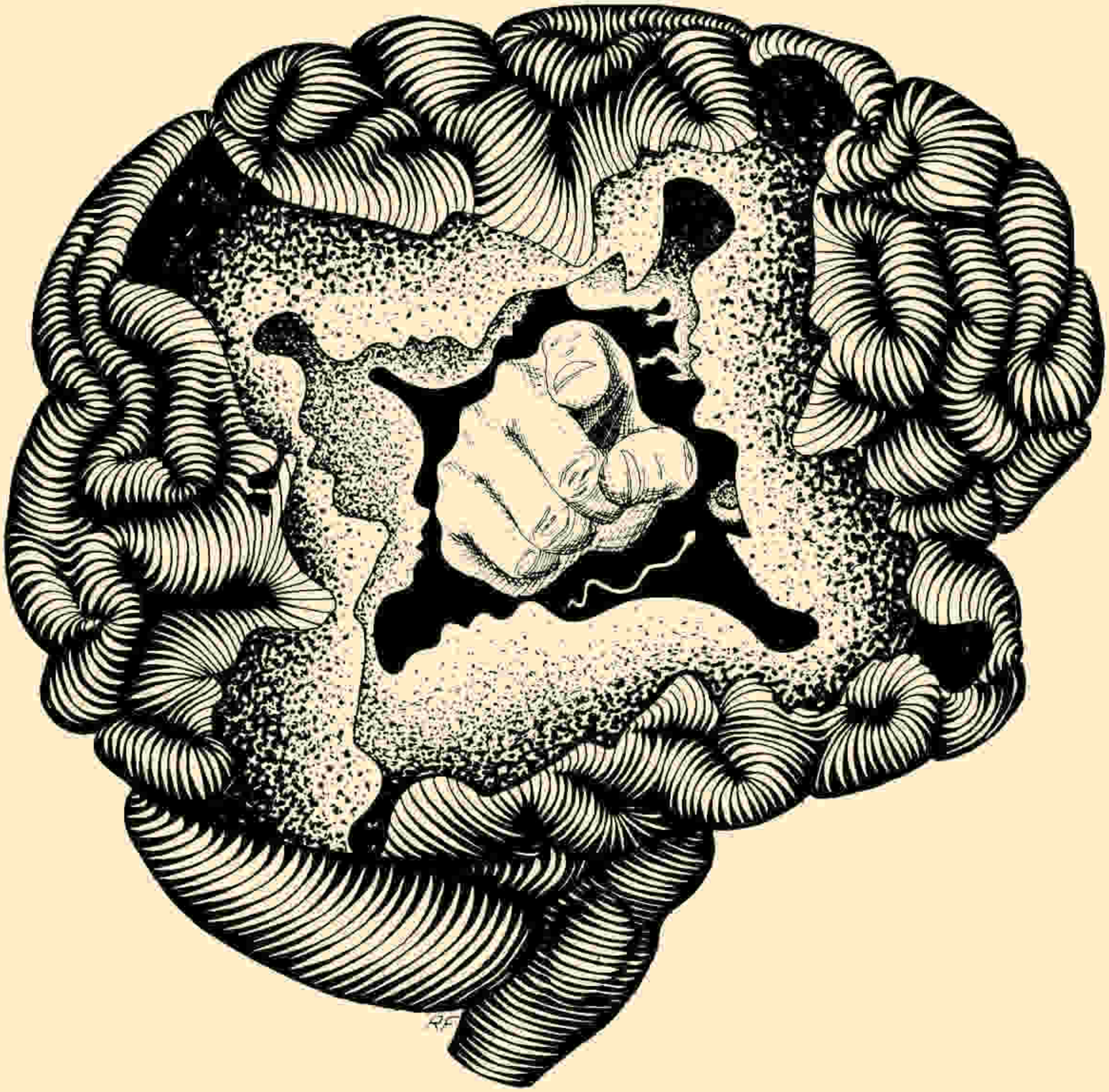
Fundamentals of Psychology

AN INTRODUCTION



Michael S. Gazzaniga

ACADEMIC PRESS INTERNATIONAL EDITION

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Michael S. Gazzaniga
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To all the girls
Linda, Marin, Anne, Kate, and
finally, Alexandra

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II. Developmental Processes

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Preface

The behavioral sciences have tackled no less a problem than to come to a rational and scientific understanding of life. While the physicist continues to unearth new subatomic particles and to work out the subtle details of the inner workings of the atom, and the biologist, just having cracked the genetic code, labors on filling in the details of biochemical pathways, the psychologist takes on the most basic question of all: "What is the nature of man?" With knowledge accumulating at an incredible rate in the physical and biological sciences, the student of behavior is faced with the question of how all of this relates to conscious experience. Progress in understanding these issues has been dramatic. Yet, even though thousands upon thousands of men and women have contributed a wide variety of fascinating and intriguing observations on the problem, many of the fundamentals of behavioral science remain elusively mysterious.

The objective of this book is to center the study of psychology around issues that cut through the artificial barriers commonly established in the study of behavior. It is an organic view, one that builds upon what is known about the physical aspects of the nervous system and then proceeds to integrate the dynamic aspects of biological function with many of the psychological findings and theories about the development and overall maintenance of behavioral patterns. The challenge in tackling the problem in this way has been great, but then again, of course, so is the need. Perspective must be sought in the study of behavior. The subject demands that we understand how the different factors interrelate. We must realize that we live and work in a gloriously complex universe, and must assume from the start that the study of behavior will be no less complex than the world in which we live.

The nature–nurture theme appears throughout the book. At almost every level in the study of behavior we are faced with the problem of determining the extent to which behavior is influenced by environmental and genetic factors. Most often, of course, behavior is the result of an interaction between the two. It is a vastly important question because if we are to understand the determinants of behavior we must know which realm to investigate.

In writing an introductory book one discovers just how complex the science of psychology has become. When I undertook this enterprise, I thought I would write every word of the book, and indeed the book as it now appears was conceived as a whole with its special approach of trying to integrate structure with function, nature with nurture. It soon became clear, however, that with today's information explosion in the behavioral sciences, one must call upon specialists for advice and help. I was fortunate in obtaining the assistance of a number of extremely talented people whose enthusiasm for their topics was contagious. In being served by this group, the reader benefits because these people have specific, up-to-date knowledge in particular psychological disciplines.

I would like to thank the following people for writing several chapters. Their help has been essential.

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Wesleyan University, Connecticut

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Stanford University, California

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New York University, New York

Personality: Andrea Velletri Glass
New York University, New York

Social Psychology: Judith Rodin
Yale University, Connecticut

Social Problems: Sheldon Cohen
New York University, New York

These contributions—plus those of many reviewers, graduate students, and others—had to be integrated into a coherent book. As a result, there have frequently been numerous changes during the many stages of revision. Thus, I must take full responsibility for any existing errors.

In addition, I would like to extend my profound thanks to Robert Filbey, the book's illustrator. From his fascinating three-dimensional brain model at the end of the book to his illustrations depicting psychological problems, Filbey has given his every talent to the task of improving the art of communication.

I would also like to thank the many reviewers, including Colin Blakemore, Charles Harris, and Leo Goldberger for their helpful suggestions during revision. I will be forever grateful to Leon Festinger, the overall editorial consultant of the book. He brought to bear on his task an extraordinarily profound understanding of the problems of behavior, and was exceedingly generous in his aid. It was an exhilarating experience for me to work closely with him.

I have taken the liberty to reserve my own views and prejudices on the subject of psychology for the last chapter wherein I review much of my own research. The objective here is to outline for the student the organization of a general laboratory research program and to inform the reader that the variety of prejudices one has in research has, as much as is humanly possible, been channeled in this book into the last chapter.

Michael S. Gazzaniga

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I

Nature of the Organism

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I

Physical Aspects of Behavior: Basic Neurology

On the night of August 2, 1958, Vernon Atchley went to the home of his wife, from whom he was separated, and shot her dead. He claimed she was behaving promiscuously.

Atchley was a borderline mental defective, with an I.Q. of only 60, and he could neither read nor write. However, he had an unusual talent for business for he was the owner of a used car lot, a number of rental properties, an 80-acre ranch, and a tavern, all in, or near, the prospering northern California town of Oroville. Nonetheless, his marriage had been a total failure. Both Atchley and his wife were alcoholics and they fought constantly. Their tavern companions grew weary of hearing them threatening to kill each other.

Atchley, then 44, was convicted of first-degree murder in Butte County Superior Court, the same county that had sentenced his brother to life imprisonment for another killing. Atchley was sentenced to die in the gas chamber on March 25, 1960, but was given a reprieve because the State Legislature was then considering the abolition of capital punishment. Subsequently, the Legislature chose not to outlaw the death penalty, and Atchley's date of execution was reset for August 23, 1961.

When Atchley's case was automatically reviewed by the State clemency secretary, it was noticed that a report from the San Quentin psychologist had indicated that Atchley had suffered a head injury in 1956, which had left him unconscious for the whole day. Since then Atchley had had "recurring nightmares and headaches and could not sleep." The psychologist concluded, however, that Atchley's responses to certain tests gave no conclusive evidence of organic brain damage. This was also the opinion of the neuropsychiatric committee that had examined the condemned man.

However, the clemency secretary observed that Atchley had never been given an electroencephalogram, an electrical measurement of the brain waves that might confirm the psychologist's findings. He was finally given such a test in San Quentin just five days before he was to die and the results were startling. "Diagnosis: abnormal brain wave with bilateral slowing, spikes indicative of unseen and traumatic central nervous system residual." These brain waves tend to be present in people who have suffered from serious brain damage and who have a residual of increased sensitivity, emotional lability, and irritability. They are somewhat less able to control emotional situations and impulses. Because of this new evidence, the Atchley case fell under the Durham rule of the Federal Court, which declares that, if a criminal act is a product of a mental deficiency or disease, the act is not punishable. Atchley's sentence was commuted to life imprisonment.

Who is to blame for Vernon Achley's plight? Is society? Is his mother? His father? Or was he born with a genetically determined predisposition for violence? Or was it the residual of his head injury? This is the kind of general problem that continually faces the psychologist. How much of any piece of behavior is the product of the social or physical environment changing the natural tendencies of the organism? Or how much of our behavior is inborn? There is no more fundamental point in psychology; the question arises in every aspect of the study of behavior, from the mating behavior of bees to personality development.

The aim of this book is the study of behavior. Before one can proceed, however, we must understand something about the fundamental nature of the controlling organ of behavior—the brain. We must know what it is capable of, what normal development is, and how much of it is physically and genetically determined. Then we can approach one of the most crucial problems in psychology, namely, how and to what extent can the environment modify the predetermined capacities of an organism?

It may come as a surprise that these are proper questions for the psychologist. But it is so. Whether he studies behavior from a genetic, developmental, physiological, or experimental basis, the psychologist is continually trying to understand the basic issues raised in the heredity versus environment issue. Separating the causes and distinguishing data from inference is the job of the psychologist.

In this section of the book, our aim is to clearly establish many of the basic, locked-in physical and psychological characteristics of the organism.

Surprisingly, until recently, few psychologists have thought it important to consider the basic properties of the nervous system. It was long part of the American psychological dream that all brains are created equal. The idea has not held up, however, and the following discussions look at the evidence for and against equality in nervous systems. Generally, our aim is to outline the kinds of existing data that indicate what nervous systems can and cannot do. Only by understanding the physiological and psychological limits of the system can we gain insight into the nature of brain and mind.

NEUROLOGICAL ORGANIZATION OF CENTRAL NERVOUS SYSTEM

The Neuron

The basic unit or building block for the entire nervous system is a slimy, extraordinarily thin, long, and magnificently mysterious piece of protoplasm called the neuron (Figure 1-1). Its basic components are the dendrites, which receive information in a bioelectric form from other neurons. The information received at the dendrites is fed into a large cell body. This electrical information produces an action potential, which amounts to one unit of electrical information and which is subsequently propagated down a long cylindrical structure called the axon. The neuron can be microscopically small or up to five feet long, as in the sensory neurons that receive information from the leg in man.

Neurons come in a variety of shapes and sizes and consist of a grayish-colored cell body which houses the metabolic machinery and sustains the cell through all of its electrical activities. The complex chemical reactions occurring in the cell body that keep the neuron alive and functioning are understandable on their own terms, yet it remains quite mysterious how these metabolic activities support the electrical activity of the neuron.

The neuron is surrounded by a membrane that is semipermeable to a variety of chemicals. In the normal resting state, an active process is going on in the neuron that maintains a critical imbalance between certain of the chemical ions in and around the neuron. This imbalance produces an electrical charge across the neuronal membrane. When a nerve impulse occurs, there is a progressive change in electrical properties of the neuronal membrane, which results in the conduction of the nerve impulse down the axon. The energy involved in producing a nerve impulse is provided by the neuron itself. The input merely serves to trigger the neuron, which means that once fired the amplitude of the electrical impulse is constant as is the speed of conduction down most of the length of the neuron.

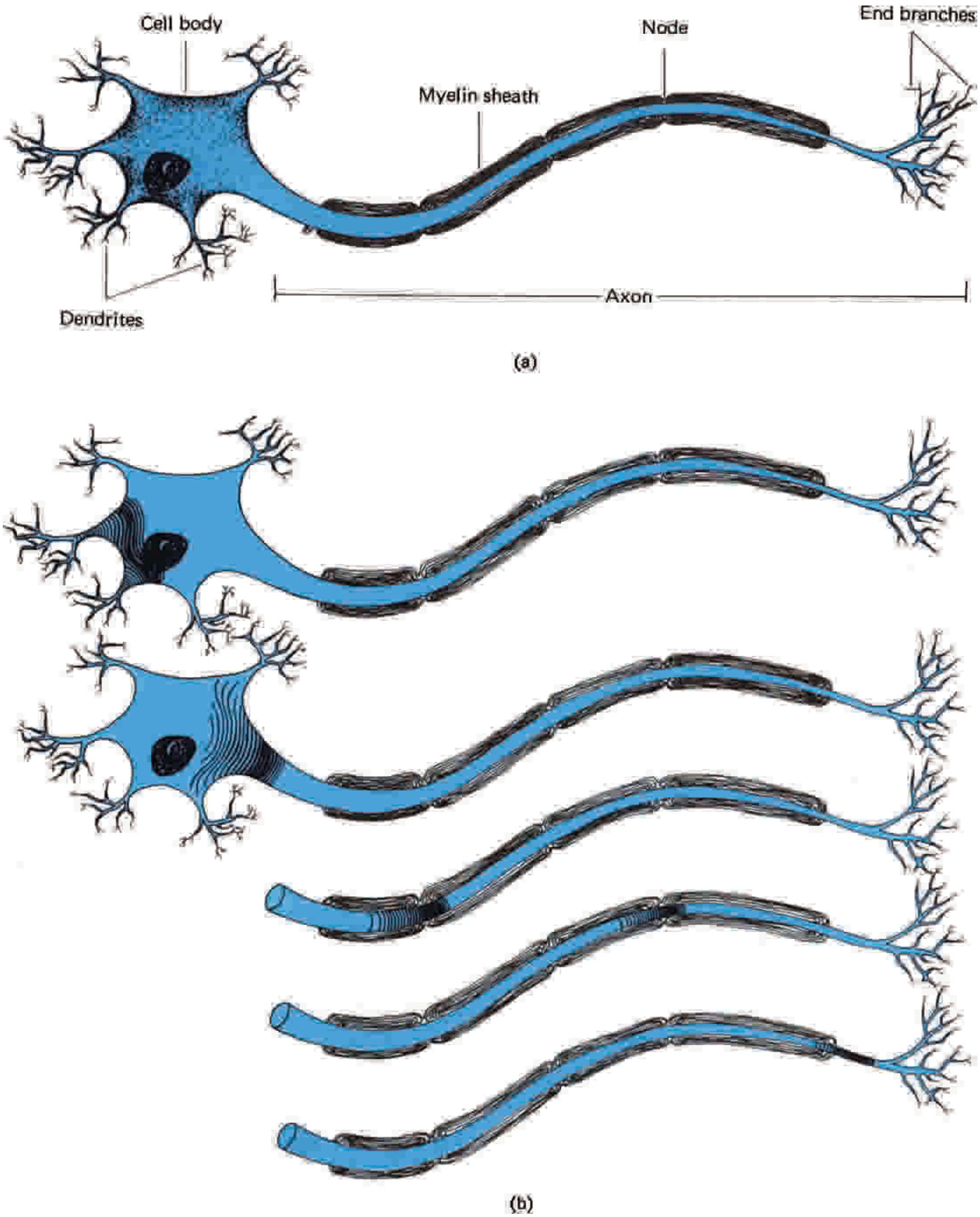

FIGURE 1-1 (a) The basic features of a neuron. (b) The propagation of the electrical impulse from the cell body to the axon terminal.

Another feature of neurons is that, after one has fired, there is a period of time within which it cannot fire again. This is called the absolute refractory period. Thus, two stimuli occurring extremely close together will probably result in a neuron firing only once.

There are many kinds of neurons. Each of them obeys the same laws for electrical propagation. There is, however, significant variation as to how they receive information at their receptor sites.

Some of the specialized neurons that receive information of a specific kind and quality are shown in Figure 1-2. For example, the olfactory neurons enable us to distinguish different smells. The mechanism of smell is fascinating and mysterious. In brief, odorous particles from the object being smelled must pass into the nose and the upper and posterior portions of the nasal cavity. There they come into contact with what is called the olfactory epithelium, which is a thin layer of tissue with many olfactory receptors embedded within. The odorous particle must dissolve in the solutions surrounding the epithelium. The resulting reaction somehow fires the olfactory receptor, which is part of the neural chain on the way into the brain. It is not at all clear how the process occurs or what characteristics the chemical stimulus must have in order to cause an olfactory response. Similar intriguing mechanisms are seen in the auditory system as well as the system that informs us of touch information on the surface of our bodies.

The Synapse

No matter what process is involved in precipitating an action potential, a neuron, once triggered, is irrevocably committed to sending the electrical impulse down its axon to the very tip. At that point it is either successful in firing the next neuron in sequence or it is not. Sir Charles Sherrington named this anatomical point a synapse (Figure 1-3), and was largely responsible for initiating the systematic exploration of synaptic mechanisms.

There are three basic kinds of synapses: one kind is excitatory, and the other two are inhibitory in nature. The excitatory synapse consists of an axon lying in direct proximity to a dendrite. The actual junction is made by the synaptic knob. Between the knob and dendrite of the receiving neuron is a space called the synaptic cleft. At present it is thought the knob secretes chemicals into the cleft, by having little tiny vesicles migrate through the knob and squirt their contents into the cleft. The postsynaptic membrane becomes affected by the secreted substance by lowering its threshold for triggering an impulse. If enough excitatory impulses are received, the neuron fires resulting in what is called an EPSP or excitatory postsynaptic potential.

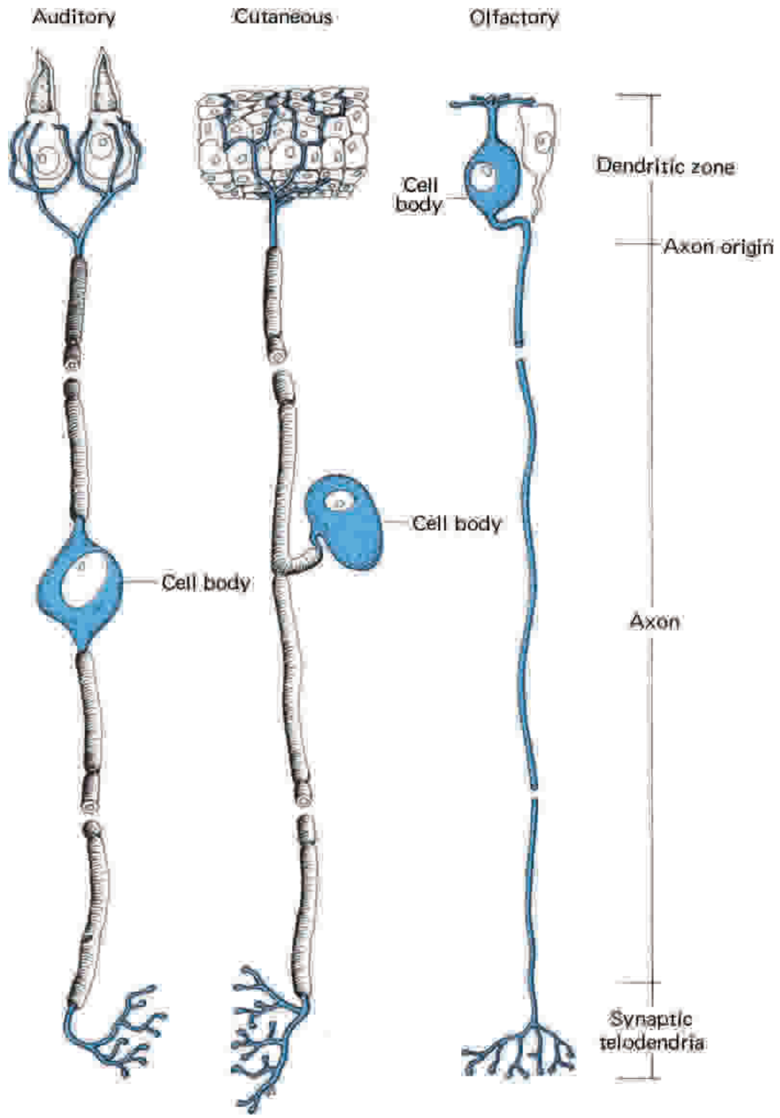

FIGURE 1-2
Three types of receptor neurons.

In addition to excitatory inputs to a neuron, there are also inhibitory inputs. These generally occur on the cell body, or soma, and are called axosomatic synapses. Anatomically, they look almost identical to excitatory synapses and the electrical potentials they produce. An inhibitory postsynaptic potential (IPSP) is the mirror image of an EPSP, that is, an inhibitory potential serves to make the internal charge of the neuron more negative, thereby decreasing the probability that it will discharge.

With these two more or less push-pull forces acting on a neuron, it is

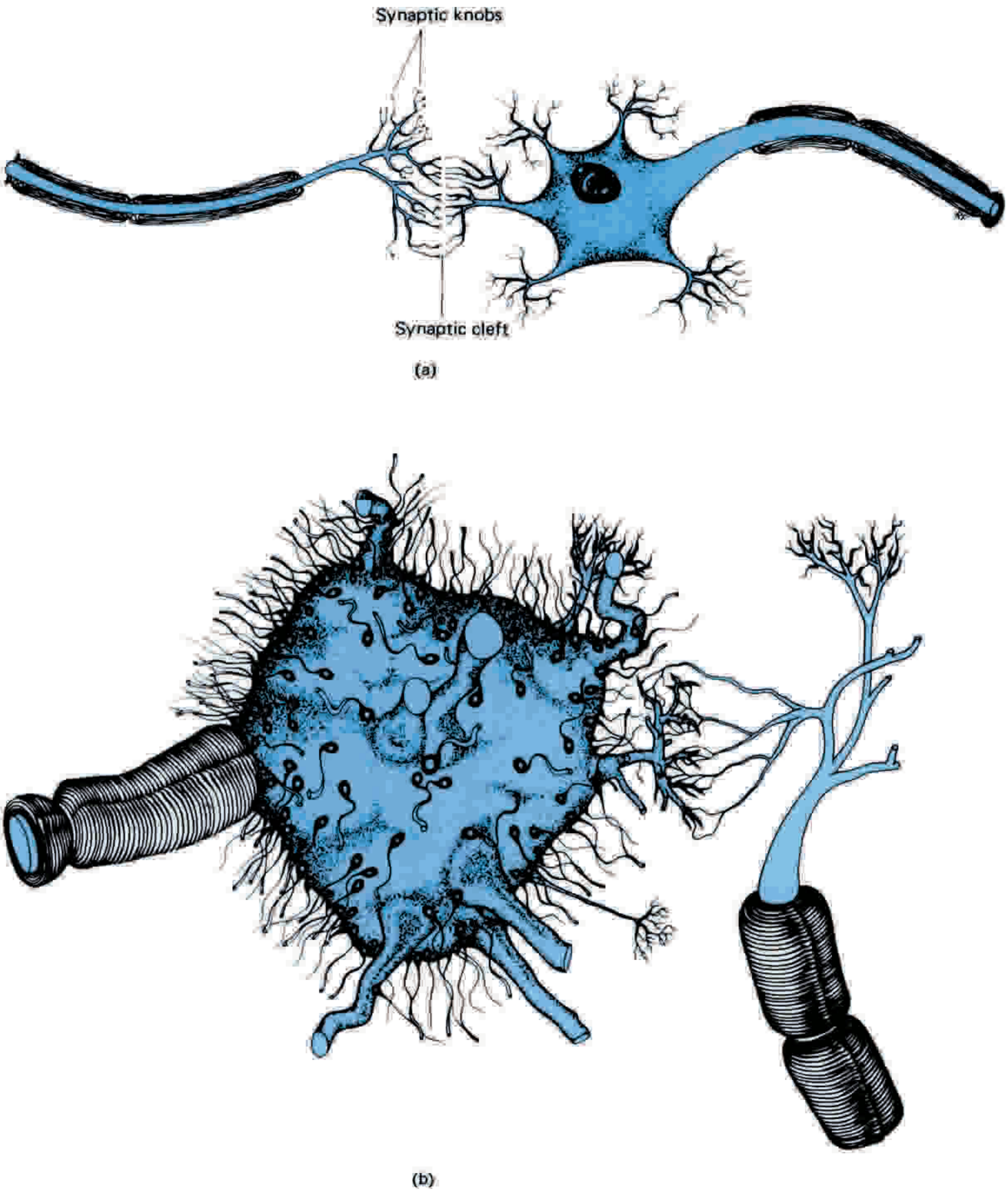

FIGURE 1-3 (a) An excitatory synapse. (b) The complexity of the synaptic connections on each neuron is apparent by noting the number of synaptic knobs.

a wonder to some that a series of neurons ever fires properly at all. Yet, the mechanism of action is quite simple. Each individual neuron simply adds up the excitatory and inhibitory influences impinging upon it. If enough excitatory influences are present to move the voltage to a state of depolarization of the membrane, an action potential is generated. If there are not enough excitatory forces, the neuron remains in its resting state.

A third kind of neural junction, seen in the central nervous system, is the axoaxonic synapse in which the axon makes functional contacts with the axon of another neuron. The kind of inhibitory influence exerted is called presynaptic inhibition. It is much more complicated than the other varieties, and it will suffice only to mention its existence.

The Organizational Principles of Nervous Tissues

Neurons are interesting and their mechanisms for action are intriguing, but to some extent the psychologist who is mainly interested in behavior only has to know that they work. A far more important question for the psychologist is "What are the laws governing neural development?" More generally, is the nervous system a fixed network of ten billion neural connections, or is it a loosely organized mass of tissue that is easily modified and changed in response to the environment? This is the most fundamental question the student of behavior can ask the student of biological systems.

In the 1920's, the predominant view was that nervous tissue grew at random and a diffuse unstructured equipotential network was established that "knew nothing" and could be altered and structured only by experience. The cry was that "function precedes form in the nervous system" and the scientific literature was replete with data to support the assertion. For example, the clinical condition of "crocodile tears" was reported to be eliminated by reeducation and practice. Here, following a facial injury severing peripheral nerves, normal regeneration frequently results in neurons, which normally innervate the salivary gland, finding their way to the tear or lacrymal gland. In such a case, when a patient saw a nice, big, juicy piece of meat, he would cry instead of salivating. With practice, however, it was maintained that he would quickly inhibit his bizarre response and everything would shift back to normal.

Alternatively in cases where nerve regeneration was impeded for one reason or another, the neurosurgeon would intervene and take a branch from the nerves normally growing out to the neck and shoulder muscles and shove it into a facial muscle. Initially, the patient's face would appear to twitch and shrug a bit, but here again it was maintained that with practice the problem corrected itself.

The dogma, then, was that the nervous system is not fixed in any way. Any particular pattern of response a neuron might have could be easily modified and changed by different environmental conditions. Today, this notion is considered totally incorrect and untenable. Yet, one can well imagine its authority in the 1920's when, at scientific meetings all across the country, biologists were telling psychologists about the wishy-washy nature of the central nervous system, and psychologists were enthralled because this went along with the view that an organism could be made into anything. "Give me," said J. B. Watson, the founder of American behaviorism, "any baby and I'll make him into anything." This apparently airtight physiological and psychological story plus wishful thinking explains why these views held up so long.

In the early 1940's, however, evidence to the contrary emerged. R. W. Sperry, in a stunning series of experiments, firmly established the dogma of neuronal specificity. He showed that each neuron in the central nervous system has its own chemical identity and is genetically predestined to hook up to a particular point in the brain. In short, a biochemical code is embedded in each individual neuron, which must, by virtue of this code, grow to a particular place.

This idea dramatically opposed the prevalent view of nonspecificity in random growth processes. But over a twenty-year period, with experiment after experiment confirming and elaborating his results, most scientists came to favor Sperry's position.

Some of the evidence for neurospecificity comes from fish (Figure 1-4). In higher organisms, however, this kind of recovery from injury is not possible. Consequently, the kind of evidence accumulated here on the question of neural wiring is of an opposite kind. It demonstrates how once the system is set it cannot be changed. In the rat, for example, the sensory nerve enervating the left leg can be surgically disconnected and stuck into the right leg. After recovery, stimulation of the right leg results in the left leg withdrawing! If reeducation and neural plasticity were possible, the rat would learn to withdraw the right leg, but it never does. This is because the wiring for this kind of behavior is fixed, and, no matter what kind of reeducation or how intense the environmental stimulus, the nervous system is never able to adapt to the change. The implications of neuronal specificity are profound. If a newborn baby has all its neural connections firmly established, then the main way for the environment significantly to modify the ultimate potential of the organism is by not providing critical stimulation to some of these prewired circuits at a particular point in development. Thus, if a cat does not see horizontal lines in its environment at an early age, there is a good chance it never will (Blakemore & Cooper, 1970). A cat is born with horizontal edge detectors, but they must be used. If they are not, they give away due to disuse or are