To navigate a complex and dynamic visual environment, our brain has to solve many different perceptual problems. One fundamental goal of our perceptual system is to partition the world into objects that can be identified and acted on. While this may seem straightforward because we see and interact with objects so effortlessly, most objects comprise many features (like color, shape and size) that we can view from many viewpoints, with many other objects and in many different contexts. How does the brain integrate different features into a coherent object representation, and how are such representations transformed to accommodate differences in viewpoint and context? I will present a series of studies that investigate the nature of the neural representations and operations that underlie such challenges of object perception. I will also discuss some new research that explores the emergence of perceptual operations by investigating failures of object perception -- visual illusions -- in artificial deep neural networks.