Modularity of brain and mind

P.N. Johnson-Laird

The Social Brain: Discovering the Networks of the Mind. By Michael S. Gazzaniga. *Basic Books:1985. Pp.240. $17.95.*
Neuronal Man: The Biology of Mind. By Jean-Pierre Changeux. Translated by Laurence Garey. *Pantheon:1985. Pp.348. $19.95.*

THE brain is the organ of the mind. If you want to understand the mind, then you had better understand the brain. These two books, not perhaps as different as chalk and cheese, but certainly as different as brie and parmesan, share this philosophy. They both aim to elucidate the mind by establishing how the brain works. Michael Gazzaniga wants to demonstrate a link between the global organization of your brain and the way in which you come to believe in certain propositions — from prosaic assumptions about yourself to your propensity to hold religious beliefs. Jean-Pierre Changeux is a Gallic ghostbuster, who aims to rid you of your faith in the "ghost in the machine". He will explain your mind away: it is nothing but neurones, synapses, and electrical and chemical signals. His motto is La Mettrie's: "The soul is merely a vain term of which we have no idea. Let us conclude boldly that man is a machine".

Gazzaniga is a distinguished neuropsychologist at the Cornell University Medical Center in New York, and is best known for his studies of the psychological consequences of the "split-brain" operation. His book is an intellectual autobiography that recounts the development of these studies, considers their implications and speculates about such larger issues as society, prehistory and religion. He writes in a loose, unbuttoned style, with numerous asides and anecdotes, and is at his strongest in describing his beautiful series of experiments on the effects of the split-brain operation.

If you fixate some point in the scene in front of you, then everything to the left of your fixation point is projected to the right half of your brain, and everything to the right of your fixation point is projected to the left half. Information is rapidly transferred from one half to the other by a massive bundle of nerve fibres, the corpus callosum. The split-brain operation is carried out to control extreme forms of epilepsy. The surgeon cuts the corpus callosum and its associated structures so as to isolate the left cerebral cortex from the right. The operation is highly beneficial in otherwise intractable cases, and, according to early results, had no effects on personality, mood or behaviour. However the absence of behavioural consequences did not square with some earlier studies on animals carried out by Roger Sperry, and so Gazzaniga decided to check again. Under Sperry's supervision, he carried out the pioneering series of studies that revealed the operation's consequences.

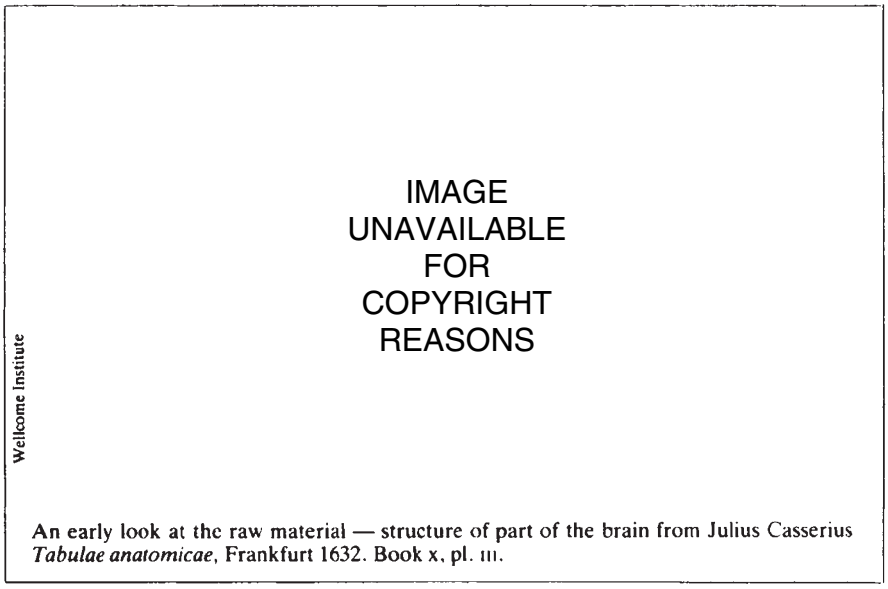
The first effect he observed was the patients' inability to name anything that lies in the left visual field: such a stimulus projects to the right hemisphere, but the main language centres are located in the left hemisphere. Information can no longer be transmitted from one hemisphere to the other, and so the patients deny seeing the stimulus. However, when they are asked to make guesses about it, their emotional evaluations are almost identical to those they make when they can see it. They become frightened by terrifying pictures, though they still deny seeing them, and may attribute the cause of their fear to the demeanour of the experimenter.

If I remove the cooling fan from my micro-computer, the machine is soon incapable of carrying out any computations. Someone who knows little about computers might therefore infer that the fan plays a central role in computation. Analogous errors are an ever-present danger in the study of brain damage. Gazzaniga wisely resists them and repudiates the one-time vogue for alleged dichotomies between left-brain thinking (analytical and verbal) and right-brain thinking (intuitive and visual). His further studies have revealed some subtle phenomena. The right hemisphere typically can create better drawings than the left. Yet the right is not necessarily a superior visualizer: it does no better than the left in matching one readily nameable picture to another. Gazzaniga suggests that perhaps the right brain does not possess a special ability at perception. Instead, if the left brain has no immediate opportunity to exercise its linguistic ability, it may concentrate still more on the verbal aspects of the task — to the detriment of its perceptual performance — whereas the right hemisphere has no such distractions and thus scores higher on perceptual tasks.

When split-brain patients are given two matching tasks, one to solve in the left brain and the other to solve in the right brain, they readily perform them, but the verbal justifications they give for the responses made by the right brain are usually false even though the responses themselves are correct. Thus, if the command "walk" is flashed to the right brain, then the patient will indeed get up and start to walk. If asked why, the left brain, which is unaware of the command, readily concocts a confabulatory explanation. Here is the seed for Gazzaniga's principal hypothesis.

The brain is organized, he claims, into separate modules that can carry out various actions, maintain moods and perceive the world. They are independent units that work in parallel; and they contribute to what we are conscious of, but we are not aware of them. They can control behaviour, and so we sometimes do things for no reason that we are aware of — we act capriciously. The module that mediates language and consciousness, however, interprets our behaviour, and instantly contrives theories to explain it. That is why we think we have free will, and why we are likely to hold beliefs for which we have no objective evidence.

Another inherent danger in interpreting brain damage is to overlook the possibility that its effects are a result of compensatory changes. A sceptic might accordingly argue that Gazzaniga is right: one half of a split brain does contrive explanations for how the other half lives, but only because it has been forced to do so as a result of the operation. Normal people behave quite differently and are conscious of the roots of their behaviour. Of course, there is a long tradition in psychology — and considerable evidence — to the contrary. Likewise, the modular hypothesis has been independently postulated by a number of cognitive scientists in order to



An early look at the raw material — structure of part of the brain from Julius Casserius *Tabulae anatomicae*, Frankfurt 1632. Book x, pl. III.

make sense of the mechanisms of vision and language, the distributions of scores on different sorts of mental test, and other neurological disturbances. What is unique in Gazzaniga's account, however, is his emphasis on the confabulatory capacity of the interpretative module.

Knowledge of the brain has changed strikingly in the past 25 years. It used to be assumed that sensory information was conducted to the cortex, where there was an interchange with other information in the so-called "association" areas, and finally neuronal signals were transmitted to the motor areas responsible for the control of actions. This picture is now known to be a vast oversimplification. Jean-Pierre Changeux, who is a molecular neurobiologist at the Collège de France, has made important contributions to these developments in his work on neurotransmitters and the growth of neural networks. His prize-winning book was evidently a best-seller in France, and it is an outstanding attempt to convey to the general public an interdisciplinary understanding of the human nervous system.

Changeux begins with the tortuous history of concepts of the brain. He records the gradual recovery from Aristotle's original blunder in assuming that it functioned as a cooling device — a case of confusing the central processor with the fan — and describes the gradual ousting of the idea of "vital forces" by the modern electrochemical theory of the propagation of nerve impulses. The brain contains a dense interlacing of the dendritic webs of thousands of millions of neurones, through which pass myriads of electrical impulses, relayed across the synapses from one neurone to another by chemical transmitters or in some cases electrically. There are dozens of chemical substances that are now known to function as neurotransmitters, or as modifiers of their actions, including the nervous system's own internal pain-killers, the enkephalins and endorphins. The principles of the "wiring" of the nervous system are the same throughout the cortex, regardless of the functional specialization of a particular area. Nature seems to use the same basic building blocks over and over again, and employs no cells, circuitry or neurotransmitters unique to human beings. Organization determines function, and the modular principle extends downwards from regions of the brain that mediate major functions to the cortical columns of neuronal structures. Changeux describes these discoveries with clarity and panache, making excursions into the brain chemistry of pain, thirst, rage and even orgasm.

Behaviour can be explained in terms of the mobilization of sets of nerve cells; their responses can be explained in physicochemical terms; and these interactions can be explained at the molecular level. But what about the subjective life of the mind, such as our ability to imagine a friend's face, our emotional experiences and our sense of self-awareness? Changeux's thesis is that mental states are identical to physical states of the brain. Percepts, images, concepts and all such "mental objects" correspond to the activity, electrical and chemical, of assemblies of neurones, dispersed through separate regions of the brain in the case of abstract ideas. Changeux admits that a given mental object may be constructed from slightly different neuronal populations, which may even differ in detail within the same individual from one moment to another. But he does not deal adequately with how the same mental state could arise from such different physical states of the brain.

The answer to this problem is to be found in a different species of materialism that can be traced back to Kenneth Craik and Alan Turing. What mentality depends on is not a particular physical substrate, but the functional organization of the processes that it makes possible. There is still no need to invoke mystical properties in explaining the mind, but this approach can be informed by the theory of computability. The brain is clearly very unlike an ordinary digital computer in the details of its construction and operation; yet it is arguably a computational device that is causally connected to the external world.

If one thinks of the brain as a system containing many processors that carry out computations in a parallel and distributed way, one can make sense both of Gazzaniga's modular hypothesis and of the relation between mentality and neurones — just as different algorithms can compute the same function, so the same mental state can arise from different configurations of neurones provided that the functional organization of their processes is the same. It is therefore necessary to understand what the mind's various computational tasks are, how they might best be carried out, and how such procedures can be neuronally embodied. It is a pity that the work of Craik, Turing and the late David Marr, who did so much to clarify these issues, lies outside the scope of these two books. The brain is the organ of the mind, but the dependence cuts both ways. If you want to understand the brain, you had better understand the mind. □

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New In paperback

The Evolution of Insect Mating Systems. By Randy Thornhill and John Alcock. *Harvard University Press.* £16.95, $19.95.

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The Mathematical Theory of Quantitative Genetics. By M.G. Bulmer. *Oxford University Press.* £12.50.

Entropy parameters and quantum jumps

Walter Gratzer

Mayonnaise and the Origin of Life: Thoughts of Minds and Molecules. By Harold J. Morowitz. *Charles Scribner's Sons: 1985. Pp.256. $15.95.*

Natural Acts: A Sidelong View of Science and Nature. By David Quammen. *Lyons Books (Schocken): 1985. Pp.221. $16.95.*

THE first of Dr Morowitz's essays finds him on the Galapagos Islands, the third in an aeroplane approaching New Delhi and not long after we meet him pacing the deck of a cruise boat on Glacier Bay in Alaska. Where other orbiting professors sort their slides or touch up the odd grant application, Dr Morowitz, it seems, reaches for his pen and kicks his muse into action.

As a popularizer of science Morowitz is by no means in the Haldane class, but, at his best, as when he is ruminating on the quirks of scientists, dead and alive, and the assaults on science by the Great Unwashed, he is distinctly good company. He writes captivatingly on the eccentric palaeontologist, John Bell Hatcher, and on the unhappy Philip Gosse, a Victorian worthy, who as a Plymouth Brother, a zoologist and FRS, and friend of Darwin, was tormented by the geological and palaeontological evidence against Bishop Ussher's chronology and by such teasers as whether the occupants of the Garden of Eden possessed navels. (Such matters were far more satisfyingly resolved by the mediaeval schoolmen: what could be more pleasing, for example, than the logic of Origen, who held that since the sphere was the most perfect of all shapes by virtue of the invariant distance between its centre and all points on the surface, we would all on the Day of Judgement be transformed into spheres and roll into paradise.) Morowitz respects men such as Gosse for their tortured honesty of intellect. He deals sharply, by contrast, with those modern fleas on the body of science, the creationists and parapsychologists. One of his most entertaining pieces is a magisterial analysis of the thermodynamics of ESP.

I am less sure about a stertorous attempt to rehabilitate Teilhard de Chardin. But then again Morowitz comes up trumps on popular perceptions of entropy, which seems to have joined parameter, extrapolate and quantum-jump in the journalistic vocabulary. Here is a political pundit, quoted by Morowitz: "Entropy helps to explain why we have runaway inflation, soaring unemployment, bloated bureaucracies, a widely escalating energy crisis and worsening pollution". Poor Boltzmann (over whose remains in Vienna is hewn in stone the inscription