

warnings of the inherent danger of the exercise.

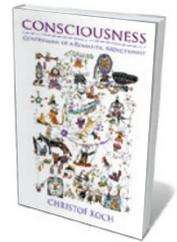
From Koch's collaborations with Crick, whom he seems to idolize, to his struggles with religion and free will, this is an engaging mixture of personal anecdote, scientific fact and pure speculation. It is often charming; Chapter 2, for instance, is entitled, 'In which I write

about the wellsprings of my inner conflict between religion and reason, why I grew up wanting to be a scientist, why I wear a lapel pin of Professor Calculus, and how I acquired a second mentor late in life.'

For many, the richest parts of the book will be Koch's lucid descriptions of experiments such as his work with Itzhak Fried, a neurosurgeon who implanted electrodes into the hippocampi of people with epilepsy. In one patient, Fried found a single neuron that responded only to the name or pictures of Saddam Hussein; in another, he found one that responded only to pictures of the actress Jennifer Aniston. In a descriptive tour de force, Koch explains that although Fried dubbed these cells concept neurons, we can think of them as "the cellular substrate of the Platonic Ideal of Jennifer Aniston".

Koch discusses the two theories that form the cornerstones of his own views of consciousness. The first, which he proposed with Crick, describes the neural correlates of consciousness as involving "reverberatory feedback loops" (which link higher-order sensory regions to the prefrontal cortex) and corticothalamic loops (which link these regions and nuclei in the thalamus). These networks then marinate in a bath of neurochemicals released by fibres coursing up from a variety of brainstem regions. How these connections produce consciousness is explained by the second theory, the integrated information theory of consciousness.

Here, the story seems to stumble. Consciousness, Koch argues, is not an emergent property of the brain. Rather, it is inherent in all matter, as "the amount of integrated information generated by the system in [a given] state above and beyond [that] generated by its parts". If this seems unclear, it is. Koch states that calculating this quantity is extremely difficult, and demands "heuristics, shortcuts, and approximations". The higher the value, he says, the more conscious the system. But what does it mean to say that one system ▶



Consciousness: Confessions of a Romantic Reductionist
CHRISTOF KOCH
MIT Press: 2012.
184 pp. \$24.95,
£17.95

PASIEKA/SPL

The brain is full of feedback loops and neuronal links that combine to give rise to consciousness.

NEUROSCIENCE

The mind mapped

Robert Stickgold revels in a lively account of a quest to quantify consciousness.

The psychologist Stuart Sutherland wrote that it is impossible to define consciousness "except in terms that are unintelligible without a grasp of what consciousness means ... Nothing worth reading has been written about it." It is arguable whether Christof Koch's *Consciousness* provides such a definition, but the book is definitely worth reading.

Koch, chief scientific officer at the Allen Institute for Brain Science in Seattle, Washington, is perhaps best known for his work with the late Francis Crick, searching for the neurobiological 'correlates of consciousness'. Here, he succinctly lays out the story of that quest. Focusing on how the brain might produce the mind, Koch mixes descriptions of major experiments with self-reflection and

► has twice as much consciousness as another?

There can also be too much gee-whiz science for my taste. For instance, talking about the nervous system of the worm *Caenorhabditis elegans* with its 302 neurons, Koch describes the creature's "state of consciousness" as the current position of the system on a 302-dimensional graph, with 2^{302} possible states (for each combination of the 302 neurons either firing or not). The neural network is a material thing, Koch argues, but the shape of the graph describes the conscious experience of the worm at that moment, "its phenomenal experience".

By this argument, the 32,768-byte computer file holding this review has a consciousness defined by its position on a 32,768-dimensional graph with $256^{32,768}$ (or, put more quaintly, 1 followed by 87,000 zeros) possible states. Personally, I don't think any of them have much chance of being conscious.

There are other points on which *Consciousness* lacks clarity. Koch tackles most of the big questions: are mice and fruitflies conscious (yes); can computers be conscious (yes); are they already (yes); is there free will (not really); can we ever understand consciousness (yes); can the mind affect our behaviour (no); and even is there a god (yes, but absent since the Big Bang). Unfortunately, it is often hard to decipher which of these he thinks are proven facts, which personal beliefs and which momentary opinions.

"What does it mean to say that one system has twice as much consciousness as another?"

In fairness, the equations are much more complicated than is described here. Still, in the end, the theory seems to me to be an example of a conflation of ignorances: saying that because we don't really understand A or B, they must be causally related. Whether they invoke quantum mechanics, microtubules or integrated information content, these explanations of consciousness are, for all their mathematical precision, no more than pure speculation. Perhaps one of them is actually right. But perhaps, like ancient Greek philosophers searching for the cause of thunder, we are still thousands of years from an answer.

I argued with Koch all the way through this book. And I loved every minute of it. ■

Robert Stickgold is an associate professor of psychiatry at Harvard Medical School in Boston, Massachusetts. e-mail: rstickgold@hms.harvard.edu



Humans have been probing the mysteries of the Antarctic for almost 200 years.

POLAR RESEARCH

Deep-frozen science

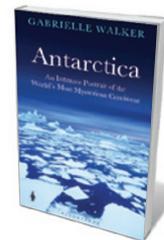
Francis Halzen is exhilarated by a trek through stories of research and exploration in Antarctica.

A dazzling array of narratives throngs *Antarctica*, collected from scientists in one of Earth's most extreme environments. Science writer and consultant Gabrielle Walker gathered these stories in the course of five trips criss-crossing the continent, mostly as a guest of the US National Science Foundation's Antarctic programme.

This is not just a highly accessible encyclopedia of Antarctic science. It interlaces researchers' stories with natural history, tales of the 'heroic age' of exploration and passages that viscerally describe the cold, isolation and beauty of the environment. Neatly organized geographically, the book covers the East Antarctic coast, with McMurdo Station (the largest community in Antarctica) and the penguins; the high plateau, with the Concordia and South Pole research stations; and the isolated West Antarctic coast.

Walker talks about the Dry Valleys near McMurdo, which run from the edge of the ice sheet that covers most of the continent down to the Ross Sea. Precious little precipitation has fallen here for millions of years: with an average temperature of -55°C , this is Mars on Earth. But it is teeming with life — cyanobacteria, found in ponds the world over. Here, they live inside the dry rock, surfacing for only a few weeks a year to find water from the little snow that fell over winter. Then they go back to sleep.

Walker learned that fascinating story on a diving expedition in Lake Hoare in the Dry Valleys with Peter



Antarctica: An Intimate Portrait of the World's Most Mysterious Continent

GABRIELLE WALKER
Bloomsbury: 2012.
416 pp. £20

Doran, a biologist at the University of Illinois at Chicago. But it isn't only researchers who feature here. The book is peppered with characters who "keep the scientists alive". On one trip we meet camp manager Rae Spain, who came to Antarctica as a carpenter and returned because she could not get the continent out of her head. "It haunts you," she told Walker.

Mars has literally come to Earth just beyond the Dry Valleys, Walker tells us. Researchers on Skidoos systematically scan the ice sheet for meteorites — a relatively easy task, given that everything stands out in this icy landscape. We accompany John Schutt, a mountaineer who has returned for the hunt every year since 1980. More meteorites have been found since the 1970s in Antarctica than over centuries in the rest of the world.

In 1982, for the first time, an Antarctic meteorite was identified as coming from the Moon. Two years later, researchers found a rock from Mars that turned out to contain structures that may be nanoscale fossils: the most intriguing indications yet that life may have existed on other planets in the Solar System, although debate is still raging.

The West Antarctic coast, as Walker shows, is out of reach of the permanent

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