Acknowledgments

Many colleagues helped me form my ideas on brain and mind and made me articulate the ideas of relational consciousness that are developed in this book. There are also those whose talks on mind and brain have stimulated me. All of these I would like to thank, most especially Farrukh Alavi, Igor Aleksander, Bernie Baars, Bill Banks, Raju Bapi, Paul Bressloff, Guido Bugmann, Walter Freeman, Chris Frith, David Gaffan, Jean-Phillipe Gaussier, Denise Gorse, Jeffrey Gray, Steve Grossberg, Stuart Hameroff, Simon Hastings, Jim Hopkins, Andy Ioannides, Lutz Jaencke, Bart Krekelberg, Dan Levine, Ben Libet, Tony Marcel, Tom Metzinger, Robin Merris, Luchas Mihalis, Ouri Monchi, Hans Mueller-Gartner, Jim Newman, Gerry Orchard, David Papineau, Roger Penrose, Ras Petersen, Bill Phillips, Karl Pribram, John Shah, Tim Shallice, Neil Taylor, Alessandro Villa, Doug Watt, and Stephen Zrehen. I thank Hans Mueller-Gaertner, Director of the Institute of Medicine, Juelich, for inviting me to work as a guest scientist at the institute for one and a half years to search for consciousness with the new machines, and his colleagues John Shah, Berndt Krause, Andy Ioannides, and Stephen Posse for providing expertise, enthusiasm, and a stimulating environment during my stay there. I also thank my late editor, Harry Stanton (I am sad to say, no longer with us), and his replacement Michael Rutter, for being so supportive, and the reviewers for making such excellent suggestions for its improvement. Finally I thank my wife, Pamela, for her unstinting help in editing the book through several of its drafts.

I

Introduction to Consciousness

1

The Race Begins

Away went Gilpin—who but he?
His fame soon spread around.
He carries weight, he rides a race!
'Tis for a thousand pound!
—Wallace Cowper

The Racing Scene

The race for consciousness has started. Consciousness is the most subtle and complex entity in the universe. With it, humans have duplicated here on Earth the awe-inspiring methods by which stars produce their energy. By creative thinking the forces of nature have been probed from across the vastness of the visible universe to deep inside the atom; a beautiful theme for the construction of the whole has been powerfully constructed: "the Universe in a grain of sand and a twinkling star," to extend the poet William Blake. By artistic imagination humans have created emotionally satisfying alternative universes that allow us to have new and surprising views of this one. These magnificent products have all been achieved by human consciousness.

But what is this elusive thing called consciousness, which is so important in the process of creativity and thinking? Our very experience is based on our being conscious. How does this subtle process, regarding which philosophers and theologians have argued and fought for several millennia, emerge from brain activity in what looks just like "two fistfuls of porridge"? Or is there more to mind than mere matter? To answer these deep questions at the basis of the human condition, science is

turning its sights onto the mind; the race is on to be the first ever to discover the scientific nature of consciousness.

We all love winners. We look up to them, even revere them, as well as envy them. In the poem, John Gilpin became famous in peoples' minds because they thought he had entered a race for what was a huge amount of money in those days. While bringing in a tidy sum in prize money, a Grand National winner today will be worth far more (many millions) in stud fees to its owners. But it is not just for the money but also for the sheer guts shown in winning that crowds show such admiration. Red Rum, one of the greatest Grand National winners of all time, had a special place in the hearts of many for his plucky rides over what is acknowledged to be a terrifying course.

Such, then, are the prizes in all types of races—satisfaction, fame, and fortune. But to win, skill and strength must be developed by training over lengthy periods, and strategy must be carefully designed to exploit the weaknesses of opponents. This can be done because races are over well-defined obstacles, and rules are designed to prevent any unfair advantage going to one or other of the competitors.

Scientific races are different. For them, anything goes in trying to win. Scientists race against each other to try to solve some conundrum, but do so without rules about styles, techniques, equipment allowed, or ideas used to help suggest crucial experiments. They can do what they want as long as they produce a solution to the problem that started it and that stands up to the rigorous test: does it work? Any number of scientists may enter the race, but it is usually those who are either most conversant with the particular area or who are best equipped who will win. Two examples of recent scientific races, one of a mathematical nature, the other experimental, clearly demonstrate this difference.

Fermat's last theorem had been unproved for over 200 years. It is very simple to state: lots of pairs of numbers have squares that, when added, give the square of a number, for example, $3^2 + 4^2 = 5^2$; are there any pairs that when cubed and added give the cube of a number? The French mathematician realized that this was a simple but interesting problem and claimed to be able to show that no such pairs of numbers can exist: this is Fermat's last theorem. However, his proof never surfaced; he died without ever writing it down. Since then many have labored mightily to

prove the theorem; a prize was awarded several times for supposed solutions that were all later shown to be wrong. Numerous mathematicians (and others with little technical training) still entered the race to prove Fermat's last theorem, in the process giving an enormous advance in understanding general aspects of number theory (the relevant branch of mathematics).

In 1995 British mathematician Andrew Wiles, working in Princeton, finally produced a proof (his first effort was not quite right, but the latest version has now been accepted). Wiles struggled with this problem with dedication and secrecy over several years. To throw his colleagues off the scent he published a trickle of papers in mathematics journals on an altogether different problem. His dedication, cunning, and enormous technical expertise in all the branches of number theory together allowed him to produce a proof of the theorem before anyone else, and so win one of the most important mathematical races of all time.

A completely different race was run to find the elusive and subtle W and Z mesons, particles that justified the beautiful theoretical unification of electromagnetism and radioactivity suggested in the 1960s by Salam, Weinberg, and Glashow. The photon is the "glue" that binds charged particles together, carrying the force of electromagnetism between them; it was suggested that analogous glue would carry the force of radioactivity. It was even predicted how massive these glue particles should be, in addition to some of their other properties. Italian physicist Carlo Rubbia persuaded the powers that be to have a machine built, the big electron-proton collider particle accelerator at the particle physics laboratory CERN in Geneva. This particle smasher would generate enough energy in particle beams as they clashed that they could produce, out of the debris, a few of these glue particles—the W and Z mesons. This was done, and when the experimental results were analyzed they showed clear traces of the exotic short-lived particles. Rubbia and the designer of the machine were awarded the Nobel prize for their work.

These are two scientific races in which the winning posts were crystal clear, as were the winners when they reached them. The race was won by those with appropriate technical equipment, whether it was expertise in number theory or access to a very large particle accelerator.

The race for consciousness seems to be different. Is it a race at all? What can be scientific about it? Where is the winning post? Is there only one? If the race exists, can it be run by amateurs, or is it only the professional scientist who is expected to win, as in the two examples above?

The Consciousness Scene

The interest in consciousness is exploding. Many are involved across the whole spectrum of intellectual life, from philosophers to quantum physicists. All are having their say and claiming things about consciousness from their own viewpoint. All well and good, and they have every right to have opinions about things that cannot be proved. That is what opinions are for, to make up for lack of real knowledge on which all have to agree if possible. The recent spate of books on consciousness only confirm such a feature—philosophers and quantum physicists and others joining the battle to air their opinions on the subject.

Yet the subject of consciousness is now moving out of the arena of opinion against opinion into that in which the problems are being clarified. Scientific tools and expertise are becoming available to provide competitors with the best sorts of support to enable them to win. Noninvasive instruments—so called because they can be used without cutting open the skull and sticking electrodes in the brain—are allowing enormous strides to be made in appreciating the magnificence of the brain as the most subtle and powerful natural system ever looked at scientifically. These tools are exposing the mysteries of the brain and giving new direction to the search for how consciousness is supported.

These enormous advances are such that opinion is being replaced by science. Opinions are now seen as either irrelevant or helpful only as a ground-clearing exercise before the true scientific race can begin. However, the core problem of consciousness as a subtle inner experience remains. Many still ask, ''How can science ever get to the 'inside' of my experience?'' Science considers the outside only, in an objective manner. How can it ever probe the subjective inner world we each inhabit? What is more, how can it construct a clear winning post, that of giving a truly scientific explanation of consciousness, if it cannot get inside this

subjective world, which must remain terra incognita to its methods and approach?

Are we not back to the opinions of all those who, we claimed earlier, were not part of the scientific race for consciousness? Are their opinions not just as valid as those of researchers who are exploring this prohibited inner world? Indeed it could be claimed that no progress has really been made by importing more science into a scientifically intractable problem.

The Scientific Approach to Consciousness

More clarity is being brought to the consciousness arena than these pessimistic remarks would grant. A clearer vision is arising not only from results flooding in from noninvasive instruments and new understanding of the brain thereby obtained, but also from ideas of a more theoretical nature.

The brain is composed of myriad living nerve cells (the ''atoms'' of the brain, the nerve cell being the smallest living unit). The manner in which these nerve cells combine to enable the brain to support the mind is being tackled by workers in the discipline of neural networks. This was initiated over fifty years ago in a remarkable paper by American scientists Warren McCulloch and Walter Pitts (1946). They showed that a network constructed of the simplest possible kind of such cells influencing each other was powerful enough to perform any logical computation that we ourselves could do. This amazing result was a big fillip to the development of the digital computer and ushered in the age of the computer.

That was only the beginning. Additional neural networks were designed by keeping closer to the way the living nerve cells work in the brain. This led to numerous artificial neural networks that were developed to solve difficult problems, such as tracking unexpected changes in buying and selling shares on the Stock Exchange so as to catch insider trading, or so as to make better investment of bonds or shares by predicting how their prices would change in the near future. Many artificial neural systems are now in operation in a wide range of industries and across commerce.

All these developments have gone hand in hand with similar increases in theoretical understanding of how the neural networks of the brain

perform. From the retina (an approachable part of the brain) to the frontal lobes (the thinking center), artificial neural network models are being built that attempt to capture ever more closely the patterns of activity and response possessed by people or animals (e.g., monkeys, cats, and rats). This work is proceeding at an ever greater rate now that noninvasive machines are pouring out their results; attempts are even being made to construct very simple models of the whole human brain. Such is the present avenue of neural networks—more properly called computational neuroscience—that is adding a deep theoretical underpinning to the neuroscientific approach to the brain and mind.

It is this experimental and theoretical underpinning that I claim is beginning to make a difference in the investigation of consciousness. It brings a broad theoretical framework inside which testable models of behavior can be constructed and refined by further experiment. The analogy to the two races—Wiles's proof of Fermat's last theorem and Rubbia's discovery of W and Z particles—is that Wiles used the latest tools of number theory (some of which he helped to construct) and would not have been successful without them. In the search for W and Z particles Rubbia had the accelerator designed solely on the basis of the unification of radioactivity and electromagnetism, a theory of highest scientific subtlety based on the latest and fullest knowledge of the intricacies of particle physics.

The race to discover the W and Z particles represents just a minute part of scientific knowledge; the vast remainder is an impressive monument to the creativity and dedication of scientists increasingly to master the material world. From the time of Sir Francis Bacon's eloquent *Novum Organum* published over 370 years ago, the scientific method has probed the mysteries of matter using his guidance: ever more precise experiments to test present understanding lead to its continued improvement.

What a head start the science of matter has had over that of mind! The beautiful ideas of Sir Isaac Newton in the seventeenth century began the race toward the center of the atom; this was speeded up by the genius of Albert Einstein at the beginning of this century, and since the late 1920s knowledge has moved ahead even faster, until we are now inside the inside the inside of the atom, so to speak.

Despite some of the ancient Greeks coming close to modern ideas of the brain as the controlling organ of mind, the dead hand of the past

restricted knowledge of the mind vastly more than that of matter. Only in the last century did the science of mind begin to emerge from antique traditions and appeals to ancient authority.

Finally, toward the latter part of the last century the brain was convincingly shown to be divisible into parts specialized for different functions. For example, in 1861 Parisian surgeon Paul Broca revealed that patients with certain speech disorders usually had damage to a particular area of the cortex. Since then our understanding of brain and mind gathered speed, and is now neck and neck with research into unthinking matter. At a recent neuroscience conference in New Orleans in October 1997, 23,000 brain scientists attended; the subject has come of age.

The time has come for the race to understand consciousness to proceed with the most appropriate scientific tools available—noninvasive instruments, neuroscience of the brain (neuroanatomy and neurophysiology), and the theory of computational neuroscience. Those who do not avail themselves of these tools will be heading down the track in the wrong direction, away from the winning post. They will still keep galloping as fast as ever, and some spectators may cheer them on. But the spectators themselves will be rallying around the wrong post.

But where is the winning post? Isn't that one of the main problems in the first place? No one knows where the elusive winning post is or even if it exists. If we have no scientific definition of consciousness, all the scientific tools and theories in the world will never help us reach a winning post.

Science proceeds by reducing a problem to looking at its parts; in general, the parts are much easier to solve than the whole. Then partial solutions are combined eventually. This is sometimes called the method of divide and conquer. It is the way to proceed with consciousness, and inch by painful inch move toward a definition of it. Consciousness is not a monolithic whole, as seen by the way that bits of it become "chipped off" when a person has an injury to part of the brain from a stroke or accident. Parts of its structure and neural support are easier to understand than others. The manner in which the whole of conscious experience arises can be tackled in terms of the decomposed parts; that is indeed the manner in which science is approaching the brain.

In that case, won't there be several winning posts? Even the notion of a race for consciousness may have to disappear, since it may be seen as