

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

Jon H. Kaas, Christine E. Collins



The Primate Thalamus:

The Primate Thalamus A. Earl Walker, 1938 Thalamus The Primate Thalamus Arthur Earl Walker, 1966 **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 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 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

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

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

The Oxford Handbook of Eye Movements Simon Livsedge, Iain Gilchrist, Stefan Everling, 2011-08-18 In the past few years there has been an explosion of eye movement

research in cognitive science and neuroscience The Oxford Handbook of Eye Movements provides the first comprehensive review of the entire field of eye movement research This book is the definitive reference work in this field

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

Advances in Diencephalon Research and Application: 2013 Edition ,2013-06-21 Advances in Diencephalon Research and Application 2013 Edition is a ScholarlyBrief that delivers timely authoritative comprehensive and specialized information about Epithalamus in a concise format The editors have built Advances in Diencephalon Research and Application 2013 Edition on the vast information databases of ScholarlyNews You can expect the information about Epithalamus in this book to be deeper than what you can access anywhere else as well as consistently reliable authoritative informed and relevant The content of Advances in Diencephalon Research and Application 2013 Edition has been produced by the world s leading scientists engineers analysts research institutions and companies All of the content is from peer reviewed sources and all of it is written assembled and edited by the editors at ScholarlyEditions and available exclusively from us You now have a source you can cite with authority confidence and credibility More information is available at <http://www.ScholarlyEditions.com>

Thalamic Networks for Relay and Modulation Diego Minciacchi,Marco Molinari,Giorgio Macchi,2013-09-03 Thalamic Networks for Relay and Modulation is the third in a series that springs from an idea of Giorgio Macchi who wished to establish periodical updates on thalamic research by bringing to Italy investigators who would engage in an international sharing of ideas and experiences It reflects the renewed interest in the modulation of thalamic relay activity by intrinsic and extrinsic sources while continuing to underscore the essential role of the thalamus as the gatekeeper

of the cerebral cortex and of the pathways to perception The papers that form the substance of this book were presented at a Symposium held at the Catholic University Rome Italy in September 1992 as a Satellite to the 15th Annual Meeting of the European Neuroscience Association The volume is organized into four parts Part I is basically concerned with developmental and evolutionary approaches Part II highlights relay functions of visual motor and somatosensory relay nuclei and relay functions of the intralaminar nuclei Part III deals primarily with the pharmacology of thalamic neurons Part IV emphasizes the mechanisms that underlie the functional assembly of thalamic cells into collectively acting ensembles largely revealed in rhythmic oscillations and on the behavioral manifestations that accompany them **The Human Nervous System** George Paxinos,2012-12-02

The Human Nervous System is a definitive account of human neuroanatomy with a comprehensive coverage of the brain spinal cord and peripheral nervous system The cytoarchitecture chemoarchitecture connectivity and major functions of neuronal structures are examined by acknowledged authorities in the field such as Alheid Amaral Armstrong Beitz Burke de Olmos Difiglia Garey Gerrits Gibbins Holstege Kaas Martin McKinley Norgren Ohye Paxinos Pearson Pioro Price Saper Sasaki Schoenen Tadork Voogd Webster Zilles and their associates Large clearly designed 8 1 2 x 11 format 35 information packed chapters 500 photomicrographs and diagrams 6 200 bibliographic entries Table of contents for every chapter Exceptionally cross referenced Detailed subject index Substantial original research work Mini atlases of some brain regions **Cumulated Index Medicus** ,1988 **Utopics** Manel Pretel-Wilson,2020-10-06 The book

consolidates systems thinking as a new world hypothesis that is already suggesting itself behind the advancement of quantum mechanics and Ashby s cybernetics In particular it shows how Einstein s misgivings about quantum mechanics boil down to his persistence in defending the principle of contiguity at the root of the modern cosmology and in relation to neo cybernetics the book rediscovers Ashby s theory of adaptive behaviour enabling a new synthesis between physiology psychology and ethology that has implications for systems practice Furthermore this new cosmology comes with a new anthropology that informs utopics the science of utopic systems and sheds new light on the actual founding fathers of the domain of human science In particular the book provides an understanding of how our human world works and how it is being constituted by utopic systems that look into the future to realize something possible Finally it points the way to the future unification of knowledge bringing together systems philosophy and systems science given that world hypothesis is what makes logically possible the development and consolidation of all the different domains of science **The Cognitive**

Neurosciences, sixth edition David Poeppel,George R. Mangun,Michael S. Gazzaniga,2020-04-21 The sixth edition of the foundational reference on cognitive neuroscience with entirely new material that covers the latest research experimental approaches and measurement methodologies Each edition of this classic reference has proved to be a benchmark in the developing field of cognitive neuroscience The sixth edition of The Cognitive Neurosciences continues to chart new directions in the study of the biological underpinnings of complex cognition the relationship between the structural and physiological

mechanisms of the nervous system and the psychological reality of the mind. It offers entirely new material reflecting recent advances in the field covering the latest research, experimental approaches and measurement methodologies. This sixth edition treats such foundational topics as memory, attention and language as well as other areas including computational models of cognition, reward and decision making, social neuroscience, scientific ethics and methods advances. Over the last twenty five years the cognitive neurosciences have seen the development of sophisticated tools and methods including computational approaches that generate enormous data sets. This volume deploys these exciting new instruments but also emphasizes the value of theory, behavior observation and other time tested scientific habits.

Section editors: Sarah Jayne Blakemore and Ulman Lindenberger, Kalanit Grill-Spector and Maria Chait, Tom S. Ryan and Charan Ranganath, Sabine Kastner and Steven Luck, Stanislas Dehaene and Josh McDermott, Rich Ivry and John Krakauer, Daphna Shohamy and Wolfram Schultz, Danielle Bassett and Nikolaus Kriegeskorte, Marina Bedny and Alfonso Caramazza, Liina Pylkkänen and Karen Emmorey, Mauricio Delgado and Elizabeth Phelps, Anjan Chatterjee and Adina Roskies.

From Anatomy to Function of the Central Nervous System Brandon Matteo Ascenzi, 2024-08-25. From Anatomy to Function of the Central Nervous System: Clinical and Neurosurgical Applications features neuroradiologic images that represent today one of the most effective resources able to detect the anatomy of the nerve structures. Simultaneously featuring neuroimages, readers can study the functional aspects of the entire central nervous system with detailed captions that describe in detail how to use and interpret them. This book includes images of the brain dissected with the Klingler's method and white matter fiber dissection. By integrating the anatomic-functional description with the synaptic organization of the CNS, this reference is useful for anyone who wants to understand how the activity of a nerve structure arises, describing its microstructure, neurotransmitter phenotype and neural activity. It also features descriptions of pathologic conditions which result from neuroanatomical and/or neurofunctional alterations and includes neurosurgical aspects. Integrates anatomic-functional descriptions with the synaptic and neurochemical organization of the CNS. Allows readers to better understand the morphology and topography of encephalic structures. Features neuroradiological images and human brain dissections using the Klingler's method. Chapters have references, key articles, books and protocols for additional detailed studies.

Advances and Technical Standards in Neurosurgery F. Cohadon, 2012-12-06. As an addition to the European postgraduate training system for young neurosurgeons we began to publish in 1974 this series of Advances and Technical Standards in Neurosurgery which was later sponsored by the European Association of Neurosurgical Societies. This series was first discussed in 1972 at a combined meeting of the Italian and German Neurosurgical Societies in Taormina, the founding fathers of the series being Jean Brihaye, Bernard Pertuiset, Fritz Loew and of European colleague Hugo Krayenbühl. Thus were established the principles of operation which have been born from the European spirit, flourished in the European Association and have throughout been associated with this series. The fact that the English language is well on the way to becoming the international medium at European scientific

conferences is a great asset in terms of mutual understanding Therefore we have decided to publish all contributions in English regardless of the native language of the authors All contributions are submitted to the entire editorial board before publication of any volume Our series is not intended to compete with the publications of original scientific papers in other neurosurgical journals Our intention is rather to present fields of neurosurgery and related areas in which important recent advances have been made The contributions are written by specialists in the given fields and constitute the first part of each volume

The Senses: A Comprehensive Reference, 2020-09-30 The Senses A Comprehensive Reference Second Edition Seven Volume Set is a comprehensive reference work covering the range of topics that constitute current knowledge of the neural mechanisms underlying the different senses This important work provides the most up to date cutting edge comprehensive reference combining volumes on all major sensory modalities in one set Offering 264 chapters from a distinguished team of international experts The Senses lays out current knowledge on the anatomy physiology and molecular biology of sensory organs in a collection of comprehensive chapters spanning 4 volumes Topics covered include the perception psychophysics and higher order processing of sensory information as well as disorders and new diagnostic and treatment methods Written for a wide audience this reference work provides students scholars medical doctors as well as anyone interested in neuroscience a comprehensive overview of the knowledge accumulated on the function of sense organs sensory systems and how the brain processes sensory input As with the first edition contributions from leading scholars from around the world will ensure The Senses offers a truly international portrait of sensory physiology The set is the definitive reference on sensory neuroscience and provides the ultimate entry point into the review and original literature in Sensory Neuroscience enabling students and scientists to delve into the subject and deepen their knowledge All inclusive coverage of topics updated edition offers readers the only current reference available covering neurobiology physiology anatomy and molecular biology of sense organs and the processing of sensory information in the brain Authoritative content world leading contributors provide readers with a reputable dynamic and authoritative account of the topics under discussion Comprehensive style content in depth complex coverage of topics offers students at upper undergraduate level and above full insight into topics under discussion

Surgery of the Diencephalon Robert Holtzman, 2012-12-06 The problems of surgical intervention in and about the diencephalic region have stimulated the interest of neurosurgeons throughout the world It was therefore not totally surprising when Professor A N Konovalov proposed this topic for discussion at the Fifth Annual Stonwin Medical Conference Bringing the leading figures in this area to New York for a roundtable conference was an exciting challenge Professor Russel H Patterson Jr generously consented to be our guest of honor The conference was held at the Winston Estate on July 13 14 1987 and met our every expectation for a vigorous exchange of individual experiences and more importantly for a dialogue directed toward present and future expectations in the surgery of this region In addition the discussions at that small dinner at the Harvard Club of New York led to the creation of an exchange

program for neurosurgical residents fellows and faculty members of the N N Burdenko Neurosurgical Institute Academy of Medical Science and the Department of Neurosurgery of the New York Neurological Institute which was planned for the spring and summer of 1988 The Stonwin Conference and the exchange agreement and program fostered by the Harry Winston Medical Foundation Inc represent the fulfillment of goals conceived by Harry Winston and promulgated by his sons Ronald and Bruce Henry B Roberts Jr

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