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2 SENSATION AND PERCEPTION

LEARNING OBJECTIVES

2.1 Discuss normative, common, and abnormal changes in vision.

2.2 Identify the limits of normal hearing as well as the psychosocial implications of hearing loss.

2.3 Discuss how touch, proprioception, and balance change with age.

2.4 Explain the interplay between taste and smell, their limited changes in older adulthood, and their link to cognitive impairment.

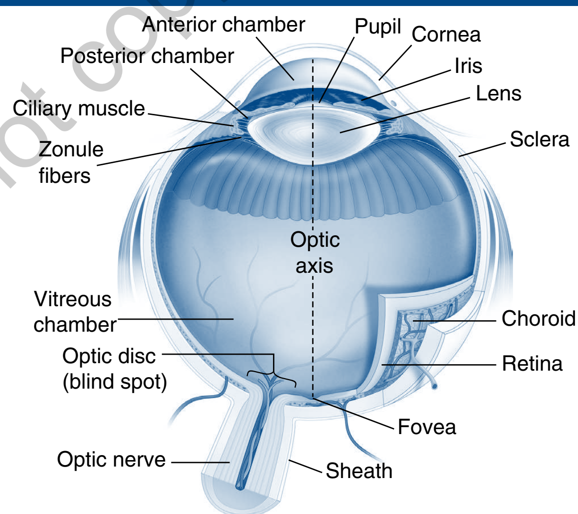
I was once in a book group at the public library. Every month, we would all check out the same book and then meet back up at the library to discuss the book. One member of the group, an older woman, would always check out an audiobook version of each month's selection to compensate for her visual deterioration caused from macular degeneration. However, one month, the book selection was not available on audiobook. So, her husband sat and read the book to her—all 500 pages of the historical romance novel (notably, this was not his preferred genre, nor is it mine). This was a sweet demonstration not only of the love he had for his wife, but of one of our fears surrounding the myth of sensory aging: that we'll inevitably lose our eyesight. This is a myth, fully and deeply. In this chapter, you will read that while there are some changes that occur with our eyes and vision as we age, losing our sight to the point of being unable to read even with the assistance of glasses is not a part of normal aging.

VISION

As we age, there are some normative changes that occur with the structure of the eye. And, while common, none of these inevitably lead to blindness. In fact, many of them require only small adjustments to our day-to-day life to approximate near-youthful eyesight.

First, we'll discuss the changes to the basic structures of the eye (see Figure 2.1). To address these, as well as the lifestyle and psychological impacts these changes may have, we should first review the basic flow of light information in the eye. When light from our environment comes to our eye, it first passes through the **cornea**. This structure is the clear outer coating of the eye itself. Its purpose is to protect the eye and maintain a balance of moisture, but also to focus light further into the eye. Next, light will move through the **pupil**, which necessarily dilates or contracts to allow more or less light into the eye (as needed, depending on the lighting in the environment). The pupil is controlled by the iris, the colored part of the eye, which dictates

FIGURE 2.1 ■ Anatomy of a Human Eye



Source: Schwartz, B. L., & Krantz, J. H. (2023). *Sensation and perception.* SAGE, p. 69.

how much light the pupil should let in. Directly behind the pupil is the **lens**. The lens serves to complete the focusing of the light that is moving into the eye so that it can land properly on the back of the eye. To do this, the pupil will change shape, a process known as **accommodation**. It will get short and fat or long and thin or anything in between to do its job. Once the light lands on the back of the eye, an area known as the **retina**, receptors (called **rods and cones**) are waiting to transduce the light stimulus to neural signal. When **transduction** occurs, the environmental stimulus has changed format into something that the neurons and the brain can understand.

Now that we understand what happens to light as it moves through the sensory organ for vision, we can ask the question: What changes are reasonable to expect with age, and how might they affect day-to-day functioning?

Changes in the Cornea, Pupil, and Lens

The cornea, pupil, and lens serve to adjust and funnel light into our eye in a specific way that deals only with the stimulus itself. That is, these structures function early on in the process of taking in visual stimuli. As you can imagine, when changes happen to the structures that are responsible for focusing light, letting light in, and allowing for clear vision, a potential for noticeable vision changes arises.

With the cornea, there are a couple of small changes that an older adult may encounter. The first is dryness. Dry eyes can occur at any time during the lifetime, but in older age this is more common because of an inefficiency in the maintenance of hydration in the body (e.g., Lavizzo-Mourey, 1987; Walsh et al., 2012). The second change that can arise in the cornea has to do with ultraviolet (UV) exposure over time. Since an older adult has lived a longer life, it is likely that they have been exposed to more UV rays than, say, someone in their 20s. The impact of UV rays on the cornea is in its coloring (e.g., Lombardo et al., 2015; vanKujik, 1991)—making the cornea turn a bit yellow, like an old newspaper. This does not affect the function, per se, but does impact the type of light wavelengths that can move through the cornea and into the eye. With a yellowed cornea, an individual may prefer to see colors like red, orange, and yellow. However, besides mismatched clothes (e.g., a red shirt with yellow pants, because those are the colors someone with a yellowed cornea may prefer), the majority of integrity and functionality of the cornea remains intact. In addition to color changes, many older individuals may experience a thickening of the cornea (e.g., Hayashi et al., 1995). This may lead to incorrect focusing of the light entering the eye, and ultimately a need for contact lenses or glasses to adjust the light and compensate for the changes occurring in the cornea.

Similar to the cornea, the lens may also be impacted by UV light (e.g., Lindsey & Brown, 2002). Research demonstrates that exposure to UVB rays over time increases the **lens bruescence**, where lenses tend toward absorbing shorter wavelengths (blue) and allowing longer wavelengths (yellow and red) to pass through (e.g., Kessel et al., 2010; Lindsey & Brown, 2002), and can result in a lens nearly three times as dense in adults over 60 years of age as those under 60 (e.g., Pokorny et al. 1987). Like many normative changes within the eye, each of these is not a particular problem, but transmission of light through the lens as a whole spectrum may be problematic. Colors may look a little yellowed and less true than in younger eyes, and less light overall may get through. Less light overall through the lens can be problematic in dim-light situations in particular (e.g., Watson, 2001). With less light in the environment, even fewer light waves enter the eye. And, since light is information, the older adult will receive less information to their eye than is ideal.

Additionally, aging lenses may become harder. This hardening of the lens, known as **presbyopia**, starts as early as age 40 and can easily diminish the lens's ability to do its job (e.g., Patel & West, 2007). For a lens to focus light onto the retina, the lens needs to accommodate (i.e., change shape). A dense, hardened lens won't change shape easily, and the individual will experience blurry vision. You may notice an older adult (or yourself) stretching an arm out with a book or restaurant menu to get a "good look" at it. This isn't being dramatic, but rather the outstretched arm is holding the reading material at a place where the lens can focus it. Any closer, and the hardened lens can't fully adjust to focus the letters appropriately. The good news is that presbyopia is easily corrected with the use of glasses or contact lenses (e.g., Mercer et al., 2021; Wolffsohn & Davies, 2019). As long as the individual is willing to wear them, correction is easy.

Light entering the eye needs to pass through not only the cornea and the lens, but also the pupil. In fact, the pupil is the opening in which the light gets through to the lens. Any changes here can affect the flow of light to anything beyond it. And changes do occur. In older age, the ability of the pupil to dilate and allow more light into the eye can diminish (e.g., Bitsios et al., 1996; Daneault et al., 2012). The reason this occurs is the weakening in the ciliary muscles whose job it is to control the dilation (i.e., enlargement) and contraction (i.e., shrinking) of the pupil. When weakened, the pupil does not adjust properly to the changes in environmental light stimuli. In a bright situation, like outside in the middle of the afternoon, the sun can be particularly bothersome. The result of a pupil that does not fully dilate in dim light? Poorer vision. Light is information in our sense of vision, and as such we need the light to tell us what is in front of us. No light, no information. Less light, less information. The impact of the changes in the pupil can be difficulty in driving at night (though older adults' driving will be addressed more fully in Chapter 3), potential trip-and-falls from walking around one's home in the evening and night hours, and trouble in power outage situations (e.g., McMurdo & Gaskell, 1991).

Changes in the Retina

In addition to changes in the front portion of our eye, we can see some small changes to the back of our eye. The most common change here is one where the peripheral area of the retina thins out, resulting in a reduced concentration of the rods in our eye (e.g., Freund et al., 2011; Sturr et al., 1997). The purpose of the rods is to transduce light (i.e., convert light signal to neural signal), primarily in dim lighting situations. Fewer rods means less transduction (i.e., conversion to neural signal) in dim light. Couple this change with the reduced dilation of pupils discussed earlier, and we can see a significant impact in vision in dim-lighting scenarios. While there is not much we can do about preventing this change, as would be the case in preventing UV exposure and its impact on the cornea and lens, the solution here is adjustment to lighting in one's environment. As with the easy adjustments made to manage difficulty resulting from pupils' inefficient dilation, adding lighting around one's home can be achieved and can make a tremendous impact on visual experience.

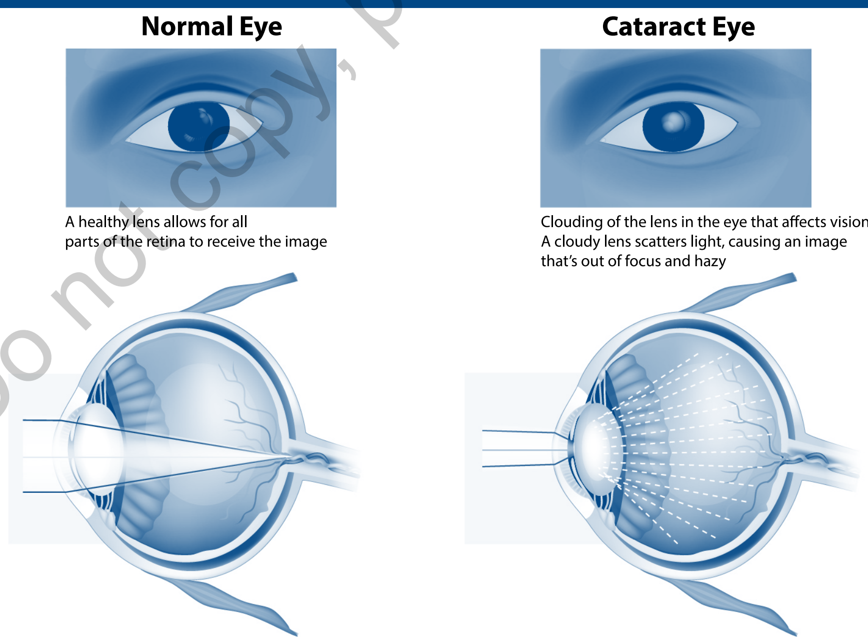
Atypical Changes

While the changes described in the previous section are considered normative changes to aging eyes (I was reminded of presbyopia at my most recent trip to the optometrist: "You know what happens over age 40, right?"), there are some other changes that may represent something entirely different that are the result not of aging, but rather of illness. The experiences described as follows are not normative but may be common. And you may know many individuals who experience instances of cataracts, glaucoma, or macular degeneration. But anecdotal evidence aside, these are not universal, nor are they to be expected with advancing age. Aging does not equal disease.

Cataracts

If you have ever heard someone describe that they see "floaters," they are more than likely describing cataracts (see Figure 2.2). According to the University of Michigan Kellogg Eye Center (n.d.), "By age 65, over 90 percent of people have a cataract and half of the people between the ages of 75 and 85 have lost some vision due to a cataract." Cataracts (the most common of these atypical changes) result from protein buildup in the lens. This protein buildup can cause light to reflect incorrectly off the protein and become unfocused when finally landing on the retina. Alternatively, the cataracts may be sufficiently large as to block some light from going through the lens altogether. As you can imagine, both of these will result in poor vision. However, this change is something that simply slipping a pair of glasses on cannot reasonably fix. Treatment for cataracts is more involved, including lasers to break up the protein in smaller bits so as to not cloud the vision and/or complete lens replacements. These surgeries can help restore vision for an individual who has been struggling with the impact of cataracts, and can be a great relief (e.g., Stuen & Faye, 2003).

FIGURE 2.2 ■ Healthy Lens Compared to a Lens With Cataracts



Source: https://glaucomaassociates.com/wp-content/uploads/2017/10/Cataract-cloudy-vision.jpg

Glaucoma

Like cataracts, glaucoma can occur in conjunction with any or all normative vision changes. According to the National Institutes of Health, National Eye Institute (2010b), Black Americans are most at risk for developing glaucoma (compared to white Americans, Hispanic Americans, or those identifying as *other race*), with nearly 6% of Black Americans over the age of 60 inflicted. This rate increases to 12% for individuals over the age of 80 (National Institutes of Health, National Eye Institute, 2010b). In this illness, an individual experiences increased pressure within the eye (i.e., intraocular pressure). Some amount of pressure pushing outward from the inside of the eye is good. It allows the eye to keep its shape and allows for fluid exchange around the eye. However, too much pressure can cause problems in the retina, and for the optic nerve. Pushing too hard on the optic nerve can result in the delay or cessation of sending signals from the eye to the brain. Checking the pressure in your eye is a regular part of a thorough eye exam, and you likely have experienced it with a small tool (called a *tonometer*) applied to the front of the eye (Icahn School of Medicine at Mount Sinai, 2024). Most individuals come away from this exam with a clean bill of health and return in a year or two to check again. If pressure is too much, the optometrist or ophthalmologist may prescribe treatment to bring down the pressure before damage to the eye and/or optic nerve occurs. Adjustment here for eye health is (once again) more than just a pair of glasses or contact lenses. Often, eye drops designed to lower and maintain proper pressure in the eye are given (e.g., Xalatan or Rescula; Sponsel et al., 2002), along with continual checkups by an optometrist or ophthalmologist to monitor any future changes in pressure or progression of glaucoma or vision loss.

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An older adult is getting an eye exam, which often includes a test for glaucoma.

Macular Degeneration

This final of the eye-related illnesses we'll discuss is one that affects the retina. This is the one that affected my fellow book club member, ultimately preventing her from reading books the way she always had. Age-related macular degeneration, in both its wet and dry forms, affects approximately 2% of adults over the age of 50, with the largest proportion of these individuals experiencing dry macular degeneration (see National Institutes of Health, National Eye Institute, 2010a). In macular degeneration, an individual's **macula** begins to deteriorate. The macula is the center of focus on the retina, where the main object in a scene (e.g., the letters on a page or screen as you read) is focused. As it deteriorates, the receptors (i.e., rods and cones) in the macula no longer serve their function to transduce light into its corresponding neural signal. Over time, the area of the retina that is affected expands, moving outward from the center of focus. In macular degeneration, an individual loses vision in their center of focus that slowly moves beyond the center and begins to impinge on the periphery.

Approximately 90% of instances of age-related macular degeneration are what are called dry AMD (e.g., Salvi et al., 2006). In these cases, individuals experience damage to and atrophy of the cells in the center of focus. Vision is gradually distorted and progresses toward vision loss. The other approximately 10% of cases of age-related macular degeneration are referred to as wet AMD. Here, fluid leakage (hence why it's called *wet*) from abnormal vessels in the retina lifts and separates the layers of the retina at the macula area. As leakage progresses, so does vision loss. Individuals with a family history of macular degeneration (as well as those with a history of smoking behaviors) have an increased likelihood of developing AMD in their later years. However, research suggests that quitting smoking, eating dark leafy vegetables (such as spinach or kale), and supplementation with vitamin C, vitamin E, and beta-carotene can mediate the risk of progression to advanced AMD (e.g., Salvi et al., 2006). The Amsler Grid, pictured in Figure 2.3, is one tool that the optometrist/ophthalmologist will use to test for macular degeneration.

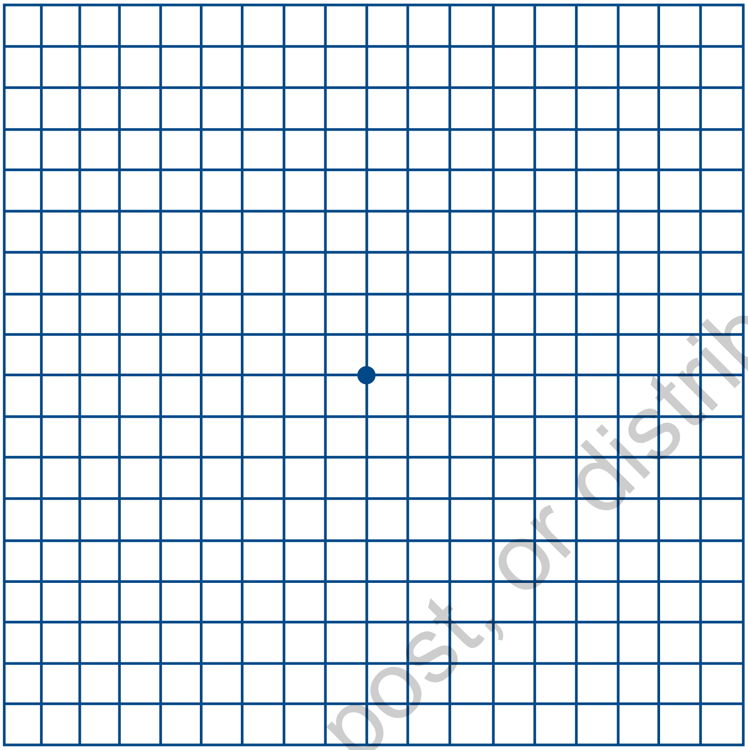
Effects of and Adjustments to Visual Changes

The effects of changes in vision can range from small wonderings about needing glasses to large changes in lifestyle. However, as we'll see, the psychological and behavioral implications can be significant, even in the most subtle of normative eye changes.

Driving at Night

With the changes that we commonly see in the pupil and reduction in the concentration of rods, we may see a significant impact on an individual's ability to see in the dark. This has a large behavioral impact in their ability to drive at night (e.g., Gruber et al., 2013; West et al., 2003). Imagine guiding a large motor vehicle down a highway at 70 miles per hour, only to realize that you can't see the lane lines or the cars that are stopped up ahead. Not only could that be terrifying for the driver, but it would also be dangerous for all involved, including the other drivers on the road. The discovery of changes to night vision could necessarily impact someone's desire to or ability to travel after the sun goes down. The trickle effect of this change could mean

FIGURE 2.3 ■ Amsler Grid



Source: https://www.aao.org/image.axd?id=4a0d828b-c698-47cf-9455-e265332e7968&t=635998033438800000

disengagement from their community (e.g., no more evening club or town meetings), or a feeling of losing independence and "becoming a burden" on friends and family (e.g., Burmedi et al., 2002). While neither of these are always necessary, some amount of creativity in working around this limitation is needed (e.g., Gottlieb & Gillespie, 2008) to avoid the negative mental health and socioemotional outcomes that may result from that sort of disconnection (e.g., Burmedi et al., 2002). However, vision is just one contributor to success, confidence, and safety while driving; further discussion of this topic can be found in Chapter 3, where we'll address perception and attention (the next steps in information processing) with respect to driving as well.

At Home

A reduction of visual capacity in dim lighting doesn't just affect driving. Hazards can also exist within the home, impacting how one moves around their living space (e.g., Lord, 2006). Poor lighting or getting up in the middle of the night to use the restroom could be dangerous. Imagine not seeing the edge of the stairs. Yikes! Fortunately, night lights are an inexpensive tool to plug in and increase the lighting around your home. They are even available with an automatic sensor that turns on and off depending on how much ambient light is available in the area. Additionally, marking the edge of the stairs with brightly colored tape can enhance them, even when light is scarce (e.g., McMurdo & Gaskell, 1991). Creativity and adaptability are key here, though. Being able to adapt to changes allows for independent living, rather than limiting behavior (e.g., Steinman et al., 2009)—and, truth be told, many of these adjustments are great for people of all ages and ranges of abilities.

Changes in Reading Behaviors

Reading behaviors can be severely impacted by even just a small, normative age-related vision change (e.g., Goertz et al., 2014). For individuals who've lived with typical/healthy vision their whole lives, this can be quite impactful. Remember our discussion on presbyopia from earlier in this chapter? Presbyopia can put a damper on an individual's reading behavior because the hardening of the lens limits the lens's ability to do its job to focus the small letters onto the retina, leaving the reader to do it on their own—moving the reading material further and further away from their eyes until it is in focus. The problem here is that our arms are only so long, and at some point we're putting additional strain on the lens and increasing the likelihood of a headache (Patel & West, 2007). Moving to a point where an older adult needs glasses to adjust for presbyopia can signal to a person that they are getting older. Admitting to the need for glasses (and actually using them) and an option for books in large print are reasonable accommodations for this normative vision change (e.g., Whiteside et al., 2006).

HEARING

There are several different types of hearing changes to anticipate with advancing age, but many of them are not noticeable until far into our old age (e.g., age 80 or beyond)—researchers often refer to individuals in these age groups as the oldest old (e.g., Solé-Auró & Crimmins, 2013; VonFaber et al., 2001). This section will discuss normative and non-normative age-related changes in hearing, accommodations and adjustments we can make as speakers or listeners, and the impact changes in hearing may have on relationships and social interactions.

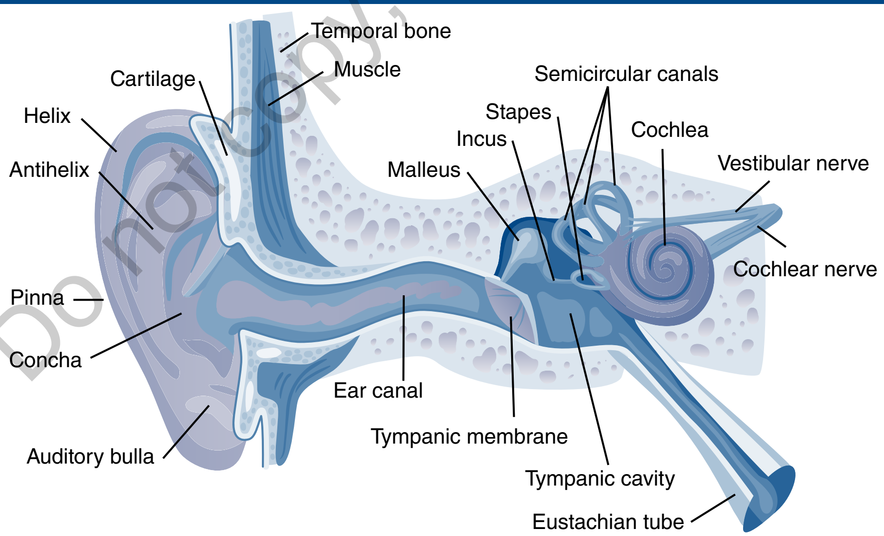
Presbycusis

One hearing change that we may experience is called **presbycusis**. Presbycusis occurs when an individual loses detection of high-frequency hearing (i.e., sounds that come in at a higher pitch). This type of hearing loss, which occurs when years and years of listening to loud sounds add on to a genetic predisposition (Gates & Mills, 2005), can begin as early as age 60 (though it isn't often noticeable until many years later) and is quite common past the age of 80 (Walling & Dickson, 2012). The loss of high-frequency hearing can significantly impact speech perception—an important part of life as a human. And, interestingly, Gates and Mills (2005) report that many of the complaints of those encountering presbycusis are not that they can't hear, but that they can't understand what's being said. I'm sure you can imagine that the social implications of hearing loss are large (and we'll address those in just a bit). And while presbycusis is specific to high-frequency hearing, many individuals use this term interchangeably with age-related hearing loss because, when progressed, presbycusis can ultimately move toward lower-frequency ranges of hearing. And, when it does, it encroaches on speech perception and communication, especially in noisy environments (Gates & Mills, 2005). But the result is the same: loss of hearing. The cause can be one of many.

Changes in the **cochlea** (in the inner ear, shown in Figure 2.4) and in the **auditory nerve** (carrying signals out of the ear to the brain), as well as changes in the **tympanic membrane** (i.e., the ear drum) and neurons in the auditory centers in the brain, can result in a markedly increased **auditory threshold**—where the quietest sound an individual can detect is louder than it was at a younger age (see Figure 2.5). Thresholds can increase as much as 40 decibels for the high-frequency range of sounds (Gates et al., 2008; Wiley et al., 2008). Individuals most at risk for developing presbycusis are those with a family history of age-related hearing loss, those who are exposed to loud noises as part of their occupation, those who smoke, and those with hypertension (i.e., high blood pressure) or kidney disease (e.g., Gates & Mills, 2005). Moreover, some medications may accelerate and/or exacerbate high-frequency hearing loss (Joo et al., 2020). Any neural loss that occurs as the result of stroke, injury, or general atrophy can also impact the progression of hearing loss (e.g., Kuo et al., 2016; Walling & Dickson, 2012).

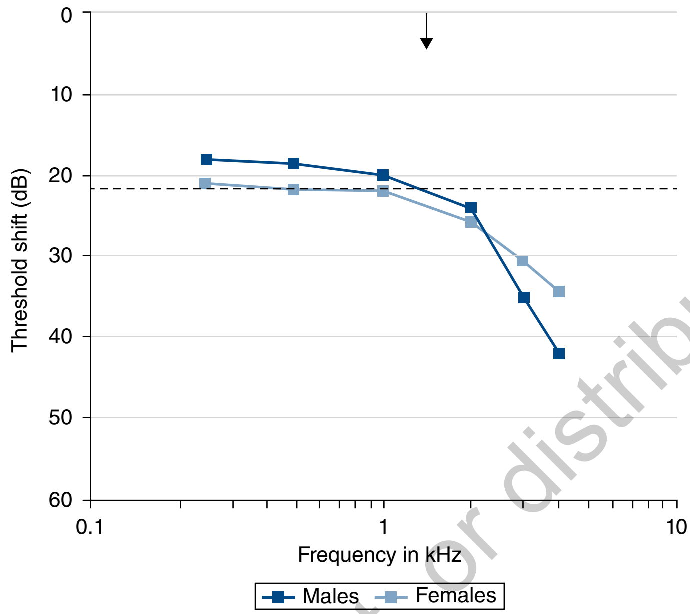
One common presentation of age-related hearing loss is the result of hardening or stiffening of the membranes in the ear (Purdy, 2001), including the tympanic membrane or the basilar membrane in the cochlea. Regardless of which membrane begins to harden, the result is the same: The membrane doesn't move the way it should, to progress the sound waves into the ear

FIGURE 2.4 ■ Anatomy of the Human Ear



Source: https://media.istockphoto.com/id/1150305939/vector/human-ear-anatomy-ears-inner-structure-organ-of-hearing-vector-illustration.jpg?s=612x612&w=0&k=20&c=6BNBHTPNY9ZkGgTWHFU7-or-UKRrPSKjYH_2TIzzfu4=

FIGURE 2.5 ■ Threshold Changes for Older Adults



Source: Gates, G. A., & Mills, J. H. (2005). Presbycusis. *The Lancet, 366*, 1111–1120.

to be transformed into a neural signal for the brain. Those sound waves are the stimulus we need to hear, and without the membrane moving them into the auditory system at a sufficient amplitude, hearing won't occur.

Other types of hearing changes that an older adult may experience are the result of damage to hair cells or changes in neurons (Walling & Dickson, 2012). Damage to hair cells often comes from prolonged exposure to loud sounds, which can happen over a lifetime and affect the onset of hearing loss (e.g., Cruickshanks et al., 2010). When hair cells are damaged, they cannot serve their purpose: to transform sound waves into neural signal (i.e., transduction). So, the sound signal will never get past the ear. Only neural changes happen after that point in the hearing process, as degradation of the auditory nerve, atrophy of neurons in the brain stem, or even **apoptosis** (i.e., programmed cell death) of neurons in the temporal lobes and beyond (e.g., Eckert et al., 2019; Golub, 2017). Once sound gets transduced into neural signal—any changes that can happen in the auditory nerve, in the brain stem, or into the hearing centers of the brain—the temporal lobe can impact hearing at the neural level. Neural changes can be the result of atypical aging (e.g., Alzheimer's disease or stroke) or advanced age (i.e., those in the oldest-old group). Regardless, the result will be a loss of hearing that simply raising the volume cannot remedy.

However, there are instances when presbycusis is not only *not* harmful, but maybe useful. One example is the implementation of the *mosquito tone*. A Welsh security firm first developed the mosquito tone to combat young people taking over a shopping district. More older adults liked to shop in that shopping district, but the young adults and teenagers would create problems, mischief, and ruckus, and the older adults would be annoyed. Since these businesses' target clientele was the older adults, the younger individuals were driving away their sales opportunities. In response, the security firm decided to play a very high-pitched (high-frequency) tone, which bothered the young people—they left. The older people, some of whom dealt with presbycusis, didn't feel the effects because they didn't hear the sound. It's sort of the same premise as a dog whistle. It's high enough for dogs to hear, but not in the range for human hearing so humans don't get bothered by it. The mosquito tone was high enough to be within the range that younger people could hear but many older people couldn't. According to my students, this sound has more recently been developed into a cell phone ringtone—presumably so the younger students can hear their phones and their older teachers won't. Nobody has yet to admit using it in my class (ha ha!).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Effects of and Adjustments to Hearing Changes

As with changes in vision, living a whole life with healthy hearing and then experiencing changes can be quite challenging. I know this to be true from personal experience—as I am now the proud owner of significant hearing loss in my right ear. While I use this to my advantage, needing to cover only my left ear when I want it to be quiet, it is also difficult. I often find myself asking my family and my students to repeat themselves, and then feel bad when I've asked them to do so several times in a row. I know it's frustrating for them too. And certainly, conversations are interrupted, are misunderstood, or at the very least lack the flow that they once did. Social implications for hearing loss are large because, as humans, it is in our very nature to communicate through speech—and when that's how we've done it our whole lives, and it needs to change, the adjustment can be difficult.

Social Isolation

In many cases, the result of hearing loss can be unnoticed for a very long time. We can compensate for many things in our life—ask our friends and family to speak louder, ask people to repeat themselves, and turn up the volume on the television and radio. Add this to the social stigma associated with getting older and hearing aids (e.g., Wallhagen, 2010), and we can see that an older adult may be resistant to using this tool. In fact, some estimates are that only 30% to 40% of individuals who have a hearing aid actually use it (Barker et al., 2016; Hanratty & Lawlor, 2000).

However, at some point, the resistance becomes problematic (who wants to ask their friend to repeat themselves 16 times? That's where I was at. And it's hard), and without compensation we can experience things like social isolation (e.g., Maharani et al., 2019; Mick et al., 2014; Shukla et al., 2020). When we can't engage in conversation with more than one person because following the conversation across a large group or incorporating lipreading becomes too complex, we give up.

Social isolation is the last thing we want to happen in our later years. Social support is important, and without it, many older adults decline quickly (e.g., Mick & Pichora-Fuller, 2016). Social support (discussed in Chapters 8 and 10) can help with coping (Krause, 1986) and cognitive stimulation (e.g., Adams et al., 2002) and can even contribute to maintaining physical well-being through activity (e.g., Fransen et al., 2015). But, the loss of hearing can make social situations difficult, frustrating, and unappealing (e.g., Ciorba et al., 2012). Additionally, hearing loss can result in the degradation of the quality of life (e.g., Ciorba et al., 2012; Mosnier et al., 2015).

Research on the relationship between hearing loss and social isolation further demonstrates that self-reports of hearing loss are associated not just with isolation, but with the psychological ramifications of that isolation (e.g., depression and mood changes; Saito et al., 2010; Tambs, 2004). In a longitudinal study on hearing loss, social isolation, and cognitive function, Maharani and colleagues (2019) examined the relationships between these variables. Specifically, these researchers investigated what they called the "cascade hypothesis" in adults over age 50—that hearing loss cascades down the line to social isolation, loneliness, and cognitive decline. This hypothesis was supported by the data, demonstrating that the worse an individual's hearing status, the more likely the same individual would score high on the social isolation and loneliness measures. Additionally, results showed that when an individual showed severe loneliness, they also were likely to demonstrate cognitive impairment. Moreover, data showed a direct connection between hearing impairment and cognitive function, which the researchers explained could be the result of poor input. Without stimulation going in through hearing stimuli, the brain becomes starved of information, resulting in cognitive impairments. This explanation is supported in neuroimaging studies that show clear brain atrophy in individuals who've had long-term uncorrected hearing loss (e.g., Peelle et al., 2011).

There is good news, however: Remediation works. That is, research has also demonstrated that corrected hearing—whether by hearing aid (e.g., Weinstein et al., 2015) or by cochlear implant (e.g., Mosnier et al., 2015)—can create positive change to the cognitive capabilities, quality of communication with others, social and emotional well-being, and overall quality of life. In practice, Weinstein et al. (2015) evaluated patients at an audiology clinic before and after hearing aid fittings. These patients averaged 80 years of age and were getting hearing aids for the first time. Measures of social and emotional loneliness as well as perceived social isolation demonstrated some positive changes after just four to six weeks of hearing aid use. At postmeasure, patients with moderate or severe hearing loss demonstrated significant improvements in their social and emotional loneliness measures as well as their perceived judgments of social isolation. These results clearly demonstrate that the hearing aid was beneficial for these individuals and may serve as a tool to help reverse the social and emotional implications of hearing loss.

Impact on IADLs

In day-to-day life, individuals who have lost even some of their hearing can feel an impact on their ability to complete the activities they are used to doing. For example, someone experiencing hearing loss may not be able to make a phone call to the bank when they see a discrepancy on their bank statement because hearing the bank representative on the other end of the phone will be difficult. The result? Their bank account discrepancy remains, or they must rely on others to do this for them. Certainly, this instance is unappealing and requires disclosing private information. Tasks such as these are known as IADLs, or instrumental activities of daily living, introduced in Chapter 1 (Elsawy & Higgins, 2011). While these activities are not required for survival (as are activities of daily living, or ADLs, like eating and drinking), tasks like balancing a bank account, going grocery shopping, doing laundry, navigating public transportation, and other daily tasks required for independent living are still important. Loss of hearing can impact these tasks (e.g., Borda et al., 2019; Keller et al., 1999) and result in a lower quality of life. Research on the impact of hearing loss on IADLs shows that individuals with significant hearing loss who do not use a hearing aid show marked impairments in their performance on IADLs compared to individuals without hearing loss (e.g., Borda et al., 2019).

Strategies to Help

Perhaps one of the most common, and obvious, ways to help an older adult with hearing loss is with a hearing aid. Hearing aids can be quite helpful in increasing the volume/amplitude of the incoming sound. Research on the impact of hearing aids demonstrates that their use can improve older adults' execution of IADLs, making their performance comparable to that of an individual without any hearing loss (e.g., Borda et al., 2019).

How could something so small have such a profound impact? If the individual's hearing loss is the result of stiffening of membranes (tympanic and/or basilar), increasing the amplitude of sound (and thereby increasing the force with which the membranes are pushed) can be an effective way of getting the membranes to move the way they need to in order to get the sound stimulus into the auditory system. However, with every solution comes some pitfalls. Hearing aids can increase sounds' volume, but when we increase both the sounds we want to hear and the sounds we don't want to hear, we may still have trouble. The trouble here is being able to differentiate between the target sound and the background noise. Luckily, modern models of hearing aids have been able to adjust and accommodate for that, allowing the devices to amplify speech sounds and not amplify sounds occurring in other frequency ranges (Hear.com, 2023).

Jozef Polc / Alamy Stock Photo

Listening to others in a crowded environment can be difficult.

Unfortunately, like much of the thought surrounding the aging process, there is a stigma surrounding the use of hearing aids (e.g., David & Werner, 2016; Wallhagen, 2010). There is an idea that "hearing aids are for old people," and if we need one, we may be reluctant to use it, lest we accept that we are aging and no longer a desired "youth." The truth of the matter is that hearing aids can be very useful in any individual (young and older) whose hearing loss comes from a mechanical issue like a hardening of the membranes in the ear (e.g., Walden & Walden, 2004). The hearing aid will amplify the sound waves, making a louder volume of sound. The louder volume will push more forcefully on the hardened membranes in the ear and can be particularly helpful in situations where you can't turn up the volume (e.g., a family dinner conversation). However, in instances where hearing loss is due to damage to hair cells in the cochlea or a neural issue, as may occur in the auditory nerve, the temporal lobe, or the hearing centers of the brain or brainstem, increasing volume isn't helpful. Compensation here is more challenging.

In response to a loss of hearing function from problems at transduction (the hair cells), a cochlear implant may be suggested. A cochlear implant stimulates the auditory nerve, instead of allowing the hair cells to serve that function, thus bypassing the mechanical portion of the auditory system (F. R. Lin et al., 2012). While older adults are eligible for cochlear implants, a cochlear implant is not always an ideal solution for an older adult. The rationale here is that a cochlear implant provides an electrical impulse to stimulate the auditory nerve but isn't the same as a sound stimulus. Therefore, a degree of learning about this new kind of stimulus is necessary to adjust to the implant (Glennon et al., 2020). This works well in a younger person's neural system that has not already spent half a century learning sounds and wiring the brain to those connections. Learning for an older adult can be slower and more effortful (as you'll learn in later chapters). Adding this effort to our later years may be beneficial for some individuals, but for others it may not be worth it. The additional time, energy, and mental effort to adjust to the new kind of sound stimulus, alongside the risks associated with the surgery of implanting the cochlear implant itself, need to be weighed against the benefits of regaining hearing function. For many, the benefits don't outweigh the costs. That's not to say that age should eliminate one from considering a cochlear implant, but some considerations of just how much improvement can be made over the long term should be had (e.g., Hiel et al., 2016). Other adjustments can also be included in remediation for hearing loss, such as speechreading, closed captioning, and auditory training (Dubno, 2013). Assisted listening devices, including vibrating alarm clocks, flashing-light doorbells, and the like, can also be helpful for individuals adapting to hearing loss.

The good news is that aging alone does not cause hearing loss, and hearing loss is not universal (F. R. Lin et al., 2011). F. R. Lin et al. (2011) report that only about one-third of adults between ages 65 and 75 experience notable hearing loss, and this statistic only jumps to about half of older adults over the age of 75. Much of the hearing loss individuals experience is minor and manageable with things such as the closed-captioning function on the television or leaning on the support of friends and family (e.g., Moser et al., 2017). These social supports can do things like turn down the background noise and speak directly to you so you can see their lips to facilitate speechreading. They can speak clearly, being careful not to "dumb down" the language—this is termed **elderspeak** and can be condescending and insulting to an older adult (Kemper, 1994). The individual has lost hearing, not cognitive capacity. Here, support matters and can help in the compensation and adaptation for an older adult (Williams et al., 2005). In the context of social support, not only can older adults with hearing loss manage, but they can thrive. There is no need to limit oneself when there are supports and tools.

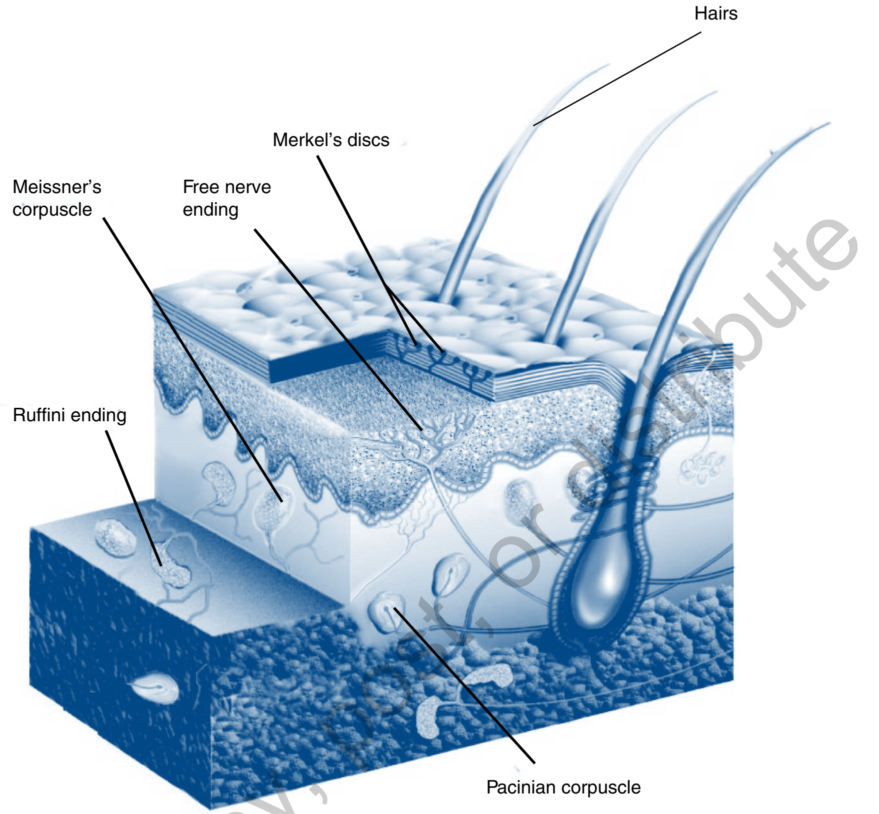
TOUCH, PROPRIOCEPTION, AND BALANCE

Touch, proprioception (i.e., limb and body position), and balance are discussed together in this section because of their relationship with one another. Additionally, changes in the mechanisms in the skin, and the skin itself, are related to temperature regulation (e.g., Blatteis, 2012; Kenney & Munce, 2003). What we may have heard or experienced, anecdotally, is that older adults are always cold and are most certainly at risk for falling and breaking their hips. While some individuals are in line with this myth, like many things discussed in this book, it is not the default or inevitable way of aging. Understanding changes in the skin, the touch receptors, and the other related mechanisms will help us distinguish typical aging from disease-related changes and further understand the simple modifications we can make to help an older adult adapt to minor or moderate changes. Adaptation isn't necessarily negative.

Skin

Much like the other sensory organs, skin has receptors to help take information from the environment and turn it into neural signal (i.e., transduction). In the skin, these receptors are called **mechanoreceptors** (see Figure 2.6) (Hao et al., 2015). Four types of mechanoreceptors in the

FIGURE 2.6 ■ Mechanoreceptors in the Skin



Source: Schwartz, B. L., & Krantz, J. H. (2023). *Sensation and perception*. SAGE, p. 454.

skin differentially respond to different types of stimuli. For example, one type of mechanoreceptor might respond to heat, while another would respond to pressure. The distribution of mechanoreceptors in our skin is dependent on the sensitivity of the area of the body, and the necessary precision needed within the sense of touch (e.g., Vallbo & Johansson, 1984). That is, there are more tightly packed mechanoreceptors in the fingertips than in the back of the leg to more precisely define the touch in the fingertips—as would be necessary in a task like typing. The back of the leg doesn't need that level of specification.

With age, we can see a change in mechanoreceptor distribution along with a thinning of the layers of the skin. Together, these can have implications on an older adult's ability to discriminate and identify by touch (e.g., feeling the difference in the shape and size of an object), temperature regulation, hydration levels, and sensitivity to pain and heat (e.g., García-Piqueras et al., 2019).

However, these changes need not be limiting. In fact, some research has demonstrated that maintaining attention to touch throughout the lifetime, as does someone who is blind and reads Braille with their fingertips or someone who plays the piano proficiently and often, can allow an individual to retain precision in this sense (e.g., Legge et al., 2019). Other research has shown that older adults simply need to change their strategy. Norman et al. (2013) asked young and older participants to judge the curvature of an object using either static or dynamic touch (i.e., touching when holding an object still vs. manipulating it in the hands). When using static touch, older adults performed more poorly than young adults. However, when using dynamic touch, older adults were able to judge the curvature of an object just as effectively as a young adult. The shift in strategy to moving the hands along the object changed which mechanoreceptors were responding (and in which proportions) as well as began to involve the muscles and joints (and their corresponding neurons). The additional information facilitated their judgments and resulted in better task performance. This is consistent with previous research demonstrating additional proprioceptive (limb position) information from active touch, providing support for object and shape perception (e.g., Gibson, 1962; Heller & Myers, 1983).

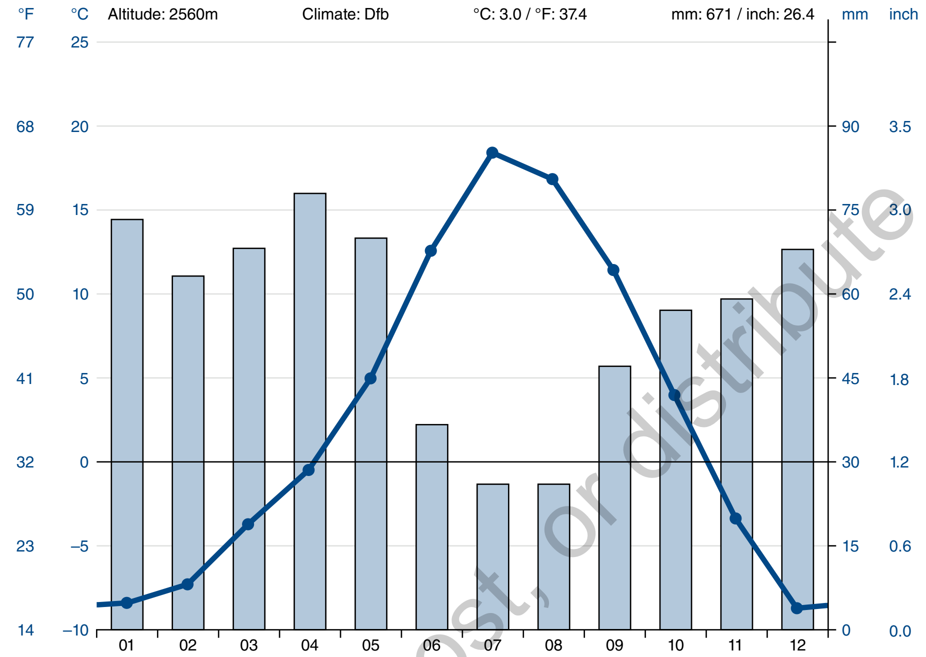
Temperature Regulation

With the thinning of the skin, an older adult may be more susceptible to some physiological changes that can make temperature regulation more difficult (Blatteis, 2012). One of the reasons for this is that when skin thins, it loses moisture more easily, leaving the older adult more vulnerable to dehydration (e.g., Farage et al., 2008, 2013) as well as other outside influences like weather. When an individual becomes dehydrated, their ability to maintain internal temperatures in the context of more extreme hot and cold temperatures becomes more difficult (e.g., Calleja-Aguis et al., 2007; Gross et al., 1992). This might be why older adults may be more inclined to adjust living situations to make themselves more comfortable and ease the strain on their body's temperature regulation system (see Figure 2.7). That is, when they have the financial means to do so, older adults may want to stay in their northern home in the summer and a southern home in the winter (for an individual in the United States or Canada)—individuals engaging in this type of shifts in residency are commonly called *snowbirds*. In fact, rates of this temporary migration show Florida, Arizona, and Texas as common locations for older adults to spend their winters (e.g., Smith & House, 2006), where weather is consistently warm through most months of the year. This pattern allows individuals to escape both extreme cold (as they'd experience in the northern winters) and extreme heat (as they'd experience in southern summers).

Alternatively, an older adult may wish to simply stay inside more often, where they can control the temperature of their home with the use of central air-conditioning and heat. However, there are implications to this with regard to social relationships. Staying in one's own home constantly removes the individual from social situations in which they are likely to engage with others in conversation, and other more physically active hobbies (e.g., Barrenetxea et al., 2022; Cornwell & Waite, 2009). Not only could this be detrimental to an older adult's social relationships, but it could play a negative role in their physical health as well (e.g., Cornwell & Waite, 2009; Farrell et al., 2022; Holt-Lunstad, 2017).

The positive aspect of these changes is that it really is relatively simple to be able to maintain temperature regulatory systems, or assist them, with the right preparation. Hydration is important; drinking water from a special cup—many people find using a straw an effective way of

FIGURE 2.7 ■ Older Adult Migratory Behavior, Based on Temperature Changes Throughout the Year



Source: https://images.climate-data.org/location/124464/climate-graph.png

drinking more water (see Williams Integracare Clinic [n.d.] for more information)—or keeping a pitcher on your kitchen counter to pour from all day can make this easy. Taking advantage of resources to maintain cooler temperatures in the summer and warmer temperatures in the winter may be easy with central air-conditioning and heat but may be more difficult without these resources available in the home. And, of course, these are not available to everyone at every income level. However, free community resources like a library are not only readily available in most every town and city, but they have temperature regulation to make their patrons comfortable and provide mentally and socially stimulating contexts in which to continue to engage with one's community.

Vestibular System

Relatedly, the **vestibular system**—the multi-organ system that helps one maintain balance in the body—can be of concern in an older adult. In a typically aging individual, there are some changes to the vestibular system having to do with the interplay of the functioning in the inner ear, the vestibulo-ocular reflex, and postural reflexes (e.g., Hall & Meldrum, 2016). Within the ear, the fluid in the inner ear needs to be balanced and pressurized properly to maintain good balance throughout the body. The tilt of the body, natural sway, and interaction with the environment needs to be accounted for by redirecting one's gaze. And, the reflexive reaction to rebalance the body posture should respond. Without these three, one may feel dizzy or like they could fall at any moment (called **vertigo**), and dizziness is known to be a large predictor of fall risk in older adults (e.g., Herdman et al., 2000). Typically, these instances of vertigo are largely benign and easily treated with physical therapy. Resolving them, however, is important for reducing fall risk and increasing quality of life (Lindell et al., 2021).

It's important that we recognize that vision and redirecting your vision to allow the information to guide you (albeit automatic and below your level of consciousness) is a substantial component of the functioning of the vestibular system. If you are able, and feel like you can do it safely, try this: Stand up and stand on one foot. Then, close your eyes. You likely will find that you lose your balance and feel like you're about to fall over, and instinctively put your foot down. You can correct by opening your eyes, and your body will respond. But what happens if you lose a bit of your visual function from a common illness like cataracts? You are not able to just open your eyes and correct your faulty balance. The good news is that vision is not the only system that contributes to balance, nor are typical visual changes (as described earlier in this chapter) the changes that contribute to loss of balance or mobility.

Other systems, like the touch system, play a role as well. In healthy aging, we can see normative declines in the sensitivity in haptic (touch) input through the bottoms of the feet (e.g., Shaffer & Harrison, 2007), and while this may not seem impactful in terms of maintaining postural balance, it can be quite influential. That is, the input received through the soles of the feet can signal the nervous system to invoke a reflex to play out in the legs and feet (e.g., Peters et al., 2016). In one study, researchers at the University of British Columbia aimed to determine how this decline in input can be used to predict older adults' risk for balance impairments and postural stability problems (Peters et al., 2016). Here, young and older adults were stimulated on the bottoms of their feet with vibrations lasting one to two seconds. Participants were asked to report whether they felt the stimulation. Stimulations were presented at different amplitudes until their thresholds (i.e., minimum intensity to detect) were determined. Once thresholds were determined, stimulation on the bottom of the foot was given, and recordings from the corresponding leg via surface electrode pads were taken to measure reflex output. Results showed that older adults not only had higher thresholds for detecting stimulation (i.e., they needed more stimulation to notice that it was happening), but also had lower reflex output (i.e., less outgoing response to the stimulation). Researchers indicated that these findings demonstrate a relationship between the input sensitivity and the reflex output. The impact of these decreasing reflexes can be found in the risk of balance impairment in older adults. That is, if reflexes aren't working quickly enough in response to input coming through the bottom of the foot, an individual is less likely to be able to recover from an impediment in their path or more likely to lose footing in a rougher terrain (e.g., on a beach or a walking trail). The good news is that there are minor modifications, as well as practice, that can mitigate these limitations inherent in an aging nervous system that will be discussed in the next section.

Safety Concerns and Modifications

Balance impairment in an older adult seems like a terrible hazard and one we could see causing a path toward disability—the likelihood of which is not that large, and only increases when co-occurring with other physical or cognitive declines (e.g., Tu et al., 2022). The changes we see in the vestibular system and postural reflex difficulties are usually minor, and safety may just be a matter of simple environmental adaptations (like those provisions provided by the Americans with Disabilities Act, or ADA) and additional practice in movement (including physical therapy and tai chi; Komagata & Newton, 2003; Leung et al., 2011; Maciaszeck & Osiński, 2010; Silsupadol et al., 2006). Research in this area has investigated community-based exercise programs, specifically utilizing tai chi for its slow, low-impact qualities. In several studies (e.g., Jones et al., 2006; M. R. Lin et al., 2006; Taylor et al., 2012), results of tai chi as an intervention for balance impairment and fall risk have demonstrated significant improvement. Even in the instances where individuals do not show changes in muscle mass or bone density, improvements in balance, gait, posture, and risk for falling have been demonstrated in a matter of two to three months. Moreover, this type of exercise, occurring in a community setting, can be beneficial for older adults' social and emotional well-being as well. In fact, when I think back to my time as a group fitness instructor, I remember that many of the older women in my classes formed relationships and social bonds that resembled those they'd have with their own siblings, and the comments they made about those relationships told me that these were some of the most supportive and enduring friendships I'd ever seen.

Within the home, there are practical environmental changes that can be made to mitigate fall risk and help one maintain their freedom of movement. Checking the edges of rugs (and taping them down); removing cords from crossing walking paths; adding night lights in hallways, stairwells, and bathrooms; and applying brightly colored tape to the edges of stairs are all easy and cost-effective ways to improve the environment in one's home, as it relates to everyday contexts in which falls may occur. Additionally, one may add textured mats to the bottom of a bathtub or shower to minimize slipping and add a handrail to the side of the shower as well. The more of these little tweaks one can make, along with adding physical training (like tai chi) to regular exercise routines, the better the independence and lower the risk of falls. None of these modifications need to be specific to an older adult, either. People of all ages can benefit from any one, or all, of these minor changes—and that alone can help development through adulthood and minimize the stigma and fear of getting older.

TASTE AND SMELL

While the senses we've already discussed are important to interact with our world and get information, they are not the only ones. We gain information through our senses of taste and smell as well, and these are impactful on many levels—as we may have seen if we lost either or both of these during a recent COVID-19 infection. Typically, in a textbook such as this, taste and smell are addressed in tandem, mostly because these two senses work together all throughout the life span. Together, they give you an experience of **flavor**, with smell carrying most of the weight here. If you've ever tried to eat something while having a head cold and noticed that you don't taste much, you know what we're talking about here. Or, if you've ever referred to a candle's *flavor* instead of its *scent*, you also know what we're referring to here (a candle manufacturer would refer to it as *scent*, but by saying *flavor*, you really aren't that far off). With regard to aging, we tend to notice the same sort of thing. That is, while we do tend to lose some taste buds as we move through adulthood, this loss is not noticeable until late adulthood (after 80 years old; Doty, 2018). However, the sense of smell can contribute to some changes in flavor and eating experiences (e.g., Tuorila et al., 2001). Specifically, researchers in Finland (Tuorila et al., 2001) asked young and older participants to give intensity and pleasantness ratings for a variety of flavors. Analysis of the ratings showed that older adults were more impacted by the sweetness and saltiness of the flavors. Importantly, the participants' ability to rate the intensity of what they were smelling was not related to their ability to identify what they were smelling. These two mechanisms may be different, and therefore may be impacted differently by aging and/or disease processes.

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Other research suggests that the sense of smell can be linked to Alzheimer's disease and cognitive impairment in more than one way (e.g., Dintica et al., 2019; Goette et al., 2019; Kreisl et al., 2018; Park et al., 2018; Stamps et al., 2013; Swan et al., 2002). First, research shows that individuals who are less able to identify a smell are more likely to develop a cognitive impairment or Alzheimer's disease later (e.g., Goette et al., 2019). And, while this speaks to the sense of smell, it also loops in the memory component of pulling a name that labels the smell from one's memory storage. Other research shows detection of smell directly links to cognitive impairments. In a study investigating this link (Stamps et al., 2013; see Table 2.1), participants demonstrated a right nostril deficit in the detection of the smell of peanut butter in individuals with a mild cognitive impairment—before it turned to a more severe case of dementia. Here, participants with a mild cognitive impairment needed the peanut butter sample to be at nearly half the distance from their right nostril compared to their left and compared to their healthy counterparts before they could detect that the smell was present. The results here demonstrate an inexpensive test that can be used to detect Alzheimer's disease early, at a time when more

TABLE 2.1 ■ Olfactory Detection Distance Asymmetry for Individuals With Cognitive Impairments

	Symmetric	Asymmetric (Left worse)	Asymmetric (Right worse)
Alzheimer's Disease	0	18	0
Mild Cognitive Impairment	11	10	3
Other Dementias	15	0	11
Older Controls	21	2	3

Source: Stamps, J. J., Bartoshuk, L. M., & Heilman, K. M. (2013). A brief olfactory test for Alzheimer's disease. *Journal of the Neurological Sciences, 333*(1–2), 19–24. https://doi.org/10.1016/j.jns.2013.06.033

options are available for a patient to slow down progression of the disease. Interestingly, other research has demonstrated that olfactory training (OT; regularly smelling specific odorants at predetermined concentrations) can improve connections and benefit those experiencing cognitive decline (e.g., Oleszkiewicz et al., 2021).

AGING WELL: SENSORY CHANGES

Adaptability is important. Changes happen all throughout our lives. Making them positive can be simply a matter of how we adapt to them. Sensory changes are no different. Many of the sensory changes that occur as a part of normal aging processes are small, and as such, small adjustments can make a big impact. For example, reading large-print books instead of regular print or zooming in on your computer screen can ease the strain on your eyes as your lens begins to harden, and won't restrict what you like to read or stop you from reading at all. In addition, using closed captioning on the television while you're watching it and asking your friends and family to speak more slowly and clearly are easy accommodations that can make adapting to life's sensory changes easier, with very little effort. And, they are accommodations that we can make for our loved ones as well. Consider these limitations when planning your next event—maybe a wedding or birthday party. Perhaps lower the volume of the music during dinner to allow those with difficulty hearing to participate fully in conversation. Or, we can help locate ramps and handrails for our loved ones. These small actions may mean a world of difference.

KEY TERMS

accommodation
apoptosis
auditory nerve
auditory threshold
cochlea
cornea

elderspeak
flavor
lens
lens bruescence
macula
mechanoreceptors
presbycusis
presbyopia
pupil
retina
rods and cones
transduction
tympanic membrane
vertigo
vestibular system

COMPREHENSION QUESTIONS

1. In the absence of disease, explain why seeing at night while driving may be difficult.
2. What are some simple changes one can make to adjust to minor vision changes? Why do these work?
3. Identify three ways in which vision may change that are not consistent with healthy aging.
4. In what ways does smell change with age? How can these impact how an older adult eats?
5. Why can hearing loss lead to social isolation?
6. How can hearing loss be corrected? And why are individuals resistant to these modifications?
7. Is balance a particularly large problem in an older population? How can physical fitness help maintain or correct balance?
8. How are touch and temperature regulation related?
9. How is touch related to balance?

ADDITIONAL READINGS

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