Chapter 50: Sensory and Motor Mechanisms

50.1 Describe the overall process by which specialized receptors convert sensory input into nervous system signals.

50.2 Discuss the common role of mechanoreceptors in detecting vibration, movement, and body position.

50.3 Outline how the human eye transduces light energy to the brain as visual information.

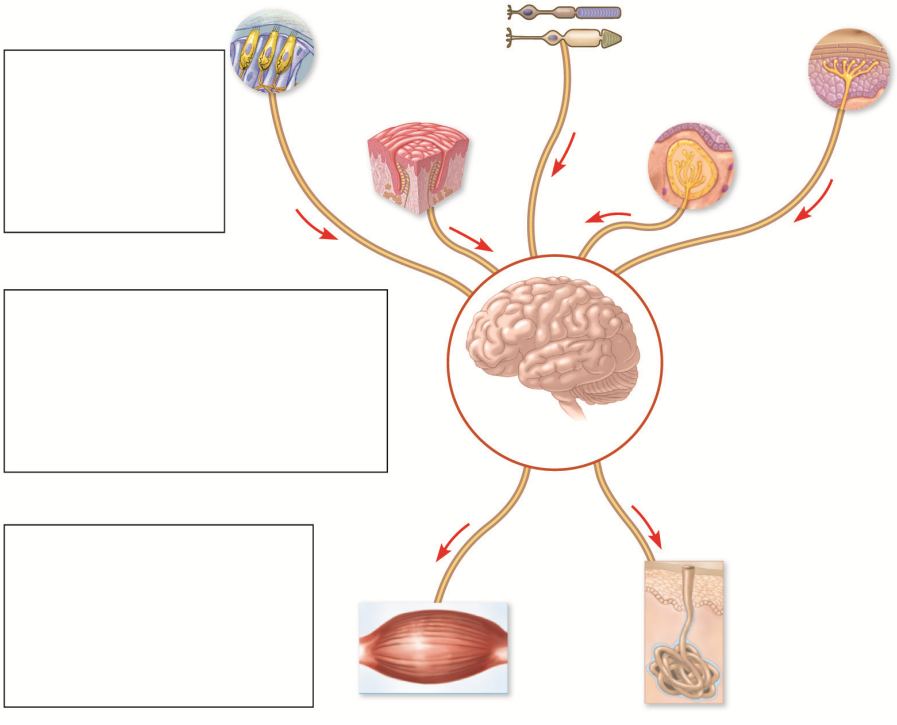
50.4 Use examples to illustrate how the human sensory system distinguishes different tastes and smells.

50.5 Explain how the interaction and movement of filaments provides the basis for muscle contraction.

50.6 Compare and contrast the structure and function of internal and external skeletal systems.

This chapter deals with how specialized cells receive sensory information, process these signals and respond. Processing occurs within the central nervous system, and responses include movement of muscles and secretion by glands. What causes muscle contraction? Nerve cells transmit a signal to muscle cells at the synapse, which initiates changes within the muscle cells. You will learn both the anatomy of different types of sense organs and muscles, and how these organs detect and respond to stimuli.

Study Tip: Label the five receptor types shown in Figure 50.1 and then describe the three steps that link sensory stimuli to animal activity in the boxes that are provided.



Concept 50.1 Sensory receptors transduce stimulus energy and transmit signals to the central nervous system

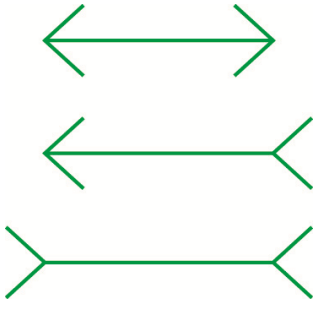
LO 50.1: Describe the overall process by which specialized receptors convert sensory input into nervous system signals.

1. In Chapter 49, you labeled a reflex pathway, including *receptors*. This is the simplest type of reflex as there was no further processing in the brain involved in the response. However, many (most?) sensory pathways involve brain circuits that can lead to varied responses. They all begin with *sensory reception* by specialized receptor cells. Some receptors are within the body (pressure receptors in the gut detect bloating) while other detect stimuli from outside the body such as light. What occurs at the cellular level with all stimuli?

2. What is sensory transduction?

3. How does sensory information travel through the nervous system?

4. What is *perception*? Explain the difference between what you *see* and what you *perceive* when you see an optical illusion like this.



5. What occurs in *sensory adaptation*? Give one example of this that you have personally observed.

6. Here is a list of the different types of receptors. Explain each type and give two examples.

Receptor Type	How It Works	Examples
mechanoreceptors		
chemoreceptors		
electromagnetic receptors		
thermoreceptors		
pain receptors		

Concept 50.2 In hearing and equilibrium, mechanoreceptors detect moving fluid or settling particles

LO 50.2: Discuss the common role of mechanoreceptors in detecting vibration, movement, and body position.

7. What are *statoliths*?

8. Explain how *statocysts* function.

9. The ear has receptors for two senses: hearing and balance or equilibrium. What are the receptors (sensory cells) that detect sound waves?

10. In order to understand how sound waves are transduced, transmitted and processed in the brain, you need to have a basic understanding of the ear's anatomy. Label Figure 50.10 as indicated, and for each structure, give its function.

    outer ear

    tympanic membrane

    malleus, incus, and stapes

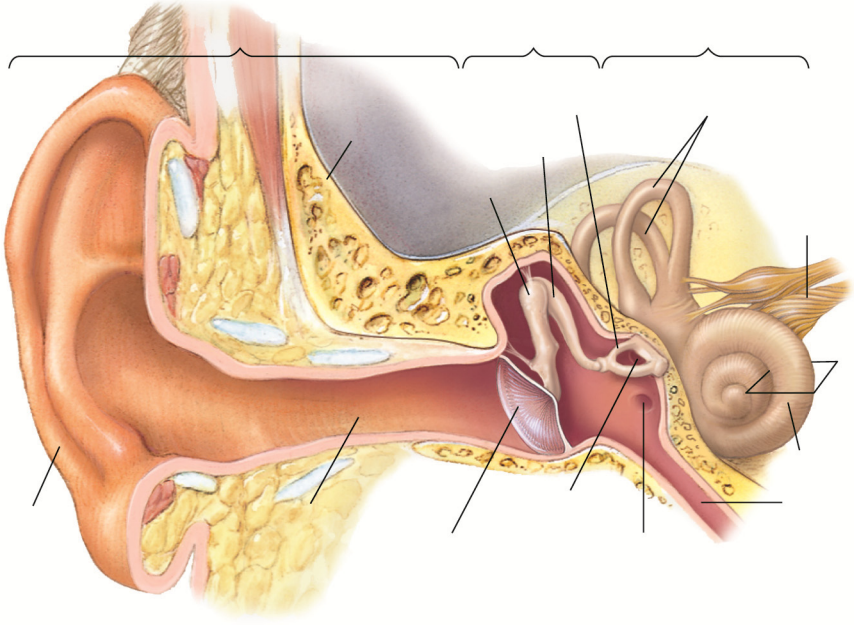
    eustachian tube

semicircular canals

cochlea

organ of Corti

auditory nerve



11. What structures are found within the *middle ear*? How is pressure in the middle ear equalized?

12. What two major structures are contained within the *inner ear*?

13. Explain how the ear is able to detect both the *volume* and the *pitch* of sounds.

14. Read the section on *Hearing*, p. 1114, very carefully. Refer to Figure 50.10 and your text to write a list of events. The first step is done for you, and prompts are given for the next events.

    a. Moving air waves cause the *tympanic membrane* to vibrate.

    b. Bones/*stapes*

    c. *Oval window*

    d. Fluid inside the *cochlea*

e. *Hair cells*/mechanoreceptors

f. *Round window*

15. The sense of equilibrium is centered in the inner ear. Explain how the three fluid-filled *semicircular canals* and *otoliths* allow you to detect motion in different planes.

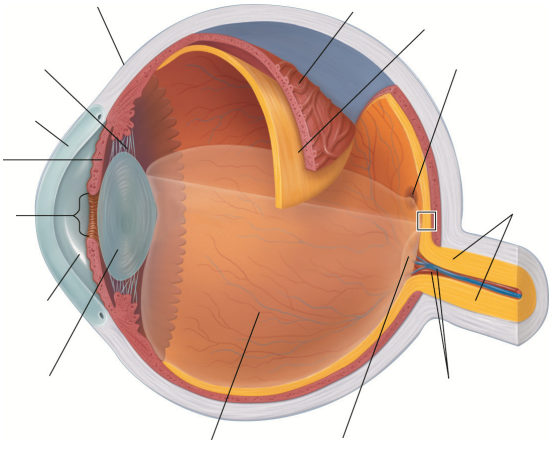
Ready for a study break? Try this! Lay your head on your right shoulder and twirl about in circles as you often did when a small child. Come to a stop and try to walk forward. Describe what you perceive and what happens. Can you explain this? ***Safety note:*** You may fall when doing this, so give yourself plenty of space and a safe landing spot—outside on the lawn is a good place.

Concept 50.3 The diverse visual receptors of animals depend on light-absorbing pigments

LO 50.3: Outline how the human eye transduces light energy to the brain as visual information.

16. There are diverse light detectors in the animal kingdom, but they all contain special cells with light-absorbing pigments. What are these receptors called?

17. Just as with the ear, to understand how photons of light are transduced, transmitted and processed in the brain, we will begin with the anatomy of the vertebrate eye. Label Figure 50.17 as indicated, and for each structure, give its function.



sclera

choroid

retina

fovea

cornea

pupil

iris

lens

aqueous humor

vitreous humor

optic nerve

18. We will focus on the vertebrate eye, but you should note this section includes information about the evolution of visual perception in other groups. Read the section on the retina and photoreceptor cells (pp. 1118–1119). Complete the following chart to name and describe the two types of photoreceptor cells in the eye.

Photoreceptor	Function	Location

19. When you wish to see an object clearly in bright light, where is it focused in the retina? And when you wish to get your best view of an object at dusk on a dark sidewalk, what should you do?

20. Devise a diagram to show the conversion of *retinal* + opsin to *rhodopsin*. Include light activation as well as the return to the inactive state. (Figure 50.17, part 4, will help, as will the discussion on p. 1120.)

Note that the rhodopsin system uses G proteins and signal transduction. In the next section, you will learn that sensations of sweet, umami, and bitter, as well as scent detection, all require G protein-coupled receptors and a signal transduction pathway with second messengers—just another reminder that this is a common mechanism!

Concept 50.4 The senses of taste and smell rely on similar sets of sensory receptors

LO 50.4: Use examples to illustrate how the human sensory system distinguishes different tastes and smells.

21. Smell and taste both involve what type of receptors?

22. What are the five tastes we are able to distinguish?

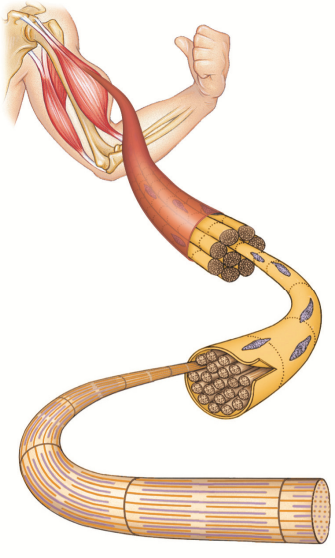
23. Specifically, where are most of the *taste buds* located?

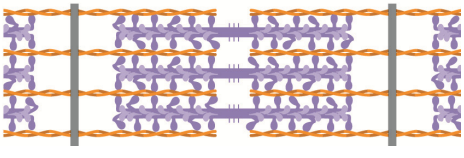
24. The sensory cells of smell are neurons which line the nasal cavity. There are numerous genes that code for unique protein receptors. How many different odorants can a receptor detect? Study Figure 50.25 in your text to see this.

Concept 50.5 The physical interaction of protein filaments is required for muscle function

LO 50.5: Explain how the interaction and movement of filaments provides the basis for muscle contraction.

25. A single muscle cell is also called a *muscle fiber*. Each muscle fiber has a hierarchy of smaller and smaller units. Label this diagram of skeletal muscle and give a description of each term.





muscle

muscle fiber

myofibrils

sarcomere

thick filaments (myosin)

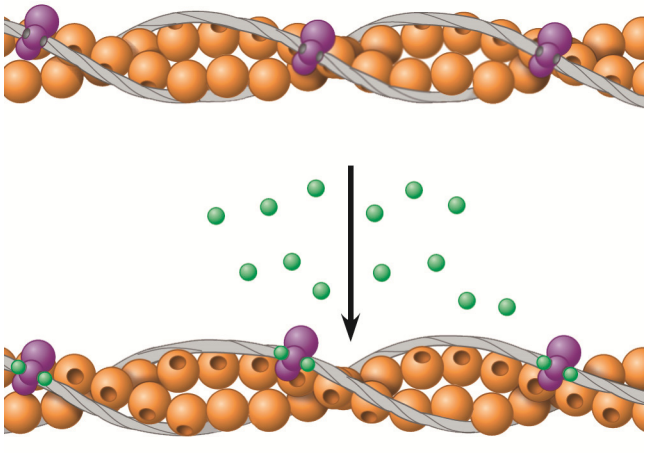
thin filaments (actin)

26. The mechanism of muscle contraction is described by the *sliding-filament model.* In the following space, draw a sketch of a *sarcomere* in a relaxed muscle. Then draw a sketch of a sarcomere in a fully contracted muscle. On your figures, label the *Z line* and *actin* and *myosin.*

27. Describe the *myosin* molecule.

28. As you see in Figure 50.28, muscle contraction occurs when actin and myosin interact. Myosin heads bind to actin, forming cross-bridges. What molecule binds to myosin to provide the energy of contraction?

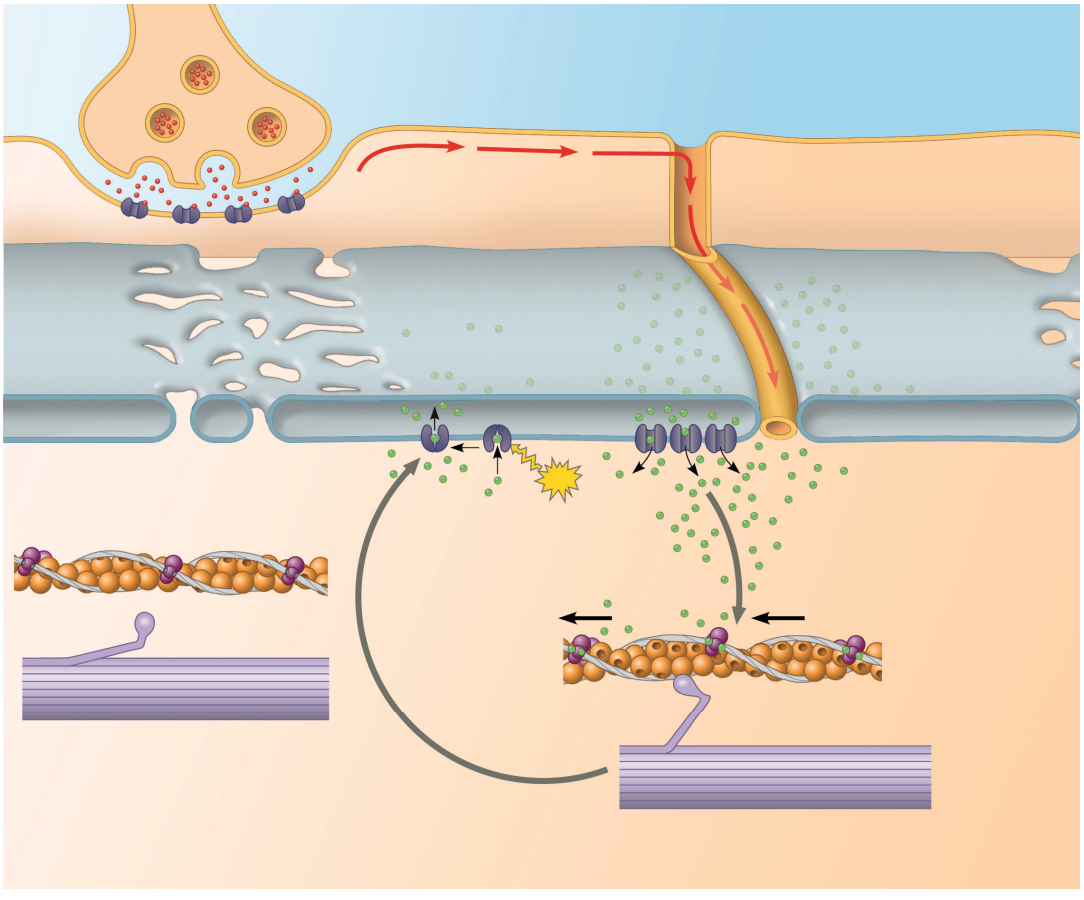
29. In the relaxed muscle fiber, the myosin-binding sites are blocked by regulatory proteins bound to the actin. Use Figure 50.29 for help in labelling the diagram below. Label *actin*, *tropomyosin*, *troponin complex*, Ca^{2+}, and Ca^{2+} *binding sites*.



30. What is the specialized endoplasmic reticulum in a muscle fiber? What is stored here?

31. What causes the release of Ca^{2+}?

32. As you recall from Chapter 48 on nerve impulse transmission, an action potential will cause the release of neurotransmitter at the stimulated neuron's synaptic terminal. Let's put all this together with a careful study of Figure 50.31. The stimulated neuron is a *motor neuron* that will release the neurotransmitter *acetylcholine*. Label this figure with all possible details. Focus on how the neuron produces a signal and the responses that occur in the muscle cell.



33. Here is a jumbled summary of steps involved in muscle contraction. Put them into correct order in the following chart, and then place the number for each step in the correct location on the preceding diagram. (These numbers will *not* correspond with the blue ones in the text—we have included more detail here.)

- Calcium ions bind to troponin molecules of thin filaments.
- Acetylcholine is released from synaptic vesicles of a neuron.

- Acetylcholine binds to receptors on the muscle fibers. This allows Na^{+} ions to rush in, causing depolarization of the muscle fiber membrane and an action potential.
- The troponin/tropomyosin complex is moved so the myosin-binding site of actin is exposed.
- Depolarization continues across the sarcolemma and down the transverse tubule system.
- Ca^{++} is released from cisterns of the SR (sarcoplasmic reticulum).
- Nerve impulse arrives at the neuromuscular junction.
- Myosin heads rotate, bind the actin, and pull the actin fibers toward the center of the sarcomere.
- In the presence of Ca^{++}, myosin acts as an enzyme. It catalyzes the breakdown of ATP. Energy is transferred from ATP to the myosin head, and myosin is activated.

	Steps of Muscle Contraction
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	

Note: Remember to go back and add the numbers for each step above to the diagram on the preceding page.

34. What is meant by a *motor unit*?

35. Similar to neurons, the contraction of a muscle fiber (a twitch) is an all-or-none phenomenon and an action potential is propagated. Sufficient depolarization of the sarcolemma must occur to reach a threshold. How, then, do we get stronger contractions or smooth, sustained contraction?

36. Ever wonder why the breast meat of a chicken is white, while the thighs are dark meat? Read about *Oxidative and Glycolytic Fibers* and give the scientific explanation for this.

37. Most human skeletal muscles contain both *fast-twitch fibers* and *slow-twitch fibers*. The relative proportions of each are genetically determined, in part explaining why an individual may be a better sprinter than a marathoner. Which do you predict to be greater in an Olympic sprinter?

38. There are three types of muscle: s*keletal*, *cardiac*, and *smooth*. Select from these three choices to answer the following questions:

    a. Which has *intercalated disks*?

    b. Which lacks striations?

    c. Which is striated and voluntary?

    d. Which has both *fast-twitch* and *slow-twitch fibers*?

    e. Which is associated with the heart?

    f. Which is found in the wall of your small intestine?

Concept 50.6 Skeletal systems transform muscle contraction into locomotion

LO 50.6: Compare and contrast the structure and function of internal and external skeletal systems.

39. Your text describes three types of skeletons. What are they?

40. Explain how a *hydrostatic skeleton* works.

41. List three phyla that have a hydrostatic skeleton.

42. What is an *exoskeleton*?

43. What material makes up the exoskeleton of a clam? of insects?

44. All chordates have an *endoskeleton*. What minerals are common in bone and cartilage?

Test Your Understanding, p. 1138.

1. _____ 2. _____ 3. _____ 4. _____ 5. _____ 6. _____