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Biological Aging and Health

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Miguel just celebrated his 70th birthday, and he feels extremely fortunate to have lived well beyond the age of his father, who passed away at age 60 after suffering from hypertension and diabetes. Unlike his father, Miguel gave up smoking some years back, and he is proactive about scheduling regular visits to his doctor and adhering strictly to the medication regimen his doctor prescribes for hypertension. Although Miguel usually feels stiff when he wakes up in the morning, he often joins a neighborhood group of early morning walkers. He is convinced that this exercise helps him work out the kinks and keeps him limber and just as physically fit as he was when he was 50. It helps too that he and his wife of many years are determined to keep their weight in check and enjoy preparing meals that feature plenty of fish and vegetables. Miguel's wife still works, so Miguel visits the local farmers' market several mornings a week to select fresh ingredients for their dinners. He spends most afternoons at the community center where he swims and plays cards with several cronies. Miguel is bilingual, but he is concerned his Spanish is getting rusty from lack of use, so he is planning to audit a Spanish course at the local college. He thinks retaining his facility in Spanish is an intellectual challenge that will keep his mind sharp.

The Meaning of Longevity

Why does aging occur and what determines how long people will live? In this chapter, we'll

explore the biological aspects of aging. Unlike psychological aging, which includes both increments (gains) and decrements (losses), biological aging generally involves “decremental physical changes (both structural and functional) that develop with the passage of time and eventually end with death” (Busse, 1995, p. 754). Even so, these changes do not usually prevent people from leading productive and enjoyable lives.

Biological aging is gradual and cumulative. Biological functioning usually reaches a peak in early adulthood, after which it declines, but the rate of decline is not the same for everyone. Some people experience noticeable physical changes in their mid-60s or earlier, while others (like Miguel, who was described earlier) are able to maintain the physical capabilities of the average middle-aged adult into their 70s or later. Frequently we hear reports in the popular media about individuals in their 80s or even 90s who climb mountains, run marathon races, or work in demanding full-time jobs. Such older adults are not in the majority. Even so, most older adults are neither helpless nor dependent.

Some scientists think biological changes are a consequence of the aging process rather than the result of disease (Hayflick, 1995). However, aging in the absence of any disease process is rare because the likelihood of certain diseases increases with age (Masoro, 2006a). Also, although scientists have debated as to whether some diseases are an integral part of aging, it seems likely that aging can affect the consequences of disease when it does occur (Masoro, 2006a).

People who study biological processes in large populations use the terms **morbidity** and **mortality**. Morbidity refers to illness and disease, and mortality refers to death. These two terms are related because illness and disease can result in death, and death is often preceded by illness and disease. However, morbidity does not necessarily result in mortality – people with chronic illnesses can live for a long time with the proper treatment. **Longevity** refers to the length and duration of life. Two aspects of longevity are **life expectancy** and **life span**. As we will see shortly, life expectancy and life span are related but they are not one and the same.

Life Expectancy

Life expectancy is the average number of years people in a particular cohort are expected to live. Life expectancy figures indicate what is anticipated, on average, for large numbers of people but they cannot forecast how many years an individual cohort member will live.

Life expectancy at birth

Life expectancy at birth is the average number of years people born in a specific year (that is, a birth cohort) are expected to live. It is affected by factors such as level of nutrition, sanitary conditions, and medical care, including antibiotics and immunizations that are available to the population of a particular country.

Table 3.1 *Life expectancy at birth (in years) in the United States*

Source: National Center for Health Statistics (2010a, p.27).

Year of birth	Both sexes	Males	Females
1900	47.3	46.3	48.3
1970	70.8	67.1	74.7
1980	73.7	70.0	77.4
1990	75.4	71.8	78.8
2000	76.8	74.1	79.3
2007	77.9	75.4	80.4

Table 3.2 *Life expectancy at birth by race and sex in the United States*

Source: National Center for Health Statistics (2010a, p.27).

Year	European American			African American		
	Both sexes	Males	Females	Both sexes	Males	Females
1970	71.7	68.0	75.6	64.1	60.0	68.3
1980	74.4	70.7	78.1	68.1	63.8	72.5
1990	76.1	72.7	79.4	69.1	64.5	73.6
2000	77.3	74.7	79.9	71.8	68.2	75.1
2007	78.4	75.9	80.8	73.6	70.0	76.8

Table 3.1 shows that infants born in the United States in 1900 had an average life expectancy of 47.3 years of age, but by 1970 the average life expectancy was 70.8 years. This dramatic increase is attributable chiefly to medical advances that reduced infant mortality,

mortality from childhood diseases, and maternal mortality. Since 1970, life expectancy in the United States has continued to climb gradually, no doubt due to improvements in public health that further reduced mortality from infectious diseases. In addition, medical advances that prevent or treat cardiovascular diseases and cancer have helped boost life expectancy.

With regard to gender, the gap between female and male infants born in 1900 was only two years, but by 1970, it had widened to 7.6 years. By 2007, the gender gap in life expectancy was a somewhat narrower 5.0 years. [Table 3.2](#) shows life expectancy figures by race and sex. Note that the figures for African American infants are lower overall, but the same gender gap exists for African Americans and European Americans. Only time will tell whether this gap will remain stable or whether it will shrink over time.

In the United States, life expectancy at birth could continue to rise gradually with further medical advances, especially as more effective treatments become available for diseases that occur in the middle and older adult years. However, there is some speculation that life expectancy could actually decrease because of a surge in the rate of obesity (National Institutes of Health [NIH], 2005). It is estimated that about 27% of Americans aged 60+ are obese (*A Profile of Older Americans*, 2010). However, the life-shortening effect of obesity could be moderated by efforts to engage in exercise and adhere to diets that insure long-term weight control.

Global considerations

Not surprisingly, life expectancy at birth varies from country to country (see [Figure 3.1](#)). In developed countries (for example, Japan, Sweden, Australia, Canada, New Zealand, United Kingdom, and United Arab Emirates), life expectancy at birth is about the same or slightly higher than that in the United States. Life expectancy at birth is much lower in less developed countries (for example, Afghanistan, Rwanda, and Uganda), no doubt because of less available medical care, poor nutrition, and less sanitary public health conditions.

Life expectancy at ages 65 and 75

Once people celebrate their 65th birthday, how much longer will they live? In the United States, those who reach 65 represent a select group that has survived obstacles that ended the lives of some fellow cohort members, and those reaching age 75 are even more select. [Table 3.3](#) shows life expectancy figures for European Americans and African Americans who reach age 65 and age 75. Note that, on average, men who reach age 65 and age 75 have fewer years left than women do. Also note that at age 75, the gap in life expectancy between European Americans and African Americans is small.

Life Span

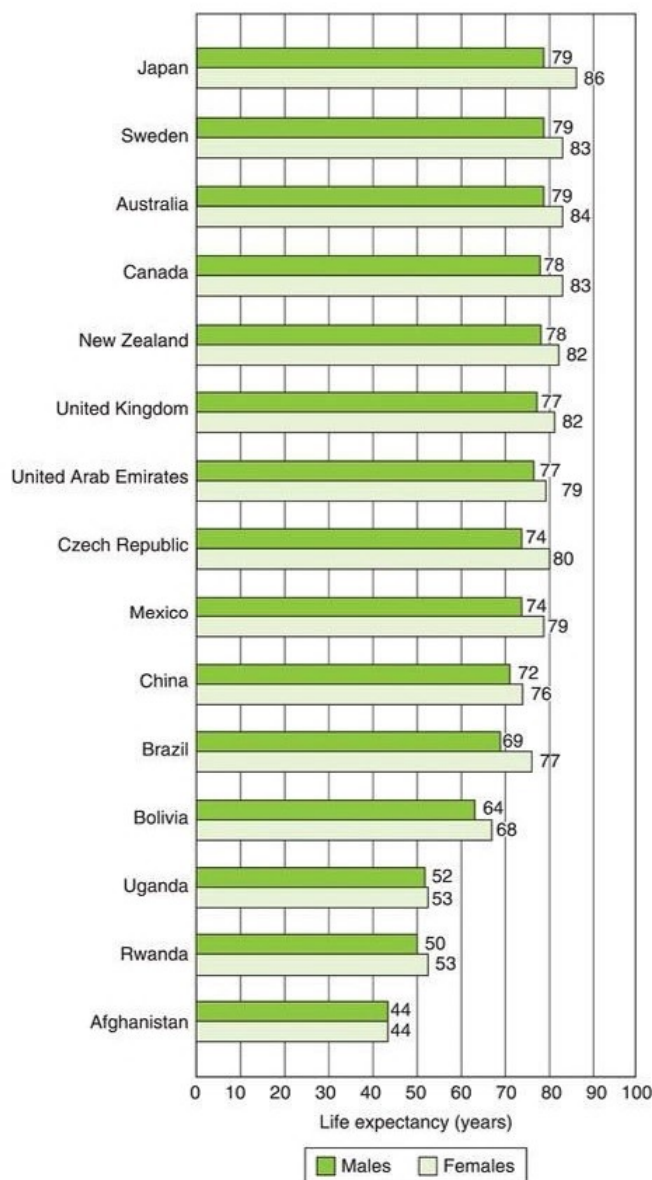
Life span is the maximum longevity, or extreme upper limit of time, that members of a species can live. What is that figure for humans?

In the 1970s, there were reports of villagers in isolated mountainous regions of Russia, Turkey, and Ecuador who claimed to be **centenarians** (living to the age of 100). In fact, some gave ages up to 160 (Beller & Palmore, 1974; Kyucharyants, 1974; Medvedev, 1974). Scientists flocked to these remote areas only to discover that these phenomenally old ages were exaggerated. The confusion was due partly to inaccurate birth records but also to the common practice of duplicating names across several generations.

Until recently, the oldest person with a documented birth record was a woman named Jeanne Calment of Arles, France, who was born in 1875 and died in August 1997, at the age of 122 (Weiss, 1997). This record has been challenged by a Brazilian woman, Maria Olivia da Silva, who was born in 1880 and died in 2010, presumably at the age of 130. However, this claim, which was reported on the Wikipedia website, has not been firmly established.

[Figure 3.1](#) *Male and female life expectancies at birth in selected countries.*

Source: Population Reference Bureau (2010).



Rectangular survival curve

Although human life expectancy has increased dramatically over the past century in the United States and other developed countries, the human life span has remained relatively constant over time and across cultures. Today, however, the chances of approaching maximum human longevity are higher, especially in developed countries, so more and more people are living closer to the maximum human life span.

Table 3.3 Life expectancy at ages 65 and 75 by race and sex in the United States, 2007

Source: National Center for Health Statistics (2010a, p.27).

Age	European American			African American		
	Both sexes	Males	Females	Both sexes	Males	Females
65	18.7	17.3	19.9	17.2	15.2	18.7
75	11.7	10.6	12.4	11.2	9.9	12.1

As hygienic conditions improve, as disease-related causes of death are prevented or delayed, and as more people adopt healthy lifestyles, life expectancy should continue to increase gradually and more people will approach the maximum human life span. The term **compression of mortality** (Fries, 1995, 1997) refers to a phenomenon whereby a greater proportion of deaths will occur during a very narrow time period toward the upper limit of the human life span. In other words, more and more people will live closer to the maximum human life span, with the resultant **rectangular survival curve** shown in [Figure 3.2](#).

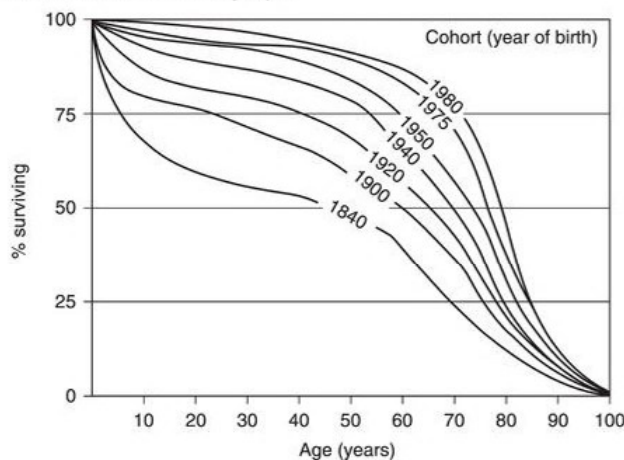
Quality of life

If people live a long time, will their final years be characterized by disability, dependency, and disease, or will they enjoy independence and robust health (Fries, 1997; Schneider, 1997)? In other words, will compression of mortality be accompanied by a corresponding **compression of morbidity**? Compression of morbidity means that illness or extreme disability will occur only during a narrow period of time immediately prior to death. To the extent that onset of disease and disability can be delayed until a short interval of time late in life, quality of life should remain high until very close to its end.

In summary, human life expectancy has been increasing, but human life span has changed very little over time. The rectangular survival curve illustrates that a larger proportion of people are approaching maximum life span, so more individuals could become centenarians. However, life span is not likely to change until the key to aging is discovered (Hayflick, 1994; Olshansky et al., 2002). Meanwhile, a more realistic goal is to maximize the quality of the years that we have left.

Figure 3.2 *The rectangular survival curve.*

Source: Adapted from Katchadourian (1987).



The Biological Aging Process

What is biological aging? Will it happen no matter where or how a person lives, and does it occur earlier under some circumstances than others? According to some theories, biological aging occurs within the organism regardless of outside forces. Other theories contend that biological aging is influenced by our environment and daily habits and also by the way we cope with life's challenges (VonDras & Blumenthal, 2000).

Primary and Secondary Aging

Some researchers distinguish between two categories of biological aging: **primary aging** and **secondary aging**. Primary aging refers to the unavoidable (inevitable) biological processes that are universal, meaning that all members of a species are affected. Its effects may not become apparent for many years, but primary aging is set in motion early in life and progresses gradually over time. However, there are individual differences in the rate at which it occurs. In addition to being inevitable and universal, primary aging is intrinsic, meaning it is determined by factors within the organism. Some scientists use the term *senescence* to mean primary aging (Busse, 1995).

Secondary aging refers to processes experienced by most, but not necessarily all, members of a species. Thus, it is neither inevitable nor universal. Unlike primary aging, secondary aging is associated with defects in biological functioning resulting from hostile environmental influences (Busse, 1995). In short, secondary aging is attributed to disease, disuse, and abuse. Diseases can accelerate aging, as can disuse from lack of exercise, as well as abuse from habits such as smoking, excessive consumption of alcohol, poor nutrition, or overexposure to sun or loud noise. Note that Miguel, who was described earlier, has made a conscious effort to avoid sources of disuse and abuse.

The distinction between primary and secondary aging is not accepted by everyone, nor is it always possible to differentiate the effects of aging from the symptoms of diseases that occur frequently in the later years (Masoro, 2006a). Also, primary aging may render us more vulnerable to disease and other sources of damage usually associated with secondary aging. However, a conceptual distinction can heighten our awareness of aspects of our lives over which we may exert some control.

Theories of biological aging are often grouped into two general categories: programmed and stochastic (Cristofalo, Tresini, Francis, & Volker, 1999). [Table 3.4](#) lists several prominent theories identified with each category, but not every theory falls strictly into one category or the other.

Table 3.4 *Theories of biological aging*

Programmed theories	Stochastic theories
Time clock theory	Error theory

Immune theory	Wear and tear theory
Evolutionary theory	Rate of living theory
	Stress theory
	Cross-linking theory
	Free radical theory

Programmed Theories of Biological Aging

Programmed theories of biological aging consider aging to be under the control of a genetically based blueprint (Hayflick, 1994). As such, these theories are closely related to primary aging.

Cellular aging

Time clock theory was based on Hayflick's early research on cells that were removed from tissues of various organisms and grown in culture. Cells taken from a human infant doubled approximately 50 times, whereas cells from a mouse (maximum life span of only 3 years) doubled only 10–15 times. This suggested that the life span of a species was controlled by a genetically determined time clock operating at the cellular level.

Even within the human species, cells from infants and young children divided more times than cells from older adults, which presumably had already used up part of their program. Also, cells from children with Down syndrome (a genetic abnormality associated with shorter than average life expectancy) and children with progeria (a rare genetic abnormality characterized by premature aging and extremely reduced life expectancy) divided fewer times than did cells from genetically normal individuals of the same age (Hayflick, 1995). Even so, it was not clear exactly what determined the number of times cells would divide. Furthermore, Cristofalo et al. (1999) contend that the number of cell divisions may be more related to health than to age. Nonetheless, Hayflick's research opened the door to programmed theories of aging.

Understanding Aging Box 3.1

Longevity: Genetic Mutations and Human Growth Hormone

According to an article in *The New York Times* (Wade, 2011), in 1987 physician Dr. Jaime Guevara-Aguirre came across a group of 99 individuals living in a remote village in Ecuador whom he diagnosed with a type of Dwarfism known as Laron syndrome, which is characterized by very short stature (under 3½ feet) and an unusually youthful appearance. Members of this group are descendants of Sephardic Jews from Spain and Portugal who converted to Christianity but were persecuted nonetheless. After following this group for 24 years, Dr. Guevara-Aguirre noted that their incidence of cancer and diabetes was practically nonexistent even though area inhabitants of normal height suffered from these diseases at the usual rate. More recently, he teamed up with cell neurobiologist Dr. Valter Longo of the University of Southern California to study why the mutated gene that blocks the body's reaction to growth hormone in Laron syndrome individuals seems to protect them from these age-related diseases. Unfortunately, the Laron syndrome individuals have a higher than average death rate from alcoholism and accidents. Otherwise, their longevity might far exceed the average.

Photo 3.1 Children with a rare genetic disorder, progeria, experience premature aging and reduced life expectancy. Photo © Eddie Adams/AP/Press Association Image



Recently, researchers have focused on **telomeres**, the protective caps at the tail ends of the chromosomes located in each cell. Each time a cell divides, telomeres lose some length and, when they become too short, cell division is no longer possible and cells become senescent (Cristofalo et al., 1999). Thus, the length of the telomeres may determine cell longevity and perhaps, indirectly, the longevity of the organism. Researchers are trying to determine whether supplying cells with an enzyme called telomerase can lengthen or maintain the telomeres, making it possible for cells to continue dividing and avoid becoming senescent. However, there may be a trade-off between stimulating telomerase activity to prevent cell senescence and promoting abnormal cell division typically seen in diseases such as cancer (Harley, 2006).

The immune system

The immune system defends the body against invasion of foreign substances by producing antibodies that circulate and deactivate substances not recognized as self. According to *immune theory*, the immune system is programmed to maintain its efficiency for a certain amount of time, after which it starts to decline. A compromised immune system may not produce sufficient antibodies to protect against foreign invaders. Furthermore, it may produce inferior antibodies, which mistakenly attack and destroy normal cells. Weakened immune system functioning has been linked to age-related diseases such as cancer (Effros, 2006). However, it is premature to conclude that immune system decline is the cause rather than the result of normal aging (Hayflick, 1994).

Evolution

According to the *evolutionary theory* of biological aging, members of a species are genetically programmed to bear and rear their young. Once they reproduce and raise their offspring to independence, they have fulfilled their service in perpetuating the species. Researchers have found that fruit flies forced to delay reproduction to later ages live longer than fruit flies that reproduced early (Phelan, 2006). Nonetheless, even after reproduction, organisms may have sufficient energy to coast along for some period of time. Once excess energy is used up, however, susceptibility to disease increases. Hayflick (1994) likens the years beyond reproduction and raising offspring to the ticking of a watch after the warranty period is over. He suggests that instead of asking, “Why do we age?” we should ask, “How do we manage to live as long as we do?”

Stochastic Theories of Biological Aging

Stochastic theories of biological aging focus on random damage to our vital systems that occurs with the process of living, so these theories are closely related to secondary aging. As damage accumulates, we cease to function efficiently and eventually life becomes impossible to sustain. Support for stochastic theories comes from the fact that aging occurs at different rates even among identical twins who have exactly the same genetic makeup but rarely live exactly the same amount of time. Also, certain environmental factors are associated with accelerated aging and shortened longevity (Cristofalo et al., 1999).

Errors

Error theory postulates that errors occur at the cellular level, resulting in the production of faulty molecules. Errors can result from the organism’s metabolic processes or exposure to environmental factors such as radiation. Cells have protective mechanisms that repair errors,

but these may not keep up with the damage created by faulty molecules. Over time, unrepaired damage builds up, eventually resulting in metabolic failure and ultimately death (Turker, 1996). We have much to learn about what causes errors and exactly how they are repaired, but this theory is a promising approach to understanding biological aging (Hayflick, 1994).

Wear and tear

Not surprisingly, damage to the body can build up during the course of living. The *rate of living theory*, which is a variant of the *wear and tear theory*, postulates that we begin life with a fixed amount of physiological energy. If we expend it quickly, aging begins early and proceeds rapidly. However, we can retard aging by conserving energy. Appealing as this sounds, there is little direct evidence that taking it easy will retard aging. For example, people who work in physically strenuous jobs do not show signs of aging any earlier than those who work in less physically demanding jobs (Hayflick, 1994, 1995).

Stress

Life can be demanding in ways that are not physical, and according to the *stress theory* of aging, the biological system sustains damage from prolonged exposure to stress. The body has two regulatory systems for responding to stress – the sympathetic nervous system (SNS) and the neuroendocrine hypothalamic-pituitary-adrenal (HPA) axis. Stress triggers physiological activation that results in secretion of stress-related hormones called glucocorticoids (GC). In young organisms, the HPA axis quickly returns to a normal level following exposure to stress. In older organisms, the HPA axis takes longer to return to a normal level, which means that older organisms have prolonged exposure to GC hormones that have been secreted in response to stress. Prolonged exposure to GC increases the risk of high blood pressure (hypertension) and cardiovascular disease. Ultimately, stress-related damage to the biological system can accelerate the aging process (Nichols, 2006).

Finch and Seeman (1999) describe a study that used a driving simulation test to assess reactions to stress. Young (aged 30–39) and older (aged 70–79) adults responded to potentially dangerous situations similar to those encountered in real-world driving. GC levels were measured prior to the simulated driving test (baseline) and several times later on, up to two hours after the test was completed. GC levels of the younger adults returned to baseline levels well before two hours had elapsed, evidence for greater resiliency. In contrast, GC levels of the older adults remained elevated after two hours, indicating less resiliency. However, the GC level of the less healthy older adults, many of whom suffered from diabetes (discussed later on) and high blood pressure, remained elevated for longer than the GC level of the healthier older adults. Uchino, Berg, Smith, Pearce, and Skinner (2006) studied cardiovascular reactivity in younger and older adults as they confronted daily life stress. Older adults showed greater reactivity (increase in blood pressure) than younger adults did even though older adults' heightened physiological responsiveness was not coupled with an increase in self-reported negative affect.

Exercise and dietary regulation seem to have a protective effect on older adults' neuroendocrine and cardiovascular functioning. For example, regular exercise and restricted diets often result in lowered blood glucose, which could offset the negative effects of exposure to stress-related hormones. In addition, being part of a social network is beneficial for feelings of psychological well-being, which in turn has been associated with less exaggerated responses to stress. Miguel, described at the beginning of the chapter, is well positioned in terms of a social network that includes a long-term marriage as well as companions with whom to socialize. In older adults, feelings of loneliness are associated with higher blood pressure (Hawkey & Cacioppo, 2007). At present, we cannot make cause-and-effect statements, but longitudinal studies could help clarify the picture.

Build-up of damaging substances

Some biological theories of aging focus on damaging substances or waste products that could disrupt physiological functioning. *Lipofuscin*, a substance that accumulates in the brain and in heart muscle cells, increases with age, although it has not been established whether, or even how, it interferes with functioning.

Collagen is a common protein that surrounds and supports tendons, ligaments, bone, cartilage, and skin. It consists of parallel molecules held together by ladder-like rungs, or cross-links. When neighboring molecules are joined by a small number of cross-links, they

remain pliable. As the number of cross-links increases, the ladders become less pliable. Age-related changes in the skin are a visible example of cross-linking. In young adults, the skin is soft and pliable, but with increasing age and more cross-links, it becomes less so. According to the *cross-linking theory* of aging, cross-linking affects metabolic functioning because it obstructs the passage of nutrients and waste products into and out of cells. As with lipofuscin, cross-linking increases with age, but it is still not clear whether cross-linking is a cause, or simply a by-product, of the aging process (Hayflick, 1994).

Free radical theory focuses on unstable molecular fragments (free radicals), which are formed as a by-product of the body's normal metabolic processes. Because of their instability, free radicals unite with molecules that happen their way, thereby preventing those molecules from functioning normally. Free radicals can damage proteins, fats, and lipids, and they have been implicated in the production of cross-links. They have also been associated with changes in the brain and with cardiovascular disease, cancer, and even the formation of cataracts on the lens of the older eye (Rowe & Kahn, 1998).

There is evidence that antioxidants (including vitamins E and C and beta-carotene) serve to chemically inhibit the formation of free radicals, or at least compromise their ability to unite with susceptible molecules (Rowe & Kahn, 1998). Consumption of antioxidants has been associated with lowered incidence of cardiovascular disease and cancer, both age-related diseases. There are some reports that animals fed antioxidants live longer on average compared to control animals not fed extra antioxidants. However, it has yet to be shown that antioxidants actually increase the maximum longevity (life span) of a species (Hayflick, 1994).

In sum, lipofuscin, collagen, cross-linking, and free radicals accumulate as we age, but do these substances actually cause aging? Olshansky et al. (2002) question the claim made by the anti-aging industry that antioxidant supplements can slow down aging. Antioxidants occur naturally in the body and in fruits and vegetables, but supplements could be harmful because we need some free radicals for certain necessary steps in internal biochemical reactions.

Caloric Restriction and Longevity

The role of diet in aging and longevity has intrigued researchers for decades. In an early study, McCay, Crowell, and Maynard (1935) demonstrated that rats fed a severely reduced number of calories lived longer than rats allowed normal caloric intake. Recent studies have shown that as long as they have nutritionally sound diets, rats that consume 50% fewer calories and weigh 50% less than normally fed control rats have a lower incidence of cancer, increased longevity, and the sleeker appearance of younger rats. Vasselli et al. (2005) reported that rats restricted throughout life had the greatest longevity, whereas those obese throughout life had the shortest longevity. The longevity of rats that had been obese but then lost weight did not differ from that of rats that were nonobese throughout life, which indicates that dietary changes can have a positive effect on longevity.

There are several hypotheses about why caloric restriction has a positive effect on rodents (Weindruch, 1996). Caloric restriction may slow the rate of cell division, thereby reducing the chances of the uncontrolled cell division characteristic of late-life cancers. Also, caloric restriction is associated with lower blood glucose level, which reduces the chances of damage from the build-up of sugar on proteins. Additionally, caloric restriction may limit the formation of free radicals. At present, there is no one answer as to why caloric restriction increases average longevity in rodents. It may slow down the aging program or perhaps it simply delays the onset of disease.

It remains to be seen whether caloric restriction is beneficial for humans. There is evidence that people living on the Japanese island of Okinawa, whose diets are low in calories but high in nutrients, enjoy greater than average longevity. Also, people with reduced caloric intake have a lower incidence of some forms of cancer. Weindruch (1996) recommends a diet that reduces the level of blood glucose and cholesterol, and he suggests that people strive to weigh 10 to 25% less than their natural "set point." Miguel, who was described earlier, tries to keep his weight in check, as does his wife. Clearly, obesity is a risk factor that can shorten life, although questions remain about the benefits of caloric restriction for normal-weight humans.

In summary, there are numerous theories about why biological aging occurs, but no one theory has proved definitive. As yet, no single fundamental mechanism has been identified as holding the key to the process of aging (Martin, 2007). Also, theories of biological aging are

often categorized as programmed or stochastic, but keep in mind that genetic programming could render organisms either more or less vulnerable to damage from internal and external sources.

Individual Differences in Longevity

The upper limit of the human life span is approximately 120 years, but why do some people live closer to that limit than others? Studying individuals who live a long time is one way to explore this question.

In the United States, the Georgia Centenarian Study has been following people 60 to 100 years of age to determine the relationships between family longevity, social and environmental support, personality characteristics, adaptational skills, satisfaction with life, loneliness, nutrition and dietary patterns, and health (Fees, Martin, & Poon, 1999; Poon, Sweaney, Clayton, & Merriam, 1992). So far, continued follow-up of these individuals indicates that those who control the stress in their lives, engage in regular physical activity, and maintain a good level of nutrition are less likely to show an increase in fatigue over time (Martin, Bishop, Poon, & Johnson, 2006). Harvard Medical School researcher Thomas Perls and his colleagues have studied 150 centenarians. Based on their findings, they developed a quiz people can take to determine their chances of living to 100 (see [Table 3.5](#)).

Nature and Nurture

Who among us will have the good fortune to remain healthy and vigorous into the ninth decade or later? To answer this question, scientists are investigating factors related to both nature and nurture.

Nature

Nature refers to heredity, or genetic makeup. The number of genes that underlie the aging process is not known (Turker, 1996), although heredity does seem to be a factor in longevity. Most people who live beyond age 70 have at least one parent or grandparent who lived into the 70s. Those who live into their 90s are likely to have at least one very long-lived parent, though the age of the mother's death seems to be a better predictor of a person's longevity than the age of the father's death (Hayflick, 1994).

Identical twins have exactly the same genetic makeup and are more similar in longevity compared to fraternal twins, who are no more genetically related than other siblings. Even so, identical twins do not always age in a completely parallel fashion, nor do they live exactly the same amount of time (Hayflick, 1994). Thus, nature cannot fully account for the rate at which people age and how long they live.

Understanding Aging Box 3.2

Gender Crossover in Late Older Adulthood

In his investigation of older adulthood, Thomas Perls (2004b) reports that starting in the 8th decade but more so in the 9th decade, men are often better off mentally and physically than women. In terms of absolute numbers, more women than men are still alive at age 95. At this very late stage of life, however, a larger proportion of men than women enjoy a high level of mental and physical fitness that allows them to lead lives of relative independence with few major health problems and little need for special care. For reasons we do not yet fully understand, men who survive into their 90s seem to be spared from some of the health problems experienced by many women their age.

Table 3.5 *Will you live to be 100?*

After completing a study of 150 centenarians, Harvard Medical School researchers Thomas Perls, MD, and Margery Hutter Silver, EdD, developed a quiz to help you calculate your estimated life expectancy.

Score

1. Do you smoke or chew tobacco, or are you around a lot of secondhand smoke? Yes (-20) No (0)
2. Do you cook your fish, poultry, or meat until it is charred? Yes (-2) No (0)
3. Do you avoid butter, cream, pastries, and other saturated fats as well as fried foods (e.g., French fries)? Yes (+3) No (-7)
4. Do you minimize meat in your diet, preferably making a point to eat plenty of fruits, vegetables, and bran instead? Yes (+5) No (-4)
5. Do you consume more than two drinks of beer, wine and/or liquor a day?(A standard drink is one 12-ounce bottle of beer, one wine cooler, one five-ounce glass of wine, or one and a half ounces of 80-proof distilled spirits.) Yes (-10) No (0)
6. Do you drink beer, wine, and/or liquor in moderate amounts (one or two drinks/day)? Yes (+3) No (0)
7. Do air pollution warnings occur where you live? Yes (-4) No (+1)
8. (a) Do you drink more than 16 ounces of coffee a day? Yes (-3) No (0) (b) Do you drink tea daily? Yes (+3) No (0)
9. Do you take an aspirin a day? Yes (+4) No (0)
10. Do you floss your teeth every day? Yes (+2) No (-4)
11. Do you have a bowel movement less than once every two days? Yes (-4) No (0)
12. Have you had a stroke or heart attack? Yes (-10) No (0)
13. Do you try to get a sun tan? Yes (-4) No (+3)
14. Are you more than 20 pounds overweight? Yes (-10) No (0)
15. Do you live near enough to other family members (other than your spouse and dependent children) that you can and want to drop by spontaneously? Yes (+5) No (-4)
16. Which statement is applicable to you? (a) "Stress eats away at me. I can't seem to shake it off." Yes (-7) (b) "I can shed stress." This might be by praying, exercising, meditating, finding humor in everyday life, or other means. Yes (+7)
17. Did both of your parents either die before age 75 of nonaccidental causes or require daily assistance by the time they reached age 75? Yes (-10) No (0) Don't know (0)
18. Did more than one of the following relatives live to at least age 90 in excellent health: parents, aunts/uncles, grandparents? Yes (+24) No (0) Don't know (0)
19. (a) Are you a couch potato (do no regular aerobic or resistance exercise)? Yes (-7) (b) Do you exercise at least three times a week? Yes (+7)
20. Do you take vitamin E (400-800 IU) and selenium (100-200 mcg) every day? Yes (+5) No (-3)

STEP 1: Add the negative and positive scores together. Example: -45 plus +30 = -15. Divide the preceding score by 5 (-15 divided by 5 = -3).

STEP 2: Add the negative or positive number to age 84 if you are a man or age 88 if you are a woman (example: -3 + 88 = 85) to get your estimated life span.

The Science Behind the Quiz

Question 1: Cigarette smoke contains toxins that directly damage DNA, causing cancer and other diseases and accelerating aging.

Question 2: Charring food changes its proteins and amino acids into heterocyclic amines, which are potent mutagens that can alter your DNA.

Questions 3,4: A high-fat diet and especially a high-fat, high-protein diet, may increase your risk of cancer of the breast, uterus, prostate, colon, pancreas, and kidney. A diet rich in fruits and vegetables may lower the risk of heart disease and cancer.

Questions 5,6: Excessive alcohol consumption can damage the liver and other organs, leading to accelerated aging and increased susceptibility to disease. Moderate consumption may lower the risk of heart disease.

Question 7: Certain air pollutants may cause cancer many also contain oxidants that accelerate aging.

Question 8: Too much coffee predisposes the stomach to ulcers and chronic inflammation, which in turn raise the risk of heart disease. High coffee consumption may also indicate and exacerbate stress. Tea, on the other hand, is noted for its significant antioxidant content.

Question 9: Taking 81 milligrams of aspirin a day (the amount in one baby aspirin) has been shown to decrease the risk of heart disease, possibly because of its anticlotting effects.

Question 10: Research now shows that chronic gum disease can lead to the release of bacteria into the bloodstream, contributing to heart disease.

Question 11: Scientists believe that having at least one bowel movement every 20 hours decreases the incidence of colon cancer.

Question 12: A previous history of stroke and heart attack makes you more susceptible to future attacks.

Question 13: The ultraviolet in sunlight directly damages DNA, causing wrinkles and increasing the risk of skin cancer.

Question 14: Being obese increases the risk of various cancers, heart disease, and diabetes. The more overweight you are, the higher your risk of disease and death.

Questions 15,16: People who do not belong to cohesive families have fewer coping resources and therefore have increased levels of social and psychological stress. Stress is associated with heart disease and some cancers.

Questions 17,18: Studies show that genetics play a significant role in the ability to reach extreme old age.

Question 19: Exercise leads to more efficient energy production in the cells and, overall, less oxygen radical formation. Oxygen (or free) radicals are highly reactive molecules or atoms that damage cells and DNA, ultimately leading to aging.

Question 20: Vitamin E is a powerful antioxidant and has been shown to retard the progression of Alzheimer's, heart disease, and stroke. Selenium may prevent some types of cancer.

Nurture

Nurture refers to environmental influences such as the quality of air a person breathes, diet and exercise habits, educational and work history, level of stress in the environment, and health care. It can also include factors such as marital status and social relationships. Rowe and Kahn (1998) contend that as we grow older, genetics become less important, but where and how we live become more important. Miguel, who was described earlier, is acutely aware

of the importance of nurture in insuring a long and healthy life.

The Nun Study

The Nun Study, a longitudinal research program under the direction of University of Kentucky epidemiologist Dr. David Snowdon, has been following over 500 School Sisters of Notre Dame who reside in religious communities across the United States (Snowdon, 1997). In 1997, when they agreed to take periodic test batteries and to donate their brains to science after their death, these Sisters ranged from 75 to 102 years of age. All of the Sisters have similar educational backgrounds, they all worked throughout their adult lives in teaching and service careers, and they lived for decades in religious communities and had similar dietary and exercise habits. They never married or had children, nor did they indulge in habits such as smoking or drinking alcoholic beverages. In short, for these Sisters, the influence of nurture has been similar from early adulthood when they entered the religious order. Nonetheless, the variability among them is striking. Some have remained healthy and active, both physically and cognitively, well beyond their ninth decade. Others are confined to wheelchairs or suffer from cognitive impairments due to strokes or dementia. Such individual differences suggest that nature, or more likely the interaction between nature and nurture, plays a role in health and longevity. However, the influences of nurture could have varied prior to the Sisters' joining the religious order, so we cannot rule out early environmental influences as a reason for their late-life variability in health and longevity.

Marital status

Marital status has been investigated with regard to both health and longevity. Schone and Weinick (1998) inspected the self-reported health habits of 4,443 community-living men and women aged 65 and older who participated in the U.S. National Medical Expenditure Survey (NMES) administered in 1987. Marital status was clearly associated with preventive health behaviors. Those who were married were more likely to have healthy habits such as physical activity, eating breakfast, wearing seatbelts, and abstaining from smoking. However, the association between marriage and engaging in healthy habits was stronger for older men than it was for older women. Miguel, who was described earlier, looks forward to preparing healthy meals alongside his wife. Even so, Schone and Weinick speculate that women value health more than men do, so they may take the lead in monitoring or encouraging husbands to engage in healthy behaviors. Also, those who were African American, lower in economic status, or had fewer years of education were less likely to engage in healthy behaviors. In addition, older adults with fewer social contacts were less likely to have healthy habits than those with more social contacts. Widowed women have more social contacts than widowed men. For women, healthy behaviors may be associated more with social contacts than with marital status.

Tucker, Wingard, Friedman, and Schwartz (1996) studied marital status and longevity by examining data from 1,077 men and women from the Terman Life-Cycle Longitudinal Study that was initiated in 1921. Terman study participants were a select group of intelligent, educated, middle-class, primarily European American children born in 1910. Tucker et al. categorized the Terman study participants according to their marital status as of midlife (in 1950) as follows: (1) consistently married (married with no prior marital breakups); (2) inconsistently married (married, but with a prior marital breakup); (3) separated or divorced; (4) single. When the mortality of these individuals was checked in 1991, those married as of 1950 were found to have lived longer than those separated or divorced as of 1950. This suggests that when it comes to longevity, marriage is indeed a protective factor.

However, several additional findings serve to remind us that we need to exercise caution before concluding that marriage has a uniformly positive effect on longevity. First, in this select sample, individuals who were single as of midlife (1950) had no greater mortality risk than did those married as of 1950. Second, particularly for men, those individuals who were married at midlife but had already experienced a marital breakup (inconsistently married) had a higher mortality risk than those who were consistently married. Tucker et al. speculate that marital breakup may have long-term negative effects that are not completely reduced by remarriage. However, marital inconsistency could also be associated with lower conscientiousness about health. These findings may not generalize to samples with greater diversity or from different birth cohorts, but they should increase our awareness that when it comes to longevity, marital history rather than marital status may serve as a protective factor.

In sum, investigators have tried to study the role of nature and nurture in longevity.

However, longevity is most likely based on a complex mix and interaction of genetic and environmental factors.

Can Social Scientists Predict Longevity?

With such wide variation in human longevity, it is no wonder that social scientists are interested in predicting who will live a long time and who will not. Accurate prediction is a first step toward possible control through interventions that could enable more people to live closer to maximum human longevity.

Tests of cognitive ability, and in some cases self-report measures of health and well-being, have been used to detect whether the end of life is near. In an early study, Kleemeier (1962) administered the Wechsler Adult Intelligence Scale (discussed in more detail in Chapter 6) to 13 elderly men on four occasions over 12 years. During the 12-year interval, the men's scores declined, but the decline was much steeper for the 4 men who were deceased at the end of the 12-year period than it was for the 9 men who survived. Kleemeier's finding of a steeper decline in the deceased individuals became known as **terminal drop** and has been the subject of many subsequent research studies that aim to determine what variables predict mortality.

Deary and Der (2005) tested 898 men and women on several measures in 1988, when they were in their mid-50s. Fourteen years later, 185 people (99 men and 86 women) had died. Reaction time (discussed in Chapter 4) was a strong predictor of mortality – those who were quicker in their 50s were more likely to be alive 14 years later than those who were slower.

Maier and Smith (1999) inspected scores on tests of intellectual functioning administered to 516 individuals (ages 70–103) as part of the Berlin Aging Study in Germany. Each individual was tested only once between 1990 and 1993. By 1996 (3 to 6 years later), 50% of these individuals were deceased, and low test scores were strongly associated with high risk of mortality. To a lesser but still significant extent, subjective feelings of dissatisfaction with aging were also associated with elevated mortality risk. Thus, predictors of mortality were not limited to cognitive functioning, but also included self-evaluations of personal well-being.

Similar findings were reported by Menec, Chipperfield, and Perry (1999) when they inspected data from 1,406 older (ages 65–85+) residents of Manitoba who participated in a longitudinal survey conducted by the Canadian government. Older adults who rated their health as “bad” were more than twice as likely to die within the following 3-year period compared to older adults who rated their health as “excellent.” The association between self-perceived health and mortality risk was significant even when information about the number of physician visits, hospitalizations, and disease diagnoses was taken into account. Clearly, we need to learn more about what factors underlie the relationship between self-perceived health and mortality.

Findings from the Nun Study described earlier indicate it may be possible to predict longevity on the basis of cognitive and emotional measures made much earlier in life. Approximately 180 Sisters who entered convents between 1931 and 1943 at age 22 were required to write an autobiography, which was preserved in the archives of the convent. These authenticated handwritten autobiographies were made available to the Nun Study investigators, who analyzed them for grammatical structure and content. By 1991, the Sisters who had written autobiographies as young adults ranged in age from 75 to 95. By the year 2000, 104 Sisters (58%) were still living but 76 Sisters (42%) were deceased. Not only was the level of linguistic ability evident in autobiographies written six decades earlier positively related to survival, but so was emotional content (Danner, Snowdon, & Friesen, 2001). Sisters whose autobiographies contained positive emotional expressions (happiness, interest, hope, gratefulness, contentment, amusement) were more likely to have survived compared to Sisters whose autobiographies expressed negative emotional expressions (sadness, fear, confusion, hopelessness, anger, disgust). Possibly, the autobiographical content reflects a lifelong pattern of emotional response to life events. That positive feelings may predict survival was also suggested by Gruenewald, Karlamangla, Greendale, Singer, and Seeman (2007), who followed a sample of older adults (ages 70–79) from the MacArthur Study of Successful Aging over a 7-year period. Those who reported at the outset that they felt useful to others were more likely to have survived than those who said they did not feel useful to others.

The studies just described are retrospective. Participants were tested and, later on, investigators looked back to assess whether cognitive test scores, self-reported health ratings,

or indices of emotional well-being and feelings of usefulness differed for those who survived and those who did not. Hopefully, the findings of such studies will allow us to determine whether a low score on a cognitive test or a self-reported health or emotional scale signals impending mortality. The goal would be to predict which individuals are at risk and then intervene to delay mortality.

Maximizing Longevity

From the beginning of time, people have searched for ways to retard the aging process. In the 20th century, affluent people traveled to Romania for special vitamin injections, to Switzerland for injections of cells from a lamb fetus, and to London for injections of genetic material and enzymes from fetal cells. Many who sought these treatments reported that the effort and expense were worthwhile, but there is little scientific evidence that such treatments restored youth or extended life (Woodruff-Pak, 1988). Furthermore, there is little empirical evidence to support recent claims made by the anti-aging industry that some products currently on the market can reverse aging (Olshansky et al., 2004; Perls, 2004a).

Even so, certain lifestyle practices hold promise for maximizing longevity. First, abstention from smoking decreases the risk of cancer and heart disease. Individuals who give this habit up enjoy an immediate benefit of reducing the risk of heart disease and a long-term benefit of reducing the risk of cancer and other lung diseases (Rowe & Kahn, 1998). Miguel, described earlier, gave up smoking, a habit he had shared with his father.

Modifications in diet such as cutting down the intake of fat and sugar can reduce the risk of heart disease and some forms of cancer. Obesity and sedentary living have become a public health issue, and older adults are no exception. Among community-living older adults, approximately 37% of men and 36% of women aged 65–74 are obese, as are approximately 26% of men and 26% of women aged 75 and older (National Center for Health Statistics, 2010). However, proper diet and daily physical activity reduce obesity and the concomitant health risks in older adulthood. Both physical activity and positive feelings about physical capability are associated with a reduced likelihood of functional limitations (McAuley et al., 2007). Also, exercise can minimize the effects of circulatory diseases and contribute to the maintenance of bone density in middle-aged and older adults. Miguel, described earlier, tries to lead his life accordingly. But some older adults shy away from physical activity because they are fearful that muscle strength and flexibility exercises will do them harm (Cousins, 2000). Clearly, we need to customize exercise programs to the needs of individual older adults, who should be given encouragement and positive feedback on their progress.

In addition to adequate medical care and sufficient physical and intellectual stimulation, social factors are important. Health and vitality tend to be preserved when individuals are emotionally engaged and socially integrated, as is the case with Miguel. Rowe and Kahn (1998) emphasize the importance of close relationships and regular activities that make life meaningful and exciting. Note that the Longevity Quiz in [Table 3.5](#) includes items that tap lifestyle habits and social factors.

Physical Changes and Disease

Physical changes take place over the course of adulthood, although there is considerable variation in the rate at which they occur. Within the same individual, changes may be more noticeable in some parts of the body than in others. Also, as mentioned earlier, a distinction is often made between aging and disease, although certain diseases become more frequent as age increases (Masoro, 2006a). Some diseases are associated with pain, disability, or limitations in functioning even in the early stages. Other diseases have no noticeable symptoms until they are advanced, at which point they can be difficult to treat. Now we will look at some of the age-related physical changes and diseases often encountered in older adulthood.

Body Systems

Some physical changes hold considerable meaning for how aging individuals feel about themselves as well as how people view them. Others are important because they affect how older adults function, especially under demanding and stressful conditions.

Skin and hair

Visible signs of aging in the texture and appearance of the skin and hair are among the first to be noticed. With increasing age, the skin becomes drier and begins to sag and show wrinkles. Thinning and graying of hair (and for men, loss of hair) become more prevalent.

In a classic article, Sontag (1972) argued that Americans have a *double standard of aging* – visible signs of aging are viewed more negatively in women than they are in men. For example, facial wrinkles and gray hair are to be avoided at all costs by women, whereas men’s wrinkles are a sign of “character” and their gray hair is a sign of distinction. Furthermore, men are especially harsh in judging signs of aging (Kogan & Mills, 1992).

Two decades after Sontag’s article was published, Harris (1994) investigated attitudes toward visible signs of aging by asking people (ages 18 to 80) to read a scenario in which a male or female protagonist (target) was described as having gray hair, sagging skin, and facial wrinkles. The target in the scenario either uses age concealment techniques (such as coloring hair, getting a facelift, or using wrinkle cream) or refuses to use age concealment techniques. Survey participants thought the target’s physical signs of aging were unattractive with one exception: The male protagonist’s facial wrinkles were not viewed negatively. Apparently, Sontag’s double standard of aging is alive and well. Surprisingly, however, participants did not have a favorable view of targets that used age concealment techniques. They especially disapproved of male targets who attempted to conceal their wrinkles and gray hair. In addition, Harris found another type of double standard: Even though survey participants did not approve of the target’s attempts to combat the signs of aging, they felt that it would be acceptable if they themselves used age concealment techniques.

The musculoskeletal system

Muscle mass and strength gradually decrease with age, and older adults often take longer than young adults do to recover from exertion (Tonna, 1995). In the musculoskeletal as well as other organ systems, there is an age-related decrease in **reserve capacity** – under ordinary conditions, older adults may function just as well as young and middle-aged adults, but age-related differences become apparent when situations require more than the normal capacity.

With increasing age, joints show degenerative changes. Arthritis, a condition caused by degeneration of the joints, can cause pain and often loss of movement. *Osteoarthritis* (OA) is the most common form of degenerative joint disease, and risk factors include increasing age, obesity, heredity, low socioeconomic status, and female gender (Walji & Badley, 2007). Typically, OA is confined to weight-bearing joints such as the knees, hips, and spine, but it can also affect fingers, wrists, elbows, and neck. OA can result from injury but usually it is due to degeneration from wear and tear over time. If untreated, OA can limit mobility and, in extreme cases, it can lead to loss of physical independence. It is rarely fatal (Solomon, 1999), but it can reduce the quality of life. Fortunately, advances in surgical techniques, including hip and other joint replacement, as well as appropriate use of medication, physical therapy, and exercise, make it possible for older adults with OA to lead relatively pain-free and active lives (Rowe & Kahn, 1998). Miguel, described at the start of the chapter, handles his early morning stiffness by taking a walk, and he keeps limber with this exercise routine.

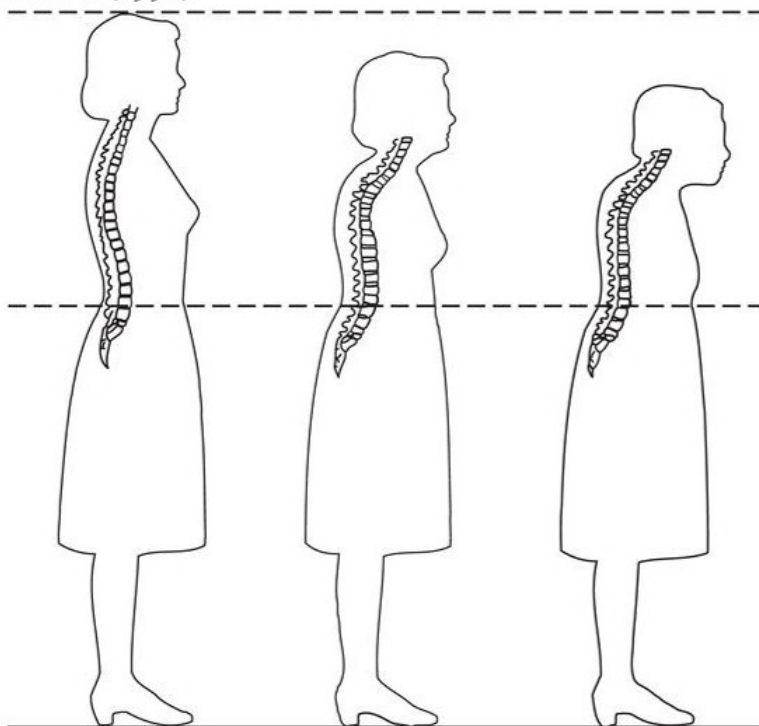
Loss of bone density in the vertebrae can lead to decreased physical stature (see [Figure 3.3](#)). Between ages 55 and 75, men can lose up to an inch and women up to two inches in height (Kausler, Kausler, & Krupshaw, 2007). Along with shortened stature, there can be a rounding of the back and stooped posture, especially in older women.

Osteoporosis is a skeletal disease characterized by extreme loss of bone mass and deterioration of bone tissue, resulting in bone fragility and susceptibility to fracture (Gueldner, Grabo, Britton, Pierce, & Lombardi, 2007). Risk factors include increasing age, female gender (especially small-framed northern European and Asian women), family history of osteoporosis, cigarette smoking, low lifetime calcium and vitamin D intake, and inactive lifestyle. The extensive loss of bone density can result in fractures of the vertebrae, hips, wrists, and ankles when there is slight or no apparent trauma. These fractures can be painful and can result in long periods of immobility. In its earliest asymptomatic stages, osteoporosis can be detected with scan technology for bone density, and medications can control the bone loss. In addition, intake of calcium and vitamin D together with a well-managed regular exercise program and abstention from smoking are important for the maintenance of bone density.

Figure 3.3 *Loss of bone density and cartilage can result in compression of the spine. As a*

result, older adults lose some height and many develop a rounded, stooped posture.

Source: Ebersole & Hess (1998).



Respiratory and cardiovascular functioning

The respiratory and cardiovascular systems become less efficient with advancing age but, again, the concept of reserve capacity applies. Older adults are most likely to notice changes in functioning when conditions are stressful (Rowe & Kahn, 1998). A decrease in lung elasticity results in smaller lung volume (Cherniack & Cherniack, 2007), and the smaller reserve capacity from this reduced volume may limit lengthy participation in strenuous exercise. However, normal age-related changes in lung capacity do not prevent older adults from engaging in exercise, which can help them maintain respiratory capacity.

Understanding Aging Box 3.3

African American Men, Self-Reliance, and Health

Intuitively, one might assume that self-reliance, a quality we usually consider typical of traditional masculinity role norms, would be associated with neglecting or delaying matters related to health. Surprisingly, however, research reported by Jay Wade (2008) as well by Wizdom Hammond and colleagues (2010) has found just the opposite. African American men identified as high in self-reliance were more likely to schedule health care checkups, including cholesterol level and blood pressure screenings, and to be proactive in managing their health compared to African American men identified as low in self-reliance. This finding suggests that effective public health campaigns might do well to focus on communicating messages focusing on the idea that self-reliance entails taking responsibility for seeking preventive health services.

The cardiovascular system consists of the heart and blood vessels throughout the body (Sullivan, 1995). Arteries are the thick-walled tubes that carry blood away from the heart to a branching network of vessels that distribute blood to tissues throughout the body. Arteries terminate in small thin-walled vessels called capillaries, which transfer nutrients and waste products between the blood and surrounding tissues. Eventually, the capillaries join together and meet in veins, which are the larger vessels that collect blood and return it to the heart. Over time, the walls of the arteries become less elastic and blood pressure often increases. Despite some loss in reserve capacity, however, the cardiovascular system can continue to perform very well in older adulthood.

Even so, cardiovascular disease becomes more frequent with age and it affects approximately one-third of the U.S. population aged 65 and over (Rowe & Kahn, 1998). *Atherosclerosis* is a build-up of a substance called *plaque* that causes a narrowing of the arterial walls and leads to restriction in blood flow. Early on there may be no noticeable symptoms, but later, symptoms appear under stressful conditions and eventually even at rest. *Hypertension* is the term used when blood pressure is elevated to a danger zone, beyond what is typical with increasing age. Over time, hypertension can damage arterial

walls and increase the risk of heart attacks, aneurysms, and strokes. *Aneurysms* are weaknesses in the arterial walls that lead to bulging and possible rupture. *Strokes* are disruptions in blood flow to the brain, resulting in temporary or permanent damage depending upon which part of the brain is affected.

Photo 3.2 *Engaging in exercise has many benefits, one of which is maintaining respiratory capacity. Photo © Photodisc/Getty Images*



Another disease that can affect the vascular system is *diabetes mellitus*, a chronic condition caused by the body's inability to create or effectively use its own insulin. Insulin is a hormone that converts food into glucose, which the body needs for energy. Without sufficient insulin, the level of glucose in the blood is not adequately controlled and this may lead to permanent damage of blood vessels, with complications such as blindness and arterial disease in the heart and peripheral vessels (National Academy on an Aging Society, 2000). Type I (insulin-dependent) diabetes is usually diagnosed in childhood, but Type II (noninsulin-dependent) diabetes is often diagnosed in middle age or older adulthood. To some extent, Type II diabetes is hereditary, but losing excess weight and increasing exercise can reduce the risk. Once diagnosed, Type II diabetes can sometimes be controlled through changes in diet and physical activity, although oral medication and in some cases insulin therapy may become necessary. Type II diabetes is a major health problem (McNamara, 2006). It is costly to manage but, left untreated, complications can result in disability and death. If individuals with this disease follow the necessary diet, exercise, and medication regimen, they are usually able to lead active lives. Miguel, described earlier, is well aware of the importance of healthy eating habits, regular exercise, and a well-monitored prescription medication regimen.

In general, proportion of body fat increases from young adulthood to the early 60s, and not surprisingly, it is higher among sedentary than among active individuals. However, regional distribution of fat (specifically, greater abdominal fat) seems to be more important than absolute amount of body fat as far as predicting diseases such as Type II adult-onset diabetes mellitus, coronary heart disease, and stroke (Masoro, 2006b). A large proportion of American men and women are overweight. However, women tend to carry weight on their hips and thighs ("pear shape"), whereas men carry it on their waistlines ("apple shape"). Although the reasons for this gender difference are not clear, abdominal obesity in men is riskier than lower-body obesity in women (Simon, 2004).

The brain

Much of our information about the aging brain has been obtained through autopsy of young and older brains, but such post mortem studies have included only limited sample sizes. In recent years, scientists have learned more by employing **neuroimaging** techniques that visualize the structure and function of the living brain (in vivo assessments). Brain structure can be assessed using CT (*computerized tomography*) scans, which take multiple X-rays of the brain from many angles. MRI (*magnetic resonance imaging*) scans use magnetic fields to map out brain structure. A related technique, fMRI (*functional magnetic resonance imaging*), monitors changes in brain activity using magnetic resonance signals that vary with changing levels of blood oxygenation that signal brain activation as individuals engage in cognitive tasks. PET (*positron emission tomography*) scans are also used to study ongoing

neural functioning in different areas of the brain by introducing radioactive chemicals that mark blood flow and metabolic activity (see Kramer, Fabiani, & Colcombe, 2006). According to Reuter-Lorenz & Park (2010), however, the fMRI imaging technology is being used more frequently than PET scans to measure age-related changes in attention and speed of processing (covered in Chapter 4) and Memory (covered in Chapter 5).

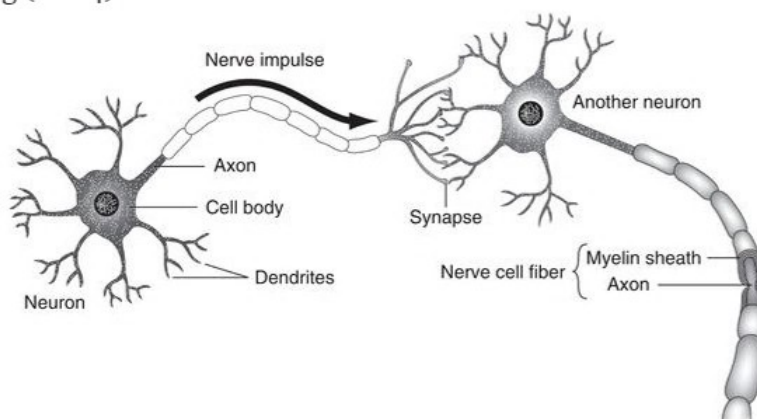
What changes occur in the human brain as people grow older? The weight of the brain reaches a peak between ages 20 and 30, but weight can decrease by 10% by the 10th decade (Bondareff, 2007; Brody, 2006). Also, there is shrinkage in brain volume, which is seen in imaging as an increase in the fluid between the brain and the skull, especially in men. With increasing age, there are more fluid-filled spaces in the brain itself. The shrinkage in brain volume seems to begin in the 40s and to increase after age 60. However, it has not been highly correlated with any abrupt decline in cognitive functioning (Greenwood, 2007).

The brain contains 10 to 20 billion nerve cells (*neurons*). As seen in [Figure 3.4](#), each neuron has a *cell body*, an *axon* that transmits messages, and *dendrites* that branch out to receive messages from the axons of other neurons. The *synapse* is the gap between the axon of one neuron and the dendrites of another. Nerve impulses must cross the synapse for neurons to communicate with one another, and *neurotransmitters* are chemical messengers at the synapses that facilitate the transfer of information between neurons. Some studies have found a reduction in the number of neurotransmitters in various areas of the brain, which could account for difficulties many older adults experience with sleep, with processing sensory information, with motor movements and slowing, as well as with memory (Bondareff, 2007; Kausler et al., 2007).

After age 30, neurons die or become less functional, possibly due to a build-up of lipofuscin (mentioned earlier). Also, aging brains accumulate neurofibrillary tangles (filaments of abnormal protein wrapped around the neuron cell body and axon) and senile plaques (consisting partly of beta-amyloid protein fragments), which could interfere with the functioning of normal neurons. Tangles and plaques occur with normal aging but with disease the build-up is more extensive. In addition to the build-up of tangles and plaques, the dendrites of a neuron can atrophy, which results in fewer connections with other neurons. Clearly, strokes can damage or destroy neurons, and diseases such as Alzheimer's and Parkinson's (discussed in Chapter 11) are associated with extensive neuronal damage and loss, often with accompanying difficulties in physical and/or cognitive functioning. However, neuron loss during the course of normal aging is less likely to have an appreciable effect on brain functioning.

Figure 3.4 Axons and dendrites allow neurons to communicate over synapses. Neurons in the brains of rats housed in stimulating and complex environments show more dendritic branching than do neurons in the brains of rats housed in unstimulating environments.

Source: Sternberg (2004).



Various parts of the brain serve different functions, and individual structures of the brain are affected differentially by normal aging (Kausler et al., 2007). As seen in [Figure 3.5](#), the brain stem (hindbrain) appears as a cap on the spinal cord, and its function is to process and integrate sensory information and outgoing motor instructions. The *cerebellum* controls posture, eye movements, and auditory and vestibular functions. Dysfunction of the cerebellum can result in unsteadiness of gait, difficulty performing rapid movements, and tremors. Dizziness, which is a common complaint of people aged 75 and over, can be a symptom of neuronal dysfunction of the cerebellum but could also result from problems in other parts of the brain (Brody, 2006).

The symmetrical left and right cerebral hemispheres, which are connected by bundle of nerve fibers (*corpus callosum*), are situated above the cerebellum and lie within a bony structure called the *cranium*. The cerebral hemispheres are surrounded by several protective

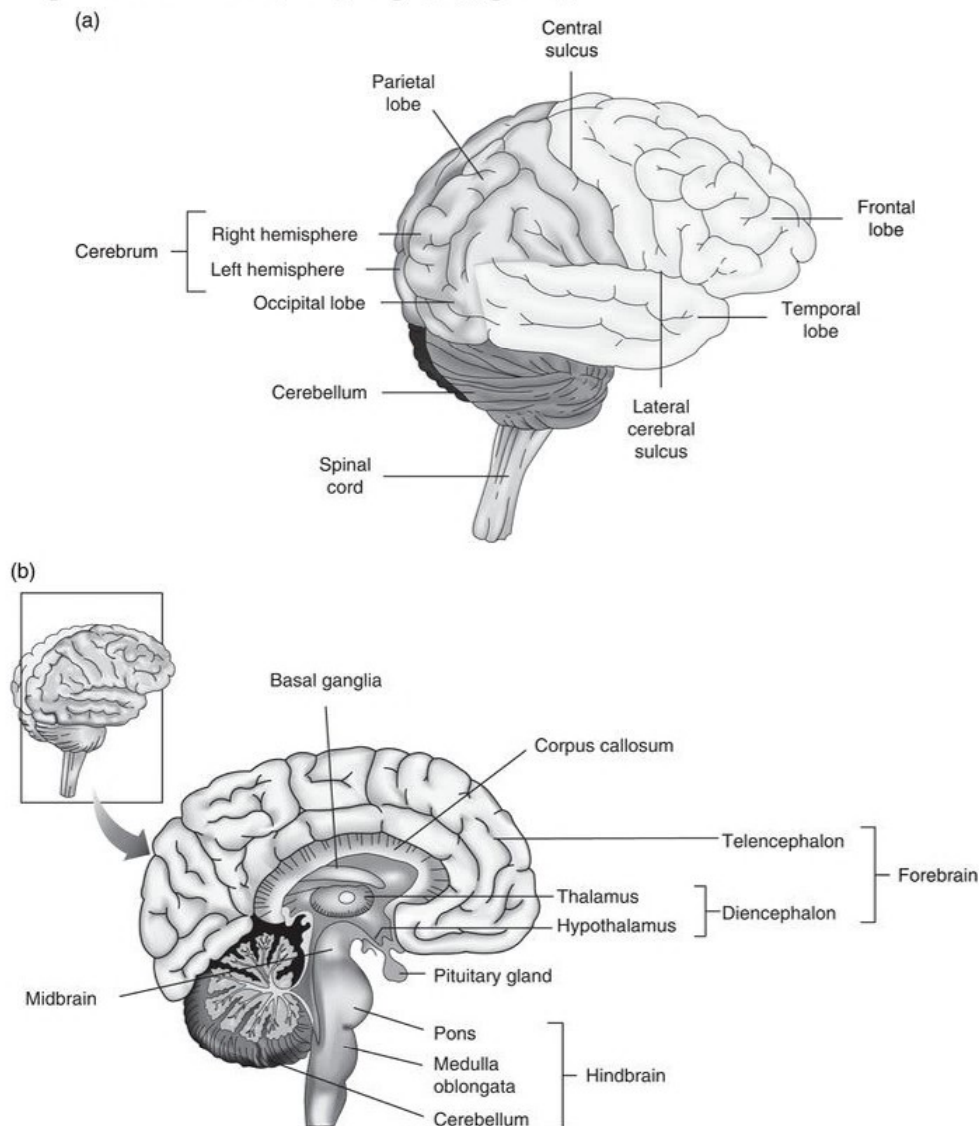
membranes (*meninges*) as well as a layer of *cerebrospinal fluid* (CSF). The structures of the cerebral hemispheres are covered by a thin surface called the *cerebral cortex*. Each cerebral hemisphere is divided into four lobes (*frontal, parietal, occipital, and temporal*), and the surface of each lobe is folded into convolutions (*gyri*) that are separated from each other by grooves (*sulci*).

On the basis of CT and MRI imaging, the brain occupies 90% of the cranial cavity between ages 20 and 50 but thereafter occupies progressively less space, with a concomitant increase in the volume of CSF and widening of the sulci. However, brain volume shrinkage and neuron atrophy have been noted mainly in the frontal lobe and temporal lobe (and the hippocampus, which is the bundle of neurons located in the deeper region of the temporal lobe) as well as in the corpus callosum. Such changes are associated with dementia but are found to a lesser degree with normal aging in individuals who show no significant cognitive impairment (Bondareff, 2007).

Each of the four lobes has specific functions, but the frontal and temporal lobes (as well as the hippocampus) seem to be most affected by the aging process as indicated by the disproportionate number of tangles and plaques and greater widening of the sulci. Frontal lobe functions affected include reasoning, decision making, and control of impulses (see Chapter 4 for a discussion of the frontal lobe model of attention). With regard to the temporal lobes and hippocampus, the processing of auditory information (see Chapter 4) and some types of memory are affected. The parietal and occipital lobes, which process somatic and visual information, respectively, show a lesser degree of age-related changes.

Figure 3.5 *Two views of the human brain.*

Source: Adapted from Tobin (2003, Fig. 42.5, p. 867).



Neuropsychology is the study of brain–behavior relationships. Neuropsychologists use psychological tests and cognitive tasks to evaluate how impairments in various areas of the brain affect cognitive functioning, including memory. On the basis of neuroimaging studies, some of which have tested individuals with known brain lesions, there is evidence that the frontal and temporal areas of the cerebral cortex play a role in conscious memory. The frontal area seems to be the primary center for working memory, whereas the temporal lobe area (including the hippocampus) is the primary center for long-term episodic memory (West, 1996; Woodruff-Pak & Papka, 1999). Chapter 5 describes these types of memory in greater detail. Structural and functional changes in different areas of the aging brain may be related to specific types of memory decrement, even in older adults who are free of dementia

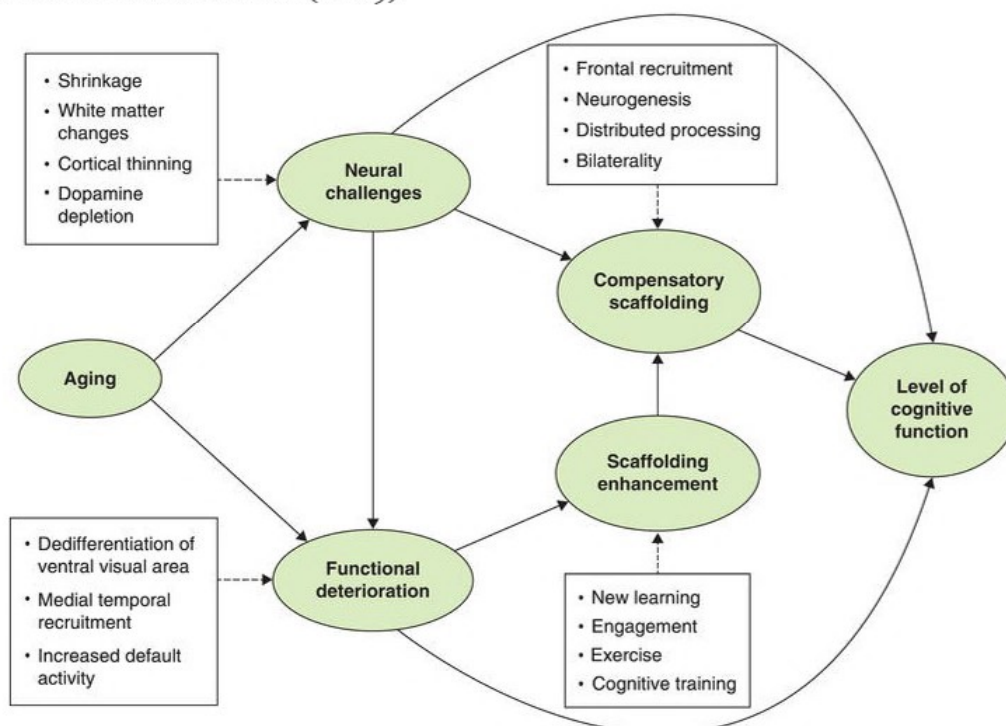
or other pathological conditions (West, 1996).

Using neuroimaging techniques such as fMRI and PET, neuroscientists have discovered age-related differences in the pattern and in some cases the extent of brain activation when young and older adults perform various cognitive tasks (Reuter-Lorenz & Cappell, 2008). According to Kramer et al. (2006), some studies have found a lower level of activation in older brains, possibly due to loss of neural resources or to inadequate recruitment of neural resources. In other studies, the brains of older adults show activation in different areas or broader areas, compared to that found with young adults, whose brains show more selective activation. For example, performing a cognitive task may be associated with cortical activity confined to one hemisphere in the young brain, whereas it may result in bilateral activity in the older brain. One hypothesis for the less specialized cortical activation pattern in the older brain is that the older brain is compensating for loss in a specific area. The less specialized activation in the older brain could reflect adaptation to loss and thus be a sign of brain plasticity (Greenwood, 2007). However, bilateral recruitment (or activation of more, or different, brain regions in older compared to younger brains) could also indicate that older brains are reaching their resource limits sooner than young brains (Kramer et al., 2006). Interestingly, Greenwood reports neuroimaging findings that show increased brain activation in areas of the cortex adjacent to those with the most significant age-related atrophy and shrinkage. Further research is needed before we can make definitive statements about the relationship between a specific type of brain atrophy and either the generality or the extent of activation (Raz, 2007; Salthouse, 2007a).

To integrate recent concepts and findings in the field of cognitive neuroscience and aging, Park and Reuter-Lorenz (2009) have proposed the **scaffolding theory of aging and cognition (STAC)**. The STAC model, which is illustrated in [Figure 3.6](#), accounts for the possibility of both deficient and preserved performance on cognitive tasks. The model acknowledges that the aging brain must adapt to neural challenges including atrophy. To cope with such challenges, the brain builds alternative neural circuitry, or scaffolds. These scaffolds, which represent compensatory strategies that are designed to offset age-related decline in functioning, may not be as efficient as the more focused circuitry of young adult brains. For example, the scaffolds may result in less differentiated areas of activation and, in some instances, overactivation. Nonetheless, they allow older brains to maintain a high level of functioning. The scaffolding process does not begin in old age; rather, it occurs throughout the life span when the brain is confronted with cognitive challenges. According to the STAC model, the brain's effectiveness at building scaffolds is assisted by experience, or nurture, which includes factors such as maintaining cardiovascular health and engaging in mentally challenging activities. Overall, an individual's level of cognitive functioning will be a function of the magnitude of the brain's neural deterioration and the effectiveness of the compensatory scaffolds that have been constructed (Park & Reuter-Lorenz, 2009; Reuter-Lorenz & Park, 2010).

Figure 3.6 A conceptual model of the scaffolding theory of aging and cognition (STAC).

Source: Park & Reuter-Lorenz (2009).



There has long been interest in how the environment affects brain functioning. Early studies comparing the brains of old rats housed in complex toy-filled group environments

with the brains of old rats housed in standard minimally stimulating cages found (on autopsy) that rats in the complex environments have more extensive dendritic branching of neurons in several areas of the brain. This suggests that density of dendrites is fostered by environmental stimulation. Dendritic connections between neurons are an important factor in brain functioning that could compensate for whatever neuron loss may occur in old age (Black, Greenough, Anderson, & Isaacs, 1987).

Although there is some evidence for neuronal plasticity, with new synapses replacing those that are lost (Bondareff, 2007), it is difficult to conduct well-controlled research on exactly how environmental stimulation affects the human brain. Even so, there is reason to believe that maintaining good health, as well as engaging in mental and physical exercise, fosters maintenance of dendritic density. Engaging in physically and intellectually challenging activities beginning in early adulthood and continuing into middle age and later may protect brain functioning in older adulthood (e.g., Kausler et al., 2007). Interestingly, there is some indication that bilingual individuals possess a type of cognitive reserve that could protect them from age-related decrements in cognitive functioning and may even delay the onset of dementia such as Alzheimer's disease (Craik, Bialystok, & Freedman, 2010). Thus, Miguel, who was described earlier, should benefit from keeping up with his second language of Spanish. Controlling stress levels can also be beneficial for brain functioning (Raz & Rodrigue, 2006).

Keep in mind that it is difficult to know whether age-related differences found with in vivo studies of the brain are due to aging or whether they result from disease or accumulated effects of substances such as medications and alcohol (Bondareff, 2007). Most in vivo studies of the brain are cross-sectional and wide individual variation can make it difficult to determine whether any differences found are actually a function of age. Raz and Rodrigue (2006) contend that when the brains of super-healthy older adults are compared with the brains of young adults of average health, age effects may be underestimated. Alternatively, older adults who appear healthy may actually have preclinical forms of conditions that inflate estimates of age effects. Measurement of the extent and nature of age-related changes in the brain are likely to be more accurate with longitudinal studies as opposed to the more typically conducted cross-sectional studies.

Urinary and bowel functioning

Age-related changes in urinary and bowel functioning are not uncommon, and in mild forms they do not affect everyday functioning to a large extent. Sometimes symptoms are relieved through changes in dietary and exercise habits. The incidence of urinary incontinence (characterized by loss of bladder control) is higher among older women than older men, but it may affect 30% of community-living older adults and 50% of nursing home residents. Bowel incontinence is less common but more socially disruptive and more likely to lead to institutional living (Engel, 1995). Urinary and bowel incontinence can stem from a number of physical reasons, but in some cases cognitive impairments can interfere with toileting habits. Care can include the use of diapers, medications, and in some instances surgical intervention. Some cases of incontinence have been treated successfully with behavioral intervention techniques such as prompting individuals to use toilet facilities at regular intervals (Burgio & Burgio, 1991).

Sexual functioning

There is a common myth that sexuality is of no interest to older adults, and that older adults who show interest in sexual activity are either silly or sinful (Kausler et al., 2007). In actuality, we have limited information because early surveys on sexual behavior by Kinsey and others did not include many people over age 60, and older adults are often hesitant to discuss sexuality (Starr, 2006). However, recent years have seen a "growing acceptance among health professionals, educators, and older people themselves that sexual interest, capacities, pleasures, and libido remain throughout the life span into the ninth and perhaps the tenth decades" (Weg, 1996, p. 479). Indeed, as baby boomers enter older adulthood, attitudes toward sexuality may be changing (Starr, 2006). Evidence for this is the extensive media exposure of Viagra and similar drugs that treat male erectile dysfunction.

Several factors play a role in older adults' sexual functioning (Starr, 2006). First, earlier interest and enjoyment of sexual activity seem to be reliable predictors for later life. Second, moderately good physical and psychological health is usually needed for continuing sexual interest and expression. Heart disease, strokes, diabetes, pelvic disorders, arthritis, and enlargement of the prostate gland may interfere with the desire and ability to participate in

sexual activity (Weg, 1996). Medications, both prescription and over the counter, that are sometimes used to treat chronic conditions can affect older adults' sexual desire and capabilities. Finally, availability of a partner is important. Lack of a partner (especially for older women, who are less likely to remarry when they become widowed) may be a limiting factor. Men's sexual partners are typically similar in age or younger, whereas women's partners are similar in age or older (Stones & Stones, 2007). Since older women greatly outnumber older men (see Chapter 1), they have fewer sexual opportunities.

Normal age-related physical changes mean that the nature of sexual activity may vary from young to middle to older adulthood. The time it takes to become sexually aroused may increase with age, especially for older men. Furthermore, the refractory period prior to physiological readiness for sexual activity may be longer. For some but not all older women, hormonal changes can affect comfort with sexual activity, but these can often be treated. Again, the main barrier to intimate sexual relations in older adulthood is usually lack of a partner.

There is relatively limited information on sexuality in gay, lesbian, and bisexual older adults (Stones & Stones, 2007). But older gay partners tend to maintain longer relationships than young gay partners (Weg, 1996). The absence of legal marriage in many states in the United States may limit opportunities that are readily available to heterosexual married couples, and gay older adults may be hesitant to discuss medical issues with their physicians (Kimmel, 2006). Further study is needed regarding the social supports available to these older adults.

In sum, physical changes occur as people grow older, but these do not necessarily interfere with adequate functioning. Some older adults are more prone than others to specific chronic diseases, and proper screening for risk factors can lead to early diagnosis and hopefully to control with medication, surgery, and changes in diet and exercise routines. Older adults with chronic diseases can often function with little or no disability if they receive proper medical care and follow a recommended regimen of diet and exercise.

Table 3.6 *Leading causes of death at age 65+ in the United States for all races and both sexes*

Source: National Center for Health Statistics (2010b, p.22).

Rank	Cause	Percentage of total deaths
1	Heart disease	29.0
2	Malignant neoplasms (cancer)	22.0
3	Cerebrovascular disease (stroke)	6.7
4	Chronic lower respiratory diseases	6.1
5	Alzheimer's disease	4.1
6	Diabetes mellitus	3.0
7	Influenza and pneumonia	2.8

Table 3.7 *The seven leading causes of death at age 65+ in the United States by race and sex*

Source: National Center for Health Statistics (2010b, pp. 32–64).

Rank	European American males	European American females	African American males	African American females	Hispanic American males	Hispanic American females
1	Heart disease	Heart disease	Heart disease	Heart disease	Heart disease	Heart disease
2	Malignant neoplasms	Malignant neoplasms	Malignant neoplasms	Malignant neoplasms	Malignant neoplasms	Malignant neoplasms
3	Chronic lung diseases	Cerebrovascular diseases	Cerebrovascular diseases	Cerebrovascular diseases	Cerebrovascular diseases	Cerebrovascular diseases
4	Cerebrovascular diseases	Chronic lung diseases	Diabetes mellitus	Diabetes mellitus	Diabetes mellitus	Diabetes mellitus
5	Diabetes mellitus	Alzheimer's disease	Chronic lung disease	Nephritis (kidney disease)	Chronic lung diseases	Alzheimer's disease
6	Alzheimer's disease	Influenza and pneumonia	Nephritis (kidney disease)	Alzheimer's disease	Influenza and pneumonia	Chronic lung diseases
7	Influenza and pneumonia	Diabetes mellitus	Influenza and pneumonia	Chronic lung diseases	Nephritis (kidney disease)	Influenza and pneumonia

Leading Causes of Mortality

In the United States, heart disease and cancer are the two leading causes of mortality in individuals age 65+ (see [Table 3.6](#)) regardless of race and sex. However, there is some variation among these groups with regard to the next five most frequent causes of mortality. For example, Alzheimer's disease is a more frequent cause of death for European American and Hispanic American women than it is for the other groups (see [Table 3.7](#)). Also, diabetes is a more frequent cause of death for African Americans and Hispanic Americans than it is for European Americans. This may reflect the fact that for socioeconomic reasons, medical care is less available to these groups than it is to European Americans. The symptoms of diabetes mellitus are not always obvious in the early stages, but managing the disease at later stages is costly.

Olshansky, Carnes, and Grahn (1998) contend that modern medicine has been successful in preventing or treating health problems that, in earlier times, caused death well before old age. For example, screening for heart disease and treating it through diet, medication, or surgery means that individuals who may have suffered from fatal heart attacks and strokes in their 50s and 60s can now live into late old age. Cancer treatments are more effective as well. Older adults of today and tomorrow have a better chance of enjoying productive, independent lives than their parents or grandparents did.

Everyday Functioning and Health Care

How do changes that occur more frequently with increasing age affect older adults' everyday functioning? What kinds of support should older adults seek to insure that their lives have the highest possible quality?

Activities of Daily Living and Instrumental Activities of Daily Living

Activities of daily living (ADL) is a term that refers to basic self-maintenance tasks, including eating, dressing, bathing, toileting, transferring into and out of a bed or chair, and getting around the house (Fillenbaum, 1995). Ability to perform all or most of these functions is necessary if older adults are to live independently in the community. ADL assessments are often used to determine disability and possible need for health-care services. Among community-living older adults, the percentage with ADL limitations is much higher among those aged 85+ than it is among those aged 65 to 84 (*A Profile of Older Americans*, 2010).

Instrumental activities of daily living (IADL) is a term that refers to the more complex activities required for carrying out the business of daily life, including preparing meals, shopping, managing money, doing housework, using the telephone, and taking medications (Lawton & Brody, 1969). Some older adults can continue to live in private homes or apartments if they have help with such activities.

In sum, many older adults (but especially those 85+) have some trouble performing ADLs or IADLs. Approximately 37% of community-living older adults experience difficulty that limits their activities (*A Profile of Older Americans*, 2010).

Medication

It is not uncommon for older adults to have at least one chronic disease but, fortunately, many diseases can be controlled with medication. Today, many drugs are available and physicians are prescribing them. Hypertension, a frequent condition in older adulthood, can usually be managed successfully by strict adherence to a prescribed medication regimen (as with Miguel, described at the beginning of the chapter). However, many older adults do not take their medications exactly as directed. Morrell, Park, Kidder, and Martin (1997) recorded whether older adults adhered to antihypertensive medication regimens over a two-month period of time. Those in the old-old age category (75–84) did not adhere as strictly as did those in the young-old (65–74) age category. Many older adults take several prescription medications for more than one chronic condition, so they would likely benefit from the assistance of charts and containers for keeping track of what pills to take at various times of

day (see Chapter 5 for a discussion of memory mnemonics). Liu and Park (2004) followed older adults over a period of three weeks to check how closely they followed instructions on when to carry out home glucose tests. Those who adhered best to the monitoring schedule had a specific plan for when and where they would carry out the glucose tests and they visualized themselves doing so.

With so many effective medications to control chronic health conditions, older adults can live with less pain and greater independence than was possible in the past. Furthermore, medications often enable older adults to avoid hospitalization. For people aged 65+, the average number and average length of hospital stays have decreased significantly since 1980 (*A Profile of Older Americans*, 2010).

Health Insurance

Most older Americans (65+) are covered by **Medicare**, which is the federal health insurance program initiated in 1965. Medicare Part A covers hospital costs and brief stays in a skilled nursing home or short-term home health care following a hospital stay. Medicare Part B covers a portion of physicians' fees, laboratory tests, services such as physical therapy, and some medical equipment. Medicare Part D covers certain costs of prescription drugs.

Medicare does not cover all health care costs, and there are deductibles and co-payments even for covered services. Also, Medicare does not pay for nursing home care on a long-term basis. Private insurance companies offer *Medi-gap* policies to cover deductibles and co-payments that are not covered by Medicare. Unfortunately, many unsuspecting older adults have become victims of scams related to the purchase of expensive *Medi-gap* policies that do not deliver the benefits they thought were covered. Private insurance companies also offer long-term care (LTC) policies that cover the cost of extended nursing home stays and home health care. However, such policies are expensive, especially if purchased late in life. Understanding what is covered by a specific LTC policy can be confusing, and older consumers must determine what type of coverage will best suit their circumstances and needs (see Chapter 7 for discussion of decision making with regard to LTC policies).

Health coverage is also available to older Americans through **Medicaid**. Unlike Medicare, Medicaid is *means tested* – to qualify for coverage, individuals must fall below a certain income level and own only limited assets (savings and personal property). Although short nursing home stays are sometimes covered by Medicare, older adults are responsible for the cost of more lengthy nursing home stays. If they “spend down” sufficiently to deplete their assets, they qualify for Medicaid coverage for continued nursing home care. This may not take long, given the high monthly cost of nursing home care.

Revisiting the Selective Optimization with Compensation and Ecological Models

The Selective Optimization with Compensation (SOC) (Baltes & Baltes, 1990) and Ecological (Lawton, 1989; Lawton & Nahemow, 1973) Models can be readily applied to biological aging and health. With increasing age, biological functions generally progress in the decremental direction, but this does not usually deter older adults from leading lives that are active and satisfying.

According to the SOC Model, an effective strategy for maintaining optimal functioning is to focus on aspects of living that are most important. If functioning declines in some areas, older adults can compensate by putting more effort into areas that can be maintained or improved. The trick is to capitalize on one's physical strengths, taking whatever actions are necessary to control lifestyle habits of diet, exercise, and exposure to stress. The earlier in life this is done, the better the chances of deriving long-term benefits. The SOC Model can be applied to brain functioning as well, given the evidence of compensation that seems to occur in the face of age-related neurological changes.

With regard to the Ecological Model, decline in biological reserve capacity means that more attention must be paid to the environmental conditions in which older adults live, and a proper match between biological competence and environmental press becomes more important with increasing age. Conditions that are too challenging may accelerate the biological aging process and cause difficulties in adaptation. On the other hand, conditions with too few demands may not be sufficiently challenging and could result in poor adaptation. An environment with the appropriate level of challenge for the individual older adult is most likely to allow him or her to achieve the highest possible level of adaptation.



Questions to Consider

1. In the future, do you think that the gender gap in life expectancy will get even larger (favoring females) or that it will shrink?
2. Do you know anybody who is over the age of 100 (centenarian)? If so, what is that person's lifestyle?
3. What kinds of things do you do in your everyday life that could either promote or delay secondary aging?

Key Points

- Life expectancy is the average number of years individuals in a particular birth cohort can be expected to live on the basis of current information that affects mortality.
- Life span is the maximum longevity, or extreme upper limit of time, members of a species can live. As life expectancy approaches life span, the survival curve takes on a more rectangular shape.
- *Morbidity* refers to illness and disease, and *mortality* refers to death. These two terms are related but they are not the same.
- Primary aging refers to unavoidable (inevitable), intrinsic biological processes that affect all members of a species. Secondary aging refers to biological processes due to disease, disuse, and abuse.
- Biological theories of aging can be categorized as programmed or stochastic. Programmed theories focus on genetic blueprints of various species. Stochastic theories focus on random events and damage that occur as a function of living.
- Scientists have studied the influence of nature and nurture on longevity and have tried to determine whether cognitive test scores, health self-ratings, marital status, and emotional outlook can predict how long an individual will live.
- With increasing age, physical changes occur and reserve capacity decreases, but within the same person, changes may be more noticeable in some parts of the body than in others.
- Neuroimaging studies have found changes in the structure and functioning of the aging brain, but there is promise that

the brain is capable of compensating for any age-related decline.

- Certain chronic diseases occur more frequently in older adulthood. However, these can often be treated and controlled and older adults can usually lead active and independent lives.
- Older adults often take prescription drugs for chronic health conditions. However, many do not take medications exactly as directed.
- Activities of daily living (ADL) include basic personal care tasks required for self-maintenance; instrumental activities of daily living (IADL) include more complex activities required for carrying out the business of daily life. Limitations in either or both occur more frequently in the 85+ age group.

Key Terms

- activities of daily living (ADL) 95
- centenarians 65
- compression of morbidity 67
- compression of mortality 67
- instrumental activities of daily living (IADL) 95
- life expectancy 63
- life span 63
- longevity 63
- Medicaid 97
- Medicare 96
- morbidity 63
- mortality 63
- neuroimaging 86
- neuropsychology 89
- primary aging 68
- programmed theories of biological aging 69
- rectangular survival curve 67
- reserve capacity 83
- scaffolding theory of aging and cognition (STAC) 90
- secondary aging 68
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- telomeres 70
- terminal drop 80

4

Sensation, Perception, and Attention

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Revisiting the Selective Optimization with Compensation and Ecological Models

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Close-ups on Adulthood and Aging

At 68, Louis prides himself on feeling youthful and doing pretty much what he has always done. Even so, he is noticing some changes when it comes to driving, the most obvious being that driving after dark seems harder, especially on unlit side streets. Yet, headlights from cars approaching from the opposite direction or from SUVs behind him often interfere with his ability to see where he is going. Louis has no trouble reading large signs on the road, but he has some difficulty seeing the small gauges on his dashboard. Also, there are times he does not notice a passing vehicle until it is just about even with his car. As well, by the time he hears high-pitched sirens from police cars or firetrucks, they are usually close by. A more subtle development is that he no longer finds it easy to converse with his wife when he is driving in heavy traffic. Louis has a cell phone for emergencies, but he does not use it while driving. The same goes for his new GPS, which he only consults prior to starting out on a route. Parallel parking is becoming a challenge, but Louis assumes the city is shrinking spaces so it can collect more money at the meters. Finally, he is not as confident at estimating the speed of oncoming traffic, so he is especially cautious when making left turns.

Sensory Processes

To adapt to and interact with the environment we must be able to take in, or register, what is

going on around us. For this purpose we depend upon our eyes, ears, nose, and other sensory organs, through which we experience our initial contact with stimulus events and objects in our environment. Our senses include taste, smell, touch, vision, hearing, as well as a sixth sense that includes proprioception. Researchers who study aging have noted the importance of sensory processes; according to the **common cause hypothesis**, the link between sensory processes and cognitive functioning becomes stronger in older adulthood than it was earlier in life (Baltes & Lindenberger, 1997).

Although age-related differences in cognitive functioning may not be fully explained by sensory declines (Anstey, Luszcz, & Sanchez, 2001; Lindenberger, Scherer, & Baltes, 2001), there is little question that having good sensory capabilities is related to good memory and verbal abilities (Schneider & Pichora-Fuller, 2000; Wingfield, Tun, & McCoy, 2005). Also, good sensory capabilities, particularly vision and hearing, are associated with the ability to perform self-care activities (for example, bathing, dressing, and grooming), to do household chores and go shopping (Marsiske, Klumb, & Baltes, 1997), and to take part in social activities.

Once the sensory organs register it, information can be passed along to the central nervous system for higher-level, perceptual processing, which entails interpreting what the information means and making decisions about how to respond. Often, there is more information in our environment than we can possibly register, let alone process, at any given time. Attention has to do with exactly what information we will process from the large array of stimuli that impinge upon our senses.

Threshold and Sensitivity

Sensory organs need a certain intensity of stimulation before they register the presence of a signal, or stimulus. The term **threshold** refers to the minimum amount of stimulation a sensory organ must receive before the presence of a particular stimulus is registered. For example, a burst of sound must have sufficient intensity for the ear to register that it occurred. The term **sensitivity** refers to the capability of the biological system to respond to stimulation. Sensitivity is the inverse of threshold – the greater the sensitivity to a particular type of stimulation, the lower the threshold will be. Individuals with a high level of sensitivity have a low threshold because they need only a low intensity of stimulation before they register its presence. In contrast, individuals with a low level of sensitivity have a high threshold because the intensity of the stimulation will have to be stronger before they register its presence.

Absolute Threshold

Absolute threshold refers to the intensity of stimulation needed in order for a stimulus to be detected 50% of the time when it is present. To illustrate, let's suppose that an individual is fitted with headphones, seated in a soundproof booth, and instructed to press a key each time a particular tone is heard. The tone is presented numerous times at varying levels of loudness, or intensity. At low levels of intensity, the individual will not hear the tone and thus will not press the key. As the decibels (dB, which is a measure of the intensity of an auditory stimulus) of the tone gradually increase, eventually the individual will register its presence by pressing the key. Absolute threshold is the specific level of intensity the tone must reach before the individual registers its presence (by pressing the key) on half of the occasions when it is presented. If the tone is presented 10 times at the same level of intensity, the individual will register its presence on five occasions.

For auditory thresholds, qualities other than intensity can influence an individual's threshold. For example, threshold can vary depending upon the frequency, or pitch, of the tone (high or low). For older adults, thresholds are often lower for low-pitched tones than they are for high-pitched tones. In the case of visual stimuli, color can affect threshold. An individual may be able to identify one color more readily than another. Older adults are more sensitive to (have lower thresholds for) red, orange, and yellow than they are to blue, green, and purple. Similarly, thresholds can vary for specific odors and tastes and for specific kinds of tactile stimulation.

Signal Detection

Determining thresholds does not take into account decisional processes that enter into an

individual's success or failure to register the presence of a stimulus. Assume for a moment that two individuals, Paul and Juan, are instructed to press a key when they hear a tone. Paul presses the key when he has even a slight suspicion the tone has been sounded. Juan is more cautious – he will press the key only when he is certain the tone has been sounded.

The **signal detection model** of determining threshold takes into account not only sensitivity but also decisional response criteria (Green & Swets, 1966). Paul, the less cautious decision maker, will have more *hits* (saying “yes” when the tone is actually present) than Juan will. However, Paul will also have a considerable number of *false alarms* (saying “yes” when the tone is not present). Juan, the more cautious, conservative decision maker, will have fewer hits, but he will also have fewer false alarms.

The signal detection model is important in the study of aging because older adults tend to be more cautious than young adults (Botwinick, 1984). In general, older adults have fewer false alarms (saying “yes” when a stimulus is not present) compared with young adults. By the same token, the more cautious older adults will have more *misses* (saying “no” when the stimulus is indeed present) compared with young adults. Older adults' higher decisional criteria could result in an underestimate of their actual sensitivity.

In sum, older adults' cautiousness can inflate estimates of age-related differences in sensory processes. However, even when age-related differences in decisional criteria are taken into account, some age-related increase in sensory thresholds remains.

Speed of Response

Sensation is related to the sensory organ's initial registration of physical stimulation. Perception refers to the subsequent interpretation of stimuli at the central level (in the brain). Depending on how stimuli are interpreted, decisions will be made about how to respond. Usually responses are visible, but it is difficult to observe what takes place in the brain between the onset of a stimulus and the initiation of a response.

Reaction Time

Reaction time is the interval that elapses between the onset of a stimulus and the completion of a response (Cerella, 1995; Salthouse, 2007b). In a controlled laboratory setting, we can measure reaction time by presenting a visual stimulus such as a light, or an auditory stimulus such as a tone. We can instruct individuals to make a motor response such as pressing a key as soon as they see the light or hear the tone. Or we could instruct individuals to give a vocal response (such as “yes”) to register the presence of a stimulus.

Reaction time tasks fall into several categories: simple, choice, and complex. In a simple reaction time task, there is only one stimulus and one possible response. In a laboratory situation, individuals might be instructed to look for the appearance of a cursor on a monitor and as soon as they see it, to make a motor response by pressing a key.

In a choice reaction time task in the laboratory, individuals are on the lookout for two different signals, or stimuli, each requiring a different response. They might be told to press the key on the left when they see a red light and the key on the right when they see a green light. Or they might be instructed to press the key on the left when they hear a high tone and the key on the right when they hear a low tone. Usually, there is greater age-related slowing on choice reaction time tasks than there is on simple reaction time tasks.

Complex reaction time tasks are extensions of choice reaction time tasks because there are more than two stimuli and each one requires a different response or combination of responses. In the laboratory, one of three different shapes (a square, a circle, or a triangle) might be displayed on a screen. Each shape calls for a different response, such as pressing a key on the top, middle, or bottom row of a keyboard, respectively.

Reaction time has two components: premotor time (PMT) and motor time (MT) (Botwinick, 1984). PMT is the time elapsing between the onset of a stimulus and the initiation of a motor response. MT is the time elapsing from the initiation to the completion of the motor response. If we instruct an individual to listen for a tone and press a key as soon as it is heard, PMT would be the time elapsing between the onset of the tone and the initiation of a muscle response in the forearm. PMT is difficult to observe directly because it consists mainly of the time taken for the brain to process information. MT (the time that elapses between the initial muscle activation and the actual lifting of the finger to press the key) can be measured using electromyographic recordings of muscle-action potentials

(Kausler, 1991). Approximately 84% of total reaction time is attributable to PMT, while the remaining 16% is attributable to MT (Botwinick, 1984). The relatively large proportion of time devoted to PMT suggests that reaction time is largely a function of central processing in the brain.

Slower reaction time seems to be an inevitable consequence of normal aging (Kausler et al., 2007), but why is it important to study age-related differences in reaction time? From a theoretical point of view, reaction time can assess the organization and efficiency of the central nervous system (Cerella, 1995). Speed of response, even on simple reaction time tasks, can be an indicator of brain functioning (Salthouse, 2007b). From a practical point of view, slowing is important for many aspects of everyday functioning, especially when it comes to safety. The older adult who is slow to enter a revolving door at the entrance to a public building is at risk for sustaining physical injury. The older pedestrian who is slow to respond to a “Walk” sign at an intersection may not make it across a busy street before the sign turns to “Don’t Walk.” Fatal injuries have resulted when impatient drivers do not realize that older pedestrians need extra time, and car accidents often occur when a driver does not react quickly enough to avoid a dangerous situation.

Applying Research Box 4.1: Reaction Time and Driving

Driving calls for simple, choice, and complex reaction time. *Simple reaction time*: A driver spots a pedestrian in a crosswalk and responds by stepping on the brake; a driver hears an ambulance siren and responds by pulling over to the curb. *Choice reaction time*: A driver approaches a fork in the road and must decide whether to go left or right. *Complex reaction time*: A driver spots an object in the distance that appears to be road debris but he/she must evaluate its spatial placement and composition (metal or cardboard). When deciding how to respond (step on the brake, swerve to the left or to the right, or drive right over the debris), the driver must also consider surrounding traffic conditions. In a tragic case in California in 2003, an 86-yearold driver sped into a crowded farmers’ market, killing 10 and injuring more than 70 people. The true cause of this devastating incident will never be known for sure, but the driver’s defense attorney argued that he was the victim of “pedal error,” mistaking the accelerator for the brake. Following this incident there was national debate over whether to require old drivers to take road tests to renew their licenses.

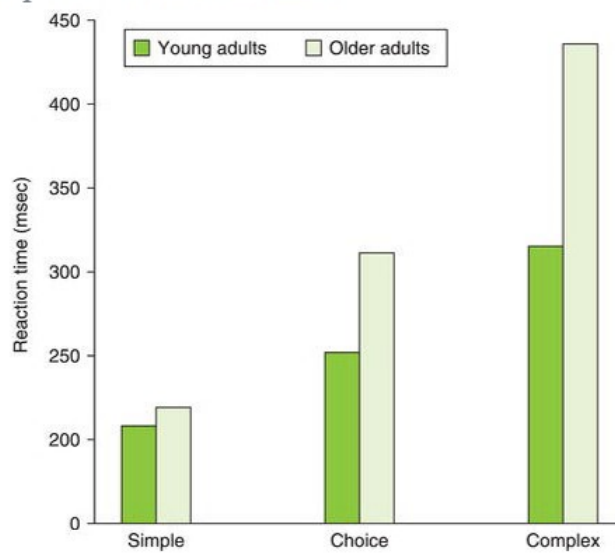
Age–Complexity Hypothesis

The complexity of a task affects how quickly people respond – the more complex the task, the slower the responses will be. Task complexity can also affect how much slower older adults will be compared to young adults. However, older adults are more variable than young adults are in how quickly they perform reaction time tasks (Verhaeghen, 2006).

According to the **age–complexity hypothesis** (Salthouse, 1991), older adults will be at a greater disadvantage relative to young adults as task complexity increases. As [Figure 4.1](#) illustrates, the gap between young and older adults’ speed of response becomes larger as tasks go from simple to choice to complex. Compared with simple reaction time tasks, choice and especially complex reaction time tasks require more extensive central (brain) processing (Cerella, 1995). Thus, some investigators think that age-related differences in reaction time are related to age-related decline in the brain’s speed of processing information.

Some researchers contend that older adults’ decline in speed on reaction time tasks can be attributed to one factor – a generalized slowing in cognitive processing. Other researchers postulate that slowing is one of many factors that play a role in the age-related differences found on various cognitive tasks (Cerella, 1994; Fisk & Fisher, 1994; McDowd & Shaw, 2000). Whether slowing is a common factor that can completely explain age-related differences on all cognitive tasks (reaction time, perceptual processing, memory, and so on) has been a subject of considerable debate (Salthouse, 1996; Salthouse, 2007b; Schulz, 1994; Verhaeghen, 2006; Verhaeghen, Cerella, & Basak, 2006). In addition, there is some debate about the specific origins of age-related slowing – among the suggestions for why central slowing occurs have been loss of neurons, reductions in dendritic branching, and lower quantities of neurotransmitters (Salthouse, 2007b). Chapter 3 discusses age-related changes in the brain.

Figure 4.1 Hypothetical comparison of young and older adults' speed of response on simple, choice, and complex reaction time tasks.



Stimulus Persistence Theory

In an early article published in the *American Psychologist*, Birren (1974) proposed that the tendency toward slowness with advancing age reflects a basic change in the speed with which the central nervous system processes information. **Stimulus persistence theory** (SPT) is one theoretical model that attempts to explain why such central slowing occurs (Botwinick, 1984; Gilmore, 1996). According to SPT, a stimulus registered by a sensory organ takes longer to be processed and cleared through the nervous system of an older adult than it does through the nervous system of a young adult. If a second stimulus were to follow quickly, then older adults will be less efficient at processing it because they are still clearing the first stimulus through the system. For this reason, older adults have greater difficulty than young adults do when they must process a series of stimuli that are presented at a rapid rate. Older adults need more time between stimuli than young adults do.

To build a case for SPT, Botwinick (1984) described a phenomenon that occurs when stimuli are presented one right after the other: When individuals are shown a sequential series of light pulses at a low rate, they report seeing separate pulses of light. As the rate of the light pulses increases, they eventually report seeing a continuous light because individual pulses of light are perceived as one blended light. The critical flicker fusion (CFF) threshold is the pulse rate at which this blending occurs. A number of studies have reported age-related decline in the CFF threshold (Kline & Scialfa, 1997), so at a relatively high pulsing rate, young adults are still able to distinguish separate pulses of a flickering light, whereas older adults see one continuous light. According to SPT, there is a backup in older adults' central nervous system processing, with the result that sequential stimuli blend together and older adults perceive them as one.

The stimulus persistence model is an intriguing way to conceptualize age-related differences in perceptual processing. Unfortunately, it cannot account for all the research findings on age and perceptual processing (see Botwinick, 1984). Also, the specific mechanism that mediates the slower processing has yet to be specified clearly. Even so, studies that have tested this model demonstrate that older adults will surely benefit when information is not presented too quickly.

Moderating Age-Related Slowing

In general, older adults do not respond as quickly as young adults do, but are there ways to moderate age-related slowing? First, older adults who exercise regularly react more quickly compared to older adults who are not physically active. In fact, some older exercisers have reaction times as fast as many young adults (Kausler et al., 2007). However, the findings for short-term exercise are mixed. Hawkins, Kramer, and Capaldi (1992) found older adults improved their speed of performance after participating in a 10-week aerobic exercise program. However, others (Blumenthal & Madden, 1988; Madden, Blumenthal, Allen, & Emery, 1989) do not find that short-term exercise results in faster responding. Extended periods of training, long-term habits of physical activity, and general physical fitness seem to be the most effective means of increasing older adults' speed of processing.

Second, older adults can increase their speed of responding when they have opportunities to practice (Kausler, 1991). However, young adults also get faster with practice, so the

difference between young and older adults' speed of responding cannot be attributed wholly to older adults' lack of practice on a particular task. Age-related differences in speed of responding are not likely to disappear when young and older adults are both allowed to practice, especially when tasks are complex. Still, practice is important for older adults' real-world functioning.

The Senses: A Closer Look

Changes in sensory capabilities usually occur gradually from middle adulthood on. Although there are individual differences, older adults are often less sensitive than young adults are when it comes to registering sensory information. Changes also occur at the perceptual level, which refers to the higher-order central processing that takes place in the brain.

Smell and Taste

The majority of older adults experience some loss in smell and taste sensitivity, which often becomes apparent at around age 60 and tends to progress with increasing age. Loss of sensitivity to odors can stem from anatomical and physiological changes in the olfactory system that are associated with normal aging, but losses could also be caused by smoking, diseases, and use of some medications (Schiffman, 1996). Schiffman contends that the sense of smell can serve as a warning signal, so loss in smell sensitivity could represent a risk that smoke, gas leaks, or food spoilage will not be readily detected. Loss of taste sensitivity is associated more with medications and medical conditions than it is with anatomical and biological losses that occur with normal aging. When older adults have no diseases and take no medications, there are only minimal increases in their thresholds for salty, sweet, sour, and bitter tastes. However, when changes in smell and taste sensitivity do occur, they can affect older adults' appetite because food loses its appeal. Nutritional deficiencies resulting from poor eating habits can have a negative effect on older adults' general health and psychological well-being.

Touch, Proprioception, and Pain

The sense of touch includes tactile sensations related to pressure and temperature, whereas the sense of proprioception refers to an awareness of the position and movement of the body and limbs in space. Both touch and proprioception are mediated by sensory structures as well as higher-order perceptual processes, both of which are susceptible to the effects of aging (Weisenberger, 2007). Older adults have higher thresholds than young adults for detecting vibration and thermal (hot, cold) stimulation. In addition, older adults have a higher threshold for detecting limb movements and changes in position, especially for the lower extremities such as knees, hips, and ankles. Older adults do not seem to differ from young adults in their ability to maintain balance under normal conditions because they compensate for proprioceptive losses by using cues from other sensory sources. However, limitations in cues from other senses, particularly vision, can result in difficulty with balance (Weisenberger, 2007).

With increasing age, there is a greater risk of falls from loss of balance, perhaps more so for women than for men. In any given year, more than one-third of people over age 65 experience a fall, and the incidence is even higher among the very old. Falls can result in hip fractures that necessitate hospitalization and rehabilitative services (Vercruyssen, 1997). Because falls can compromise older adults' mobility and independence, fall prevention programs that include muscle strength and balance training (SBT) have become a public health priority. Yardley et al. (2006) interviewed community-living older adults in six countries (Denmark, Germany, Greece, Switzerland, the Netherlands, and the United Kingdom) about their attitude toward fall prevention programs. Surprisingly, older adults in all these countries tended to deny they were at risk of falling, although many claimed they would be interested if such programs would benefit their general health and well-being. In a subsequent survey conducted in the United Kingdom (Yardley, Donovan-Hall, Francis, & Todd, 2007), older adults were more motivated to undertake SBT when they perceived it as potentially beneficial in terms of enjoyment and general health than they were if they viewed it as something that would prevent the threat and consequences of falling.

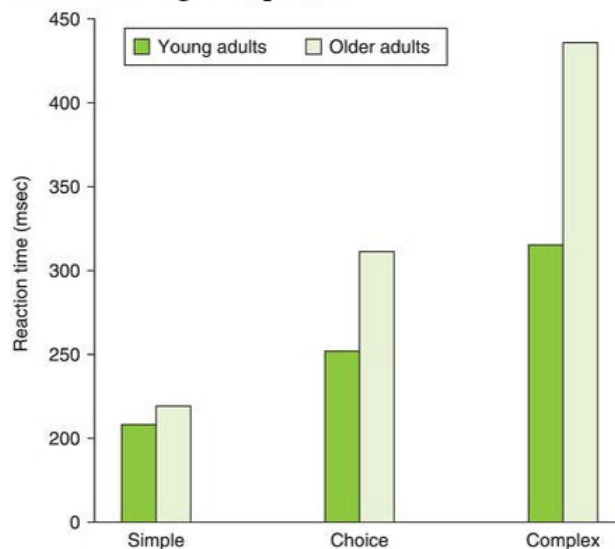
With regard to pain, measuring responsiveness is complex, as individuals vary not only in

their sensitivity but also in their willingness to report it (Weisenberger, 2007). Harkins and Scott (1996) point to the special difficulties in assessing pain in older adults. First, older adults may be suffering from health problems associated with chronic pain (for example, osteoarthritis, osteoporosis, or diabetes). Such chronic pain could interact with pain stemming from acute conditions. Second, older adults who experience pain from a chronic condition may have less reserve capacity for coping with additional pain from acute sources compared with young adults who are otherwise in relatively good health. Third, it can be difficult to assess pain in older adults with dementia, who are limited in their ability to report the nature and extent of any pain they are experiencing. (See Chapter 11 for further discussion of dementia.) Finally, older adults may have a different criterion from young adults for reporting the point at which they feel pain.

Vision and hearing have received the most extensive and detailed attention from researchers in aging. The following sections describe the age-related differences/changes that occur in the anatomical structures of the eye and ear, as well as those that seem to take place in visual and auditory perception.

Figure 4.2 *The human eye.*

Source: Sigelman & Rider (2003, Fig. 6.6, p. 156).



Vision

In general, there are changes in visual capability, often beginning in the 30s, but these are gradual. Beginning in their 40s, many people notice that newspaper print seems light and faded, and numbers in the telephone book appear very small and difficult to decipher. Furthermore, driving at night is often more effortful, as with Louis, who was described at the beginning of the chapter.

Structure of the eye

Some visual changes that occur with aging can be traced to changes in the anatomical structures of the eye (see [Figure 4.2](#)).

The cornea, the refractive surface that also serves a protective function, undergoes a slight age-related decrease in sensitivity to mechanical stimulation, which means that older adults are not as ready as young adults to detect the presence of a foreign body in the eye. In addition, the luster, thickness, and curvature of the cornea can change, which creates the need for new corrective lenses. In most cases, these changes are not large enough to have a substantial effect on visual functioning (Kline & Scialfa, 1996).

The aqueous humor, the fluid-filled chamber that lies between the cornea and the lens, is the conduit through which nutrients are carried into the lens and metabolic waste products are carried out. Blockages can create increases in pressure. **Glaucoma** is a disease characterized by elevated pressure in the aqueous humor. The onset of age-related glaucoma is often gradual. Initially, it may affect peripheral (side) vision, but over time, central vision may be affected as well. In its early stages, glaucoma can be treated with medication but more advanced cases require surgery (Roberts, 1995). Regular ophthalmologic checkups are the best means of early detection. If left untreated, the prolonged elevation in pressure can cause irreversible damage to the nerve cells in the retina.

The pupil, the opening of the eye surrounded by the iris, controls the amount of light that enters the eye and ultimately reaches the retina. With increasing age, the diameter of the pupil decreases (Kline & Scialfa, 1997), admitting less light into the older eye. Under the

identical level of illumination, there is a linear decrease from age 20 to age 60 in the amount of light reaching the retina (Botwinick, 1984). This means that with increasing age higher levels of illumination will be needed.

In addition to a smaller diameter, the pupil becomes less able to adjust its size in response to changing levels of light. Especially at low levels of illumination, the older eye is not as sensitive as the young eye and this undoubtedly contributes to the difficulties older adults experience with nighttime driving, as with Louis, who was described earlier. In older adulthood, pupillary adjustment takes longer after exposure to glare from the bright headlights of passing cars. During this prolonged period of adjustment, visual sensitivity is reduced. Louis finds that bright headlights interfere with the acuity of his vision.

The lens of the eye transmits light. It also changes in shape and thus refractive power. Changes in refractive power (accommodation) allow the eye to focus on both near and far objects. With increasing age, the lens increases in size and thickness and decreases in flexibility (Kline & Scialfa, 1996). These changes make it difficult for the older eye to focus on near objects, resulting in farsightedness that is termed **presbyopia**. Louis is experiencing such a change as indicated by his difficulty in reading the gauges on his car's dashboard. Presbyopia differs from myopia (near-sightedness), which is a condition whereby the eye cannot focus on objects that are far away. Beginning in middle age, many individuals who never wore glasses before find they need them for reading. Those who already wear corrective lenses for distance vision often need bifocal lenses that correct for both distance and close-up vision.

Photo 4.1 *With age-related changes in vision, older adults begin to have difficulty reading small print that is up close, so they often compensate by holding items with small print at a slight distance.*



In addition to becoming larger and less flexible, the lens tends to yellow with age. Less light can pass through a yellowed lens than through a clear lens, which is one more reason a room that might seem bright enough to the young eye can seem dim to the older eye. Furthermore, the yellowing of the lens results in a modest decline in the ability to discriminate between colors with short wavelengths (Kline & Scialfa, 1997), so older adults have difficulty discriminating between various shades of blue, violet, and green. However, the ability to discriminate shades of red and yellow is usually maintained.

With increasing age, the formation of **senile cataracts** becomes more prevalent. Cataracts are areas of cloudiness or opacity in the lens. Not all older adults develop cataracts, but they are common. Risk factors for cataracts include sunlight, steroid use, and smoking (Kline, 2006). By age 75, approximately 50% of adults in the United States have the early stages of cataracts. By age 80, 70% have clinically significant cataracts. Cataracts reduce visual acuity and also scatter light, which causes increased susceptibility to glare. Although older adults require higher levels of illumination, indirect lighting is preferable for limiting glare. Surgery for cataracts involves replacing the natural lens with a synthetic one and has a high rate of success. However, many older adults must cope with the milder effects of cataracts until such time as they become candidates for surgery.

Ultimately, images are focused on the retina. With age, the number of retinal ganglion cell axons declines (Kline & Scialfa, 1997), and changes in blood vessels that nourish the retina can result in retinal damage. **Macular degeneration** is a disease associated with

irreversible loss of nerve cells in the central area of the retina. The macula is located near the fovea and consists of a high concentration of receptor cells that are susceptible to circulatory insufficiencies that may increase with age (Roberts, 1995). Degeneration of these receptor cells affects vision for fine detail, resulting in difficulties with activities such as reading and driving. Several new and very costly drugs show some evidence of slowing the progression of macular degeneration in 25% to 50% of those afflicted. Also, there are reports that wearing sunglasses with UV protection and following a diet that includes leafy green vegetables as well as a daily glass of red wine and/or a cup of green tea may reduce the risk of this disease.

Diabetic retinopathy is a disease resulting from complications of long-term diabetes (described in Chapter 3), whereby changes in the structure and function of blood vessels cause damage to receptor cells in the retina (Kline & Scialfa, 1996). Often, the extent of damage can be controlled through proper monitoring of blood sugar levels. Macular degeneration and diabetic retinopathy are not inevitable with increasing age, but they do become more prevalent, and the consequences of both are serious.

Visual perception

Not all changes in vision can be traced to changes in the structure of the eye. Vision is also a function of central processing in the brain.

Useful field of view (UFOV) is the visual area over which stimuli can be recognized and localized without a person's making any eye or head movements (Kline & Scialfa, 1996). Thus, UFOV measures the amount of information that can be processed during a brief glance (Rogers, 1997), and it is affected by factors such as number of competing attentional demands and distinctness of the visual stimuli (Ball & Owsley, 1991). In general, UFOV is more restricted in older adults than it is in young adults, although it can be expanded with training and practice (Ball, Beard, Roenker, Miller, & Griggs, 1988; Kline & Scialfa, 1997). Louis, described earlier, does not always see passing vehicles in his peripheral vision until they are parallel with his car, whereas a younger driver may detect the passing vehicle earlier. Some investigators have found UFOV scores are a significant predictor of older drivers' road test performance and crash frequency (Ball & Rebok, 1994), perhaps more so than measures of reaction time and visual acuity (Carr, Jackson, Madden, & Cohen, 1992). Also, older drivers with low UFOV scores are more likely than those with high UFOV scores to report that they purposely avoid difficult driving situations, such as when there is rain or heavy traffic (Ball et al., 1988). Although UFOV is a promising indicator of driving ability, Hoffman and McDowd (2010) followed 114 licensed adult drivers aged 68–90 who took both driving simulator and UFOV tests. They found that performance on a driving simulator device was more useful than the UFOV measure in predicting self-reported incidents of at-fault driving impairment that occurred in the subsequent five years.

Motion perception is another aspect of visual perception most likely related to central processing, and many older adults have decreased ability to process quickly changing visual stimuli. Relatedly, they are slower to respond to moving objects and are less sensitive to differences in velocity (Gilmore, 1996; Kline & Scialfa, 1997). Motion perception is a critical skill in driving, and older drivers tend to overestimate the velocity of slow-moving vehicles, which means they anticipate slow-moving vehicles will arrive more quickly than they actually do. This is one reason older drivers like Louis wait before turning into traffic while impatient young drivers honk their horns because they are certain there is plenty of time to make the turn.

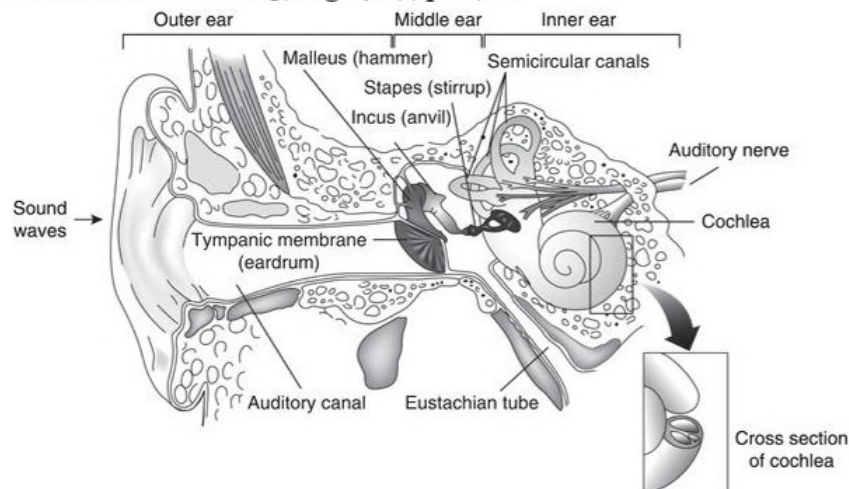
Depth perception requires the use of visual cues to determine which objects in the environment are closest and which are farthest away. Decline in depth perception becomes apparent in the 50s, with further modest decline through the 70s. With regard to driving, poor depth perception can make parallel parking difficult because the driver must judge the distance between the car he or she is trying to park and the adjacent cars (Kausler et al., 2007). Louis attributes his recent difficulty with parallel parking to his belief that the city has been shrinking the allotted size of metered parking spaces.

Hearing

Hearing consists of peripheral and central systems. Sounds are registered by the peripheral system (the outer, middle, and inner ear) and carried by the auditory nerve to the central nervous system, where they are processed and interpreted (see [Figure 4.3](#)).

Figure 4.3 *The human ear.*

Source: Adapted from Tobin (2003, Fig. 42.7, p. 872).



Applying Research Box 4.2: Technology Use Among Older Adults

Given the increasing longevity of the population, it stands to reason that older adults should be taking advantage of the numerous technological advances that have been made just as readily as other age groups do. Charness and Boot (2009) contend that while greater numbers of older adults use technology now than in the past, they still lag behind other age groups. The age-related gap in technology use could be due, at least in part, to the fact that many devices do not take into account age-related changes in sensory and perceptual capabilities (see also Gonsalves & Pichora-Fuller, 2008). One means of ameliorating this situation would be for those designing new devices to take into consideration age-related changes in vision and hearing. For example, cell phones and iPhones could have larger buttons or icons and simpler menus, and there could be greater efforts to develop devices that minimize background noise. With regard to internet use, website designers could take into account age-related changes in color vision, susceptibility to glare, the need for high contrast between relevant information and visual background, as well as older adults' slower processing speed. Technology is increasingly important in all aspects of modern life, so understanding the potential constraints older users may experience should be helpful in the development of devices that will be well suited to their needs.

Hearing loss is among the most common conditions affecting older adults. Approximately 30% of adults over age 65 have noticeable hearing impairment (Kausler et al., 2007), and older adults are more likely than young adults to report problems with everyday tasks that involve hearing. Hearing difficulties are associated with poor physical health and reduced levels of psychosocial functioning (Strawbridge, Wallhagen, Shema, & Kaplan, 2000).

Structure of the ear

Auditory stimuli must be sufficiently loud, or intense, to be registered by the peripheral system. Impairments of a mechanical nature can impede the passing of sound waves through the outer or middle ear and thus can contribute to age-related hearing loss. Changes in the auditory canal, including the presence of impacted wax, can cause *conductive* hearing loss. With increasing age the ear drum becomes stiffer, thinner, and less elastic and thus less easily displaced as a function of sound intensity (Kline & Scialfa, 1997).

In the middle ear, three tiny bones, or *ossicles* (hammer, anvil, and stirrup), transmit acoustic energy to the inner ear by creating mechanical vibrations at the entrance to the fluid-filled inner ear, or cochlea. Over time, calcification of the ossicles decreases their mobility, which results in conductive hearing loss. Conductive loss from age-related changes in the outer and middle ear usually affects all frequencies (high- and low-pitched) to a similar degree.

The inner ear consists of two structures. The semicircular canals control the sense of balance and the cochlea is associated with hearing. The cochlea is a fluid-filled chamber with a membrane (basilar membrane) running down the center. Mechanical vibrations created by the ossicles of the middle ear set the cochlear fluid in motion, which bends the hair cells on the basilar membrane. Bending of the hair cells converts sound waves into neural energy by stimulating the release of neurotransmitter substances at their base, thus initiating nerve impulses that will be transmitted to the brain (Gordon-Salant, 1996). Any damage to the

delicate hair cells on the basilar membrane results in *sensorineural* hearing loss. Such damage can be caused by exposure to loud noise or illness, but some degeneration of the hair cells could occur simply with aging. The hair cells in the basal region of the basilar membrane are resonant to high-frequency tones, and it is in this region that hair cells show the most pronounced degeneration in older adults. Accordingly, older adults become less sensitive to high-frequency sounds such as high-pitched doorbells and smoke alarms, birds' chirping, cats' meowing, the sizzle of frying bacon, and the high notes on a piano keyboard (Slawinski, Hartel, & Kline, 1993). As mentioned at the beginning of the chapter, Louis does not hear the high-pitched sirens of fire trucks and police cars until they are close by.

Auditory perception

Signals from the cochlea are transmitted via the auditory nerve to the brain stem and ultimately to the cortex. Neurons in the auditory nerve undergo some degree of age-related degeneration, which could distort auditory signals (Gordon-Salant, 1996). The central auditory system consists of neurons in the brain stem, mid-brain, and temporal lobe, where complex acoustic information is translated into meaningful signals (Figure 3.5 shows these brain structures). Although there is considerable individual variability, there is evidence for age-related decline in the ability to process auditory information at the *central* level.

Comprehension of speech is a complex activity that involves simultaneous processing of incoming information and previously received information. Under normal conditions, speech comprehension is well maintained with age, although some decline has been noted under challenging listening conditions. Using functional magnetic resonance imaging (fMRI), which was described in Chapter 3, Peelle, Troiani, Wingfield, and Grossman (2010) measured young and older adults' brain activation while they listened to recorded sentences of varying syntactic complexity that were presented at varying rates. When syntactically complex sentences were presented at a higher rate, older adults' brains indicated a lesser degree of activation in what is normally considered the core speech-processing network. At the same time, however, older adults showed broader recruitment of activation in the frontal region of the brain, an area associated with working memory (discussed further in Chapter 5). These age-related differences in patterns of brain activation, especially under challenging listening conditions, indicate that the older brain may be compensating with a less specialized but broader area of activation.

Presbycusis

Presbycusis is a pattern of hearing loss associated with aging and characterized by an increased threshold for high-frequency tones. Diminished sensitivity to high-frequency tones can begin in the 30s but usually does not become noticeable until the 40s, 50s, or later. As high-frequency loss progresses, it affects speech sounds that fall into the high-frequency range. Thus, older adults have increased thresholds for high-frequency consonants (for example, k, s, sh, f, t, th). With regard to speech perception, older adults have difficulty discriminating between words with high-frequency consonants (for example, "fit" and "sit").

For reasons not completely understood, presbycusis begins earlier and progresses more rapidly in men than it does in women. Also, European Americans are more likely than African Americans to experience presbycusis, and the gap between these two groups widens with increasing age (National Academy on an Aging Society, 1999).

Difficulty with speech perception can be attributed in part to older adults' decreased sensitivity to high-frequency speech sounds. However, older adults often comment, "I hear it but I cannot understand it," a phenomenon known as **phonemic regression**. Older adults' understanding of speech or other complex signals is poorer than it should be based solely on their sensitivity to pure tones (Tun & Wingfield, 1997). Some increase in loudness, or intensity, can be helpful for older adults who experience difficulty with speech perception. However, increased intensity does not usually eliminate difficulty in understanding speech. In fact, speaking too loudly could actually be detrimental. Rather than a speaker's raising his or her voice in an attempt to help the older listener, it is usually preferable to speak somewhat more slowly and to substitute key words that have fewer high-frequency consonants.

Older adults with presbycusis have trouble understanding speech in noisy conditions. They experience greater difficulty than young adults do with understanding speech against a background of noise or "babble" from one or numerous other talkers (Schneider & Pichora-Fuller, 2000; Tun & Wingfield, 1997, 1999). This difficulty is compounded when older adults are attempting to understand rapid (time-compressed) speech (Tun, 1998; Wingfield, 1996).

In summary, presbycusis is associated with sensorineural loss in the inner ear as well as difficulty in processing complex auditory information (such as speech) at the central level. Age-related changes in attentional capacity (discussed later in this chapter), as well as in memory (discussed in more detail in Chapter 5), could also contribute to difficulties in processing auditory information. Older adults benefit greatly if given sufficient time to process auditory information.

Causes of presbycusis

Even though presbycusis is a commonly reported problem among older adults, not all older adults suffer from hearing difficulties. What causes presbycusis? One hypothesis is that presbycusis results from the accumulated effects of exposure to environmental noise from traffic or from disturbances in the workplace. In cross-cultural comparisons, age-related hearing loss is less prevalent in relatively noise-free nonindustrialized societies (for example, the Maaban tribe in Africa) compared to noisy industrialized countries such as the United States (Gordon-Salant, 1996). Within the United States, the rate of occurrence is higher among those who worked in occupations such as farming, machine operations, and transportation as opposed to occupations with less noise exposure (National Academy on an Aging Society, 1999). If noise exposure is indeed the source of presbycusis, future cohorts of older adults may have a high incidence because of having attended rock concerts in their younger years and possibly due to their excessive use of headsets that are turned to a high volume.

Although noise probably contributes to presbycusis, there is no proof that presbycusis is attributable solely to noise exposure. Other factors being investigated include diet, medications, alcohol consumption, smoking, hypertension, and genetic influences. As yet, cause-and-effect relationships between presbycusis and these factors have not been clearly established. Presbycusis may be attributable, at least in part, to intrinsic, age-related deterioration of the auditory system. It has even been suggested that presbycusis renders older adults more vulnerable to noise-induced hearing loss. If so, then avoiding exposure to noise is especially important for older listeners (Kline & Scialfa, 1997).

Hearing aids

Hearing aids can be fitted to one ear (monaural) or both ears (binaural) to increase, or amplify, sound. The degree of sound amplification must be sufficient so that auditory signals will cross the individual's threshold. At the same time, the intensity of the signals should not be so great as to be uncomfortably loud. A hearing aid must be tailored to the individual user's profile of hearing loss. For example, someone with a hearing loss in the high-frequency range should wear a hearing aid that amplifies high-frequency but not low-frequency signals.

Among people in the United States with hearing loss, those aged 65 and over are more likely than young and middle-aged adults to wear hearing aids. Even so, two out of three older (65+) individuals with hearing loss do not use a hearing aid (National Academy on an Aging Society, 1999), and only about a quarter of older adults who might benefit from a hearing aid actually own one (Schneider & Pichora-Fuller, 2000). Relatedly, a large-scale study conducted in Australia assessed the hearing level and hearing aid use of approximately 3,000 individuals aged 49–99, with an average age of 67.4 (Hartley, Rochtchina, Newall, Golding, & Mitchell, 2010). Although 33% of the study participants had a hearing loss, only 11% owned a hearing aid. Of those that owned a hearing aid, 24% reported that they never used it.

What are the barriers to hearing aid use? In a survey of 2,300 hearing-impaired individuals over age 50 (National Academy on an Aging Society, 1999), the reason more than half of the respondents gave was cost. In addition, some did not think their hearing was poor enough to necessitate the use of a hearing aid. Indeed, hearing loss can have such a gradual onset that older adults are not aware of it. But approximately 20% reported concerns related to vanity and the belief that a hearing aid carries a social stigma. Some older adults fear that wearing a hearing aid signifies that they are not competent, and they consider a decline in hearing acuity to be a threat to their self-image (Ryan, Hummert, & Anas, 1997). However, reluctance to deal with hearing difficulties often creates more problems than it solves. As the baby boom generation moves into older adulthood and a larger proportion of the population experiences age-related hearing loss, there may be less hesitancy to acknowledge hearing difficulties and more attempts to do whatever is necessary to maximize auditory functioning. Perhaps the recent popularity of Bluetooth technology will make it more difficult to distinguish between hearing aid users and those who want to talk on a hands-free phone!

Although hearing aids amplify sound, they do not address difficulties with auditory processing at the central level (Wingfield et al., 2005). Also, hearing aids have limited usefulness in helping older adults to understand speech when there is background noise (Schneider & Pichora-Fuller, 2000). Newer digital hearing aids have circuitry that selectively reduces the amplification of noise (Gordon-Salant, 1996), but digital hearing aids are costly and far from perfect. Even so, many older adults could derive some benefit from them even if their hearing difficulties are not completely alleviated.

Visual cues

Visual cues, which a listener can derive from reading a speaker's lips or observing a speaker's facial expressions or body language, provide additional information about a speaker's communication. Older adult listeners can use visual cues to compensate for degraded auditory signals, so speakers should make every effort to face older adult listeners so they can take advantage of such cues.

Visual alerting signals can be attached to safety devices designed for individuals with hearing difficulties. Some smoke alarm systems set off flashing lights in addition to auditory signals. It is possible to install strobe lights that flash when telephones or doorbells ring. Many movies and television programs have a captioning option for the benefit of individuals with hearing difficulties.

Bottom-up and top-down strategies in language processing

Listeners use a combination of **bottom-up and top-down strategies in language processing** (Tun & Wingfield, 1997; Wingfield, Prentice, Koh, & Little, 2000). A bottom-up strategy calls for registering and processing the details of the sensory-perceptual input. A top-down strategy uses contextual information about the semantic (word meaning) and syntactic (grammatical) structure of language as well as its prosodic features (intonation, stress, and timing). Older adults with presbycusis lose some efficiency in bottom-up strategies, particularly when auditory signals are in the high-frequency range. However, they can compensate for such limitations by relying more heavily on top-down strategies derived from their knowledge of the language. Top-down strategies are based on the excess information (redundancy) in spoken language, and listeners can use contextual cues to fill in the details of a speaker's message. For example, if the speaker says, "I want to ... down," the English-speaking older adult with presbycusis may not be able to distinguish whether the missed word is "sit" or "fit" purely on the basis of bottom-up processing. However, an older listener familiar with language probabilities can make an educated guess that the missed word is "sit" rather than "fit." Listeners can use top-down processing more readily when speakers (a) talk at a normal rate, (b) use sentences that are not too long or too grammatically complex, and (c) use normal prosodic features (intonation, stress, and timing) in their speech (Wingfield & Stine-Morrow, 2000).

Communicating with older adults

Elderspeak refers to a particular style of speaking people tend to use when communicating with older adults. Kemper (1994) demonstrated that service providers and caregivers are more likely to reduce the length and grammatical complexity of what they say, to use simpler words and more repetitions, and to speak more slowly when addressing a group of older adults than they do when addressing a group of young adults.

Elderspeak is characterized not only by shortened sentences, simplified grammar, and slower speech, but often by exaggerated pitch and intonation (exaggerated prosody) as well. But which components of elderspeak are beneficial for older adults and which ones are not helpful? Kemper and Harden (1999) had older adults watch a videotape in which a speaker described a route that was also traced on a map. The older adults reported that the instructions were easier to follow when the speaker reduced the grammatical complexity (that is, minimized the number of subordinated and embedded clauses) and used semantic elaboration (that is, repeated and expanded upon what was said). Simpler grammar and semantic elaboration also helped older adults improve their accuracy when they had to reproduce the same route on a map of their own. In contrast, shortening the length of the speaker's utterances into two- and five-word sentences did not improve the older adults' comprehension of the instructions, nor did it improve their performance when they traced a map of their own. Also, the older listeners did not find that an extremely slow rate of

speaking with many pauses or exaggerated prosody were helpful. Apparently, being spoken to in a slower than normal speed and in short phrases with exaggerated pitch and intonation does nothing to enhance older adults' ability to comprehend speech.

The communication predicament of aging model

When people hold stereotyped expectations that older adults cannot hear and are dependent and cognitively incompetent, they often modify their speech patterns to fit these assumptions. People who assume older adults are not competent tend to use patronizing communication in their conversations. Features of patronizing communication include the overly simple grammar and short sentences found in elderspeak. In addition, patronizing communication often entails speaking at a louder than normal level of intensity and using exaggerated prosody and exaggerated nonverbal gestures and terms of endearment such as "honey" and "dear." This form of communication can result in the **communication predicament of aging model** (Ryan, Hummert, & Boich, 1995), whereby the speaker's patronizing manner of communication imposes unnecessary constraints on interactions with an older adult, with the result that both the speaker and the older listener find the exchange to be unsatisfactory. The unfortunate outcome is that both speaker and listener tend to avoid communicating with one another on future occasions.

Ryan, Bourhis, and Knops (1991) and Ryan, Hamilton, and Kwong See (1994) had people read written scripts or listen to tape-recordings of a nurse communicating with an older nursing home resident. People formed an unfavorable impression of a nurse who communicated in a patronizing manner ("I'm here to give you your pills. Be a good girl and take them right now." "There you are, Maggie. Come on, Sweetie. It's time to go to the dining room for supper, remember?"). People thought more highly of the nurse who communicated in a neutral manner ("It is time to take your pills. Here's your glass of water, but take your time." "Mrs. Fields, I've been searching everywhere for you. It's time to go to the dining room for supper."). Not only did people view the patronizing nurse herself as less competent, less respectful, and less benevolent than the neutral nurse, but they also thought that the nursing home resident spoken to by the patronizing nurse was more helpless than the resident spoken to by the neutral nurse. Clearly, the manner in which the nurse communicated made a difference to people's impressions of both the nurse and the older nursing home resident.

Patronizing communication is not limited to conversations between nursing home staff members and nursing home residents. Ryan, Anas, and Gruneir (2006) had young adults read a script of a conversation in which an older male customer asks a female salesperson for help while shopping in a department store. The young adults thought more highly of the salesperson, and they thought that the customer would be more satisfied, when the salesperson addressed the customer in a professional manner. They were less positive when the salesperson showed an overhelping style, using exaggerated intonation and offering too much direction and too strong an opinion about what the older shopper should purchase.

But do older adults always view patronizing communication as negative and insulting? O'Connor and Rigby (1996) recruited older adults from both a senior citizen activity center and a nursing home and told them to imagine they were attending an entertainment event and that, during the intermission, another person comes over and asks if they would like some refreshments. In the neutral scenario, the person says, "I came over to see whether you are enjoying the show and to ask whether you would like some dessert." In the patronizing scenario, the person says, "I've brought some COFFEE and a plate of GOODIES for you, dear. I hope you're COMFY and ENJOYING the SHOW." The nursing home participants, who were chronologically older and lower in self-reported functional health than the activity center participants, did not react as negatively to the patronizing scenario as the activity center participants did. Furthermore, the older adults who expressed a high need for love and reassurance (that is, they endorsed questionnaire statements such as, "I like to be with protective and sympathetic people") felt that the patronizing communication was warm. Also, the older adults with high self-esteem (that is, they endorsed statements such as, "I feel I am a person of worth") reacted less negatively to the patronizing communication than did those with low self-esteem. These findings suggest that older adults' reactions to communications that we might consider to be patronizing are associated with their individual needs and feelings of self-worth (or possibly with cultural differences).

Attention

Our senses are bombarded by many more stimuli than we can register, let alone process in a meaningful way. Fortunately, attention allows us to direct our efforts to processing some portion of the stimulation we receive. But do older adults have the same amount of attentional resources, or attentional capacity, as young adults? How many stimuli can young and older adults process at the same time? How do young and older adults deal with stimuli that are unimportant (irrelevant) and possibly distracting when they are trying to process stimuli that are important (relevant) to the task at hand?

Theoretical Models

First we will examine three theoretical models related to age and attention. Then three types of attention will be described along with some general findings about the capabilities of young versus older adults.

The reduced attentional resources/capacity model

The **reduced attentional resources/capacity model** postulates that the quantity of processing resources (or the amount of attentional capacity) declines with increasing age (Craik & Byrd, 1982; Salthouse, 1991). On simple tasks, older adults do not experience difficulty because their attentional resources are sufficient. However, the processing resources needed for more complex tasks may exceed older adults' capacity, thus rendering them less efficient and/or less accurate than young adults, who have sufficient resources to handle the demands of complex tasks. The reduced attentional resources/capacity model is related to the age–complexity hypothesis described earlier. The greater the complexity of a task, the more attentional resources will be required. If older adults' attentional resources have limitations, their performance will suffer on complex tasks.

The reduced attentional resources/capacity model has generated a great deal of research, described later in the section on divided attention. However, a criticism of this model has been its lack of clarity about how resources or capacity should be defined and measured (Salthouse, 1991). Some researchers have expressed concern that the reduced attentional resources/capacity explanation of age-related differences in perceptual processing is somewhat circular. Further research is needed to specify the mechanism(s) by which resource limitations affect attention (McDowd, 1997).

The inhibitory deficit model

A second theoretical model is the **inhibitory deficit model** (Hasher & Zacks, 1988), which postulates that aging is associated with a decrease in the ability to ignore irrelevant stimuli (stimuli that are not important for performing a particular task, sometimes called *distractors*) and focus attention on relevant stimuli (stimuli important for performing the task, sometimes called *targets*). If attention to distractors is not suppressed (inhibited), then some portion of attentional capacity will be wasted processing information that is not important and too little will remain for processing important target stimuli. As with the reduced resources/capacity model, the inhibitory deficit model is related to the age–complexity hypothesis because sources of distraction are likely to be more extensive in complex attention tasks than they are in simple ones.

The inhibitory deficit model has generated a great deal of research, described in the section on selective attention. However, this model is not without its critics. One problem has been the lack of clear agreement on how to define inhibitory mechanisms (McDowd, 1997). Also, the model's predictions about age-related differences are not always accurate (Tun & Wingfield, 1997). Nonetheless, this model has been a useful framework for organizing research on aging and cognitive processes, including attention.

The frontal lobe model

Two different neural systems appear to play a role in attentional functioning. One is located in the frontal area of the cortex and the other is in the occipital and parietal areas of the cortex (see [Figure 3.5](#)). A third theoretical model to explain age-related decline on attention tasks postulates that the frontal lobes are more susceptible than other regions of the brain to the effects of normal aging (Arbuckle & Gold, 1993; Hartley, 1993; Kramer, Humphrey, Larish, Logan, & Strayer, 1994). The **frontal lobe model** has received support from cognitive neuroscience research that uses neuroimaging techniques such as positron emission tomography (PET) scans, which measure cerebral blood flow and metabolic activity

in regions of the brain when individuals are in a resting state and when they are performing various tasks (Madden & Allen, 1996). Reductions in cerebral blood flow seem to occur earlier and be more pronounced in the frontal lobe area than in other regions of the brain. Also, age-related loss of neural tissue is more prominent in the frontal area than it is in other regions of the brain (Arbuckle & Gold, 1993; Kramer et al., 1994).

The frontal lobes are responsible for executive functions such as decision making, planning, and coordinating the processing of multiple streams of stimuli, the initiating and stopping of behaviors, and impulse control. Patients with known frontal lobe damage have difficulty shifting from one type of response to another. For example, if instructed to sort cards on the basis of the color of the object pictured on each card, they have difficulty when they are told to switch to sorting cards on the basis of the shape of the object pictured on each card. Such individuals perseverate, meaning that they revert back to sorting cards based on color.

The frontal lobe model predicts that age-related differences in attention will be most pronounced on tasks that depend heavily on frontal lobe functioning. Kramer et al. (1994) found that older adults had difficulty on two tests (card sorting and stopping) that require the inhibitory functioning that is associated with frontal lobe processing. Older adults made more perseverative errors than young adults when they had to shift to a new criterion for sorting cards. Likewise, older adults were slower than young adults when they were required to react to an occasional signal to abort, or stop, the responses they were making to a visual display. In contrast, age-related differences were much smaller on tests of spatial attention, which do not call for frontal lobe processing – for example, responding quickly to a visual display in which a target letter is surrounded by distractor items.

Arbuckle and Gold (1993) noted that perseveration can take the form of “off-target verbosity,” which has been detected more often in the speech patterns of older adults than young adults. Off-target verbosity is characterized by a lack of focus or coherence, and it could be related to difficulty with inhibiting task-irrelevant thoughts, possibly stemming from a decrement in frontal lobe functioning. [Table 4.1](#) gives an example of responses that are low and high in off-target verbosity. Interestingly, however, older adults display more off-target verbosity when answering personal questions than they do when answering factual questions (James, Burke, Austin, & Hulme, 1998).

Such findings are important, but it would be premature to conclude that the frontal lobe model explains all age-related inhibitory difficulties (McDowd & Shaw, 2000). Also, inhibitory mechanisms may not be located exclusively in the frontal lobes of the brain.

Table 4.1 *Examples from Arbuckle and Gold (1993) in answer to the question, “How much education did you get?”*

Source: Arbuckle & Gold (1993).

<p><i>Low off-target verbosity</i> “I finished high school and then a bit of college.”</p> <p><i>High off-target verbosity</i> “Well, let’s see. I went to school in ... where, uh, uh, I grew up in ... Back in those days, they didn’t have the big high schools that they have now. When I went back there a few years ago in ... uh, I don’t remember exactly when it was. I think it was the summer of 1980 or maybe it was 1981. I went for my brother’s 50th wedding anniversary and I didn’t recognize the place at all. We went to a small school, the only school in town. It was the only place to go. All the children were in one room. The school only went to grade 9 or uh, uh, I think it was ... was it Grade 9? No, it was only grade 8 because ... [neighbor’s daughter] left to go to nursing school and she had to go to ... to finish Grade 9. She never finished nursing anyway. She got married and it didn’t last long.”</p>
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Attention Tasks

Attention tasks fall into three basic categories: sustained attention, divided attention, and selective attention (Kausler, 1994).

Sustained attention

Sustained attention, or **vigilance**, calls for monitoring a situation and remaining ready to detect any change that occurs in a pattern of stimuli that is usually stable and unchanging (Kausler, 1991). On a classic visual vigilance task called the Mackworth Clock Test, individuals monitor the pointer on a clock-like device. The pointer moves in discrete steps much like a second hand on a clock, but individuals must remain ready to detect an occasional two-step jump. In the real world, a quality control manager must be on the lookout to detect a defective product while inspecting a steady stream of that product, or an employee must monitor a piece of equipment for any auditory cue that signals malfunction.

Over extended durations, vigilance tasks can lead to fatigue and ultimately to a decline in accuracy. However, on simple tasks, the accuracy of older adults does not suffer any more than that of younger adults (Kline & Scialfa, 1997). With the Mackworth Clock Test, there is a high level of accuracy in the first 15-minute segment of an hour, with a gradual decline in accuracy over the next three 15-minute time segments. But this decline is no more pronounced for older individuals than for younger ones (Madden & Allen, 1996).

Simple vigilance tasks do not make excessive cognitive demands, and age-related differences are usually small or nonexistent. In fact, older adults are less prone than young adults to having task-unrelated thoughts, or mind wandering, while performing simple vigilance tasks (Giambra, 1989). However, older adults' accuracy suffers more than that of young adults when changes in monitored stimuli occur at a high rate or when vigilance tasks become complex (Kausler, 1991; Rogers & Fisk, 2001). For example, an individual may be required to monitor a screen for a sequence of numbers (for example, 5, 2, 8) as opposed to the simpler task of monitoring the screen for a single number such as 5. Both young and older adults have greater difficulty in monitoring for a three-digit sequence than for a single digit. However, the increased complexity of the three-digit task has a greater negative effect on the performance of older adults than it does on that of young adults, most likely because it requires more attentional resources. Even so, both young and older adults benefit from practice on vigilance tasks (Rogers & Fisk, 2001).

Understanding Aging Box 4.1

Cell Phones and Street Crossing

Mark Neider and his colleagues at the University of Illinois (Neider et al., 2011) investigated young and older adults' performance on a simulated street crossing task when they had no distractions as opposed to when they were asked to either converse on a hands-free cell phone or listen to music on an iPod at the same time. Neider et al. created virtual walking and street crossing scenarios of varying difficulty using a treadmill for walking and visual goggles to give the illusion of crossing a street and through which "walk" and "don't walk" signals could be flashed. In general, there were no dual-task costs for young adults – neither cell phone conversations nor iPod listening interfered with their initiation or completion of street crossing in the allotted time. In general, older adults took longer than younger adults to initiate crossing when the "walk" sign flashed, especially in difficult crossing situations. Listening to an iPod at the same time did not affect older adults' performance, but conversing on a hand-free cell phone had definite costs, as reflected in greater delay in initiating crossing and failure to complete it in the allowed time. This finding points to the potential risk of multitasking for older adults, even when they are engaging in everyday locomotion activities such as crossing streets.

Divided attention

Divided attention is required when attention must be paid to more than one thing at a time, or when two or more stimulus inputs must be processed concurrently. In some dual-task situations, both inputs are presented to the same sense (visual or auditory). In other dual-task situations, one input is presented to one sense (visual) but the other is presented to a different sense (auditory).

In a dual processing task performed in the laboratory, individuals might be required to monitor a screen and respond when a particular geometric form appears. At the same time, they are also required to respond whenever a tone is sounded. The speed and accuracy of their responses when they are required to perform only one of these tasks can be compared with the speed and accuracy of their responses when they must perform both tasks

concurrently.

Researchers have used such dual attention tasks to determine the extent of age-related decline in processing resources, or capacity. Somberg and Salthouse (1982) demonstrated that young and older adults are equally capable of dividing their attention if tasks are relatively undemanding. As tasks become more demanding, however, the *cost* of dividing attention between more than one of them is greater for older adults than it is for young adults. Cost is measured by comparing how well a task is performed by itself with how well it is performed when a second task must be performed at the same time. Perhaps young adults have sufficient attentional resources to perform both tasks with little cost. However, dual-task demands may exceed the processing capacity of older adults, whose performance will suffer by becoming slower or less accurate.

Photo 4.2 *Trying to drive and carry on a cell phone conversation can be hazardous, particularly in heavy traffic and bad weather conditions because combining these activities could exceed our attentional capacity. Photo © KG Photography/Corbis*



Kemper, Schmalzried, Herman, & Mohankumar (2011) asked young and older adults to engage in a two tasks simultaneously – giving detailed verbal responses to questions (talking) and tracking a pursuit rotor. In a variation on the typical dual processing task, monetary incentives were offered for participants to attend more to the talking task even though they were required to continue performing the tracking task. For young adults, reward for talking resulted in more rapid speech and also in more grammatically complex sentences. When older adults were rewarded for talking, they also spoke more rapidly, but the complexity of their grammar did not increase. It is possible that for older adults, there may be a ceiling on grammatical complexity in a dual processing situation even when incentives for language production are offered.

Some tasks require a great deal of attention at first, but with practice they require much less attention. Driving is a real-world example. When we first start to drive, we devote considerable attentional resources to learning how to operate the car and follow the rules of the road. With practice, driving requires less effort so it demands fewer attentional resources. In fact, when the weather is good and traffic is light, most of us have little difficulty driving while listening to the radio or carrying on a conversation with a passenger. When weather is inclement or traffic is heavy, we must allocate more attentional resources to our driving. Under demanding conditions, driving while listening to the radio or talking on a cell phone could exceed our attentional capacity. When this happens, the risk of accidents increases. This principle holds true for young and older adults alike, but attentional capacity may be exceeded at an earlier point for older adults. Thus, young drivers might have little difficulty listening to the radio or conversing when it is raining lightly or when traffic conditions are only moderately heavy. Older drivers like Louis, who was described at the beginning of the chapter, might find it necessary to turn off the radio or cease talking under these conditions.

McKnight and McKnight (1993) had young, middle-aged, and older participants view videos of traffic situations that called for them to respond by manipulating simulated vehicle controls. At the same time, some study participants engaged in distracting activities such as talking on a cell phone, while others had no distractions. For the oldest group of study participants (ages 50–80), failure to make the appropriate response on the simulated controls was significantly more likely if they were talking on the phone than it was when there were no distractions.

An intriguing study conducted in Finland assessed the strategies used by young (average age 37) and older (average age 68) drivers, mostly men, all of whom owned cars with manual gears (Hakamies-Blomqvist, Mynttinen, Backman, & Mikkonen, 1999). Study participants were allowed to practice driving a 1987 Audi test car that had manual gears. The car was

fitted with seven hidden sensors that recorded the driver's use of its controls. After practicing, they drove this car under normal traffic conditions along a previously planned route. The young and older drivers who came to the study with more everyday driving experience tended to use the car's controls in a more parallel manner, meaning that they operated four or more controls simultaneously. Young and older drivers with less prior driving experience did not use as many controls at the same time. Rather, they operated the controls in a more serial manner, using no more than three at a time. In addition to driving experience, age made a difference. Overall, older drivers used car controls in a more serial manner, while young drivers used car controls in a more parallel manner. In sum, drivers with less prior experience and older drivers were more likely to use the car controls in a serial rather than a parallel manner. Perhaps the serial strategy lowered the demands on their attentional capacity. A serial strategy may work well when traffic conditions are not overly demanding. When driving conditions are complex, however, the serial strategy could increase the risk of accidents because it is more time-consuming than the parallel strategy. This could explain the increased number of traffic accidents involving older adults when driving conditions are demanding.

As with vigilance tasks, practice on divided attention tasks is beneficial for both young and older adults. In the real world, experience can perfect skills. Older adults may be capable of performing several tasks at the same time if they develop expertise in carrying out those tasks (Rybash, Hoyer, & Roodin, 1986). This was illustrated in Hakamies-Blomqvist et al.'s (1999) study, which showed that a greater amount of everyday driving practice was associated with a greater likelihood of the drivers using a parallel strategy to operate the car's controls.

Selective attention

Of all the stimuli that impinge upon us, we must often focus our attention on what is important, or relevant, to the task at hand. We must not allow ourselves to be distracted by unimportant, or irrelevant, information. **Selective attention** is required when we must pay attention to some information while ignoring other information.

Real-world situations often call for selective attention. For instance, a college student trying to study in the library must ignore ongoing conversations taking place nearby despite the posted "Quiet" signs. For the student trying to earn a good grade, the material in the textbook or on the computer monitor is the relevant (target) stimulus. Nearby cell phone conversations represent irrelevant (distracting) stimuli. In this situation, the relevant and irrelevant stimuli are presented to different senses (vision and hearing). The student must attend selectively to the target visual stimuli (the textbook or computer monitor), while suppressing attention to the distracting auditory stimuli (other people's cell phone conversations). In other instances, relevant and irrelevant stimuli may impinge upon the same sense. For example, someone trying to focus on a restaurant companion's dinner conversation (target stimulus) must "tune out" all sources of background noise (distracting stimuli). The use of the World Wide Web calls for visual selective attention because many web sites place patterned backgrounds behind the text and include unnecessary and distracting graphics and animation (Rogers & Fisk, 2001).

According to the inhibitory deficit model, older adults have particular difficulty selectively focusing on relevant stimuli and ignoring irrelevant distracting stimuli. Inefficient inhibition allows irrelevant stimuli to intrude, which causes errors in processing the relevant stimuli or just slows down processing altogether.

In visual search tasks, the measure of performance is usually the amount of time it takes to locate a target item that is placed among distractor items. The search will take a fair amount of time if individuals must scan all of the distractor items to locate the target item. The search will be quicker if there is spatial precuing in the form of prior information on where the target item will be located among the distractor items. The search will also be quicker if individuals know ahead of time that the target item has certain distinguishing physical characteristics such as color or shape. With precuing about the spatial location or distinctive physical characteristics of a target item, older adults are often no slower than young adults are in locating it (Hartley, 1995). Without precuing, visual search will be slower for both young and older adults, but older adults will be at a greater disadvantage – they will be even slower than young adults. In sum, when visual displays are complex, when distractor stimuli must be scanned and target objects have no outstanding physical characteristics, older adults will have more difficulty than young adults.

Figure 4.4 *Example of a Stroop color–word test.*



The Stroop color–word test (Stroop, 1935) is a well-known visual selective attention task. On this test, the name of a color (for example, “white”) is typed in an opposing color of ink (for example, “black”) (see [Figure 4.4](#)). The task is to name the color of the ink (“black”), while ignoring the fact that the letters typed in black ink spell the word “white.” To perform this task, individuals must focus their attention on the color of the letters while suppressing a natural tendency to read the name of the word. What makes the Stroop test especially difficult is the virtual impossibility of completely ignoring the irrelevant stimulus (typed name of the color), which is embedded in the relevant stimulus (the color of the type). This test is difficult for people of all ages, but it is especially challenging for older adults.

To summarize, older adults find it more difficult than young adults do to ignore distracting stimuli, and to focus their attention on target stimuli. One hypothesis is that age-related differences on tests of selective attention stem from inhibitory deficit. We know that older adults are often more susceptible than young adults to interference from distracting stimuli when environments are complex, so distracting stimuli should be kept to a minimum.

Revisiting the Selective Optimization with Compensation and Ecological Models

The Selective Optimization with Compensation (SOC) (Baltes & Baltes, 1990) and Ecological (Lawton, 1989; Lawton & Nahemow, 1973) Models are readily applied to sensory and perceptual processes. With regard to SOC, many older adults make adjustments as they adapt to potential or actual changes in their sensory and perceptual capabilities (Salthouse, 2004). Visual capabilities are optimized if older adults have access to medical screening for diabetes, glaucoma, and cataracts. Prosthetic devices such as reading glasses or bifocals can help older adults compensate for visual changes. Older adults may become selective about the visual conditions under which they function – for example, many limit nighttime driving and drive only when weather conditions are good and traffic conditions light. In many communities, courses are available to train older adults (ages 55+) on how to improve driving skills, and some insurance companies reward the successful completion of such courses with a reduction in auto insurance premiums. With regard to audition, some older adults compensate for hearing loss with hearing aids tailored to their individual needs and many learn to make better use of visual cues. When they plan to engage in meaningful conversations, they may also be selective in choosing environments with minimal background noise.

The Ecological Model would stress the importance of an appropriate match between older adults’ sensory and perceptual capabilities and the level of sensory and perceptual challenge in the environment. Individuals with no sensory or perceptual difficulties adapt well in a broad range of environments, but those with limitations adapt best when environments are tailored to their capabilities. Age-related changes in visual functioning call for insuring adequate levels of illumination from light sources that prevent glare. In addition, there should be decreased demand for close visual work. More and more publishers are responding to older adults’ need for large print, and many public libraries and bookstores have entire sections of large-print books. Signs posted in areas frequented by older adults should have large letters or numbers printed on a plain and clearly contrasting background. Older adults who give up driving because of visual changes will adapt best in environments that provide transportation such as van service or access to public transportation. Individuals with reduced auditory competence will do well when speakers do not talk too quickly or use too many high-frequency consonants. Ideally, background noise and reverberation should be minimized to insure that auditory challenge is within the adaptation range of the older listener.



Questions to Consider

1. Do you think talking on the cell phone using a headset will have any effect on how well people in your generation will hear when they get older?
2. Some researchers think that playing video games will sharpen the minds of older adults. Do you agree?
3. Do you think banning handheld cell phones in cars but allowing hands-free devices would greatly reduce the number of accidents among those who talk and drive at the same time? Also, what kinds of driving distraction can be created by having global positioning system (GPS) tracking devices in cars?

Key Points

- Sensory threshold is the minimum amount of stimulation a sensory organ must receive before the presence of a particular stimulus is registered. Sensitivity is the inverse of threshold.
- The signal detection model of determining sensory threshold takes into account sensitivity and decisional response criteria (that is, level of cautiousness). Older adults are often more cautious than young adults.
- Sensation refers to registration of physical stimulation by the sense organs, while perception is the subsequent processing and interpretation of the stimuli at the central (brain) level.
- On reaction time tasks, older adults are usually slower than young adults, and this is more so on complex tasks than on simple ones.
- The nervous system of an older adult takes longer to process information and clear it through the system than the nervous system of a young adult.
- Age-related changes in vision call for greater illumination. There are also changes in color vision and an increasing incidence of presbyopia, although the effects of such visual changes can be minimized. Problems with the retina can result in partial or complete blindness.
- Age-related changes in hearing include presbycusis, which affects high-frequency tones and the ability to understand speech. However, the effects of these auditory changes can be minimized. Also, at the central level, older adults may process speech via a broader region of brain activation.
- People who communicate with older adults often use elderspeak, some aspects of which are beneficial. However, patronizing speech can result in the older adult's withdrawal from the communication process.
- Older adults may have less attentional resources/capacity compared to young adults. Also, they have greater difficulty

inhibiting the effect of distracting stimuli when trying to focus on relevant stimuli.

- Changes in the frontal lobes of the cerebral cortex could be related to deficits on attention tasks that call for inhibiting responses or shifting from one response to another.
- Older adults may have difficulty in complex vigilance tasks and in divided attention tasks that exceed their processing capacity. Also, they have difficulty in selective attention tasks when they must focus on relevant target information and ignore irrelevant distracting information.

Key Terms

absolute threshold **103**
 age–complexity hypothesis **106**
 bottom-up and top-down strategies in language processing **119**
 common cause hypothesis **102**
 communication predicament of aging model **120**
 diabetic retinopathy **112**
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