsible for the "fight-or-flight" response.
- ✓ It contains nerves that arise from the thoracic and lumbar regions of the spinal cord.
- ✓ It is a network of short efferent central nervous system fibers and long efferent neurons extending from the ganglia directly to each organ.