Captain, art thou sleeping there below?

The Restless Sea
by Robert Kunzig
W. W. Norton: 1999. 336 pp. $24.95, £16.95

Alan Longhurst

If Francis Drake, "slung between the round-shot, in Nombre de Dios Bay", had toboganned down the continental slope into deep water, he would not, as Robert Kunzig pretends, have been crushed "in an instant" to a small fraction of his former volume, like the Styrofoam cups that oceanographers delight in attaching to their instruments for the subsequent bafflement of their spouses. Instead, sewn into sailcloth, he might still be in quite good shape, integrating gently into the dark world of the depths, to judge by the famous apples recovered from the sunken submersible *Alvin*. Bacterial physiology at great pressure runs slowly, except in special places.

Science is a minefield into which even a specialized journalist treads at his peril, and Kunzig's text slips out of focus now and then. The trick is to keep going, ignoring what doesn't seem quite right. For the lay reader, this probably won't matter, because the large fabric is clearly explained; this recounting of recent advances in the ocean sciences presents a lot of fundamental Earth science in easily understood terms.

In ten chapters, some of the jam — but not much of the bread and butter — of oceanography is reviewed. From the motions of tectonic plates and the dynamics of the consequential mid-ocean ridges, we travel to the sulphur-based benthic ecosystems of the rift valleys, the gelatinous plankton of the great depths and the iron-starved algal cells of the Southern Ocean. Finally, we reach the great conveyor belt of the oceanic thermohaline circulation and the possible consequences for global climate of a change in its state. These chapters are sandwiched between accounts of the probable cosmic origins of water on Earth and how it will be dissipated as our Sun becomes a red giant.

Each chapter is a conversational retelling of how American oceanographers solved enigmas over the past 40 years or so. Idiosyncratic personalities and the informality of oceanography in the 1960s and 1970s come across rather well.

As I read, I began to speculate why solutions appeared when they did. Had nobody before the young Hank Stommel thought to apply the conservation of angular momentum to explain the intensification of western boundary currents like the Gulf Stream? If a first-year graduate student with "sulphur bacteria on her brain" had not gone to a seminar on the anatomy of *Riftia*, how long would we have waited to discover the symbiotic sulphur-oxidizing bacteria living in the trophosome of this abyssal tube worm? And from this, that Earth has two ecosystems, one based on the oxidation of geothermal hydrogen sulphide in abyssal rift valleys, the other based on energy from sunlight. In this case, somebody must surely have spotted quite soon how the exuberant growth of the vent fauna is supported.

And what about iron limitation of phytoplankton in the high nitrate/low chlorophyll areas of the Southern Ocean and parts of the eastern Pacific? On EASTROPAC, the 1960s international expedition, we were already at sea — literally and figuratively — looking for the missing nutrient. But it was John Martin, unwittingly prepared by his mastery of trace-metal assay, who solved the problem in 1986. Had we earlier realized that high nitrate/low chlorophyll areas correspond with places where little terrestrial dust falls on the ocean, the solution might have been found more quickly.

But history is much more complex than Kunzig allows, and although the simple historical introductions to each chapter serve his purpose well enough, they obscure the true complexity of events. For example, Eric Mills' *The Sea* (Wiley-Interscience), a rich account of the exploration of deep-sea biology, suggests several places where Kunzig missed the point. But at least the flavour is there for the lay reader. I particularly liked Kunzig's evocation of the dark world of the plankton deep in the ocean, where relative water motion is negligible and everybody waits for an invisible somebody else to make a move so they can be grabbed.

Kunzig hints at, but doesn't quite grasp, the speed at which the practice of ocean science is changing. The submersibles once used to explore the ocean depths are unavailable or otherwise employed; research funds are now allocated to coordinated projects with practical aims. Oceanography has entered a new phase, in the sense of Mills — for whom oceanography, unlike mathematics, has no internal dynamic, but instead is driven by external forces. At the end of the nineteenth century, British marine science was turned deliberately away from deep-sea exploration towards coastal biology and fisheries, a policy that has marked it to this

In shallower waters

Australian photographer Roger Steene works with marine scientists to record sea life around the world. Among the 340 colour photographs in his *Coral Seas* (Firefly, $50) are creatures — from microscopic organisms to a super-mimic octopus — that have not yet been officially discovered or named. Those that have include, from top, the pink anemonefish, whose body mucus contains chemicals that protect it from its host's stinging cells; the triggerfish, whose dorsal fins lock upright to wedge it safely into a sleeping space; and the rhinoceros triplefin.

day. Now the Cold War is over, the US Navy is losing interest in basic deep-sea science, and executive empowerment is eroding the initiative of individual oceanographers. Russian institutions are in deep recession, and in Canada there has been a massive diversion of oceanographic resources to the problems of the collapsed fisheries.

Perhaps the next phase of oceanography will see an even greater divergence between the ocean and its coastal regions, between global climate-related studies in the ocean basins and pollution- and fishery-related problems around the edges. The curiosity-driven initiatives that served us so well and revolutionized our understanding of the oceans in the previous phase from 1950 to 1990 will wither. Those of us who participated were indeed fortunate.

But, returning to Kunzig, most writing about the sea, even in the scientific literature, addresses only coastal or continental-shelf phenomena, and I value this book for its almost exclusive attention to the neglected deep oceans. If it is read by enough lay people, perhaps I shan't have to explain so often that, no, oceanographers don't all go to sea wearing red watch caps, and we don't all have scuba tanks slung over our shoulders. □

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More from the depths
Essentials of Oceanography, 6th edn
by Al Trujillo & Hal Thurman
Prentice Hall: 1999. 526 pp.
$42.99, £22.99 (pbk)

Firing up the power plant in our heads

Evolving Brains
by John Morgan Allman
W. H. Freeman/Scientific American: 1999. 256 pp. $34.95, £23.95

Bob Martin

Although this book is one of tens in the Scientific American series, it is quite remarkable in presenting a radically novel picture of the evolution of the brain. A major milestone in this field, as John Allman himself notes, was the publication in 1973 of Harry Jerison's monograph *Evolution of the Brain and Intelligence*. That treatise wove many disparate threads into an entirely new tapestry and stimulated much subsequent research. *Evolving Brains* now provides us with another milestone — it is a masterpiece of synthetic presentation and evocative interpretation.

An appreciation of biological continuity can greatly enrich our understanding of the evolution of brains, as Allman elegantly demonstrates. Indeed, he goes back as far as the first unicellular organisms in his search for guiding principles, and reminds us, for instance, that photoreceptors and olfactory receptors are derived from modified cilia. This illustrates the fact that evolution of the CNS, just like that of any other organ system, has depended heavily on conversion and duplication of pre-existing structures: innovation wedded to an astonishing degree of conservatism. Perhaps the most striking example of conversion is provided by genes with the ancient function of controlling formation of the gut,which now control growth of the forebrain in mammals.

Allman goes on to show that we can learn much about the organization and functioning of the human brain through lessons drawn from evolutionary history. To do so, he considers two contrasting components of the CNS: the ancient serotonergic system of chordates (involving a gene family of serotonin receptors) and the neocortex (a novel structure in mammals).

He draws connections between duplication of genes, duplication and modification of structures in development through corresponding changes in homeotic genes, rhombomeres (repeating segments in the hindbrain), and possible duplication of topographic maps in the neocortex. His use of a power-plant analogy, for the progressive overlaying of new structures on an organ that can never cease functioning, is an example of his ability to create graphic metaphors.

The strength of Allman's review is clearly attributable to his unusual background. He originally studied anthropology at the University of Chicago, during which time he became aware of the special significance of vision in primate evolution and developed an interest in the transfer of the visual image from the retina to the brain. In order to pursue this, he obviously needed to study neurophysiology. His adviser, Clark Howell, suggested that he could continue to be based in Chicago while working at the laboratory of neurophysiology at the University of Wisconsin. There, under the guidance of Clinton Woolsey and Wally Welker, he initiated his primary research on primate visual systems and began his collaboration with Jon Kaas on mapping studies of the visual cortex in owl monkeys.

In 1974, he moved to the California Institute of Technology and has remained there ever since, continuing his research into the primate central nervous system (CNS). Throughout, his training in anthropology has been reflected not only in a broad-based approach to primate evolution, but also in a strong emphasis on biological continuity and historical background. All these factors are combined in the thought-provoking synthesis he presents in *Evolving Brains*.

The comparative approach inevitably looms large in his synthesis. Comparisons show, for example, that the neocortex in all mammals (but not other vertebrates) is a six-layered structure developed from the roof of the forebrain. Hence, the neocortex is as much a defining characteristic of mammals as are mammary glands, hair or ear ossicles.

In a more restricted example, Allman and his colleagues have shown that, among mammals, primates have a special pattern of visual projection in the optic tectum that eliminates redundancy by representing only one half of the binocular field on each side of the brain. (It was this discovery that first drew my attention to Allman's pioneering work in 1980.) This may be linked with their developing an ability to fix their gaze on objects of interest — primates, in fact, have an apparently unique centre for visual guidance of body movements, called the ventral premotor area. Incidentally, Allman finds no support for John Pettigrew's proposition, in 1986, that fruit-bats (but not other bats) share this special pattern of visual projection with primates and are therefore related to them. As molecular evidence now overwhelmingly indicates that bats are monophyletic, the 'flying-primate hypothesis' must be regarded as severely disabled.

As with Jerison's book, allometric scaling comparisons also play a prominent role. Allman's research group has made notable contributions to this field in recent years. For instance, it was demonstrated that the long-mooted connection between brain size and lifespan is confined to particular brain parts and is (for some reason) less clear in prosimians than in simian primates. Subsequently it was shown that — whereas females typically outlive males in primate species lacking paternal care — males live as long as, or longer than, females in species with extensive paternal care. Allman also rightly emphasizes the central importance of energy relationships, for example, in accounting for the grade shift in relative brain size between cold- and warm-blooded vertebrates.

One weakness in this book is that Allman does not pay much attention to the problem of potential confounding variables — a correlation between brain size and some other feature does not necessarily indicate a direct causal connection. He does not mention the recent debate about potential statistical problems arising from differential relatedness between species in comparative analyses. For instance, leaf-eating monkeys belong to just a few groups of closely related species, so their smaller brains may be traced to just a few ancestral changes. This, however, is just a special case of the general problem that correlation between two variables may exist because both are connected with one or more other variables — numerous additional biological factors as well as phylogenetic relatedness. A case in point is provided by the Aiello/Wheeler 'expensive tissue hypothesis', according to which there was a trade-off between brain size and gut size in primate evolution. Allman integrates this hypothesis