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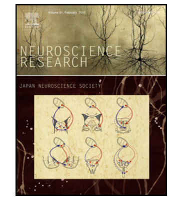

Review article

The marmoset monkey as a model for visual neuroscience

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ABSTRACT

The common marmoset (*Callithrix jacchus*) has been valuable as a primate model in biomedical research. Interest in this species has grown recently, in part due to the successful demonstration of transgenic marmosets. Here we examine the prospects of the marmoset model for visual neuroscience research, adopting a comparative framework to place the marmoset within a broader evolutionary context. The marmoset's small brain bears most of the organizational features of other primates, and its smooth surface offers practical advantages over the macaque for areal mapping, laminar electrode penetration, and two-photon and optical imaging. Behaviorally, marmosets are more limited at performing regimented psychophysical tasks, but do readily accept the head restraint that is necessary for accurate eye tracking and neurophysiology, and can perform simple discriminations. Their natural gaze behavior closely resembles that of other primates, with a tendency to focus on objects of social interest including faces. Their immaturity at birth and routine twinning also makes them ideal for the study of postnatal visual development. These experimental factors, together with the theoretical advantages inherent in comparing anatomy, physiology, and behavior across related species, make the marmoset an excellent model for visual neuroscience.

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1. Introduction

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Vision is central to human cognition and has long been an important model system for studying principles of brain function. Humans, like other primates, depend upon vision extensively for navigation, interaction with other individuals, manipulation of

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objects, and many other aspects of daily life. The coevolution of the eye and visual brain in our distant primate ancestors brought with it many adaptations that benefit diurnal and arboreal living as well as social living in larger extended family groups. These changes are manifest as a pattern of specific features of the visual system that support unique perceptual and behavioral abilities (for review, see Kaas, 2013). Visual neuroscience has benefitted from decades of comparative studies, as the parallax afforded by studying multiple species has helped to identify traits that are core features of the mammalian brain and other traits that are unique to primates, including humans.

The present article reviews primate vision from a comparative standpoint and places focus on the common marmoset (*Callithrix jacchus*), an arboreal, small-bodied New World primate. The review is motivated by growing interest in the marmoset as a model species to complement the rhesus monkey (*Macaca mulatta*) and laboratory mouse (*Mus musculus*), which are commonly used to study neural circuits supporting human vision. Humans' most recent common ancestor with the marmoset lived approximately 35–40 million years ago, before our most recent ancestor with the macaque (25–30 million years ago) and long after our most recent ancestor with the mouse (80–90 million years ago) (Janecka et al., 2007; Springer et al., 2011). Thus from a purely phylogenetic standpoint, the marmoset offers an intermediate point of comparison between these species (Fig. 1). For visual neuroscience, the marmoset also provides a number of distinct experimental advantages over each of these model systems, and we point to areas where a fully developed marmoset animal model promises to cast new light on mechanisms of visual cognition in the human brain.

It makes sense to begin by hailing a success story in neuroscience: the recent flourishing of the mouse model, the facility of its genetic manipulation, and its use as a tool to probe the exquisite detail of the brain's functional circuitry. Advances in the mouse have set new standards for the precision with which animal models can contribute to the investigation of the brain (Callaway, 2005; Deisseroth et al., 2006; Bernstein and Boyden, 2011). In particular, the development of transgenic lines, such as CRE lines, combined with viral-based optogenetics, have made it possible to express light sensitive opsins such as Channel rhodopsin (ChR2) in highly specific neuronal classes and then causally manipulate their activity with light (Livet et al., 2007; Cardin, 2012). This approach can be used to study functioning of specific anatomical pathways and has been used to link activity of specific cell types in the mouse visual cortex to distinct functional roles (Wilson et al., 2012) and to perceptual decisions (Lee et al., 2012; Zhang et al., 2014). There is at present a concerted push toward assembling a comprehensive

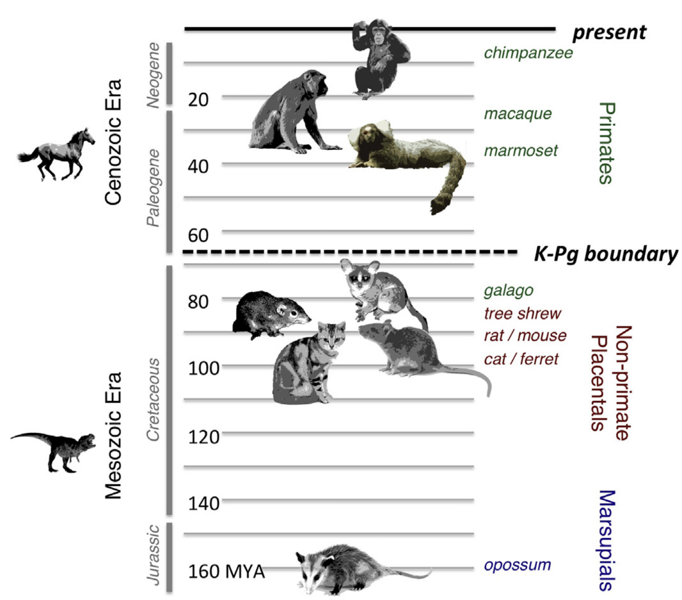

Fig. 1. Phylogenetic portrait of common mammalian experimental models for visual neuroscience, now and from previous scientific generations. Representative species are arranged with respect to human ancestry. The vertical timeline indicates for each species the period of which the most recent common ancestor with humans lived. For the macaque and marmoset, this ancestor lived near the end of the Paleogene Period, long after the so-called K-Pg boundary that marked the end of the Mesozoic Era. However, for other mammalian models, including prosimian primates, the most recent common ancestor lived during the Cretaceous Period, in the Mesozoic Era. MYA, million years ago.

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