

The Primate Thalamus Is a Key Target for Brain Dopamine

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The thalamus relays information to the cerebral cortex from subcortical centers or other cortices; in addition, it projects to the striatum and amygdala. The thalamic relay function is subject to modulation, so the flow of information to the target regions may change depending on behavioral demands. Modulation of thalamic relay by dopamine is not currently acknowledged, perhaps because dopamine innervation is reportedly scant in the rodent thalamus. We show that dopaminergic axons profusely target the human and macaque monkey thalamus using immunolabeling with three markers of the dopaminergic phenotype (tyrosine hydroxylase, dopamine, and the dopamine transporter). The dopamine innervation is especially prominent in specific association, limbic, and motor thalamic nuclei, where the densities of dopaminergic axons are as high as or higher than in the cortical area with the densest dopamine innervation. We also identified the dopaminergic neurons projecting to the macaque thalamus using retrograde tract-tracing combined with immunohistochemistry. The origin of thalamic dopamine is multiple, and thus more complex, than in any other dopaminergic system defined to date: dopaminergic neurons of the hypothalamus, periaqueductal gray matter, ventral mesencephalon, and the lateral parabrachial nucleus project bilaterally to the monkey thalamus. We propose a novel dopaminergic system that targets the primate thalamus and is independent from the previously defined nigrostriatal, mesocortical, and mesolimbic dopaminergic systems. Investigating this "thalamic dopaminergic system" should further our understanding of higher brain functions and conditions such as Parkinson's disease, schizophrenia, and drug addiction.

Key words: dopamine; dopamine transporter; dopaminergic systems; thalamus; human; monkey

Introduction

The thalamus transfers sensory information from the periphery to the cortex through first-order relay nuclei. In addition, it is a nodal point in cortico-cortical communication through higher-order relay or association nuclei (Sherman and Guillery, 1996). These functions are subject to extensive modulation, and thus the transfer of information through the thalamus depends on the state of wakefulness of the subject and on attentional or behavioral demands (McCaig, 1992; Sherman and Guillery, 1996; Steriade et al., 1997; Guillery and Sherman, 2002). In fact, the vast majority of synapses in the thalamus are from modulatory afferents. The other main targets of thalamic efferents are the striatum, the nucleus accumbens, and the amygdala (Steriade et al., 1997).

Dopamine is an important transmitter molecule in the brain. By modulating neuronal excitability and synaptic plasticity

(Nicola et al., 2000; Bissiere et al., 2003), dopamine is essential for motor control (Agid, 1991), working memory (Brozoski et al., 1979), sensorimotor learning (Aosaki et al., 1994), and reward-related learning and motivation (Schultz, 2002). These functions depend on the dopamine innervation of the striatum, cerebral cortex, nucleus accumbens, and amygdala. This innervation originates in dopaminergic neurons of the ventral mesencephalon and makes up the nigrostriatal, mesocortical, and mesolimbic dopaminergic systems (Lewis and Sesack, 1997).

The presence of dopamine in the thalamus of primates was reported a long time ago using biochemical tools (Brown et al., 1979; Goldman-Rakic and Brown, 1981). More recently, axons that were immunoreactive (ir) for the dopamine transporter (DAT) have been reported in the monkey mediodorsal thalamic nucleus (MD) (Melchitzky and Lewis, 2001). Despite these reports, the notion of a significant and widespread dopamine innervation of the primate thalamus is not currently recognized (Sherman and Guillery, 1996, 2004; Steriade et al., 1997), probably because the dopamine innervation of the rodent thalamus is reportedly scant (Groenewegen, 1988; Papadopoulos and Parnavelas, 1990). However, thalamic abnormalities related to dopamine and its receptors have been found in the thalamus of schizophrenic patients (Oke and Adams, 1987; Talvik et al., 2003; Yasuno et al., 2004), and thalamic alterations exist in Parkinson's disease (Ruf et al., 2002), a disorder in which dopamine plays a major role.

The present study examines the presence of dopamine in the thalamus of adult human and macaque monkey brains using antibodies against tyrosine hydroxylase (TH; one of the enzymes in the dopamine synthesis pathway), dopamine, and DAT. In

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The Primate Thalamus

Jessica J Manson



The Primate Thalamus:

The Primate Thalamus A. Earl Walker, 1938 Thalamus The Primate Thalamus Arthur Earl Walker, 1966 The Primate Nervous System, Part I Floyd E. Bloom, A. Bjorklund, T. Hokfelt, 1997-05-07 This volume is a new timely and fitting extension to the Handbook of Chemical Neuroanatomy focussing on the neurochemical circuitry of the primate brain The book will compliment the growing efforts to apply the analytical strategies of chemical neuroanatomy to the primate brain The goal of this volume is to develop a broad based coverage of human and non human primate chemical neuroanatomic details together within a volume in which details on transmitters and systems can be appreciated The eight comprehensive chapters that comprise this volume deal with large global concepts and datasets which not only create an initial coverage of the entire primate neuraxis but also capture useful points of information on the chemical neuroanatomy of the primate nervous system An excellent informative book and a welcome addition to the sparse literature in this field **The Primate Visual System** Jon H. Kaas, Christine E. Collins, 2003-07-28 The last 20 years of research have been marked by exceptional progress in understanding the organization and functions of the primate visual system This understanding has been based on the wide application of traditional and newly emerging methods for identifying the functionally significant subdivisions of the system their interconnections the *The Primate Nervous System, Part II* T. Hokfelt, A. Bjorklund, Floyd E. Bloom, 1998-09-17 This volume is the second in the planned coverage of the neurochemical circuitry of the primate central nervous system While this volume contains only two chapters their topics and the extraordinarily comprehensive coverage with which the authors have dealt with their topics will nevertheless contribute equal amounts of knowledge wisdom and opportunities for future research extensions as have every volume in this unique series As such these chapters extend the goals of this primate series to develop a broad coverage of human and non human primate chemical neuroanatomic details in a volume which makes clear the known and desirable appreciation for differences between and among subsets of primate brains The first chapter covers the primate thalamus with equal emphases on new world old world pro simian and human anatomic details and their differences The second undertakes a comparably comprehensive examination of one of the most intensively studied regions of the primate brain namely the primate visual cortex While much has been studied both chapters also reveal how much remains for future efforts in these enormously important regions which are the archetypes of primate sub cortical and cortical function **The Pulvinar Thalamic Nucleus of Non-Human Primates: Architectonic and Functional Subdivisions** Ricardo Gattass, Juliana G.M. Soares, Bruss Lima, 2017-11-06 This book discusses the hypothesis that the primate pulvinar contains an original scaffold which is derived from cytoarchitectural markers and specific protein distributions Thereafter along primate evolution different selective pressures acted in order to shape and fine tune the connectivity of the pulvinar with specific regions of the neocortex This divergence created among other things the different sets of retinotopic map representations in the pulvinar nucleus depending on functional and behavioral requirements of each

species The pulvinar the largest nucleus of the primate thalamus has extensive and reciprocal connections with several areas of the neocortex These input output loops suggest that the pulvinar may regulate the flow of information within and between cortical areas in a highly dynamic fashion Therefore understanding the anatomical subdivisions within the pulvinar and its connectivity with the cortex is paramount to understanding pulvinar physiological function However there is a stark contrast regarding the way that the pulvinar is subdivided depending on the technique employed Cytoarchitectural and immunohistochemical methods reveal a very similar pattern of pulvinar subdivision across Old and New World monkeys On the other hand electrophysiological and connectivity studies expose clear discrepancies in pulvinar organization across primate evolution

Stereotactic Atlas of the Macaca mulatta Thalamus and Adjacent Basal Ganglia Nuclei Igor A. Ilinsky, Kristy Kultas-Ilinsky, Boyd Knosp, 2012-12-06 Despite numerous studies devoted to the thalamus its function as a whole and specifically the functional role of the individual thalamic nuclei outside those regions that are involved in the processing of the sensory information still remains in the realm of speculation The latter have been the primary focus of thalamic investigations whereas other regions have received little attention especially in primates Complexity of the thalamic structure that does not lend itself to easy experimentation lack of agreement among investigators on thalamic parcelations and nomenclature unavailability of atlases especially in primates that provide not only maps of the nuclear outlines but cytoarchitectonic and current experimental data used as rationale for the latter are just some of the factors that have impeded the studies on the thalamus The present atlas has been designed as an interactive tool for investigators interested in pursuing studies on the thalamic structure and function in nonhuman primates The maps of the outlined thalamic nuclei based on the cytoarchitecture and available data on the distribution of subcortical afferents in the monkey thalamus are presented in both electronic and paper formats The atlas does not aspire to present the final word in thalamic parcelations but should be regarded as a working version that may be modified as new data are accumulated The atlas format will allow incorporate these changes and thus it can be updated with ease

Handbook of Chemical Neuroanatomy: The primate nervous system, pt. 2 Anders Björklund, Tomas Hökfelt, 1998

The Thalamus Michael M. Halassa, 2022-09-01 The thalamus is a key structure in the mammalian brain providing a hub for communication within and across distributed forebrain networks Research in this area has undergone a revolution in the last decade with findings that suggest an expanded role for the thalamus in sensory processing motor control arousal regulation and cognition Moving beyond previous studies of anatomy and cell neurochemistry scientists have expanded into investigations of cognitive function and harness new methods and theories of neural computation This book provides a survey of topics at the cutting edge of this field covering basic anatomy evolution development physiology and computation It is also the first book to combine these disciplines in one place highlighting the interdisciplinary nature of thalamus research and will be an essential resource for students and experts in biology medicine and computer science

Evolutionary Neuroscience Jon H Kaas, 2009-07-28

Evolutionary Neuroscience is a collection of articles in brain evolution selected from the recent comprehensive reference Evolution of Nervous Systems Elsevier Academic Press 2007 The selected chapters cover a broad range of topics from historical theory to the most recent deductions from comparative studies of brains The articles are organized in sections focused on theories and brain scaling the evolution of brains from early vertebrates to present day fishes amphibians reptiles and birds the evolution of mammalian brains and the evolution of primate brains including human brains Each chapter is written by a leader or leaders in the field and has been reviewed by other experts Specific topics include brain character reconstruction principles of brain scaling basic features of vertebrate brains the evolution of the major sensory systems and other parts of brains what we can learn from fossils the origin of neocortex and the evolution of specializations of human brains The collection of articles will be interesting to anyone who is curious about how brains evolved from the simpler nervous systems of the first vertebrates into the many different complex forms now found in present day vertebrates This book would be of use to students at the graduate or undergraduate levels as well as professional neuroscientists cognitive scientists and psychologists Together the chapters provide a comprehensive list of further reading and references for those who want to inquire further The most comprehensive authoritative and up to date single volume collection on brain evolution Full color throughout with many illustrations Written by leading scholars and experts

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