

"BREAKS NEW GROUND."

—Antonio Damasio

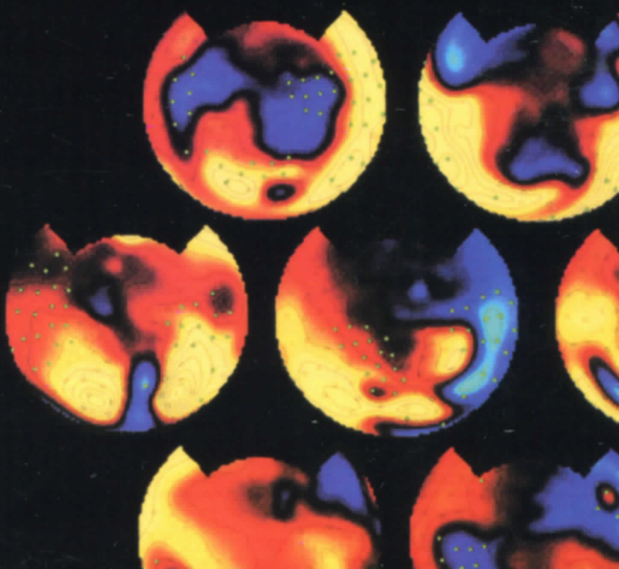
**GERALD M. EDELMAN**

NOBEL LAUREATE and author of *BRIGHT AIR*, *BRILLIANT FIRE*

**GIULIO TONONI**

**A UNIVERSE OF  
CONSCIOUSNESS**

HOW MATTER BECOMES IMAGINATION



What goes on in our heads when we have a thought? Why do the physical events that occur inside a fistful of gelatinous tissue give rise to the phantasmagoric world of conscious experience, a world that contains everything we feel, everything we know, and everything we are? Scientists and philosophers have pondered these questions for eons, but until now their answers could never be grounded in observable scientific experiment. In *A Universe of Consciousness*, Edelman builds on the radical ideas he introduced in his monumental trilogy—*Neural Darwinism*, *Topobiology*, and *The Remembered Present*—to present for the first time an empirically supported full-scale theory of consciousness. Edelman and Tononi show how they use ingenious technology to detect minute brain currents and to identify the specific brain waves that correlate with particular conscious experiences. The results of this pioneering work challenge much of the conventional wisdom about consciousness: In support of Freud's theories, the authors show that the so-called unconscious occupies a much larger part of brain activity than previously thought. And in a radical departure from the concept of consciousness as a unified entity, they argue that each person has a unique "consciousness footprint," underscoring the centrality of human individuality.

"A sense of excitement runs through all of Edelman's books."

—Oliver Sacks

"Edelman and Tononi's work breaks new ground."

—Antonio Damasio, author of *The Feeling of What Happens*

"The best and most accessible introduction to Edelman's ideas on consciousness... Explaining consciousness has become the Holy Grail of modern neuroscience. Any reckoning on who has found the true path is surely premature. Nevertheless, the account of consciousness provided by Edelman and Tononi is certainly highly plausible and can be recommended as one of the most ambitious accounts around."

—Nature

"[Edelman and Tononi] have compelling evidence for privileging the exponential progress of science in studying the brain over the slow mediation of philosophy over the past millennia, and their resulting text contributes richly to both."

—The Boston Book Review

**Gerald M. Edelman, M.D., Ph.D.** is Director of The Neurosciences Institute and Founder of the Neurosciences Research Foundation. He received the Nobel Prize for Medicine in 1972. He is the author of *Neural Darwinism* (1987), *Topobiology* (1988), *The Remembered Present* (1989), and *Bright Air, Brilliant Fire* (1992), all published by Basic Books.

**Giulio Tononi, M.D., Ph.D.** is a Senior Fellow in Theoretical and Experimental Neurobiology at the Neurosciences Institute. He is the editor with Olaf Sporns of *Selectionism and the Brain*. Both authors live in San Diego, CA.



DETAIL FROM MICHELANGELO'S CREATION OF ADAM IN THE SISTINE CHAPEL. God is pictured on a background that bears more than a passing resemblance to a section of the human brain. A detailed comparison can be found in F. L. Meshberger, "An Interpretation of Michelangelo's *Creation of Adam* Based on Neuroanatomy," *Journal of the American Medical Association*, 264 (1990), 1837-41.

# A Universe of Consciousness

HOW MATTER BECOMES  
IMAGINATION

GERALD M. EDELMAN  
AND GIULIO TONONI

BASIC  
  
BOOKS

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# Contents

<i>Illustrations</i>	<i>vii</i>
<i>Acknowledgments</i>	<i>ix</i>
<i>Preface</i>	<i>xi</i>

## PART I

### THE WORLD KNOT

1 Consciousness: Philosophical Paradox or Scientific Object?	3
2 The Special Problem of Consciousness	10
3 Everyman's Private Theater: Ongoing Unity, Endless Variety	20

## PART II

### CONSCIOUSNESS AND THE BRAIN

4 Building a Picture of the Brain	37
5 Consciousness and Distributed Neural Activity	51
6 Neural Activity Integrated and Differentiated	62

## PART III

### MECHANISMS OF CONSCIOUSNESS: THE DARWINIAN PERSPECTIVE

7 Selectionism	79
8 Nonrepresentational Memory	93
9 Perception into Memory: The Remembered Present	102

## PART IV

DEALING WITH PLETHORA:  
THE DYNAMIC CORE HYPOTHESIS

- |    |   |     |
|----|---|-----|
| 10 | Integration and Reentry   | 113 |
| 11 | Consciousness and Complexity                                    | 125 |
| 12 | Determining Where the Knot Is Tied: The Dynamic Core Hypothesis | 139 |

## PART V

## UNTANGLING THE KNOT

- |    |                                   |     |
|----|-----------------------------------|-----|
| 13 | Qualia and Discrimination         | 157 |
| 14 | The Conscious and the Unconscious | 176 |

## PART VI

## OBSERVER TIME

- |    |                          |     |
|----|--------------------------|-----|
| 15 | Language and the Self    | 193 |
| 16 | Thinking                 | 200 |
| 17 | Prisoners of Description | 207 |

- |                     |     |
|---------------------|-----|
| <i>Notes</i>        | 223 |
| <i>Bibliography</i> | 253 |
| <i>Credits</i>      | 265 |
| <i>Index</i>        | 267 |

## Illustrations

- |  |     |
|--|-----|
| Frontispiece: Detail from Michelangelo's <i>Creation of Adam</i>                 | 5   |
| 1.1 Diagram by Descartes on how the brain forms mental images                    | 13  |
| 2.1 A skeleton observing a skull, an engraving by Andreas Vesalius               | 18  |
| 2.2 William James  | 21  |
| 3.1 <i>Virgin Forest with Setting Sun</i> by Henri Rousseau                      | 25  |
| 3.2 An ambiguous figure  | 28  |
| 3.3 Drawing by a patient with left hemineglect                                   | 30  |
| 3.4 Shot sequence from Eisenstein's <i>Potemkin</i>                              | 38  |
| 4.1 Gross anatomy of the brain   | 39  |
| 4.2 Two illustrations by Ramon y Cajal   | 41  |
| 4.3 Diagram of a synapse   | 43  |
| 4.4 Three topological arrangements of brain neuroanatomy                         | 56  |
| 5.1 Distributed neural processes underlying conscious experience revealed by MEG | 63  |
| 6.1 The corpus callosum  | 65  |
| 6.2 Anna O., a patient of Sigmund Freud  | 70  |
| 6.3 Coherence of neural processes underlying consciousness                       | 72  |
| 6.4 EEG patterns during epilepsy and sleep                                       | 73  |
| 6.5 <i>La Notte (The Night)</i> , by Michelangelo                                | 80  |
| 7.1 Charles Darwin   | 84  |
| 7.2 Diagram of the theory of neuronal group selection                            | 89  |
| 7.3 Diagram of a value system  | 90  |
| 7.4 Darwin IV tracking colored cubes   | 96  |
| 8.1 Diagram of a global mapping  | 100 |
| 8.2 Knik glacier, Alaska   | 108 |
| 9.1 Mechanisms of primary consciousness  |     |

10.1	What is connected to what in the cerebral cortex	115
10.2	Diagram of a computer model of cortical integration	116
10.3	Solving the binding problem	117
10.4	Diagram of functional clustering	122
11.1	Diagram of mutual information	128
11.2	Diagram of complexity	129
11.3	How complexity varies, depending on neuroanatomical organization	132
12.1	M83, a spiral galaxy, in Hydra	145
13.1	Color space	162
13.2	Qualia space	164
13.3	Spring model of the dynamic core	172
14.1	Structures and connections mediating conscious and unconscious processes	179
15.1	A scheme of higher-order consciousness	194
17.1	Diagram of a Turing machine	213
17.2	<i>Counterpart</i> , by Arcimboldo	221

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# Preface

Consciousness has been seen as both a mystery and a source of mystery. It is one of the main targets of philosophical inquiry, but only recently has it been accepted into the family of scientific objects that are worthy of experimental investigation. The reasons for this late acceptance are clear: Although all scientific theories assume consciousness and conscious sensation and perception are necessary for their application, the means to carry out scientific investigations of consciousness itself have only recently become available.

There is something special about consciousness: Conscious experience arises as a result of the workings of each individual brain. It cannot be shared under direct observation, as the physicist's objects can be shared. Thus, studying consciousness presents us with a curious dilemma: Introspection alone is not scientifically satisfactory, and though people's reports about their own consciousness are useful, they cannot reveal the workings of the brain underlying them. Yet, studies of the brain proper cannot, in themselves, convey what it is like to be conscious. These constraints suggest that one must take special approaches to bring consciousness into the house of science.

In this book, we do just that, and we develop ways to answer the following questions:

1. How does consciousness arise as a result of particular neural processes and of the interactions among the brain, the body, and the world?
2. How do these neural processes account for key properties of conscious experience? Each conscious state is unified and indivisible,

yet at the same time, each person can choose among an immense number of different conscious states.

3. How can we understand different subjective states—so-called qualia—in neural terms?
4. How can our understanding of consciousness help connect strictly scientific descriptions to the wider domain of human knowledge and experience?

To describe the neural mechanisms that give rise to consciousness, to show how the general properties of consciousness emerge as a result of the properties of the brain as a complex system, to analyze the origins of subjective states or qualia, and to show how the successful pursuit of all these efforts may change our views of the scientific observer and of long-held philosophical positions is, of course, a tall order, and in the short compass of this volume much of interest must be omitted. But the main outlines of a solution to the problem of consciousness can be sketched by paying close attention to our four basic questions. Our answers are based on the assumption that consciousness arises within the material order of certain organisms. However, we emphatically do not identify consciousness in its full range as arising solely in the brain, since we believe that higher brain functions require interactions both with the world and with other persons.

Once we establish this new understanding of how consciousness emerges, we touch on several interesting issues that derive from this perspective. We propose a new view of the scientific observer, and we explore how we can know what we know—the realm of epistemology. Finally, we discuss the question of which subjects are appropriate for scientific study. Exposing these matters to scrutiny is important because our position—that consciousness arises as a particular kind of brain process that is both highly unified (or integrated) and highly complex (or differentiated)—has wide-ranging implications.

To untangle the bases of consciousness and account for some of its properties, we consider a number of challenging subjects. Indeed, before we get to the central issue, the neural substrate of consciousness, we review structural and functional features of brain organization, as well as certain essential aspects of brain theory. To make the task easier for the reader, we have prefaced each major part of the book with a prologue and each chapter with a brief introduction. We suggest that to obtain a synoptic view, the reader peruse in order the six prologues and the introductions to the chapters. Doing so will help keep the whole picture in mind, especially in chapters

that are necessary for analyzing consciousness but are not directly concerned with it. As for the later chapters, only two (chapters 10 and 11) have explicit mathematical content. The reader who is not inclined to follow the details may get a reasonable understanding of their meaning by perusing the figures and “humming the tune.” For those who wish to pursue specific issues or references, we have placed notes at the back of the book. The notes are not, however, necessary for comprehending our argument. We hope that by the end of the journey through the text, readers will find themselves with a new view of how matter becomes imagination.