

Functional Analysis of Neural Systems

A wide range of physiological methods is now available to evaluate the electrical (and metabolic) activity of the neuronal circuits that make up a neural system. Two approaches, however, have been particularly useful in defining how neural systems represent information. The most widely used method is **single-cell**, or **single-unit electrophysiological recording** with microelectrodes (see above; this method often records from several nearby cells in addition to the one selected, providing further useful information). The use of microelectrodes to record action potential activity provides a cell-by-cell analysis of the organization topographic maps (Figure 1.15), and can give specific insight into the type of stimulus to which the neuron is “tuned” (i.e., the stimulus that elicits a maximal change in action potential activity from the baseline state). Single-unit analysis is often used to define a neuron’s **receptive field**—the region in sensory space (e.g., the body surface, or a specialized structure such as the retina) within which a specific stimulus elicits the greatest action potential response. This approach to understanding neural systems was introduced by Stephen Kuffler and Vernon Mountcastle in the early 1950s and has now been used by several generations of neuroscientists to evaluate the relationship between stimuli and neuronal responses in both sensory and motor systems. Electrical recording techniques

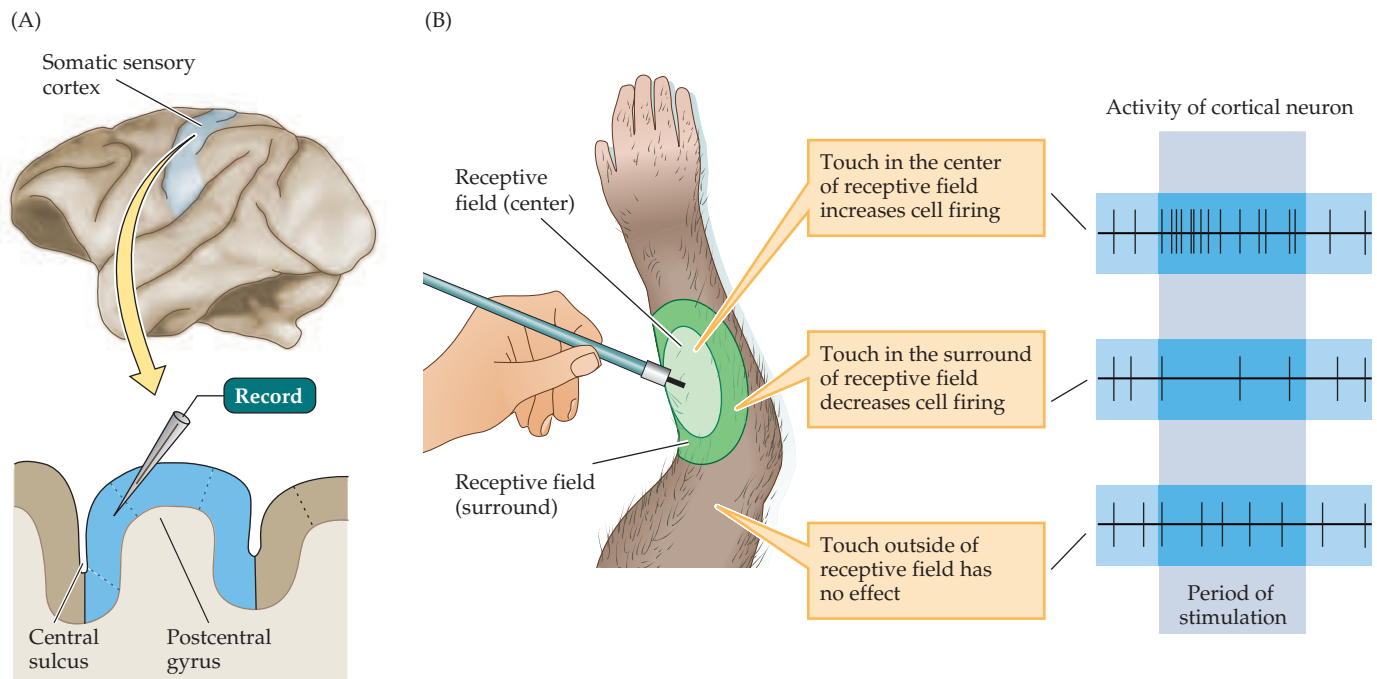


Figure 1.15 Single-unit electrophysiological recording from cortical pyramidal neuron, showing the firing pattern in response to a specific peripheral stimulus. (A) Typical experimental set-up. (B) Defining neuronal receptive fields.

at the single-cell level have now been extended and refined to include single and simultaneous multiple cell analysis in animals performing complex cognitive tasks, intracellular recordings in intact animals, and the use of patch electrodes to detect and monitor the activity of the individual membrane molecules that ultimately underlie neural signaling (see Unit I).

The second major area in which remarkable technical advances have been made is **functional brain imaging** in human subjects (and to a lesser extent animals), which has revolutionized the functional understanding of neural systems over the last two decades (Box A). Unlike electrical methods of recording neural activity, which are invasive in the sense of having to expose the brain and insert electrodes into it, functional imaging is noninvasive and thus applicable to both patients and normal human subjects. Moreover, functional imaging allows the simultaneous evaluation of multiple brain structures (which is possible but obviously difficult with electrical recording methods). The tasks that can be evaluated with functional imaging permit a far more ambitious and integrative approach to studying the operations of a neural system.

Over the last 20 years, these noninvasive methods have allowed neuroscientists to evaluate the representation of an enormous number of complex human behaviors, and at the same time have provided diagnostic tools that are used more and more routinely. Many of the resulting observations have confirmed inferences about functional localization and the organization of neural systems that were originally based on the study of neurological patients who exhibited altered behavior after stroke or other forms of brain injury. Others findings, however, have given new insights into the way neural systems function in the human brain.

Analyzing Complex Behavior

Many of the most widely heralded advances in modern neuroscience have involved reducing the complexity of the brain to more readily analyzed components—i.e., genes, molecules, or cells. Nevertheless, the brain functions as a whole, and the study of more complex (and, some might argue, more interesting) brain functions such as perception, language, emotion, memory, and consciousness remain a central challenge for contemporary neuroscientists. In recognition of this challenge, over the last 20 years or so a field called **cognitive neuroscience** has emerged that is specifically devoted to understanding these issues (see Unit V). This evolution has also rejuvenated the field of neuroethology (which is devoted to observing complex behaviors of animals in their native environments—for example, social communication in birds and non-human primates), and has encouraged the development of tasks to better evaluate the genesis of complex behaviors in human subjects. When used in combination with functional imaging, well designed behavioral tasks can facilitate identification of brain networks devoted to specific complex functions, including language skills, mathematical and musical ability, emotional responses, aesthetic judgments, and abstract thinking. Carefully constructed behavioral tasks can also be used to study the pathology of complex brain diseases that compromise cognition, such as Alzheimer's disease, schizophrenia, and depression.

In short, new or revitalized efforts to study higher brain functions with increasingly powerful techniques offer ways of beginning to understand even the most complex aspects of human behavior.