Introduction

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Plasticity—the ability of the brain to change adaptively during learning and memory or in response to changes in the environment—is one of the most remarkable features of higher brain function. Five years ago, in the third edition of *The Cognitive Neurosciences*, researchers described many new mechanisms at multiple levels of the neuraxis that produce and regulate neuroplasticity. These included the genesis of new neurons and glia throughout life, and the role of adult stem cells in plasticity. The papers comprising the plasticity section in 2004 were all conducted in non-human animals. Over the last five years animal studies of neuroplasticity have continued apace. Additionally, a burgeoning literature on human neuroplasticity has emerged. The papers in the current section on plasticity describe both animal and human research and have several themes in common. Several point to the key role of attention in neuroplasticity and also to the malleable nature of attention itself. Several also describe the two sides of plasticity: the systems that are most changeable by environmental input are both more enhanceable and more vulnerable to deficit. Another theme that was repeated and that is important to reiterate is that different functions and related brain systems display different degrees and time periods of maximal plasticity, whereas others display equivalent plasticity throughout life. An exciting new development is the recognition of the key role that genes and molecules play in neuroplasticity. Allelic variation within several specific genes is a major determinant of the degree to which neuroplasticity is evident in both animals and humans. Furthermore, plasticity is manifested through molecular mechanisms that transduce electrical activity in the brain into changes in the weights of synapses or into patterns of synaptic contact and network connections. While these mechanisms have been studied extensively in animal models of developmental or adult plasticity, they have clear implications for understanding neuroplasticity in the human brain.

Topographic projections, or maps, are fundamental for representing and analyzing sensory information in the brain. In chapter 6, Horng and Sur describe guidance and patterning molecules that underlie the formation of retinotopic maps in the visual pathway. Such maps form a scaffold of connections that is subsequently refined by activity-dependent plasticity. Target molecules themselves can be altered to induce "rewiring" of inputs from the retina to the auditory pathway in ferrets and mice. The auditory cortex, when driven by vision, develops key features of the visual cortex such as visual-orientation-selective cells and maps, demonstrating that the nature of input activity during development is crucial for creating networks that process the input. Finally, the projection from the two eyes to primary visual cortex forms another model system in which molecular mechanisms that refine cortical connections are being rapidly discovered.

In chapter 7, Whitlock and Moser describe mechanisms of plasticity in a brain region that is critical for the formation of episodic memory and that has been studied extensively in the adult animal brain: the CA1 region of the rat hippocampus. They describe the link between long-term synaptic potentiation and behavior, and show how synaptic plasticity supports the formation of place cells in the rat's hippocampus. More generally, place cells are part of neural networks which have different states that can aid in the storage or recall of representations or memories.

In chapter 8, Li and Gilbert describe plasticity in the primary visual cortex of adult primates as a correlate of perceptual learning. Even early sensory cortical areas retain the capacity for synaptic and network changes, so that repeated perceptual experiences and familiarity elicit enhanced sensitivity to specific stimulus features. Such plasticity often involves an interplay between top-down and bottom-up processing, such that neuronal responses are often dynamically influenced by the nature of the task being performed or the context in which a stimulus appears. The efficient encoding of behaviorally relevant stimuli within a dynamic cortical network is a manifestation of the plasticity seen in perceptual learning.

In chapter 9, Pasqual-Leone describes neuroplasticity in studies of sighted and blind individuals and those who have sustained brain damage. Employing transcranial magnetic stimulation of different frequencies, he can enhance and decrease neuroplasticity. Furthermore these studies can differentiate the neural changes that are necessary for improvement in behavior from those changes that are not, and from changes that instead are harmful. He also describes several genetic polymorphisms that constrain the neuroplasticity in these populations.

In chapter 10, Bavelier, Green, and Dye describe the remarkable enhancements in several cognitive functions in individuals who engage in fast-action video games. They propose that such activity results in Bayesian learning—that is, enhanced learning in the course of optimizing the rewards associated with success in video gaming. They discuss the different ways that harnessing the factors that are important in these effects could benefit educational programs and performance in the workplace.

In chapter 11, Stevens and Neville describe the different profiles of neuroplasticity and the two sides of neuroplasticity in the human visual, auditory, language, and attentional systems. These studies have been conducted on individuals with visual or auditory deprivation and of children of different ages. They also describe their recent studies of interventions that target the most plastic and vulnerable brain systems in children with or at risk for neurocognitive deficits.