Course: Animal Form and Function

COMMUNICATION II: Senses

1) HEARING AND EQUILIBRIUM IN AIR

2) HEARING AND EQUILIBRIUM IN WATER

1) HEARING AND EQUILIBRIUM IN AIR:

The vertebrate ear has two functional units:

(1) the auditory apparatus is concerned with hearing.

(2) the vestibular apparatus is concerned with posture and equilibrium.

Adaptation to hearing in air resulted from the evolution of an acoustic transformer that incorporates a thin, stretched membrane, called either an eardrum, tympanic membrane, or tympanum, that is exposed to the air.

Structure of ear in amphibians:

- ✓ The ears of anurans (frogs) consist of a tympanum, a middle ear, and an inner ear.
- ✓ Touching the tympanum is an ossicle (a small bone or bony structure) called the columella or stapes.
- ✓ High-frequency (1,000 to 5,000 Hz) sounds strike the tympanum and are transmitted through the middle ear via the columella and cause pressure waves in the fluid of the semicircular canals

- ✓ A second small ossicle, the **operculum**, also touches the oval window.
- ✓ Substrate-borne vibrations transmitted through the front appendages and the pectoral girdle cause this ossicle to vibrate.
- ✓ The resulting pressure waves in the inner ear stimulate a second patch of sensory receptor cells that is sensitive to low-frequency (100 to 1,000 Hz) sounds.
- ✓ Muscles attached to the operculum and columella can lock either or both of these ossicles, allowing a frog to screen out either high- or low-frequency sounds

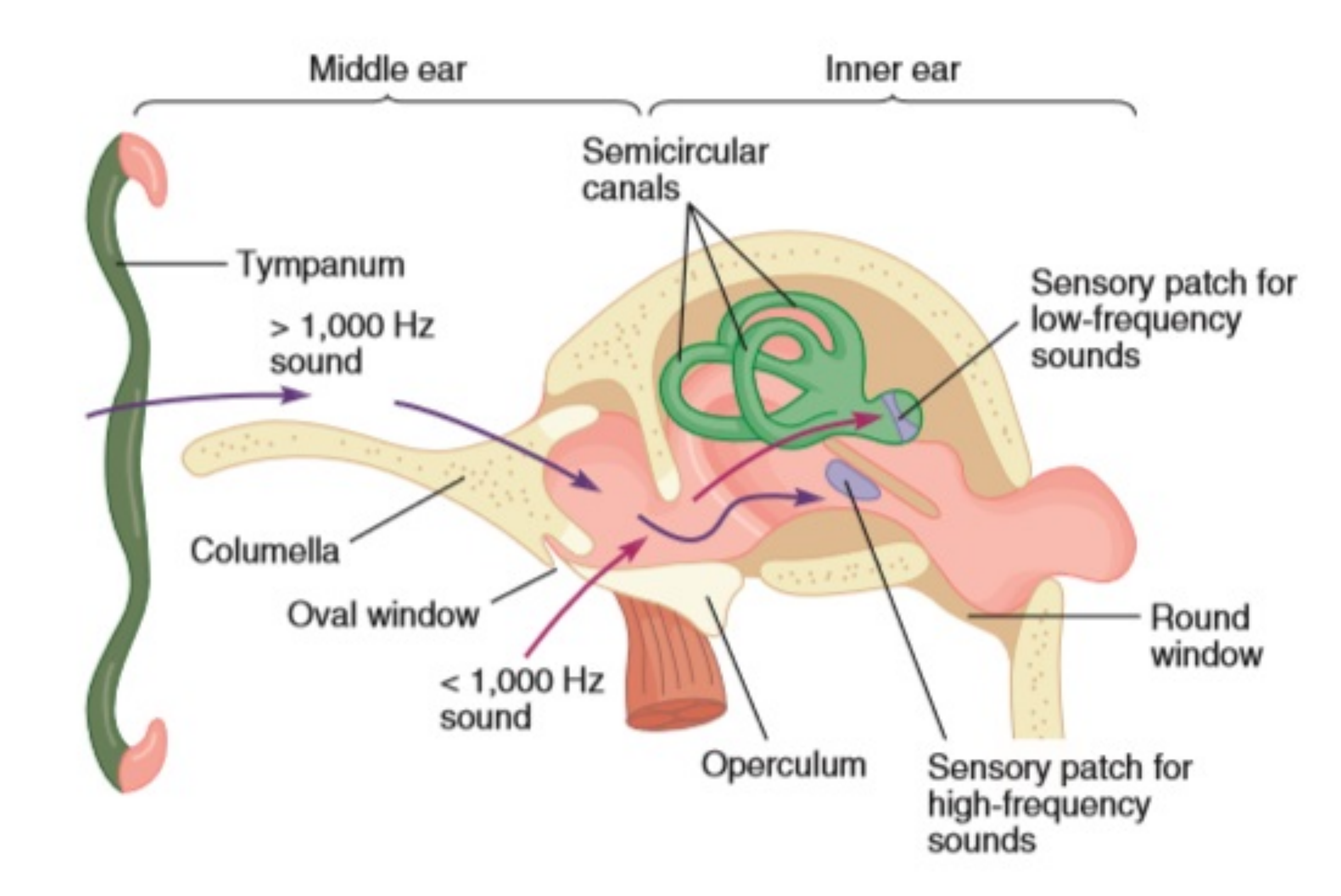

Fig: Ear of an Anuran (Posterior View). Red arrows show the pathway of low-frequency sounds, via the operculum. Dark-blue arrows show the pathway of high-frequency sounds, via the columella (stapes).

Structure of ear in Salamanders:

- ✓ Salamanders lack a tympanum and middle ear.
- ✓ They live in streams, ponds, and caves, and beneath leaf litter.
- ✓ They have no mating calls, and the only sounds they hear are probably transmitted through the substratum and skull to the inner ear.

Structure of ear in reptiles:

- ✓ The structures of reptilian ears vary.
- ✓ For example, the ears of **snakes** lack a middle-ear cavity and a tympanum.
- ✓ A bone of the jaw articulates with the stapes and receives vibrations of the substratum.
- ✓ In other reptiles, a tympanum may be on the surface or in a small depression in the head.

Structure of ear in birds:

- ✓ Hearing is well developed in most birds.
- ✓ Loose, delicate feathers cover the external ear opening.
- ✓ Middle- and inner-ear structures are similar to those of mammals.

Structure of ear in Mammals:

- ✓ In mammals, the long, coiled, sensory structure of the inner ear that contains receptors for sound is the **cochlea.**
- ✓ **This structure provides more surface area for receptor cells and gives mammals greater sensitivity to pitch and volume than is present in other animals**

human ear has three divisions

the outer ear

consists of the auricle and external auditory canal

Middle ear

- begins at the tympanic membrane.
- ends inside the skull, where two small membranous openings, the oval and round windows, are located.
- malleus (hammer), incus (anvil), and stapes (stirrup).
- The auditory (eustachian) tube extends from the middle ear to the nasopharynx

inner ear

- The inner ear has three components.
- The first two, the vestibule and the semicircular canals, are concerned with equilibrium, and
- the third, the cochlea, is involved with hearing

Process of hearing:

- Sound waves enter the outer ear and create pressure waves that reach the tympanic membrane.
- Air molecules under pressure vibrate the tympanic membrane. The vibrations move the malleus on the other side of the membrane
- The handle of the malleus articulates with the incus, vibrating it.
- The vibrating incus moves the stapes back and forth against the oval window.
- The movements of the oval window set up pressure changes that vibrate the fluid in the inner ear. These vibrations are transmitted to the basilar membrane, causing it to ripple.

- **Receptor hair cells of the organ of Corti that are in contact with the overlying tectorial membrane are bent, causing a generator potential, which leads to an action potential that travels along the vestibulocochlear nerve to the brain for interpretation.**

↓

- **Vibrations in the cochlear fluid dissipate as a result of movements of the round window.**

- ✓ Humans are not able to hear low-pitched sounds, **below 20 cycles per second**, although some other vertebrates can.
- ✓ Young children can hear high-pitched sounds up to **20,000 cycles per second**, but this ability decreases with age.
- ✓ dogs can easily detect sounds of **40,000 cycles per second**

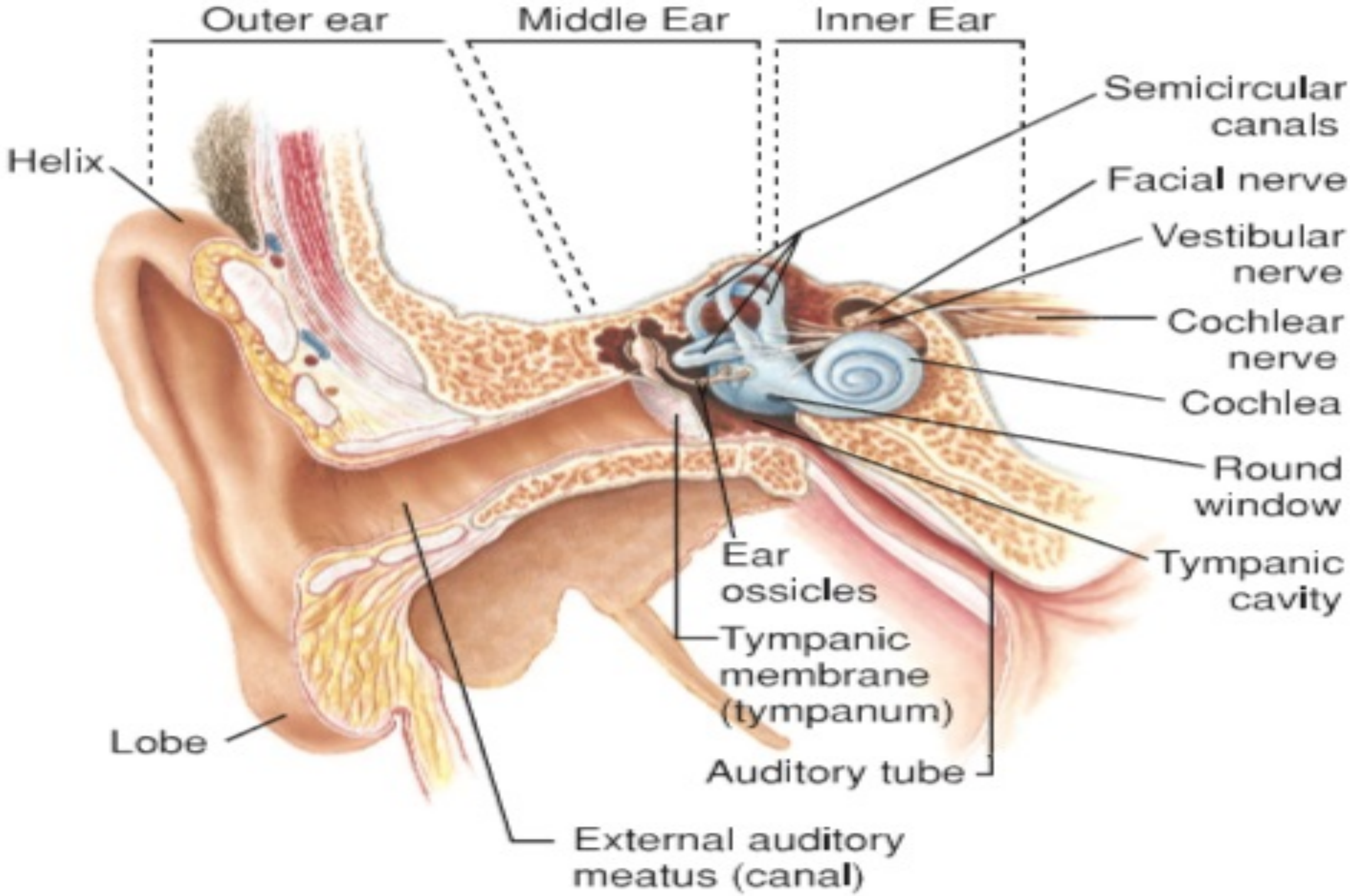

Fig: Anatomy of the Human Ear. Note the outer, middle, and inner regions. The inner ear includes the semicircular canals, which are involved with equilibrium, and the cochlea, which is involved with hearing.

Sense of equilibrium (balance)

Static equilibrium

- refers to sensing movement in one plane (either vertical or horizontal).
- When the body is still, the otoliths in the semicircular canals rest on hair cells

Dynamic equilibrium

- When the head or body moves horizontally, or vertically, the granules are displaced, causing the gelatinous material to sag.
- This displacement bends the hairs slightly so that hair cells initiate a generator potential and then an action potential

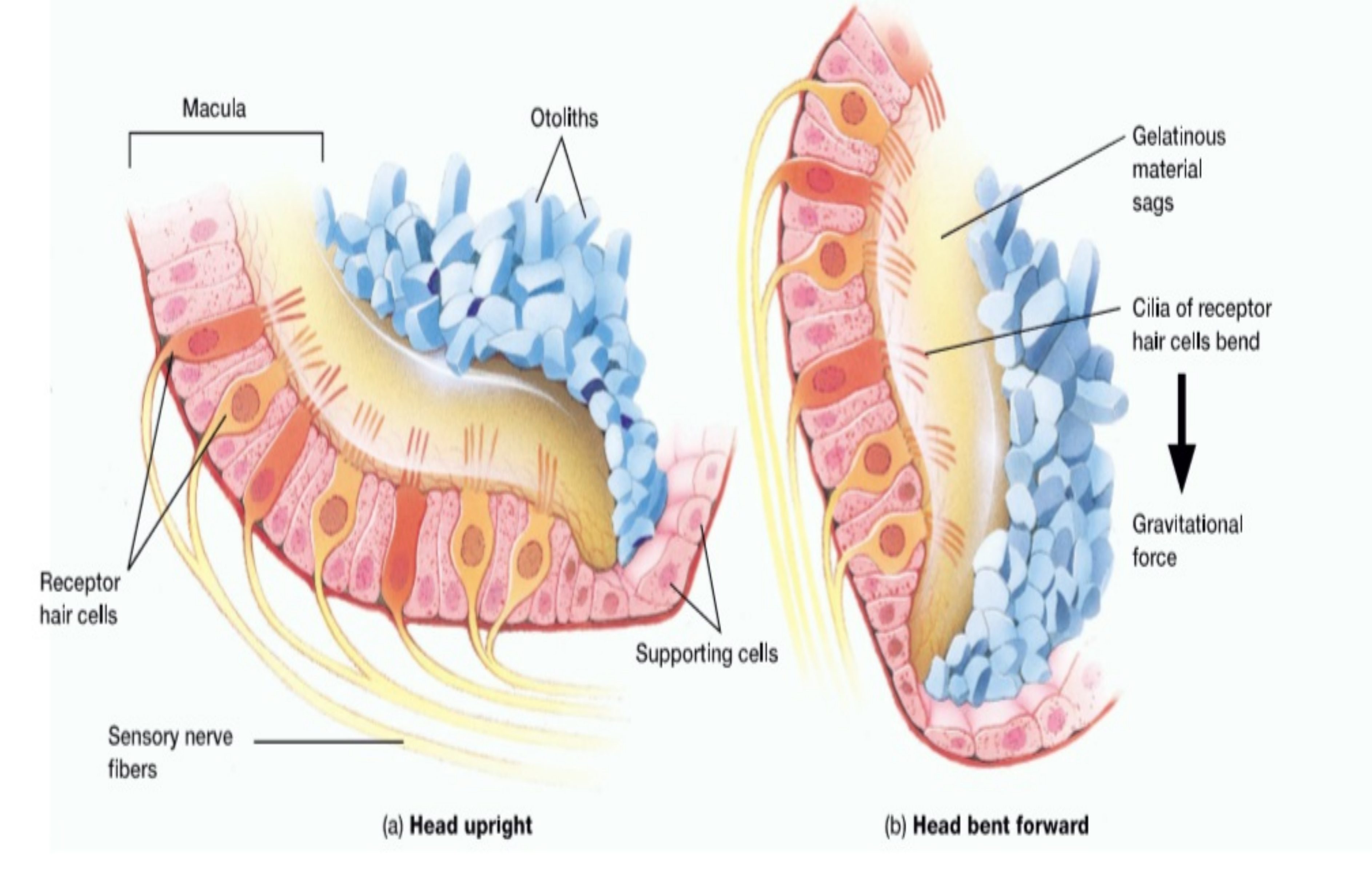

Fig: Static Equilibrium (Balance). Receptor hair cells in the utricle and saccule respond to sideways or up or down movement. (a) When the head is upright, otoliths are balanced directly over the cilia of receptor hair cells. (b) When the head bends forward, the otoliths shift, and the cilia of hair cells bend. This bending of hairs initiates a generator potential.

2) HEARING AND EQUILIBRIUM IN WATER:

In bony fishes,

- ✓ receptors for equilibrium, balance, and hearing are in the inner ear, and their functions are similar to those of other vertebrates.
- ✓ For example, semicircular canals detect rotational movements, and other sensory patches help with equilibrium and balance by detecting the direction of gravitational pull.
- ✓ Since fishes lack the outer and/or middle ear so, vibrations pass from the water through the bones of the skull to the inner ear.
- ✓ A few fishes have chains of bony ossicles (modifications of vertebrae) that pass between the swim bladder and the back of the skull.

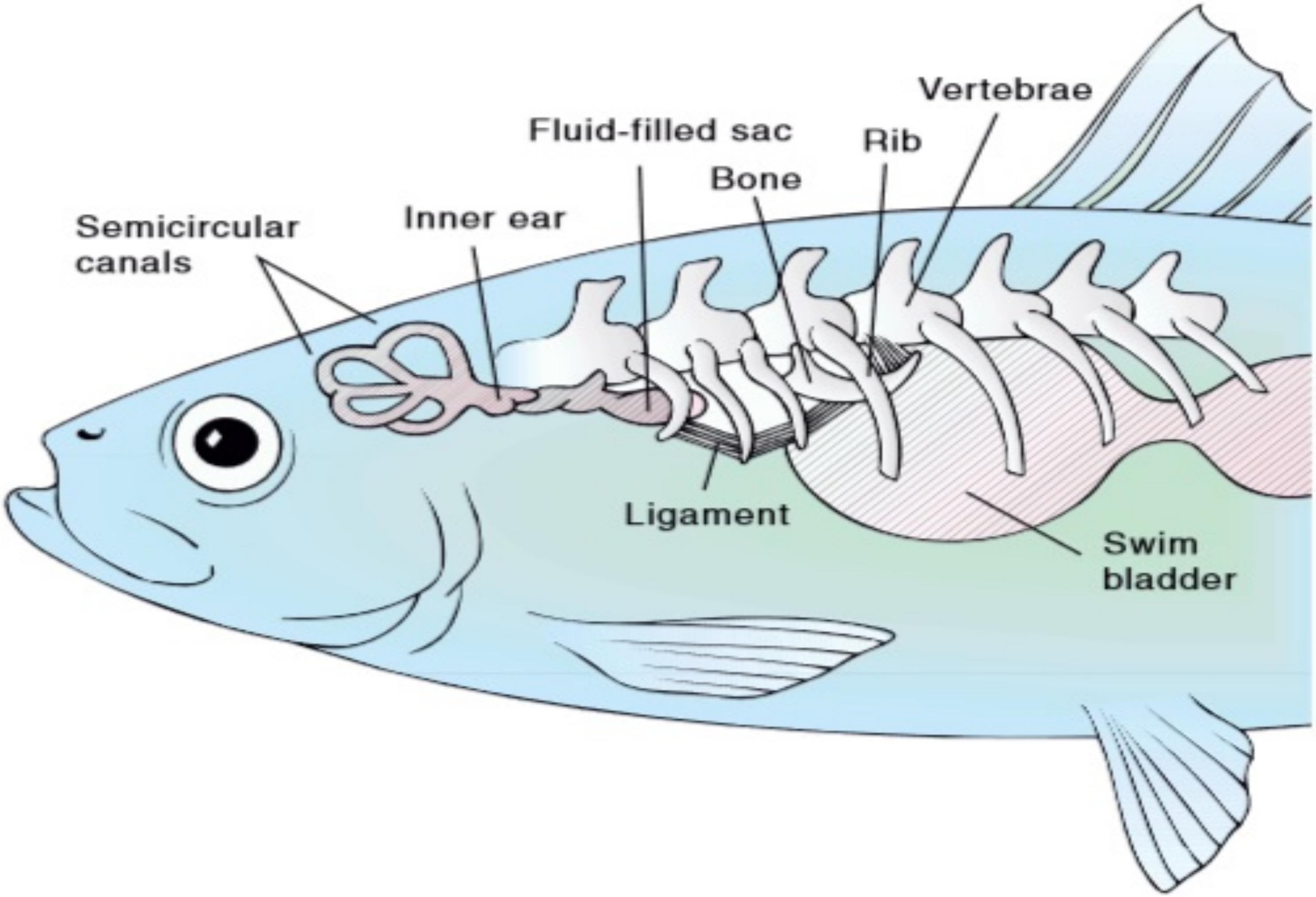

Fig: Inner Ear of a Bony Fish. Sound waves that enter the pharynx are transmitted to gas in the swim bladder, causing it to expand and contract at frequencies and amplitudes corresponding to the incoming sound waves. Contacting the swim bladder is a bone that is suspended by ligaments and vibrates at the same frequency. The vibrations pass forward along a chain of bones (ossicles) and then to a fluid-filled sac connected directly to the inner ear.

SKIN SENSORS OF MECHANICAL STIMULI

i. SONAR
ii. SMELL
iii. TASTE
iv. VISION

SKIN SENSORS OF MECHANICAL STIMULI:

Mechanical sensory receptors in vertebrate skin detect stimuli that the brain interprets as light touch, touch-pressure, and vibration.

Receptors

bare sensory nerve endings and tactile (Meissner's) corpuscles.

- ✓ involved with pain and thermal stimuli, as well as light touch.

bulbs of Krause

- ✓ found in the dermis
- ✓ respond to some physical stimuli, such as position changes

Pacinian corpuscles

receptors for touch-pressure

organs of Ruffini

receptors for touch-pressure

Vibrissae

- ✓ specially adapted sensory hairs
- ✓ on their wrists, snouts, and eyebrows

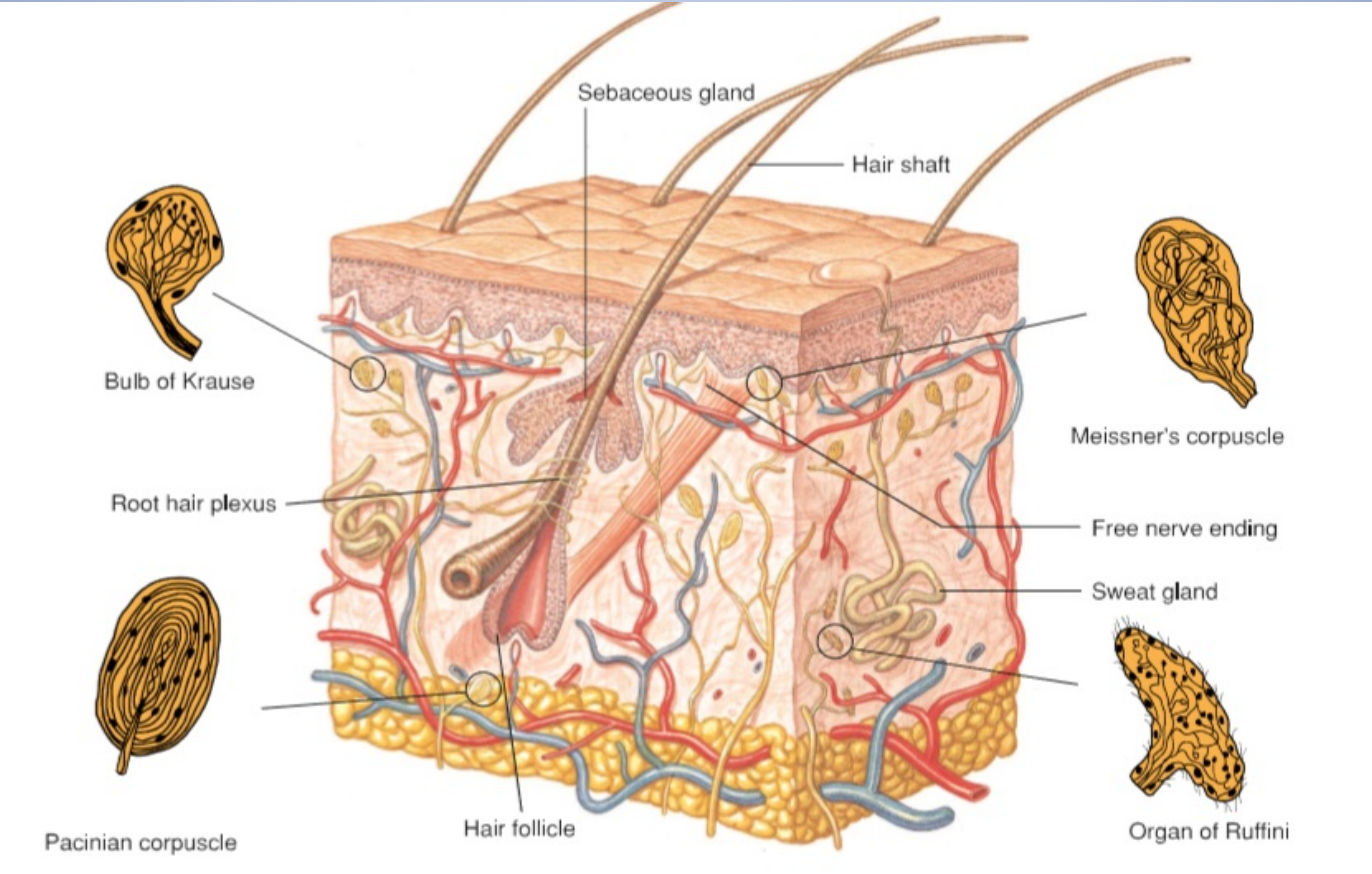

Fig: Different Sensory Receptors to Mechanical Stimuli. Sensory receptors in the skin for light touch (Meissner's corpuscles), touch-pressure (organs of Ruffini and Pacinian corpuscles), position (bulbs of Krause), and pain (free nerve endings).

i) SONAR

Bats, shrews, several cave-dwelling birds (oilbird, cave swift-let), whales, and dolphins can determine distance and depth by a form of echolocation called sonar (bio-sonar).

- ✓ These animals emit high-frequency sounds and then determine how long it takes for the sounds to return after bouncing off objects in the environment.
- ✓ For example, some bats emit clicks that last from 2 to 3 milliseconds and are repeated several hundred times per second.
- ✓ The returning echo created when a moth or other insect flies past the bat can provide enough information for the bat to locate and catch its prey.

ii) SMELL

- The sense of smell, or olfaction is due to olfactory neurons (receptor cells) in the roof of the vertebrate nasal cavity.
- odor molecules physically interact with protein receptors on the receptor-plasma membrane.
- Such an interaction somehow alters membrane permeability and leads to a generator potential.

In most fishes

- ✓ openings (external nares) in the snout lead to the olfactory receptors. Some fishes rely heavily on their sense of smell

For example

- ✓ **salmon and lampreys** return to spawn in the same streams in which they hatched years earlier are guided by the fishes' perception of characteristic odors of their spawning stream

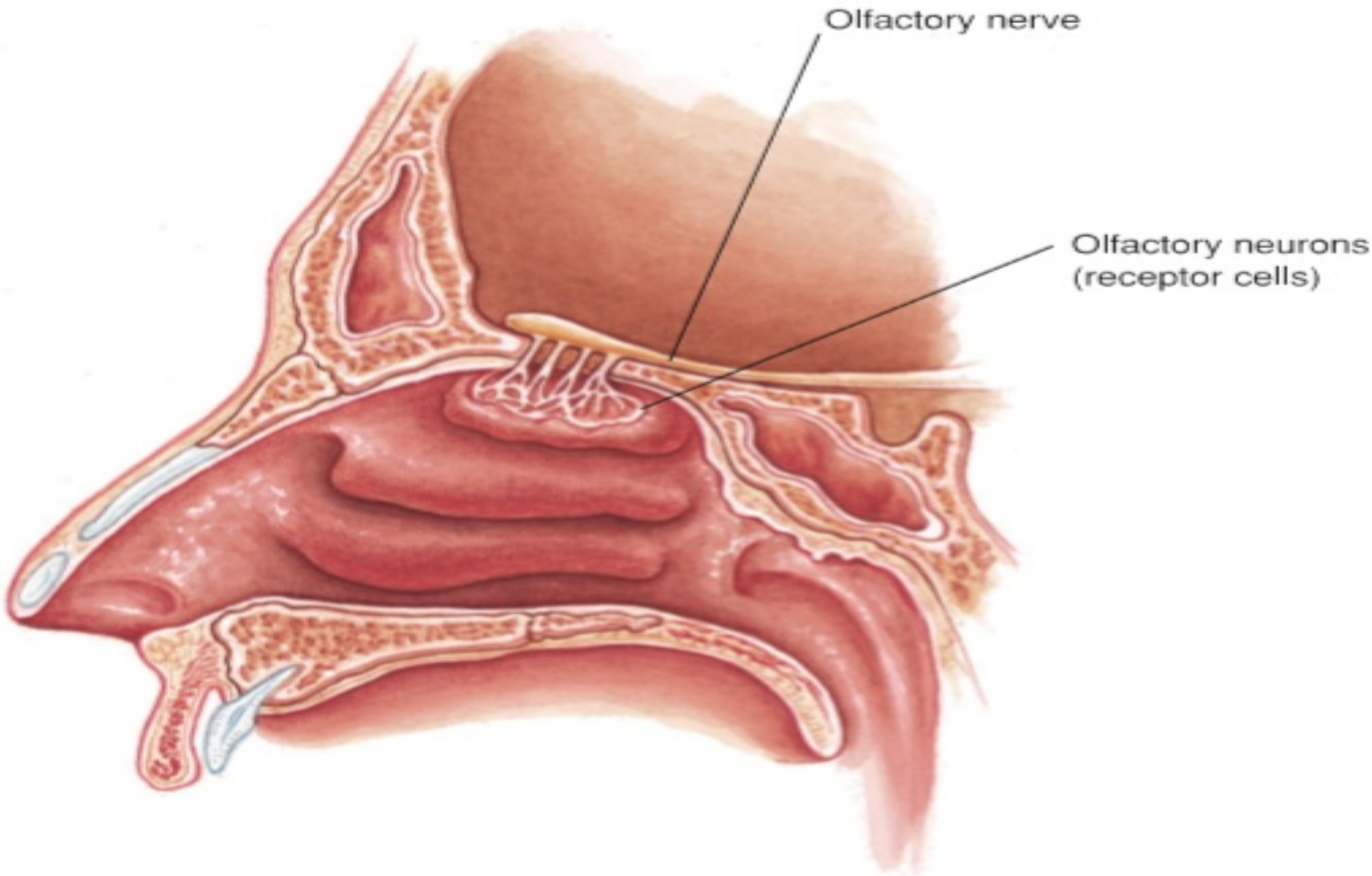

Fig: Smell. Position of olfactory receptors in a human nasal passageway. Columnar epithelial cells support the receptor cells, which have hair like processes (analogous to dendrites) projecting into the nasal cavity. When chemicals in the air stimulate these receptor cells, the olfactory nerves conduct nerve impulses to the brain.

In Amphibians

- ✓ It is used in mate recognition
- ✓ in detecting noxious chemicals
- ✓ locating food.

In reptiles

most reptiles (except crocodilians) possess blind-ending pouches that open into the mouth. These pouches, called **Jacobson's (vomeronasal) organs.**

Examples:

- ✓ A **snake**'s tongue flicks out and then moves to the Jacobson's organs, which perceive odor molecules.
- ✓ **Turtles and the tuatara** use Jacobson's organs to taste objects held in the mouth.

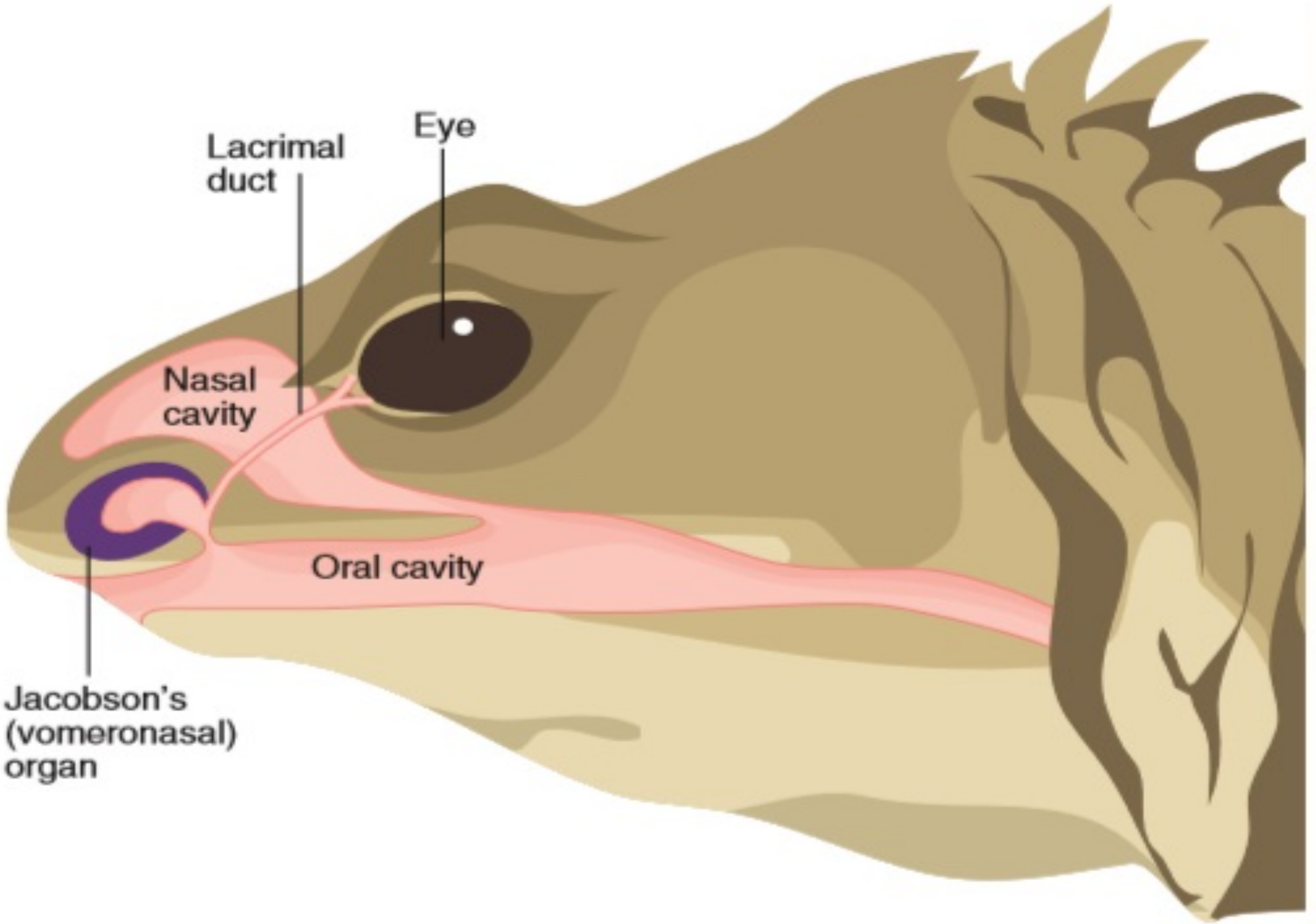

Fig: Smell. Anatomic relationships of Jacobson's (vomeronasal) organ in a generalized lizard. Only the left organ alongside the nasal cavity is shown. Jacobson's organ is a spherical structure, with the ventral side invaginated into a sphere the shape of a mushroom. A narrow duct connects the interior of Jacobson's organ to the oral cavity. In many lizards, fluid draining from the eye via the lacrimal duct may bring odoriferous molecules into contact with the sensory epithelium of Jacobson's organ.