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 neurally 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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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 captivately 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

New In paperback

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

Animal Thinking. By Donald R. Griffin. *Harvard University Press*. £6.95, \$7.95. which was reviewed in *Nature* 313, 410.

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

$S = k \log \Omega$) surely did not foresee this.

Morowitz offers some agreeable literary diversions and his thermodynamite's view of the passage in *Ulysses*, in which Leopold Bloom boils a kettle for his shaving water, deserves to be preserved. He is also rather good on dentists: he enjoys the "intellectual and aesthetic pleasure" of feeling a craftsman at work in his mouth. (Bernard Shaw took the same view: there was nothing more soothing, he wrote in one of his music criticisms, after a harrowing series of recitals, than to have one's teeth drilled by a finely-skilled hand.) There is much in this collection to entertain, sometimes to annoy and only occasionally to bore.

David Quammen disarmingly confesses to being a dilettante rather than a scientist, "a haunter of libraries and a snoop". He writes natural history in an unmistakably American style and is given to apostrophizing his reader in sporting metaphors. "Truly", he says, speaking of the larger kind of sea cucumber, "these guys are out in left field". This, I own, stretches my tenuous grasp of baseball. And what, for that matter, is this Hostess Twinkie, that a seal allegedly resembles in section?

The sea cucumber opens Quammen's collection, and its trials are considerable: the tiny parasitic *candiru* fish, for instance, enters and leaves the cucumber with impunity by way of the nether passage, lingering only to feed on its vitals. "You'd think", Quammen exclaims, "the little bugger was selling encyclopaedias". Well, these are not the lapidary periods of a Medawar or Gould; but we do learn how the resourceful cucumbers deal with the situation when they eventually weary of the tiresome intruder: they evert themselves and "blast their own gut and internal organs out through their own anus". Humans are denied this recourse, and, says Quammen, when the *candiru* enters the urethra it lodges there, its spines facing backwards, and the only alternative to death by blood poisoning is amputation. Beginning to feel faint, I passed on to the next story, which is about bats, and here was rewarded by an account of a scheme by the American military during the Second World War to subdue the Japanese by dropping bats, each fitted with a napalm bomb and a little parachute, on their cities.

Quammen's book is full of strange information about animals and their habitat, about Tycho Brahe's artificial nose, and other such oddities. His exuberance carries one, sometimes unwillingly, along. He has a penchant for the poetry of Donne, and an informed concern for wildlife and the environment that is altogether heartening; his book deserves every success. □

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Behind the scenes in the fight on tropical diseases

Adetokunbo O. Lucas

From the Face of the Earth*. By June Goodfield. *André Deutsch*: 1985. Pp. 256. £10.95.

THE public exhibit an insatiable hunger for news about medicine and the medical sciences. In this book June Goodfield provides a five-course offering to feed the layman's appetite for "stories of medical achievement". As popular science, it translates into everyday language scientific information that is often obscured by jargon. The story telling is enlivened by taking the reader behind the scenes of scientific events — we read not only of dedication and the determination to succeed, but of personal disputes, divorce, dementia and other such human problems.

The first story about Kuru contains all the excitement of a strange disease, uniformly fatal among the sufferers, with a maximal impact on women and children and threatening to wipe out a whole community. This account highlights the role of those who finally solved the mystery. At the top of the list is Carleton Gajdusek, the deserved winner of a Nobel prize for identifying the cause of Kuru and for the discovery of slow viruses as causes of human disease. June Goodfield, however, notes but does not stress the point that control of Kuru in Papua New Guinea did not result directly from the outstanding biomedical and behavioural research which she so vividly describes. Rather, the decline in the incidence of Kuru apparently stemmed from action taken by some person(s) unnamed, who, in the 1950s, forced a cultural change in the ritual method of disposing of the dead. Who,

*In the United States *Quest for the Killers*, published by Birkhäuser price \$24.95.

one wonders, were these faceless persons? What was their motive? Was it mere abhorrence of a strange cultural practice, or did they somehow intuitively sense that such practices could have fatal consequences?

The Kuru story illustrates the fall-out effect by which research on a specific problem can generate new knowledge of fundamental importance and unexpected benefit in other areas. Thus the work in Papua New Guinea has brought to Europe and North America new insights to diseases of local interest, such as Gerstmann-Sträussler Syndrome and Creutzfeldt-Jakob Disease.

Discipline, dedication and imaginative resourcefulness are the main ingredients of the next story on hepatitis B vaccine. Illustrated here is the point that the identification of the appropriate risk groups is an essential stock-in-trade of the epidemiologist, from classical studies on scurvy among English sailors, to research into cancer of the lung among smokers.

"The Three Valleys of St Lucia" deals with a large operational research programme aimed at comparing strategies for the control of schistosomiasis. Unlike Kuru, a unique disease in an island population, schistosomiasis is widespread in the tropics, affecting some 200 million people. It is not new — its eggs have been found in an Egyptian mummy — but it presents a fresh challenge where projects such as irrigation schemes and man-made lakes result in expansion of the population of the vector snails, an increase in man-water contacts, and thus intensification and broadening of the distribution of the disease.

The St Lucia story well illustrates the practical questions that need to be answered in translating theoretical options into effective strategies. And, again, the research provided answers that were useful not only on St Lucia but also in other areas. Recently, the World Health Organization proposed new strategies for the control of schistosomiasis which owe much to the findings at St Lucia, updated to take note of recent advances in technol-

Schistosome sporocysts in the head-foot region of a snail. From *Schistosomiasis: The St Lucia Project* by Peter Jordan. Cambridge University Press. To be reviewed in *Nature*.