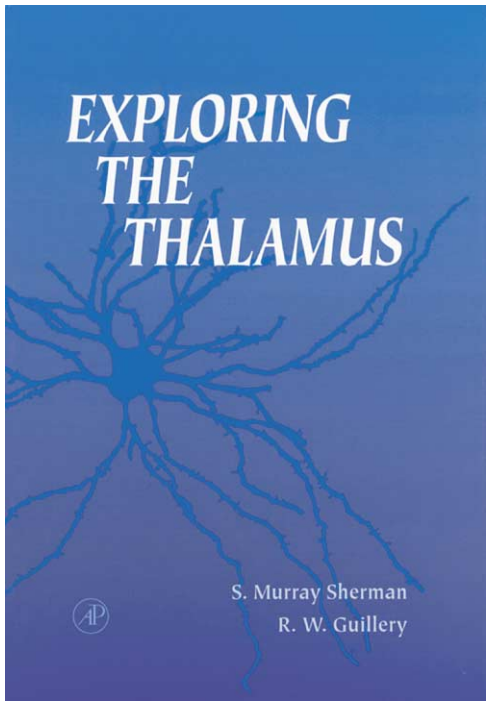
Neuron, Vol. 34, 507–508, May 16, 2002, Copyright ©2002 by Cell Press

Book Reviews

The Thalamus: A New Proposal

Exploring the Thalamus
S.M. Sherman and R.W. Guillery
Academic Press (2001)
328 pp, $59.95 hardcover



Rarely in neuroscience does an idea come along that illuminates an entire field of work and promises to shape its future—this may have just happened for the thalamus and the way we view its relationship with the cerebral cortex.

The mammalian thalamus is a paired structure comprising a relatively small group of neuronal nuclei that sits in roughly the center of the brain, on either side of the third ventricle. Virtually all sensory information coming from the periphery must first pass through the thalamus before reaching the cerebral cortex. Despite its key location, or perhaps because of it, the thalamus has traditionally been viewed as a simple relay that passes on messages to the cortex largely as they come in and that does little in the way of information processing or integration. This view of the thalamus as merely a relay has recently been called into question, and evidence is beginning to accumulate that, while the thalamus undoubtedly relays inputs to cortex, it may actually play a much more dynamic role in the processing and transmission of information. In "Exploring the Thalamus," S. Murray Sherman and Ranier W. Guillery, two neuroscientists who have devoted their careers to studying the thalamus, tackle the problem of trying to make sense of what is known (and not known) about the thalamus and to move toward an understanding of what role(s) the thalamus plays. They succeed admirably and, in the process, make a novel proposal for a role for the thalamus in cortical function that might do no less than transform the field.

The title is apt, conveying well the thrust of the book. As mentioned in the preface, the intention of the authors is not to provide a complete documentary account of everything that is known about the thalamus. Other more weighty tomes already do a good job of this (E.G. Jones's "Thalamus," for example). The book by Sherman and Guillery is more approachable, being a relatively slim volume—it weighs in at a fairly modest 270 pages or so of text. There are a number of figures throughout the volume. Many of these are line drawings that illustrate specific points; others are graphs or illustrations of dendritic or axonal structure at the light or electron microscopic level. The figures are well produced and clearly described, and they complement the text well. Do not be fooled by the modest size of this volume. Although not a comprehensive survey of all the literature, information is densely packed between its covers. The authors have done an impressive job of bringing together large amounts of older and recent evidence to provide clear background to their reasoning and to synthesize their suggestions as to what the role of the thalamus might be.

The book can be divided into two parts. The first presents many of the known structural and functional features of the thalamus. This moves from a somewhat traditional overview of the thalamus in chapter I, to a more detailed look at the different classes of neuron that make up the thalamus in chapter II. Chapter III looks at the types of afferent that provide input to the thalamus. Differences in the structure of afferents are clearly demonstrated at both the light and electron microscopic level. In chapter IV, the intrinsic electrophysiological properties of thalamic neurons are discussed. This chapter starts with an overview of cable theory and then moves on to explain how neurons display numerous nonlinear membrane properties that make the view of thalamic neurons as passive relays inappropriate. The physiological basis of the low-threshold calcium current, a key property of thalamic neurons that determines whether a thalamic neuron will fire in burst or tonic mode, is described. Chapter V focuses on the different types of synaptic inputs to thalamic cells. Particular emphasis is placed on the different roles that metabotropic and ionotropic receptors play in thalamic transmission, the different types of afferents that are associated with these receptors, and the potential role that the metabotropic inputs may play in activating or de-inactivating the low threshold calcium current. Together, the early chapters establish a solid anatomical and physiological foundation for the second half of the book, which moves toward a unifying view of the functional role of the thalamus. In chapter VI, the functional significance of the

burst and tonic modes of firing are discussed. Chapter VII looks at what we can learn and discern from the presence (or absence) of topographic maps within a projection. Chapter VIII describes the anchoring concept of first order and higher order relays to cortex. Finally, chapter IX cements the authors' view that inputs to the thalamus and to cortex can be divided into two classes: drivers and modulators. It also points out general principles that can be applied to the identification of drivers and modulators in thalamic nuclei which are not currently well understood and which would provide important insights into the role of these nuclei.

The concept of drivers and modulators forms the core of the proposed hypothesis of thalamic function and is a central theme of the book. Drivers are considered to be inputs that provide the information content that a given thalamic relay passes on to the cortex. In contrast, the input provided by the modulators is not transmitted through the thalamus but serves rather to adjust the nature of thalamic transmission. Modulators actually provide the numerical majority of inputs to the thalamus and can arise from a number of sources for any one thalamic nucleus, but most notably from cortical layer VI and the brainstem. The authors do note that while the driver inputs are well characterized in specific cases, particularly for the first order sensory nuclei (for example: the retinal inputs to the lateral geniculate nucleus in the visual system; the medial lemniscal inputs to the ventroposterior nucleus in the somatosensory system; the brachial inputs to the medial geniculate nucleus in the auditory system), the identity of the drivers for other nuclei is not so clear. They suggest, on the basis of several lines of anatomical and physiological evidence, that for higher order thalamic nuclei, the input from cortical layer V back to the thalamus in fact provides the driver input. The final step of the proposal follows logically: they suggest that the transmission of information from one cortical area to another actually occurs via a corticothalamic-thalamocortical loop through higher order thalamic nuclei, and that the direct corticocortical transmission serves primarily to modulate this input.

This is a radical idea and a profound one, and the authors have recently expanded on it (R.W. Guillery and S.M. Sherman [2002], Neuron *33*, 163–175). The function of large chunks of the thalamus, including for example the pulvinar, has simply been unknown and even unsuspected to date. A logical extension of the authors' proposal is that the thalamus acts as the driver for all of cortex, be it primary sensory cortex or higher "association" cortex. The hypothesis provides a unifying theme for a large body of previous work and opens up the field for future experiments.

Much of what is presented throughout the book is based on studies performed in the visual system. This not only reflects the expertise of the authors but also the fact that a substantial part of what is known about the thalamus at this stage comes from work done in the visual pathway. Wherever possible, however, parallels and comparisons are drawn with other thalamic nuclei.

Throughout the book, the authors point out the gaps and holes in our knowledge of the thalamus which impede a full understanding of its role. At the end of each chapter, there is a list of unresolved questions, many of which would make excellent starting points for research projects and possibly PhD theses. The book is extremely well written. Background is developed, ideas are formulated, and questions are asked in a logical flow. An effort has been made to make each chapter accessible to readers without their necessarily having read previous ones. Particularly salient pieces of information from one chapter that are critical for understanding the next are described briefly without interrupting the flow of ideas. This feature would make individual chapters of the book excellent resource material for graduate courses in neuroscience. Postdocs and more senior researchers would also find it to be a wonderfully compact, up-to-date reference jam-packed with facts, theory, and interesting ideas about how we can think about the thalamus and its interrelationships with the cortex. It would also provide a useful guide and reference to the anatomy and physiology of the thalamus for those interested in more computational aspects of neuroscience.

Despite the fact that the book contains a huge array of information—everything from a brief review of action potentials to the functional significance of maps and gating of firing states—it does not read as a dry text. Effort is made at every stage to link anatomy and structure with physiology and function. The authors have a depth of knowledge and passion for their topic that shines through the pages. At times their excitement becomes infectious, making you want to turn the page faster to find out what the answer is, and even at times making you feel as though you should run off into the lab and start recording or injecting right there and then to figure it out. Indeed, the proposal about a principal role for the thalamus in corticocortical communication is really a bonus; it is presented as a hypothesis that needs to be tested, which you can take or leave. Equally important is the knowledge and understanding about the thalamus one can gain from reading this book.

The mammalian thalamus and cortex evolved together and are extensively interconnected. Virtually all of the cortex relies heavily on the thalamus for its input, and, without each other, neither the thalamus nor cortex would amount to much. Understanding the role that the thalamus plays in the processing of information is critical to understanding cortical function. Sherman and Guillery have done a wonderful job of bringing together salient facts and features of the thalamus and its connection with the cortex, and their ideas should form the basis for the next leap in understanding what the thalamus does and why it exists.

Catherine A. Leamey and Mriganka Sur
Department of Brain and Cognitive Sciences
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139