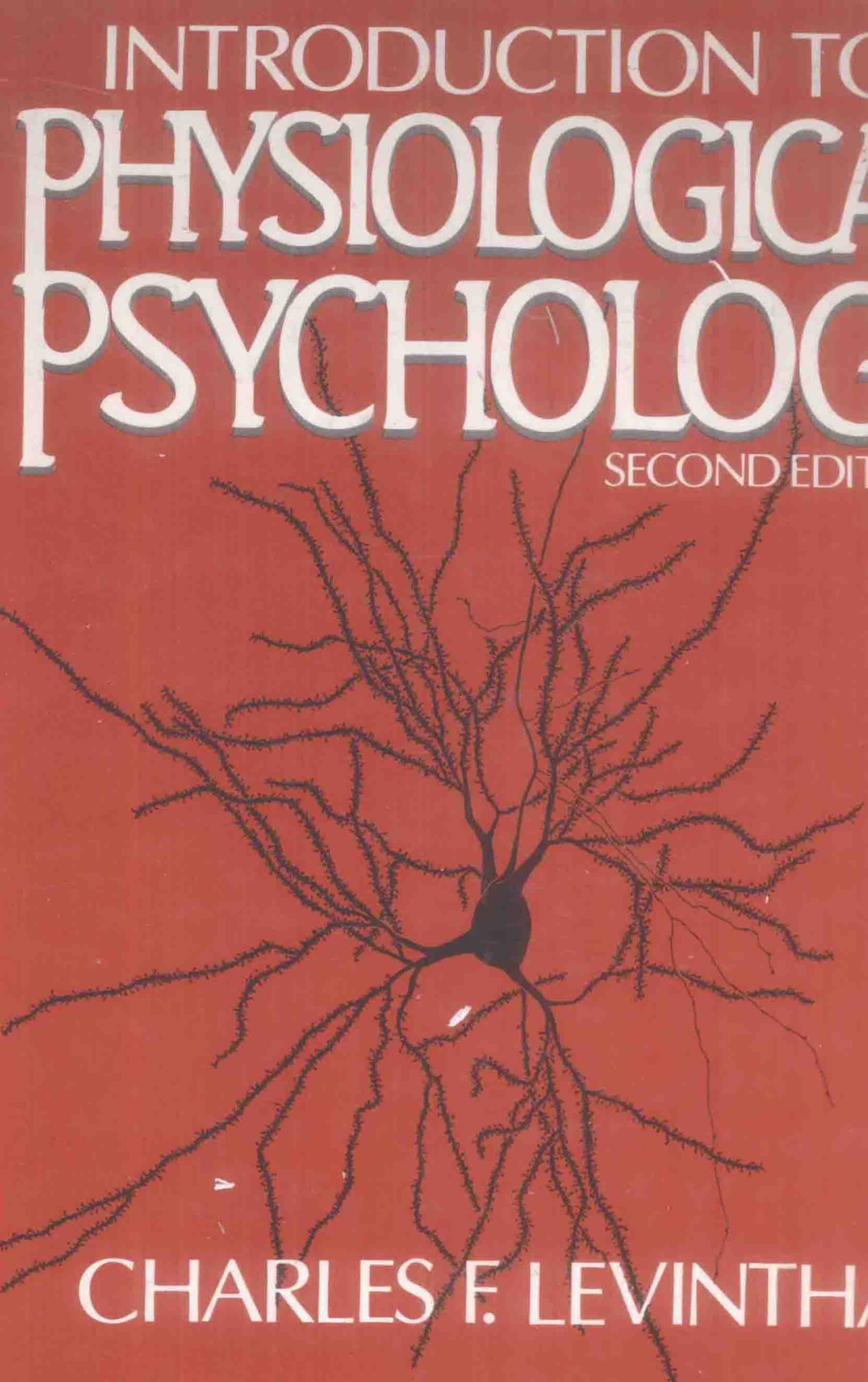
INTRODUCTION TO PHYSIOLOGICAL PSYCHOLOGY

SECOND EDITION



CHARLES F. LEVINTHAL

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FOR BETH

Preface

In the history of our understanding of the brain and its relationship to behavior, we are now at a watershed. For the first time, we can see, through PETT-scanning and cerebral blood flow studies, the direct functioning of the human brain *while thinking is actually taking place*. For the first time, we can grasp the physiological roots of schizophrenia and depression, through an understanding of brain chemistry. For the first time, we can relate conscious experience in general to physiological processes.

Physiological psychology will never be the same.

This second edition has been written specifically to reflect, not only the traditional areas known collectively as physiological psychology, but also the excitement of the current conceptual and methodological breakthroughs in neuroscience research. The primary audience is the undergraduate student, for whom an introductory course in physiological psychology may be the only formal exposure to this field. Yet, at the same time, for students inclined toward advanced study, *Introduction to Physiological Psychology* lays the foundation for a more detailed examination of the research literature in later courses. This book should also be useful to students in social work, psychiatric nursing, and sociology—fields in which an understanding of the physiology underlying behavior can be applied. No specific background in biology is assumed: all terms are either explained in the text or defined in the Glossary. Moreover, the length of the book has been deliberately kept within limits that are comfortable for a one-semester introductory course.

A major emphasis of the book, written as it is by a psychologist whose background includes both general experimental and physiological specializations, is on the ways in which physiological psychology fits into the larger framework of psychology in general and on the ways in which physiological psychology can be applied to everyday human experience. Consistent with these aims, the book will feature examinations of the relationship between left hemisphere/right hemisphere specializations and modes of thinking (Chapter 4); the influence of hormones in stress and sexual responding (Chapter 5); the biochemical theories behind the effects of psychiatric drugs (Chapter 6); the physiology of color blindness (Chapter 7) and deafness (Chapter 8); the sources of vertigo and motion sickness (Chapter 9); the disturbances of sleep (Chapter 10); the condition of human obesity (Chapter 11); the physiological bases for lie-detection tests and the complex relationship between brain disorder and aggressive behavior (Chapter 12); and the physiological causes of certain types of amnesia (Chapter 14).

Above all, the goal of *Introduction to Physiological Psychology* is to be understandable, relevant, and exciting. It is hoped that readers will want to learn more about the topics presented here, either by finding the articles cited in the text or by looking up the material listed as "Further readings," at the end of each chapter. There can be no better form of reinforcement for any teacher or author than this.

A number of individuals should be acknowledged for their help in the second edition of this book: Riki Bazell, Gary Book, Anna Halatyn, Eric Kuby, Joel Reicherter, and Barbara Rosenblatt for providing background information; Alice Kelly for supplying the derivation of words in the Glossary; Marcus Gmelin and Donald Pace for their technical assistance; Marion Anthony for typing the Instructor's Manual, and Donald Fagelman, Joanna Fowler, and Alfred P. Wolf for their cooperation in the gathering of information related to brain scanning.

I would also like to thank the following colleagues for their constructive comments on my manuscript: C. Sue Carter, University of Illinois at Urbana-Champaign; George S. Grosser, American International College; Yoshito Kawahara, San Diego Mesa College; John Liebeskind, University of California, Los Angeles; and Richard L. Russell, Santa Monica College.

Most important, I am grateful for the help of my wife in preparing a second edition of this book. She typed the entire manuscript and provided invaluable editorial assistance throughout the writing process. Her collaboration on this project made a potentially arduous and lonely task pleasurable. As always, her love and support made it all worthwhile.

Charles F. Levinthal

Contents

"Like the Milky Way entering upon some cosmic dance,
the brain is an enchanted loom where millions of
flashing shuttles weave a dissolving pattern, always
a meaningful pattern though never an abiding one;
a shifting harmony of subpatterns."

Sir Charles Sherrington

1

Introduction

For most of the time, the brain works quietly and unobtrusively. We tend to become aware of its functioning only when something goes wrong (as in an epileptic seizure) or when we try to push its capacity too far ("If I could only remember her name . . ."). And yet, it is nearly impossible to overestimate the importance of the brain in our everyday lives. Every gesture we make, every experience we have of our surroundings, every insight or memory, is a result of a complex, beautifully modulated series of events in a collection of twelve billion cells that we call the human brain. We owe our entire cognitive universe, our entire subjective experience, all of what we are or think we are to the functioning of these cells.

In 1906, the pioneering British neurologist Sir Charles Sherrington called the brain "an enchanted loom" and imagined it meticulously fashioning an enormous, interwoven tapestry. We may wish to update the metaphor to today's electronic age and call it "an enchanted computer," but it is certain that the enchantment has not diminished. There is no doubt that an understanding of the human brain remains both an awesome task and one of the greatest intellectual adventures that can be conceived. We are trying to understand more than simply an organ of the body. We are trying to understand ourselves as well. As the Spanish neuroanatomist Santiago Ramón y Cajal expressed it in 1934, at the end of a long and illustrious career, "As long as the brain is a mystery, the universe, the reflection of the structure of the brain, will also be a mystery."

Physiological psychology is a branch of psychology which concerns itself with the understanding of the relationship between the nervous system and behavior. Whenever we seek answers about the physiological processes underlying our perceptions of the world, our movements, our needs and desires, our knowledge of the past or our ability to learn, then we are dealing in the province of physiological psychology. The research in this area consists of a search for an understanding and

explanation of behavior in terms of the functions (hence the physiology) of the body. In particular, we have interest in the functions of the brain and spinal cord, and of specialized sense-organs, muscles and glands. Naturally, the primary focus of concern is upon the brain.

It is curiously ironic that, in the course of inquiring about the working of the brain, we are making use of that which is being inquired about. We are using our brains, as best we can, in order to understand how our brains work. In no other branch of science does that irony exist. Certainly, we make use of our hearts during the course of understanding how the heart functions (both as a source of information and to keep us alive); but it is not the heart which is trying to understand how the heart works. Yet we can understand how our brains function only to the extent that *our own brains* can find ways to search out, analyze, and integrate relevant information. The end product of all this intellectual activity is more than simply acquired knowledge. "One gains knowledge from words," the American biologist George Wald has said, recollecting the mood of Hermann Hesse's *Siddhartha*, "but wisdom only from things . . . . That is what science is all about, an attempt to extract wisdom from things." We may well add that what physiological psychology is all about is an attempt to extract wisdom from the brain.

THE HISTORY OF IDEAS ABOUT THE BRAIN

Despite the modern views concerning the relationship between the brain and behavior, the idea that the brain is important at all has gained acceptance only within the last three hundred years. In the Melanesian culture, the function of memory was attributed to the stomach, probably on the assumption that a repository of food would hold ideas as well. Likewise the larynx was considered to be the seat of the intellect since it was associated so closely with the production of speech. However, the majority of early cultures—the ancient Hebrews, Chinese, and Hindus—saw the heart as the seat of the mind. When the ancient Egyptians embalmed their dead Pharaohs, the heart and aorta remained within the body, the various other organs were venerated in special containers, but the brain was casually discarded (Broad, 1978; Doty, 1965).

At least a few prominent Greek philosophers viewed the brain as the seat of the mind. The words of Hippocrates in 450 B.C. stand as an eloquent and amazingly modern position on the subject.

> Men ought to know that from the brain and from the brain only, arise our pleasures, joys, laughter and jests, as well as our sorrows, pains, griefs and tears. Through it, in particular, we think, see, hear, and distinguish the ugly from the beautiful, the bad from the good, the pleasant from the unpleasant . . . In these ways I hold that the brain is the most powerful organ of the human body, for when it is healthy it is the interpreter to us of the phenomena caused by the air, as it is the air that gives it intelligence. Eyes, ears, tongue, hands and feet act in accordance with the discernment of the brain. . . . (Hippocrates, trans. Jones, 1923)

The writings of Hippocrates contained bold assertions (for their time) that such maladies as insanity and epilepsy were due to abnormalities of the brain.

Unfortunately, the views of Hippocrates were not shared by all of the other major Greek thinkers who followed. Plato (427–347 B.C.) agreed with Hippocrates,

though on the admittedly shaky grounds that the brain's roughly spherical shape and relative proximity to the heavens seemed to suggest an appropriate place for the seat of reason. But Aristotle (384–322 B.C.) disagreed, arguing that he could touch the brain and observe no sign of sensation. He concluded that the only function of the brain was to cool off the head and that the heart was the seat of the soul. The enormous influence of Aristotle as an authority on the natural world, as well as other matters, extended well into the Renaissance and made the cardiocentric (heart-centered) theory of the mind a viable alternative to the encephalocentric (brain-centered) view. As late as 1588, anatomy students at the University of Padua were being taught that "the heart is not only the origin of all the veins but also of the nerves." The philosopher and mathematician René Descartes could note in 1649 that some of his contemporaries still believed in the heart as the location for the mind, even though he personally opted for a small area in the center of the brain called the pineal gland. Shakespeare's *Merchant of Venice*, written in 1596, contains two lines that reflect, perhaps facetiously, a still-smouldering controversy:

> Tell me where is fancie bred
> Or in the heart or in the head
> (Act III, Scene 2)

The prominence of the heart in the description of emotional feelings even today seems ample proof that the Aristotelian viewpoint lingers on.[1]

A number of early scientific writers, however, focused upon the functions of the brain and served to counterbalance the influence of Aristotle. Galen (130–200 A.D.), a physician and surgeon to gladiators in Rome, asserted the importance of the brain to sensation, intellect, and memory. Yet Galen's interest in describing the anatomy of the fluid-filled ventricles coursing through the brain, instead of brain matter itself, led others to imagine that all the mental functions could be attributed to the ventricles themselves. Around 400 A.D., Bishop Nemesius of Emesa (now Syria), adopting the ventricular orientation of Galen, saw the ventricles as chambers and from this postulated three "psychic cells" in the brain. The first cell was the "sensus communis," responsible for sensations. The second cell was the "imaginativa," a seat of reasoning and judgment. The third cell was the "memorativa," where memories were stored and bodily movement initiated. Strangely, the "cell doctrine" lasted for more than a thousand years as the standard model of how the mind arose from the workings of the brain. A philosopher and mystic, Robert Fludd, proposed in 1619 a cosmic relationship between the three cells in the brain and the constellations in the sky (Figure 1-1).

The growing empirical orientation of the Renaissance eventually cast the cell doctrine into oblivion. Leonardo da Vinci in 1506 was able to visualize brain ventricles by the ingenious technique of injecting hot wax into the ventricles of an ox and then waiting for the wax to harden. The brain matter was then gently removed to reveal the ventricles themselves (Figure 1-2). The brain was still considered, as one writer has put it, "mere padding" (Broad, 1978) until Thomas Willis in 1664 began to theorize that mental functions were results of brain matter itself. In doing so he laid the foundation for modern neuroanatomy.

[1]We seldom leave our brains in San Francisco, nor does the brain figure conspicuously on St. Valentine's Day.

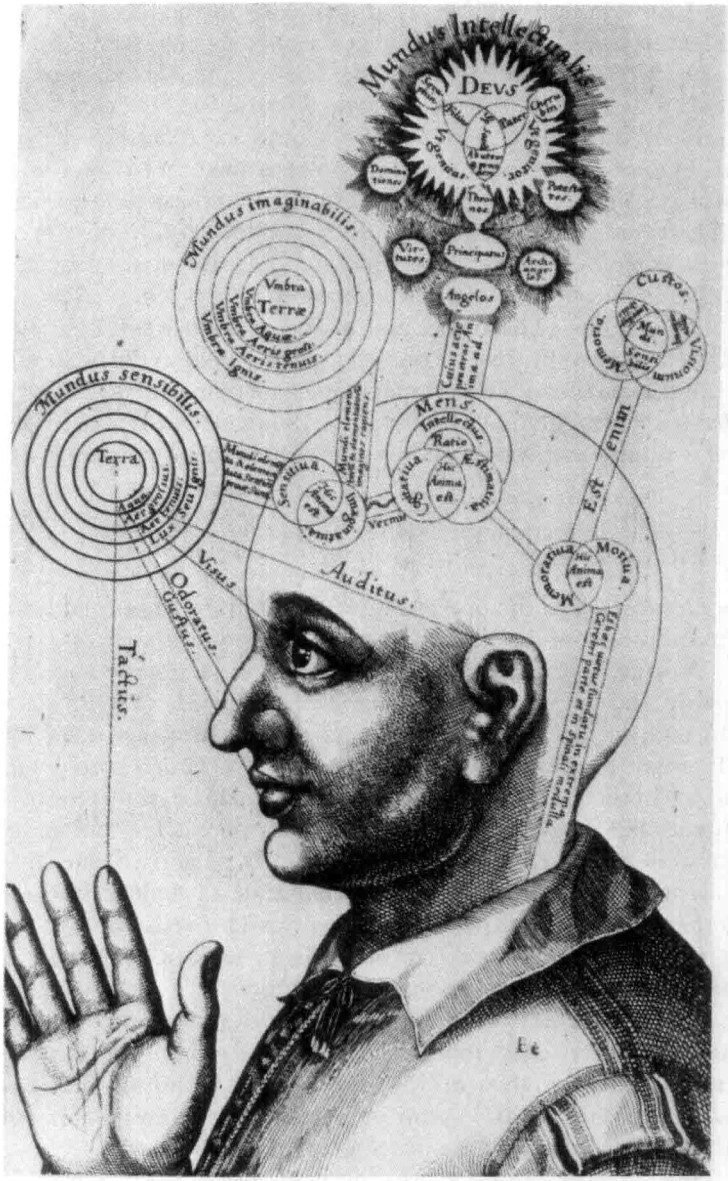

Figure 1–1. The "orbits of the mind" according to mystic Robert Fludd (1574–1637), based upon the three-cell conception. (From Blakemore, C. *Mechanics of the mind.* Cambridge: Cambridge University Press, 1977, p. 18. Originally from the *Utriusque Cosmi,* dating 1619–1621.)

In the latter part of the eighteenth century, two German anatomists, Franz Joseph Gall (1758–1828) and Johann Spurzheim (1776–1832), took Europe and later America by storm in proposing that personality traits could be attributed to specific regions of the brain and that the bumps and depressions of the skull surface

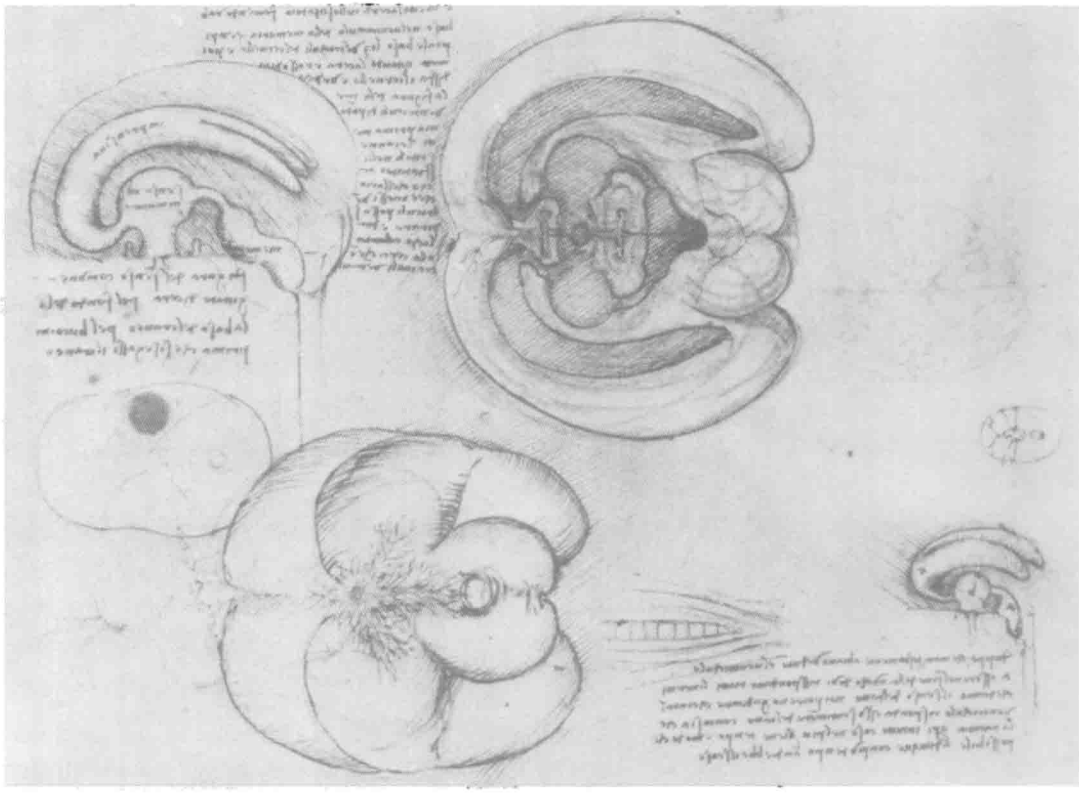

Figure 1–2. Leonardo da Vinci's drawing of the ventricles, as observed through his wax casts. (From Blakemore, C. *Mechanics of the mind.* Cambridge: Cambridge University Press, 1977, p. 20.)

could show correlations with different types of human behavior. Gall had noticed as a boy that individuals with certain skull shapes seemed to have had certain dominant personality traits. The study of these relationships became known as **phrenology**.[2] While eventually discredited by most scientific authorities, the appealing notion of phrenology captured the imagination of the general public. The original classification scheme of Gall listing 27 traits was expanded by Spurzheim (Figure 1–3), and later versions eventually included 160 "centers." Phrenology journals continued publication well into the twentieth century. As late as 1938, there was an Ohio State Phrenological Society with its own journal (Blakemore, 1977).

While the extreme claims of Gall and Spurzheim are now viewed as ridiculous, it should be pointed out that the phrenology movement encouraged scientific research into possible relationships between specific brain areas and types of behavior. The most notable success during the nineteenth century was a finding by the French physician Pierre-Paul Broca (1824–1880). In 1861, Broca examined a

[2]All terms printed in boldface type will be defined in the Glossary at the end of the book.