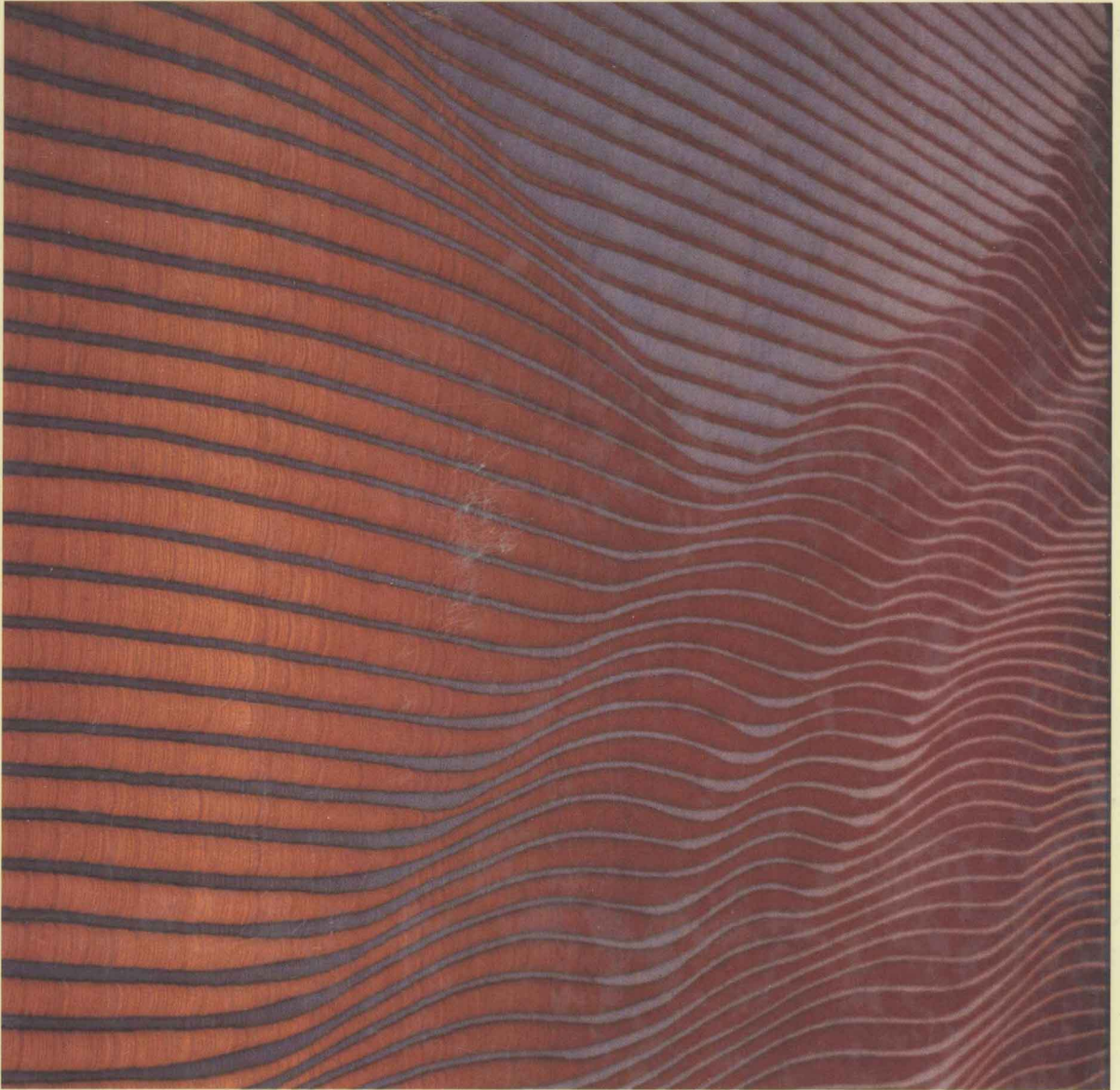


# SENSATION & PERCEPTION



E. BRUCE GOLDSTEIN

**4**<sup>TH</sup> EDITION

# SENSATION AND PERCEPTION

FOURTH EDITION

E. BRUCE GOLDSTEIN

University of Pittsburgh



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TO ESTHER S. GOLDSTEIN  
AND  
IN MEMORY OF  
HAROLD T. GOLDSTEIN  
(1911-1995)

## ABOUT THE AUTHOR



E. Bruce Goldstein is Associate Professor of Psychology at the University of Pittsburgh. He received his bachelor's degree in chemical engineering from Tufts University, his Ph.D. in experimental psychology from Brown University, and was a post-doctoral fellow in the biology department at Harvard University. Bruce is the author of *Psychology* (also published by Brooks/Cole) and has published numerous papers on visual physiology and visual perception. He teaches sensation and perception, introductory psychology as a natural science, the psychology of gender, and the psychology of art.

## PREFACE

My first research projects as a graduate student at Brown University asked the following questions about early events in the process of visual perception: How do visual pigments in the receptors react to light, and what is the nature of the electrical signals generated by these pigments? In my youthful enthusiasm I thought I would be able to understand perception by answering questions such as these about events in the receptors. I was not totally wrong, because the receptors do play a crucial role in the perceptual process. However, as I took my first graduate vision seminar with Lorrin Riggs, I soon realized that the perceptual process extends far beyond the receptors, stretching into the visual cortex and—as research was just beginning to suggest in the late 1960s—even into cortical areas beyond the visual cortex. I also became aware that perception cannot be understood by studying physiology alone. I learned that psychophysics—the study of the relationships between stimuli and perception—is central to our understanding of perception.

My appreciation for both the psychophysical and physiological underpinnings of perception has been reflected in each of the editions of *Sensation and Perception*, beginning with the first edition, which I began writing in 1977 and which was published in 1980. As I wrote the first edition and the revisions that followed, I have been motivated by a desire to tell both the psychophysical and physiological parts of the story of perception in a way that students will find interesting and easy to follow and which transmits the excitement I feel about this fascinating topic. As I have

pursued this goal in each edition I have made changes to update the story to reflect new developments in the field and to improve its telling to make it clearer and more accessible. In this, the fourth edition, I have made numerous changes in both content and presentation, while keeping the characteristics that so many people have appreciated in the previous editions. The following summarizes some of the features and changes in this edition of *Sensation and Perception*.

### *Telling the Story of Perception More Clearly*

The story of perception is a fascinating one that includes one of the most profound questions posed by nature: “How are electrical signals processed and interpreted by the nervous system to create perceptions?” The story of the search for the answer to this question is a theme that runs through this book. This story begins with a completely rewritten Chapter 1, which introduces the basic principles behind the physiological, psychophysical, and cognitive approaches to perception. Those familiar with the third edition will notice that the psychophysical methods, which previously were described in an appendix at the end of the book, have been moved to a more prominent place in this opening chapter.

Chapters 2 and 3 have also been reorganized to create a more logical unfolding of the story as we follow the visual process from the receptors (Chapter 2) to the lateral geniculate nucleus and

cortex (Chapter 3). The first three chapters are designed to provide the basic tools that the student needs to understand the rest of the book. As the story of perception continues past these introductory chapters we consider the specific visual qualities of color, form, depth, and motion. The third edition's chapter on brightness and contrast has been eliminated to make space for new developments in perception. However, much of the material from this chapter has been moved to Chapters 2 and 4. The chapters on hearing have also been reorganized, moving the physiological story to the front, followed by psychophysics and then speech perception. The result is a clearer, more logical treatment of the sense of hearing.

This edition's organization has also been streamlined by eliminating the Boxes that appeared in the third edition. Although many readers appreciated the interesting material contained in the boxes, others felt that they broke up the flow of the text. My solution was to eliminate the boxes, but to integrate most of the previously boxed material into the text.

### *New Research and Expanded Coverage*

One of the most rewarding aspects of preparing this revision was the opportunity it afforded to explore the new research in perception that has appeared in the seven years since I completed the third edition. There are far too many new additions to list them all here, but some examples are research on the binding problem in vision, parallel processing in the visual system, the newly proposed timing code for auditory localization, the phenomenon of duplex perception in speech perception, psychophysical channels for tactile perception, and new information on the role of genetics in determining taste experience. In addition, I have updated or expanded many topics, including neural coding, biologically based motion, the computational and spatial frequency approaches to visual perception, Fourier analysis

in hearing, auditory masking, and the perception of flavor.

### *Principles That Cut Across Senses*

An important theme of this text is that although each of the senses has its own unique qualities, there are basic principles that cut across all of the senses. This idea of basic principles is mentioned a number of times in the text but is especially highlighted in a few places. The chapter on color vision (Chapter 4), ends with a table showing how principles introduced in Chapters 2 and 3, such as convergence, excitation and inhibition, columnar organization, and parallel pathways, apply to the processing of information for color perception. The chapter on auditory physiology (Chapter 8) ends with a section called "Comparing the Senses," which points out parallels between audition and vision. Finally, the chapters on the somatic senses (Chapter 11) and chemical senses (Chapter 12) draw numerous parallels with the other senses.

### *Demonstrations*

The *Demonstrations*, a popular feature of previous editions, have been continued in this one. The purpose of these demonstrations is to provide perceptual experiences to illustrate some of the principles discussed in the text. The philosophy behind the demonstrations is to make them simple so that students will do them, and to integrate them into the flow of the text so that they become part of the ongoing story. This edition contains 52 demonstrations, a dozen of which are new.

### *The Medical Side of Perception*

Although material on the treatment of medical problems connected with the senses has not traditionally been included in books such as this

one, I decided to add material on clinical aspects of vision to the second edition because of my own curiosity about what was going on when I had my eyes examined. I have found that students think this material is as interesting as I do, and for this edition I have therefore expanded this chapter (Chapter 13) to include clinical aspects of hearing. It is particularly fitting that the book ends with a description of the cochlear implant operation, which was made possible by research on basic principles of auditory physiology described in Chapter 8.

### *The Illustration Program and Color Essays*

The extensive illustration program for which this text is known has been continued in this edition. There are over 600 diagrams, anatomical drawings, graphs, and photographs, about a dozen more than the number in the third edition; however, over 200 of these illustrations are new to this edition! Old illustrations were pruned and new ones added to reflect advances in research since the last edition. In addition, I have taken a new approach to color illustrations. Rather than presenting a group of color plates that are referred to at various places in the text but seem unrelated to each other, I have written three short “color essays,” which stand on their own but which also illustrate phenomena that are described elsewhere in the text.

### *Developmental Dimensions*

Perhaps the most obvious change in this edition are two new end-of-chapter features, *Developmental Dimensions* and *Other Worlds of Perception*. The Developmental Dimension feature expands the treatment of perceptual development to include all of the senses by presenting material on perceptual development in a special section at

the end of each chapter. Each of the Developmental Dimensions can be considered separately along with the chapter to which it relates, or a number of them can be combined to create customized units on perceptual development (see Appendixes A and B).

### *Other Worlds of Perception*

*Other Worlds of Perception* answers students’ questions about what nonhuman animals perceive. However, the purpose of this feature goes beyond simply answering students’ questions about what their dog or cat sees and hears. Its broader purpose is to introduce the idea that other species experience different perceptual realities than humans (such as the bat’s perception of sonar pulses and the honeybee’s perception of ultraviolet light) and that these different perceptual realities are interesting not only because they make us think about the nature of other animal’s experiences, but also because they emphasize the fact that the nature of perceptual reality is determined by the functioning of an organism’s sensory systems. Thus, *Other Worlds of Perception* reinforces one of the central themes of this book: Perceptual abilities can be traced to the way sensory systems are constructed. They also make the additional point that an animal’s sensory systems are often adapted to fit the animal’s needs and environment.

### *Other Learning Aids*

Another new feature is the end-of-chapter *Review*, with a general outline of the chapter in the left column and questions related to this outline in the right column. The data behind this new approach, which combines what used to be separate sections titled “summary” and “study questions,” is to provide a more meaningful and effective way to review the chapters. The outline provides a context for the study questions, which

the students can answer by returning to the keyed pages in the text. Another change is the placing of all of the definitions of bold-faced terms in a single glossary at the end of the book.

### *Help for the Instructor*

Two teaching aids, available to instructors, are a set of transparencies of some of the text's illustrations and a test bank, which I have written. The test bank, which is available both as a book and, for the first time, in computerized form, includes over 600 questions, many of which I have "class tested" in my own classes.

### *Exploring Perception CD-ROM*

*Exploring Perception*, a CD-ROM for Macintosh and IBM Windows is an exciting new ancillary available from Brooks/Cole. This interactive CD-ROM, which has been developed by Colin Ryan of James Cook University, North Queensland, Australia, gives students an opportunity to actively explore many of the concepts described in the text, including psychophysics, physiological principles, and perceiving color, form, motion, and depth. For further information about *Exploring Perception*, instructors can contact their local Brooks/Cole representative or inquire via email to [info@brookscole.com](mailto:info@brookscole.com).

### *A Message to the Student*

Although most of this preface has been directed to instructors, I want to close by addressing a few words to the students who will be using this book. As you read this book you will see that it is a story about experiences that may initially seem simple, such as seeing a face or smelling a rose, but that turn out to be extremely complex. I hope that reading this book helps you appreciate both the complexity and the beauty of the mechanisms responsible for these experiences. I hope that as you gain an appreciation for the impressive advances that researchers have made toward understanding perception, you will also appreciate how much is still left to be discovered. But most important of all, I hope that reading this book will make you more aware of how perception affects you personally. After all, perception is something you experience all the time, and the study of perception can enhance this experience. I've found that studying perception has made me more observant of my environment, more aware of my perceptions, and more appreciative of the miraculous process that transforms energy falling on receptors into the richness of experience. I hope reading this book has the same effect on you. If you have questions, comments or other feedback about this book, I invite you to communicate with me via email at [bruceg+@pitt.edu](mailto:bruceg+@pitt.edu).

*E. Bruce Goldstein*



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