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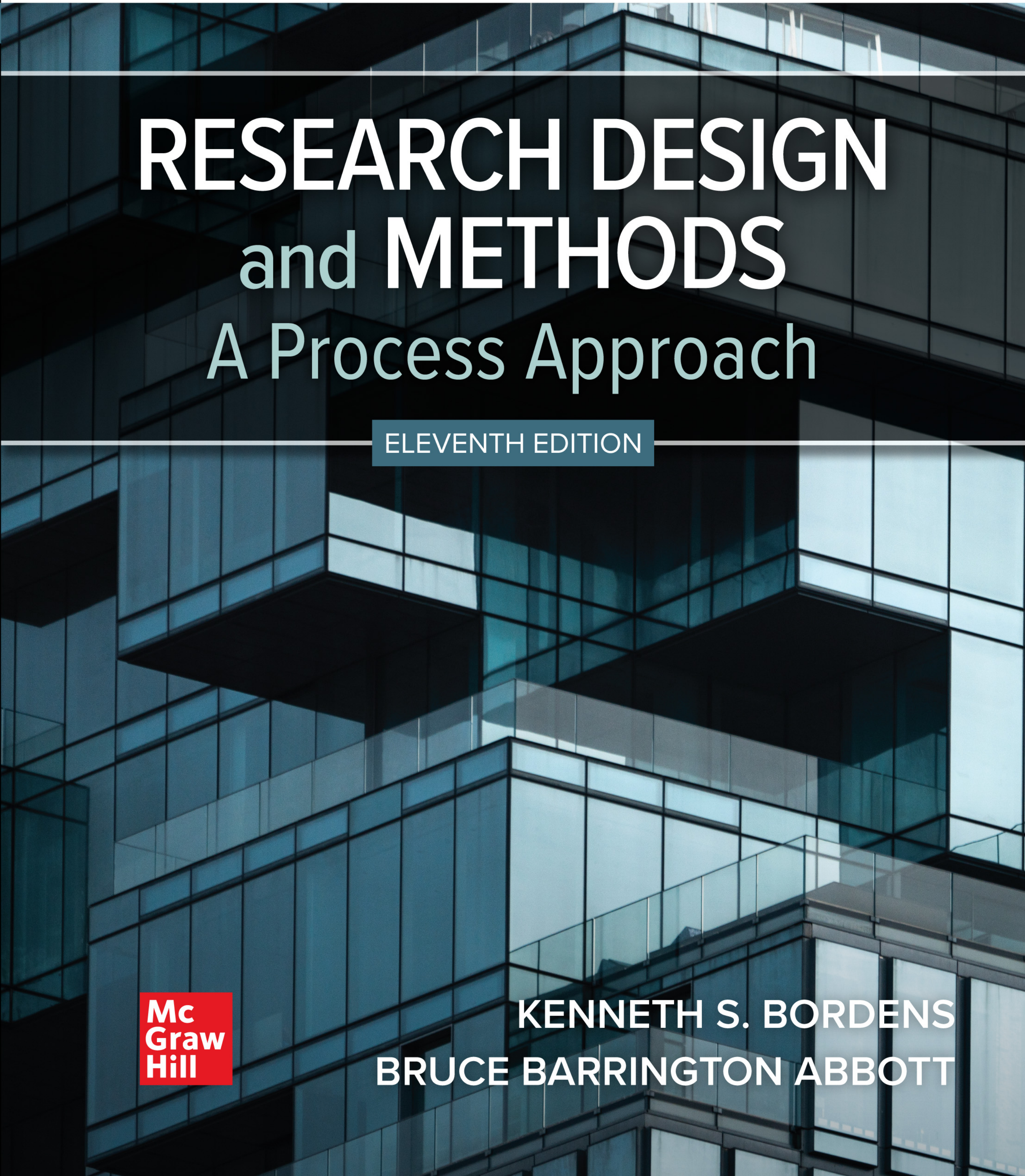

RESEARCH DESIGN and METHODS
A Process Approach

ELEVENTH EDITION

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Hill

KENNETH S. BORDENS
BRUCE BARRINGTON ABBOTT

Research Design and Methods

A Process Approach

ELEVENTH EDITION

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RESEARCH DESIGN AND METHODS

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We dedicate this book to our wives, Ricky Karen Bordens and Stephanie Abbott, and to our children and grandchildren.

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PREFACE

This, the eleventh edition of *Research Design and Methods: A Process Approach,* reflects a revolution in research practices that has overtaken psychology and other fields that have relied on null hypothesis significance testing (NHST). This revolution followed the discovery that many established research findings fail the test of replication. The "open science initiative," whose elements are designed to increase the transparency and reliability of research, is being increasingly adopted by journals and funding agencies as requirements. Additionally, are being taken to supplement—or replace—traditional NHST methods with other analytic approaches such as Bayesian analysis and "the new statistics" (estimation, confidence intervals, and meta-analysis). We cover these changes and the issues that motivated them, especially in Chapters 3, 4, and 14.

We have also partially rewritten Chapter 1 to align its coverage with the "Next Generation Science Standards" (NGSS). The NGSS view science as a set of practices that researchers engage in at various times in the research process, rather than a set of steps called "the scientific method" that researchers follow in a rigid order. Primary and secondary schools are adopting the NGSS curricula for teaching science, so we thought it important to be consistent with the NGSS standards in our coverage.

One of the criticisms raised against psychology as a science is its failure to emphasize theory development over purely empirical research efforts. Scientific theories of the sort found in disciplines such as physics, earth sciences, and biology continue to be rare in psychology, and not just because of the difficulties inherent in probing the workings of highly complex biological systems whose behaviors can be altered through learning. Instead, most researchers have been content to investigate empirical questions, adding to what Forscher (1963) likened to mere "bricks" as opposed to building a theoretical edifice. We have included a chapter on theory (Chapter 2) since the first edition of this book because we believe that our science cannot truly progress without significant theoretical development. The widespread availability of powerful computers may provide the key to such progress, particularly in the form of computer simulation.

CHANGES IN THE ELEVENTH EDITION

Organization

Some of our reviewers suggested moving the chapter on research ethics closer to the front of the book to reflect its importance in the research process. Consequently, it now appears as

Chapter 3 (formerly Chapter 7). The chapter, as in previous editions covers ethical treatment of subjects as well as the ethical treatment of science. Among other important issues raised is the damage to science that arises from scientific misconduct.

Another organizational change is that references now appear at the ends of the chapters in which they are cited. The book includes 130 newly cited references. Also, glossary items now include chapter numbers in brackets to make it easier for students to find them in the text.

Throughout the Book

When revising each of the chapters we worked to improve the conciseness and clarity of the writing. We also made changes in content to keep abreast of current trends in research methods and views of scientific practice. The following sections summarize the changes made to each of the chapters.

CHAPTER 1: EXPLAINING BEHAVIOR

A new opening vignette emphasizes the danger of uncritical acceptance of information presented on the Internet and other places. This leads to a discussion of science as an approach to knowledge about the natural world characterized in part by the collection and critical evaluation of empirical evidence.

We rewrote the discussion of science and what scientists do to align it with the Next Generation Science Standards (NGSS) put out by the National Research Council for science teaching. The NGSS abandons the concept of "the" scientific method as a series of steps carried out by scientists conducting scientific research, focusing instead on a set of eight "practices" that characterize the work of scientists.

We removed the "Scientific Method" subsection from Methods of Inquiry for two reasons. First, the practices of science were already described earlier in the chapter, and second, we wished to avoid implying that there is only *one* acceptable method for doing science, called "the scientific method." The revised section, now entitled "Other Methods of Inquiry," presents the Method of Authority and the Rational Method as approaches to acquiring knowledge.

The final section presents the research process that is the organizational theme of the book, as followed in the typical empirical research paper published in scientific journals.

CHAPTER 2: DEVELOPING AND EVALUATING THEORIES OF BEHAVIOR

We moved the example of the Rescorla-Wagner model of classical conditioning, previously found in Chapter 3, to Chapter 2 to illustrate a model as a specific implementation of a more general theory.

We added the Åström and Murray (2020) model of predator-prey dynamics to show how computer modeling can account for cyclical changes in Canadian lynx versus snowshoe hare population sizes, replacing the Nerb and Spada (2001) example.

We shortened the description describing Norman Anderson's (1968) information integration theory found in the section on quantitative theory and illustrated it with a study by Leon (1982) on how children make moral judgments.

The final section on theory-driven versus data-driven research now ends with a paragraph bemoaning the lack of attention to theory development and testing in psychology and related disciplines, and challenging the student to take up this essential scientific activity.

CHAPTER 3: UNDERSTANDING ETHICAL ISSUES IN THE RESEARCH PROCESS

We moved this chapter on research ethics (previously Chapter 7) forward in the book to emphasize its importance.

We added a new discussion of ill-gotten information (added as a new key term) to the section on the Nuremberg Code. This discussion includes a definition of ill-gotten information and the two ethical dilemmas posed by such information: Should the research yielding ill-gotten information be done and for existing ill-gotten information, should it be used? Arguments for and against using ill-gotten information are presented.

We clarified the Principle of Justice in the section on the Belmont Report.

We added the APA (2020) guidelines on ethical issues relating to Internet research to the section on Internet research ethics, and discussed the issue of ill-gotten information obtained in Internet research.

We clarified the definition of the least-publishable unit rule through Fishman's (2011) example of "salami science." Fishman likens getting as many publications out of one research project to getting salami sliced as thinly as possible to get as many sandwiches as possible. We thought this vivid image would help students better understand the idea of the least-publishable unit rule.

A new paragraph in the section on detecting and dealing with research misconduct brings in Fanelli et al.'s (2015) finding suggesting that pressure to publish may be a larger factor in research misconduct for researchers early in their careers than for established researchers, based on what studies get retracted versus corrected. We also added a discussion of what to do about research misconduct, based on a survey of researchers by Pratt and colleagues (2015). We also added a discussion of the effectiveness of methods for dealing with research misconduct. We now discuss how journals can help guard against research misconduct by requiring that raw data be submitted as a condition of publication.

CHAPTER 4: GETTING IDEAS FOR RESEARCH

In Chapter 4 we deleted the extended example of using theory to get research ideas. In its place we provided a new example of how applied issues can be a source of research ideas, focusing on how naltrexone used for opioid addiction affects males and females differently.

In the section on asking important questions, we added information on replicating existing research findings. This includes the importance of replications in science and questions that should be addressed in replication research.

In the section on scholarly journals as sources of information, we added a sub-section discussing open-access journals.

Because most students are most likely familiar with using databases to search the literature, we eliminated the extended example of using EBSCO in favor of a more general discussion of using EBSCO.

We updated the section on problems with peer review. It now includes reference to a study by Bornmann and colleagues (2010) that found a distressingly low level of inter-reviewer reliability. We also added new information on the problem of homophily in the selection of peer reviewers, showing that women are underrepresented as peer reviewers. We updated the information on bias against women authors to include reference to a study by Fox and Paine (2019) showing a bias against women authors in ecology and evolution journals. We updated the section on improving the peer review process to include a study by Sciullo and Duncan (2019) identifying five problems with the peer review process and solutions to those problems, and added a table (Table 4-3) summarizing them. Additionally, this section now describes a study by Horbach and Halffman (2019) comparing the effectiveness of several types of peer review and provides a new table (Table 4-4) showing the results.

We updated the section on values in science to include information on the bias in psychology against evolutionary psychology and on how ideology can affect interpretation of measures. We also added new information on how liberal ideas are described more positively than conservative ideas in the scientific literature and how liberal ideas are viewed as more normative than conservative ideas (Eitan et al., 2018).

The section on how values influence what and how scientists study now includes information on critical feminist psychology and how adherents maintain that the idea of objective science is a fallacy. The new information includes a discussion of five critical methodological questions raised by critical feminist psychology.

We updated the information on the role of gatekeepers in science to include the role of ideology in the gatekeeping process.

CHAPTER 5: CHOOSING A RESEARCH DESIGN

We clarified the definition of exploratory data collection and analysis and added an example.

We provided a new example of correlational research that focuses on the relationship between being a victim of bullying and suicidal ideation among children and adolescents.

We added a new example of experimental research that examines the relationship between playing violent video games and aggressive emotions.

In the section on external validity we added Meltzoff and Cooper's (2018) questions to consider when evaluating one's research with respect to external validity.

We updated the section on internal versus external validity to include a distinction between efficacy and effectiveness research when assessing the importance of the two types of validity.

To the section on using simulation methodology we added new information on virtual reality simulations.

The section on the field setting now features a new example of a field experiment. This example focuses on whether subtle forms of prejudice influence how church personnel respond to potential new members of different ethnic/racial groups.

CHAPTER 6: MAKING SYSTEMATIC OBSERVATIONS

We updated the section on choosing measures to discuss the differences between physical and psychological measures and provided examples of each type.

To illustrate a physiological measure, we added a new figure (Figure 6-4) showing a polygraph taken during sleep.

We deleted the section on choosing when to measure.

CHAPTER 7: CHOOSING AND USING RESEARCH SUBJECTS

We augmented the information on crowdsourcing sources for research participants to discuss how the increased use of sources such as Amazon Mechanical Turk may lead to a shift in research and theory in social psychology (the MTurkification of social psychology).

We updated the section on voluntary participation and cut down the previously extensive coverage of research on the topic published in 1975.

To the section on deception in research we added a discussion of two forms of deception: indirect (not disclosing the full purposes or goals of a study) and direct (deliberately providing misinformation). The section discusses how direct deception poses more serious threats to a participant's well-being than indirect deception.

We updated the section on the effectiveness of debriefing to include a recent study (Miketta & Friese, 2019) showing that the effects of negative feedback about a participant's intelligence persisted for two weeks and that a debriefing session with a trained psychologist helped to remove the negative effects of false information.

Results of more recent polls were added to the section on how the public views animal research, together with a new figure (Figure 7-3) showing how attitudes toward using animals in medical testing have changed between 2001 and 2019.

CHAPTER 8: DOING NONEXPERIMENTAL RESEARCH

We added an example of recording behavior sequences.

We updated and expanded the section on live versus recorded observations. There are discussions of the human observer as "low fidelity recorders of behavior" and of how recording can circumvent the problems of live observation.

To the section on qualitative data we added new information on the grounded theory approach to data collection and provided an example of how the grounded theory approach is used.

We updated the information on unobtrusive observation to include a discussion and example of contrived observation, where an observer elicits behaviors from participants.

In the section on observing as a participant or nonparticipant, we updated the discussion to include the use of polymorphous engagement technology (e.g., the Internet) in participant observation. We also added information on the problem of participant reactivity in participant observation.

A new example of ethnography focusing on the type of feedback received by medical students replaces the one we previously used.

A new example of content analysis focusing on how individuals with cognitive impairments communicate using Facebook replaces the older one.

To the section on data mining we added new information on digital traces research. We describe how you can use routinely collected data in research and how you can use those data to create digital dossiers of attitudes and behavior.

CHAPTER 9: DOING SURVEY RESEARCH

A new example of survey research opens the chapter. The new example focuses on attitudes toward technology companies. The subsequent examples of different types of survey questions have been updated to follow the new example.

We updated the data on the percentage of people who use the Internet and the demographics of those people.

In the section on telephone surveys we expanded and updated conducting surveys to include targeting smartphone users. We present research on the differences between landline and smartphone users and how those differences could affect survey methods and results.

We updated the final note on survey techniques to include research indicating that nonresponse bias may not be as large a problem as previously believed and that researchers should monitor ongoing survey research for nonresponse bias and take steps to correct it.

We rewrote the section on assessing the reliability of a questionnaire to clarify how to use the test-retest and parallel forms methods to assess the reliability of questionnaire questions.

CHAPTER 10: USING BETWEEN-SUBJECTS AND WITHIN-SUBJECTS EXPERIMENTAL DESIGNS

No substantive changes.

CHAPTER 11: USING SPECIALIZED RESEARCH DESIGNS

We added new examples illustrate equivalent time samples design, non-equivalent time samples design, and pretest-posttest design.

CHAPTER 12: USING SINGLE-SUBJECT DESIGNS

The discussion of multiple baseline designs now distinguishes three types: multiple baseline across behaviors, multiple baseline across subjects, and multiple baseline across settings.

CHAPTER 13: DESCRIBING DATA

No substantive changes.

CHAPTER 14: USING INFERENTIAL STATISTICS

The chapter now distinguishes two uses of inferential statistics: estimation and traditional null hypothesis significance testing (NHST). The section on the logic of inferential statistics now begins with estimation. It introduces point estimates and confidence intervals, then explains how a 95% CI around a point estimate (e.g., sample mean) can be expected in the long run to overlap the equivalent population parameter in 95% of random samples. We illustrate confidence interval variability across samples by portraying Geoff Cumming's (2014) "dance of the confidence intervals." An example two-group experiment includes a figure showing the 95% CIs around the two group means and the 95% CI for the effect size (difference between means).

New figures illustrate the logic of NHST, showing scenarios for a two-group experiment when the null hypothesis is true (no experimental effect present) and when it is not (effect present). Sample data from the two groups are represented by 95% CIs in the new figures.

A new section, "NHST and the Replication Crisis," replaces "Alternatives to Inferential Statistics." As the heading suggests, it addresses widespread replication failures in psychology and other disciplines that rely heavily on NHST to assess reliability, and identifies several unhealthy practices encouraged by the need for statistical significance as a criterion for publication (*p*-hacking and data mining). Solutions being implemented to address this problem in the form of the "open science" initiative are introduced, including preregistration, open data and code, and open access to research reports. Also emphasized are encouraging researchers to conduct replications of their own and other's studies and to submit properly conducted studies with null results. The section ends by discussing the so-called "New Statistics" (estimation, confidence intervals, and meta-analysis) as a replacement for traditional NHST methods. While the latter only rule on whether an effect is either present or absent, the former indicate the likely sizes of effects in the population and the precision of those estimates.

We deleted examples illustrating various NHST analyses and a few figures and tables to make room for the added coverage. We now refer the reader to Internet sources for the information contained in the deleted tables.

CHAPTER 15: USING MULTIVARIATE DESIGN AND ANALYSIS

We updated the section on data transformations to include a brief discussion of the problem of interpreting transformed data.

We updated the formula for determining a sample size for multiple regression.

To the section on the types of multiple regression we added a discussion of logistic regression and an example of it.

A new example of multiple regression focusing on the relationship between types of humor used by adolescents and becoming a bully replaces the previous one.

CHAPTER 16: REPORTING YOUR RESEARCH RESULTS

We updated the entire chapter to be consistent with the seventh edition of the APA publication manual.

To be consistent with the seventh edition of the APA manual, we updated the section on avoiding biased language. We updated the information on avoiding labeling groups in a way that presents the groups in stereotypical ways, on avoiding terms of reference that demean participants, and on the issues of racial and ethnic identity, gender, sexual preference, and disabilities.

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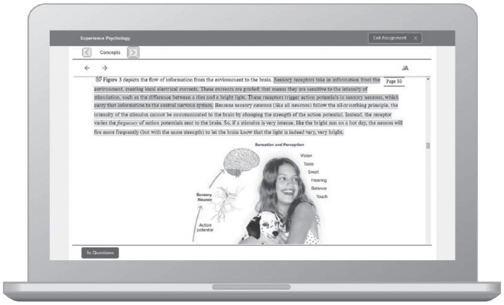

Figure 3 depicts the flow of information from the environment to the brain. Sensory receptors take in information from the environment, creating local electrical currents. These currents are graded; that means they are sensitive to the intensity of stimulation, such as the difference between a dim and a bright light. These receptors trigger action potentials in sensory neurons, which carry that information to the central nervous system. Because sensory neurons (like all neurons) follow the all-or-nothing principle, the intensity of the stimulus cannot be communicated to the brain by changing the strength of the action potential. Instead, the receptor varies the *frequency* of action potentials sent to the brain. So, if a stimulus is very intense, like the bright sun on a hot day, the neuron will fire more frequently (but with the same strength) to let the brain know that the light is indeed very, very bright.

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Finally, we offer a special thanks to our wives, Stephanie Abbott and Ricky Karen Bordens, for their support and encouragement, and to our families.

Kenneth S. Bordens
Bruce B. Abbott

CHAPTER 1

Explaining Behavior

CHAPTER OUTLINE

Edgar Maddison Welch thought of himself as one of the good guys. So when he learned from Internet, talk-radio, and other sources that a certain pizzeria in Washington, D.C., was running a child sex ring out of hidden rooms in the restaurant and that nobody in authority seemed to be doing anything about it, Welsh decided to take action. He drove directly to the restaurant from his home in North Carolina and entered the store holding an assault-style rifle across his chest. Panicked customers and employees fled the store as he moved toward the back in search of those hidden rooms, intent on freeing the children even if it meant engaging the perpetrators in a gun battle. Encountering a locked door, Welsh tried to jimmy the lock with a butter knife and then shot at the lock three times in a futile attempt to gain access to the room. Then, by standing on some furniture to peer over the top of the wall, he could see that the room held only computer equipment (Sands, 2015).

By this time the police had arrived and cordoned off the area surrounding the store. When they demanded he come out, Welch placed his rifle and a revolver that he was also carrying onto the restaurant floor and surrendered peacefully. According to the *New York Times,* Welch "almost immediately apologized, saying that he had made 'an incredibly ill-advised decision' to try to save endangered children who were never there" (Haag & Salam, 2017, para. 3). He pleaded guilty to the charges levied against him in court and was sentenced to four years in prison plus two years of probation (Sands, 2015).

Welch had fallen for a conspiracy theory known as "pizzagate," and he was not alone. The owners of the pizzeria received numerous death threats, and someone later set fire to a back room while the restaurant was open; fortunately, the employees were able to extinguish the fire before it spread. The Welch incident itself could have been much worse had Welsh entered the building with guns blazing.

Unfounded conspiracy theories (and there are many) are not the only examples of erroneous beliefs with the potential to cause serious harm. Another example is the persistent belief among some that vaccination—especially with the MMR (measles, mumps, and rubella) combination—causes autism. Autism is typically diagnosed in early childhood shortly after the time of the MMR vaccination, and this association led to the inference that the vaccine causes autism. It was also proposed that the mercury-based chemical thimerosal, used as a preservative in some vaccines (but not in the MMR vaccine), might also cause autism, presumably by damaging the developing brain. Although this chemical was removed from vaccines decades ago, and although scientific research has amassed substantial evidence against any linkage between vaccination and autism, a minority of parents still refuse to have their children vaccinated because of the fear that the children will develop autism as a result. Consequently, many children have gone unvaccinated and today several childhood diseases that these vaccines effectively prevent are on the rise, with potentially deadly consequences.

As such cases demonstrate, believing things that are not true can have serious consequences. Unfortunately, it is easy to buy into such beliefs. We human beings are extremely good at detecting patterns because throughout our evolutionary history finding reliable patterns in space and time has meant the difference between feasting or starving, between eating or being eaten, between leaving offspring to populate the next generation or dying childless. Knowing the patterns of, say, prey migration and the changing seasons, one can predict where the prey is likely to be at any given time, or when will be the best time to plant the crops or to harvest them.

Knowledge of patterns may indicate causes and, given an ability to manipulate those causes, make it possible to establish control. But as Michael Shermer (2011) has noted, being overly open to detecting such patterns can lead to false positives—the detection of patterns where none are present. We connect the dots where no real connection exists.

To make matters worse, we humans have a strong bias to search for evidence that supports our beliefs while simultaneously discounting or ignoring evidence that weighs against them, a cognitive shortcut called **confirmation bias**. We uncritically accept evidence we view as consistent with our beliefs while rejecting contradictory evidence as unreliable, erroneous, or invalid. In this way we convince ourselves that our beliefs are justified. Put these two factors together—the search for meaningful patterns and confirmation bias—and you have a powerful mechanism for developing and strengthening false beliefs.

The beliefs we have been discussing are beliefs about real-world events and relationships. The pizzagate conspiracy theory was about a real place, involving real people who were said to be enslaving real children, and the belief that vaccinations cause autism asserts a (false) relationship between real events. When you are confronted with such claims, is there a way to assess their validity? The answer is "yes." The approach is called *science.*

Science has proven wildly successful in advancing our knowledge of and beliefs about the natural world and its processes, and in freeing us from false beliefs. We as a society no longer believe, as we once did, that diseases are caused by bad air (the name of the disease called "malaria" literally means "bad air"), that earth, air, fire, and water are the basic elements of matter, that the Earth sits immobile in the center of the universe, or that mental illness is caused by demonic possession. Through scientific inquiry, such beliefs have been displaced by conceptions that have proven far more adequate to describe the natural world and explain its workings.

But what is science, and how is it done? In the next section we explain what science is (and is not), why the methods and techniques of science are so effective, and describe what scientists do in their pursuit of scientific knowledge.

PRACTICING SCIENCE

Science is a set of activities aimed at producing a systematic, reliable body of knowledge about the natural world and developing valid explanations for its workings. Doing science has often been described as a set of steps, called “the scientific method,” that scientists follow when doing science. Critics have argued that this depiction of science is a myth (e.g., Brown & Kumar, 2013; Thurs, 2015; Woodcock, 2014) It is a myth for two reasons. First, it suggests that there is only one method, “the” scientific method that scientists follow when doing science. In fact, scientists employ many methods when doing scientific work, not just those typically presented as the “steps.” Second, it suggests that doing science involves mechanically carrying out a specific series of steps. In fact, science is a messy process that this depiction fails to adequately describe.

Criticisms of textbook portrayals of the scientific method have led in the United States to the development of the “Next Generation Science Standards,” a framework for teaching science in grades K–12 (National Research Council, 2013). Among other elements, the framework outlines a set of eight Science and Engineering Practices: behaviors that scientists engage in “as they investigate and build models and theories about the natural world and the key set of engineering practices that engineers use as they design and build models and systems” (p. xv). Table 1-1 lists those practices and provides a brief description of the associated activities.

As you can see from the table, scientists engage in a variety of activities in the course of their work: asking questions about the natural world, planning and carrying out investigations, analyzing data, constructing explanations for the observations, arguing in support their interpretations against alternatives, communicating their ideas, results, and interpretations, and so on. There is no set order to these activities, although some obviously depend on the results of prior work (e.g., you cannot analyze data until you have data available to analyze). Furthermore, some scientists may engage in certain activities more than others do. Physicists, for example, tend to fall into one or the other of two categories: theoretical physicists (who develop new theories and explore their implications) and experimental physicists (who develop ways to experimentally test those theories). The division is less rigid in other scientific disciplines; still, some scientists may be more adept at developing sophisticated mathematical models or computer simulations, others may be more expert at devising crucial experimental tests of hypotheses and yet others in making detailed observations of spontaneous behavior in the natural world. As a scientist, would you prefer working in a laboratory, out making observations in the field, or doing clinical research? As a scientist, you have considerable latitude within which to match your research to your personal interests and talents.

Scientists engage in these practices to improve their knowledge of the natural world and develop better explanations for its phenomena. That word “natural” in this statement is important, for it defines the kinds of questions that science can and

TABLE 1-1 NGSS Practices of Scientists and Engineers

Asking Questions and Defining Problems	A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested.
Developing and Using Models	A practice of *both* science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations.
Planning and Carrying Out Investigations	Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters.
Analyzing and Interpreting Data	Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis.
Using Mathematics and Computational Thinking	In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; statistically analyzing data; and recognizing, expressing, and applying quantitative relationships.
Constructing Explanations and Designing Solutions	The products of science are explanations and the products of engineering are solutions.
Engaging in Argument from Evidence	Argumentation is the process by which explanations and solutions are reached.
Obtaining, Evaluating, and Communicating Information	Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity.

SOURCE: National Science Teaching Association (2015).

cannot answer. Science can answer only *empirical questions*—questions that can be answered through objective observation and analysis, and for this reason, science is said to be **empirical**. Why do people help others in some situations and not others, and are there specific factors relating to why a person helps or not in an emergency situation? These are empirical questions because they can be answered through systematic observation, and as such they can be subject to scientific investigation. In contrast, science cannot tell you whether a rose is more beautiful than a daffodil, whether there are circumstances in which euthanasia is justified, or whether there is an afterlife following death. As we have no way to answer such questions via objective observation, they are not empirical and therefore cannot be answered by science. Instead, you must turn for answers to your own esthetic sense, to philosophy, or to religion.

From reading the eight scientific and engineering practices described in Table 1-1, it may not be clear why scientists engage in these practices. What purposes do they serve? The next section we describe how these practices apply to the processes of scientific investigation and the development of scientific explanations.

What Scientists Do

To learn what's out there in the natural world, scientists make *systematic observations.* Astronomers observe the stars and other astronomical objects and measure their characteristics. Naturalists go out into the world to observe and catalog the kinds of living organisms they discover there. Psychologists set up experiments to observe behavior under a variety of conditions. But observations do more than identify "what's out there" in the natural world, they also provide evidence to support or refute proposed explanations for the observed phenomena. To qualify as scientific, such explanations must appeal to natural causes and lead logically to the phenomena to be explained. (We have much more to say about scientific explanations in Chapter 2.) An explanation that is not supported by the evidence must be rejected.

Systematic observations produce *data*, which can take the form of quantitative numerical measurements or qualitative verbal descriptions. Conducting such observations sometimes leads to discovery, as when a biologist finds a previously unknown species of frog or a psychologist identifies a new factor motivating behavior that is inconsistent with current theory. Such discoveries often raise new empirical questions to be addressed in further research.

Scientists submit their data to various forms of *analysis* designed to bring out hidden features or relationships, clean up imperfections (e.g., filter out extraneous "noise") or assess the reliability of the observations (e.g., how much do repeated measurements on the same object fluctuate?). From the data, scientists draw conclusions they believe the data support.

Scientific facts and explanations are established through a process that, boiled down to its essence, comes down to *arguing from evidence.* Scientists argue about everything. They argue whether the observations are reliable, whether the evidence brought to bear to support or refute an explanation is relevant or trustworthy, whether the conclusions drawn from a given experiment are justified by the results obtained, and much more. The goal is to convince other scientists in their field that their data are reliable, that their logic is correct, that their results are consistent with the network of previous findings, that their explanation of a phenomenon is supported by the evidence and leads to testable predictions. If, as a scientist, you succeed in convincing your scientific colleagues, then your observations, conclusions, or explanations become—provisionally—part of accepted science.

Provisionally? Yes, provisionally. Scientists recognize that any scientifically accepted conclusion may be overturned by new evidence, that any explanation may be replaced if it conflicts with accepted evidence or, indeed, if someone comes up with a better explanation that also fits the evidence. *Scientific findings are always provisional.* This means, regardless of what you might have been told, even apparently *settled science* may not always be.

Despite the provisional nature of scientific findings, science progresses. Because flaws in observation, data recording, analysis, or reasoning eventually surface through further research and the critical review of scientific colleagues, *science is ultimately self-correcting*. Previously accepted observations found to be unreliable get replaced with more reliable ones; technology improves, making observations more precise; theorists develop new explanations that do a much better job of accounting for available evidence and of predicting outcomes. Over time, our knowledge of the natural world improves, as does our ability to explain its workings. Better explanations yield improved predictions and more reliable means of exerting control over nature. For this reason, *science is cumulative.*

The fact that progress in science depends on presenting and critiquing evidence-based arguments also means that *science is collaborative.* Most scientists today work with colleagues, as evidenced by the huge number of scientific papers with multiple coauthors. For those working in academia these colleagues may include undergraduate or graduate students, post-doctoral students, and fellow faculty. Other colleagues may work together in government-sponsored laboratories (e.g., the Centers for Disease Control and Prevention) or industrial laboratories (e.g., pharmaceutical labs).

Collaborative research groups tend to develop among scientists who share similar theoretical views; often these are individuals who were trained under the same professors in graduate school and therefore share similar ideas about how their subject matter should be approached, what questions need to be addressed, what methods of investigation and analysis are appropriate, and which explanations are best. Groups with different intellectual heritages tend to adopt an adversarial relationship, arguing against each other's methods, findings, and interpretations and thus assuring that each other's papers are submitted to the sharpest critique. Those findings and explanations that survive this process to become generally accepted by the scientific community form the current state of scientific knowledge on the topic. Even scientists who conduct their research alone participate in this collaborative process when they present their work for evaluation and criticism by other scientists in scientific journals and other public forums such as professional meetings.

The collaborative process cannot take place without *communicating ideas and findings.* In scientific work the gold standard is getting your work published in scientific, peer-reviewed journals. You write up your work in the format required by the journal and submit it to the journal editor. The editor then sends your paper to at least two reviewers who are knowledgeable in the area that your paper deals with (your research peers); they read the paper and conduct a critical evaluation of its merits. Based on this evaluation they decide whether it merits publication in the journal. (See Chapter 4 for more information about peer review.) Peer review does not guarantee that your work is free of flaws, but it does help to weed out papers that are seriously deficient.

To contribute usefully to a given field of science, you must become something of an expert on it. At a minimum this means reading the scientific literature in that field and becoming fluent in its phenomena, research findings, current and proposed theoretical explanations, methods, and techniques. In graduate school, students work under a professor and develop the required knowledge of the field by reading the literature extensively and by conducting original research under supervision. Even after graduate school, scientists must try to stay current by reading the latest papers in their area of specialization. The practice of reading and digesting the scientific literature on a given topic is called *reviewing the literature*. (See Chapter 4 to learn how to find and read the scientific literature on a given topic.) A recent assessment found that reading the scientific literature consumes about a quarter of a working scientist's time (Phillips & Norris, 2009).

We hope all this doesn't sound like pure drudgery to you. As in any field of human endeavor, it does take a lot of hard work and time to become proficient in any given field of science and to stay proficient. However, few would expend the effort were it not for the pleasures and rewards that come from doing science and doing it well. No, we're not talking about winning a Nobel Prize, although some do![1] It's about discovering new phenomena, pursuing nagging questions until you find the answer, solving difficult puzzles, advancing human understanding of nature, identifying causes, developing better explanations, becoming respected for the quality of your work, contributing new knowledge that can be used to make better predictions, bringing natural phenomena under better human control, and improving the conditions of life, both physically and psychologically.

As an example of what scientific curiosity and persistence can accomplish, consider the work of Jaak Panksepp, a world-class Estonian-American experimental psychologist who developed a driving interest in discovering the biological basis of the emotions.

Panksepp began his graduate training in clinical psychology but soon developed a strong interest in studying the effects of brain stimulation in laboratory rats and switched to neuroscience. It was known that rats would press a lever at high rates for hours on end if each lever press delivered a brief tickle of electricity to a brain structure known as the medial forebrain bundle (MFB), and from this finding researchers had concluded that the MFB serves as a "reward center" in the brain. But Panksepp noticed that, following each electrical tickle, his rats would energetically explore the experimental chamber, something they would not do following the delivery of other kinds of reward, such as food or water. For Panksepp this was a clue that the stimulation might be delivering more than mere pleasure; perhaps it energized an emotional system that drives exploration of the environment. (He was later to label this system the SEEKING system.) At this time in psychology, little research attention was being paid to the emotions, partly because psychology was then dominated by behaviorism, a school of thought which insisted that behavior could be understood without appeal to mental processes. Panksepp did not agree with this position and developed a research program to investigate the brain circuitry and associated neurochemicals that underpin emotions.

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[1] But not if you are doing research in psychology! The psychologist Daniel Kahneman did win a Nobel Prize, but it was the Nobel Prize in Economics, since Nobel did not see fit to include psychology among the scientific fields in which his award could be given.

At this point in his career, Panksepp took a faculty position in the Psychology Department at Bowling Green State University in Bowling Green, Ohio, where he was asked to take over a laboratory that was investigating attachment in puppies—the process whereby puppies become emotionally attached to their mothers, try to stay close to them, and become agitated, upset, and highly vocal if separated from them, an emotional state called "separation anxiety." The attachment phenomenon has been observed in a wide variety of species, ranging from geese to humans. Panksepp found that tiny doses of the opiate drug morphine eliminated signs of separation distress (such as incessant whining), as if their mothers had been restored to them. This led him to speculate that the presence of mother might activate certain neural networks in a puppy's brain that release endogenous opioids. Panksepp labeled this emotional system the PANIC system and suggested that it is part of a more extensive system orchestrating social attachment and also involves the neuropeptide *oxytocin* and the hormone *prolactin,* responsible for lactation.

In an extensive series of studies spanning decades, Panksepp developed evidence for the existence in the brain of seven distinct emotional systems. This work culminated in a now-classic book whose title named the field of research that Panksepp pioneered: *Affective Neuroscience* (Panksepp, 1998). Today that field is being actively pursued by researchers across the world.

Science as a Way of Thinking

It is important for you to understand that science is not just a means of acquiring knowledge; it is also a way of thinking and of viewing the world. A scientist approaches a problem by carefully defining its parameters, seeking out relevant information, and subjecting proposed solutions to rigorous testing. The scientific view of the world leads a person to be skeptical about what he or she reads or hears in the popular media. Having a scientific outlook leads a person to question the validity of provocative statements made in the media and to find out what scientific studies say about those statements. In short, an individual with a scientific outlook does not accept everything at face value.

Let's see how thinking like a scientist might be applied. Imagine that you are having difficulty relaxing while taking important exams, resulting in poor performance. One night while watching television you see an advertisement for something that might help you relax. According to the advertisement, a new extract of lavender has been discovered that, when inhaled, will help you relax. There are several testimonials from users of the product to back up the claims made in the ad. The question is whether to shell out the money for the lavender scent.

A person who is *not* thinking like a scientist will pull out a credit card and place the order. A person who *is* thinking like a scientist will question the validity of the claims made in the ad and make an effort to find out whether the lavender scent will in fact reduce stress and improve performance. This involves taking the time and making the effort to track down relevant research on the effectiveness of aromatherapy, specifically the effects of lavender scent on stress. Imagine you do a quick literature search and find an article by Howard and Hughes (2008) that tested the effect of a lavender scent against a placebo scent (a scent without any purported therapeutic value) and against no scent on stress responses. Howard and Hughes, you discover, found that scents had no effect on stress unless participants were specifically led to expect the scents to have an effect. In short, the effect of the lavender scent could be explained by expectation effects. So, you decide to save your money.

This is but one example of how thinking like a scientist leads one to question a claim and look for empirical evidence, which we discuss in more detail later in this chapter. There are many other situations where thinking like a scientist can better allow you to evaluate the validity of a claim or a conclusion. For example, during an election year we are bombarded with poll after poll about candidates and who is in the lead. Rather than accepting on face value that candidate X has a lead over candidate Y, you should obtain a copy of the actual survey results (often available online at the pollster's website), and then look at the sample employed and how the questions were worded. As we will see in later chapters, biased samples and question wording can affect the validity of survey findings. Similarly, if you take a scientific approach, you will not take at face value social media claims such as those linking autism to vaccines; instead you will seek out the scientific literature on the topic and base your conclusions on the weight of the evidence presented there.

QUESTIONS TO PONDER

1. What are the eight practices of scientists and engineers identified in the Next Generation Science Standards?
2. What is science, and what do scientists do?
3. What is meant by the statement that science is a way of thinking? (Explain.)

Basic and Applied Research

Scientists work in a variety of areas to identify phenomena and develop valid explanations for them. The goals established by scientists working within a given field of research may vary according to the nature of the research problem being considered. For example, the goal of some scientists is to discover general laws that explain particular classes of behaviors. In the course of developing those laws, psychologists study behavior in specific situations and attempt to isolate the variables affecting behavior. Other scientists within the field are more interested in tackling practical problems than in finding general laws. For example, they might be interested in determining which of several therapy techniques is best for treating severe phobias.

An important distinction has been made between basic research and applied research along the lines just presented.

Basic Research You conduct **basic research** to investigate issues relevant to the confirmation or disconfirmation of theoretical or empirical positions. The major goal of basic research is to acquire general information about a phenomenon, with little emphasis placed on applications to real-world examples of the phenomenon (Yaremko et al., 1982). For example, research on the memory process may be conducted