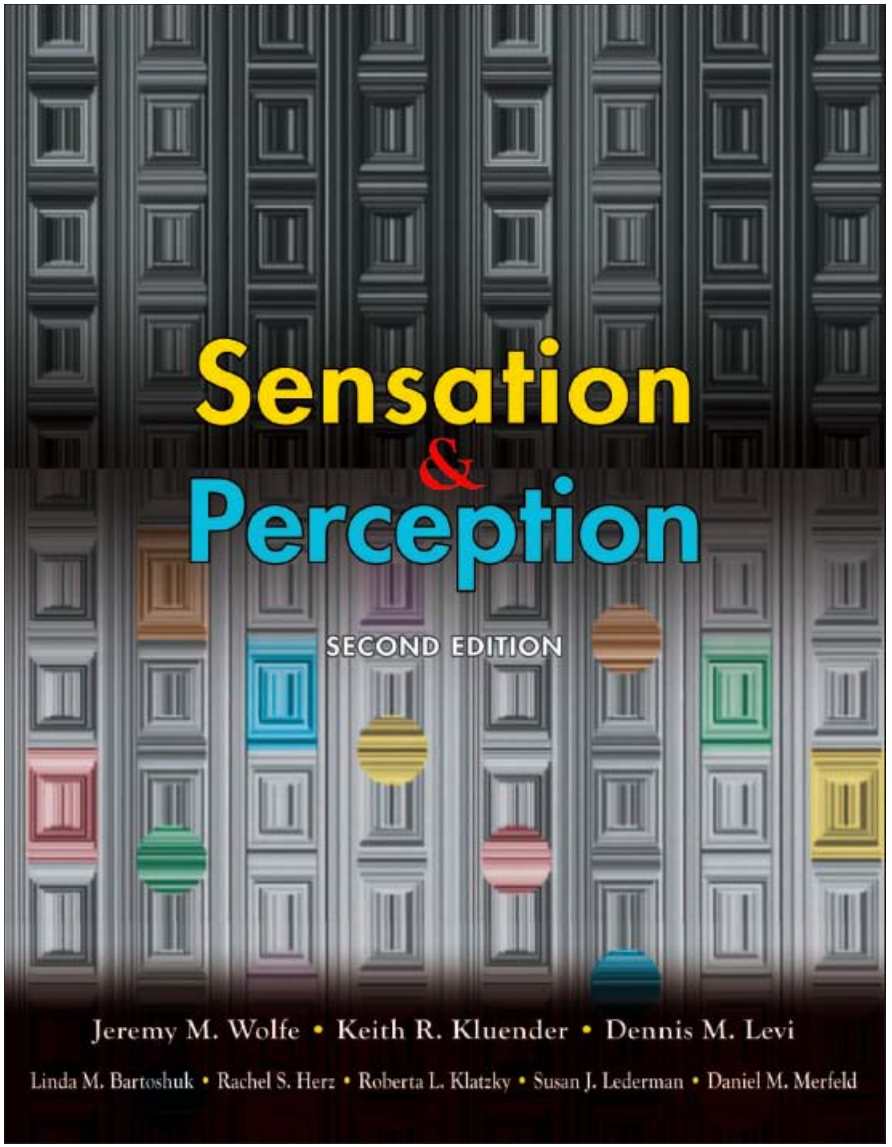


Wolfe, JM, Kluender, KR, Levi, DM, Bartoshuk, LM, Herz, RS, Klatzky, RL, Lederman, SJ, Merfeld, DM (2008). Sensation and Perception, Second edition. Sinauer Associates, Inc. Sunderland MA.

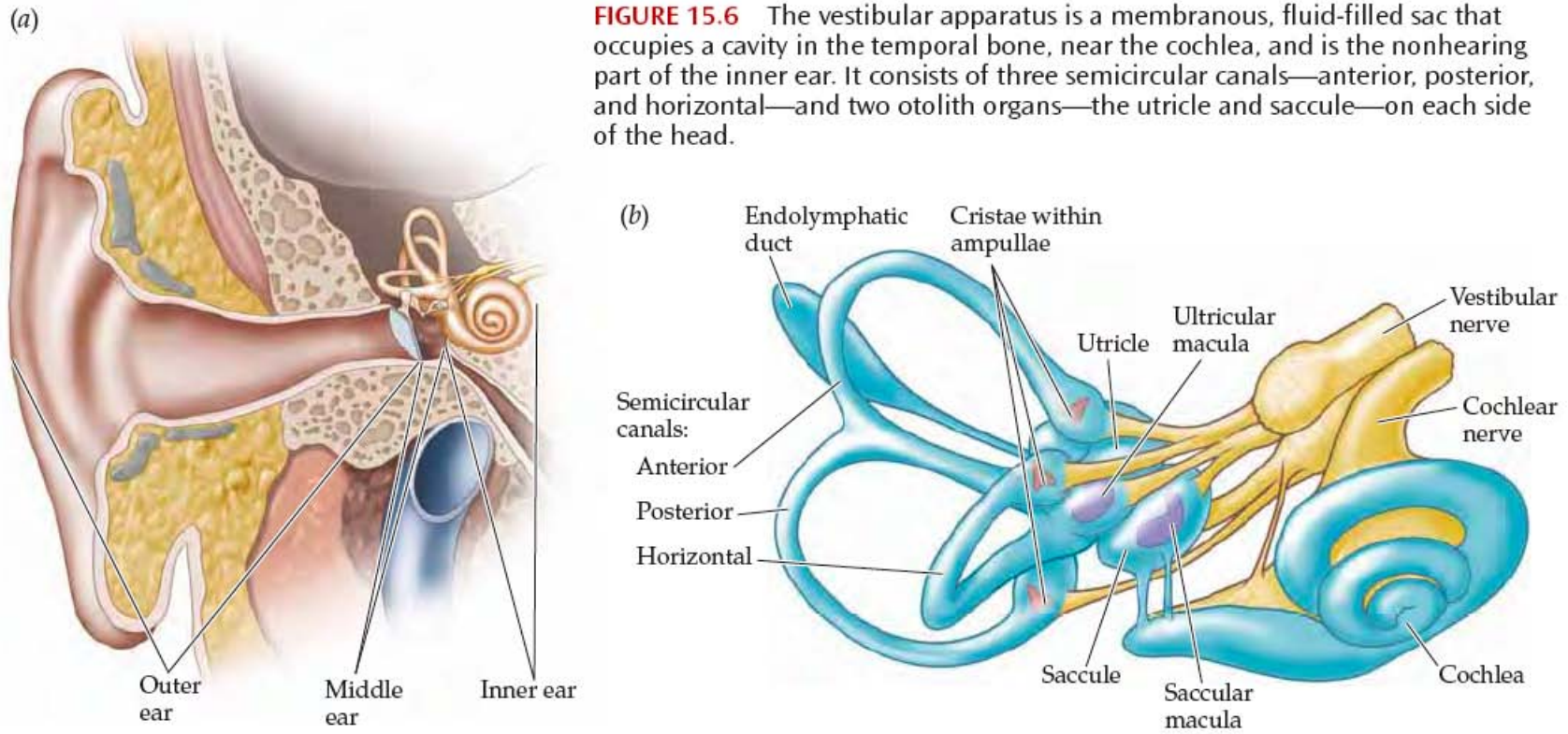


FIGURE 15.6 The vestibular apparatus is a membranous, fluid-filled sac that occupies a cavity in the temporal bone, near the cochlea, and is the nonhearing part of the inner ear. It consists of three semicircular canals—anterior, posterior, and horizontal—and two otolith organs—the utricle and saccule—on each side of the head.

From: Wolfe, JM, Kluender, KR, Levi, DM, Bartoshuk, LM, Herz, RS, Klatzky, RL, Lederman, SJ, Merfeld, DM (2008). Sensation and Perception, Second edition. Sinauer Associates, Inc. Sunderland MA.

Hair Cells

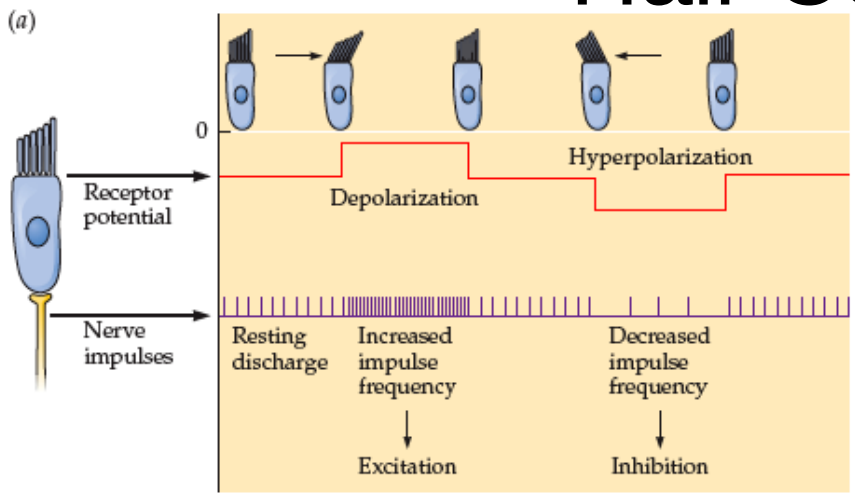
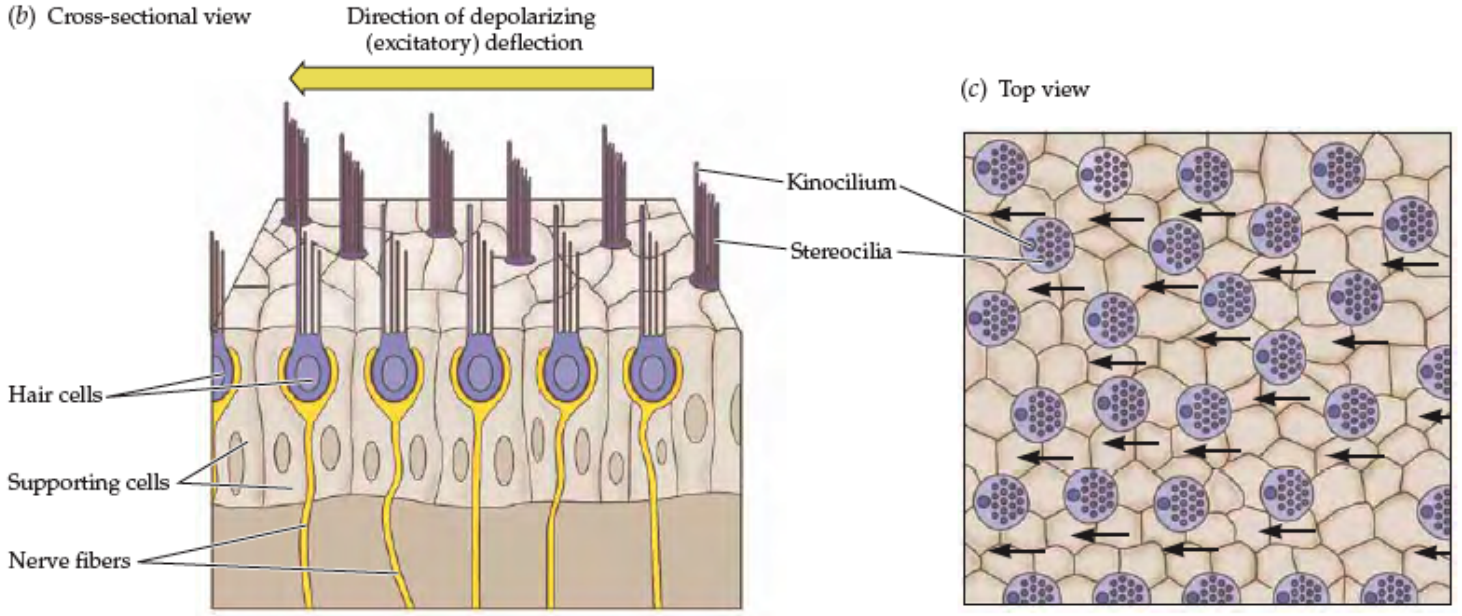
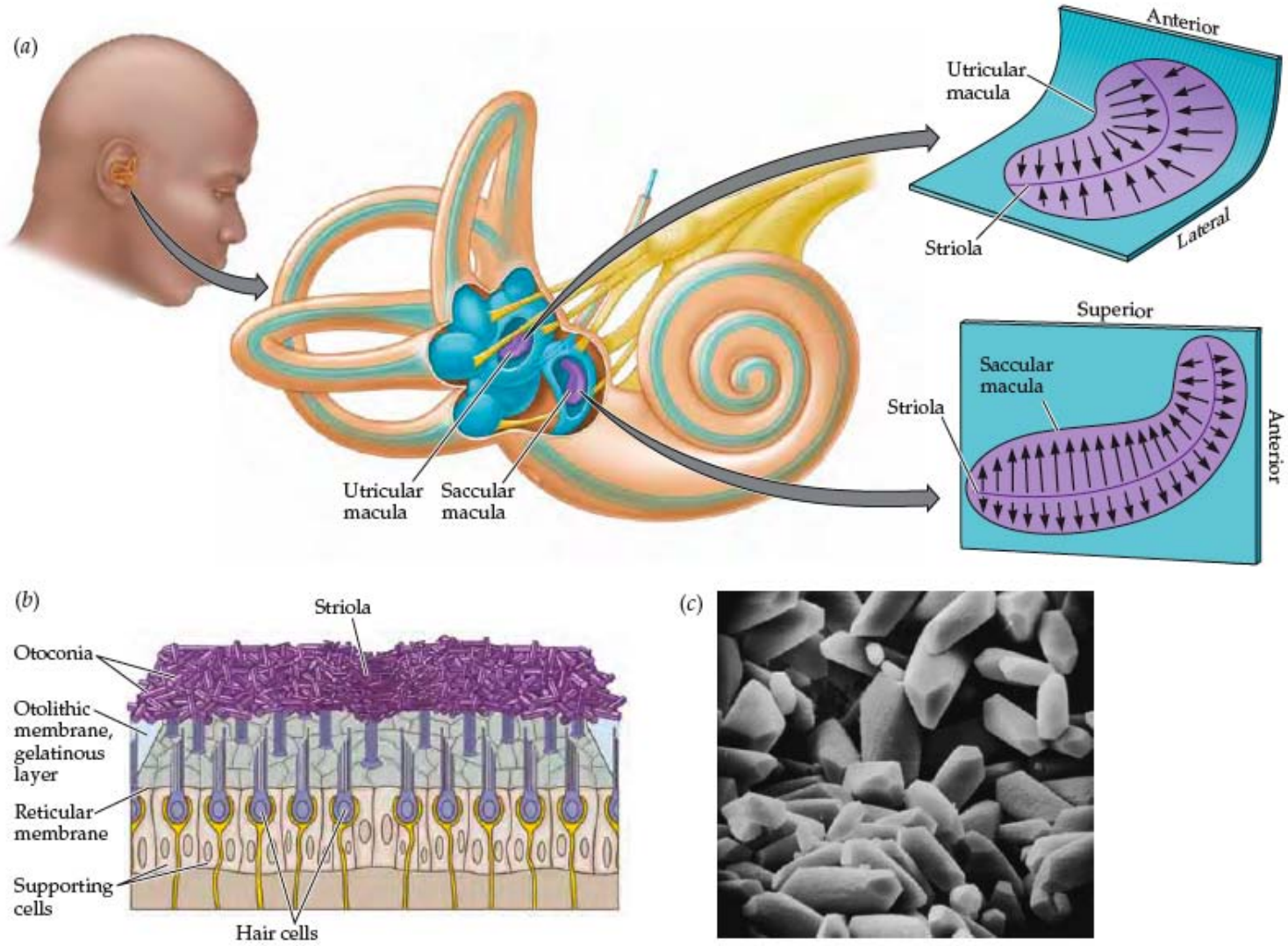


FIGURE 15.7 Hair cell responses. (*a*) In the absence of stimulation, the hair cells have a negative voltage and release neurotransmitter at a constant rate, evoking a constant rate of action potentials in the afferent nerves. When hair cell stereocilia bend toward the kinocilium and the tallest stereocilia, the hair cell voltage becomes less negative (depolarizes). When the stereocilia bend away from the kinocilium, the voltage becomes more negative (hyperpolarizes). These voltage changes control the rate at which hair cells release neurotransmitter. (*b*) A cross-sectional view of a hair cell array, showing the direction of deflection that causes depolarization. (*c*) A top view of a hair cell array.



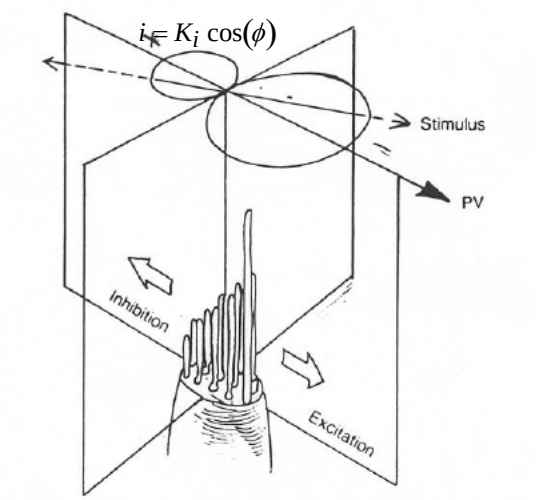
From: Wolfe, JM, Kluender, KR, Levi, DM, Bartoshuk, LM, Herz, RS, Klatzky, RL, Lederman, SJ, Merfeld, DM (2008). Sensation and Perception, Second edition. Sinauer Associates, Inc. Sunderland MA.

Otolith Organs



From: Wolfe, JM, Kluender, KR, Levi, DM, Bartoshuk, LM, Herz, RS, Klatzky, RL, Lederman, SJ, Merfeld, DM (2008). Sensation and Perception, Second edition. Sinauer Associates, Inc. Sunderland MA.

$i = K_i \cos(\phi)$



ϕ

$e = K_e \cos(\phi)$

Figure 110-6. The directional sensitivity of the hair cell approximates a cosine function of stimulus direction; the output varies as the cosine of the angle between the direction of maximum sensitivity and the applied displacement. (Adapted from Loewenstein WR. Handbook of sensor physiology. Vol 1. Principles of receptor physiology. New York: Springer Verlag, 1971:415.)

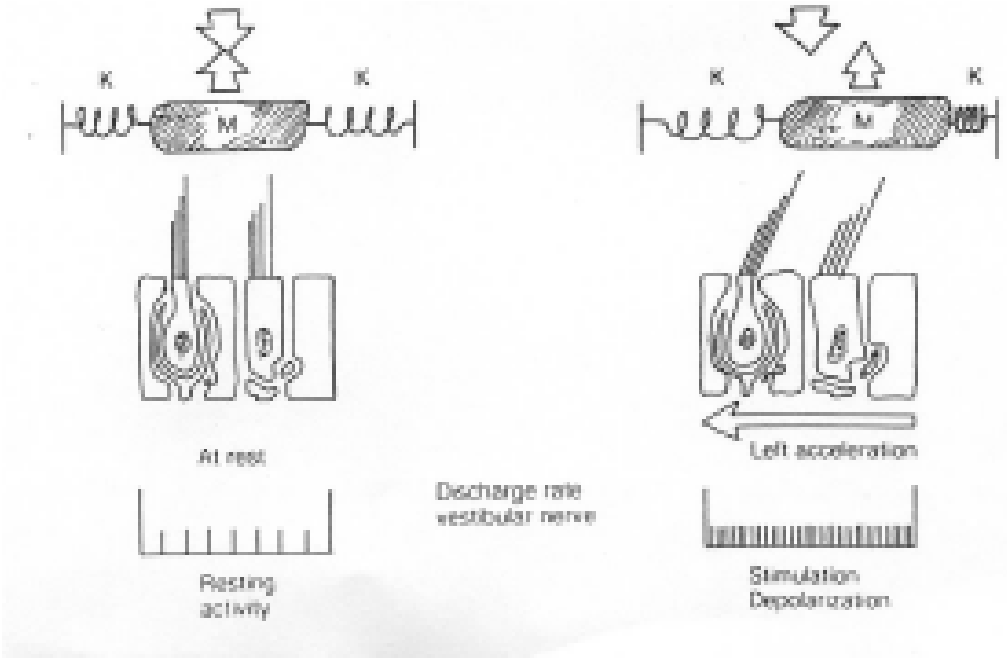


Figure 110-3. Elementary model of vestibular motion sensor. (A) The head is at rest. (B) The head is accelerating to the left. The seismic mass (M) is suspended by two restoring spring forces (K). Acceleration to the left displaces the mass to the right relative to the hair cells. This increases the discharge rate of the afferent fibers attached to them.

Semicircular Canals

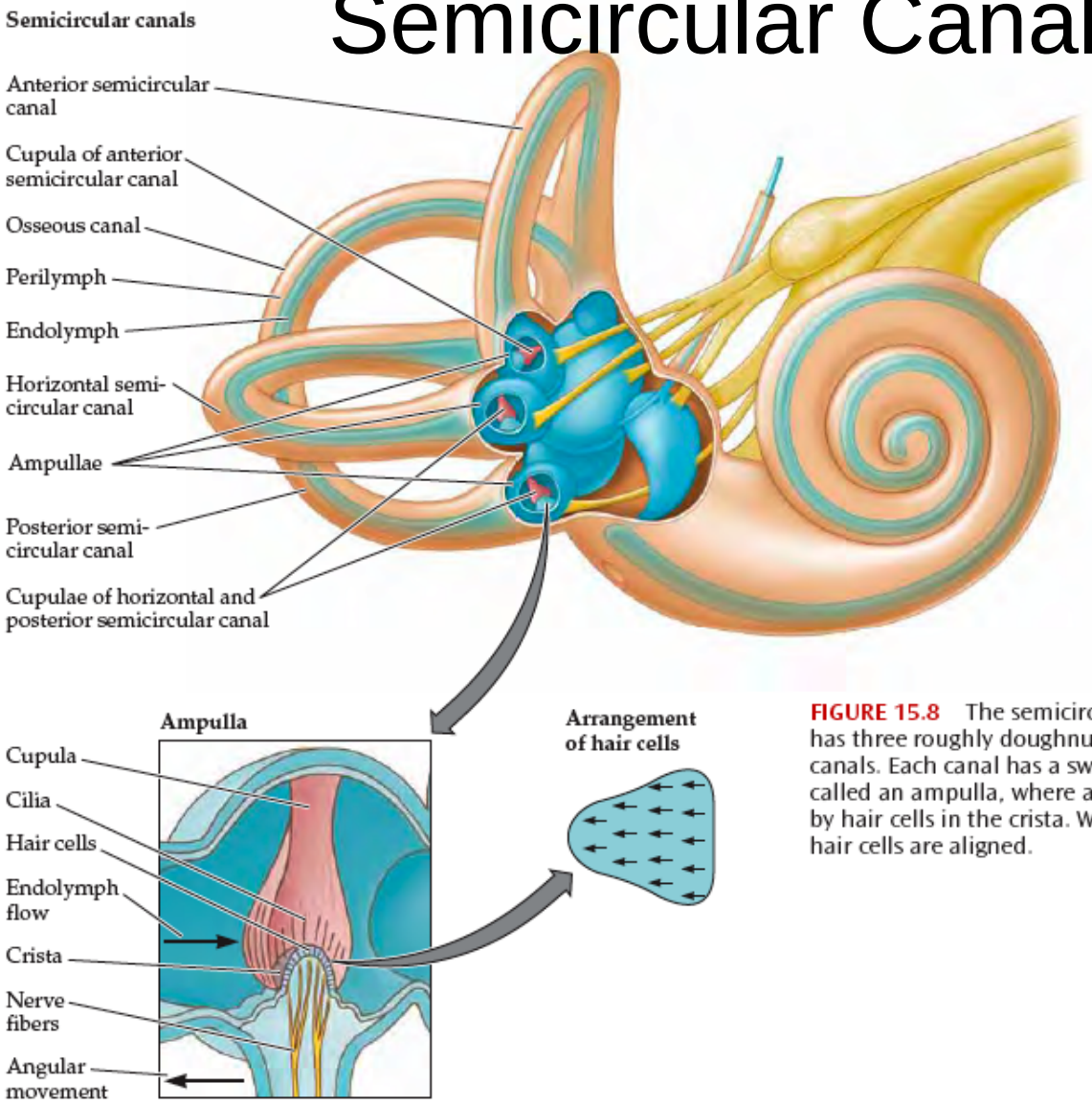
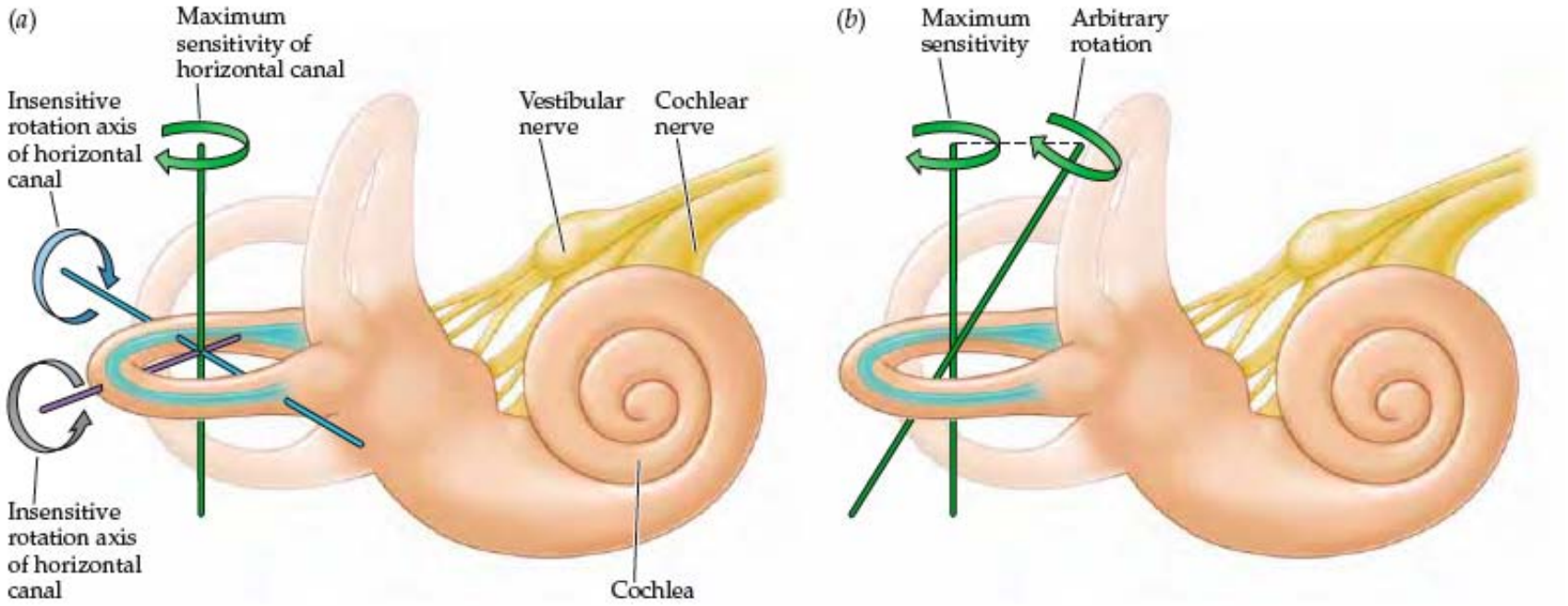


FIGURE 15.8 The semicircular canals. The inner ear has three roughly doughnut-shaped semicircular canals. Each canal has a swelling near the vestibule called an ampulla, where angular motion is detected by hair cells in the crista. Within each crista, all of the hair cells are aligned.

From: Wolfe, JM, Kluender, KR, Levi, DM, Bartoshuk, LM, Herz, RS, Klatzky, RL, Lederman, SJ, Merfeld, DM (2008). Sensation and Perception, Second edition. Sinauer Associates, Inc. Sunderland MA.



From: Wolfe, JM, Kluender, KR, Levi, DM, Bartoshuk, LM, Herz, RS, Klatzky, RL, Lederman, SJ, Merfeld, DM (2008). Sensation and Perception, Second edition. Sinauer Associates, Inc. Sunderland MA.

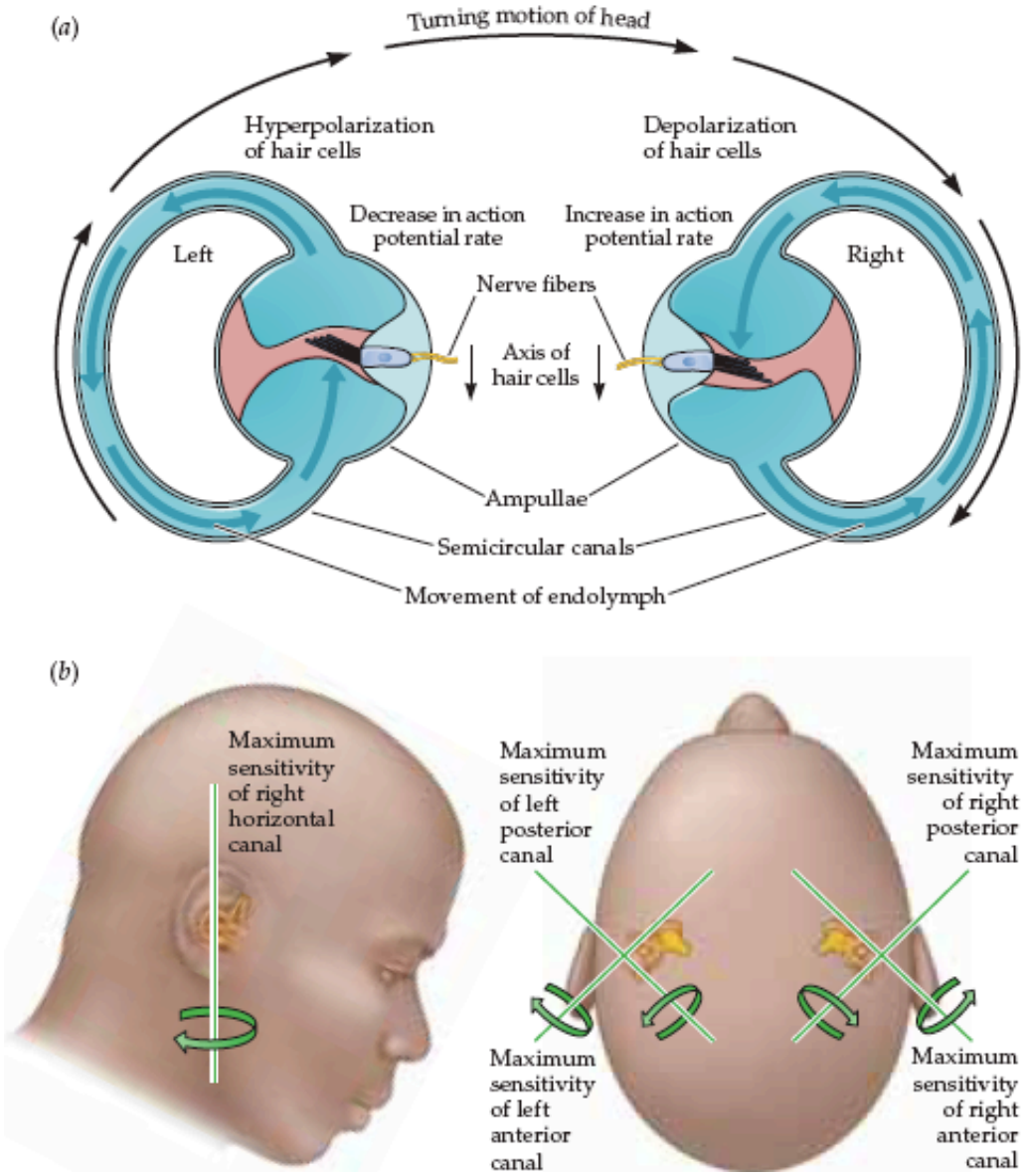


FIGURE 15.10 The semicircular canals function in pairs that have a push–pull relationship. (*a*) Bilateral stimulation of the horizontal semicircular canals as the head turns to the right (a yaw head rotation as shown in Figure 15.3*c*, but in the opposite direction). This yaw rotation produces relative movement of the endolymph in the horizontal semicircular canals on both sides of the head. The movement of the fluid bends the hair cells toward the tallest stereocilia on the right side, which depolarizes these hair cells and increases the rate of action potentials for neurons from the right side. The hair cells move away from the tallest stereocilia on the left, hyperpolarizing the hair cell voltage and decreasing the rate of action potentials for left-side neurons. This response—an increase on one side coupled with a response decrease on the other side—is often called a "push–pull response." (*b*) Arrangement of the canals in functional push–pull pairs. The two horizontal canals form one pair. The right anterior canal and the left posterior canal form another pair. Note that the maximum-sensitivity axes for the right anterior and left posterior canals are parallel. This means that they maximally respond to rotations around the same axis. The push–pull nature of this canal pair is a consequence of the opposite directions of their maximum-sensitivity rotations, as shown by the green arrows. The left anterior canal and the right posterior canal also form a similar push–pull canal pair.

From: Wolfe, JM, Kluender, KR, Levi, DM, Bartoshuk, LM, Herz, RS, Klatzky, RL, Lederman, SJ, Merfeld, DM (2008). Sensation and Perception, Second edition. Sinauer Associates, Inc. Sunderland MA.

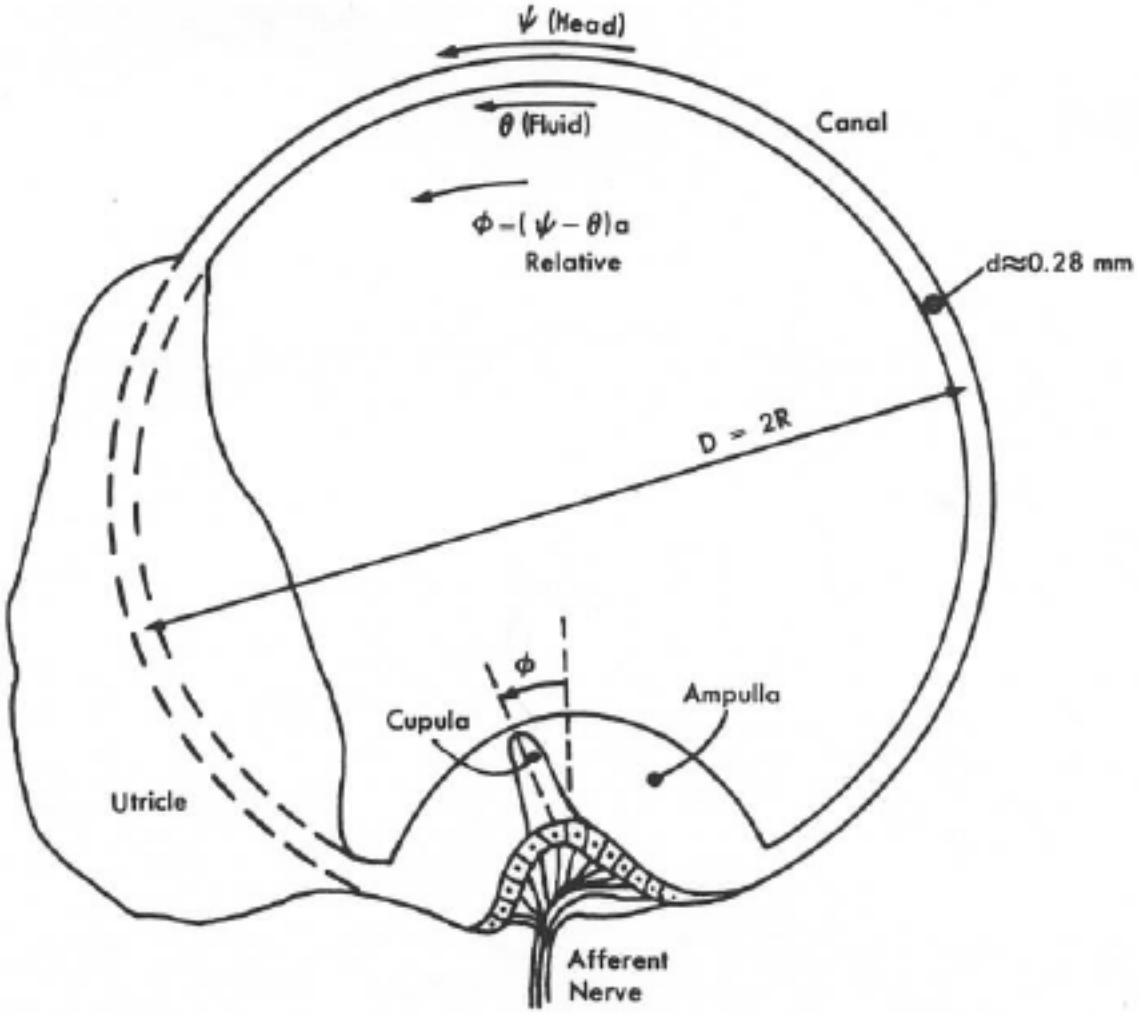
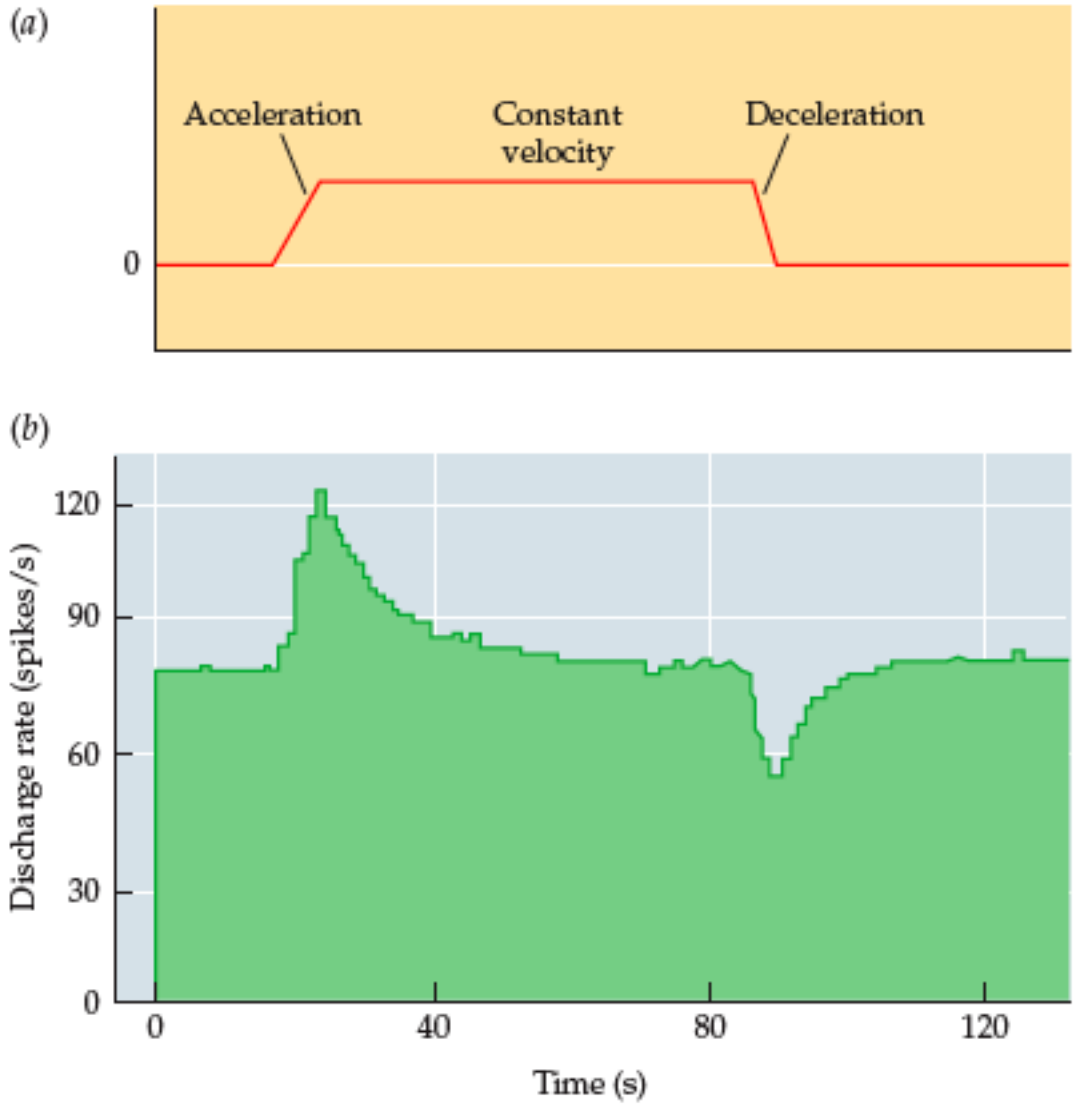


FIG. 8.5 The semicircular canal (diagrammatic). *(From Jones and Milsum.)*



From: Wolfe, JM, Kluender, KR, Levi, DM, Bartoshuk, LM, Herz, RS, Klatzky, RL, Lederman, SJ, Merfeld, DM (2008). Sensation and Perception, Second edition. Sinauer Associates, Inc. Sunderland MA.

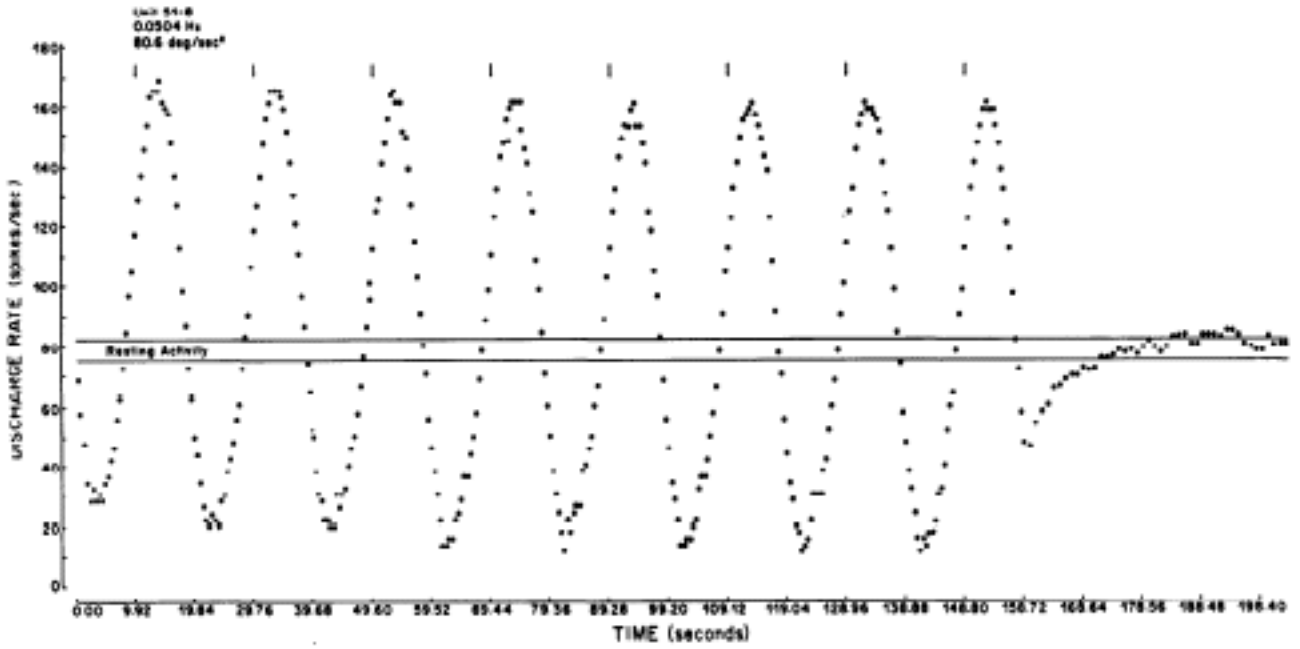
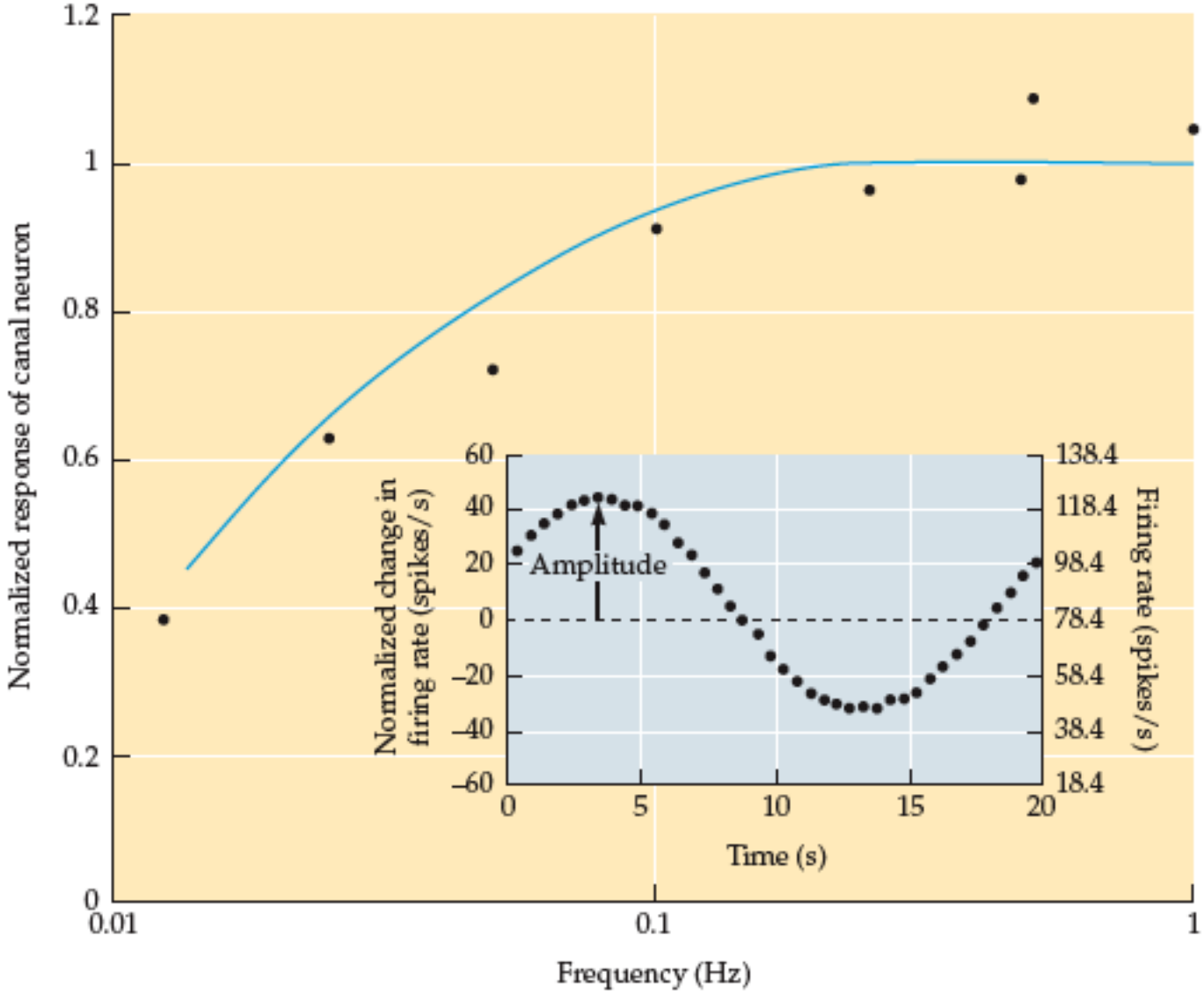


FIG. 1. Response of unit *51–8* (superior canal) to 8 cycles of a sinusoidal stimulus, 0.0504 Hz, 80.6°/sec². Stimulus ends at 185.72 sec. Each point, average discharge rate for $\frac{1}{40}$th of sine-wave cycle (0.496 sec). Vertical marks, instants of peak excitatory acceleration. Lower and upper horizontal lines, respectively, resting discharge before and after stimulation.

From: Fernandez, C. and J. Goldberg, Physiology of peripheral neurons innervating semicircular canals of the squirrel monkey. II. Response to sinusoidal stimulation and dynamics of peripheral vestibular system. J. Neurophysiology, 1971. 34: p. 661-675.



From: Wolfe, JM, Kluender, KR, Levi, DM, Bartoshuk, LM, Herz, RS, Klatzky, RL, Lederman, SJ, Merfeld, DM (2008). Sensation and Perception, Second edition. Sinauer Associates, Inc. Sunderland MA.

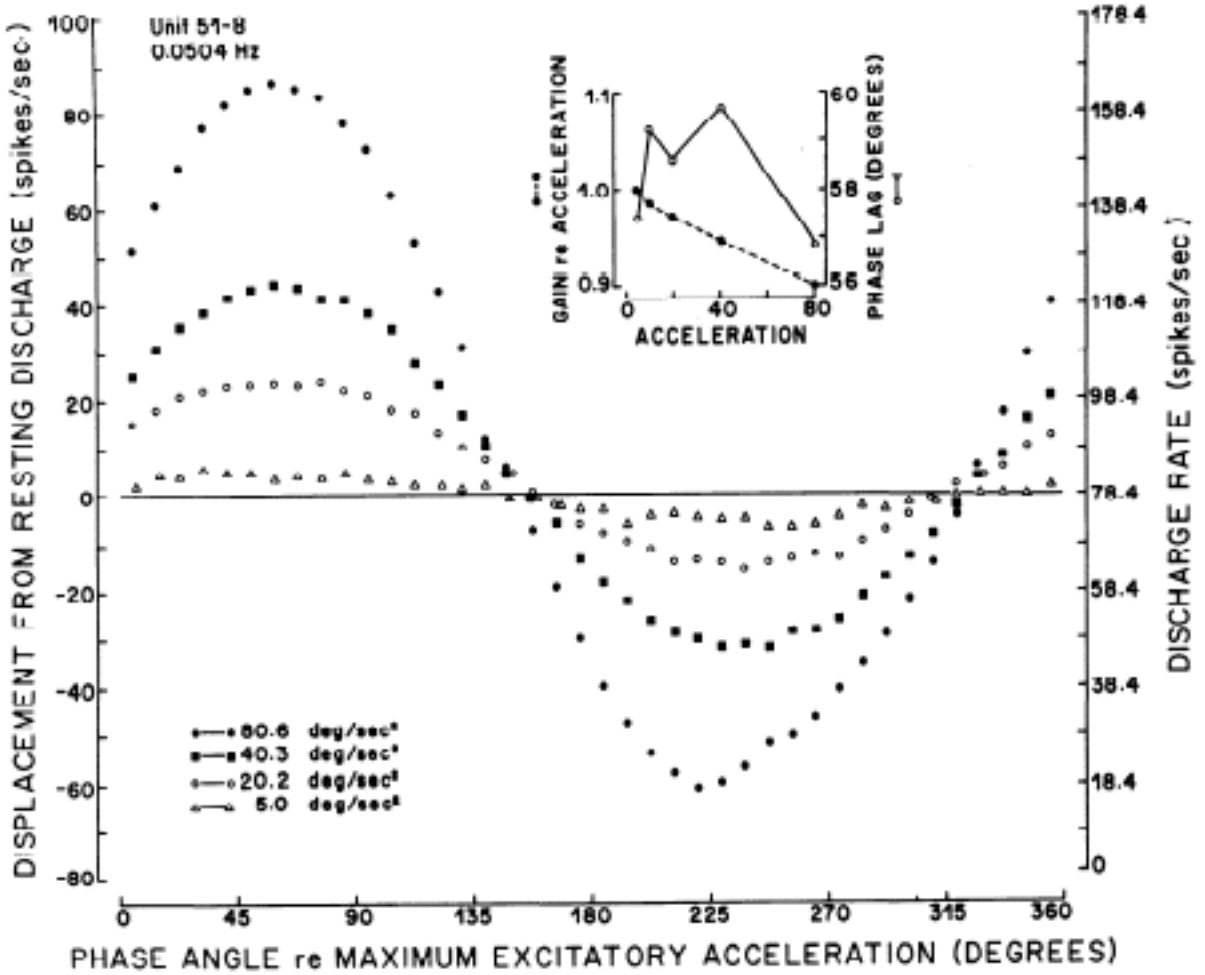


FIG. 2. Steady-state responses of unit *51-8* (superior canal) to series of 0.0504-Hz sine waves. See key for accelerations. Zero degrees, peak excitatory acceleration. Inset plots gain and phase as functions of acceleration; included are points for one acceleration (10.1°/sec²) not shown in main graph.

semicircular canals of the squirrel monkey. II. Response to sinusoidal stimulation and dynamics of peripheral vestibular system. J. Neurophysiology, 1971. 34: p. 661-675.

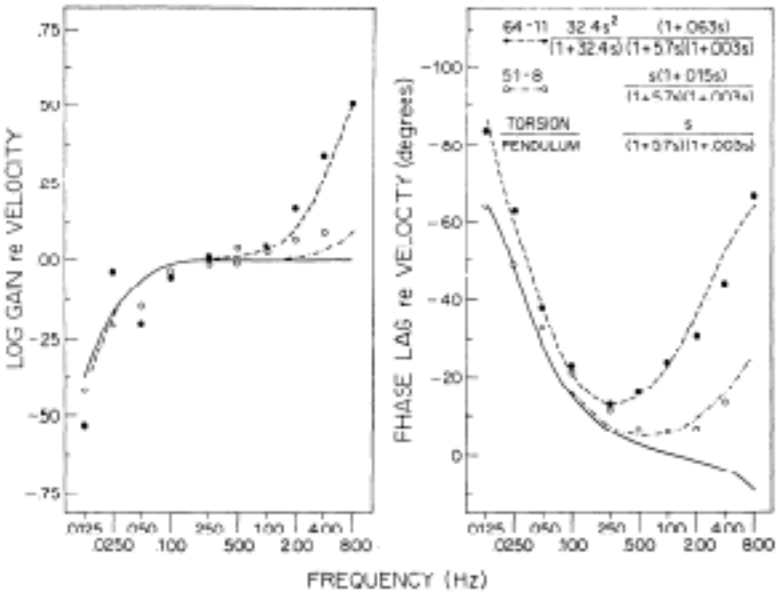


FIG. 12. Bode plots (re velocity) for two units. Data replotted from Fig. 5.

From: Fernandez, C. and J. Goldberg, Physiology of peripheral neurons innervating semicircular canals of the squirrel monkey. II. Response to sinusoidal stimulation and dynamics of peripheral vestibular system. J. Neurophysiology, 1971. 34: p. 661-675.