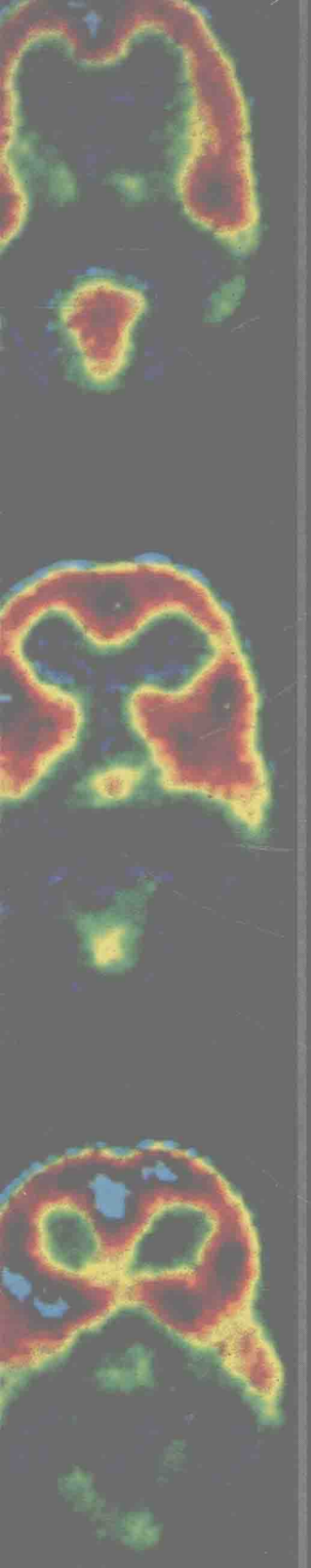

THE MAKING OF MEMORY

From molecules to mind

STEVEN ROSE

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THE MAKING OF MEMORY

Also by Steven Rose

THE CHEMISTRY OF LIFE
THE CONSCIOUS BRAIN

MOLECULES AND MINDS
NOT IN OUR GENES
(WITH RICHARD LEWONTIN AND LEO KAMIN)

SCIENCE AND SOCIETY
(WITH HILARY ROSE)

PREFACE AND ACKNOWLEDGEMENTS

I've wanted to write this book – or at least a book like this – for many years now. The ways in which my many non-scientist friends and colleagues often regard me as a laboratory scientist – with incomprehension and awe, tinged, I sometimes feel, with faint patronage – engendered in me the idea of a sort of apologia for laboratory life. Could I explain what I did day by day in the laboratory in a way which could give a sense of this arcane activity? Furthermore, could I make it clear why I believe these minuscule observations help cast light on what for most of my working life I have seen as one of the most challenging of all biological and human phenomena, that of memory? And could I in doing so avoid the naïve positivism which is how most of us as working scientists go about our day-to-day labours, but instead set this account of my own laboratory practice into the richer and more complex context which the present-day philosophy, politics and sociology of science have revealed as framing scientific theory and experiment?

Memory is a rich area of interpretation and research, and the very term means many things to many people. So, apologies, from the start, to those readers who have picked up this book in the expectation of an engagement with literary criticism, psychoanalysis, neuropsychology or cognitive neuroscience, or, for that matter, a text-book approach to my theme. What I am trying to do draws on all of these disciplines, and several more besides, but it is at once more and less ambitious. I will attempt no further summary or apologia here; the chapters that follow must speak for themselves.

There is no doubt as to who the main influence on me has been as I have tried to develop the synthesis in the following pages: thirty years of living and working – sometimes writing – with the feminist sociologist of science Hilary Rose have been a continuous dialectic (a word she herself abjures) whose traces are apparent throughout this book. No book whose central characters are young chicks could be complete without a tribute to Pat Bateson, who was responsible, back in the 1960s, for my first blind date with what has become a continuing obsession, and who since then has continued to sharpen the experimental wits of one whose first training was, after all, in the most reductionist of the neurosciences. The experimental programme that forms the core of Chapters 2, 3, 10 and 11 has involved the collaboration of many scores of colleagues, visitors from five continents, students and technicians within the Brain and Behaviour Research Group in the years since we established it in 1969. Some of them are mentioned in the text, others in the references to particular pieces of research. Two not specifically mentioned there I would like to pay special tribute to: Arun Sinha, who joined me first as technician, later as student and then postdoctoral colleague, and was with me through all the early years at Imperial College and the Open University; and John Hambley, an early graduate student at the OU, working on imprinting, a great lovable shambling bear of a man, and a loyal comrade, who died tragically young in Sydney in 1990. Others who have worked in the group but are not mentioned by name here may feel that I have missed their own special contribution to the research I describe; my apologies for any omissions: I have valued working with you all over the years. Thanks especially, though, to group members Terri Patterson and Mike Stewart, who commented on various sections of the text, and to four people who are too often invisible supports but without whose constant and committed backup it would be impossible for us to maintain a laboratory, rear animals, run experiments or manage people, grants, budgets and the multifarious activities of a university department. For the chicks, the subjects/objects of my research (and who deserve their own dedication), I thank Dawn Sadler and Steve Walters. For much else besides, Heather Holden and Les Pearce.

Wanting to write this book and finding the space and energy to do so are two separate things. What made it possible has been a precious year away from the responsibilities of being head of a

busy university teaching department, and which I could therefore devote entirely to research, through the generosity of the Wolfson Foundation. Anthony Sheil, my agent, has borne with me patiently and with continued enthusiasm during various hiccups in the writing process, and I have been especially fortunate to meet again, in Bantam UK, an old acquaintance, Jim Cochrane, a sensitive and dedicated editor. None of the above of course is responsible for any remaining errors, misinterpretations or infelicities; they are all mine.

Because this book is in no way intended to provide a comprehensive introduction to memory, but rather to chronicle an adventure in research, illustrate the nature of doing science, and reflect on a theory of mind, I have been a little concerned as to how to deal with the need to explain certain vital aspects of brain structure and biochemistry, necessary to follow the arguments, without formally 'teaching' it. I've opted to introduce key ideas about the brain, neurons, proteins and so on where they are needed for the story line, rather than systematically at the beginning. I hope this will enable a reader, however unfamiliar with the brain, to follow the argument without having to learn too many new bits of biologese. The illustrations have been especially prepared for this book by Debra Woodward, and I hope will help illuminate difficult concepts as well as being pleasing in their own right. I've adopted a similar approach to the conventional academic apparatus of references and credits for research, where I've made a sort of compromise. Some reflections or deepenings of issues raised in the main body of the text will be found in footnotes. Key references are indicated by number and collected at the back of the book. Some chapters are only lightly referenced, and colleagues in the memory mafia whose work is not referred to directly (and I know that the first thing many of us do when we see a new book is to check the references in case we have been cited!) will I hope forgive me. The key 'experimental' chapters, 8–11, are, however, more conventionally densely referenced.

In addition to Debra Woodward's drawings I would like to thank Mike Stewart for permission to use the light and electron micrographs of Figures 3.2, 3.3, 10.2, 10.6, and Larry Squire and the *Journal of Neuroscience* for the NMR photograph of Figure 5.4.

Steven Rose, *London, January 1992*

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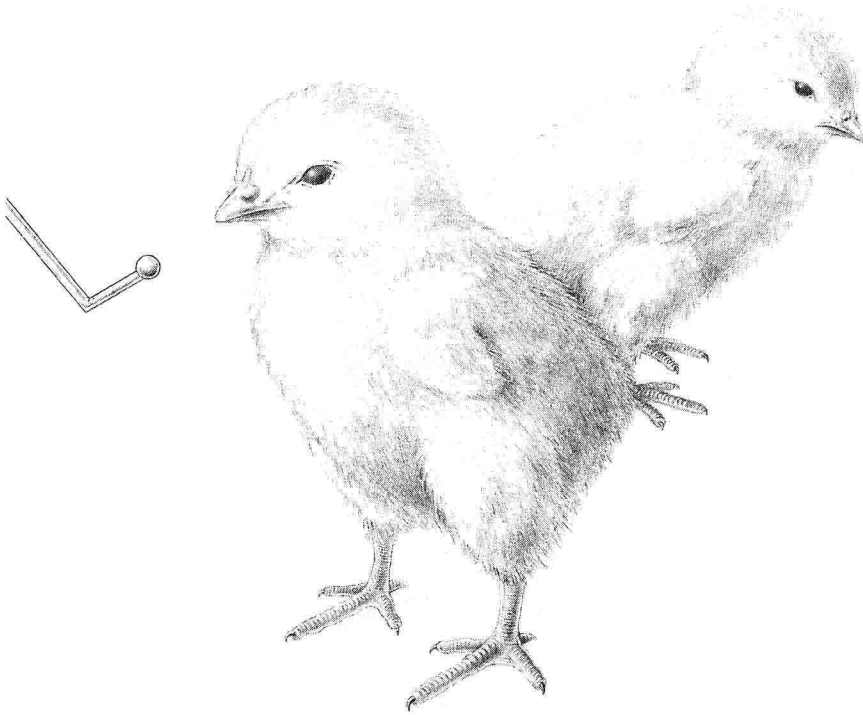

CONTENTS

Chapter 1

THE SEARCH FOR THE ROSETTA STONE

Memories are our most enduring characteristic. In old age we can remember our childhood eighty or more years ago; a chance remark can conjure up a face, a name, a vision of sea or mountains once seen and apparently long forgotten. Memory defines who we are and shapes the way we act more closely than any other single aspect of our personhood. All of life is a trajectory from experienced past to unknown future, illuminated only during the always receding instant we call the present, the moment of our actual conscious experience. Yet our present appears continuous with our past, grows out of it, is shaped by it, because of our capacity for memory. It is this which prevents the past from being lost, as unknowable as the future. It is memory which thus provides time with its arrow.

For each of us, our memories are unique. You can lose a limb, have plastic surgery, a kidney transplant or a sex-change operation, yet you are still in an important sense recognizably yourself so long as your memories persist. We know who we are, and who other people are, in terms of memory. Lose your memory and you, as *you*, cease to exist, which is why clinical cases of amnesia are so endlessly fascinating and frightening. Advocates of crionics, that Californian fantasy of quick-freezing the dead until future advances in medical technology can bring them back to life, recognize this; they propose a computer backup store for the frozen corpse's memories which may somehow be read into the revived body at a future time. But our own human memories are not embedded in a computer, they are encoded in the brain, in the

ten thousand million nerve cells that comprise the human cerebrum – and the ten million million connections and pathways between those cells. Memories are living processes, which become transformed, imbued with new meanings, each time we recall them.

Most of us worry that we have a poor memory, that we forget names, faces, vital appointments. Yet the scale and extent of what any one of us can remember are prodigious. Imagine sitting down and looking at a photograph for a few seconds. Then another, then another, then another . . . Suppose that a week later I show you the photographs again, each accompanied by a new, different one, and ask you to say which you had seen before. How many photographs do you think you could identify correctly before your memory ran out or you became confused? When I asked my colleagues in the lab, their guesses ranged from twenty to fifty. Yet when the experiment is done in reality most people can identify accurately at least *ten thousand* different photographs without showing any signs of 'running out' of memory capacity.

Do we then really forget at all? Are all our past experiences, as some schools of psychoanalysis maintain, encoded in some way within our brains, so that, if only we could find the key to accessing them, every detail of our past would become as transparent to us as is the present moment of our consciousness? Or is forgetting functional, so that we record and remember only those things which we have reason to believe are important for our future survival? If that were so then to have a perfect memory would not be a help but a hindrance in our day-to-day existence, and the long search for techniques or drugs to improve our memory – a search which goes back far into antiquity – would be at best a chimera.

Above all, how do we remember at all? How can the subtleties of our day-to-day experiences, the joys and humiliations of childhood, the trivia of last night's supper or the random digits of a passing car's numberplate become represented within the mix of molecules, of ions, proteins and lipids that make up the ten billion nerve cells of our brains? If it is hard to envisage such a great number of cells, it is enough to note that each human brain contains getting on for three times as many nerve cells as there are people alive on the earth today, and that if you were to begin counting the connections between them at the rate of one every second, it would take you anything from three to thirty million

years to complete your tally. Enough here perhaps to store the memories of a lifetime . . .

And yet there is a problem. During a human lifetime every molecule of our body is replaced many times over, cells die and are replaced, the connections between them are made and broken thousands, perhaps millions of times. Yet despite this great flux which constitutes our biological existence, memories remain. No memory within a computer could survive such a complete turnover of all the machine's constituent parts. Somehow, just as the shapes of our bodies persist despite the ceaseless ebb and flow of their molecular components, so do our memories, embedded in the structure and processes of the brain.

It is this central paradox which dominates the dramatic progress that neuroscience (brain research) is making as we move through the 1990s – a period which in the US has been labelled the 'decade of the brain'. It has dominated my own thoughts and laboratory work for many more years than that, ever since, some thirty years ago, I first felt able to call myself a neuroscientist. When we talk about memory in our day-to-day lives, we refer to it as a feature of our minds, our sensations, thoughts and emotions. But in this book I will mostly be talking not about the mind but about the brain. Neuroscientists are committed to the view that not only is it possible to explore the workings of the mind in all its many dimensions by the methods of science; those workings can also be described in terms of the properties, structures and processes of the brain.

There are some who would view such a statement as either sacrilegious or absurd. The methods of science, or at least biological science, they would maintain, cannot provide understanding of the mind, either because the mind is fundamentally inaccessible to materialist investigation or because our techniques, while they may be applicable to understanding animal brains and behaviour, fail when confronted with the complexities of human thought, speech and social existence. Or maybe we are simply asking the wrong questions; to try to understand the mind and its memories by understanding the brain is like trying to understand how a computer and its programs work by analysing the chemical constituents of the machine and its disks. But when I talk about 'the methods of science' in this somewhat formal way I certainly don't mean 'the methods of nineteenth-century physics' as if there were only one science – as if a slightly old-fashioned view of

physics, actively propagated by traditional philosophers of science and virtually all school teaching, was what every different science, from chemistry to psychology and economics, aimed to become.

What I mean by science and its methods is something a good deal broader and less restrictive: a commitment to a unitary, materialist view of the world, a world capable of exploration by methods of rational enquiry and experiment. If I can achieve what I am setting out to do in this book, then what *that* description of science means in practice, and why I believe it can be applied to the study of memory, will become clear.

My task as a neuroscientist, I believe, is to try to put flesh on the bones of this statement of faith. The workings of the mind, I repeat, are to be described in terms of the properties, structures and processes of the brain, and describing them in this way will help us understand some of the fundamental questions that all of us as humans ask about our own existence, who we are and why we are as we are. Please note that I do not write that the workings of the mind 'are to be explained . . .' To use the term *explain* might seem to imply that if I could describe precisely the molecular and cellular components of the brain, the complex organizing relationships between them and their evolutionary and developmental history, then I would have said all there was to be said about the mind; I would have emptied the word of any meaning at all, reduced it to nothing but an assemblage of brain processes. I do not mean this; describing mind in terms of brain is not the same as explaining mind away. I am not planning, as did some of the schools of psychology which flourished earlier in this century, and as some sociobiologists do today, to try to abolish mind terms from any account of how and why we are what we are; why we do what we do; why I write and you read these sentences. Let me try an analogy.

Pass through the massive neoclassical entrance to the British Museum in London, turn left through the shop and pick your way through the throngs of tourists tramping the Egyptian and Assyrian galleries. A knot of Japanese lean over a slab of black stone mounted at a slight angle to the floor. If you can interpose your body between the tourists and their miniature videocameras, you will see that the flat surface of the stone is divided into three sections, each covered with white marks. The marks in the top third are ancient Egyptian hieroglyphs; those in the middle are in a cursive script, demotic Egyptian; and if you had what used to be

regarded as a 'sound classical education' or have been to Greece on holiday, you will recognize the writing on the lower third as Greek. You are looking at the Rosetta stone, the text of a decree passed by a general council of Egyptian priests who assembled at Memphis on the Nile on the first anniversary of the coronation of King Ptolemy in 196 BCE. 'Discovered' (in the sense that Europeans talk of artefacts of which they were previously unaware, irrespective of what the local population might have known of them) by a Lieutenant of Engineers in Napoleon's Egyptian expeditionary force in 1799, the stone became British booty of war with the French defeat, and was brought back to London and placed ritually amongst the great heap of spoils of ancient empires with which the British aggrandized themselves during their own century of imperial domination.

But the importance of the Rosetta stone lies not in its symbolism of the rise and fall of empires (even the Greek portion of its three scripts indicated that, at the time it was carved, Egyptian power was in slow decline and Europe's pre-eminence was beginning). The fact that its three scripts each carry the same message and that nineteenth-century scholars could read the Greek meant that they could begin the task of deciphering the hitherto incomprehensible hieroglyphs that formed ancient Egypt's written language. The simultaneous translation offered by the Rosetta stone became a code-breaking device, and for me it is a metaphor for the task of translation that we face in understanding the relationships between mind and brain.

As humans trying to understand and act upon the world we inhabit, we work with several languages. Speaking of our own experience we talk personally, subjectively. The classical goal of science has been to eliminate this personal subjective quality of language and replace it with a public voice of claimed objectivity. Yet this is easier to do if we are dealing with physics or chemistry than if we are concerned with the biological and psychological worlds. Dealing with psychological, mental experience, describing what we and others do, why we do it and how we feel about it, we have available at least two alternative languages, each of which makes claims to objectivity – that of mind and that of brain. Brain language has many dialects, spoken by many different sorts of biologists – physiologists, biochemists, anatomists – and handles its claims to objectivity with confidence. Mind language can be – generally is – subjective, the language of everyday life, or of the

poet or novelist. But in the hands of psychologists, it too aspires towards objectivity. One of the tasks of the new breed of neuroscientist that was born in the 1960s, grew through the 1980s and has matured into this new and scientifically glorious decade of the 1990s is to learn how to translate between the two objective languages of mind and brain. To help that translation we need a Rosetta stone, some inscription in which the two languages, the Greek of mind and the hieroglyphs of brain, can be read in parallel and the interpretation rules deciphered. Deciphering translation rules is not the same as reducing one language to the other. The Greek is never *replaced* by the Egyptian; the mind is never replaced by the brain. Instead, we have two distinct and legitimate languages, each describing the same unitary phenomena of the material world. The separate histories of these languages as they have developed over the past century have hitherto made them sometimes rivals, sometimes allies. But within this current decade of the brain the prospect of unity, of healing old divisions and of learning the translation rules, has never seemed brighter. I believe, for reasons that this book will I hope make clear, that the study of memory gives us the best chance of learning these rules, that memory will turn out to be the brain's Rosetta stone.

Is this claim arrogant? Memory has fascinated philosophers since ancient times. Every culture has offered its own analogy for human memory. For the Greeks, it was inscriptions on wax tablets, for the medievals a complex system of hydraulics, of pipes and valves. At the birth of modern western science in the seventeenth century clockwork mechanisms seemed the appropriate metaphor; clockwork was replaced in the nineteenth century by electricity, and in the late twentieth by computers. I will argue that none of these analogies captures the richness of real human memory, whose understanding lies in the biology of the brain itself, the dynamics of the structural, chemical and electrical interactions between its molecules and cells, but which cannot be reduced to 'merely' these.

To some of the more vociferous critics of modern science, this can never be enough. Memory is not only – or even, some would say, primarily – the terrain of the sciences of brain and behaviour. To achieve my translation, I have abolished the subjective at the stroke of a computer key, and offered instead merely the objective language of psychology. Yet for each of us our personal memories are profoundly subjective. Day by day in the lab I explore the

biology of memory in experiments with young chicks; in the evening I go home to a world richly inhabited by my own personal memories. How do these two halves of my life relate? To heal the split in our own lives between subjective and objective surely requires more than just translation between two equally objective languages – the bridging of a much more profound chasm that has developed within the fragmented culture of western industrialized society, a chasm that the very power and professed objectivity of science are seen by some as deepening. Can we be at peace with ourselves if we recognize that our deepest, most sacred feelings, of love for others and awe at the universe in which we find ourselves, are at the same time represented inside our own heads by patterns of connections between nerve cells and the electrical flux between them, the synthesis of particular proteins and the breakdown of others? I believe we have to learn how to integrate these separate knowledges and feelings if we are to achieve the potential that our very humanity, our own evolved brains and societies, offer us.

I have to accept the limits of neuroscience, to concede that it has so far been left to the other half of our fragmented culture, the terrain traditionally inhabited by poets and novelists, to try to explore the subjective meanings of memory. Memory pervades ancient ballads and modern novels alike. Especially in the present century, from James Joyce and Marcel Proust to the new writing of Margaret Atwood, of J. G. Ballard, Toni Morrison, Salman Rushdie and Alice Walker, the theme of personal memory, of the constant examination, interpretation and reinterpretation of lived experience, is central. Can I integrate the minuscule observations of this behaviour of the chicks I work with and the chemistry of their brains with such richness of evocation? Or are we doomed to live always in the divided worlds of subjectivity and objectivity, with no translation possible between *these* languages?

Further, by offering merely to translate between the languages of brain and mind, biology and psychology, I have ignored the fact that humans are not isolated monads, existing trapped inside their own heads, but are profoundly social beings, continually interacting with the outside worlds of things and people. Humans, their minds and brains, are not closed but open systems. To understand ourselves demands a recognition of this openness, and of the fact that the sciences which can account for its consequences are no longer those of individual psychology or neuroscience, but of the collective of individuals who comprise human society. Ecology