CHAPTER

2

Nineteenth-Century Foundations

Timeline

1830

1831 Charles Darwin embarks on a round-the-world journey aboard the *Beagle*.

1836 Charles Darwin returns to England with a reputation as a first-rate naturalist.

1840

1850

1851 Gustav Fechner publishes *Zend-Avesta*.

1859 Charles Darwin publishes *On the Origin of Species*.

1860

1860 Gustav Fechner publishes *Elements of Psychophysics*.

1869 Francis Galton publishes *Hereditary Genius*.

1870

1871 Charles Darwin publishes *The Descent of Man*.

1872 Charles Darwin publishes *The Expression of the Emotions in Man and Animals*.

1874 Francis Galton publishes *English Men of Science*.

1879 Gustav Fechner publishes *The Day-View Opposed to the Night-View*.

1880

1885 Hermann Ebbinghaus publishes *On Memory*.

1890

Learning Objectives

After reading this chapter, you should be able to:

- Outline Darwin's theory of natural selection and the historical context in which he developed it.
- Identify and evaluate the contributions Francis Galton made to the development of psychology as an empirical science.
- Explain the importance of psychophysics as a foundation for experimental psychology.
- Discuss the work of the early experimental psychologists Hermann von Helmholtz, Christine Ladd-Franklin, and Hermann Ebbinghaus.

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Looking Back

The 1800s could be called the “Century of Polymath.” A **polymath** is *a scholar who makes important contributions to several different fields*. Sometimes the term “Renaissance man” is used, and certainly great men of the Renaissance, such as Leonardo da Vinci (1452–1519) and Galileo Galilei (1564–1642), come to mind.

But there was something about the nineteenth century that enabled scientists with talent and ambition to excel in multiple disciples. For one thing, travel and communication had become easier. Books and letters could be distributed around the world, and travel to other lands for meetings or study was now within the reach of many scholars. For another thing, the natural sciences were still young, and there was less material to master before you could make an original contribution.

In this chapter, our story focuses on two countries, England and Germany. These two nations drove the phenomenal growth of science and technology in the nineteenth century. Yet they each had a different model for doing science.

The German system is more familiar to modern readers. Germany had developed a network of research universities in which professors were paid to do research and train graduate students. In other words, the scientist was an employee of the university whose job was to do science. Moreover, “science” had a broader meaning in German than it did in English—German scientists were seekers of new knowledge, whatever that may be.

In England, the situation was quite different. There were only two major universities in the entire country—Oxford and Cambridge—and both were dominated by the Anglican Church. Although there was some research going on at “Oxbridge,” the role of the professor was to provide a well-rounded education to the next generation of the British upper class.

Thus, there were few paid positions for scientists in England. Instead, science was a hobby for those with the financial means to support their interests. Those without independent means could join the clergy as one route to fund a research career. A parson’s duties were light, and the job provided a comfortable living. Since his father didn’t approve of his “beetle collecting” at first, Charles Darwin thought he might have to take this route.

Most British “men of science” were financially secure. They had the leisure to do research and the funds to pay for their expensive hobbies. As we’ll see, both Darwin and his cousin Francis Galton were members of a wealthy extended family, and each pursued his career as a gentleman-scientist.

Despite the two different approaches to research, scientists in England and Germany laid the groundwork for an experimental approach to psychology. And generally speaking, they helped build a scientific psychology only after first making significant contributions in the natural sciences. The nineteenth century was indeed the century of the polymath.

Charles Darwin

Charles Darwin was the son and grandson of doctors, so it was assumed he’d follow in the family tradition (Dewsbury, 2009). But young Charles didn’t like studying medicine at Cambridge. Instead, he passed the time playing cards and riding horses. He also picked up the hobby of collecting beetles, which was something of a fad among Cambridge students back then. Seeing his son’s interest in specimen collecting, Charles’s father suggested he study for the Anglican priesthood. That way, Charles could earn his keep and still have plenty of time for his hobby. And so that’s what he did.

After graduation, however, one of Darwin’s teachers recommended him for the position of naturalist on board the *Beagle*, which was embarking on a five-year exploratory mission around the world (Burghardt, 2009). His job entailed keeping the captain company and collecting specimens of plants and animals to send back to England from the places they visited. Against his father’s wishes, Darwin accepted the unpaid position. The specimens Darwin sent back astounded scientists in England, and when he returned in 1836, he found that his

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reputation as a first-rate naturalist had preceded him. Darwin's father was also impressed by the accomplishments of his ne'er-do-well son, and he established an investment portfolio so his son could live as a gentleman-scientist.

Although we now know **Charles Darwin** (1809–1882) as a *nineteenth-century English scientist who proposed the theory of evolution by natural selection*, he already had a brilliant career as geologist, naturalist, and world traveler long before he proposed his famous theory (Dewsbury, 2009). In fact, when he sailed from England in 1831, Darwin still accepted the Biblical story of creation. But after his experiences traveling around the world, he came to realize that tale just couldn't be true.

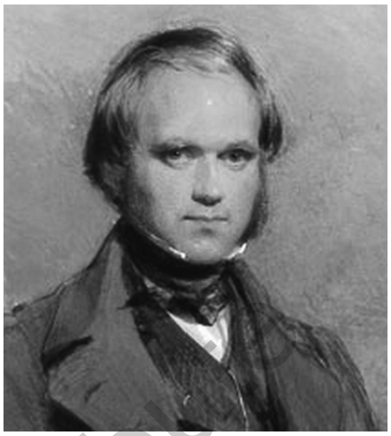
George Richmond, via Wikimedia Commons

Photo 2.1
Portrait of Charles Darwin

Two Questions

In the early nineteenth century, most scientists assumed there was no conflict between science and religion (Burghardt, 2009). They generally accepted the Genesis account that God had created the Earth with all its plants and animals around 6,000 years ago in their current state. In other words, the ways things are now was the way they'd always been.

As scientists looked closely at the world, however, they found anomalies that appeared to contradict Genesis (Burghardt, 2009). For example, geologists observed seashell fossils in rocks far from the ocean. And naturalists discovered remains of animals that had gone extinct long ago. These anomalies were explained in terms of a theory known as **catastrophism**. This is *the idea that the Earth's geological features were formed during a small number of major cataclysms during the last few thousand years.* In particular, it was believed that the Great Flood could explain these oddities. The rising waters washed seashells to the mountaintops, and any animals not on board Noah's Ark were of course drowned in the flood.

However, some scientists were already beginning to question the accuracy of this account (Burghardt, 2009). In particular, they asked two questions:

- Is the Earth young or old?
- Do species change or remain the same?

Biblical scholars interpreted the Bible as saying that the Earth was young and that species were immutable. Yet the accumulating geological and fossil evidence suggested otherwise.

Among the doubters was **Charles Lyell** (1797–1875), an *early nineteenth-century geologist who argued that the Earth was very old* (Dewsbury, 2009). In his 1830 book *Principles of Geology*, he presented his theory of **uniformitarianism**, which is *the idea that the Earth's geological features were formed gradually over hundreds of millions of years through uniform processes still occurring today*. According to Lyell, the surface of the Earth was built up by volcanos and earthquakes and worn away by erosion from wind and water. Darwin read the *Principles of Geology* on board the *Beagle*, and the geological formations he encountered during his voyage accorded with Lyell's descriptions. While in South America, he even experienced an earthquake that changed the local landscape. By his return to England, he was convinced that the Earth was very old and that its features had changed slowly over time (Figure 2.1).

During his voyage on the *Beagle*, Darwin also became a convert to another theory, this one about biology rather than geology (Buss, 2009). When he left England, he still subscribed to **creationism**, which is *the idea that the various species existing today were created in their present form*. However, evidence from fossils suggested that species had changed over time, with some going extinct while others arose anew, and several theories of evolution had already been proposed to explain these observations. The term **evolution** refers to *the idea that species change over time as they adapt to new environments and challenges*. In fact, Charles's grandfather Erasmus Darwin (1731–1802) had proposed just such a theory.

At the time, the most widely accepted account of speciation was the one developed by French naturalist Jean-Baptiste Lamarck (1744–1829; Burghardt, 2009). Known as

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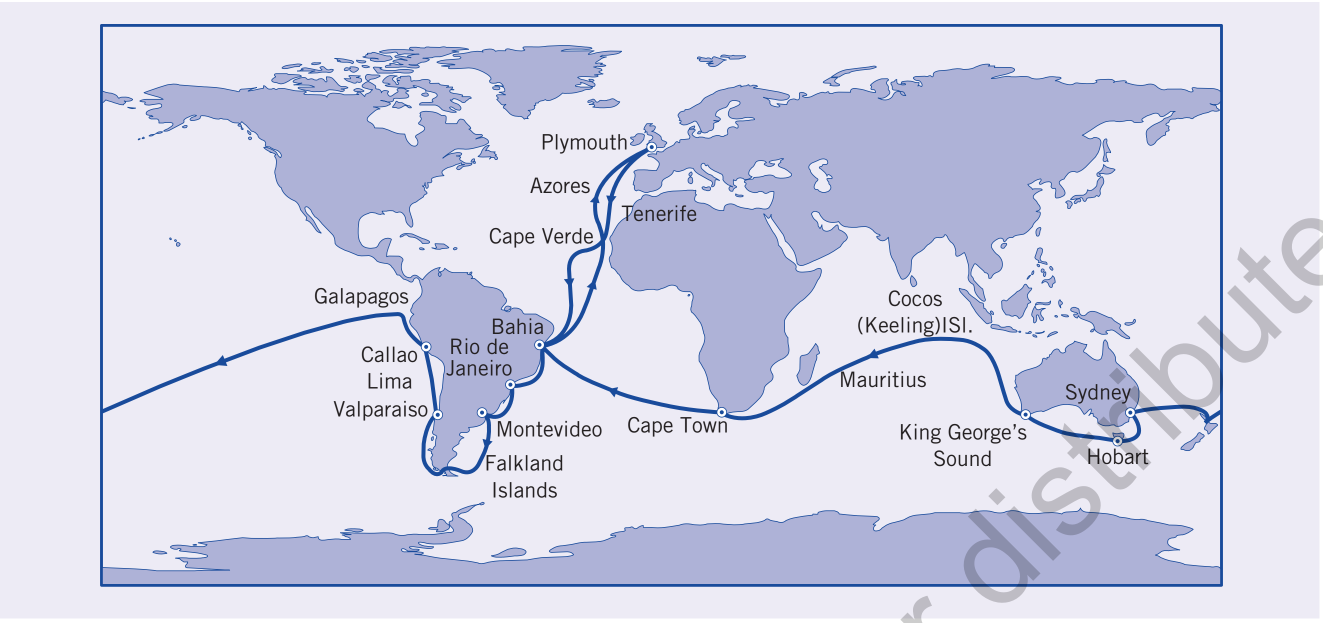
Figure 2.1 Voyage of the *Beagle*



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Lamarckism, this was *a theory of evolution proposing that characteristics acquired during an organism's lifetime can be passed on to its descendants*. For example, it was believed that giraffes had evolved from earlier deer-like creatures. But how did they get such long necks? The Lamarckian explanation was that the first generation stretched their necks slightly to reach leaves on higher limbs. Their offspring were then born with slightly longer necks, which they stretched even more. In this way and through many generations, giraffes acquired the long necks they have today. Although still a doubter of evolution when he departed on his journey, Darwin changed his mind as his careful study of plant and animal specimens around the world convinced him that some sort of evolution had to be taking place. And since he was already a convert to Lyell's uniformitarianism, there certainly was plenty of time for Lamarckian evolution to have occurred.

Natural Selection

After his return to England, Darwin continued thinking about the evidence for evolution he'd observed during his travels and in the specimens he'd sent back (Burghardt, 2009). He was amazed by the seemingly infinite variety of life forms, and he was also impressed by how well each species was suited to the environment it inhabited. In his notebooks, he drew diagrams and jotted down ideas as they came to mind. Traditionally, naturalists had organized species according to a Ladder of Life, with the least developed creatures at the bottom and humans, of course, at the top. However, Darwin began to think in terms of a Tree of Life. All currently existing species were like the leaves on a tree, but if you traced the history of each species, you would eventually find that all of them had evolved from a single life form in the distant past.

Still, there was the question of what drove species to change (Buss, 2009). One piece of the puzzle clicked into place when Darwin read *An Essay on the Principle of Population*, which the English economist Thomas Malthus (1766–1834) had published in 1798. According to Malthus, poverty was inevitable because a population would always grow beyond its ability to produce food. When food was scarce, there would be a struggle for existence, and only the strongest would survive the inevitable famines, wars, and plagues. Although Malthus

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was specifically talking about human populations, Darwin understood the same principles would apply to species living in the wild.

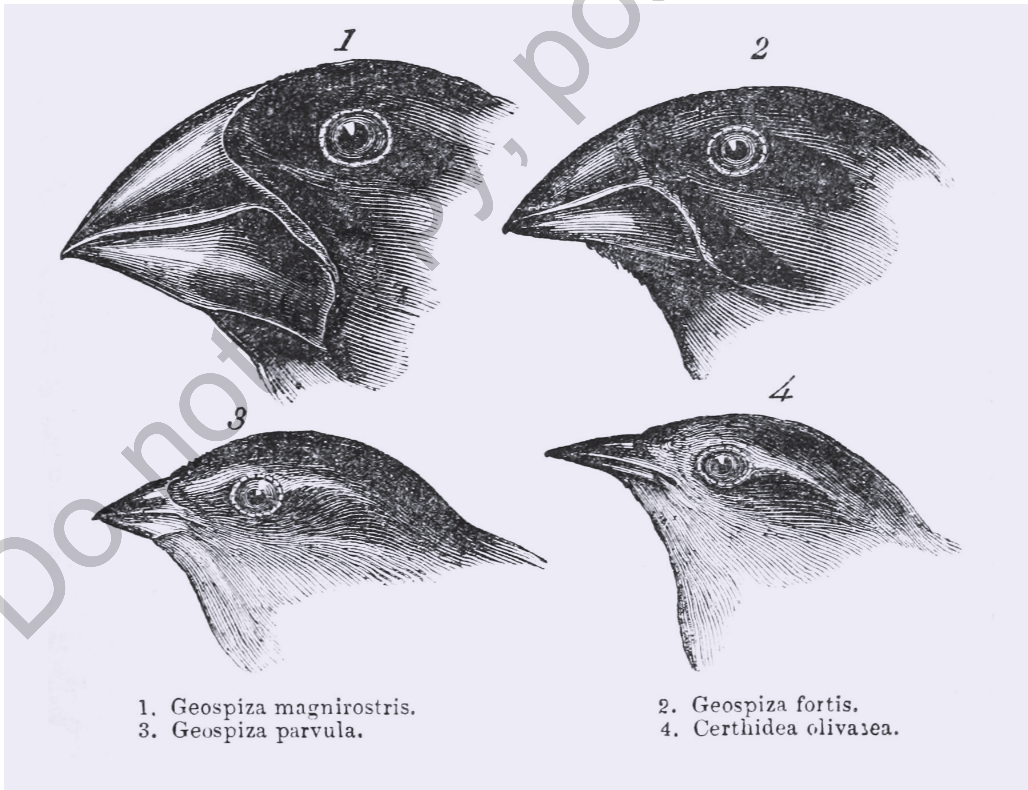
Darwin found another piece of the puzzle in the practices of plant and animal breeders (Darwin, 1859/2002). For example, there are many breeds of dogs, each with certain characteristics. Some are good at hunting, while others are good at herding. But to preserve those traits, you have to in-breed the animals. Through the process of **artificial selection**, or *the intentional breeding of desired characteristics in domestic animals and plants*, you get future generations with even stronger traits—better hunters or herders. In fact, all domesticated plants and animals have been intentionally bred to produce the tangiest peaches and the tastiest tomatoes, the fattest pigs and the fastest horses.

Putting these pieces together, Darwin came to understand that species are constantly adapting to their environments through a process he called **natural selection** (Dewsbury, 2009). This is *a theory of evolution proposing that individuals which are better suited to current circumstances are more likely to survive and reproduce*. The theory of evolution by natural selection has three interlocking components:

- *Variability*: individual members of a species range widely in a large number of characteristics.
- *Competition*: in any population, far more offspring are born than can survive to maturity, so there's a constant competition for resources.
- *Heritability*: those individuals which survive to reproduce will pass on their advantageous features to the next generation.

In this way, species are reshaped over time in response to environmental changes (Figure 2.2).

Figure 2.2 Darwin's Finches



Source: John Gould, from "Voyage of the Beagle," via Wikimedia Commons.

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For two decades, Darwin struggled to fit the pieces of evolution together (Dewsbury, 2009). Although he published widely on other subjects in the meantime, he presented nothing about natural selection to the public. However, he did circulate a number of manuscripts outlining his ideas to his close colleagues, so it was generally known in scientific circles what problem Darwin was working on and which direction his thinking was headed.

There were two reasons Darwin hesitated to publish (Dewsbury, 2009). The first, of course, was concern about the response of the religious elite. After all, any theory of evolution would contradict a literal interpretation of the Bible. But that wasn't the most pressing issue, since it was the approval of his scientific colleagues and not the approbation of church officials that Darwin sought. The second, and more important, reason why Darwin delayed publication of his theory was that there was still a missing piece. Namely, he couldn't explain how parental traits were transmitted to offspring. Ironically, the Austrian monk Gregor Mendel (1822–1884) was working out the principles of genetics with his famous pea-plant experiments right around the same time. But Darwin never knew about Mendel's findings.

On June 18, 1858, a letter arrived from Malaysia (Dewsbury, 2009). It was from **Alfred Russel Wallace** (1823–1913), a *nineteenth-century British naturalist who was working on the problem of natural selection around the same time as Darwin*. Although Wallace didn't use Darwin's terms, and his theory wasn't fleshed out in as much detail, the essential principles were the same. Darwin was distraught that he hadn't established his priority by publishing sooner. But he was an honest man, and he gave Wallace's essay to Charles Lyell, who by now had become a dear friend. Lyell arranged a joint reading of Wallace's essay with one of Darwin's manuscripts at the Linnean Society the following month, even though neither Wallace nor Darwin was in attendance. Wallace was still abroad, and Darwin was mourning the death of his baby son.

During the following year, Darwin assembled his various manuscripts into the work he's best known for today, his 1859 book *On the Origin of Species* (Burghardt, 2009). In this volume, Darwin laid out his theory of evolution by natural selection, making the case by analogy to artificial selection. He also supported his argument with ample evidence from his *Beagle* collection as well as from farmers and hobbyists who selectively bred domesticated plants and animals. The first edition sold out immediately, and the book became a popular bestseller that went through six editions. It continues to be widely read today.

The religious backlash wasn't nearly as severe as Darwin had anticipated (Dewsbury, 2009). In part, this was because the idea of evolution was already familiar to educated British audiences, which had an overall favorable attitude toward scientific progress and were willing to interpret Genesis as allegory rather than history. Additionally, Darwin was careful in the *Origin* not to discuss the evolution of humans. That way, he wouldn't offend readers who were willing to accept that other species had evolved even if humans had not. Nevertheless, the implication of human evolution was evident to anyone willing to consider it.

Sexual Selection

Perhaps emboldened by the positive reception of the *Origin*, Darwin fleshed out his ideas on human evolution in two additional books (Shields & Bhatia, 2009). In his 1871 book *The Descent of Man*, he openly argued that humans evolved from earlier primates through the same process of natural selection that applied to all other species. However, he also introduced a new type of evolutionary process that he called **sexual selection**. This is *a theory of evolution proposing that traits can be selected through competition for mates and the preferences of mating partners*.

The classic example of sexual selection is the tail feathers of peacocks (Buss, 2009). The extravagant feathers that male peacocks sport are difficult to explain in terms of natural selection. After all, the bright colors are easy for predators to spot, and the excessive weight makes it difficult for them to escape. According to natural selection, peacocks with big bright feathers should have died out, leaving only those with small dull ones to mate with the female peahens. But that's not what happened. As it turns out, peahens are very picky about who they mate with, and only peacocks with the gaudiest tail feathers will do as father for

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their baby peachicks. Of course, it doesn't matter what peahens prefer if the best and brightest peacocks have already become somebody else's dinner. Instead, the brightly colored tail feathers serve as an honest signal of health and strength. It's almost as if the peacocks were saying: "Look at me! Even with my big heavy tail, I can still escape any predator. I'm just that good!" Apparently, peahens find that very sexy.

Examples of sexual selection abound in nature (Shields & Bhatia, 2009). The horns or antlers of many male quadrupeds developed in this way. Likewise, the males of many songbird species are brightly colored to attract mates, while the females are drab to avoid predation. Horns and coloration serve the same purpose as peacock tail feathers. Darwin believed that many of the sex differences we see in humans, such as the contrast in body shape and size, are due to sexual selection.

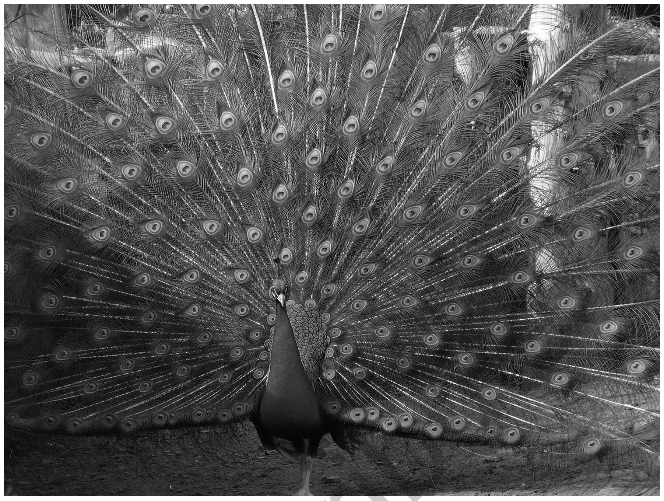
Peter Carson, (Pete121), via Wikimedia Commons

Photo 2.2
Peacock tail feathers

In 1872, Darwin published *The Expression of the Emotions in Man and Animals* (Hess & Thibault, 2009). In *Origin* and *Descent*, he'd focused mainly on the natural selection of physical traits. However, in this third book he emphasized the idea that natural selection can shape behaviors as well. He introduced this idea by exploring the various ways mammals display emotions, showing that they're quite similar from one species to another. Consider your relationship with your pet dog: Can you read her emotions from her facial expressions? And can she read yours? Most dog owners have deep emotional bonds with their pets.

Darwin argued that facial expressions of emotion evolved from behaviors that typically accompany that emotion (Hess & Thibault, 2009). Imagine a bug has just flown into your mouth. What do you do? You purse your lips, protrude your tongue, and spit the damned thing out. And how do you feel? Most people will say "disgusted." Now imagine your friend is telling you about a recent trip to Beijing, where he ate a local delicacy—deep-fried scorpions on a stick. If this sounds disgusting to you, pay careful attention to the facial expression you're making right now—pursed lips, protruding tongue, almost spitting. Your facial expression of disgust mimics the behaviors you would engage in to remove something disgusting from your mouth.

The full impact of Darwin's theory of evolution by natural selection wasn't felt until half a century after his death (Buss, 2009). Although Darwin could see that natural and sexual selection were the driving forces behind long-term changes in species, he was always troubled by the fact that he couldn't explain *how* traits were passed on to offspring. At the time, it was assumed that children inherited a mixture of their parents' traits. But if that were the case, each generation should become more homogeneous, and there was no way to explain the variation that can be seen in each generation. In fact, the mechanics of particulate genetics was being worked out around the same time by the Austrian naturalist Gregor Mendel. However, Darwin and his contemporaries never learned of this work. Well into the early decades of the twentieth century, scientists debated the relative merits and weaknesses of Darwinian and Lamarckian evolution.

It wasn't until the 1930s and 1940s that scientists began to see the connection between Darwin's and Mendel's work (Dewsbury, 2009). This led to the **modern synthesis**, which was *an explanation of Darwinian evolution in terms of Mendelian genetics*. In brief, traits are transmitted to offspring by means of the genes that encode them. Over all, you're a mixture of your parents' traits. However, each trait that you have is either from your mother or your father, not a mixture of both. In this way, traits are passed on to the next generation with enough variation for natural selection to do its part. Those with traits suitable to the current environment prosper and reproduce, while those with unsuitable traits do not. Today, we can even read and manipulate these genes, creating a genetic selection process far more efficient than nature could ever have devised.

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In sum, Darwin's work provided important conceptual foundations for a scientific psychology. After all, rats running mazes and pigeons pecking keys would tell us nothing about human behavior if they didn't have nervous systems that were evolutionarily related to those in humans. Darwin's demonstration that humans evolved from primate ancestors and that all species have a common origin in the distant past greatly motivated the development of experimental psychology in the late nineteenth century. Darwin's theory has also forced us to rethink our position in the world and our relationship with it. No longer were we the special product of divine creation, graced with an immortal soul and striving for redemption in an afterlife. Instead, we were creatures of this world, caught in the struggle for survival and striving to pass our traits to the next generation.

Francis Galton

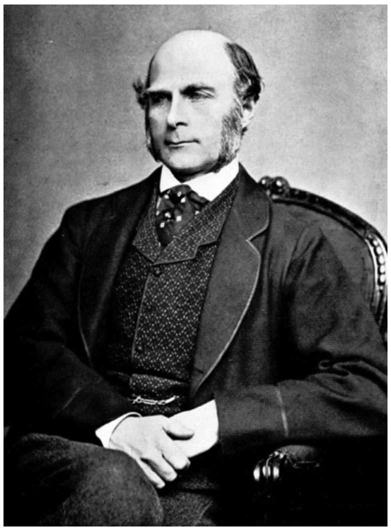
From Karl Pearson's *The Life, Letters, and Labors of Francis Galton*

Photo 2.3
Francis Galton

Francis Galton and Charles Darwin were cousins (Fancher, 2009). Both were grandsons of Erasmus Darwin, Charles on his father's side and Francis on his mother's side. The extended Darwin family was financially well off and extraordinarily talented, and many of Erasmus's descendants—both men and women—had notable careers in a variety of fields. As one of the great polymaths of this period, **Francis Galton** (1822–1911) gained his fame as a *nineteenth-century English scientist who developed data gathering and analysis methods and who coined the term "nature and nurture."*

Excellence was simply expected in the Darwin-Galton extended family, but young Francis especially looked to his older cousin Charles as a role model (Fancher, 2009). In his youth, Darwin had made a name for himself as a world traveler, writing about his adventures for the popular press. After that, he'd settled into the career of a gentleman scholar, rising to eminence as a man of science. Galton was determined to pursue a similar life course for himself. In his early adulthood, he personally financed an exploratory expedition to Africa. On his return to England, he published popular and scientific accounts of his travels, thus establishing himself as a public figure and distinguished scholar. Although they corresponded and visited occasionally, there was no collaboration between the cousins, as their scholarly interests had little in common.

Galton and Darwin also differed in their personalities and work habits (Fancher, 2009). On the one hand, Galton excelled at mathematics, whereas Darwin had always been weak with numbers. On the other hand, Darwin was a methodical worker who patiently gathered overwhelming evidence before stating his case, while Galton quickly jumped to radical conclusions from relatively meager data. Thus, Galton can be considered the more controversial of the two.

Galton's "Religious" Conversion

Well into his late thirties, Galton jumped from topic to topic without a coherent research plan (Fancher, 2004). But all that changed when he read Darwin's *On the Origin of Species*. Before that, he had been a devout Anglican who believed in Genesis as historical fact. When Galton read *Origin*, though, he had something of a religious conversion. Rejecting the darkness of religion and reveling in the light of evolution, Galton decided to devote his career to applying the principles of natural selection to the benefit of humankind.

As already mentioned, the extended Darwin-Galton family displayed exceptional talent, and Galton noticed that talent seemed to cluster in other families as well (Fancher, 2004). Gathering data from an encyclopedia of eminent men in British history, he performed a statistical analysis to demonstrate that intellectual eminence clustered in families to a greater extent than would be expected by chance. Applying Darwinian logic to the problem, Galton came to the conclusion that intelligence must be a trait that can be passed down from parents to offspring. Galton published this analysis in an article in 1865, but he knew the data

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were too meager to be convincing. So he extended his investigations to include the family relationships of current eminent men. This led to the publication of his book *Hereditary Genius* in 1869.

The book was remarkable not only for its content but also for the statistical methods Galton developed to analyze his data (Fancher, 2009). Influenced by the Belgian statistician Adolphe Quetelet (1796–1874), who'd demonstrated that inherited physical traits such as height and weight ranged along a "bell curve," Galton asserted that psychological characteristics such as intelligence must be normally distributed as well. This was the first application of a normal distribution in a psychological study. Galton also demonstrated that the inheritance of features—whether physical or psychological—was a matter of probability and not certainty.

Galton believed that science could be used to improve the human condition, and he wasn't satisfied with simply explaining how the inheritance of intelligence worked (Simonton, 2003). Rather, he wanted to apply this knowledge to increase the overall intellectual capacity of humankind. If humans were subject to the laws of natural selection, Galton argued, then they were also amenable to artificial selection. He believed that if the most intelligent men married the most intelligent women, and if they bore plenty of children, the average intelligence of the human population would increase over the course of a few generations.

The idea that the human race can be rapidly improved through artificial selection techniques came to be known as **eugenics** (Fancher, 2004). Galton only advocated for *positive eugenics*, which involved the provision of government subsidies to couples of high intelligence to encourage them to have more children. However, some scholars and politicians picked up the idea and called for *negative eugenics*, that is, the elimination of "undesirables" from the population. In the early decades of the twentieth century, many countries, including the United States, enacted eugenics laws that mandated the forced sterilization of criminals and the mentally disabled, and the Nazis carried negative eugenics to its logical conclusion. Although he was an ardent eugenicist, Galton would never have approved of such deplorable measures.

Nature and Nurture

Galton was convinced that intelligence was inherited, but the received wisdom was that education and family environment were far more important factors in developing the intellect (Simonton, 2003). Still, he pressed forward and collected more data. For his next book, he distributed questionnaires to around 200 top British scientists, asking about their upbringing, education, and family relationships with other eminent men. This was the first time a questionnaire had been used to gather data for a psychological study.

In his 1874 book *English Men of Science*, Galton coined the expression **nature and nurture** as *a catchphrase to describe the respective impact of biological inheritance and environmental upbringing on human development* (Simonton, 2003). He conceded that nurture also played a role, but he asserted that biology influenced intellectual outcomes far more than upbringing or education. To this day, the question of the relative contributions of nature and nurture is an important and hotly debated issue in psychology.

Next, Galton turned his questionnaire method to the study of twins (Fancher, 2009). He understood the biological difference between identical and fraternal twins, and he reasoned that identical twins should have very similar levels of intelligence while fraternal twins would be no more similar than any other siblings. He also understood that carefully devised twin and adoption studies could be used to tease out the separate influences of nature and nurture. Today, these are standard techniques in psychology for studying the hereditary and environmental contributions to intelligence, personality, and other traits.

It's obvious that identical twins are more similar to each other than fraternal twins, and likewise with siblings compared to cousins, but Galton puzzled over how to quantify the degree of similarity for any given trait (Fancher, 2004). He found that he could lay out the corresponding values on a two-dimensional


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Photo 2.4
Identical twins

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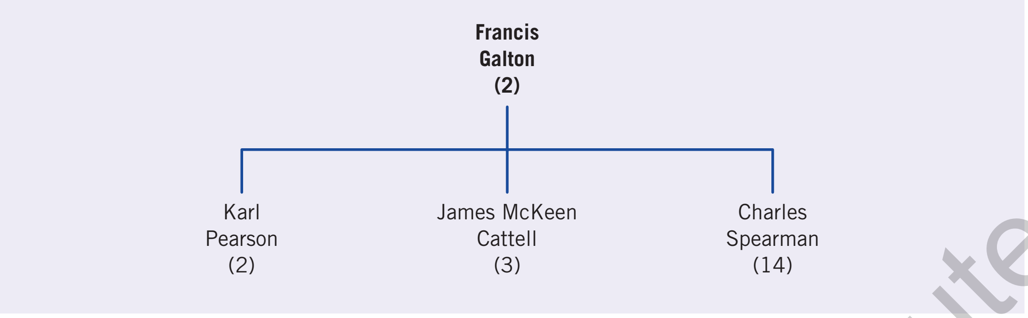
Figure 2.3 Academic Family Tree of Francis Galton



graph, creating what is now known as a scatterplot. A “best-fitting” regression line could then be drawn through the points on the scatterplot, and the slope of the line provided a numerical value for the degree of relatedness ranging from 0 to either -1 or $+1$. These ideas were then fleshed out by Galton’s student **Karl Pearson** (1857–1936), the *British statistician who developed the methods of correlation and regression*. These are still standard statistical techniques for analyzing data in psychology today.

During these years, Galton further developed his thoughts on eugenics (Fancher, 2004). If we could arrange for eminent men and women to intermarry, he reasoned, the average intelligence of the human race would increase. However, there was a problem in that people marry and bear children in early adulthood, but eminence doesn’t appear until much later, after people have developed their careers. What was needed was a test of natural ability administered in youth that would predict later accomplishments in life.

Galton assumed that intelligence was a product of brain size and efficiency, so he speculated that measurements of head size, reaction time, and sensory acuity would be good predictors of native intelligence (Fancher, 2004). However, to test this hypothesis, he would need data from lots of people. To this end, he set up an “Anthropometric Laboratory” at London’s South Kensington Museum. For a small fee, people could undergo a series of tests that would measure their physical and mental characteristics. The participants got a personal data sheet, and Galton got data on thousands of people. Afterward, Karl Pearson calculated the correlations on these data sets, but he found them to be quite weak. It seemed that simple physical and behavioral measurements weren’t good predictors of intelligence after all. Nevertheless, Galton sparked interest among many psychologists in measuring individual differences and in developing tests that would be good predictors of intelligence (Figure 2.3).

In sum, Francis Galton was a great innovator who made significant contributions to the concepts and methods of experimental psychology (Diamond, 1998), as follows:

- *Normal distributions* to describe data
- *Questionnaires* to collect data
- *Nature and nurture* as the interaction of heredity and environment
- *Twin studies* to explore the relative contributions of nature and nurture
- *Scatterplots* to represent correlated data
- *Correlation and regression* to analyze data
- *Test batteries* to assess individual differences

Francis Galton is clearly one of the founders of experimental psychology. He invented many of the research methods and statistical analyses that are a standard part of the psychologist’s toolkit today. In this way, he helped lay the foundation for the scientific study of the human mind.

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Psychophysics

Inspired by Darwin's theory of evolution by natural selection, Galton developed methods for measuring individual differences and statistical tools for analyzing these data. Meanwhile in Germany, the approach to psychology was undertaken by way of physics and **physiology**, which is *a subfield of biology that studies the processes and functions of living organisms*. In this section, we'll learn about the development of **psychophysics**, which is *the study of the relationship between physical stimuli and the sensations associated with them*. By demonstrating that sensations could be rigorously measured, the psychophysicists demonstrated that psychological phenomena could be studied in a scientific fashion after all, contrary to the sentiments of the day.

Gustav Fechner

In the early 1820s, a series of satirical pamphlets circulated around the campus of Leipzig University in Germany (Marshall, 1987). The essays mocked the foibles and follies of the medical faculty, penned by an unknown author calling himself "Dr. Mises." As it turned out, this Dr. Mises was none other than **Gustav Fechner** (1801–1887), a disgruntled medical student at the university. Although Fechner passed his exams and earned his medical degree, he never practiced medicine. He just didn't have the stomach for it. Today, Gustav Fechner is known by psychologists as the *nineteenth-century German scientist who founded the field of psychophysics*.

After giving up medicine, Fechner wrote a dissertation in philosophy on the concept of "organism," hoping to get a professorship, but none was forthcoming (Marshall, 1990). Instead, he made a living translating physics and chemistry textbooks from French to German. As he translated these books, he also performed the experiments they described so he could understand them for himself. In doing so, he taught himself the natural sciences, and he even published the results of his own experiments in physics. He developed a reputation as an expert on electricity, and occasionally he was called on to teach science courses.

When he was thirty-three years old, Fechner was finally offered a professorship in physics at Leipzig, Germany's premier university (Meishner-Metge, 2010). He'd just gotten married, and now he was financially secure, doing work he loved. So life was good. But Fechner was a workaholic, and the strain of teaching, research, publishing, and editing took its toll. He'd also taken an interest in the study of vision, and in the process he nearly destroyed his own.

Exhausted from overwork and unable to stand bright light, Fechner retreated to his darkened room (Balance & Bringmann, 1987). He stayed there for three years. Although he had only been a professor for six years, the university provided a generous disability pension for the rest of his life. As his health gradually returned, he lectured part-time to show his appreciation for his pension. But he no longer lectured about physics.

During the years of his "mysterious malady," Fechner's thoughts had turned to a new direction—the mind-body problem (Arnheim, 1985). He viewed his convalescence as a spiritual rebirth, and his thinking was imbued with religion, but not of the traditional type. He was impressed by Spinoza's double-aspect monism, in which the physical and the mental were but two views of the same natural world. Accordingly, Fechner took on *the belief that all things in the universe, whether animate or inanimate, have consciousness*, a stance known as **panpsychism**.

In the cumbersome three-volume *Zend-Avesta* that Fechner published in 1851, he laid out his views that the entire universe and everything in it was conscious, from pebbles to plants and from people to planets (Meishner-Metge, 2010). The book was a financial flop. Even more disappointing to Fechner, his colleagues dismissed it as the rantings of a madman, since it accorded with neither orthodox religion nor the materialist worldview. However, near

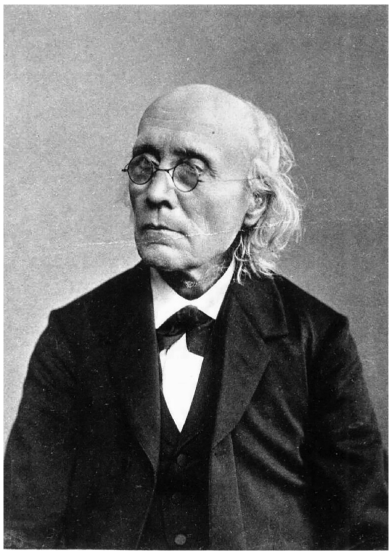

Photo 2.5
Gustav Fechner

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the end of this expansive work, Fechner offers a glimpse of what would become his most important contribution to psychology.

The Weber-Fechner Law

The eighteenth-century German philosopher Immanuel Kant (Chapter 1) had famously proclaimed that psychology would never become a natural science because there was no way to measure mental processes (Adler, 1993). However, Fechner believed he'd found a method for measuring the mind. According to the double-aspect monism he espoused, the physical and the mental were always related. If only you knew the exact relationship between the two, you could measure the mind indirectly by observing its physical correlates. The work of one of his colleagues showed him the way to do this.

Ernst Weber (1795–1878) was a German physiologist best known for his discovery that human sensory systems are limited in their ability to detect differences (Murray, 2000). One phenomenon he studied was the **two-point threshold** (Figure 2.4). This is *a measure of skin sensitivity in which two points are gradually brought closer together until they are experienced as a single point*. Using a compass, Weber found that different parts of the body had different sensitivities. For instance, two points on the back are still felt as a single point at a much greater distance than two points on the palm of the hand.

Another phenomenon Weber studied was the **just-noticeable difference** (JND; Murray, 2000). This is *the amount a stimulus has to be increased or decreased before a change in the stimulus can be detected*. What he found was that the JND increases in proportion to the original stimulus. Imagine we're asking a person to judge the weight of two objects placed in the hand. Let's say the first item weighs 40 grams, the second item weighs 41 grams, and the participant can just notice that the second is heavier than the first. We might say the person has detected a 1-gram difference. However, if we try this again with an 80-gram weight, we'll have to increase the second one to 82 grams before the difference can be detected. Thus, the just-noticeable difference is always a proportion of the original stimulus and not an absolute value (Figure 2.5).

What Fechner saw in Weber's work was a passageway from the physical to the mental (Meischner-Metge, 2010). After all, the distance between two points and the weight of an

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Figure 2.4 Two-Point Threshold

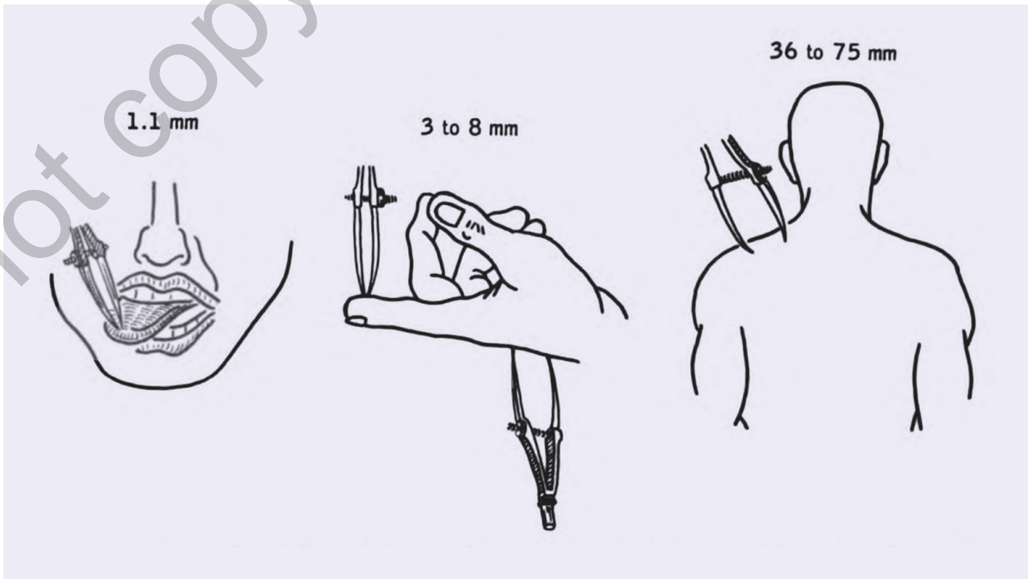

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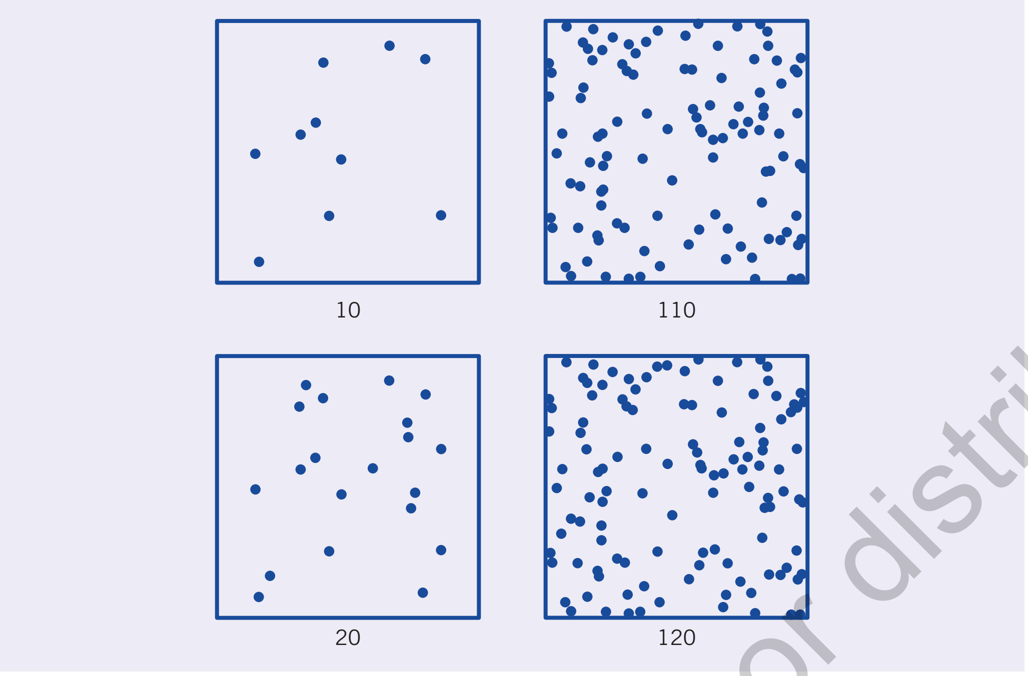
Figure 2.5 Just-Noticeable Differences



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Ernst Heinrich Weber (1795–1878), German physiologist and anatomist via Wikimedia Commons

Photo 2.6
Ernst Weber

object were physical quantities, and yet they were always accompanied by mental sensations. Weber had collected vast amounts of data on the JND, using a wide range of stimuli and testing a variety of sensory modes. *The finding that the just-noticeable difference is always a proportion of the original stimulus* occurred throughout Weber's data, and Fechner dubbed this **Weber's law**.

Working from Weber's law, Fechner derived a mathematical relationship between the physical stimulus and the mental sensation (Adler, 1993). **Fechner's law** is *the proposal that the intensity of the sensation is related by a logarithmic function to the intensity of the stimulus*. In plain English, this means that the intensity of the sensation increases at a much slower rate than the intensity of the stimulus. The classic example of Fechner's law is the perception of octaves in music. Here, the pitch is the sensation and the frequency in Hertz is the stimulus. In modern tuning, the A above middle C (called A_4) is set at 440 Hz. The octave below (A_3) is 220 Hz, while the octave above (A_5) is 880 Hz. In other words, each higher octave doubles in frequency, and yet the perception is that all octaves are equally spaced on the pitch scale.

Thus was born the science of psychophysics, demonstrating that psychological phenomena could in fact be studied in a scientific fashion (Robinson, 2010). Fechner conducted numerous experiments testing various stimuli and sensory modalities to garner evidence for his law. Since Weber's and Fechner's laws are related, most psychophysicists today group them together as the Weber-Fechner law. This foundation of psychophysics remained unchallenged for nearly a century, until the American psychologist S. S. Stevens (Chapter 11) proposed a revision to it now known as Stevens' power law.

Elements of Psychophysics

In 1860, Fechner published his best-known work, the *Elements of Psychophysics* (Murray, 1990). In this book, he describes the methods of psychophysics that he and others had

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developed. These methods inspired a generation of experimental psychologists, most notably Wilhelm Wundt (Chapter 3), who established the first psychology laboratory in the world at Leipzig University two decades later. However, Fechner also included a discussion of a distinction between "outer psychophysics" and "inner psychophysics." This was largely ignored by Fechner's contemporaries, but it has gained more relevance in recent decades.

By outer psychophysics, Fechner meant the relationship between stimulus and sensation (Robinson, 2010). Traditionally, psychophysicists have only been interested in outer psychophysics. Likewise, stimulus-response psychology can be considered a part of outer psychophysics. We control the stimulus and measure the response without much concern for the mental processes mediating the two. More generally, outer psychophysics looked at how the external physical world and the internal mental world were related.

Because of his double-aspect monism, Fechner saw brain activity and mental states as correlated (Robinson, 2010). This relationship between brain and mind was the subject matter of inner psychophysics. He certainly understood that such an undertaking was far beyond the technology of his time, but he hoped someday it would become a reality. Although his contemporaries hailed Fechner as a genius for his psychophysical methods, they dismissed his notion of inner psychophysics as eccentric fantasy. Indeed, it's only been since the advent of neuroimaging technology in the late twentieth century that Fechner's dream of inner psychophysics has become a reality. Neuroscientists often say their goal is to find the "neural correlates" of mental states. This emphasis on correlation between brain and mind, as opposed to causation, is a sentiment Fechner would have approved of.

Much of the early experimental research in psychology at the end of the nineteenth century was built on the psychophysical methods Fechner developed (Murray, 1990). However, even in his day, there was a lot of debate about the validity of Fechner's law. While it works fairly well within normal ranges of stimulation, it usually fails at the high and low extremes. From Fechner's time until the present, the debate has largely centered on whether a logarithmic function or a power function better describes the psychophysical relationship between sensation and stimulus.

Incidentally, Fechner claims that his great insight for psychophysics came in a dream on the morning of October 22, 1850 (Murray, 1990). He was still working on the *Zend-Avesta* at the time, and so he tacked it on at the end. Today the date is celebrated as "Fechner Day" by psychophysicists around the world as the inauguration of their field.

For the rest of his life, Fechner continued performing experiments in psychophysics, mainly to address challenges from rivals (Meischner-Metge, 2010). But even though he was a rigorous experimentalist, this doesn't mean he gave up his philosophy of panpsychism. In 1879, he published the book *The Day-View Opposed to the Night-View*, in which he clearly and concisely laid out his reasons for believing the entire universe and everything in it was conscious. By "night-view," Fechner was referring to the atheistic materialism of nineteenth-century science. He believed that such a worldview was far too limiting, as it blinded people from seeing the true beauty of the world. Instead, he called on his readers to "Wake up!" from their slumbers and experience the world from the "day-view" of panpsychism, which revealed the universe in all its splendor.

Scientists adopted atheistic materialism to protect their model of the universe as a closed mechanical system from the threat of orthodox religion (Chalmers, 2014). After all, if miracles can occur, what value do the laws of physics have? But Fechner maintained that his day-view with its Spinozan "God-as-nature" was entirely compatible with empirical science. Few scientists in Fechner's time or in our own have accepted Fechner's panpsychism. However, the idea of a conscious universe is still considered a possibility by some philosophers and scientists.

In sum, Fechner was a pioneer in experimental psychology, establishing methods that would enable a laboratory-based study of the mind (Meischner-Metge, 2010). Fechner molded the shape of late nineteenth-century psychology, influencing the thinking of contemporaries

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such as Hermann von Helmholtz, whom we'll meet next, as well as nurturing the careers of young psychologists such as Wilhelm Wundt, whom we'll meet in Chapter 3. As a philosopher, Fechner developed a rich theory of universal consciousness, which still has some adherents today. In addition, we shouldn't forget Fechner the prankster as his alter ego "Dr. Mises." He began his literary career as a disgruntled medical student under that pen name. So it seems only fitting that his final publication—a satirical essay about a new fountain in Leipzig—was also signed "Dr. Mises."

Early Experimental Psychology

Until the mid-nineteenth century, it was easy for scientists to simply ignore questions of the mind. According to Descartes (Chapter 1), the universe was divided into two worlds—the physical, which was the purview of science, and the spiritual, which could only be understood through religion and philosophy. However, as physiologists began studying the structure and function of the nervous system, it was only natural that they would broach questions about the relationship between mind and body. In this way, physiology set the stage for psychology.

Hermann von Helmholtz

As the paramount polymath of the nineteenth century, **Hermann von Helmholtz** (1821–1894) made foundational contributions in virtually every field of science (De Kock, 2014). The physicists saw him as one of their own for his work on energy physics and electrodynamics. The mental philosophers recognized him as the great successor to Berkeley and Kant (Chapter 1). And practitioners of the newly emerging experimental psychology hailed him as the founder of their discipline for his work on the physiology of sensation. Helmholtz did employ psychological notions in that work, but he saw psychology as belonging to the realm of philosophy, not natural science. Today we know Helmholtz as a *nineteenth-century German scientist who made important contributions to the physiology of the nervous system and the senses*.

Helmholtz's contributions to early psychology come indirectly through his work in physiology (Turner, 2000). In the 1850s, he studied muscle movement and the conduction of neural impulses. Using a dissected frog leg, Helmholtz measured the speed of electrical transmission in the nerve. Although he found it to be quite fast, this finding contradicted the general assumption that neural conduction was instantaneous or nearly so. The relevance to psychology is the fact that mental processes take time, and so the measurement of reaction time has been an important tool for experimental psychologists since the beginning of the field.

Photo 2.7
Hermann von Helmholtz

Helmholtz then turned his attention to the physiology of the sensory organs, especially the eye and the ear. He was an early advocate of the three-receptor theory of color vision (De Kock, 2014). First proposed by English scientist Thomas Young (1773–1829), this model of color vision argues for three color receptors in the retina—red, green, and blue. Today it's known as the Young-Helmholtz theory. For years, Helmholtz engaged in a bitter rivalry with fellow German physiologist Ewald Hering (1834–1918), who argued that color vision took place through an opponent process—red opposing green and yellow opposing blue. As we'll see shortly, his American student Christine Ladd-Franklin developed an evolutionary theory of vision that incorporated both the three-receptor and the opponent-process theories.

Certainly Helmholtz's greatest contribution to psychology was the modern conceptualization of the relationship between sensation and perception (Epstein, 1991). In the Cartesian worldview that still dominated nineteenth century science and philosophy, thinking about these concepts was muddled. On the one hand, sensation—detecting objects and events

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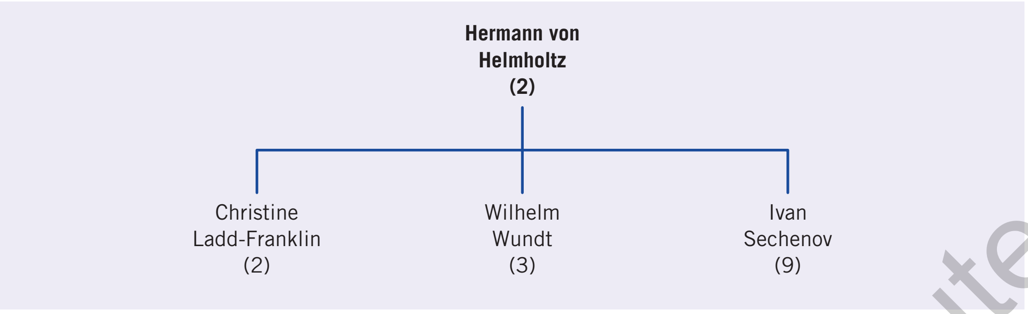
Figure 2.6 Academic Family Tree of Hermann von Helmholtz



in the environment—was a process of the material body. On the other hand, perception—conscious awareness of those objects and events—was a process of the immaterial soul. However, Helmholtz was committed to the materialist worldview from early adulthood, so he snatched perception from the soul and placed it squarely within the brain.

Helmholtz also challenged the received wisdom that perception was an accurate representation of reality (De Kock, 2014). The sense organs have no direct access to objects or events in the environment. Rather, they detect energy—in the form of light or sound, for instance—that's given off by those objects or events. The sense organs convert this environmental energy into nervous energy, which is then transmitted to the brain. Thus, sensation isn't a faithful copy of the original but rather is symbolic of the real world.

Helmholtz argued that perception is a constructive process (Epstein, 1991). Based on previous experience, the brain interprets the sensory input as symbolic of something it's experienced before. Here, he both agrees and disagrees with his intellectual predecessor, Kant, who argued that we construct perception on the basis of innate categories. Helmholtz agrees that perception is a constructive process, but he also maintains that it's learned in infancy, much as Berkeley had argued. The question of which aspects of perception are acquired or innate is still a contentious issue for psychologists in the twenty-first century.

Furthermore, Helmholtz maintained, perception isn't just a passive process of receiving sensory inputs, as was generally believed (Turner, 2000). *Helmholtz's position that perception is a rational process of finding the best interpretation of the sensory input* is known as **unconscious inference**. In other words, we don't have direct access to objects and events in the world. Rather, all we have is elemental sensations such as lights of various colors and brightness, and from this information we make our best guess about what's out there in the world. Thus, perception works just like any other reasoning process, except that it operates entirely at an unconscious level.

Helmholtz's ideas on sensation and perception have had a significant impact on psychology into the twenty-first century. Not all of his contemporaries agreed with his views, but there was a resurgence of interest in Helmholtz with the cognitive revolution during the last half of the twentieth century (Chapter 11). He also inspired those who worked with him (Figure 2.6). As we'll see, he was a mentor for both Hermann Ebbinghaus (next section) and Wilhelm Wundt (Chapter 3). As one of the great polymaths of the nineteenth century, physicists, philosophers, and psychologists all count him as one of their own.

Christine Ladd-Franklin

In the nineteenth century, a woman's place was in the home, and if a woman were ambitious enough to pursue a career, she had to forsake marriage and family (Furumoto, 1992). But **Christine Ladd-Franklin** (1847–1930) wanted to have it all. Today we know her as the *early American psychologist who developed the modern evolutionary theory of color vision*.

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Christine Ladd grew up in an affluent family that encouraged education for its daughters, and several women relatives were active members of the suffragette movement (Furumoto, 1995). After earning a bachelor's degree from Vassar, Ladd was permitted to attend graduate courses at Johns Hopkins as a nondegree-seeking student. Although she completed all the requirements for a Ph.D. in mathematics, the university refused to award her a degree for the simple reason that she was a woman. She did, however, find a husband in her math professor Fabian Franklin, adding his last name to her maiden name.

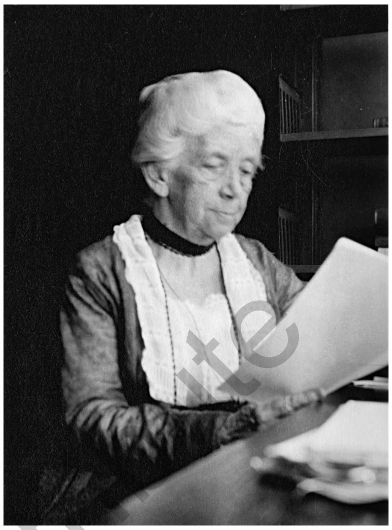
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Photo 2.8
Christine Ladd-Franklin

At that time, marriage spelled the end of a woman's career, but Ladd-Franklin's husband held liberal views about gender equality, and he did all he could to encourage and support his wife's interest in doing research (Furumoto, 1992). For many years, she held an unpaid lectureship at Columbia University, where her husband was on the faculty. Despite the insult of not receiving a salary for her services, the position did provide her access to the university's facilities, which she could use for her research. Although Ladd-Franklin had completed her dissertation on the mathematics of optics, her interest shifted to the physiology of color vision. So when her husband spent his sabbatical year (1891–1892) in Germany, she had the opportunity to work in Helmholtz's lab. During this and other visits to Germany, she conducted the research that resolved the Helmholtz-Hering debate.

As you recall, Helmholtz favored Young's three-receptor theory of red-green-blue color vision, whereas Hering argued that color vision worked through an opponent process that contrasted red with green and blue with yellow (Furumoto, 1995). Ladd-Franklin's solution to this debate was to propose that both theories were correct, in that each described a different stage in visual processing. By applying evolutionary theory to the problem of color vision, she was able to demonstrate how such a two-stage process could have evolved in order to produce the full range of color vision in humans. Ladd-Franklin spent decades promoting her theory by presenting at conferences and publishing theoretical articles. At the time, few of her (almost all) male colleagues were convinced of her solution to the problem, instead preferring to bicker about the relative merits and faults of the Helmholtz-Young three-receptor theory and the Hering opponent-process theory. Nevertheless, her theory aligns well with modern thinking on the mechanics and evolution of color vision, even though her role in its development is often still overlooked.

Despite institutionalized prejudice against women, Ladd-Franklin's accomplishments came to be recognized (Scarborough, 1988). In a 1903 review, she was listed as one of the top fifty American psychologists. Toward the end of her life, she finally got the recognition she deserved. In 1926, Johns Hopkins awarded her doctorate, and an aging Christine Ladd-Franklin attended the ceremony to accept the degree, forty-four years after she'd earned it.

Hermann Ebbinghaus

Young **Hermann Ebbinghaus** (1850–1909) had a Ph.D., but he had no job prospects in his German homeland (Traxel, 1985). So he traveled to England for a couple of years, hoping to brush up on his English while supporting himself by tutoring. He wanted to become a professor at one of the great German research universities, but in those days you had to write two dissertations—one theoretical and another presenting original research—to qualify for a position. Eventually, Hermann Ebbinghaus built his reputation as a *nineteenth-century German psychologist whose memory research demonstrated that higher mental processes could be studied using rigorous experimental methods.*

Ebbinghaus's theoretical dissertation had been a philosophical essay on the nature of memory (Traxel, 1985). But he wondered what kind of research he could do on that topic. Browsing through the second-hand book stalls in London, Ebbinghaus found a copy of *Elements of Psychophysics*. In that book, Fechner had shown that mental processes could

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be studied experimentally by observing just-noticeable differences in sensory tasks. Likewise, Ebbinghaus would study memory by observing people's behavior in learning tasks.


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Photo 2.9
Hermann Ebbinghaus

As Ebbinghaus explored the active use of memory in various situations, he hit upon a laboratory technique that seemed to yield valid measurements of learning and forgetting (Slamecka, 1985). The task involved learning lists of nonsense syllables. For this purpose, Ebbinghaus constructed all possible consonant-vowel-consonant combinations in the German language, about 2,300 altogether, and wrote each on a separate card. He put all the cards into a container, and he drew as many as needed to create a random list. The rationale for using nonsense syllables is that they're largely meaningless. Ebbinghaus knew from his early investigations that meaningful material is more easily memorized than meaningless sequences, and he wanted to eliminate the confounding variable of meaningfulness from his experiments. Incidentally, lists of nonsense syllables are still commonly used in memory research today, and even your humble textbook author used them in his dissertation research.

Ebbinghaus also sought to avoid the creation of incidental meaningful relationships among the list items by reciting them at the steady pace of two and a half syllables per second (Tulving, 1985a). At this speed, he found it impossible to think of anything but the current item, so there was no time left for any memory-enhancing strategies. He would read the list several times, repeating it until he could recite it smoothly and error-free from memory. According to his reports, the procedure was tiresome, and it often gave him a headache. In collecting his data, he memorized thousands of lists over tens of thousands of trials. There's no question about Ebbinghaus's dedication to his research program.

Ebbinghaus's famous forgetting curve is a staple in introductory psychology classes (Slamecka, 1985). He'd memorize a list and put it away for a predetermined period of time. Then he'd test himself to see how much of the list he remembered, finding that recall of the list decayed steeply at first but then tapered off. However, this wasn't his main finding. After all, any college student already knows the forgetting curve from personal experience. You cram for the test, but most of the knowledge is gone shortly after handing in your exam paper.

For Ebbinghaus, a more important phenomenon was what's called **savings during relearning** (Nelson, 1985). This is *a process that occurs when a person learns something, forgets it, but then learns it again at a faster rate*. You've no doubt experienced this as well. Let's say you took Spanish in high school. Since then, you feel you've forgotten everything you learned, but now that you're on vacation in Mexico, those words and expressions are coming back. Ebbinghaus understood that active recall is a conscious process, but with the savings-during-relearning technique he could examine unconscious memory.

To measure savings during relearning, Ebbinghaus first studied a list until he could recite it perfectly, counting the number of trials (Nelson, 1985). He set it aside for a given time, and then he relearned it a second time. This usually took fewer trials, and this was the savings during relearning. He also found that each subsequent relearning accrued even greater savings. When he used this technique with stanzas of poetry, he had the poem permanently memorized after a few relearning sessions. This was the first demonstration of the effectiveness of distributed practice over massed practice. For example, it's more effective to study a little each day rather than cram the night before the exam. (I know, you still cram anyway.)

In 1880, Ebbinghaus presented his early data in the form of a research dissertation, with Hermann von Helmholtz as the dissertation adviser (Bringmann & Early, 2000). This got him a part-time lectureship at Berlin University. But he kept collecting data with himself as the only subject. He published his book *On Memory* in 1885, after which Berlin University offered him an untenured professorship. He later accepted a tenured position at a provincial university, but with a heavy teaching load he had little time for research. Or maybe he was just tired of memorizing lists.

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Although Ebbinghaus had few graduate students to carry on his legacy, his work nevertheless inspired generations of psychologists (Bahrick, 1985). In the late nineteenth century, introspection, or self-report, was still the gold-standard technique of psychology. However, Ebbinghaus had shown that the experimental rigor of the natural sciences could be applied to psychology as well. Ebbinghaus's work was much praised during his lifetime, and it's still held up as the benchmark for rigor in experimental psychology.

Looking Ahead

In the middle of the nineteenth century, scientists from England, Germany, and other countries laid the groundwork for a scientific psychology. In England, Darwin convinced us, with his theory of evolution, that humans are also part of the natural world and therefore an appropriate subject for a nature science. Meanwhile, Galton established methods for studying individual differences and the role of nature and nurture in development. In Germany, Fechner and Helmholtz showed that mental processes could be measured with the methods of psychophysics and physiology. And then Ebbinghaus pushed the envelope, demonstrating that even higher mental functions like memory could be studied with rigorous experimental methods.

During this time, psychology began taking shape. Of course, these pioneers weren't psychologists by training. Rather, they were eminent researchers in other fields who also had interests in psychology. These polymaths applied methods from their original fields to study human behavior and mental processes, often with no clear intention of creating a new science of the mind. But when they applied rigorous experimental procedures to important questions in psychology, they got meaningful answers in return. Early successes encouraged these proto-psychologists to journey even deeper into uncharted territory.

Many of the research methods developed during the nineteenth century are standard procedures of the experimental psychologist in the twenty-first century. Darwin's comparative methods are the stock in trade for animal research, and they inspired the development of evolutionary psychology in the late twentieth century. Galton taught us how to gather data and analyze them with the proper statistics. Fechner's psychophysics is an active area of research today, and the questions he posed are still debated. As we'll see in Chapter 11, the mid-twentieth-century psychologist S. S. Stevens continued Fechner's line of research, proposing a revision to the Weber-Fechner law that is now called the Stevens power law. Likewise, Helmholtz and Ebbinghaus have had a great influence on modern psychology, especially in the fields of cognitive psychology and neuroscience.

The groundwork had been laid, but no single edifice of experimental psychology was built upon it. As we'll see in Part II, experimental psychology fractured into several competing schools. Each had its pet questions and favored methods. And each saw itself as the "true" experimental psychology. Many psychologists toed the line of their favorite school, but some—the truly great thinkers—rose above the divisiveness to see the strengths and weaknesses of each approach. It was also open-minded thinkers who reunified psychology after World War II.

In the next seven chapters, we'll get acquainted with the different schools of psychology that arose around the turn of the twentieth century. In Chapter 3, we learn about Wilhelm Wundt and the first systematic approach to studying the mind. In Chapters 4 and 5, we consider two early American schools, functionalism and behaviorism. We then return to Germany in Chapter 6, where we encounter a group calling themselves Gestalt psychologists. In Chapter 7, we move to Austria, where we meet Sigmund Freud and the psychoanalysts. After that, we go the French-speaking world of France and Switzerland in Chapter 8, where we learn about Jean Piaget, whose work inspired the disciplines of developmental and cognitive psychology after World War II. Finally, we go to Russia in Chapter 9 to explore the unique brand of psychology that Ivan Pavlov and his compatriots developed. Today, each of these schools provides a leg that modern psychology stands on.

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CHAPTER SUMMARY

In the early nineteenth century, scientists had come to understand that the story of Genesis in the Bible could not possibly be literally true. Geological evidence demonstrated that the Earth was millions—not thousands—of years in age, and fossil evidence indicated that species of the past were quite different from their current forms. Although several theories of evolution had been proposed, it was Charles Darwin who finally discovered the mechanisms driving it, namely natural and sexual selection. Darwin's cousin Francis Galton experienced a "religious" conversion when he read *On the Origin of Species*, inspiring him to a career of measuring the individual differences among humans that were the raw material for evolution. We credit Galton with developing a number of empirical methods and statistical analyses that are still widely used in psychological research today. In Germany, the psychophysicists Ernst Weber and Gustav Fechner demonstrated that psychological processes could be studied in an experimental manner, as they mapped out the relationship between physical stimuli and their reported sensations. Hermann von Helmholtz, one of the great polymaths of the nineteenth century, explored the physiology of color vision and developed a theory of perception as unconscious inference. His student Christine Ladd-Franklin furthered this research by developing an evolutionary theory of color vision that resolved a long-standing debate in the field. Extending the work of the psychophysicists, Hermann Ebbinghaus demonstrated the even "higher" mental processes such as learning and memory could be studied in an experimental manner, developing techniques that are still used today.

DISCUSSION QUESTIONS

1. Compare and contrast the British and German models of doing science, considering the advantages and disadvantages of each approach. What is the standard model today?
2. Explain the two big questions that Darwin and his colleagues were wrestling with in the first half of the nineteenth century. How did Charles Lyell and Thomas Malthus influence Darwin's thinking?
3. Explain the differences between Lamarckism and Darwinism, especially with respect to the two metaphors for speciation, the Ladder of Life and the Tree of Life.
4. Discuss the three interlocking components of natural selection and how they work together to produce changes in species over time. Apply these components to the three types of Darwinian selection: artificial, natural, and sexual.
5. Why was Darwin hesitant to publish his theory of natural selection? What was the issue between Alfred Russel Wallace and Charles Darwin, and how did Charles Lyell resolve it?
6. Describe the studies that Galton conducted to test his idea that intelligence is an inherited trait.
7. Discuss the differences between positive and negative eugenics. Contrast eugenics as it was proposed by Galton and the way it was practiced in the early twentieth century.
8. What exactly is meant by the expression "nature and nurture"? Describe the design of a twin study, explaining its rationale.
9. Discuss the development of the Weber-Fechner law and Fechner's distinction between outer and inner psychophysics. Explain how psychophysics is relevant to psychology more generally.
10. What was the controversy between Hering and Helmholtz? How did Ladd-Franklin resolve the dispute? What were the consequences?
11. What is the difference between sensation and perception? Explain what Helmholtz meant by his conceptualization of perception as unconscious inference.
12. Describe the procedure Ebbinghaus used to study memory, considering why he focused on savings during relearning in his experiments. What was Ebbinghaus's impact on psychology?

ON THE WEB

On YouTube, you can find videos describing the lives and careers of the people discussed in this chapter. These videos are of variable quality, so watch with a skeptical eye.

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