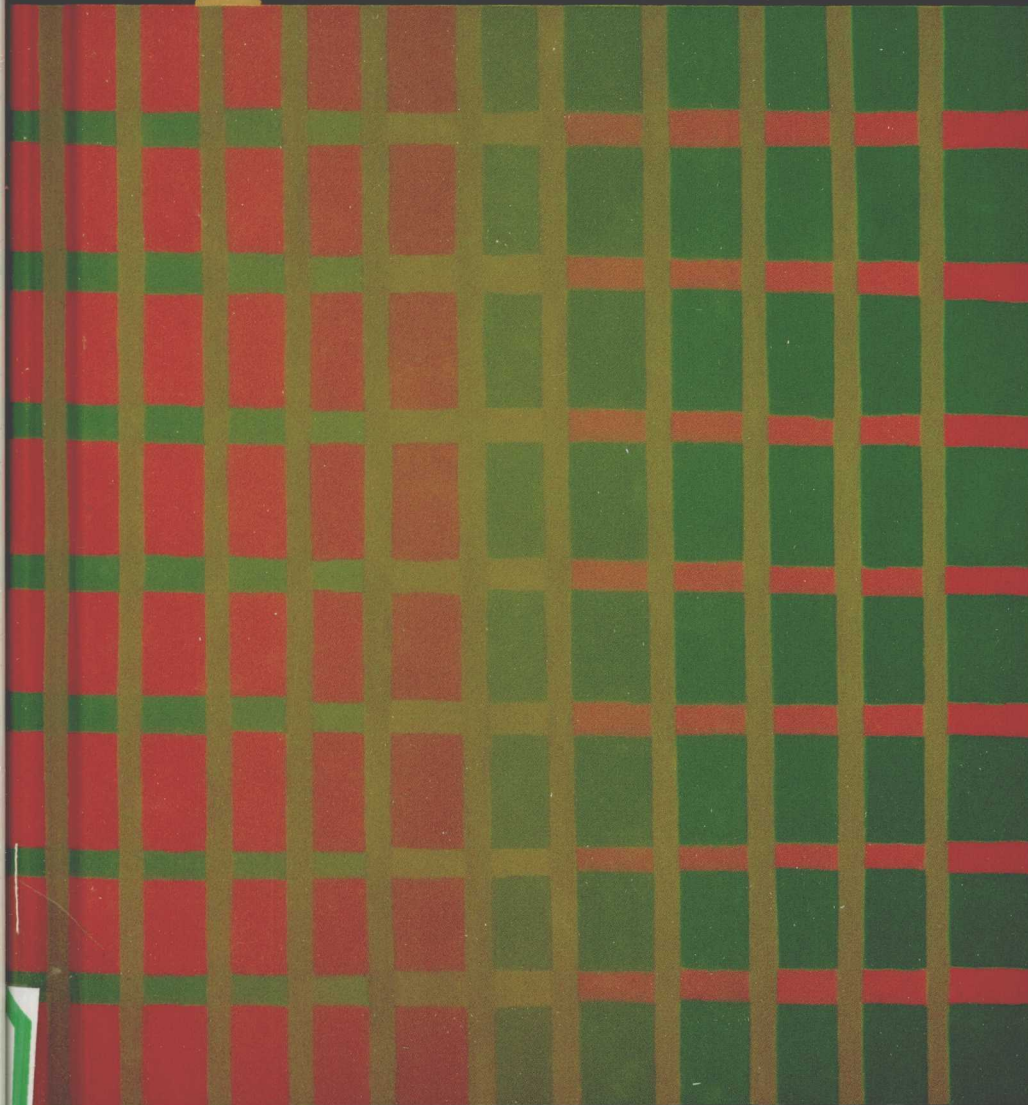


# perception

FIFTH EDITION



Randolph Blake / Robert Sekuler

# Perception

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F I F T H   E D I T I O N

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## Higher Education

### PERCEPTION

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# About the Authors



**RANDOLPH BLAKE** is Centennial Professor of Psychology at Vanderbilt University, Nashville, Tennessee, where he is also a Fellow of the Kennedy Center for Research in Human Development, a member of the Vision Research Center and the Center for Cognitive and Integrative

Neuroscience. He served as chair for the department of Vanderbilt's psychology department from 1988 to 1996. For fourteen years before coming to Vanderbilt he was on the faculty of Northwestern University. Blake received his Ph.D. from Vanderbilt in 1972 and then spent two years as a postdoctoral fellow in the Sensory Sciences Center at the University of Texas Graduate School of Biomedical Sciences.

Blake has published extensively in major psychology and neuroscience journals and has contributed chapters to edited books, including *Models of the Visual Cortex*, *Frontiers of Visual Science*, *Early Vision and Beyond*, and *the Primate Visual System* (with Sekuler), and coedited the recently published book *Binocular Rivalry*. His research, supported by grants from the National Science Foundation and the National Institutes of Health, focuses on visual perception with particular emphasis on binocular vision, motion perception, and perceptual grouping. In recent years, Blake's research has expanded to include functional brain imaging of visual areas involved in perception of human activity.

In recognition of his research contributions, Blake received a Career Development Award from the National Institutes of Health, and the American Psychological Association's Early Career Award for Distinguished Scientific Contribution. In 2002, he received the Sutherland Award for Research Accomplishment from Vanderbilt University. Blake is an elected Fellow of the American Association for the Advancement of Science, the American Psychological Society, and the John F. Kennedy Center for Research on Human Development. He is a past member of the Committee on Vision of the National Academy of Sciences/National Research Council and the Sensory Sciences Advisory Panel of the National Science Foundation. During 1992 and again during 2004, he was a Fellow of the Japan Society for the Promotion of

Science, and in 1995, he held the William Evans Professorship in Psychology at Dunedin University, New Zealand. His professional memberships include the Association for Research in Vision and Ophthalmology, Sigma Xi, the Vision Sciences Society, the American Association for the Advancement of Science and the American Psychological Society.



**ROBERT SEKULER** is the Louis and Frances Salvage Professor of Cognitive Neuroscience at Brandeis University and Consultant in Neurosurgery at Children's Hospital (Boston). At Boston University, he is Adjunct Professor of Cognitive and Neural Sciences, and a member

of the NSF-funded Center of Excellence for Learning in Education, Science, and Technology. At Brandeis, where he served as the university's provost, Sekuler is now a member of the Volen National Center for Complex Systems, an interdisciplinary center for the study of the brain, and the Program in Neuroscience, which he has chaired. After earning his Ph.D. at Brown University in 1964, he held an NIH postdoctoral fellowship at the Massachusetts Institute of Technology. For the following 24 years, Sekuler was on the faculty at Northwestern University, where he was John Evans Professor of Neuroscience, and held the rank of professor in the departments of psychology, ophthalmology, and neurobiology and physiology. After chairing Northwestern's department of psychology for six years, he went on to serve five years as Associate Dean in the College of Arts and Sciences.

A leader in the fields of motion perception and age-related changes in perception, Sekuler has published more than 200 scientific papers and has contributed chapters to various books including the *Handbook of Perception*, the *APA Encyclopedia of Psychology*, the *Handbook of Sensory Physiology*, *Stevens' Handbook of Experimental Psychology*, and the *Oxford Textbook of Geriatric Medicine*. He chaired the National Academy of Sciences' Committee on Vision, and directed the Academy's study entitled "Aging Workers and Visual Impairment" as well as its study of "Vision and Aging."

Those projects led to his coedited book, *Aging and Visual Function*. In recent years, Sekuler's research program, funded by the National Institutes of Health and the National Sciences Foundation, has expanded to include functional brain imaging and electrophysiological studies of visual memory and visual cognition.

In 2000, Sekuler was a visiting scientist at the Rotman Research Institute of Toronto's Baycrest Centre for Geriatric Care, and a visiting professor of psychology at the University of Toronto. He has served on the board of the Hugh Knowles Center on Hearing and its Preserva-

tion, and on the Sensory Physiology of Advisory Panel of the National Science Foundation. Sekuler is an elected fellow of the American Psychological Society and the American Association for the Advancement of Science; he is a member of the Psychonomic Society, the Vision Sciences Society, the Society for Neuroscience, and the Association for Research in Vision and Ophthalmology.

In addition to this book, Blake and Sekuler coauthored the award-winning *Star Trek on the Brain: Alien Minds, Human Minds* (1998; paperback and Japanese editions 1999).

**F**rom the moment you awake in the morning until you nod off at night, your mental and physical activities are guided by the barrage of environmental information supplied by your senses. All your activities—driving, reading, eating, conversing, typing, exercising—are strongly influenced by what you see, hear, feel, touch, smell, and taste. Perception is crucial to everything you do. But unlike the many abilities that you work hard to master, perception comes naturally and effortlessly: everyone is a natural-born perceptual genius. In fact, perception's effortless nature belies its complexity, and that is one reason teaching or writing about perception can be challenging: it is not immediately obvious that there is anything to be explained. If you ask a friend how he or she goes about solving a jigsaw puzzle, your friend will be able to list the steps involved (turn all the pieces face side up, arrange them in piles according to color, and so on). But if you ask the same person to explain how he or she goes about reading the words on this page, the person is likely to shrug, pause a moment, think, and then say something such as, "I just look at the page and read." Perception seems easy and automatic, but this greatly underestimates the complexity, beauty, and remarkable achievements of perception.

## Goals of this Textbook

In first writing and then revising our textbook one of our consistent goals was to help readers appreciate the complexity and intelligence of all the processes that make perception possible. Our book introduces readers to the exciting behavioral and biological research that illuminates the remarkable achievement we call perceiving. Our aims have remained constant over five editions: *By conveying science's cumulative progress, we want to give readers a fresh, new perspective on their own seeing, hearing, touching, smelling, and tasting.* Following the pattern set by its predecessors, this latest edition of *Perception* emphasizes the field's exciting new developments. In preparing this edition we listened carefully to feedback from users of previous editions and tried to accommodate their advice and suggestions. The result? A new edition that is substantively and significantly dif-

ferent from previous ones. The following sections highlight the ways in which we've tried to improve this fifth edition of *Perception*.

## Organization and Coverage

The first chapter summarizes the motivations that inspire people to study perception, as well as the various approaches that such study takes. It also outlines the framework on which the entire text is constructed. Chapters 2 through 8 discuss seeing—the biological bases of vision and the perception of pattern, color, and depth. The treatment of seeing concludes in Chapter 9 with an essay on the perception of visual events, particularly visual motion. Chapters 10, 11, and 12 provide a sweeping introduction to hearing, with special emphasis on speech and music (Chapter 12). Chapter 13 explores the sense of touch, and the book's last two chapters deal with the chemical senses, Smell and Taste (Chapters 14 and 15).

Two chapters are new to this edition, and other chapters have been revised substantially to capture and communicate the accelerating pace of significant new discoveries. Recent exciting developments in speech and music perception demanded that we devote an entire, new chapter (Chapter 12) to those topics. And dramatic growth in research on the chemical senses required such an expansion of coverage that we had to replace the previous edition's single combined chapter with two larger, separate chapters, one on smell and one on taste (Chapters 14 and 15). Material on cognitive influences on perception has been updated and expanded; in this edition, as in the previous one, we have integrated this material into the text, rather than consigning it to its own, separate chapter as was done in the first three editions. When it comes to important methodological details and techniques, we continue to believe that this material is best introduced within the context of substantive problems. So readers will be exposed to techniques such as direct scaling and multidimensional scaling within the body of the text. We do, however, offer more concentrated coverage of those techniques in the Appendix.



## Special Features of the Fifth Edition

This fifth edition of *Perception* has several noteworthy features. First, attentive readers may notice that the order of authors has been reversed, from Sekuler and Blake, to Blake and Sekuler. This change should communicate that despite the order used in all preceding editions, we have been equal partners throughout. Second, the format and layout of the book have been greatly improved. The new large format gives the book a more contemporary look, makes the text easier to read, and leaves more space for those important notes that readers will want to make in the book's margins. Third, as explained above, the book's chapter count has grown by two. We recognize that in many courses the expansion of the text makes it less likely that the entire text will be assigned reading. However, chapters have been carefully constructed so that readers would be able to sample portions of chapters without necessarily reading the whole thing. In this way, we hope that readers will be able to get a sense of important developments in topics that they might not otherwise be exposed to. Fourth, the text embeds central topics firmly in their historical context. This allows us to present today's perception research for what it really is: the product of an unfolding, continuing intellectual process. At the same time, our source materials are frankly biased toward recently published material. Because we want readers to appreciate developments at the frontiers of perception, we give thorough coverage to "hot," rapidly developing topics, at the same time ensuring that such coverage is closely integrated with its intellectual origins. For example, one chapter provides a comprehensive treatment of recent discoveries concerning natural scene statistics, and the ways in which properties of the natural world are mirrored in the properties of perception; others highlight the amazing plasticity of sensory systems; and still other chapters detail the latest thinking on genetic determinants of color vision, the chemical senses, and what is popularly known as tone deafness. In almost every chapter, pivotal ideas are illustrated by studies that exploit the technology and insights of functional neuroimaging. Our special emphasis on recent work and the most up-to-date techniques testifies, again, that perception is a dynamic and growing field.

### Illustration Program

The extensive program of several hundred illustrations, many brand new and all substantially revised for this edition, is another of this book's most important features.

And the number of all-important color plates has almost doubled from the previous edition. Our own years of teaching experience, more than six decades combined at last count, have taught us that readers don't always see in a diagram or graph exactly what was intended. In fact, the ability to read a graphic is a skill that, like any other skill, requires practice. So instead of merely directing readers to look over the figure, we crafted and coordinated the text, figures, and figure captions to ensure proper interpretation of the illustrative material. In addition, we have given extra care to the graphic presentation of complex ideas. Such ideas are often conveyed in this book by a short series of illustrations, with each illustration in a series introducing additional concepts. This approach enables every reader to get the point—even those who are novices at interpreting graphs and diagrams. Finally, illustrations that depict previously published experimental results have been adapted and redrawn to maximize clarity and consistency of presentation.

### Vocabulary and Methods of Perceptual Research

Because the study of perception draws upon a number of distinct disciplines—physics, chemistry, anatomy, psychology, computer science, and some branches of medicine, among others—its technical vocabulary incorporates the terminology of those disciplines. Beginning students of perception can feel bewildered by the flood of new terms they must master. Because we do not want technical vocabulary to obscure the book's important messages, we introduce only those terms that are absolutely necessary to the discussion. Where it is likely to aid memory or understanding, we explain the term's origin. Also, each term is carefully defined when it is first used, and all these terms appear at the end of each chapter and in a glossary at the back of the book.

We have kept detailed, abstract descriptions of research methods to a minimum. Where appropriate, we explain particular methods in enough detail that all of our readers can appreciate the methods and whatever constraints they impose on results and conclusions. Various methods for studying perception are discussed within the context of the specific problems that they were designed to solve. By integrating methods and results, we hope to facilitate the reader's genuine appreciation of both.

An appendix provides much additional information about conventional behavioral methods for studying perception. The appendix also describes contemporary variants of those methods: forced-choice procedures, signal detection theory, and adaptive psychophysical methods.

Like the rest of the book, the appendix grounds its presentation in historical context, enabling the reader to understand not only the methods but also the reasons for their development.

## Links to Everyday Life

In “Talks to Teachers” (1892), William James advised teachers how best to adapt the principles of psychology to the classroom. In one chapter, James urged teachers to recognize and exploit the natural interests that students bring to any topic. He suggested that abstract facts and new ideas are most readily assimilated when they have been linked to matters that students find inherently interesting, particularly matters that relate to their own lives. In our own classrooms and while writing this book, we kept James’s advice in mind. Perception is not just an abstract, scientific discipline, but an integral and fascinating part of everyday life. Recognizing this fact, our book consistently relates scientific research on perception to the reader’s own perceptual experiences. To underscore the relationship between science and everyday experience, we present many interesting demonstrations that readers can perform on their own with little or no equipment.

In order to anchor the discussion in the reader’s own experience, the text emphasizes the everyday behavioral needs that seeing, hearing, smelling, tasting, and touching are designed to satisfy—the functions of perception. This functional approach to perception is highlighted by the many discussions, throughout the text, of clinical disorders and their intriguing perceptual consequences. Some students will be interested in learning about these disorders for personal reasons; all students should find that the study of perceptual disorders provides insight into the nature of normal perception.

## Integration

William James also advised that teachers take care to connect new ideas and facts with what students have already learned. Associate the new with the old in some natural and telling way, so that the interest, being shed along from point to point, finally suffuses the entire system of objects of thought. In his own textbook, *The Principles of Psychology*, James followed this counsel, to great success. As we wrote and revised this book, we thought of James’s advice and have attempted to make our treatment of perception an integrated one, in part by linking ideas across chapters. These linkages reflect the fact that different areas of perception often utilize similar

techniques and related theoretical ideas. Our text is integrated in another way, blending anatomy, physiology, and psychophysics. The information and ideas from each of these three approaches have been carefully selected to ensure a coherent, complete presentation. Structure and function become more comprehensible and memorable when they are integrated. We like to think that James would approve.

Although our book is not meant to be a comprehensive reference volume, we know from experience that many readers will want to follow up with additional reading on some point that particularly caught their interest. To help this process, we provide a comprehensive list of references, with more than 1,700 entries. Scrutiny of the list reveals that 20 percent of those references are *new* to this edition; many older references from the previous edition were eliminated because they were outmoded or superseded by new references. Nearly all of the new references represent contributions published in the last three years, including 79 published in 2004 and 7 published in 2005. In addition, we have provided Web links to many exciting sites where readers can experience perception-related demonstrations and can learn more about topics introduced in the text. These Web links, which will be regularly updated, can be found at <http://www.mhhe.com/blake5>.

## Supplements

### Instructor’s Manual and Test Bank

Prepared by Robert O’Shea (University of Otago), the Instructor’s Manual provides many useful teaching tools. For each chapter, a general overview, learning objectives, detailed chapter outline, teaching tips and activities, and a summary are provided. The Test Bank also prepared by Robert O’Shea, includes matching, multiple choice, true-false, and essay questions for each chapter. Both the Instructor’s Manual and Test Bank are available on an Instructor’s Resource CD-ROM. In addition, The Instructor’s Manual can be found on the password-protected instructor’s side of the book-specific Online Learning Center [www.mhhe.com/blake5](http://www.mhhe.com/blake5).

### EZ Test

The Test Bank is also available in computerized format on the Instructor’s Resource CD-ROM. McGraw-Hill’s EZ Test is a flexible and easy-to-use electronic testing program. The program allows instructors to create tests from book specific items. It accommodates a wide range



of question types and instructors may add their own question. Multiple versions of the test can be created and any test can be exported for use with course management systems such as WebCT, BlackBoard, or PageOut. EZ Test Online give you a place to easily administer your EZ Test created exams and quizzes online. The program is available for Windows and Macintosh environments.

### Online Learning Center

The Online Learning Center website for *Perception*, Fifth Edition, includes a number of resources for instructors and students to enhance the teaching and learning experience. The Student Center includes learning objectives, chapter outlines, practice quizzes (prepared by Robert O'Shea), web links, flashcards, and other tools. Visit the Online Learning Center at [www.mhhe.com/blake5](http://www.mhhe.com/blake5).

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While we worked on the book's first two editions we were fortunate in having adjoining offices and laboratories. That physical proximity made it easy for us to share materials, ideas, comments, and suggestions, and to strengthen our friendship. It also enabled us to do much of the writing while we both sat at a single computer that was specially outfitted with twin keyboards—in the style of pianists playing music for four hands. Because our academic bases now are separated by 1,640 kilometers, we have resorted to other means to continue our close, highly interactive collaboration. We've made intense, but fun home-to-home visits—Blake to Concord, Massachusetts, and Sekuler to Nashville, Tennessee. For our more usual interaction, though, we depended upon the Internet, most recently taking advantage of Apple's iSight and iChat technologies for video visits.

Our electronic virtual closeness gave each of us complete pride of ownership for the entire text. Of course, files, comments, and drawings shared over an electronic network are not the same thing as sitting side by side, but they proved to be an acceptable substitute. Both of us have

vivid memories of weekend marathons during which we carried on prolonged, high-speed electronic dialogues over some matter or other. Even as we wrap up this fifth edition, we are working interactively, though separated by 14 time zones (Blake in Japan, Sekuler in Massachusetts). Researchers are adapting computer technology to create what is known as virtual reality, computer-mediated experiences that substitute for—and sometimes improve upon—the real thing. In this spirit, we have been delighted that the speed and ease of our largely electronic collaboration enables us to continue to be close colleagues, if only mostly of the virtual variety.

Thanks are owed to our students, colleagues, and especially our families for their tolerance and good humor during our preoccupation with this labor of love. We are also grateful to the McGraw-Hill editorial and production team, especially Judith Kromm, Senior Developmental Editor, and Cathy Iammartino, Project Manager, whose serious commitment to this new edition has made our work enjoyable and, we think, highly productive.

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# Introduction to Perception

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The world is filled with objects and events that generate a torrent of potential information. Though much of that information is irrelevant to people's daily needs, some is absolutely essential. To exploit this information effectively, human beings are equipped with specialized machinery that captures the information and translates it into the language of the nervous system. The brain refines this translated information into neural "descriptions" of behaviorally relevant objects and events in the environment. Some of these descriptions reach conscious awareness, allowing us to formulate deliberate plans for subsequent interactions with those objects; other descriptions guide immediate or reflexive reactions to objects and events.

**Perception** puts us in contact with the world we live in; it shapes our knowledge of that world, and knowledge is power. Our chances of survival improve markedly if we can detect objects and events in our environment and if we can, then, distinguish the safe from the dangerous, sort out the desirable from the undesirable. Knowing about our world allows us to predict the consequences of our actions, a critical skill in a constantly changing world.

Perception doesn't have to provide us with an accurate view of the world, perfectly detailed in every respect. What is crucial is that perception provide us with a *useful*

view of the world, where useful means being able to interact safely and effectively within our environment. As you will learn, perception accentuates the important and diminishes, or even ignores, the irrelevant. Perception may even misrepresent an object's true appearance, if that misrepresentation improves our chances of interacting effectively with that object. Sensory illusions represent an example of misrepresentation, and you'll be seeing many examples of sensory illusions as we move through the chapters. These illusions can be construed as perceptual mistakes that, paradoxically, work in our favor.

The environment generates a powerful stream of sensory information. In fact, there are so many objects and events that our perception cannot possibly process and respond to each one. Nonetheless—and fortunately for us—perception does work. Our perceptual systems overcome this potential sensory overload in several ways. For one, the world in which we live is full of regularities dictated by the physical nature of matter and energy. Those regularities make it easier to detect objects and to discriminate one object from another. For example, our visual system evolved in a world where light nearly always comes from above and, consequently, we unconsciously use that knowledge to interpret shapes of objects based on shadows. (You will see an example of

this constraint in Chapter 8.) Perception can exploit this and many other environmental regularities to make educated guesses about what in the world gave rise to a particular pattern of sensory stimulation.

There is a second effective way that perception deals with the environment's overwhelming complexity: it simply ignores much of what is going on in the world. Much of what the environment has to offer is simply of no interest to us. It is not important, for example, to sense the minute electrical fields generated by other biological creatures (including other people). Humans' keen sense of vision makes "electroreception" superfluous for members of our species. Consequently, our perceptual systems are tuned to those sensory events that are biologically relevant (or, more correctly, *were* biologically relevant to our primate ancestors). As you will learn throughout this book, animal species differ in their behavioral goals, and the goals of some species require sensitivity to sensory stimulation that falls outside our reality.

Perception arises from a complex interplay of mutually interdependent events. To understand perception completely—and no one yet does—requires knowing all the components involved in the process and the ways those components interact. To begin, we must specify the nature of the environment in which we live, for this environment determines *what* there is to perceive. Aspects of the environment are specified using terms derived from physics, because stimulation comes in various forms of physical energy: thermal, mechanical, chemical, acoustic, and electromagnetic. The physical energy that initiates the chain of events is called a **stimulus** (plural, "stimuli").

Next, it is necessary to understand how the nervous system converts patterns of physical energy into neural events. Known as **sensory transduction**, this conversion process requires an understanding of the specialized sensory receptors (such as those contained in eyes and ears) that convert physical energy into bioelectrical signals. Once this transduction has been achieved, objects and events are represented solely as patterns of neural impulses within the various sensory nerve fibers. From this point on, all further elaboration and editing of the sensory information must be performed using this neural representation.

Of course, the brain plays a central role in perception. So a full understanding of perception also requires knowing about various brain areas specialized for processing patterns of neural impulses arising from the various senses. A full understanding also requires knowledge of how the activity distributed among those many areas is combined to form our unified sense of the world. How, for example, do the neural signals conveying information about the sounds from an object combine with the signals generating the visual impressions of that object? In addition,

we need to discover how neural activity signaling the presence of objects is used to control our behavioral and emotional reactions to those objects.

A complete account of perception must incorporate a thorough description of the appearances of objects and events: we have to be able to describe systematically the sights, sounds, smells, and tastes that populate our conscious experiences. In addition to describing how things appear to us, we must also specify how our abilities to detect, discriminate, and recognize objects are governed by the information available to our senses. And, in a similar vein, we must understand the behavioral consequences of sensory stimulation, for our actions will modify those very patterns of sensory stimulation.

These tasks represent formidable challenges. Not surprisingly, scientists have developed diverse techniques for systematically cataloging the performance of our perceptual systems and relating that information to patterns of physical stimulation. The enterprise of relating physical stimulation to perceptual events is known as **psychophysics**. By specifying the relation between physical and perceptual events, psychophysics provides important clues to understanding the various steps leading from objects and events to perception.

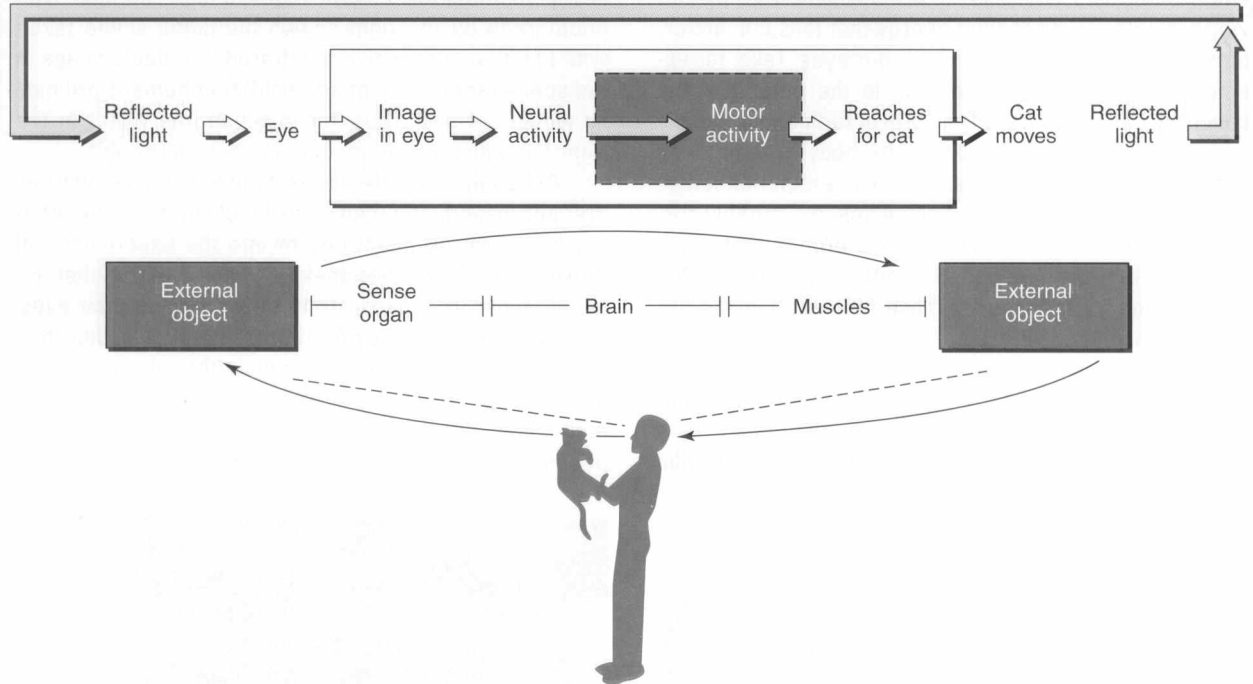
Perception constitutes a whole sequence of events, beginning with things that happen in the physical world external to the perceiver. From that start, perception proceeds through the translation of external events into patterns of activity within the perceiver's nervous system, culminating in the perceiver's experiential and behavioral reactions to those events. Those reactions, in turn, can affect the very same sensory events that triggered those reactions. All of this forms a closed loop in which perception alters behavior, and behavior, in turn, alters perception. This dynamic, continuous loop is schematized in Figure 1.1. Let's now consider several important implications of this way of thinking about perception.

## Perception Is a Biological Process

In this book, we approach perception as a *biological* process. To be perceived, *any* information about events in the world must be registered by the sensory nervous system. The noted neuroscientist Vernon Mountcastle has vividly described this constraint:

Each of us lives within . . . the prison of his own brain. Projecting from it are millions of fragile sensory nerve fibers, in groups uniquely adapted to sample the energetic states of the world around us: heat, light, force, and chemical composition. That is all we ever know of it directly; all else is logical inference. (1975, p. 131)

**FIGURE 1.1** | Perception registers and interprets sensory information from the environment, in this case light, that guides behavior, which, in turn, shapes the nature of input to the senses.



Mountcastle points out that sensory nerve fibers provide our only link to the external world; they alone represent our communication channels to reality. If environmental events fall outside the sensitivity range of our sensory channels, we will not experience those events directly. Now, it may be possible to detect some of these events indirectly, using specialized instruments that work in one of two ways. Some instruments *amplify* physical energy, making otherwise weak, undetectable signals strong enough to stimulate the senses. A microscope, for example, can magnify objects too small to be seen by the naked eye. This is the only way we're able to know what bacteria actually look like. Other instruments *convert* energy that is outside the normal bounds of any of our senses into a form that falls within those bounds. Geiger counters can warn about the presence of radioactivity, a form of energy that cannot be sensed directly by most creatures; the Geiger counter converts imperceptible radiation energy into audible sound or visible deflections of a gauge. Box 1.1 actually shows you what ordinarily invisible optical information may look like. Whether amplifying or converting energy, these specialized instruments all perform the same function—they extend the reach of our sensory systems into realms of physical reality that are normally beyond our perceptual grasp.

It may be difficult to accept that your rich perceptual world encompasses only a tiny, restricted portion of the objects and events in the natural environment. Because one's conception of reality is so intimately determined by subjective experience, it seems unnatural to distinguish between one's perception of the world and the world itself. Roger Sperry (1964) cast this distinction with beautiful clarity: "Before brains there was no color or sound in the universe, nor was there any flavor or aroma and probably little sense and no feeling or emotion." To understand perception fully, then, you have to make this distinction. Perhaps a few examples will enable you to appreciate what we mean by the limited scope of your perceptual world.

Consider, for instance, how different species of animals experience the world. It is well documented that not all animals have the same sensory systems. Consequently, various species have access to different universes of physical events (Hughes, 1999). You probably know that dogs can hear sounds in regions of the frequency spectrum where humans are deaf. You may not know, however, that bees can navigate using a quality of light, polarization, that is outside the realm of human visual experience; sharks hunt their prey by following electrical trails given off by their potential meal; bats use