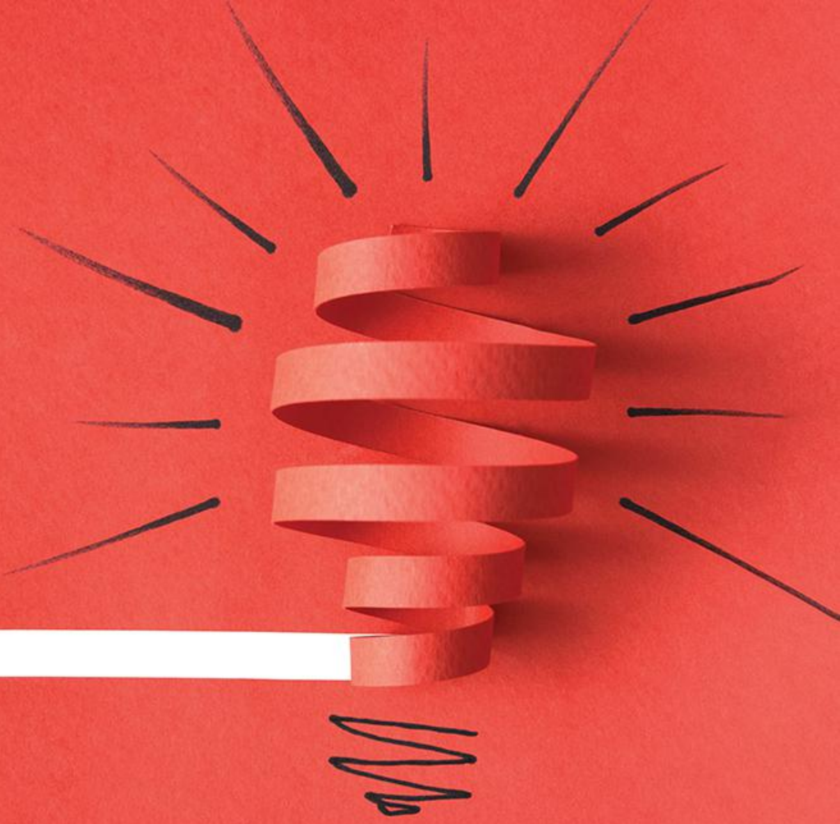

NINTH EDITION

# Research Methods: A Process of Inquiry


Anthony M. Graziano
Michael L. Raulin


Pearson

# Research Methods

## A Process of Inquiry

**NINTH EDITION**

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Pearson

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# Contents

# Preface

The ninth edition of *Research Methods: A Process of Inquiry* is the latest step in the evolution of this learning package, which now includes the most extensive and integrated website in the market. This package has evolved over more than 30 years of teaching research methods, supervising student research, conducting and reporting our own research, writing other textbooks, and revising earlier editions of this text.

## Programmatic Nature of the Text

Mastering research design involves learning a *systematic process of inquiry,* much of which is unfamiliar to students new to the field. It requires understanding and integrating concepts rather than merely learning sets of techniques. Therefore, with every edition we have emphasized concept development and integration and not cookbook-like strategies. We believe that difficult or unfamiliar concepts are best taught programmatically. Thus, we introduce complex concepts, such as validity, operational definitions, and statistical inference early in the text, but only to the degree needed for those introductory discussions. We then systematically reexamine the concepts throughout the text, adding new facets and related concepts. Our programmatic approach creates a coherent model that makes complex material more accessible and less frustrating for students.

## Features of the Text

This text includes several features designed to enhance student learning and increase interest value, including the following:

**Critical Thinking boxes** (new in this edition), which either emphasize the logic of research design and/or extend that logic to everyday situations.

**Opening Vignettes** (new in this edition), which include either classic or recent research illustrating the concepts of the chapter; we revisit these vignettes throughout the chapter.

**Historical Lessons boxes,** which use historical psychological and scientific examples to illustrate important principles of research.

**Costs of Neglect boxes,** which provide vivid examples of how poorly research can turn out if one does not pay attention to details during the design process.

**Understanding the Concept boxes,** which explain the underlying principles behind various procedures or concepts.

**Putting It into Practice,** which is an embedded feature following the chapter summary; it challenges students to apply what they have learned in the chapter to everyday situations. This makes the material more understandable and expands the *critical thinking skills* of students.

**Go with the Flow boxes,** which provide flowcharts to summarize the steps in complex procedures.

**Classic Studies,** which detail studies that changed the field of psychology.

We have included traditional pedagogical features that enhance learning, including chapter learning objectives, quick-check review questions, chapter summaries, exercises, lists of key terms, and an extensive glossary. We also use multiple examples to illustrate concepts. Finally, our discussions are presented within a context of understanding science, its history, its approach to knowledge, and its ethical responsibilities.

Our focus throughout the text is on a conceptual flow of topics, with emphasis on concepts and extensive use of illustrative examples. Secondary topics are covered in an extensive and thoroughly integrated website of support topics and hands-on activities. The appendices cover (1) how to use the textbook website, (2) a table of random numbers, and (3) answers to the quick-check review questions in the chapters.

The integrated website for the textbook is by far the most extensive in this field, providing students with a comprehensive set of learning resources. Many of these features are interactive, and others walk students through procedures with animations of what they will be doing. We list the chapter-relevant website resources at the beginning of each chapter and have inserted icons throughout each chapter. The website has been designed to promote active learning; research suggests that adding such active learning components to a course can substantially raise student performance.[1]

## The Integrated Website

This ninth edition includes a Student Resources Website that is integrated with the text (www.graziano-raulin.com). *Our goal is to provide the most comprehensive set of student learning resources of any research methods textbook on the market*.

[1]Schaffhauser, D. (2008, April 8). University of Houston study: Hybrid courses more effective for students [Preface]. *Campus Technology.* Retrieved from www.campustechnology.com/articles/60481

The Chapter Resources of the Student Resource Website provides practice for mastering concepts and developing hands-on research skills. This website also provides examples, exercises, and extended discussion of both central and supplemental topics. It includes an interactive Study Guide/Lab Manual, several research skills tutorials (many with flash animations to enhance their effectiveness), coverage of statistical theory and statistical computation, a random number generator program, and dozens of supplementary resources for the student. The relevant resources on the website are listed at the beginning of each chapter and indicated with an icon within the chapter. You can access the resources directory by going to the website and clicking Chapter Resources in the menu bar.

## A Coherent Model of the Research Enterprise

This text organizes the research process around a coherent descriptive model. This model integrates inductive and deductive reasoning, empirical observation, concepts of validity, and the phases of research (the basic steps through which each research project progresses). The model also introduces the concept of levels of constraint, which refers to the degree of control that the researcher exercises over the research process. We emphasize that valuable research can be conducted at any level of constraint. Experimental research (covered in Chapters 8 through 12) is the most rigorous and allows us to answer questions of causality. However, other research questions are also important, such as questions about the strength and direction of the relationships among variables, about differences between existing groups, and about individuals and their responses to manipulations. Furthermore, low-constraint scientific observations can suggest causal hypotheses that can be tested with higher-constraint research. We want students to learn that appropriate scientific research design depends largely on the nature of the questions asked and that research at all levels of constraint, whether naturalistic, case study, correlation, differential, quasi-experimental, or experimental, is appropriate and useful.

The text builds a conceptual foundation for all levels of research by developing each level of constraint, thereby providing students with a full spectrum of research knowledge and skills. We have devoted three chapters (6, 7, and 13) to nonexperimental research procedures—all of which are valuable tools for researchers.

## Research Ethics

Because of their importance, ethical issues are addressed in every chapter of the text. Ethical issues in research are covered extensively early in the text (Chapter 3) and, consistent with the text's organization, are revisited in each chapter for more detailed discussions. Our aim is to foster students' sensitivity to ethical issues and to teach the skills needed to address these issues. Those ethical discussions, when taken together, provide a primer on research ethics for our students. In addition to having students read the research ethics sections as they progress through the chapters, instructors might assign those sections to be read together as a unit in the latter part of the semester, for in-depth class discussion of research ethics.

## Treatment of Statistics

This is a research design text, not a statistics text. However, because research design and statistics are so closely connected, we cover basic statistical concepts. In addition, we include extensive discussion of statistical concepts and tutorials on computing statistics in the integrated website for the course.

Choosing an appropriate statistical procedure is often confusing for students. We teach that the choice of appropriate statistical analyses follows systematically from the design characteristics of the study. The Student Resources Website presents a unique addition to research methods texts—flowcharts that lead the student step-by-step through the characteristics of any basic research design to the choice of appropriate statistical analysis procedures. In addition, the website has a functional version of the flowcharts, which helps students to identify the appropriate statistical procedure and links them to detailed descriptions of how to compute the statistic.

This organization gives instructors maximum flexibility, allowing them to cover as much or as little statistical material as they wish. We hope that you will take a few minutes to explore the Student Resource Website to see the extensive resources available for you and your students.

## Instructor Resources

The adoption package includes an Instructor's Manual, a computerized test bank, a program to construct exams, and basic PowerPoint lectures. You can download any or all of these resources from the instructor's website (www.pearsonhighered.com/irc). Instructors can obtain the necessary authorization to access that website from their local sales representative. (If you do not know who your sales representative is, you can find out by visiting www.pearsonhighered.com/educator and clicking on "Find Your Pearson Rep.")

The Instructor's Manual provides extensive resources for novice and seasoned research methods instructors, including detailed learning objectives, chapter summaries, lecture outlines, lecture launcher ideas and discussion topics, key terms, website resources, and an extended bibliography.

In addition to the Instructor's Manual, there is a computerized test bank, which you can access using the MyTest Program. This program allows instructors to select from nearly 2,500 multiple-choice items, modify or write new items, and construct examinations. It is available online at http://pearsonmytest.com and is compatible with most standard web browsers. Since the tests are saved online behind an instructor password, they are more secure than offline test banks, and an instructor can access their tests from any computer.

Finally, a complete set of PowerPoint lectures is available for download from the instructor's website. These lectures include both basic coverage and supplemental slides that instructors can use if desired.

## New to This Edition

We continue to improve the text and expand the resources for the text with each edition. Some of the major changes in the ninth edition include:

- More than 75 content changes within the text, including:
  - Several new topics, many of them introduced in the new open vignettes and then revisited repeatedly in the chapter
  - Updated examples and references
  - Expanded treatment of research ethics
  - An extensively edited glossary
  - Extensive rewriting and reorganization for improved clarity
- Updating several feature boxes and creating two new features for the text (**Critical Thinking** boxes to explain the logic of research decisions and extend that logic to other areas of the students' lives and **Opening Vignettes** to introduce psychological research that illustrates the principles found in each chapter)
- An updated test bank
- Updated and expanded PowerPoint lectures

## Acknowledgments

A project of this scope would not be possible without the valuable assistance of many people. In past editions, 45 research methods instructors provided extensive feedback that has helped to improve this text, many of them reviewing several editions. We thank all of them for helping to shape this book. We also wish to acknowledge the feedback and suggestions of our reviewers on this ninth edition.

Finally, we want to thank the editors, production editors, copy editors, assistants, and support staff from the publisher who have shepherded this book through so many editions and so many mergers. In this edition, we want to acknowledge our editors, Ashley Dodge and Tanimaa Mehra, assistant, Anna Austin, Content Producer, Sugandh Juneja, and our Project Managers at Integra, Denise Forlow and Pradeep Subramani.

## Author's Statement

We hope that this text, the integrated website, and the resources available to instructors on the instructor's website will meet your teaching needs. We understand that this is a challenging course to teach and have tried to provide helpful resources. Feel free to send us your comments, questions, and evaluations of this text. You can contact us through e-mail (amgraz@buffalo.edu; mlraulin@ysu.edu).

*Anthony M. Graziano*

*Michael L. Raulin*

# Note to the Students

Before you start using this text, we want to pass on some ideas we have gained over the years about effective studying. It is worth noting that there is now extensive research backing up these ideas. Consider this scenario; we have all experienced it. You block out time to study, make yourself comfortable, and start to read a couple of chapters of your psychology text. Over several hours, you dutifully read every page of those two chapters. Shortly after you finish, you realize that you have no idea what you read. You have read every word, and not one sunk in!

Is that a familiar event? So, what happened and how can you prevent it from happening again? Let's face it, you do not have study time to waste.

Here is what happened: by the time you reach college, you are so good at reading that it has become an overlearned, fully automatic behavior that you can carry out without much thought. Most of us can read automatically, as well as walk, drive, or ride a bicycle. However, when you were learning these things, they were not automatic and they required a lot of attention. If you are learning a foreign language, you know that reading in your native language may be automatic, but reading in a new language is anything but automatic. The advantage of automatic behavior is that it takes little of our cognitive capacity, and thus, much of that capacity is available to do other things. A good typist thinks the words and they appear on the screen. Weak typists have to think about the words, and hunt for and peck the letters. Because they are using so much cognitive capacity typing, they often lose their train of thought.

We can easily read without thinking, but we CANNOT LEARN new concepts without thinking. Sure, you read every word, but that is all you did. You did not think about what you read. You did not learn the material. If, instead, you had stopped after each paragraph and asked what you had read, what it meant, and if you understood it, you would have remembered it, or at least remembered more of it. Granted, it takes you longer to read this way, but you will learn far more in each pass.

Students tend to read chapters by skipping over the "unimportant" stuff, which for most students seems to include the learning objectives, chapter summaries, footnotes, and exercises. The students' reasoning is that these sections are superfluous, containing nothing different from the material in the chapter. However, these sections are there to facilitate your active learning.

Before plunging into the chapter, take 60 seconds to go over the learning objectives and you will have a sense of what to expect in the chapter. This preparation gives you a structure for organizing and learning the new material as you read it. If you concentrate on the summaries, carefully asking yourself if you understand every point, you will identify what you do not understand and your studying will be more effective. As you read the chapter, take time to answer the Quick-Check questions. Research shows that answering questions about what you read dramatically improves your comprehension and retention of the material. Do the same with the exercises at the end of the chapter, and you will find that you will learn the material at a level impossible to reach by just reading. Testing your knowledge during the reading will also help you to remember the material longer and will improve recall in more situations, such as examinations. How many times have you faced an exam question that you knew you knew, but you could not remember it in time to answer the question correctly? When you actively use ideas in different ways, you will recall them more easily in different situations.

Active learning has two advantages. The first is that ideas that seem clear when you read them may not be clear later when you try to use them. Active learning can tell us when we really do not understand a concept, thus allowing us to clear up our confusion. The second advantage is that active learning is more dependable. You learn things better, sometimes dramatically better, when you learn actively. We hope that this brief overview will help you to use the text more effectively.

*Anthony M. Graziano*

*Michael L. Raulin*

# Chapter 1
# Curiosity, Creativity, and Commitment

*Among scientists are collectors, classifiers, and compulsive tidiers-up; many are detectives by temperament, and many are explorers; some are artists, and others artisans. There are poet-scientists, philosopher scientists, and even a few mystics.*

—Peter Bryan Medawar, *The Art of the Soluble*, 1967

## Learning Objectives

**1.1** Explain the importance of curiosity, creativity, and art to science and research.

**1.2** Differentiate among the methods used to acquire knowledge.

**1.3** Summarize the contributions from various fields to the development of modern science.

**1.4** Outline the historical milestones in the field of psychology.

**1.5** Summarize the importance of ethics in scientific research.

**1.6** Use available resources for future study.

## Web Resource Material

**See the following sections on the website for expanded material.**

| | |
|---|---|
| **01:01** | A Primer on Logic |
| **01:02** | History of Science |
| **01:03** | History of Psychology |
| **01:04** | Evolution and Psychology |
| **01:05** | APA Divisions |
| **01:06** | SPSS Tutorials |
| **01:07** | Study Guide/Lab Manual |
| **01:08** | Links to Related Internet Sites |

## Being Alone with People All around You

Shortly after 3:00 A.M. on a cold March night in 1964, a young woman named Kitty Genovese arrived home from her job as a bar manager, parking a hundred feet from the rear entrance of her apartment building. As she walked from her car to the building, she was confronted by a man with a knife and chased out into a well-lit parking area. Despite the late hour, at least 38 people witnessed part or all of the knife attack, but no one came to her rescue. After the initial attack, she crawled back to the rear entrance, but her attacker returned, found her, raped her, and stabbed her repeatedly, killing her. The attack was shocking enough, but an additional shock was that so many people witnessed it and yet no one came to her aid.

For us, research is the most fascinating, engaging, challenging, and rewarding part of psychology. But, as the vignette above indicates, it also has practical value because sometimes understanding the puzzling behavior of human beings can be a life-or-death matter. Human behavior has consequences, and understanding the factors that determine behavior is psychology's major research goal. Psychology is the science of behavior, and this text covers the methods psychologists use to study behavior.

Perhaps you might not share our enthusiasm for psychological research and are a bit wary of a course on research methods. However, consider this idea: you conduct psychological research every day, albeit, informally. Whenever you observe people and try to figure out what they are thinking and what they are going to do next, you are conducting psychological research. Whenever you try a new strategy to lose weight, improve your study habits, or impress someone, you are conducting psychological research. Think about it.

In this course, you will learn about the research strategies that psychologists use to answer questions about behavior, and you will discover that research questions are endless. For example, the death of Kitty Genovese shocked the nation. How could that have happened? Why had no one tried to help her or even called the police until it was too late? Two psychologists, Darley and Latané (1968) asked how 38 or more people could have watched what was happening but did nothing to help. We do not know what those witnesses were thinking; we know only what they did, or in this case, failed to do. Modern psychology focuses on observable behavior as much as possible. Darley and Latané sought to understand what factors influenced the witnesses' behavior.

Psychologists ask questions all the time. In what other discipline can you get paid for watching people? But watching and wondering is not enough. To study people, you must ask questions and formulate ideas about what might be happening. For example, Ainsworth (1993) asked how parents can build secure relationships with their children. She began by studying many children and determining which children had secure relationships with their parents. To do that, she had to find behaviors that indicated the level of security felt by the child. Her work, and decades of research since, taught us that how secure one feels as a child predicts how secure one will feel as an adult. More importantly, the quality of one's relationships throughout life can be predicted by knowing the security level of the child very early in life. The work of Darley and Latané (1968) and Ainsworth (1993) are only two of the thousands of questions asked by psychologists. You can create your own interesting questions. Try it. What questions interest you?

# Science

**1.1 Explain the importance of curiosity, creativity, and art to science and research.**

**Psychology** is the scientific study of behavior, and this textbook covers the research methods of modern psychology. To understand the science of psychology, you need to know something of science. This chapter offers you a background on the history and philosophy of science and scientific research.

## Science Is a Way of Thinking

**Science**, one of several ways of learning about the world, uses systematic observation and rational processes to create new knowledge. Scientists seek knowledge through a refined process of questioning. We want you to know, right here in the beginning of this text, that in science, knowing how to ask questions is as crucial as knowing how to answer them. Darley and Latané asked why so many people watched a murder and no one helped or even called police. Ainsworth asked what it meant for a child to be securely attached to parents, and what are the implications of the attachment quality. These were great questions, which led to more questions, more studies, and a better understanding of complex psychological phenomena.

Keep this basic idea in mind: **scientific research** is a process of creating specific questions and then systematically finding answers. Science is a **process of inquiry**—a particular way of thinking.

This process of scientific inquiry generates useful tools and products, such as laboratory equipment, statistical procedures, computers, medicines, and consumer goods. Too often, people mistake the tools and products of science for its essence, but that is inaccurate; the essence of science is the scientist's ways of thinking—the logic used in systematically asking and answering questions. A scientist can operate scientifically while sitting under a tree in the woods, thinking through a problem, and using apparatus no more technical than paper and pencil. It is not the bubbling liquids and laboratory equipment that make a discipline like chemistry scientific. Likewise, knowing how to use an electron microscope or run a computer program does not make one a scientist. The image of the white-coated laboratory worker surrounded by complex machines is a common visual metaphor, but it does not portray the essence of science any more than a skyscraper really scrapes the sky. *The essence of science is its way of thinking and the disciplined ways in which scientists pose and answer questions. Logical processes and demands for evidence, not technologies, lie at the center of science. Science is an intellectual process aimed at understanding the natural universe.*

### CRITICAL THINKING 1.1

### What Does It Mean to Think Critically

Much of college education is focused on improving the critical thinking skills of students. **Critical thinking** is defined as gathering and evaluating information to reach consistently reasonable decisions. You might use terms such as thinking clearly, thinking precisely, or thinking logically. You might also ask "what is the big deal? We are generally logical although not always systematic in our thinking, but we can be systematic when we need to be." Not true! We are capable of being logical, but it is not our natural state. Human beings process information every minute of every day, but we almost always rely on quick and dirty processing and rarely use the more sophisticated analysis that we call critical thinking (Gilovich, 1991; Kahneman, 2011).

This entire book and the course using it are predicated on a simple principle. We can overcome our natural tendencies to gather and process information poorly only with systematic steps that we call research procedures. Some of these procedures reduce biases in data collection; some reduce perceptual distortions that influence our observations; some provide a mechanism for being consistently logical in drawing conclusions; some provide a formal mechanism for making sense out of complex and sometimes random events. However, they all share something in common; they overcome the cognitive biases and limitations of the human mind. In other words, this text covers critical thinking procedures for the psychological researcher.

You cannot be a good researcher without thinking critically; you cannot even be a good consumer of research without thinking critically. A few of you may pursue a career in research; many of you will pursue careers that would benefit enormously from being a good consumer of research; all of you can benefit from critical thinking in your everyday lives. Because errors and biases in thinking are universal in human beings, the principles of this text have universal applications to many areas of life. We will be using these critical thinking boxes throughout the text to emphasize the reasons for using systematic research procedures to control or attenuate these errors and/or biases. But more importantly, we will use these boxes to show you how to identify these errors and biases in your everyday lives and compensate for them to help you consistently make better decisions.

## Asking Questions

Asking questions is not new. Socrates and his students asked sophisticated questions over 2,000 years ago. A question is one side of an idea; on the other side is an unknown—a potential answer. Every question points to an unknown, to some area of human ignorance or uncertainty. Socrates knew, apparently to his delight, that posing sharp questions about religion, politics, and morality could reveal the ignorance and uncertainties of even the most dignified citizens. Unfortunately for Socrates, the good citizens were made so uncomfortable that they executed him as a subversive and corrupter of youth. It was thus established early in history that asking questions could be hazardous to one's health.

Nevertheless, risk taking is part of science. Those who raise questions and expose ignorance create social and political strains, and often these people suffer reprisals. Nicolaus Copernicus (1473–1543) and Galileo Galilei (1564–1642) challenged church dogma concerning the nature of the solar system. Copernicus knew the risk of church reprisals, and he delayed the publication of his work showing that the Earth revolved around the sun. It was finally published after his death, although many scientists already had clandestine copies. Nearly a century later, Galileo was more outspoken and endured years of house arrest by the church for "blasphemy."

In the 1860s, Charles Darwin, Alfred Russel Wallace, and others implicitly challenged the biblical account of creation, asserting that the earth was millions of years old and that creatures evolved over time. However, such conflicts are not limited to the distant past. Consider the trial of John T. Scopes in 1925 (the "Monkey Trial"). Scopes, a public school science teacher, was convicted of violating a Tennessee law that prohibited teaching Darwinian evolution in public schools. The guilty verdict was later voided on a technicality, but the scripture-based Tennessee law remained and, 42 years later another Tennessee teacher was fired, prosecuted, and convicted of teaching evolution (Branch & Reid, 2017). Appeals of that conviction led, finally, to repeal of the Tennessee law.

However, the debate continues and some public school boards and administrators have tried to suppress evolution coverage in high school biology texts (Matus, 2008). In an important decision, a federal judge ruled it unconstitutional to teach intelligent design as an alternative to evolution in high school biology classes, arguing that it was a religious belief rather than a scientific theory (Goodstein, 2005). Subsequent cases have reached similar conclusions (Bailey, 2017). These issues are not unique to the United States. Recently, an anti-science, creationist movement has risen in Europe (Blancke & Kjaergaard, 2016).

Governments often try to suppress scientific knowledge. For example, in 2003, the U.S. Department of the Treasury ruled that American researchers could no longer edit scientific papers written by scientists from Iran, although the government later softened this stance (Bhattacharjee, 2003, 2004). Some states, caught up in political controversy, have proposed outlawing some types of stem cell research (Belluck, 2005). Scientists are increasingly concerned about government's growing interference with science and suppression of scientific knowledge and public information (Hahn, 2017; Union of Concerned Scientists, 2005, 2010). But, today, our government has continued to order the suppression of scientific information on some federal websites (Maron, 2016; Ritchie, Driscoll, & Maron, 2017).

Although scientific information upsets some people, scientists thrive on new knowledge. Scientists are pervasive **skeptics**, challenging accepted wisdom in their search for more complete answers. They are willing to tolerate uncertainty, and they find intellectual excitement in raising questions and seeking answers about nature (Sternberg & Lubart, 1992). Asking a question is a creative endeavor, allowing scientists the personal satisfaction of exercising their curiosity. "What," "how," and "why" are critical words in the scientist's vocabulary. Curiosity may have killed the cat, but it sustains the scientist. J. Robert Oppenheimer (1956) said that scientific research is "responsive to a primitive, permanent, and pervasive human curiosity" (p. 128). According to Linus Pauling (1981), winner of two Nobel prizes, satisfying one's curiosity is one of life's greatest sources of happiness. B. F. Skinner (1956), an influential twentieth-century psychologist, agrees, arguing that "when you run into something interesting, [you should] drop everything else and study it" (p. 223).

A scientist's pursuit of curiosity follows unknown paths, sometimes resulting in dramatic and unanticipated discoveries that can appear to be accidental. However, when scientists drop everything to indulge their curiosity, they do so with a **prepared mind**—a disciplined curiosity that makes them sharply alert to the possibility of unanticipated discoveries. As the Nobel laureate Albert Szent-Gyorgyi noted, a discovery is "an accident meeting a prepared mind" (quoted in Bachrach, 1981, p. 3). Louis Pasteur, whose research led to multiple breakthroughs in the treatment and prevention of diseases, was once asked, "Isn't it extraordinary these days how many scientific achievements are arrived at by accident?" Pasteur replied, "It really is remarkable when you think of it and, furthermore, did you ever observe to whom the accidents happen?" (Nelson, 1970, p. 263).

The work of Darley and Latané illustrates prepared minds in action. While almost everyone who read about this murder and wondered how so many people could have watched and done nothing, Darley and Latané used their knowledge of social influences on behavior to suspect that the answer to the question of why no one helped might be counterintuitive. It turned out that their suspicions were correct.

A scientist's curiosity is active, leading to discoveries, not through luck, but because the prepared mind of the scientist recognized the significance of a curious observation. It is a disciplined curiosity, sharpened by labor, frustrations, and long hours of research. Historical Lesson 1.1 illustrates the importance of a prepared mind.

## HISTORICAL LESSON 1.1

### The Three Princes of Serendip

According to the English novelist Horace Walpole, three princes from Serendip (the former name of Sri Lanka) constantly stumbled upon lucky finds. In science, **serendipity** has come to mean unanticipated discoveries. Some call them "lucky" discoveries, accidentally hit upon while the scientist was looking for something else. However, these serendipitous findings are often not the "happy accidents" that they appear to be. The scientists might have easily missed them were they not alert to the implication of their observations. Such alertness requires a prepared mind and a sense of curiosity.

There are numerous examples in science of such serendipitous findings (Roberts, 1989). Probably the best-known example of serendipity in science is Fleming's discovery of penicillin after observing the results of an accidental contamination of a specimen by a mold. Penicillin, derived from that mold, became our first wonder drug. Actually, Fleming was one of several scientists who shared the discovery and development of penicillin (Macfarlane, 1984).

Another example of a serendipitous finding was James Olds and Peter Milner's (1954) discovery of the brain's reward center when the electrode they had intended to implant in the reticular formation of one of their rats missed its target. Surgically implanting a tiny electrode in an area that is smaller than a grain of rice is difficult, and some implanted electrodes missed their mark. Usually, when the electrode missed its mark, nothing much happened. However, Olds and Milner were intrigued by the behavior of one of their rats. The rat kept returning to the place where it had previously received the electrical stimulation, almost as if it wanted more. Alert to the fact that they were observing something new, these investigators began a series of studies of how the brain shapes behavior through reward (Olds, 1958).

Another example comes from the Princeton laboratory of Charles Gross (2008). Gross was studying visual processing in the monkey brain, measuring the response of individual neurons to a standard set of visual stimuli (dots, lines, and colored squares). After hours of fruitless testing with one neuron, the researchers finally gave up. As they were about to shut down the apparatus, Gross waved good night to his monkey, and the neuron they were studying immediately responded. Puzzled but intrigued, Gross began a series of systematic studies into this chance finding. He and his colleagues (e.g., Michael Graziano & Gross, 1993, 1998) had discovered that individual neurons could be sensitive to complex stimuli, such as hands, faces, and even images of food. This discovery stimulated highly significant research into this brain area.

What do these examples have in common? Scientists' curiosity is not idle, but is active and always questioning. These were not lucky discoveries. Each of these scientists knew that they had discovered something interesting, although initially they were uncertain what it was. Their prepared minds helped them realize the importance of their puzzling results, which less insightful scientists might have dismissed as meaningless.

## Science and Art

Curiosity, creativity, skepticism, tolerance for ambiguity, systematic thinking, and hard work are universal in scientists. However, those characteristics are also well developed in poets, sculptors, painters, composers, philosophers, writers, and others. All engage in a mix of artistic and intellectual endeavors, indulge their own curiosity, and explore their worlds with skeptical questioning and sharp observations. They attempt to answer their own questions and to represent nature through their particular medium, whether it is color, shape, sound, or language. A combination of curiosity and creativity compels them to identify relationships in nature and contribute their findings to the public domain, where their work will be viewed, discussed, criticized, accepted, rejected, or worse, ignored.

This is not to argue that science and art are the same, because they are not. Yet each employs variations of the same theme—human curiosity combined with a disciplined process of inquiry to create representations of ideas. Although artists and scientists comprise only a small part of the world's population, they have created an enduring array of knowledge and products that have significantly affected the world.

There is a common belief that art and science are so different that artists and scientists are alienated from each other. People often describe a poet, musician, or actor as the "artistic type," implying that the person has no aptitude for science or math. Alternatively, they may assume that a scientist or mathematician cannot appreciate art and literature. These assumptions are false.

It is common to find young people with high achievement in science, mathematics, and technology who are also talented in other creative activities, such as music, writing, and the visual arts. This should not be surprising. The same pool of human skills generated art, science, and technology early in civilization. Historical Lesson 1.2 shows how science and art can complement one another, as illustrated by the incredible work of Leonardo da Vinci.

## HISTORICAL LESSON 1.2

### Leonardo da Vinci

The Renaissance was Europe's transition from medieval to modern life. It included a severe upheaval of the old, religious values of the Middle Ages. Humanism and the celebration of life were pursued through momentous developments in art, science, literature, architecture, and commerce—virtually all aspects of human creativity. We should note, however, that as magnificent as these achievements were, they were shared by only the top of society—the wealthy, the educated, the high church officials, and the artisans themselves. Most people were untouched by the renaissance and continued living in medieval conditions.

It was in this setting that Leonardo da Vinci (1452–1519) blended his science and art, demonstrating their natural affinity. His education was ordinary, but he did have solid training in natural sciences, mechanics (physics), and music. He even invented a new musical instrument. He apprenticed with the famous painter, Verrocchio, and within 10 years was a recognized master himself.

Leonardo studied anatomy to enhance his art. Going far beyond the artistic study of the human body, he developed detailed drawings and knowledge of the major anatomical systems: skeletal, muscular, cardiovascular, respiratory, genitourinary, and embryological. These studies reflect the meticulously detailed observation typical of both artists and scientists. He also studied comparative anatomy, dissecting animal bodies and making detailed examinations and drawings. Leonardo was the first great medical illustrator (Gross, 1997). In his studies of bird wings, he recorded his observations in detailed drawings. We see the scientist and engineer trying to understand the mechanics of the articulation of the bird's wing, such as which muscles control which actions and what happens to the particular limbs, joints, and feathers in the action of flying. From his study of bird wings, he sketched plans for a flying machine—over 500 years ago!

Leonardo was a creative genius in science, technology, and art. As a military engineer, he designed fortifications, tank-like war machines, an underwater breathing apparatus, a submarine, and a crop irrigation system. Yet, he found time for other pursuits. He sculpted a huge model for an equestrian monument, which he never completed because bronze was needed to make cannons. He drew plans for buildings and monuments, pursued studies of mathematics and anatomy, and made detailed observations of fossils, river movements, and rock strata, leading him to brilliant conclusions that modern paleontologists would not develop for another 300 years (Gould, 1997). As if this were not enough, this incredible scientist also created magnificent art, including the *Last Supper* and the *Mona Lisa*.

Leonardo's work wove together science and art; his artistic labor alternating continuously with his scientific inquiry. Although much of his work has been lost, more than 5,000 pages of drawings and notes survive (Gross, 1997). Leonardo exemplified the affinity of art and science in understanding nature. There were no arbitrary divisions between science and art in this Renaissance genius.

### Quick-Check Review 1.1

## Science

1. What is the essence of science?
2. How can a scientist practice science while sitting under a tree?
3. What is meant by a prepared mind in science?
4. What are some of the major characteristics of scientists?
5. What do art and science have in common?

# Acquiring Knowledge

**1.2 Differentiate among the methods used to acquire knowledge.**

To learn about nature, scientists employ systematic thinking and place heavy demands on the adequacy of their information and on the processes they apply to that information. Science is one way of acquiring knowledge. Others are tenacity, intuition, authority, rationalism, and empiricism (Helmstadter, 1970). These methods differ in the demands they make on the adequacy of the information and on how they process the information. *Science, which combines rationalism and empiricism, is the most demanding method for acquiring knowledge, whereas tenacity, intuition, and authority make few demands on information and require minimal processing.*

## Tenacity

**Tenacity** is a willingness to accept ideas as valid knowledge despite contrary evidence or a lack of supporting evidence. Ideas that have long been accepted or often repeated may acquire an aura of unquestioned truth. An example from the history of psychology is the powerful belief, held by early twentieth-century psychologists, that women were not as intelligent as men (Shields, 1982). Perhaps due in part to this belief, women were excluded from the all-male university programs and professions well into the 1930s. Male psychologists of that era probably did not question their tenacious beliefs, and they ignored contrary evidence.

Tenacity also operates in modern political campaigns, in which candidates or political commentators repeat distorted ideas so incessantly that voters accept them as true. Advertisers do the same thing, calculating that consumers will accept mindless repetition as truth. *When tenacity operates, there is no demand to examine the accuracy of ideas, no serious consideration of alternative ideas, and no testing of the ideas through skeptical, critical, and objective review.*

In a provocative book on how people influence others, Robert Cialdini describes a possible mechanism behind tenacity (Cialdini, 1993, 2016). People, he says, generally strive to be consistent in their behavior. They view inconsistency as a negative trait because it suggests that a person has not thought through an issue. Hence, once people act, they often have a strong need to continue to act in the same way, even if the initial action was ill advised or the situation has changed, making the action no longer appropriate. For many, it is better to have a tenacious, but incorrect, position than to be inconsistent.

## Intuition

**Intuition** is the (supposedly) direct acquisition of knowledge without intellectual effort or sensory processing. Examples include extrasensory perception (a contradiction in terms), which self-styled psychics claim to possess, and knowledge received directly from God, claimed by people who have powerful religious experiences. Mysticism, spiritualism, and even drug-induced altered states of consciousness can lead people to the conviction that they have found truth and knowledge.

Apparent intuition is common in everyday life. We may instantly like or dislike another person we have just met. We seldom examine our reactions rationally; we just "feel" them. People commonly have hunches or gut feelings. These serve us well in many situations, but they also lead to errors. Intuitive responses are rapid assessments based on unexamined experiences, attitudes, and feelings (Kahneman, 2011; Myers, 2004). What makes these experiences appear to be intuitive is that people accept the information rapidly, without rational thought or examination.

Scientists also employ hunches, making conceptual leaps without examining the facts. These hunches are often productive in advancing research. However, when scientists are wrong, the process of science will weed out the mistakes.

## Authority

**Authority** is the acceptance of ideas as valid knowledge because a respected source, such as the Bible, the Quran, Aristotle, the Supreme Court, Freud, or the president, claims the ideas are valid.

Tenacity, intuition, and authority make few demands on the adequacy of information and the processes used to evaluate that information. These methods share uncritical acceptance of information. They assert that an idea is true because (1) people have "always" accepted it as true, (2) it "feels" true, or (3) an authority says it is true.

These methods can have value in smoothing personal lives. You might, for example, accept religious teachings intuitively or on authority and experience personal satisfaction. You might accept an urge to have pasta for dinner, without any need for further evaluation. However, would you also uncritically agree to saunter across a busy highway with your eyes closed, with six lanes of vehicles hurtling by from both directions at 75 mph, because a psychic says that he knows you will be perfectly safe? Clearly, for some decisions, the information and the processes employed to gather and test the information need to be more adequate. Both rationalism and empiricism provide a stronger basis for accepting information as knowledge.

## Rationalism

**Rationalism** is a way of acquiring knowledge through reasoning. Existing information is carefully stated and logical rules are followed to arrive at acceptable conclusions. Consider this classic deductive syllogism:

All crows are black. (major premise)

This is a crow. (minor premise)

Therefore, this crow is black. (conclusion)

The conclusion is derived logically from the major and minor premises. The same logical processes would lead you to decide that the following conclusion is not warranted:

All crows are black.

This is black.

Therefore, this is a crow.

It is possible that the final conclusion is accurate, but you cannot logically decide on the accuracy from the information provided.

In the rationalistic approach, the conclusion is reached through **logic**—systematic rules that allow us to draw accurate conclusions from a basic set of facts or statements. Rationalism is a more reliable way to acquire knowledge than tenacity, intuition, or authority. However, rationalism has its limitations. Consider this syllogism:

All four-year-old children develop fears of the dark.

Lisa is a four-year-old child.

Therefore, Lisa has developed fears of the dark.

The logic is clear and the conclusion is correct, unless of course Lisa has not developed fears of the dark. What is the limitation? Rationalism is a powerful tool for analysis of propositions or theories. However, its weakness lies in its application to external events. Suppose that it is not true that all four-year-old children develop fears of the dark, or suppose that Lisa is actually seven and not four, or suppose that Lisa is a yacht and not a child. The major limitation of rationalism is that the premises must be true, as determined by some other evidence, to arrive at the correct conclusions. The accuracy of conclusions depends on both the reasoning process and the accuracy of the premises. Unfortunately, when the purely rationalistic approach is applied to external events, there is no provision for assessing their accuracy. (See the Student Resource Website at graziano-raulin.com for a primer on logic.)

01:01

## Empiricism

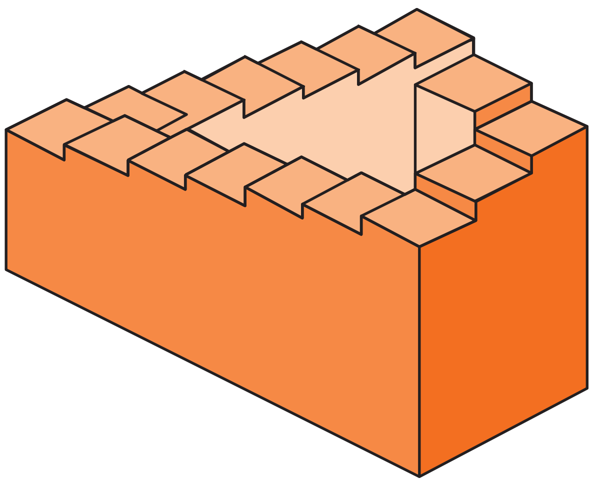
**Empiricism** involves gaining knowledge through observation—knowing something by experiencing it through our senses. For the empiricist, it is not enough to know through reason (or tenacity or intuition or authority) alone. It is necessary to experience the world—to see, hear, touch, taste, and smell it. "I won't believe it unless I see it!" is the empiricist's motto. We are good empiricists when we notice a dark sky and hear distant thunder and decide to take an umbrella. Our senses are telling us something.

However, empiricism also has limitations. There are two types of empiricism: **naïve empiricism** and **sophisticated empiricism**. The statement "I won't believe it unless I see it!" is an example of naïve empiricism. Suppose you have never seen Hong Kong, Prague, Nyack, or Chippewa Falls; does this mean that these places do not exist? Because you have never seen gravity or the measles virus, should you conclude that you will never fall down or contract measles? Suppose your empirical observations lead you to assert "I have never been run down while walking along the middle of a highway"; does that mean you can continue walking down highways with impunity? How about when you see something clearly that turns out to be an illusion, as in Figure 1.1?

Sophisticated empiricism goes further. People cannot see heat or gravity or, with unaided eyesight, the measles virus. However, they can observe the rise of the mercury in a thermometer as they turn up a heat

**Figure 1.1** Reality or Illusion?

You cannot always trust what you see.



**SOURCE:** Penrose, L. S., & Penrose, P. R. (1958). Impossible objects: A special type of visual. *British Journal of Psychology*, *49*, 31–33.

source, watch an object fall to the ground, and view a virus through an electron microscope. Empirical observations in science are not limited to direct observations; we can also observe phenomena *indirectly* by observing their impact on other objects, like thermometers.

Empirical observations (i.e., facts) are critical in science. However, if scientists did nothing but collect observations, they would achieve only long lists of facts. They would know nothing about how the facts go together or what the facts mean. Facts are most useful when people can think about them, organize them, draw meaning from them, and use them to make predictions—that is, when facts are carefully inserted into the logic of rationalism. *We need to integrate empiricism with rational thinking so that the two work together. This is what science does.*

## Science

Science brings together rationalism and empiricism, employing rational logic and checking each step with empirical observation. Scientists constantly shuttle between empirical observation, rational thought about general principles, and further empirical observation. This repeated return to empirical observation in an otherwise rationalistic process characterized the sixteenth century's surge into science. Much of the progress in science since then has focused on strengthening the empirical component by developing better observational procedures.

*Science is a way of thinking that involves a continuous and systematic interplay of rational thought and empirical observation.* Observed events, such as the movements of planets or the behavior of children, are the facts of science. The empirical observation of events and identification or listing of facts, while useful, is not sufficient in modern science. Scientists must go beyond observable facts to construct general principles and to make new predictions about nature based on those principles.

Darley and Latané began with a startling event (a fact) that a young lady was murdered while dozens of people watched and no one helped or called police. You would think that the more people around, the more likely that someone would help. But Darley and Latané reasoned that if that were true, it is unimaginable that not one of 38 witnesses helped although later information suggested that the 38 number may have been exaggerated by the reporter. So they suggested a different and counterintuitive principle that the more people around, the less likely that any of them would help. They reasoned that with lots of people to help, no single person will feel enough responsibility to step up and help. They called this principle "diffusion of responsibility." They went from observation to a (proposed) general principle. But science demands that they continue to cycle between observation and rational thought.

Although many persons do not understand or accept this idea, acquiring scientific knowledge is absolutely necessary for any modern nation's survival. Many, including elected officials, will accept technologies derived from science but reject knowledge derived from science as, for example, the often vehement denial of scientific knowledge about biological evolution and climate change. Such scientific knowledge, argues Robbert Dijkgraaf (2017) is a kind of infrastructure that is critical for modern society, and we should—for humanity's welfare—be embracing it, not denying it.

### Quick-Check Review 1.2

## Acquiring Knowledge

1. What are the common methods of acquiring knowledge?
2. Which two methods does science incorporate?
3. What is naïve empiricism? sophisticated empiricism?
4. What are the limitations of rationalism? . . . of empiricism?
5. What are the "facts" of science?

# Emergence of Science

**1.3 Summarize the contributions from various fields to the development of modern science.**

The rapid development of science through the fifteenth and sixteenth centuries may suggest that science suddenly emerged and that there was no science before Copernicus, Galileo, or Newton. However, science has been one of Western civilization's methods of acquiring knowledge since the Greeks of 2,400 years ago, and its antecedents date back 8,000 years. Not until the Renaissance did science become independent enough to develop into the powerful social movement that it is today. This section reviews the historical bases of science. (See the Student Resource Website for a more detailed History of Science overview.)

01:02

## Early Civilization

Over millennia, humans developed a broad array of skills that enabled a remarkable surge of progress from the late Neolithic period of polished stone tools into the age of metals, about 6000 to 4000 B.C. Urban settlements grew; technological, social, and intellectual tools accumulated; and societies spread around the eastern Mediterranean. The magnificent civilizations of the Babylonians, Egyptians, and others flourished. Their skills included architecture, agriculture, animal husbandry, food preparation, mining, smelting, and tool manufacturing. Their commerce depended on long-distance land and sea navigation, weights, measures, counting, written records, and accurate calendars. By 4000 B.C., there were books on astronomy, medicine, surgery, and mathematics. However, these remarkable advances coexisted with mystical beliefs about a universe filled with gods, demons, and spirits.

By 1000 B.C., there was a rich legacy of practical skills in agriculture, mining and metallurgy, manufacturing, and commerce. From such practical skills and knowledge, abstract concepts were gradually developed (Farrington, 1949a, b). For example, early farmers observed weather phenomena, moon phases, sun positions, and other changes in the sky for clues to help in farming. These observations led to the development of accurate calendars. Farmers also learned about fertilizers and plant growth and developed practical mathematics to measure plots and set boundaries. Artisans learned to recognize various ores. They knew that heat transformed solids into liquids; they could measure by weighing; and they understood proportionality, allowing them to reproduce the particular mixtures needed for various alloys. These skills required an abstract understanding of nature gathered and refined through generations of empirical observations and concrete manipulations. Apprentices of the day may not have studied abstract astronomy or mathematics, but early elements of these disciplines were embedded in their crafts. In these early Mediterranean civilizations, the components of modern science developed within the arts, crafts, and trades. Science, art, and technology were inseparable in practice.

Science rests on the **orderliness belief** (Whitehead, 1925), which is the assumption that the universe operates in an orderly manner. To apply their skills in a reliable manner, early artisans and tradesmen had to expect orderliness. How else could they depend on *this* type of rock, when heated, to release *that* kind of metal, which will always have *these* properties, regardless of the different pieces of the rock used?

## Greek Science

Empirical science dates to the pre-Socratic Greek period (c. 600–c. 400 B.C.). Thales (c. 625–c. 547 B.C.) was the first Greek philosopher to combine empirical and rational views of the universe. He lived in Ionia, a Greek colony, whose citizens developed impressive commercial skills. The Ionians were pragmatic realists—primarily artisans, farmers, and tradespeople. Empirical knowledge was basic in their culture, and when some, like Thales, turned to philosophy, they developed an empirical view of nature.

Thales' philosophy rejected mysticism and stressed the observation of natural events in a natural universe. He speculated about a natural cosmology in which water was the basic substance from which all else developed and to which all will ultimately return. He studied Babylonian astronomy and predicted the solar eclipse that occurred on May 25, 585 B.C. His observations were careful and painstaking (Whitehead, 1925). Thales founded abstract geometry and Ionian philosophy, and many historians consider him the father of science.

Thales's naturalistic speculations inspired others. Anaximander's (610–547 B.C.) observation that sharks had mammalian characteristics led him to propose that higher-order creatures, including humans, developed from fishes. Xenophanes (c. 560–c. 478 B.C.) observed rock imprints of fish and seaweed on mountains and proposed a theory of geological change over time. Hippocrates (c. 460–c. 377 B.C.) taught that demons and gods played no part in disease, and that prayers and exorcisms would not heal a sick person. The Hippocratic physician relied on careful observations of patients and on rational thought in trying to understand illness.

From Thales through Hippocrates, Ionian science emphasized the observation of naturally occurring events in an orderly universe. A later Ionian, Strato (d.c. 270 B.C.), developed another important step—making the scientist an *active* observer who manipulates and controls the conditions of observations. Strato, a successor to Aristotle, taught that the best method of acquiring knowledge was empirical manipulation and observation, that is, **experimentation**. He experimented on air and water, demonstrating many of their properties and developing general explanatory principles about nature.

However, by Strato's time, Ionian empirical science was already in decline. The mystical views of religious authorities and the philosophical views of Plato and Socrates were displacing Strato's scientific view. Then, as now, these views conflicted, leading to the suppression of early empirical science for almost 1,900 years.

After Socrates, the highest ideals were found in religion, politics, and rationalistic, mystical philosophy. Practical skills were maintained, but were left to slaves, laborers, artisans, farmers, and tradespeople. Upper-class scholars pursued pure reason and abstract ideas. As a result, scholars taught theology and philosophy and preserved their knowledge in writing, whereas empirical skills, not admitted into the realm of scholarship, remained an oral tradition. Social stratification was not the only factor contributing to the suppression of empiricism. Religious leaders used their increased social power to attack the Ionians' natural philosophy as atheistic, inaccurate, and subversive. Does this echo from 2,000 years ago sound a bit familiar? How about some of today's science-religion conflicts?

The genius of the early Greeks created an empirical science that described an orderly universe operating according to a few basic principles. Greek philosophy was one of humanity's major intellectual achievements. Yet, at the height of this achievement, Plato and Socrates led the movement away from empiricism with a focus on the pursuit of pure reason. As Farrington (1949a) noted, "When Plato died (c. 347 B.C.), he left behind a mystical view of the universe set forth in his dialogues in a unique combination of logic and drama. Its weakness was not that it lacked supports in argument, but that it was not open to correction from experience."

After 400 B.C., Greek philosophy became increasingly mystical, altering the way people viewed discoveries. For example, philosophers argued that the regularity of number relationships and the orderliness observed in astronomy were evidence that divine intelligence controlled nature. This led to a shift in the goals of philosophy and science. Earlier investigators wanted to understand and control nature, but later philosophers sought to illustrate divine intelligence through their study of nature. Science was beginning to be used in the service of religion, a role that continued for 2,000 years.